UNIVERSITAT DE BARCELONA

Assessment of bone loss adjacent to lower second molar in case of third molar impaction and other findings using Orthopantomography (OPG)

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Assessment of bone loss adjacent to lower second molar in case of third molar impaction and other findings using Orthopantomography (OPG)

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"The secret of getting a head is getting started".

Mark Twain

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ABBREVIATIONS

Abbreviations

ALADA	As low as diagnostically acceptable
AO	Alveolar osteitis
CBCT	Cone beam computed tomography
CCA	Calcified carotid atheroma
CG	Control group
CT	Computed tomography
DE	Deviation error
DICOM	Digital imaging and communication in Medicine
DM	Diabetes mellitus
EMRs	Electromagnetic radiations
ESP	Elongated styloid process
FEE	Fixed estimated effect
HOUB	Dental hospital of the University of Barcelona
HT	Hypertension
IAN	Inferior alveolar nerve
IMTM	Impacted mandibular third molar
IQR	Interquartile range
MCI	Maxillary canine impaction
MCW	Mandibular cortical width
MI	Mental index
MM	Millimeter
MRI	Magnetic resonance imaging
MSM	Mandibular second molar
OPG	Orthopantomography
SD	Standard deviation
SG	Study group
TMDs	Tempromandibular joint syndromes
TMJ	Tempromandibular joint
US	Ultrasound

ARTICLES

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SUMMARY/RSUMEN

Summary/Resumen

Introducción: la impactación dental es una situación patológica en la que un diente se incluye total o parcialmente en el hueso de la mandíbula o del maxilar. Diferentes dientes son notablemente propensos a los fenómenos de impactación, incluyendo el canino y el tercer molar superior, el tercer molar y el canino inferior. Sin embargo, el tercer molar inferior se considera el diente impactado más común, representando el 98% en comparación con otros dientes impactados. Por lo general, entra en erupción entre los 17 y 24 años. La prevalencia global de impactación del tercer molar inferior se estima en torno al 24%, sin predilección de género entre hombres y mujeres. Hay factores que hacen que un diente no erupcione en el tiempo esperado, incluida la falta de espacio, los gérmenes dentales mal posicionados, la vía de erupción anormal y las alteraciones del desarrollo de la mandíbula. La impactación del tercer molar mandibular tiene muchas complicaciones en el tejido blando adyacente y en el segundo molar. Así, la pericoronaritis es una de las consecuencias causadas por la impactación, que se manifiesta como inflamación del tejido gingival que la recubre. Otras complicaciones incluyen la caries distal, la pérdida ósea adyacente al segundo molar, formación quística y cambios neoplásicos. Las diferentes posiciones de los terceros molares mandibulares impactados pueden complicar el mantenimiento de la higiene oral y la placa control. Por lo tanto, el periodonto manifiesta la formación de bolsas que facilitan la perdida oseas en la cara distal del segundo molar. Además, el tercer molar mandibular está ubicado cerca del canal mandibular inferior el cual contiene el nervio alveolar inferior, la arteria y la vena correspondiente. La extracción quirúrgica de dicho diente puede ejercer un riesgo de lesión nerviosa que conduzca a disestesia o a parestesia. Además, el procedimiento de extracción del tercer molar puede ejercer una presión sobre el hueso que puede conducir a la fractura del ángulo de la mandíbula. Finalmente, la extracción puede afectar al 2º molar inferior. Por lo tanto, los procedimientos clínicos y diagnósticos son esenciales para abordar la posición del diente impactado, la patología asociada, la proximidad al canal nervioso y la decisión de intervención.

La ortopantomografía (OPG) es una técnica de diagnóstico por la imagen utilizada rutinariamente en el consultorio dental, que representa al maxilar y la mandíbula en una sola imagen. Tiene la ventaja de exponer los cambios dentales y óseos en la cavidad oral, incluidos los dientes impactados. Entre las ventajas de la OPG, se encuentran su rapidez y facilida, en especial el 2º molar y el canal dentro de realización, mejor

cooperación y aceptación del paciente, cobertura completa de las arcadas dentales y estructuras relacionadas (se pueden ver más estructuras anatómicas en una película panorámica que en una serie completa de radiografías intraorales), simplicidad y baja exposición a la radiación para el paciente, en comparación con la herramienta de imagen más avanzada, la tomografía computarizada de haz cónico (CBCT). Como la impactación del tercer molar es una de las patologías dentales que los odontólogos ven con frecuencia, la determinación de la posición y la relación con las estructuras cercanas, en especial el 2º molar y el canal dentario inferior, se puede predecir utilizando OPG.

Hipótesis: La impactación del tercer molar causa pérdida ósea distal al segundo molar, por lo tanto, habrá ganancia ósea distal al segundo molar después de la extracción del tercer molar. molar impactado.

Hipótesis nula: la impactación del tercer molar causa pérdida ósea distal al segundo molar, sin embargo, no habrá ganancia ósea distal al segundo molar después de la extracción dental del tercer molar impactado.

Objetivo: determinar la pérdida ósea distal del segundo molar inferior asociada a impactación del tercer molar y analizar su evolución tras la extracción del tercer molar.

Metodología: el estudio es retrospectivo de casos y controles de pacientes que visitan el Hospital Dental de la Universidad de Barcelona (HOUB). Las radiografías de los pacientes se obtuvieron desde junio 2018 hasta Agosto de 2022, y se dividieron en dos grupos: un grupo de estudio (SG) y un grupo de control (GC). El grupo de estudio contiene las imágenes de los pacientes en los que se mide el nivel óseo distal al segundo molar antes y después de la extracción del tercer molar impactado mandibular, mientras que el grupo control incluye las imágenes de pacientes que no realizan la exodoncia de sus terceros molares mandibulares impactados, en los que el nivel óseo se mide dos veces en un período de al menos 3-6 meses. Pérdida ósea distal al segundo molar se midió en ambos grupos y se comparó. Las mediciones se realizan utilizando la herramienta asociada al dispositivo de radiografía panorámica [DICOM].

Las variables analizadas son cualitativas según frecuencia y porcentajes y de las cuantitativas según medidas de tendencia central y de dispersión. Las variables cuantitativas, dependiendo de su distribución de normalidad, se estudian según la prueba de Kolmogórov-Smirnov ($p<0,05$), y se definieron según la media y desviación estándar.

Resultados:

La muestra está constituida 80 pacientes y (160) OPGs 40 pacientes por dos grupos; el grupo de estudio y el grupo control. La edad media de los pacientes por grupo estudio es 35.5 años y una desviación estándar de 15.45. De ellos 62.5% son mujeres y 37.5% son varones. Por otro lado, la edad media de los pacientes por grupo control es 33.47 años y desviación estándar 16.49. De ellos 55% son mujeres y 45% son varones. Estadísticamente, nuestros hallazgos no ilustran diferencias significativas entre ninguno de los grupos con respecto a la edad (p-valor 0.57), las categorías de grupos deedad (p-valor 0.43) y el sexo (p-valor 0.36). Obviamente la mayoría de los pacientes acudieron al hospital para la extracción del tercer molar mandibular impactado (IMTM). La mayoría de los pacientes de los dos grupos son no fumadores 73% y 75%del grupo estudio y grupo control respectivamente. La IMTM bilateral es la más frecuente entre otros procedimientos, representando el 73% del grupo de estudio y el 75% del grupo control y no hay diferencias entre ambos grupos (valor de p 0.509). Respecto de la clasificación de Winter, la impactación vertical es más frecuente en comparación de las otras. Según la medida de la perdida ósea, las mediciones del nivelóseo se calcularon e informaron en términos de media y desviación estándar entre el grupo de estudio y el grupo control, como un total, independientemente de los lados. Por lo tanto, nuestro análisis ha revelado que la media y la desviación estándar en el grupo de estudio antes de la extracción fue de 3,00 ± 1,68 mm. Por otro lado, la mediay la desviación estándar de las mediciones después de la extracción fue de 2,63 ± 1,75mm y hay diferencia estadísticamente significativa a favor de la ganancia ósea en el grupo de estudio (valor de p 0,0001). En cuanto al grupo control, la media y la desviación estándar en la radiografía basal fue de 2,73 ± 1,75 mm, mientras que despuésde la segunda radiografía se encontró que era de 3,01 ± 1,98 mm. El análisis estadístico reveló diferencias significativas a favor de la pérdida ósea (valor de p 0,001). En relación con el análisis univariado de los cambios en el estado óseo, el grupo de estudio,en el que se extrae el IMTM, muestra una ganancia ósea significativa en comparación con los controles que no extrajeron el tercer molar, con una diferencia estadísticamentesignificativa (FEE 0,73, DE 0,21, valor de p 0,0001). Con respecto al modelo multivariante ajustado, la asociación se mantiene y es independiente de los factores de confusión (efecto fijo 0,79, error de desviación 0,26, valor p 0,003) que también es estadísticamente significativo.

Conclusión:

Podemos concluir de nuestro estudio que el hueso distal al segundo molar en caso de extracción generalmente conducirá a la ganancia ósea y el cambio es estadísticamente significativo, mientras que en caso de no extracción de la impactación resultaría en pérdida ósea. La radiografía panorámica, aunque no es reproducible en la cuantificación del cambio óseo en milímetros, sigue siendo una herramienta valiosa en la identificación de los cambios óseos si permiten valores mejores o pérdida ósea.

INTRODUCTION

1. Introduction

1.1 Teeth eruption

Tooth eruption is defined as the process of teeth emergence through the soft tissues of alveolar bone and the overlying mucosa to appear in the oral cavity, contact the teeth opposing ones, and function physiologically in the proper way (1). Consequently, the awareness of the timing and sequence of the teeth development and eruption is considered a fundamental aspect for dental clinicians. It represents a base knowledge of understanding any future discrepancy in the tooth congenital absence, impaction or, or supernumerary teeth conditions. Therefore, the development of primary and permanent teeth in the proper and expected timing and sequence contributes to growth and development of the permanent teeth. The timing and sequence of tooth eruption are influenced by a variety of factors, including genetics, nutritional status, and environmental factors (2).

1.1.1 Chronology of primary teeth

Regarding primary teeth eruption, it is well known that the first teeth to emerge in a child's oral cavity are the primary teeth, known as deciduous teeth or baby teeth. The primary teeth formation starts at the fifth week of gestation period. Then, these teeth typically start to erupt between 4 to 36 months of age, with the lower central incisors usually the first to emerge. It is then followed by the upper central incisors, lateral incisors, and first molars, canines, and second molars (3–5).

The primary canines typically erupt between 16 and 20 months of age, while the second molars emerge between 20 and 30 months of age. Normally, mandibular teeth precede the maxillary ones. The chronology of primary teeth eruption is consistent among children, with individual variations of up to several months based on different races. Accordingly, factors such as tooth size, time of formation, and genetic conditions could impact the sequence of the dental eruption leading to some variations. The disturbance in the developmental process of primary and permanent dentition leading to alteration in the number of teeth is relatively common (6). The congenital absence of one or more teeth is termed hypodontia. This condition is noticed more in permanent dentition compared to the primary dentition. It is reported that the overall prevalence of such condition ranges between 1.6-9.6 apart from third molar (7). Illustration of the sequence of primary teeth eruption is presented in (Table 1). Illustration of the chronology of deciduous teeth eruption is presented in (Table 2).

Number	Tooth	sequence
1	Central incisor	1^{st} to erupt
2	Lateral incisor	2^{nd} to erupt
3	First molar	3^{rd} to erupt
4	Canine	4^{th} to erupt
5	Second molar	5^{th} to erupt

Table 1. Sequence of the primary teeth eruptions. Adapted from Aliudddin. (6)

Deciduous tooth	Tissue Calcification occurrence (In utero)	Crown completion (months)	Eruption (months)	Root completion (months)
Maxillary teeth				
Central	14 (13-16)	11/2	10 (8-12)	11/2
Lateral	16 (14-17)	21/2	11 (9-13)	2
Canine	17 (15-18)	9	19 (16-22)	31/4
First molar	15 (14-17)	6	16 (13-19)	21/2
Second molar	19 (16-24)	11	29 (25-33)	3
Mandibular teeth				
Central	14 (13-16)	21/2	8 (6-10)	11/2
Lateral	16 (14-17)	21/2	13 (10-16)	11/2
Canine	17 (16-18)	9	20 (17-23)	31/4
First molar	15 (14-17)	51/2	16 (14-18)	1/4
Second molar	18 (17-19)	10	27 (23-31)	3

Table 2. Chronology of deciduous teeth eruption. Adapted from Aliuddin. (6)

1.1.2 Chronology of permanent teeth

The emergence of permanent teeth normally starts around the age of 6 years. Usually, the mandibular central incisor and first molar develop at a similar time. After that, the lateral incisors erupt into the oral cavity. Then, the timing of canines, premolars, varies in between the mandibular and maxillary arch. An explanation of the sequence of eruptions is presented in (Table 3). A chronology of permanent teeth is presented in (Table 4).

Number	The tooth	Maxillary sequence order	Mandibular sequence order
1	Central incisor	Second	First or second
2	Lateral incisor	Third	Third
3	Canine	Sixth	Fourth
4	First premolar	Fourth	Fifth
5	Second premolar	Fifth	Sixth
6	First molar	First	First or second
7	Second molar	eventh	Seventh
8	Third molar	Eighth	Eighth

Table 3. The sequence of eruption of the permanent teeth. Adapted from Aliuddin. (6)

Teeth	Calcification	Crown completion (Years)	Eruption (years)	Root completion (Years)
Maxillary teeth				
Central incisor	3-4 months	4-5	7-8	10
Lateral incisor	10-12 months	4-5	8-9	11
Canine	4-5 months	6-7	11-12	13-15
First premolar	11/2-13/4 years	5-6	10-11	12-13
Second premolar	2-21/2 years	6-7	10-12	12-14
First molar	At birth	21/2-3	6-7	9-10
Second molar	21/2-3 years	7-8	12-13	14-16
Third molar	7-9 years	12-16	17-21	18-25
Mandibular teeth				
Central incisor	3-4 months	4-5	6-7	9
Lateral incisor	3-4 months	4-5	7-8	10
Canine	4-5 months	6-7	9-10	12-14
First premolar	13/4-2 years	5-6	10-12	12-13
Second premolar	21/4-21/2 years	6-7	11-12	13-14
First molar	At birth	21/2-3	6-7	9-10
Second molar	21/2-3 years	7-8	11-13	14-15
Third molar	8-10 years	12-16	17-21	18-25

Table 4. Chronology of the permanent teeth. Adapted from Aliuddin. (6)

1.1.3. Factors Influencing Tooth Eruption

The chronology and sequence of tooth eruption can be affected by different factors, including genetics, nutritional-based, and environmental contributing factors. Genetic factors represent a cornerstone in the process of tooth eruption. It is reported that up to 80% of the variation in eruption timing can be caused by genetic factors (6). With respect to nutritional conditions, it can exert an effect on tooth eruption process in terms of deficiencies of vitamins and minerals, like vitamin D and calcium. Therefore, it can potentially contribute to the delaying tooth appearance in the oral cavity. Furthermore, environmental factors, such as exposure to some toxins and pollutants could affect impact tooth eruption. However, there is lacking evidence about the contribution of the environmental factors on the discrepancy of tooth eruption process (2).

From the clinical viewpoint, chronology of tooth eruption is paramount in dental practice, as any deviations from the normal sequence or timing of tooth eruption can impact underlying developmental issues or systemic conditions. The failure or delay of eruption of primary teeth could be an indication of systemic conditions like hypothyroidism or nutritional deficiencies (6). In the same manner, the discrepancy in the eruption of permanent teeth can be an indication of different conditions, such as impaction, ectopic eruption, or crowding (2).

1.2 Third molar eruption

The word eruption is generally interpreted as the appearance of the tooth throughout gingival tissue in the alveolar process. It is originally derived from the Latin “erumpere”, meaning "to erupt" hence it refers to the movement of the developing tooth from its non-functional position towards the corresponding functional and anatomical position in the jaws (8). Regarding teeth development, the layer named ectoderm corresponding to the primitive oral cavity is composed of an epithelial lining. This epithelial lining contains two layers, a basal layer of columnar cells and outer layer of more flattened cells. The tooth buds are derived from this epithelial tissue that further develops the primary and permanent teeth. This tooth bud is formed of enamel forming tissue (enamel organ), dentin-pulp forming tissue (dental papilla), and the periodontal forming tissue (dental follicle or sac) which form the periodontal ligaments, alveolar bone, and cementum (9). Eruption is a complex process that is stimulated by several factors that eventually cause a tooth to migrate from the interior of the jaws into the oral cavity. It is controlled by bone remodeling mechanism regulated by dental follicle.This follicle impacts the metabolic process of alveolar bone and mediates the tooth eruption (10). Physiologically, it is a process that starts simultaneously with dental mineralization, root development and alveolar apposition. It occurs through multiple phases: pre-eruptive phase, intraosseous eruptive, mucosal penetration, pre-occlusal eruption, and post-occlusal eruption phase (10,11). The development takes place approximately at 3 to 4 years of age, with the formation of the enamel organ, followed by the appearance of the papilla and follicular wall at 6 years. The period of calcification develops between 7-10 years. Radiographically, the mandibular third molar germ becomes almost visible at the age of 9 years as the mineralization occurs between 8-10 years old (12,13). The process of development continues, and the total culmination of the crown is completed between the age of 12 and 16 years old. It is further proved that the full root formation with an open apex is attained at the age of 18 (9). According to the "normal pattern of dental eruption" it is estimated that the ages of eruption of the upper third molar tooth is between 18 to 20 years and the mandibular third molar is between 17 to 20 years. However, this eruption sequence could be subjected to delay up to the age of 25 years resulting in the status of impaction (13,14). This delayed process is provoked by different contributing factors including genetic, environmental, and pathological factors (15).

1.3 Mandibular third molar impaction (IMTM)

The phenomenon of tooth impaction is defined as the failure of a tooth to attain its physiological position in the expected time span. Generally, teeth that are frequently impacted are lower third molars, maxillary third molars, upper canines (16). It is reported that the prevalence of lower third molar impaction in population is 24 % (17).

During the eruption process, it is believed that the mandibular third molar changes the inclination from horizontal to mesioangular and finally to a vertical when the root formation is completed. The failure of achieving the vertical positioning would cause the third molar to remain horizontally or mesioangularly positioned (18). Richardson et al. (18) assumed different conditions that would lead to the occurrence of third molar impaction. Firstly, they pointed out that the third molar could be upright in the expected direction but insufficient to allow for eruption. The second condition signifies that the angular relationship of the third molar in relation to the mandibular plane remains unchanged. The third condition considers the mandibular third molar would be subjected to a reverse angular change that mediates the occurrence of impaction. Regarding the distribution of mandibular third molar impaction among genders, it was reported that it is more frequent in females compared to males (19–22). However, some other authors have defended that there is no gender predilection regarding the occurrence (15,23). Since mandibular third molar is the most frequently impacted tooth, the prediction of this condition is critical for better planning and overcoming possible complications of surgical procedures (24). Although this tooth has the potential risk of complications if it is presented as an impacted tooth, it is suggested that the routine and prophylactic removal of asymptomatic third molar lacks sufficient evidence (25). Therefore, it seems that the protocol of monitoring the condition is the most practical strategy (24).

1.4 Maxillary third molar impaction (MTM)

Maxillary third molar is expected to attain its position between the age of 18-25. However, various factors hinder the eruption process such as space insufficiency and tooth malposition. Like mandibular third molar, several complications can arise like dental caries, bone loss, pericoronitis, and cystic formation. Upon surgical intervention, other complications can occur such as maxillary tuberosity fracture, root fractures, displacement into the spaces, and maxillary sinus perforations. The location of the maxillary third molar near the maxillary sinus can lead to complications like sinus infections and oroantral fistula (26,27). According to the classification systems of the impaction positioning, maxillary third molar can attain different positions including vertical, mesioangular, distoangular, horizontal, or other direction. Yurdabakan et al. (28) addressed the angulation types of such tooth in addition to the relationship between the tooth and maxillary sinus are analyzed using cone beam computed tomography (CBCT). The findings indicated that the vertical type is the most frequent position accounting for 80.2% of their sample followed by distoangular one. In other study using panoramic radiography (OPG), Lim et al. (29) found that the vertical position is the most common type of impaction representing 38.4% followed by mesiangular, and disatnagular consecutively. Concerning the occurrence of maxillary third molar in genders, several studies have found it more frequent in females compared to males (21,22,30,31). The fact behind females preceding males in the impaction of maxillary third molar is the growth pattern in relation to gender-based differences. It was reported that the growth process in females discontinue at the time of third molar eruption in females. On the other hand, the growth process of the alveolar bone proceeds while the third molar eruption takes place. This condition describes the space availability for third molar eruption in men compare to women. Concerning the relevancy to the maxillary sinus, it is critical for the dental practitioners to be aware of the anatomical relationship between the roots of maxillary third molar and the maxillary sinus wall. On OPG, the occurrence of oroantral communication is predicted commonly when the floor of the sinus is projected over the roots of the tooth, in addition, the more the depth of the tooth, the more the risk of oroantral fistula formation (29). The oroantral communication or fistula might occur during the surgical removal of the maxillary impacted third molar as the thickness of the soft tissue and the bone can be as thin as 0.5 mm. as a result, the process of epithelialization takes place which further leads to the development of the inflammatory condition of chronic sinusitis. Studies illustrate that the surgical extraction of the maxillary third molar would lead to the perforation of the sinus cavity in around 13% of cases. Therefore, it was reported that the incidence of oroantral communication ranges between 10% to 23% considering the surgical procedure, the impaction position and depth (32). Illustration of the different types of maxillary third molar impaction is presented in (Figure 1) (33). OPG depicting Archer's 1 classification of MTMI is presented in (Figure 2). OPG depicting Archer's class 2 of MTMI is presented in (Figure 3). OPG depicting Archer's class 3 is presented in (Figure 4). OPG depicting Archer's class 4 is presented in (Figure 5). OPG depicting Archer's class 5 is presented in (Figure 6).

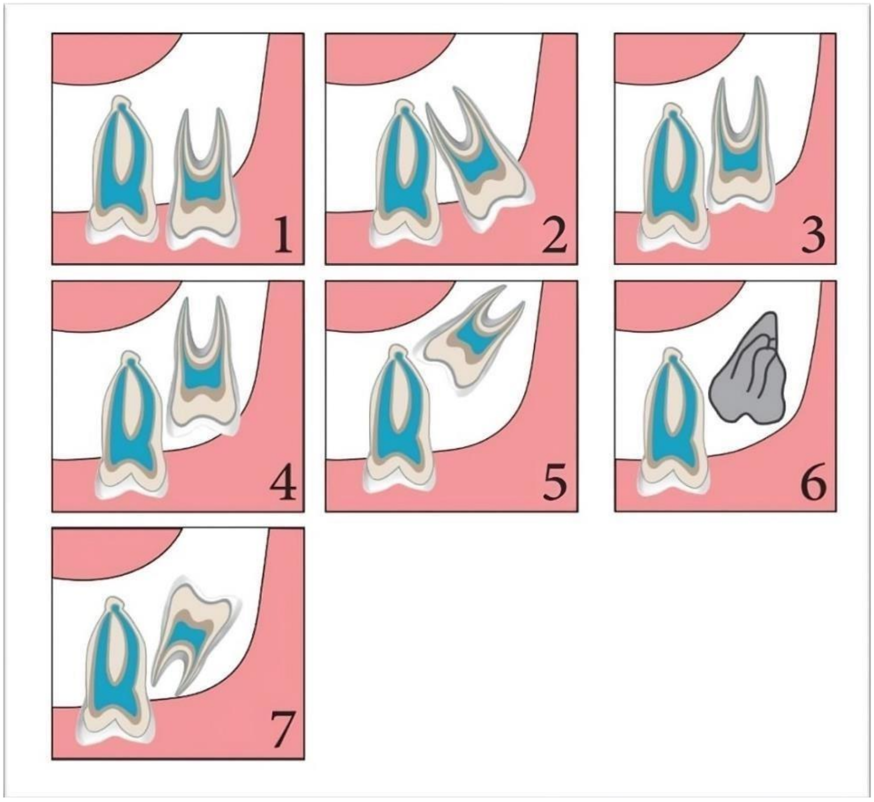

Figure 1. Archer's classification of the maxillary third molar impaction in relation to the neighboring second molar. in relation to the neighboring second molar. 1: the occlusal plane of third molar is at the level of the occlusal plane of the second molar, 2. The occlusal plane is just above the cementoenamel junction of the second molar, 3. The occlusal plane is at the same level as the cementoenamel junction of the second molar, 4. The occlusal surface is below the cementoenamel junction of the second molar, 5. The occlusal surface is above the root apex of the second molar. Recreated & adapted from: Miclotte A et al. (33)

Figure 2. OPG depicting upper bilateral third molar impaction of Archer's class 1. Image adapted from (HOUB)

Figure 3. OPG depicting upper right maxillary impacted third molars of Archer's class 2. Image adapted from (HOUB)

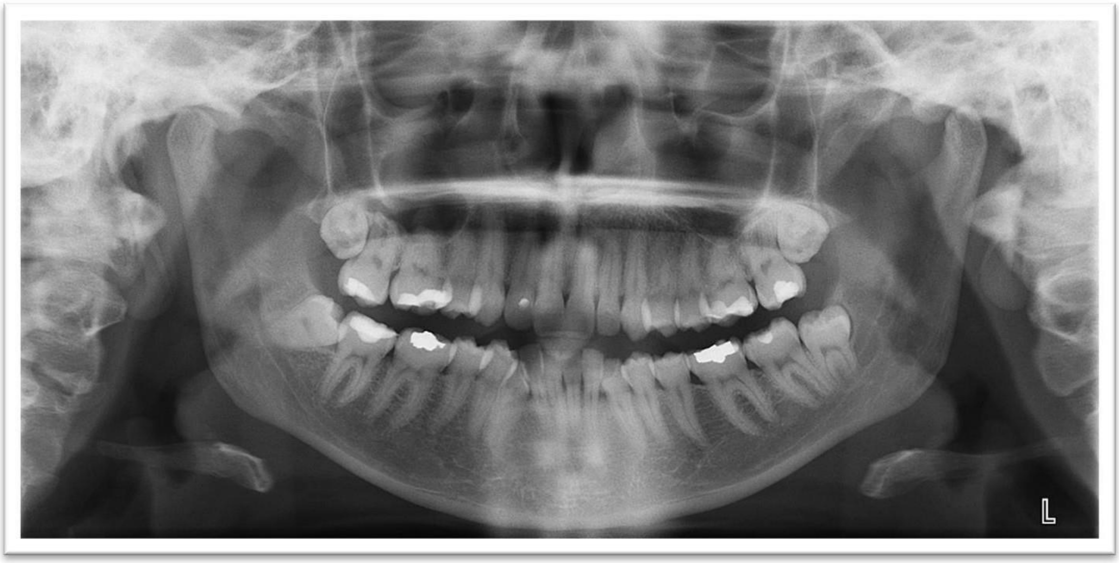

Figure 4. OPG depicting bilateral impacted maxillary third molar; Archer's classification 3. Image adapted from (HOUB)

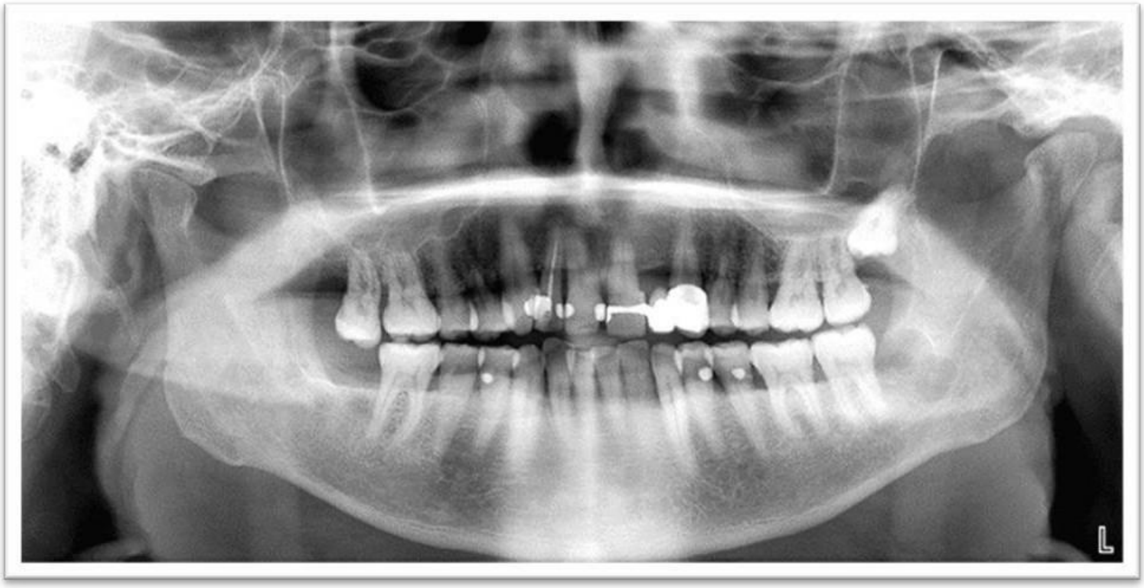

Figure 5. OPG depicting impacted maxillary third molar on left side; class 4. Image adapted from (HOUB)

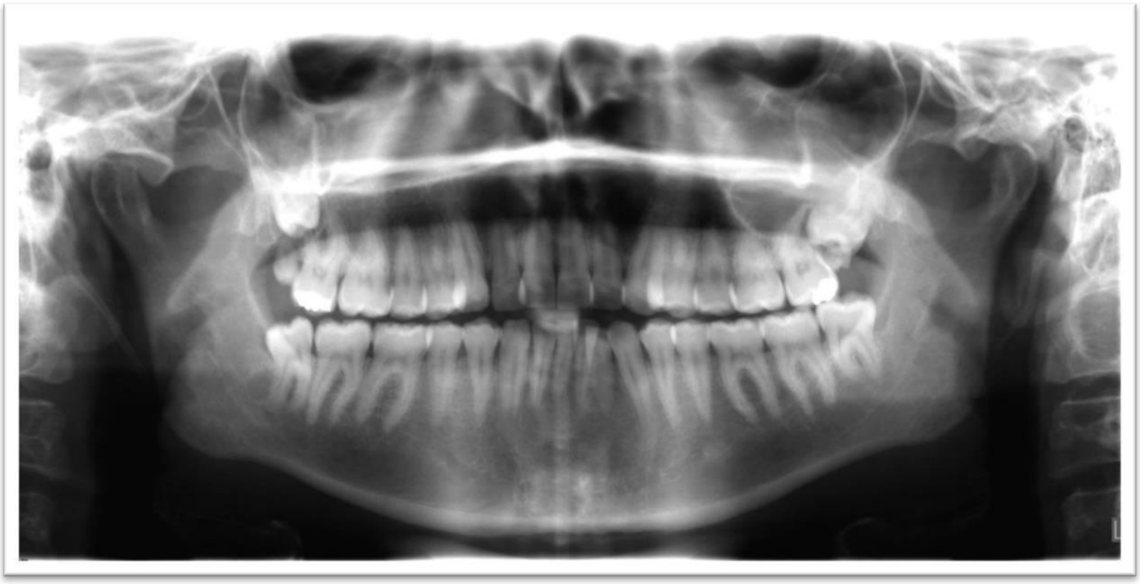

Figure 6. OPG depicting Archer's class 5 maxillary third molar impaction. Image adapted from (HOUB)

1.5 Maxillary canine impaction (MCI)

Maxillary canine impaction (MCI) is one of the commonly encountered dental problems by dental practitioners. It is considered the second impaction after third molarimpaction (34). The prevalence of MCI ranges between 0.8 to 8% based on different demographic population (35,36). The theory behind the occurrence of MCI is either thegenetic theory or the guidance theory. In genetic theory, it is assumed that genetic factors are the main cause of palatally positioned impacted canine resulting in familialtendency and gender preference. On the contrary, the guidance theory proclaimed that the length and timing of the lateral incisor root is a fundamental factor in guiding the mesially erupting canine into a preferred distal and incisor path of eruption (35). Several reasons lead to the occurrence of impacted MCI. It can be localized, generalizedor genetic causative factors. The localized factors include inconsistency of arch lengthand size, long retention of primary tooth, premature loss of primary tooth, ectopic position of the tooth bud, teeth ankylosis, presence of cyst, occurrence of tumors, abnormal configuration of the root, and idiopathic. On the other hand, the generalized factors include endocrinal insufficiency, head and neck radiation, febrile diseases, andnutritional inadequacy (37). To diagnose the maxillary canine impaction, clinical observation by noticing the absence of such tooth is the first step in expecting the problem. After that, the routine conventional radiography such as periapical and panoramic radiography indicate the presence of impaction. In their studies, Grybiene etal. (34). elaborated on the diagnostic methods and treatment strategies of impacted maxillary canine. Their results indicated that the cone beam computed tomography is accurate in determining the exact position of the canine and thereby determining the possible approach of management. Therefore, a less aggressive method can be decided.Furthermore, Novak et al. (38). Reported the use of cephalography in the late mixed dentition can identify the palatally positioned canine and thereby overcome the impaction by employing a suitable intervention. Concerning the conventional diagnostic methods, the vertical parallax technique is found to be more accurate compared to the horizontal parallax by 97.7% and 92.6% respectively (38). Althoughit is considered helpful in illustrating the presence of impacted canine, it is regarded asan inaccurate predicting method of impacted maxillary canine (39). Although panoramic imaging aids in prediction the impaction of maxillary canines, cone-beam computed tomography (CBCT) can identify the location of impacted maxillary canine precisely. The radiation can be via performing precise diagnosis in the suitable time considering the (ALARA) concept of radiology investigation; as low as reasonably acceptable (34,40). OPG revealing presence of MCI of upper left side (Figure 7).

Figure 7. OPG depicting impacted maxillary left canine. Image adapted from (HOUB)

1.6 Etiology of mandibular third molar impaction

It is documented in the literature that there are varieties of factors that contribute to the occurrence of impacted mandibular third molar (IMTM) and interfere with the tooth eruption in the anticipated time. These factors include abnormal positioning of the tooth bud, lack of space in the dental arch, presence supernumerary tooth, ankylosis of the deciduous or permanent tooth, obstruction of the pathways of eruption by pathological conditions such as cysts or tumors, and external oblique line and buccinator muscle influences (41). Additionally, it was reported that genetic factors play an important role in the process of odontogenesis. Hence, different genes in the human body regulate the development and formation of dental structures. The MSX1 and AXIN2 genes are thought to mediate the occurrence of tooth impaction in coexistence of environmental factors and other modulating genetic expressions (42). Specifically elaborating on the impaction of mandibular third molar, it is explained that imbalance between the process of bone deposition and absorption that takes place in the mandibular ramus is linked to the higher rate of mandibular third molar impaction compared to other impactions (43). Recently, the case reported by Jaiswara et al. indicated that there is a rare possible cause of mandibular third molar impaction related to the hamartomatous growth of the first and second molars (44).

1.7 Epidemiology of mandibular third molar impaction

Since the mandibular third molar is termed to be the most tooth prone to the impaction condition, multiple studies have been conducted in different demographic populations to address the impaction pattern of this tooth. Earlier in the century, Olasoji et al. (45) performed an analysis of 2400 images to investigate the impacted teeth in urban and rural parts of Nigeria. They demonstrated that the prevalence of mandibular and impacted teeth is more frequent in urban 10.7% compared to the rural civilization 1.1%. It is proposed that the diet change plays an important role in the difference of impaction rate. With respect to the pattern of impaction, it was noticed that the mesioangular impaction occurs more in the mandibular third molar compared to the vertical type in the maxillary third molar impaction. Muhammad et al. (46) analyzed the prevalence of IMTM among Arab-Israeli population. They found that the prevalence of such tooth impaction is 19.2%. The impaction presents more in males (62.2%) compared to females (37.8%) with no difference regarding the side of impaction. The mesioangular impaction was found to be the most frequent in 50% while the inverted type is the least common type of impaction. In their study, KalaiSelvan et al. (47) investigated the prevalence of IMTM in Indian population. There is a significant predominance of male 57% versus females 43% with respect to the impaction occurrence. About 1000 panoramic radiographies were retrieved for the investigation, of which 458 have impacted mandibular third molar. They indicated a prevalence of 45.8%. In addition, the mesioangular impaction is regarded as the most common type of impaction accounting for 60%. Furthermore, multiple studies have been performed in Saudi Arabia in different regions of the country. Zaman et al. (48) carried out an investigation of 17760 radiographies of non-syndromic patients. They found about 2187 images that show mandibular third molar impaction accounting for 12.31%. The mesioangular impaction are found to be more prevalent among other types of impactions. Similarly, Alfadil et al. (49) investigated the panoramic radiography of central region and found that the mandibular third molar is more impacted than the maxillary ones. Moreover, they speculated that there is no gender predilection with respect to the impaction occurrence. The most common reason behind the extraction of the impacted third molar is prophylactic followed by symptomatic. In the southern part of the country, Barimah et. al (50) found a prevalence of 16.5% of impacted mandibular third molar among their sample investigated by using panoramic radiography imaging. Females were found to have more impaction in comparison to males 59.5%, 40.5% respectively. They determined that the most frequent type of impaction is the mesioangular one. In Iranian population, Hashemipour et al. (30) concluded that the prevalence of third molar impaction in general is about 57.35% with females being dominating males. In addition, the mandibular impaction is claimed to represent 1.9 times more likely than maxillary. In 2013, Wahid et al. (20) investigated the occurrence of maxillary and mandibular third molar impaction. His findings indicated that the mandibular third molar occurs more frequently in comparison to the maxillary third molar. Regarding the impaction type, he found that the mesiaongular position is the most prevalent in the mandibular impaction. He has revealed a gender predilection in favor of females in comparison to males. In the population of Singapore Chinese, Quek et al. (21) performed the analysis using panoramic radiography of 1000 images. Their results revealed that the mandibular third molar is more frequent than maxillary one. The occurrence of impaction is higher in females 56% than in males 40%. The mesioangular impaction is noticed more frequently compared to the other classification. In Libyan population, it is found that the mandibular third molar impaction occurs more frequently compared to the maxillary impaction. The most prevalent position was found to be the mesioangular followed by the vertical type (51).

1.8 Bone on the distal surface of mandibular second molar

Teeth are embedded in the socket that is formed by bone tissue. Thus, periodontal health is paramount to the teeth survivability against bone loss. Bone loss can be caused by several factors including smoking habits, presence of impacted tooth, and general awareness of the patients. Impacted tooth including mandibular third molar impaction can possess a threat to the bone status on the bone on the distal aspect of mandibular second molar (9,12). The difficulty of cleaning access contributes to the accumulation of food and bacterial abundance that progresses to plaque formulation and the development of periodontal pockets considering other risk factors such as smoking habits. Theis leads to further manifestation of bone loss on the distal aspect of mandibular second molar that can be seen on radiographic imaging (19).

1.9 Mandibular third molar classifications

1.9.1 Winter's classification

Many classification methods of impacted third molar have been described in literature. In 1926, Winter proposed classification of impacted third molar based on the degree of angulation in relation to the adjacent second molar (52). The different subtypes of winter's classification are described as:

Vertical impaction: it is the condition where the long axis of the impacted third molar and the long axis of the second molar are positioned parallel to each other with an angulation of (10° to -10°). This is because during the tooth formation and eruption, the molar presents some obstacles, allowing the straightening of its emergence trajectory. The prevalence of the vertical impaction pattern is 38% of cases in mandibular teeth, being the third type of impaction that is difficult to extract (53–55).

- Mesioangular impaction: The long axis of the impacted third molar is projected with a mesial inclination with respect to the projection of the longitudinal axis of the adjacent second molar. The crown is in a mesioangular direction, which forms an anterosuperior angle of (11° to 79°). It constitutes approximately 43% of the total number of retained wisdom teeth, considering them to be more frequent and less difficult to extract (53,54,56).
- Distoangualr impaction: The impacted third molar is inclined in a distal direction with respect to the second molar, producing an anterosuperior angle of (-11° to -79°). Its position makes it prone to greater complication and a more invasive surgical intervention since the exit trajectory is projected inside the ascending ramus. Luckily, its frequency is low, and its prevalence represents 6% (53,54,57).
- Horizontal impaction: The projection of the axis of the occlusal plane of the impacted molar is directed towards the crown and root of the second molar in which the crown appears perpendicular to the second molar. It forms an angle of (80° to 100°) (53,54).

- Other impaction: this describes the other types of tooth impaction that are directed in a buccolingual direction with the crown being overlaps the roots. The degree forms range between (111° to -80°) (30). Schematic illustration of the different types of Winter's classification (Figure 8). Vertical and horizontal pattern of impaction is revealed in the OPG (Figure 9). Distoangular impaction pattern is presented in the OPG (Figure 10). Interesting case of both mandibular third and second molar impaction OPG (Figure 11). Transversal impaction third molar is presented in the OPG (Figure 12).

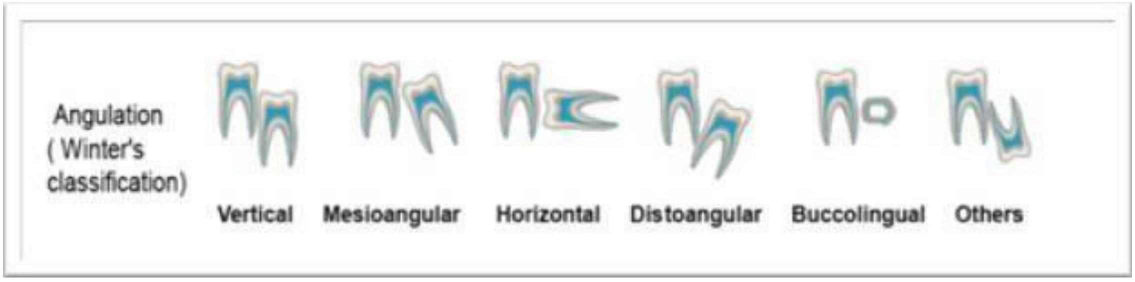

Figure 8. Schematic illustration of Winter's classification of mandibular third molar impaction. Recreated and adapted from: Muhamad et al. (46)

Figure 9. OPG depicts right vertical angulation and left horizontal angulation of impacted mandibular third molar. Image adapted from the Dental Hospital of the University of Barcelona (HOUB)

Figure 10. OPG depicting distally angulated impacted right mandibular third molar. Image adapted from (HOUB)

Figure 11. OPG depicting right inverted impacted mandibular third molar in association with distally oriented impacted mandibular second molar. Image adapted from (HOUB)

Figure 12. Panoramic image depicting mandibular transversal bilateral impacted third molar. Image adapted from (HOUB)

1.9.2 Pell & Gregory classification

Another classification of mandibular impacted tooth is adopted by Pell & Gregory (58). It is described in relation to the occlusal plane of the adjacent second molar into:

- Position A: it signifies that the crown of the impacted third molar is at the level of the occlusal plane or above it. It makes the crown of the third molar noticeable by clinical examination and can be found occluding with an opposing tooth, either with the opposing third molar or the second molar (54). Upon surgical intervention, this position represents simple extraction routes, since it is already in the occlusal plane, and it is considered that it does not present any obstacle that prevents its correct removal (30,53).
- Position B: the crown of the impacted third molar is positioned between the occlusal plane of the and the cervical line of the lower second molar. The crown of this type of impaction is immersed in the alveolar bone and soft tissue requiring a moderately invasive intervention, since they are closer to important structures and necessitate greater tissue removal (53,59).
- Position C: the crown of the impacted mandibular third molar is located below the level of the cervical line of the crown of the lower second molar. In this category, the third molar is enclosed within the maxillary or mandibular bone and covered by soft tissue, which makes it difficult to visualize by means of clinical examination (13,26,53,59). The surgical intervention increases its complexity because the third molar is retained and surrounded by hard and soft structures. Therefore, this position presents a higher incidence of complications with 39.7%, being more common the nerve damage of the lower dental arch (60,61). Additionally, Pell & Gregory subclassified the position of the impacted third molar according to the space available between the distal part of the lower second molar and the anterior part of the ascending ramus. The classification is reported as:
- Class 1: there is a sufficient space available between the anterior border of the ascending ramus and distal aspect of the 2nd molar for the eruption of the 3rd molar. The third molar has a greater or equal coronal dimension in the mesiodistal direction in relation to the space between the distal face of the second molar and the anterior edge of the ascending ramus or tuberosity of the maxilla, which allows the third molar to be confined within the space. Thus, its

location in front of these bony structures results in a proper location for intervention (56,62)

- Class 2: The space available between the anterior border of the ramus and the distal aspect of the 2nd molar is less than the mesiodistal width of the crown of the 3rd molar. It denotes that the distal portion of the crown of the 3rd molar is covered by the ramus bone. It presents a bony covering that covers the distal portion of the crown of the third molar, with a space that is less than the mesiodistal coronal diameter. Accordingly, its position results in a partially bone coverage because the mesiodistal diameter of the crown is smaller (53,59). The bony coverage covering the third molar inhibits the path of proper eruption towards the occlusal plane, which generates an increase in surgical complexity since it does not present complete path of eruption (54).
- Class 3: The 3rd molar is fully embedded in the bone at the anterior border of the ascending branch due to the absolute lack of space. It is obvious that the teeth of Class 3 present more difficulties for their extraction, since it is necessary to remove a relatively large amount of bone and there is a risk of damaging the inferior alveolar nerve (IAN) or fracture the jaw. The third molar is located inside the anterior border of the maxillary ramus or tuberosity; completely or partially, therefore it is immersed inside the mandibular ramus or maxillary tuberosity (53,54,63). The location and immersion within the bony structure provides poor accessibility and therefore an increase in the degree of difficulty in the surgical intervention and affects 70% of the. This represents the cause of approximately 15.45% of all post-surgical complications associated with paresthesia or damage to the inferior alveolar nerve (13,54,64). Schematic illustration of the different Pell & Gregory classification of IMTM is presented in (Figure 13). Position A pattern is presented in the OPG (Figure 14). Position B pattern is presented in the OPG (Figure 15). Position C pattern is presented in the OPG (Figure 16). Class 1 pattern is presented in the OPG (Figure 17). Class 2 pattern is presented in the OPG (Figure 18). Class 2 pattern is presented in the OPG (Figure 19).

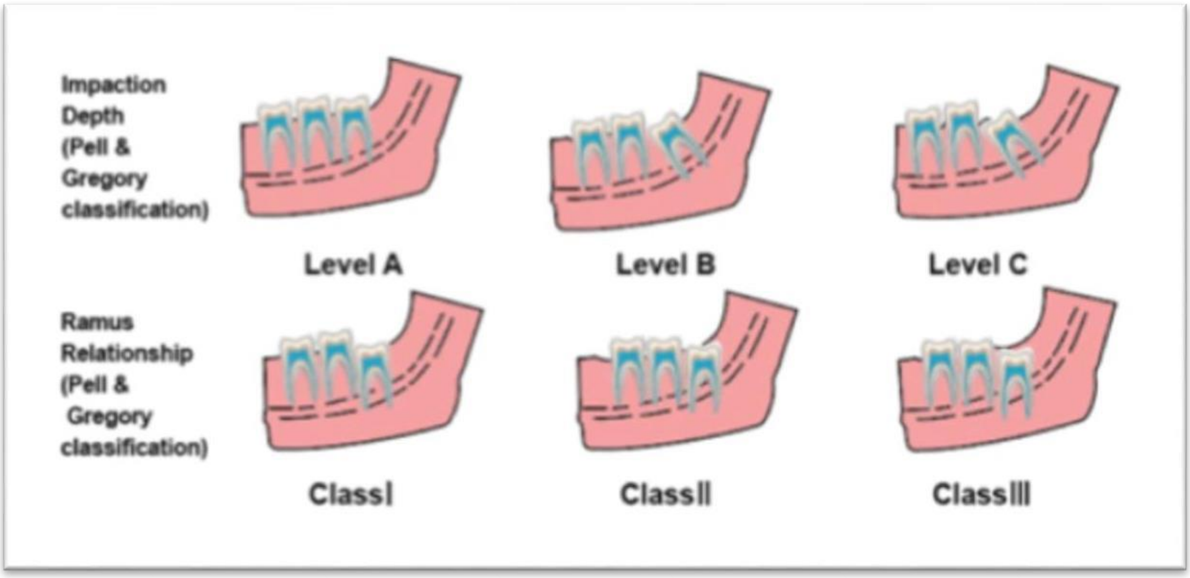

Figure 13. Schematic illustration of Pell & Gregory classification of mandibular third molar impaction. Recreated and adapted from: Muhamad et al. (46)

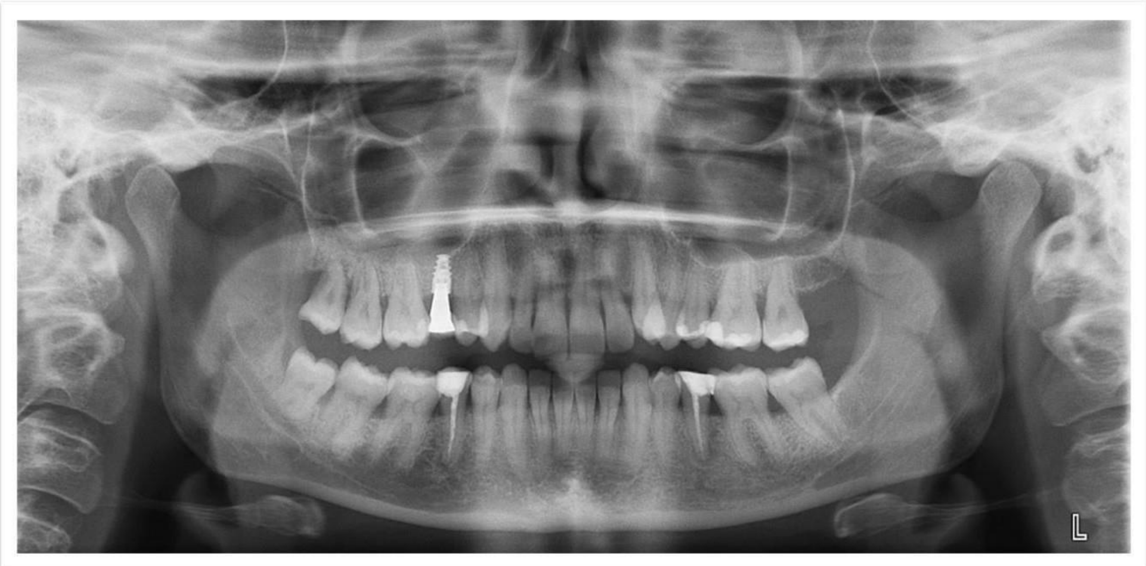

Figure 14. OPG depicting (Position A Pell & Gregory) impacted mandibular third molar on the right side. Image adapted from (HOUB)

Figure 15. OPG depicting (Position B Pell & Gregory) classification of IMTM on the right side. Image adapted from (HOUB)

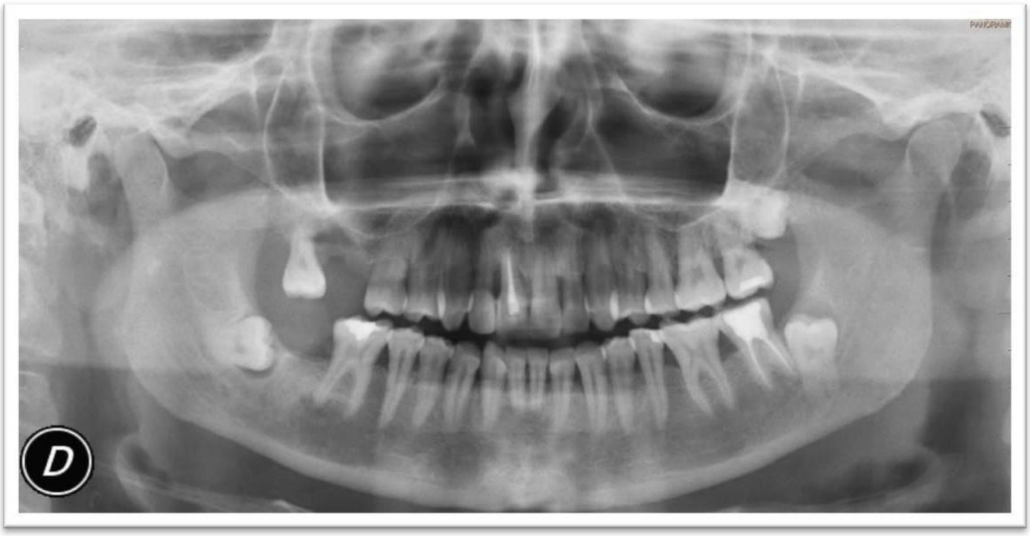

Figure 16. OPG depicting (Position C Pell & Gregory) classification of IMTM on the left side. Image adapted from (HOUB)

Figure 17. OPG depicting (class 1 Pell & Gregory classification) of IMTM on the left side where there is sufficient space to accommodate the tooth mesiodistally. Image adapted from (HOUB)

Figure 18. OPG depicting (class 2 Pell & Gregory) classification of bilateral IMTM where the space between the anterior border of the ramus and the distal wall of the second molar is less than the mesiodistal width of the IMTM. Adapted from (HOUB)

Figure 19. OPG depicting (class 3 Pell & Gregory) classification of IMTM on the right side. Adapted from (HOUB)

1.9.3 Tissue covering nature

Another possible pattern of classifying the mandibular third molar impaction is based on the nature type of tissue covering the impacted tooth (65). The soft Tissue Impaction indicates that the height of the tooth’s contour is above the level of the surrounding alveolar bone. Therefore, the superficial part of the tooth is covered solely by soft that can be dense or fibrous. Soft tissue impaction is known to be the simplest type of impacted tooth to remove. On the other hand, hard Tissue or the so called ('Bony') impaction refers to the condition where IMTM is totally covered by bone that in turns obstructs the path of eruption. This is where the wisdom tooth fails to erupt due to being obstructed by the overlying bone. This type of impaction can be furtherly subclassified into either partial and or complete bony impactions. Partial Bony impaction is the condition at which the superficial portion of the tooth is covered only by soft tissue while the height of the tooth's contour is below the level of the relevant alveolar bone. Aside from jeopardizing the gingival tissue and bone removal to expose the tooth, the tooth's roots may need to be furtherly divided. Complete Bony impaction. It is the case in which the tooth is completely enclosed in the bone. Accordingly, when the gingival tissue is cut and retracted, the tooth is not visible to the clinician. In this condition, bone removal in addition to root sectioning is necessary to remove the tooth. This type is regarded as the most complex tooth to remove (65). Complete bony impaction is shown in the OPG (Figure 20). Soft tissue impaction on the left side of the OPG is presented in (Figure 21).

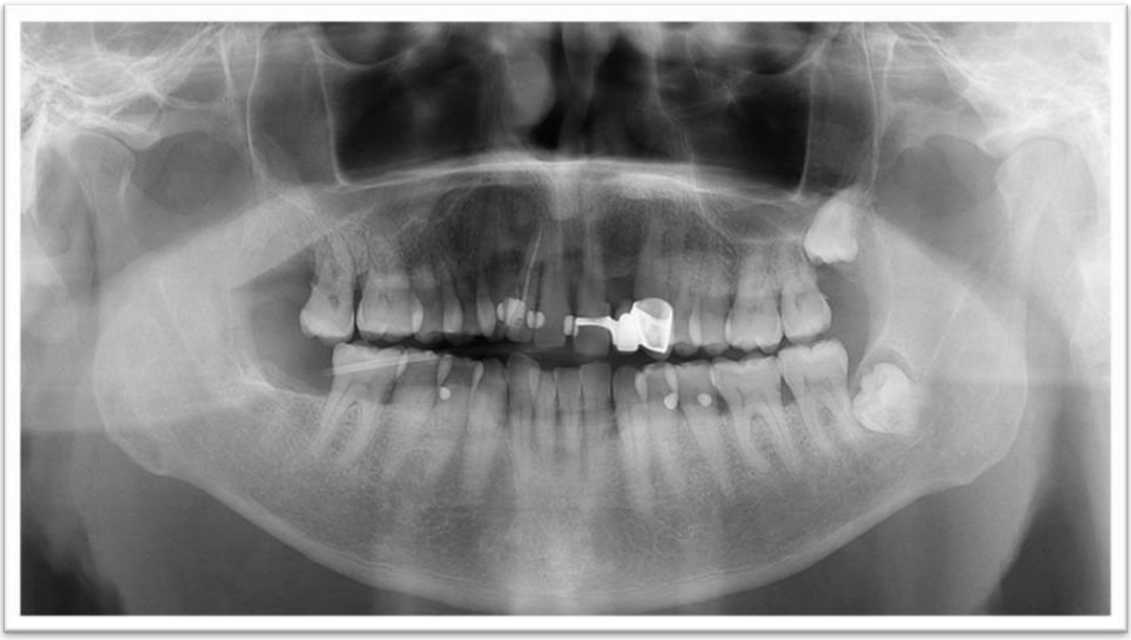

Figure 20. OPG depicting complete bone impaction of right IMTM. Image adapted from (HOUB)

Figure 21. OPG depicting soft tissue IMTM on the left side. Image adapted from (HOUB)

1.10 Radiographic diagnosis

1.10.1 Nature of x-ray

X-ray is a form of electromagnetic energy that propagates through space in the form of electrical and magnetic field. Multiple examples of electromagnetic radiations (EMRs) are illustrated in the literature including x rays, gamma rays, ultraviolet rays, radio waves, microwaves, and radar. Additionally, EMRs are termed as an ionizing radiation if they possess a significant energy that can eject electron from the irradiated atoms of the tissue passing through (66). X-ray described by Roentgen in 1896 is a form of ionizing electromagnetic radiation that has neither weight nor electrical charge. They have higher energy and can propagate through objects including the human body. To illustrate, x-rays are produced when high speed-moving electrons undergo sudden deceleration on collision and interaction with the target anode in an X-ray tube. The electrons are ejected by the cathode which is heated up by the electric current flowing through it (67). As an adjunctive method for the clinical examination, radiographic investigation contributes to a better diagnosis and understanding of any pathological condition. Accurate diagnosis is the milestone of proper surgical management in a maxillofacial region. Although definitive diagnosis might be possible in some patients relying on clinical assessment in the outpatient department or emergency setup, other cases may necessitate the use of additional investigations, including radiological imaging. It is known that the scope of radiology is vast, playing a crucial role in disease management (68,69). As a dental clinician or surgeon, after having made the diagnosis, it would be required to have a comprehensive knowledge of any ongoing disease process within the patient. Therefore, maxillofacial radiology provides an important supporting role in the guidance of the clinician to map out the region being managed. It is therefore prudent for clinicians to have acquire the knowledge of the concepts of oral radiology, aiding them understand its applications in the diagnosis of a patient's clinical task. The core of practice of an oral surgeon includes both surgical and nonsurgical conditions involving the orofacial region (69). Regarding the imaging of the maxillofacial area, there are different types of modalities that assist the managementof dental conditions and lead to better decision making (70). Dental imaging is generally divided into conventional two-dimensional imaging and the most advanced techniques of three-dimensional imaging. Conventional Radiography is one of the imaging methods that have been utilized since the early days, ever since x-rays were discovered by Wilhelm Conrad Roentgen in 1895. Yet, it is considered a poor option for anatomical assessment due to the inherited overlapping of structures particularly in the head and neck area. However, it still has its basic diagnostic use in practice. Their popularity is gained due to their availability, less time-consuming imaging, and provides a glance of the region of interest (69). Mandibular impacted third molar can be initially assessed by conventional radiography. However, in a justified case, the use of CBCT is indicated (71).

1.10.2 Intraoral radiography

Intraoral imaging is considered as the primary diagnostic tool in dental practice. There are three types of intraoral radiography projections including periapical projection, occlusal, and bitewing technique. Intraoral periapical radiography showing mandibular molars is presented in (Figure 22).

1.10.2.1 Periapical radiograph

It provides an image of the entire tooth in association with the surrounding bone structure and depicts the changes in the bone just peri apically or laterally to the root of tooth in addition to the screening of carious lesions, crown fractures, root fractures and pathology (72). Periapical imaging is obtained through either paralleling technique or bisecting angle technique. The paralleling technique is termed as the most appropriate as it produces less distortion than the other technique. It is obtained by positioning the film or digital sensor parallel to the long axis of a tooth while directing the central x-ray at right angle to the radiograph and tooth (73). To overcome the possible magnification and enhance the sharpness of the image, it is necessary to position the source of x rays in a relative distance from the teeth. The bisecting angle technique follows Cieszynski’s concept of isometry which simply states that two triangles are equal in case they share one side and two equal angles (72). This is applied in the periapical dental imaging by positioning the radiograph adjacent to tooth. Then, an imaginary line is formed between the tooth and the radiography on which the central x rays are directed. This technique is preferable where the paralleling technique is impractical due to thick sensor or abnormal anatomy of the dental arch (74,75). Periapical radiography depicts part of the inferior alveolar nerve canal and molar teeth

(Figure 22 A, B). Additionally, it identifies pathological changes like apical periodontitis and bifurcation involvement of the molar teeth. (Figure 23).

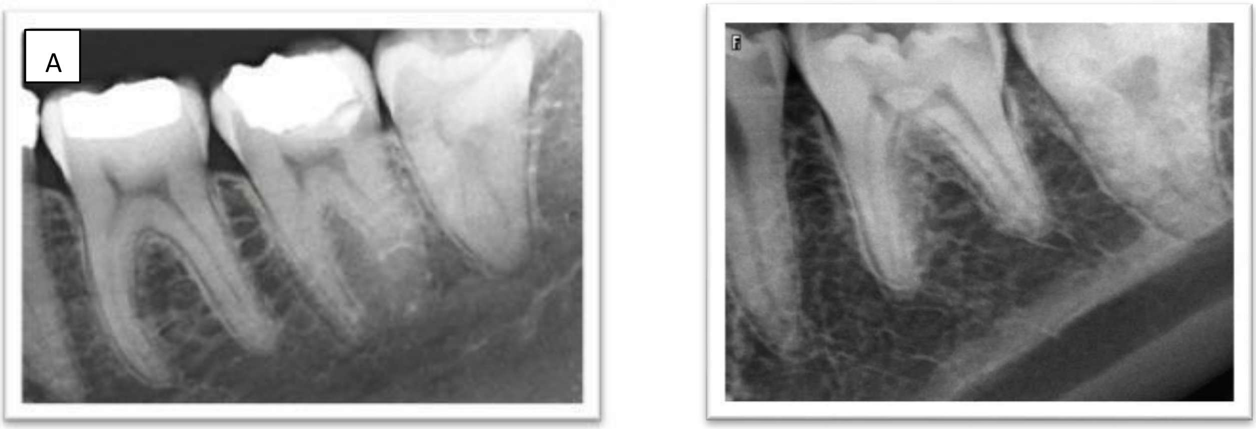

Figure 22. (A & B). Periapical radiograph depicts part of the inferior alveolar nerve canal and molar teeth. Adapted from (HOUB)

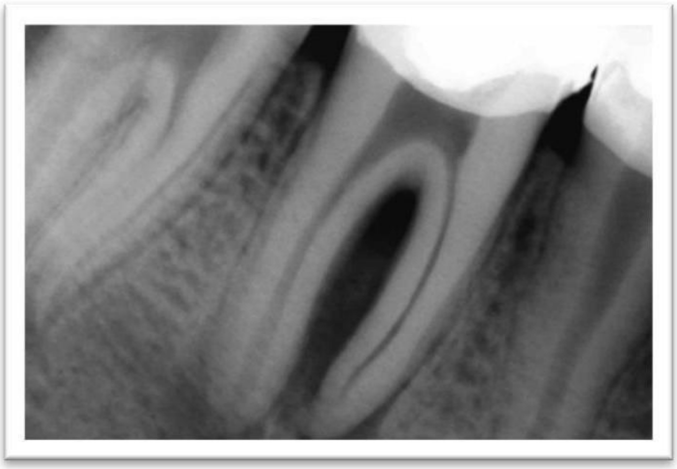

Figure 23. Intraoral periapical radiograph depicting periapical periodontitis with bifurcation involvement of the mandibular first molar. Image adapted from (HOUB)

1.10.2.2 Bitewing radiography

It simply refers to the use of a wing attached to the film to bite on by the teeth. Therefore, the name is derived from this type of radiography. The bitewing radiograph(BW) is an image that depicts the maxillary and mandibular crowns of the teeth, providing a clear image of the interproximal surfaces of the teeth and allowing for screening of interproximal carious lesions (76). At the same time, the maxillary and mandibular alveolar crests are imaged allowing for the evaluation of their levels, contributing to the assessment of periodontal status. Additional important findings weredetected on the bitewing radiograph, including the status of interproximal restorations and the presence of calculus. Mainly, this method of diagnostic radiography is used forthe detection of the interproximal caries (75). Intraoral bitewing and periapical radiographs can be taken using either film or digital sensors. Digital technology systemshave the advantages of reducing patient exposure, time savings, image improved qualities, simplicity of image storage, retrieval, and transmission (77). Series of bitewings radiographies shown in (Figure 24, 25).

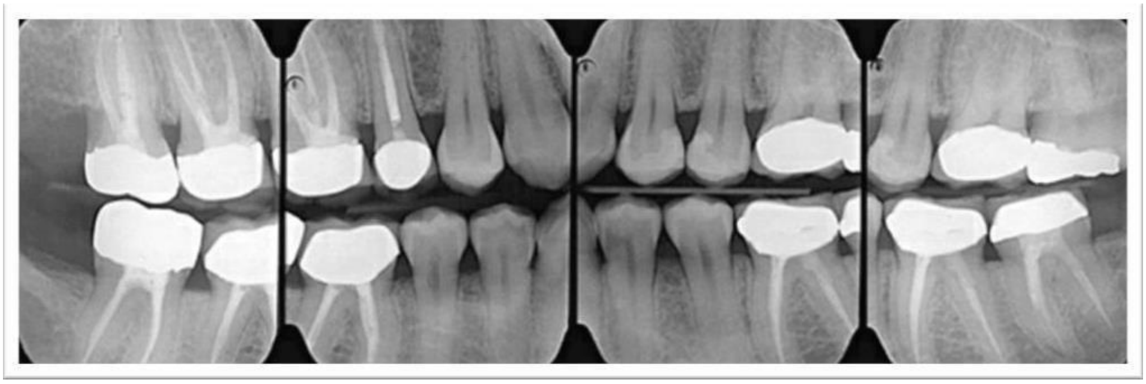

Figure 24 A set of full-mouth bitewing radiographies. Adapted from: White and Pharoah's Oral Radiology: Principles and Interpretation. Elsevier Health Sciences. (73)

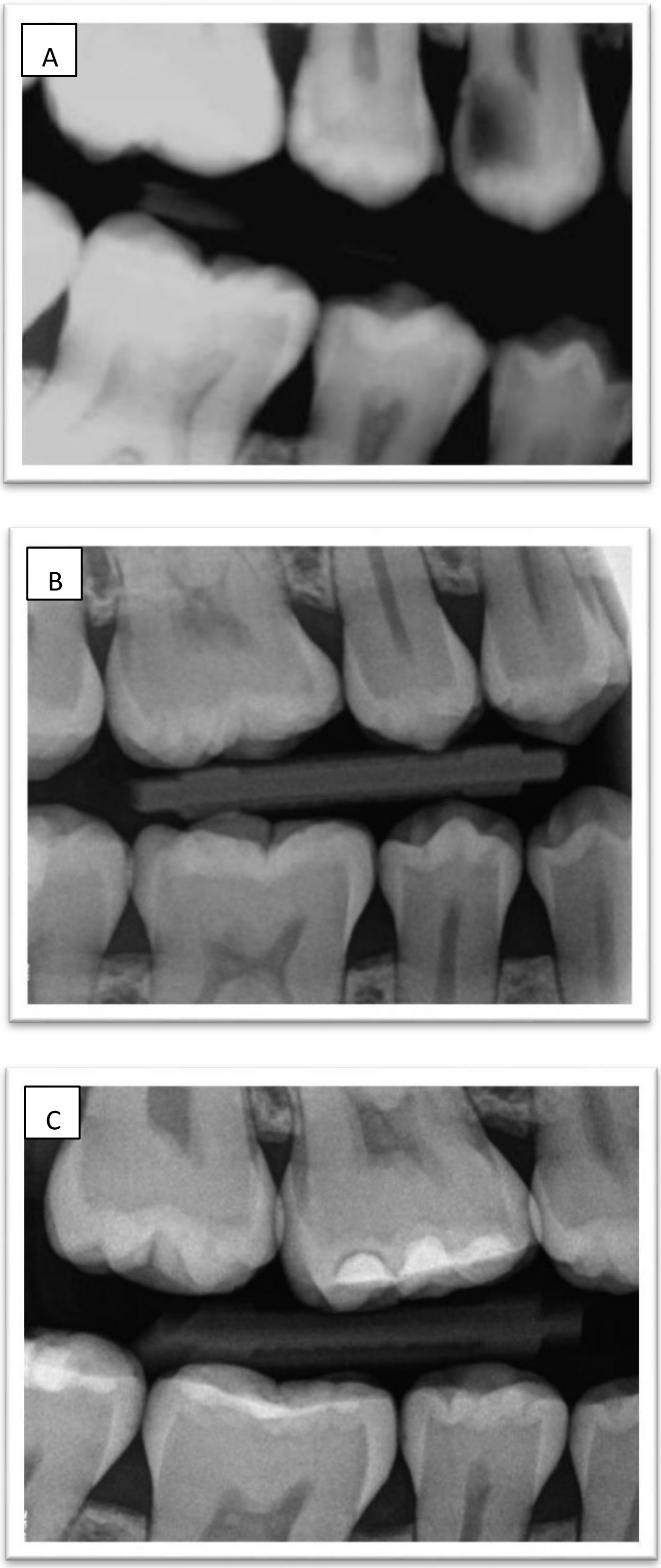

Figure 25. A).Bitewing radiography depicting proximal caries of upper premolar. B).Bitewing depicting molar and premolar teeth. C). Bitewing depicting dental restoration in upper first molar. We notice that this type of radiography technique shows clearly the occlusal part of the teeth up to the alveolar crest. Therefore, it is bebenficial in showing the caries particularly the proximal ones and if there is any sign of interproximal bone loss. All images adapted from (HOUB)

1.10.2.3 Occlusal radiography

It is a type of intraoral radiography projection that is obtained by placing the x ray film between the occlusal surface of the maxillary and mandibular teeth. The x ray beam is directed at either 90 or 50-60 based on what is required to be imaged (73). Therefore, the occlusal radiography shows a broad image of the dental arch either the mandible or the maxilla. It is thought to be useful in cases where there is limitation in mouth opening. In addition, it is valuable in revealing the status of supernumerary, unerupted or impacted teeth. Similarly, it is beneficial in the localization of foreign bodies and sialolith in the sublingual or submandibular gland. Moreover, occlusal film is thought to be valuable in localizing the position and the status of fracture displacement of the mandibular or maxillary alveolar bone (68,78). Maxillary occlusal projection shown in (Figure 26). Mandibular occlusal projection shown in (Figure 27).

Figure 26. Maxillary occlusal projection. Adapted from (HOUB)

Figure 27. Mandibular occlusal projection. Adapted from (HOUB)

1.10.3 Extraoral radiography

1.10.3.1 Panoramic radiography (OPG)

Developed by Prof. Yrjö Veli Paatero in 1948, orthopantomography (OPG) is the most commonly diagnostic tool in the field of dentistry. This technique produces a single broad image of the mandibular and maxillary arches in addition to some facial structures like maxillary sinus, zygomatic bones, nasal cavity, and temporomandibular joints (79). To capture the image, the x-ray source rotates posterior to the patient's head, producing an x-ray beam that is restricted to a narrow vertical beam through a lead collimator located at the front of the tube head. The detector holder simultaneously passes in front of the patient's head; therefore, it moves in the opposite direction to the x-ray beam allowing for exposure of only a small part of the doctor or film through a narrow slit. The rate of detector holder movement is correlated to the rate of X-ray beam motion as it sweeps through the patient's tissues, balancing the vertical and horizontal magnification of structures in the image and thus minimizing image distortion (73,78). While x ray tube and the detector rotate around patient's head, it produces a zone called focal trough. The structures located into this zone are portrayed clearly on the radiograph. Nonetheless, structures that are beyond the focal trough appear blurred, magnified, distorted, and reduced in size (80). There are several indications for the use of panoramic radiography including comprehensive assessment of the dentitions, mapping out the presence of pathology such as tumors and cysts, identification of impacted teeth, and general evaluation of maxillomandibular trauma (81). OPG is regarded as a valuable and convenient tool for patients complaining of trismus and those who are intolerable to the intraoral radiography. Furthermore, obtaining a panoramic radiograph is comparatively simple with proper patient positioning (82). Apart from this, panoramic radiography has its own limitations including the improper display of the fine details of structures, magnification of objects that complexify the linear measurement, superimposition of structures, unavoidable positioning errors of patients, and image artifacts. Due to the presence of many facial structures in the image, a better understanding of the normal anatomical structures and variations is necessary for proper assessment of the image (83). Concerning the assessment of the mandibular third molar impaction using OPG, it is still considered the baseline diagnostic imaging for assessing the type of impaction and the potential proximity to the inferior alveolar nerve canal. It was reported that the damage to the nerve ranges between 0.35%-9.4%. However, the permanent inferior alveolar nerve damage is reported to be around 1% (84,85). With all possible difficulties of using the most advanced imaging modalities. Panoramic radiography is still used widely before the removal of the third molar and predicts proximity to the inferior alveolar nerve canal relying on the criteria described by Rood and Shehab (86). Schematic illustration of panoramic radiography technique (Figure 28).

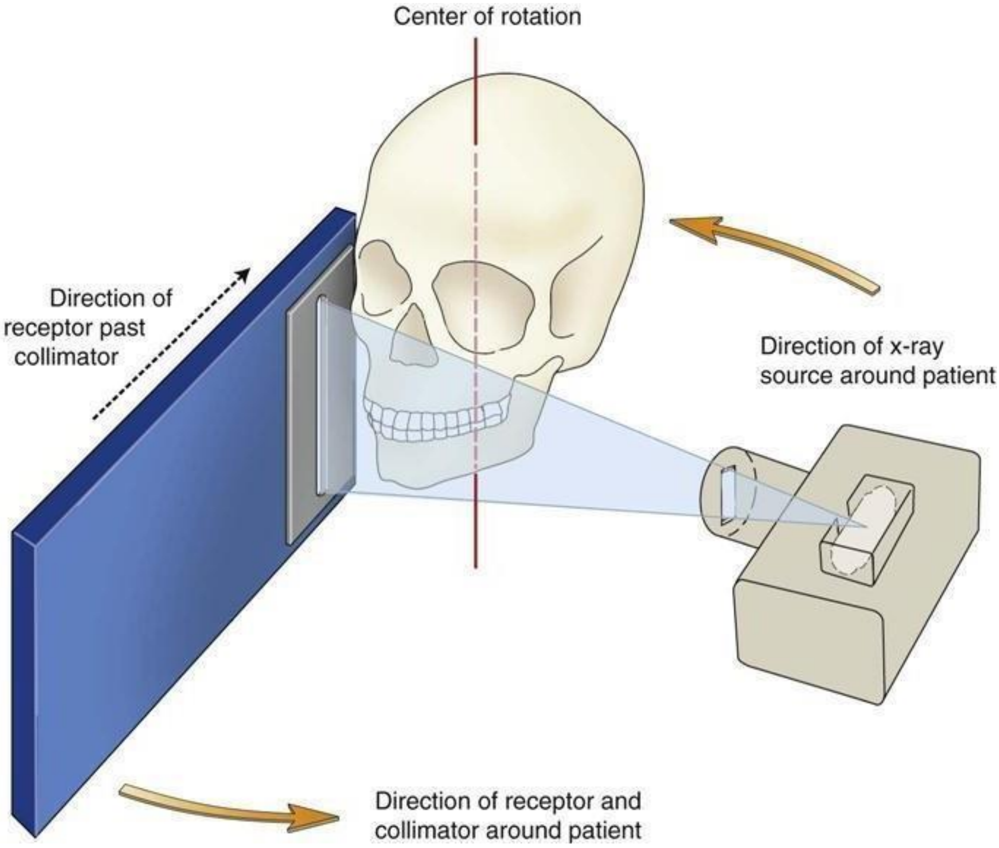

Figure 28. Schematic illustration of panoramic radiography technique. Adapted from: White SC, Pharoah MJ. White and Pharoah's Oral Radiology: Principles and Interpretation. Elsevier Health Sciences. (73)

1.10.3.2 Computed tomography (CT)

A computed tomography (CT) scan, commonly regarded as a CT, is a radiological imaging technique often used in the field of medicine including head and neck investigations. The machine was developed by physicist Allan MacLeod Cormack and electrical engineer Godfrey Hounsfield. Their pioneer work has granted them the award of the Nobel prize in Physiology or Medicine in 1979 (87). The CT scanner was installed in 1974. Since that time, technological advancement has provided the possibility of converting single images into three-dimensional informative images. Since its discovery, CT has witnessed different generations of machines, and the fourth generation is the most recent one. In this generation, the x-ray solely rotates within a full stationary ring of detectors. Compared to the third generation, the fourth-generation detector is activated less frequently providing more time to access the information in each detector and prepare it for upcoming scan. However, scattered radiation and dose are the main drawbacks of fourth-generation scanners (88). CT scanner is composed of a gantry containing the x-ray tube and the detectors, and table on which the patient lies down. The x-ray tube emits radiation in the form of fan shaped beam that passes through the patients and captured by detectors. Then, cross-sectional images are reconstructed. Formerly, the x-ray tube and the detectors move in a synchronous path around the patient. In the modern design of CT, the images are acquired in a helical form. This is called helical CT (71). To acquire the image, the patient lies down on the table which advances through the gantry while the x-ray tube and detectors revolve around the patient. The most recent type of CT is called multidetector helical computed tomography (MDCT). It was introduced in the year 1998. In this type of CT, several 64 or 128 detectors are used. Regarding the scanning time, the time required for the x-ray tube to make the image is reduced to 0.25. These advancements provided the acquisition of the images in multiple slices within a considerable short time, and thereby reducing the exposure time and possible artifacts that can be caused by the motion (72). After the emitted photons are captured by the detectors, the signal is prone to amplification and digitization. Then it is sent to the computer for analysis. The image is reconstructedby the process called Feldkamp reconstruction. The images can be viewed in axial, coronal, and sagittal forms. CT has the advantages of viewing the object in a bone window or soft tissue window according to the required area to diagnose (73). Above all, CT still has the disadvantage of delivering high radiation doses to the patients and its uses in dentistry is limited nowadays to complex pathological process and traumatized bone. However, the introduction of cone beam computed tomography has (CBCT) replaced the application of CT in dentistry unless justified (74,76). Different CT generations are presented in (Figure 29). Schematic representation of the technique of helical CT shown in (Figure 30). The coronal section of CT with soft tissue and bone windows showing the alveolar arch and soft tissue (Figure 31). (89). The coronal section of CT indicating enlargement of buccal gingiva (Figure 32). (90).

Generation	*Configuration*	*Detectors*	*Beam*	*Minimum-scan time*
First	Rotate translate	1–2	Pencil thin	2.5 min
Second	Rotate translate	3–52	Narrow fan	10 sec
Third	Rotate-rotate	256–1,000	Wide fan	0.5 sec
Fourth	Rotate-fixed	600–4,800	Wide fan	1 sec
Fifth	Electron beam	1,284	Wide fan	33 ms
		Detectors	Electron beam	

Figure 29. CT generations differences. Adapted from: Karjodkar FR. Essentials of oral & maxillofacial radiology. (89)

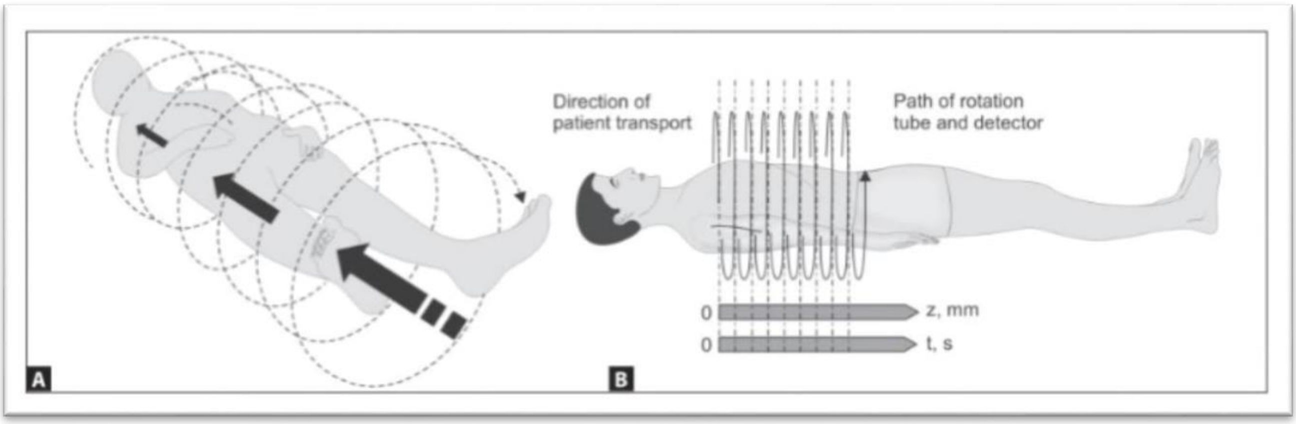

Figure 30. Schematic representation of the technique of helical CT and how it works. Adopted from the book of essential of oral and maxillofacial radiology by Karjodkar et al. (89)

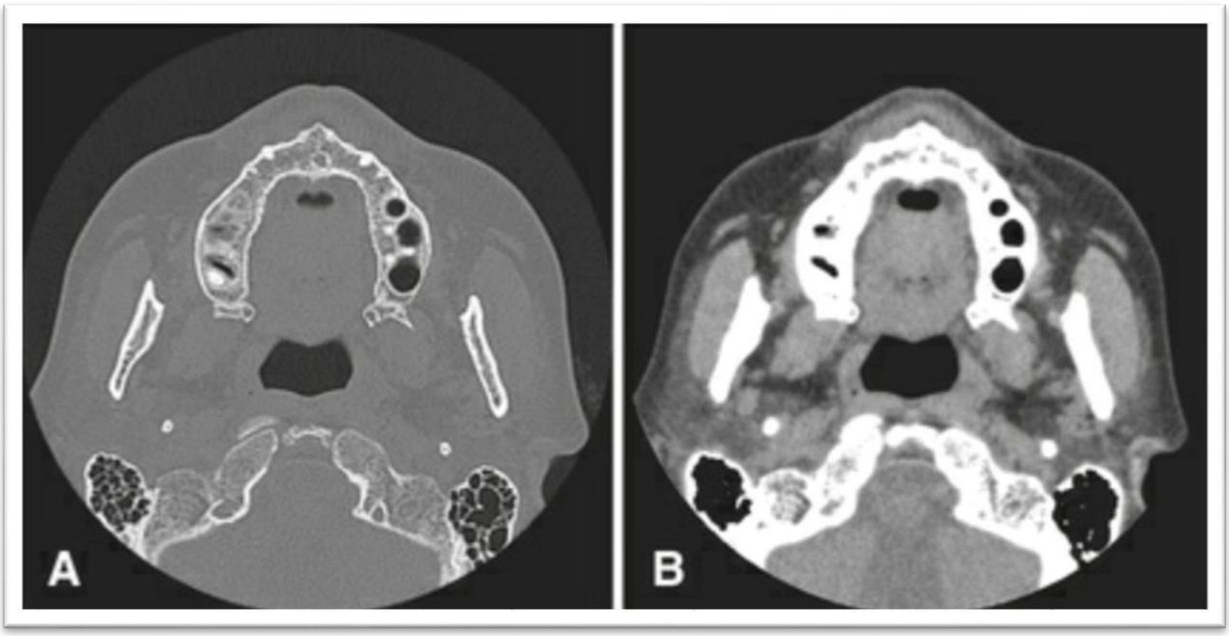

Figure 31. A) bone window of CT scan showing the alveolar arch. B) soft tissue window of CT. Adapted from: White SC, Pharoah MJ. White and Pharoah's Oral Radiology: Principles and Interpretation. Elsevier Health Sciences. (73)

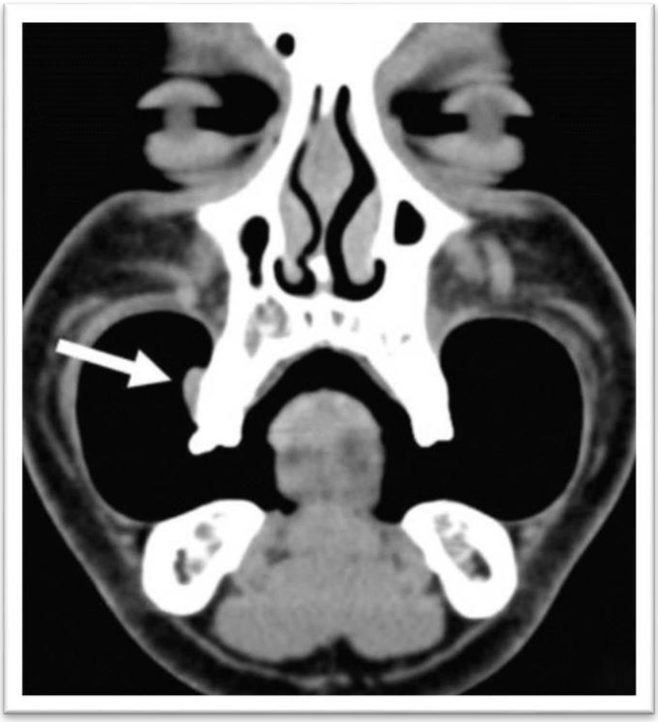

Figure 32. Coronal section of CT with soft tissue window indicating enlargement of the buccal gingiva of the maxillary right side. Coronal section of CT with soft tissue window indicating enlargement of the buccal gingiva of the maxillary right side. Adapted from: Law CP et al. (90)

1.10.3.3 Ultrasonography (US)

Ultrasound imaging is a diagnostic tool that is used in the medical field for the diagnosis of different diseases. The first pioneering use of this diagnostic modality was done by Baum et al. (91) in 1958. He tried to image the entire surface of the tooth structure using ophthalmic scanner with a frequency of 15 megahertz (MHz) (92). The sound waves exceeding 30 Hz-20KHz is termed ultrasound (93). Therefore, (US) uses high frequency sound waves that are transmitted through the body structures using transducer. The echoes from the structure are further detected and shown on the monitor's screen. The transducer is formed mainly of piezoelectric crystals. These piezoelectric crystals are made of a material that changes the electrical signal exerted on them into a mechanical vibration and vice versa. Thus, sound waves are produced and transmitted to the tissue being investigated (93). The propagation of sound waves is different between solid and liquid or soft mediums. The hard tissue like bones absorbs fewer sound waves and reflects higher waves back. On the other hand, soft tissue absorbs more sound waves and reflects fewer sound waves (94,95). Accordingly, hard tissue produces an echoic white image while soft tissue procures echoic black or dark image. In maxillofacial region, it has been stated that the major clinical application of this diagnostic modality over the past years concentrates on salivary glands pathologies and sialolithiasis (96,97). Consequently, this imaging modality has many applications in the field of maxillofacial area since it offers a non-invasive and safe alternative to the conventional imaging techniques. It is considered beneficial for visualizing salivary glands and diagnosing different pathological changes such as tumors, sialolithiasis, and salivary gland infections. It can also be utilized in the process of guide fine-needle aspiration biopsies of the salivary glands (96,97). Ultrasonography of the neck showing a stone in the left submandibular gland (Figure 33 a). The corresponding CT scan (Figure 33 b).

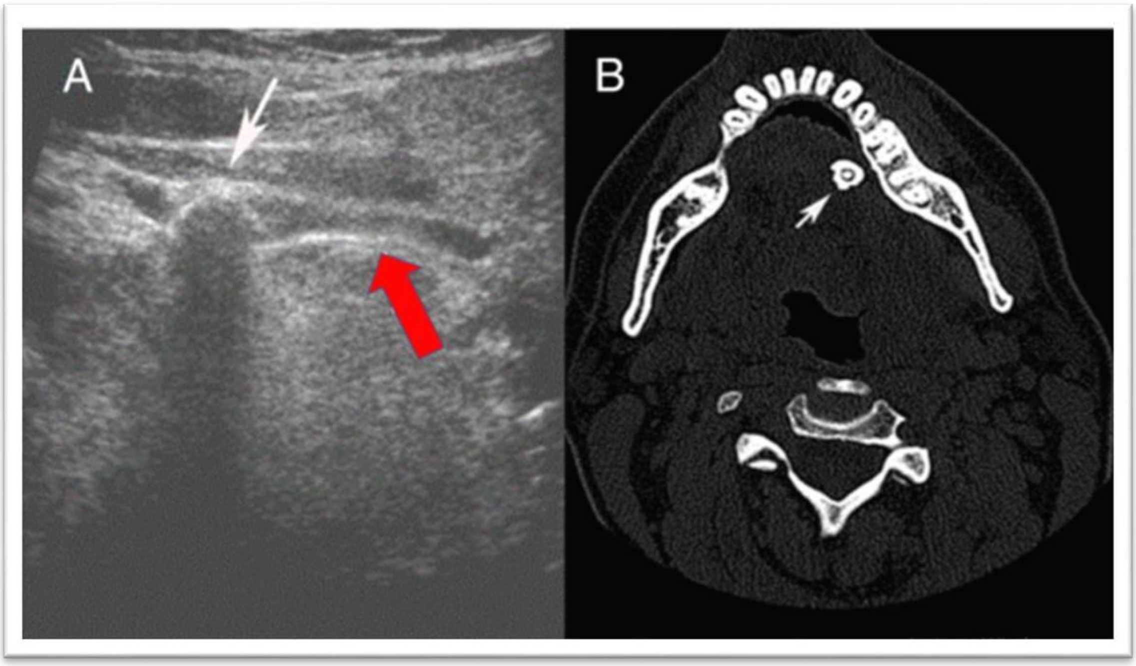

Figure 33. A) US of neck showing a stone in the left submandibular gland (white arrow) about 1 cm and the dilatation of the duct (red arrow). B) Neck axial view of the CT scan showing the stone in the left submandibular gland measuring 1 cm (white arrow). Adapted from: El-Rasheedy et al. (97)

1.10.3.4 Magnetic resonance imaging (MRI)

In 1973, y Lauterbur produced the first ever image through magnetic resonance. Mansfield is credited for his work of developing the magnetic field and mathematical algorithm for the image reconstruction. Both were granted the Noble prize in 2003 for their exceptional work on this subject. MRI is regarded as an imaging technique that uses not ionizing radiation instead of ionizing radiation to produce an image of the body structures (98). MRI scanner is basically formed of main magnet, gradient coil, radiofrequency coils (RF), and computer system. The magnetic field is produced by the electrical current through a wire that is housed by a liquid coolant containing helium. The RF coils primarily transmit radiofrequency energy to stimulate the proton of the hydrogen atoms in the human body. Then, the computer system manipulates and processes the image formed for further analysis (99). Biologically, the human body contains hydrogen atoms that are formed of single proton spinning in a random direction. Each proton has its own magnetic field. Upon application of magnetic energy like MRI in the form of radiofrequency, these atoms align themselves either in a parallel or antiparallel direction. MRI has radiofrequency coils that detect the magnetization to form an MRI image (100). The clinical application of MRI technique in the field of dentistry is commonly used for diagnosis of temporomandibular joint (TMJ) diseases that causes degeneration of the TMJ discs, inflammatory process of the facial bones, pathological changes of salivary glands, maxillary sinuses abnormalities, facial muscles related conditions, mapping out bone changes like tumors, fractures, inflammatory conditions, and hematoma (101). MRI is considered a promising imaging tool in various dental aspects since it has many advantages. It is regarded as a non-invasive technique. Furthermore, it does not expose patients to ionizing radiation. In addition, itis beneficial in the differentiation between the soft and hard tissue due to its high contrast resolution. Since MRI is independent of ionizing radiation, it is termed safe for use in children, and pregnant patients unless a contrast agent is advised. Like other three-dimensional techniques, MRI images can be viewed in sagittal, coronal, and axial. This technique can determine the invasiveness of tumors to the surrounding soft tissue (68). A study performed by Burian et al. (102) investigated the visualization and delineation of the inferior alveolar nerve and lingual nerve. The STIR sequence of the MRI provided the highest signal to noise ratio and the best muscle contract to noise ratio for both nerves. Their results are termed promising in terms of visualization of the anatomy of the nerves and in the further surgical procedure in the molar area. Illustration of histological section through second premolar in the left mandible of an ex vivo human specimen and section of MRI of the tooth with identical visible structures are presented in (Figure 34, a & b). The Sagittal section of CBCT depicts delineated details of dental pulp, gingiva, spongious bone and inferior alveolar nerve (Figure 35). Corresponding Sagittal section of MRI depicting discerned details of dental pulp, gingiva, spongious bone and inferior alveolar nerve (Figure 36). (103)

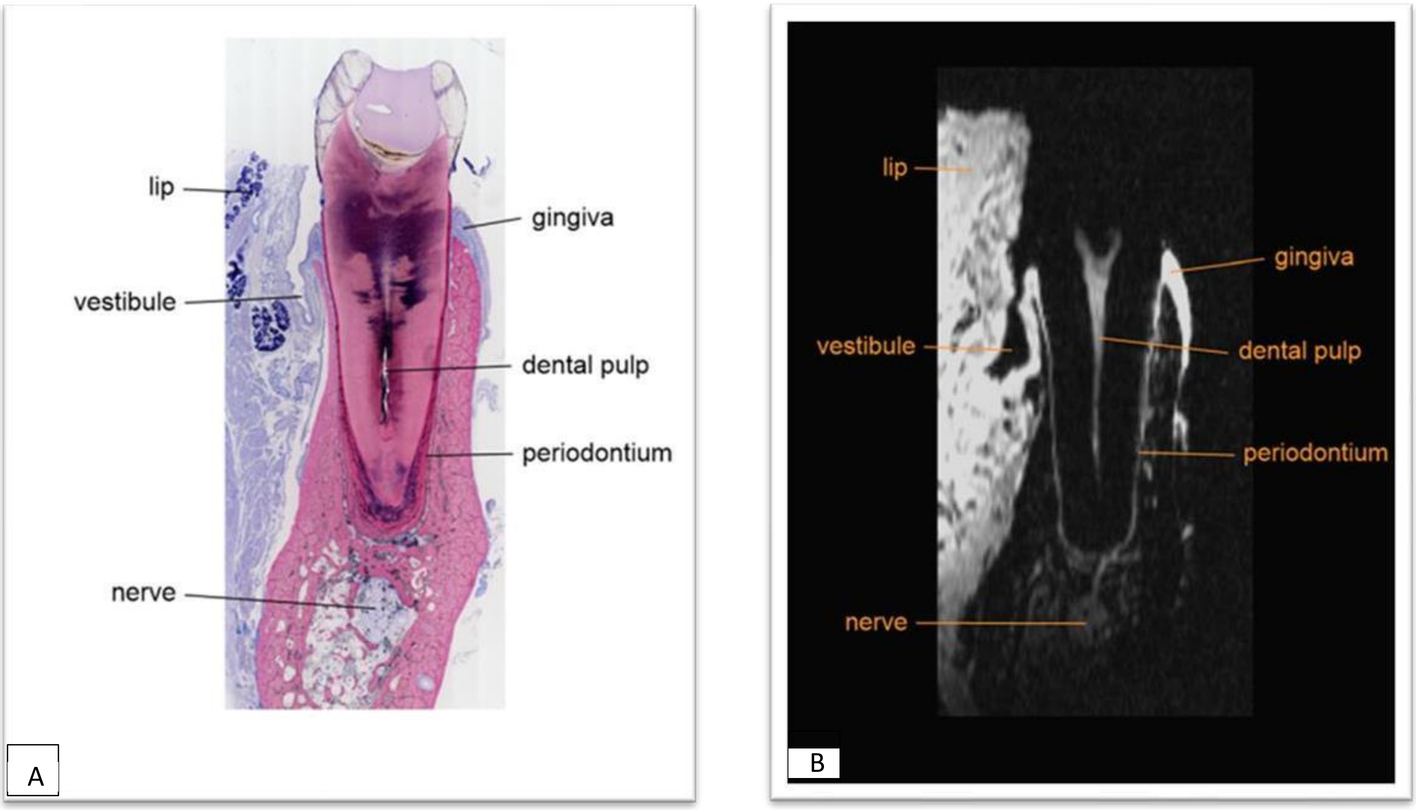

Figure 34. A). Histological section through second premolar in the left mandible of an ex vivo human specimen. B). Section of MRI of the tooth with identical visible structures. Adapted from Flügge T et al. (103)

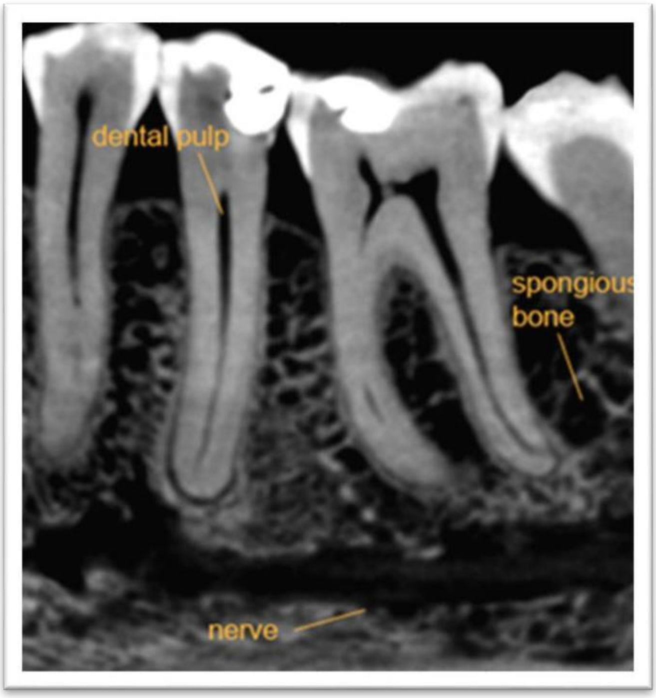

Figure 35. The Sagittal section of CBCT depicts delineated details of dental pulp, gingiva, spongious bone and inferior alveolar nerve. Adapted from: Flügge T et al. (103)

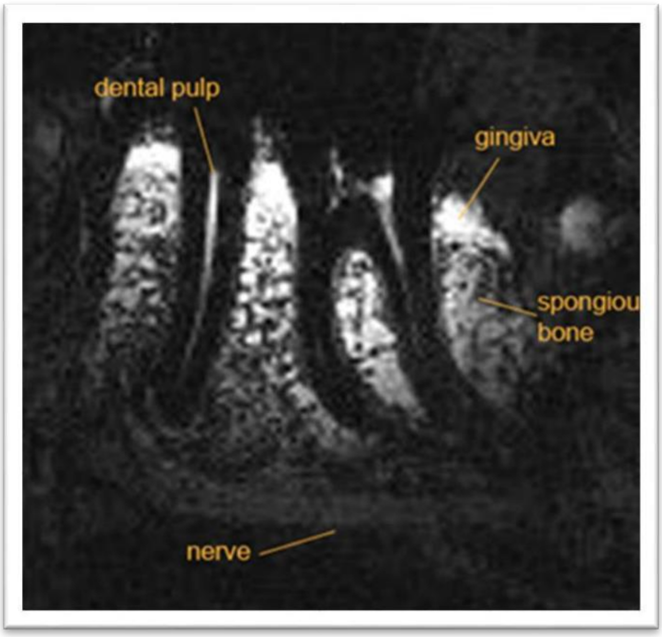

Figure 36. Sagittal section of MRI depicting discerned details of dental pulp, gingiva, spongious bone and inferior alveolar nerve. Adapted from: Flügge T et al. (103)

1.9.3.5 Cone beam computed tomography (CBCT)

It is an advanced three-dimensional technique that uses cone beam shaped x-rays to produce an orthogonal image. It has been introduced in the dental field throughout recent decades. To start with, CBCT is basically composed of x-ray tube source at which the x-rays are produced by the effect of electron circuits on the cathode and anode. It produces a cone beam x ray while rotating around the patient's head in either180°- or 360°-degree rotation. A gantry that uses a C-shaped arm to connect the tube head to the detector. The fixed C-arm allows horizontal movement that gives the advantage of patient to stand or set position. Additionally, A detector that converts the produced x-ray photons into an electrical signal. Several types of detectors have been used in the CBCT; however, the most recently used detector is called flat panel detector. Flat panel detectors have multiple advantages including reduced image distortion and multiple ranges of field of view (FOV). Flat panel detector absorbs the beam x-ray to produce numerous hundreds of 2D images (row data) that are further processed into 3D projection. The process of conversion of 2D images into 3D images is called primary reconstruction. After that, a consequent secondary reconstruction is processed to produce the images in orthogonal planes, axial, sagittal, and coronal. Then, the radiographic image can be viewed and monitored on a viewing screen (104). One of the characteristics associated with CBCT is the availability of choosing the preferable FOV. CBCT can be classified according to the field of view into large FOV that incorporate the image of the entire craniofacial structures, medium FOV that enables the imaging of maxilla or mandible or both, limited FOV which depicts only a specific region of interest (73). The choice of FOV is based on the dental conditions that need to be examined. With the concurrent use of CBCT in different dental tasks and the possible ignorance of dose impact on the patients and dental workers, a concern is raised regarding the exposure dose. The radiation doses produced from full FOV of dental CBCT scan is estimated to be 4-42 times the dose obtained from a panoramic radiograph (105). For this reason, it is crucial that the justifications of the exposure, the optimization of the dose, and the protection from radiation are well appreciated and understood by the dental practitioner who is intending to use CBCT. Therefore, it is essential to weigh the benefits of using CBCT against the risk that would occur (106).The radiation dose of CBCT is thought to be 3-6 times more than OPG and 8-14 times higher than periapical radiography (104–107). This has led to the implementation of the ALADA concept (as low as diagnostically acceptable) which has replaced the previous concept of ALARA (as low as reasonably acceptable) (107–109). It merely depends on the selection of proper and optimized FOV, mAs, and kVp settings and high-resolution parameters to get a diagnostically acceptable image. Schematic illustration of the basic principle of CBCT (Figure 37). Schematic illustration of the basic principle of capturing CBCT image vs CT image (Figure 38).

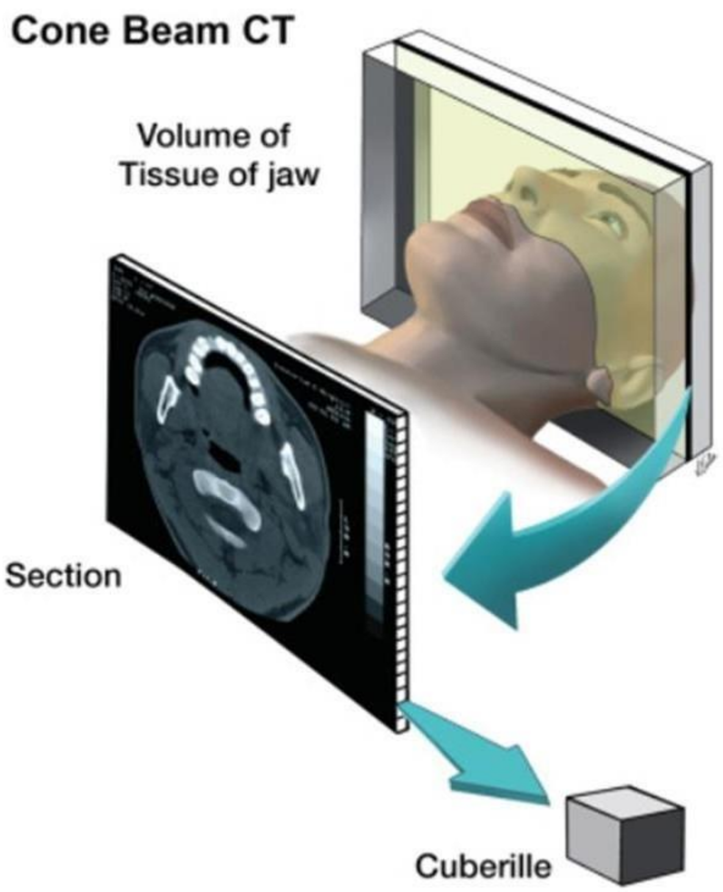

Figure 37. Schematic illustration of the basic principle of CBCT. Adapted from the book of: MacDonald D et al.(74)

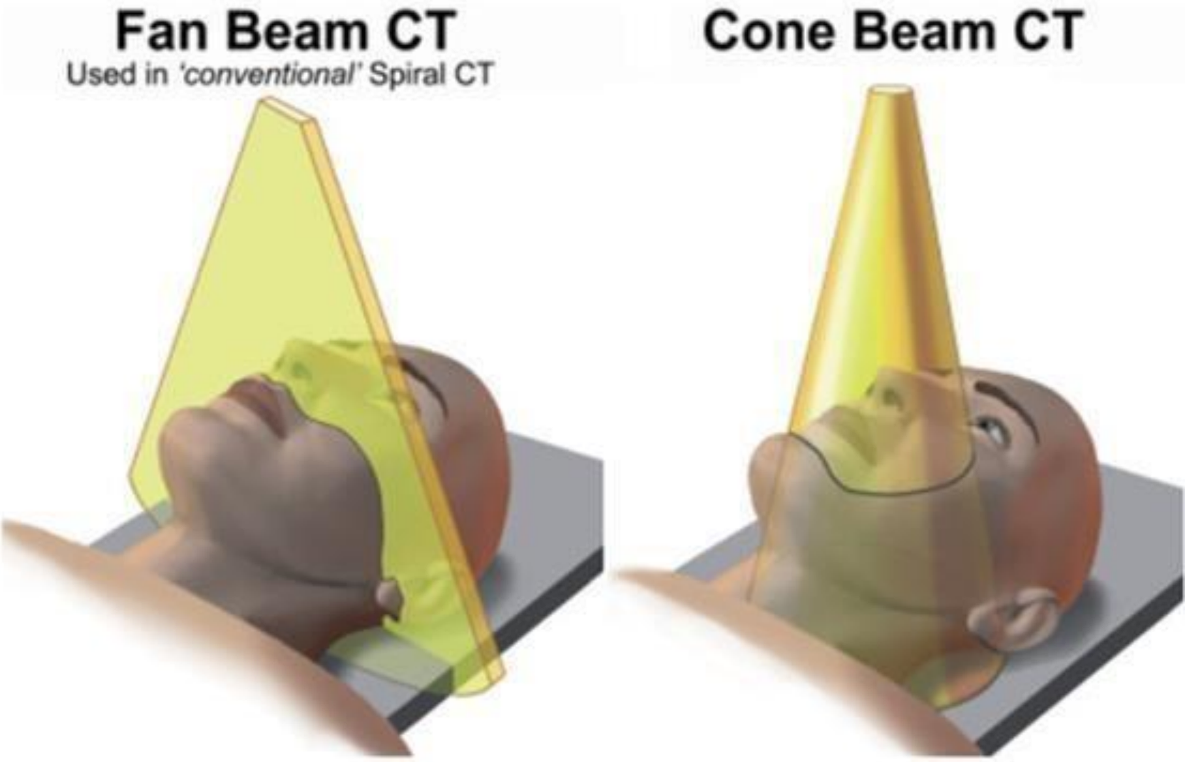

Figure 38. Basic principles of capturing CBCT image vs CT image. Notice that in CBCT, x rays are directed in the form of cone beam shape. In CT, the x rays are directed to the area of examination in the form of fan beam shape. Schematic diagram adapted from the book of MacDonald D et al. (74)

CBCT has been introduced into the dental field over decades. Hence, enormous amounts of different equipment are available for use worldwide (106,109). In the aspect of dental implantology, the three-dimensional visualization of the structures beside the low dose compared to conventional CT makes it accurate for treatment planning. In addition, the implants width and height can be planned accurately before preceding to the placement. It provides valuable information about the bone density and general profile of the alveolar bone (110). Furthermore, it helps in the assessment of the bone grafts and implant position post surgically (111). CBCT axial scan (Figure 39; A), and corresponding panoramic derived view and cross-sectional images of CBCT are Shown in (Figure 40; B & C). (112).

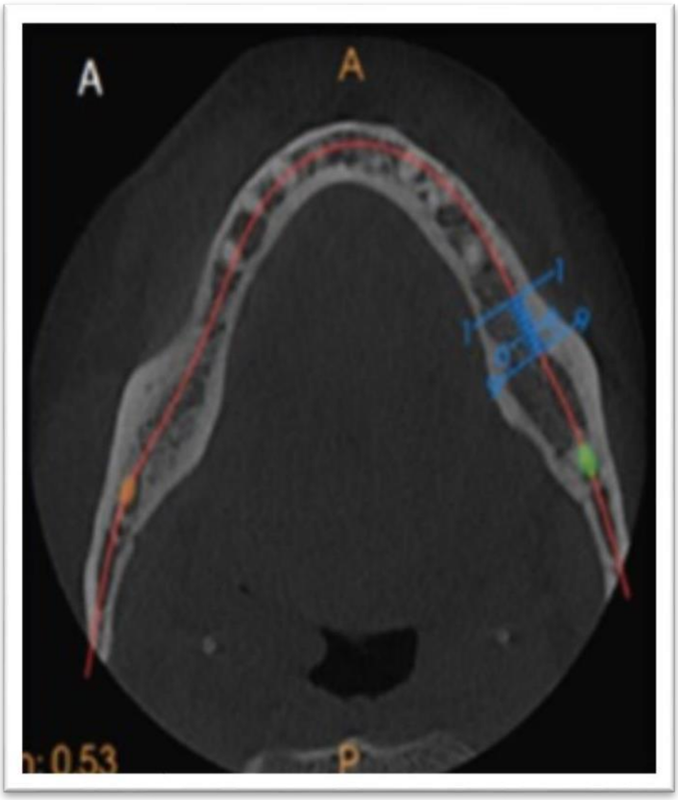

Figure 39. A). CBCT axial view with curved line for implant planning. Adapted from: Venkatesh E et al. (112)

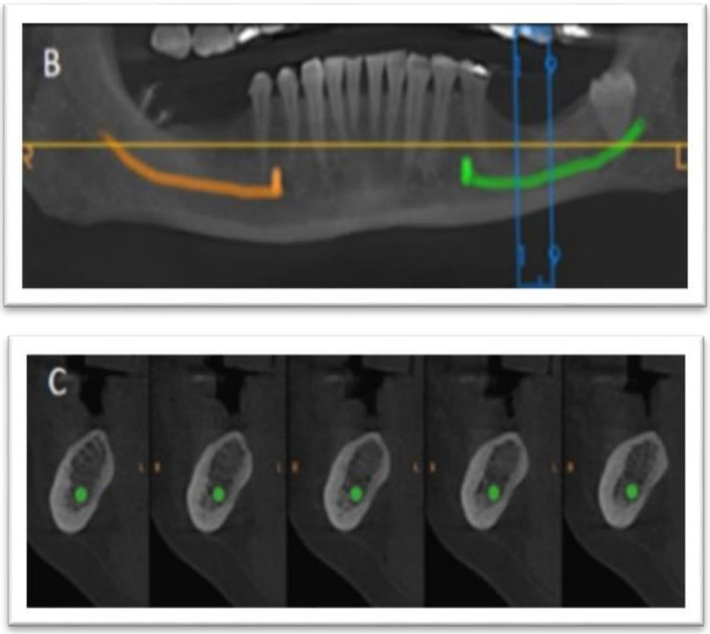

Figure 40. B) “panoramic” view, and C) a set of cross-sections, 1-mm-thick images of a potential implant site in the lower left mandible. Blue lines on the axial and panoramic images indicate the location of the cross-sections. Adapted from: Venkatesh E et al. (112)

BCT is utilized frequently in surgical procedures of traumatic injuries and the assessment of the pathology expansion considering the limitations that conventional modalities possess. In addition, it indicates the presence of pathologic findings that can be found in the maxillofacial region such as lymph nodes calcifications, presence of tonsilloliths, and sialoliths. Furthermore, it maps out the exact location of impacted teeth and its relation to the surrounding vital structures such as the proximity of mandibular third molar to the inferior alveolar nerve canal (112,113). CBCT scan and related Axial view ad derived panoramic image showing buccolingual positioning of crown and root of impacted third molar (Figure 41). Images depicting IMTM associated with radiolucent change resembling cystic lesion on CBCT section and corresponding derived panoramic view (Figure 42; A, B & C).

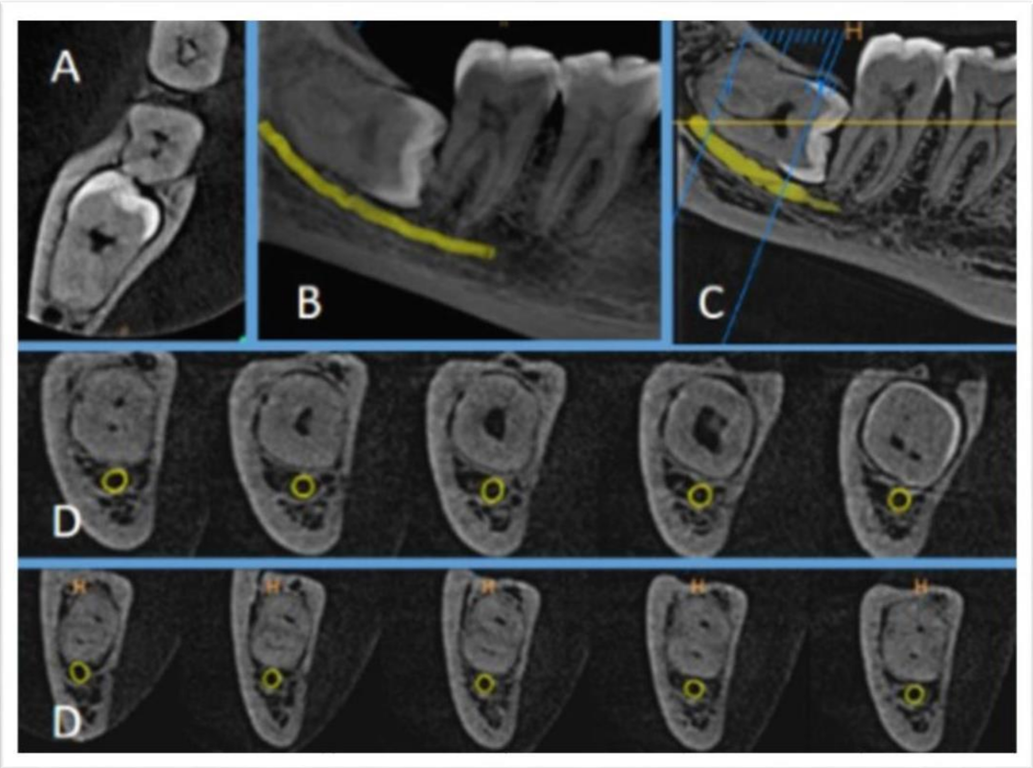

Figure 41. CBCT scan: Axial view (A) showing buccolingual positioning of crown and root of impacted third molar. Panoramic view (B and C) revealing relationship of third molar with mandibular canal and second molar. Set of cross sections (D) revealing the relationship with the mandibular canal. Adapted from: Venkatesh E et al. (112)

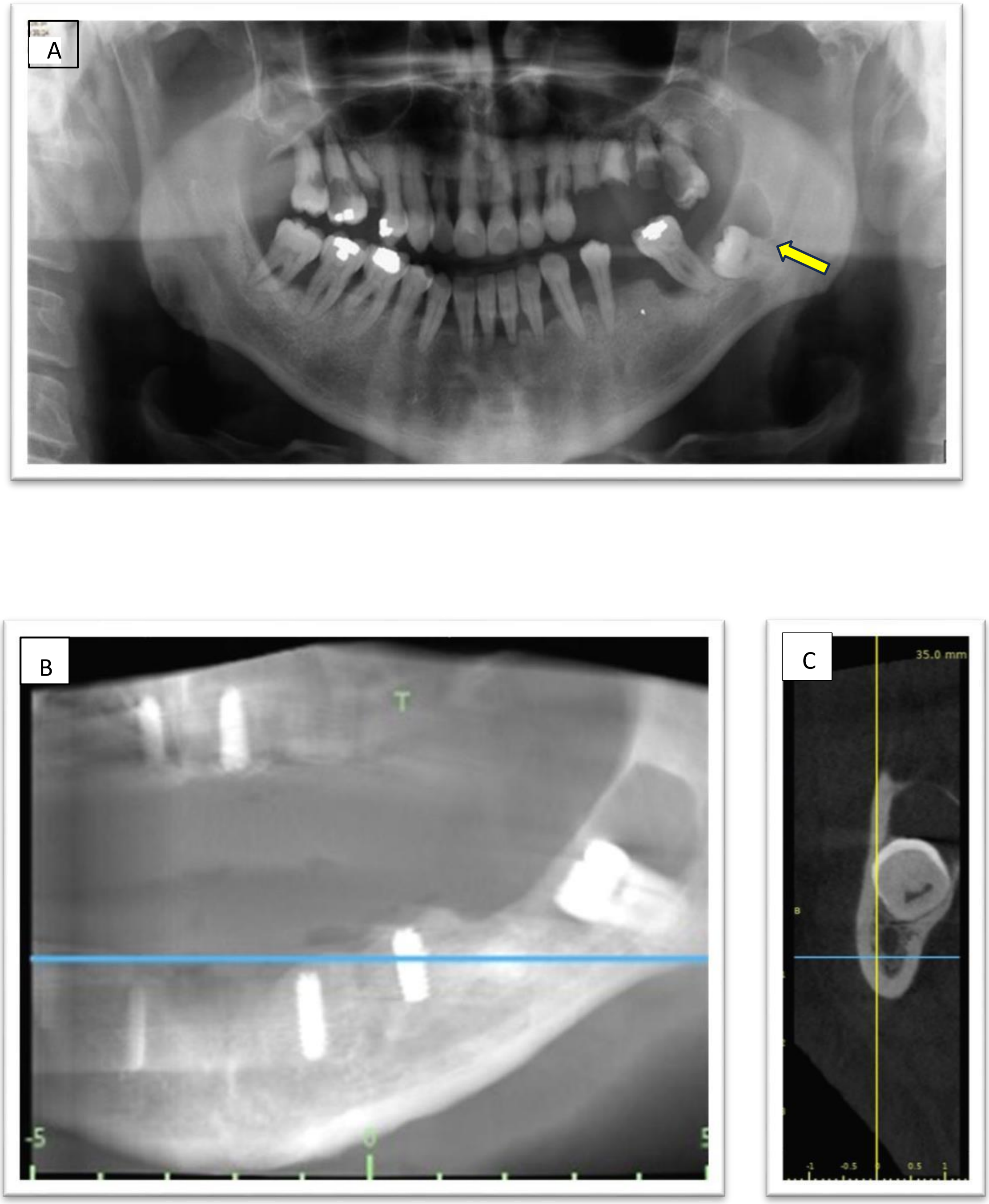

Figure 42. A). OPG image depicting IMTM associated with radiolucent change resembling cystic lesion. B). Panoramic image derived from CBCT. C). Coronal section depicting the tooth associated with cystic lesion and mandibular canal that is approximately close to the tooth. Image adapted from (HOUB)

Furthermore, CBCT is beneficial in endodontic treatments as it provides clear image of the number of roots and related canals and helps in determination of the working lengths and relates treatment procedures. In orthodontic aspect, it assists in the estimation of palatal thickness, pattern of skeletal growth, and evaluating the available bone width for the purpose of the teeth movements. Aside from that, CBCT is significant imaging tool in the evaluation and diagnosis of tempromabdibular joints (TMJ) abnormalities. It determines the position of the condyles and indicates any fibro-osseous changes in TMJ compartments (114–116). Different sections of CBCT depicting TMJ (Figure 43 A, B, C, D).

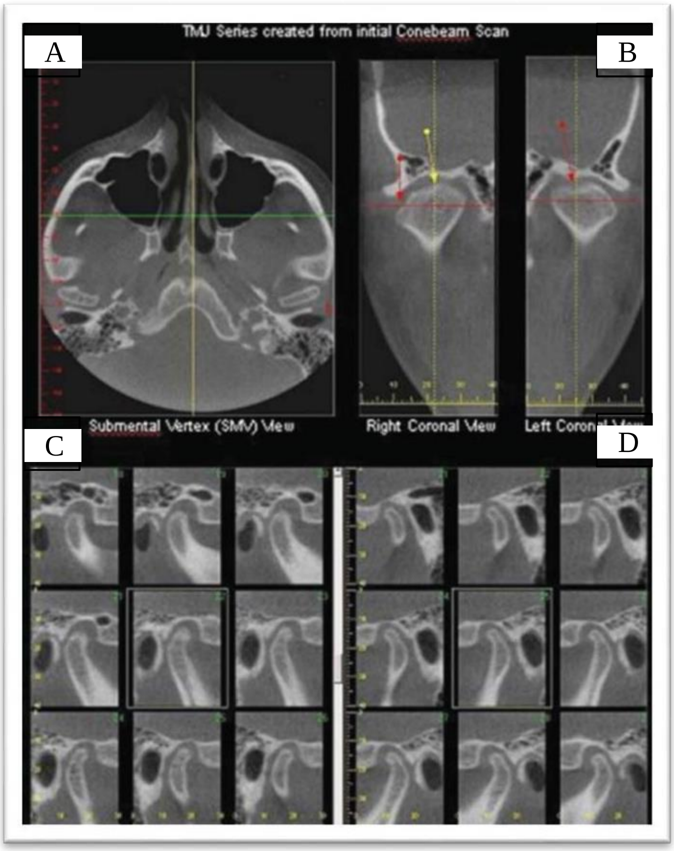

Figure 43. Different sections of CBCT depicting TMJ. A). Axial section at the level of the condyle showing degenerative changes particularly on the right condyle. B). Coronal section of CBCT. C). Sagittal section of the right condyle showing cystic changes. D). Sagittal section of the left condyle. Images adapted from Harrell. (114)

1.11 Mandibular third molar impaction complications

The complication of third molar impaction could be classified as either associated with the presence of impaction, intra-complications, or postoperative complications. The complications that might occur due to the presence of impaction include pericoronitis, marginal bone loss of the adjacent tooth, dental caries, external root resorption, cystic formation, and neoplastic changes. On the other hand, complications might arise during surgical intervention of removing tooth. It has been reported that the complications associated with surgical intervention ranges between 2.9-30.9% (117). It includes alveolar osteitis, infection, hemorrhage, nerve injuries of the inferior alveolar nerve causing paresthesia, lingual nerve injury, and temporomandibular joint damage. Generally, the overall occurrence of the postoperative complication's severity is closely related to the degree of impaction depth and patient's age (118,119).

1.11.1 Complications associated with the presence of impaction

1.11.1.1 Pericoronitis

It is defined as the inflammation of the gingival tissues surrounding the crown of an erupting or partially impacted tooth. It is frequently associated with the lower third molar although it can be noticed in other erupting or partially retained teeth (120). This infection has an impact on the quality of a patient's life if ignored. It would lead to the spread of space infection that can be a threat to life. Accordingly, the intervention and measures towards the prevention is crucial. It is documented that the occurrence of this inflammation is different based on the type of impaction. Vertical impacted tooth is prone to the infection more frequently than the horizontal ones. In addition, the impacted third molar with class A Pell & Gregory classification has the greater risk of developing pericoronitis compared to the other classification (121). Pericoronitis schematic representation (Figure 44). (122).

Figure 44. Illustration resembling pericoronitis infection related to IMTM. Adapted from: AHMED Y et al. (122)

When pericoronitis is associated with swelling, it is fundamental to distinguish between abscess and cellulitis. Cellulitis is a diffuse infection that involves the tissue facias. It is characterized by endurant, painful, and non-fluctuant swelling. The use of antibiotics is paramount to minimize the progression of the infection. On the other hand, abscess is the condition of pus accumulation that appears as fluctuant, soft, and localized swelling. Drainage is often the first line of management (123). Symptoms and signs consistent with the diagnosis of pericoronitis presented in (Table 5) (124).

Symptoms	Signs
Increasing pain for 3-4 days	Red, inflamed tissue overlying third molar
Bad odor or taste	Tissue tender to palpation with or without pus
Difficulty chewing, opening, closing, swallowing	Limited opening
Sore throat	Lymph nodes tender to palpation
General feeling of ill health	Increased temperature
Recent or concurrent respiratory infection	Partial eruption-usually vertical or distoangular
Pain when biting teeth together	Super erupted opposing maxillary third molar

Table 5. Symptoms and signs consistent with the diagnosis of pericoronitis. Adapted from: Wayland J. (124)

1.11.1.2 Bone loss

Periodontal tissue health can be affected by several factors that eventually lead to bone loss around teeth. These factors include inadequate oral hygiene, smoking habits, and the presence of impacted teeth. Impacted teeth, especially lower third molar provokes the formation of the dental pockets distal to lower second molar that increase the vulnerability of bone loss (125). Therefore, the assessment of the condition of third molar impaction and its relation to the adjacent tooth and bone tissue is necessary to plan for the treatment intervention and protect the teeth and bone structures (126). Panoramic radiography revealing bilateral bone loss associated with bilateral impacted third molars (Figure 45).

Figure 45. Panoramic radiography revealing bilateral bone loss associated with bilateral IMTM. Image adapted from (HOUB)

1.11.1.3 Cystic & tumor formation

The odontogenic cysts related to impacted third molar are the dentigerous cyst and the keratocyst. Also, the third molar impaction is possibly linked to the occurrence of odontogenic tumor known as ameloblastoma. The prevalence of cyst and tumor formation accounts for 0.001% to 11% in relation to impacted teeth (127). Vigneswaran et al. (128) reported in their study that the incidence of cysts and tumors associated with mandibular third molar impaction accounts for 1.54%. It agrees with other literature that the dentigerous cyst is the most commonly pathology noticed among other cysts and tumors representing 24.1%. Ameloblastoma was found in 15.7% followed keratocyst that was present in 14.3%. in addition, their findings indicated the radicular cysts account for 5.7%. Although considered rare, they have discovered squamous cell carcinoma in two cases of their sample. It seems that histopathological examination after tooth removal is warranted as the literature is not consistent about that fact of normal follicular. Although a size < 2.5mm is regarded normal, it is found that the size of 2,4mm has pathological changes when examined histologically (129,130). OPG depicting the associated cystic lesion with left IMTM (Figure 46).

Figure 46. OPG depicting the associated cystic lesion with left IMTM. Image adapted from (HOUB)

1.11.2 Postoperative complications

Lower third molar extraction is a common surgical procedure that is associated with several postoperative complications. The potential postoperative complications are alveolar osteitis, paresthesia, hemorrhage, infection, surrounding teeth damages, exposure of the buccal pad fat tissue, displacement into the neighboring spaces, aspiration, periodontal defects, TMJ damages, and oroantral communication in case of impacted maxillary third molar. Nevertheless, it was reported that the most common complications are paresthesia, alveolar osteitis, bleeding and hemorrhage, and infections (124).

1.11.2.1 Paresthesia

It is well known that IMTM is in an area that is near different nerves such as inferior alveolar, lingual, buccal, mylohyoid nerves. Paranesthesia can result from the isolated injury of inferior alveolar nerve or in association with lingual nerve injury. The change of the sensation postoperatively is of great importance to consider as it affects the patient's quality of life. The full recovery of the sensation could take a few weeks to return to normal. However, in case of persistence of more than three months, a referral to a maxillofacial surgeon to proceed with the management of the nerve repair is necessary. There are different criteria that are documented in the literature regarding the extent of nerve damage (124,131).

- Class 1- neurapraxia: it is described as the mildest type of nerve injury and characterized by the loss of sensation for transient time that lasts for days or few weeks without the loss of the axonal continuity.
- Class 2- Axonotmesis: this type of nerve sensation disturbance occurs secondary to the damage involving the covering layer of myelin sheath without involving the connective tissue of the axon. The continuity of the axon is disrupted yet the regeneration of the nerve is expected without any surgical intervention.
- Class3- neurotmesis: this condition is considered as the most severe form of nerve damage at which the entire part of the nerve is disrupted. Surgical intervention is necessary to manage the situation. Therefore, it can be concluded that the neurapraxia and axonotmesis are regarded as a recovering.

damage while the condition of neurotmesis is regarded as a situation that necessitates surgical intervention. The accurate determination of the proximity of impacted third molar to the roots is mandatory to avoid possible nerve damage (130,131).

1.11.2.2 Alveolar osteitis (AO)

The condition of alveolar osteitis is often regarded as the most common complication of third molar impaction removal. It has been named as a dry socket, alveolalgia, septic socket, characterized by painful symptoms associated with mal odors, throbbing pain, and radiating pain to the lateral side of the face. It mostly develops a few days after extraction due to the inflammation arise upon the failure of blood clot formation. The management of the symptoms is achieved by using palliative treatments and socket irrigation. It has been reported that predisposing factors such as pericoronitis, chronic gingivitis, and traumatic procedure contribute to the likelihood increase of alveolitis (124). Contributing factors to the occurrence of alveolar osteitis complication (Table 6).

1.11.2.3 Mandibular fracture

Mandibular fracture is considered the most facial bone prone to fractures although it is one of the strongest bony structures in the human body (132). It comprises 40%-60% of all facial structures, and the mandibular angle fractures account for 25-30% of those mandibular fractures. The angle of the mandible is the location where the third molar tooth is accommodated. Therefore, it has been stated that the risk of fracture increases 2-3 times in the presence of third molar impaction (133). It is hypothesized that the reason for fracture is because the impacted third molar occupies an osseous specs that weakens the surrounding bone (134). In addition, several factors might contribute to the fracture including the action of force transmitted and the presence of pathology at the site of impaction (135). The management of fracture can be achieved through closed reduction, open reduction, or following a protocol of soft diet based on the estimated severity of the situation and the impact of muscle movement. OPGs reveal preoperative presence of impacted mandibular and second molars, postoperative fracture (Figure 47; A & B).

Proposed AO causes	Major	Minor or unproven
Smoking	X	
Age	X	
Surgeon experience	X	
Surgical difficulty/trauma	X	
Oral contraceptives	X	
Female gender	X	
Bacterial infection		X
Systemic disease		X
Physical dislodgement of clot		X
Excessive irrigation/curettage		X
Multiple vs single extraction		X
Anesthetic & vasoconstrictor		X
Saliva		X
Bone/ root fragment in wound		X
Flap design & sutures	X	
Systemic disease	X	
Compromised blood supply	X	
Radiotherapy	X	

Table 6. Contributing factors to the occurrence of alveolar osteitis complication. Adapted from: Wayland J. (124)

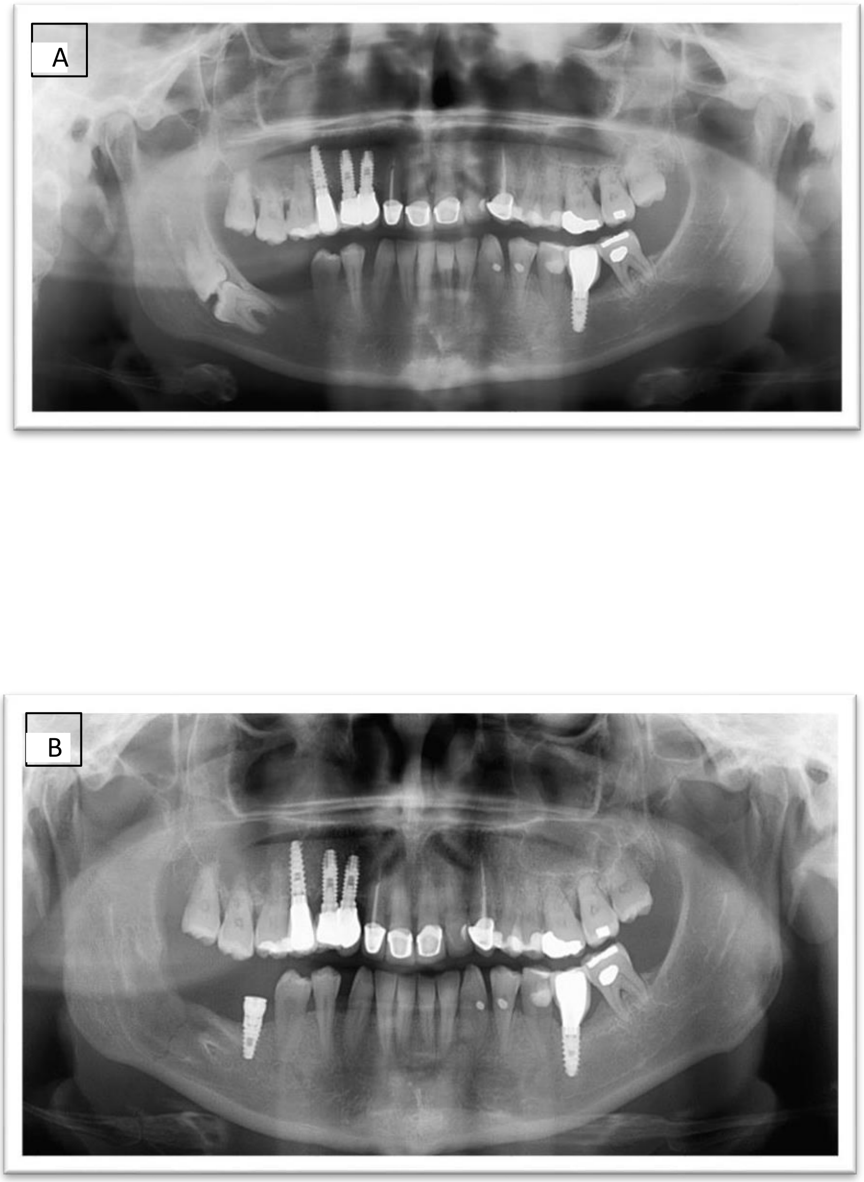

Figure 47. A). Preoperative OPG depicting impacted third and second molar. B). OPG depicting the presence of fracture line at the extraction site. Image adapted from (HOUB)

1.11.2.4 Space infection

Although it is not common, the progression of infection into deep space is critical. It is mandatory for the dental clinical or surgeon to be aware of the process of the different spaces to which the infection could reach. The spaces located in the head and neck are categorized as primary, secondary, and deep neck spaces. The route of infection spread is through the blood d vessels and lymphatics. General signs of space infections include muscle trismus, swallowing difficulty (dysphagia), breathing difficulty (dyspnea). When the infection occurs, it can spread to the primary spaces which are near the odontogenic infection such as canine, buccal, submandibular, sublingual, and vestibular species. Once the infection involves primary space, it could further spread to the secondary spaces which created by the infection spread itself. The secondary spaces formed by the infection spread involve masseteric, pterygomandibular, masticatory, temporal, and infratemporal lateral pharyngeal and retropharyngeal (124). Summary of origin, sign, and symptoms of primary, secondary, and deep neck spaces infections (Table 7, 8, 9).

	Origin of infection	**Signs/symptoms**
Primary spaces		
Canine	Maxillary canine or first premolar	Painful swelling lateral to the nose including loss of the nasolabial fold
Buccal	Maxillary or mandibular 1st, 2nd, and 3rd molars, roots outside buccinator muscle attachment	Painful swelling is ovoid, below the zygomatic arch and above the inferior border of the mandible
Vestibular	Maxillary or mandibular 1st, 2nd, and 3rd molars, roots inside buccinator muscle attachment	Painful swelling of the vestibular tissue overlying affected tooth
Submandibular	Mandibular 2nd / 3rd molars below mylohyoid muscle	Painful swelling under posterior mandible
Sublingual	Mandibular 1st / 2nd molars above mylohyoid muscle	Painful, firm swelling of the anterior floor of the mouth, difficult to swallow
Submental	Mandibular incisors	Painful swelling under anterior mandible or chin

Table 7. Summary of origin, sign, and symptoms of primary space infections. Adapted from Wayland J. (124)

	Origin of infection	Signs/symptoms
Secondary space infection		
Pterygomandibular	Mandibular 2nd/3rd molar	Significant trismus/ pain with no swelling
Masseteric	Mandibular 3rd molar via buccal space	Mild to moderate trismus, swelling of the posterior inferior border of the mandible
Temporal (deep & superficial	Mandibular 3rd molar	Rare infection, trismus, pain, swelling, possible deviation of the mandible on opening

Table 8. Summary of origin, sign, and symptoms of secondary and deep neck spaces infections. Adapted from Wayland J. (124)

	Origin	Signs/symptoms
Deep neck spaces		
Parapharyngeal (lateral) pharyngeal)	Mandibular 3rd molars	Trismus, fever, sore throat, dysphagia, swollen neck, mediastinitis, airway obstruction
Retropharyngeal	Mandibular 3rd molars	trismus, fever, sore throat, dysphagia, swollen neck, mediastinitis, airway obstruction
Prevertebral (danger space)	Mandibular 3rd molars	Trismus, fever, sore throat, dysphagia, swollen neck, mediastinitis, airway obstruction

Table 9. Summary of origin, sign, and symptoms of secondary and deep neck spaces infections. Adapted from Wayland J. (124)

1.11.2.5 Bleeding and hemorrhage

Subsequent bleeding to the surgical removal of the impacted third molar is one of the common complications encountered. Continuous bleeding that persists after 6-12 hours could be an indicator of abnormality that should be considered seriously. It was reported that bleeding after mandibular third molar impaction has more risks compared to upper third molar. Risk factors include deep impaction and proximity to the inferior alveolar nerve canal. It is expected to correspond to the age as the blood vessels become more fragile. In addition, it is reported that bleeding is more frequent in men compared to women (123). To elaborate, several criteria have been reported that could describe the condition of postoperative bleeding. It includes continuous bleeding for up to 12 hours, a bleeding that results in the formation of hematoma or ecchymosis, and bleeding that causes the patient to present to the emergency or require blood transfusion. Postoperative bleeding could either be a consequence of patient-related factors or surgical-related factors. The patient-related factors include the use of anticoagulants, underlying bleeding coagulopathy such as Von Willebrand disease, and hemorrhagic diathesis. On the other hand, bleeding secondary to surgical intervention procedure includes cortical plate damage or vascular supply injury. One of the rare life-threatening consequences of postoperative bleeding is the formation of pseudoaneurysm. It is described as the formation of hematoma secondary to arterial damage that has persistent continuity with traumatized artery. It can rupture at any point and become life threatening to the patient. Therefore, close examination and accurate assessment of the patients' susceptibility to bleeding or who underwent traumatized surgical procedure is fundamental to overcome possible risk of bleeding (136).

1.11.2.6 Osteomyelitis

It is a process of inflammation that could arise upon the contamination of the surgical wound. Although it is considered rare with the availability of antibiotics, it remains challenging when occurs. Osteomyelitis is subdivided into acute, chronic, or suppurative. Acute osteomyelitis is that that persists for a period of less than one month. It is associated with other symptoms like pain, malaise, trismus. On the other hand, the chronic form persists for more than one month. When osteomyelitis is associated with pus accumulation, it is termed suppurative osteomyelitis. It is more frequent in mandible than maxilla due to limited blood supply. There are different risk factors that could provoke the occurrence of this inflammation including alcoholism, immunocompromised conditions, chemotherapy, radiotherapy, steroids consumptions, and diabetes. Ina addition, osteomyelitis can develop after jaw fracture that results from mandibular third molar surgery. Chronic osteomyelitis can be identified by the appearance of (moth eaten) seen on diagnostic radiography (123,137).

1.11.2.7 Temporomandibular joint-related changes

TMJ is a synovial joint that connects the skull to the mandibular jaw on both sides. It is composed of two parts, the upper compartment, and the lower compartment. The upper compartment is located between the surface of temporal bone and the articulating disc. This part is responsible for the gliding and translatory movement. On the contrary, the lower compartment is located between the head of the condyle and the articulating disc. Theis part is responsible for the hinge movement. TMJ is a significant joint as it plays fundamental rule in the movement of the mandible. Therefore, the risk of changes due to trauma or pathological conditions would affect the patient's quality of life. Although the literature is still scarce about the TMJ disorders related to the presence or removal of mandibular third molar, it is suggested that the removal of such tooth plays role in the exacerbation of the TMJ disorders (138,139).

1.12 Incidental finding on panoramic radiography

Aside from using panoramic radiography for dental tasks, it is common to notice incidental findings while assessing the image. Incidental findings can be abnormal variations of anatomical structures and sometimes represents a pathology that is found coincidentally in the image.

1.12.1 Elongated styloid process (ESP)

The styloid process SP is a cylindrical bony projection that originates from the inferior part of the petrous temporal bone just anteriorly to the stylomastoid foramen (140). The 'styloid' is a term derived from the Greek word 'Stylos' which refers to pillar (141). Embryologically, this apophysis develops from Reichert's cartilage of the second pharyngeal arch (142). It is subjected to ossification from the third trimester of pregnancy through the first ten years of life. Regarding its location, it is positioned laterally in the neck between the internal and external carotid arteries and the internal jugular vein. Several nerves including the glossopharyngeal, facial, accessory, hypoglossal, and vagus are located near the SP (143). Regarding anatomic structure, the distal part of the styloid process is considered the origin of various muscles including the stylohyoid, stylopharyngeus, and styloglossus. In addition, the stylomandibular ligament and the stylohyoid ligaments emerge from part of the styloidprocess and are inserted into the ramus of the mandible and the lesser horn of the hyoidbone respectively (144). The muscles attached to the SP are known as Riolan's bouquet (145). He has described the muscles of the styloglossus, stylopharyngeus, and stylohyoid as red flowers whereas the stylomandibular and stylohyoid ligaments as white flowers (145). These structures contribute to the movement of the oropharyngeal complex. Considering the function of Riolan's bouquet, the styloglossus is an extrinsic muscle of the tongue in addition to the genioglossus, hyoglossus, and palatoglossus. Styloglossus contributes to the retraction and side elevation movement of the tongue. On the other hand, the stylohyoid muscle acts to elevate the hyoid bone during the process of swallowing. The stylopharyngeus muscle elevates and widens the pharynx during swallowing besides larynx elevation (144). Concerning the function of the ligaments, the stylohyoid ligament connects the SP to the hyoid bone and acts to elevateit. The stylomandibular ligament is attached to the medial side of the mandible and functions to limit the maximum opening and protrusion of the mandible (146). ESP is defined as the condition at which the SP exceeds 30 mm when measured from the emergency point in the temporal bone down to the tip of the process (147). Regarding the prevalence of elongated styloid process ESP, several studies have investigated the elongation of the styloid process in different populations. The prevalence ranges between 3.3% to 84.4% (148,149). From the radiographic point of view, there have been varieties in the methods used for the evaluation of the styloid process elongation that ranges from orthopantomography OPG to the most advanced technology of cone beam computed tomography (CBCT) and computed tomography (CT) (150–152). OPG provides a general perspective on pathological change in the maxilla and mandible. Therefore, OPG aids to distinguish abnormal changes and observe normality. In addition, the state of teeth impaction, dental anomalies, incidental findings, malocclusions, and abnormalities of the structures surrounding the jaws are illustrated using OPG (153). Consequently, the elongation of the styloid process unilaterally or bilaterally can be addressed via the orthopantomography technique. The elongation of the styloid process is potentially linked to the occurrence of craniofacial and cervical pain; a status described by the American Otolaryngologist Watt. W. Eagle and termed Eagle's Syndrome (154). It is characterized by episodes of pharyngeal pain referred to different areas of the cervicofacial area (152,154). It is reported in the literature that approximately 4-10.3 % of individuals with elongated SP would develop this type of pain manifestation (152). Although Eagles' syndrome has no specific behavior or pain symptoms, patients present with dysphagia and general head and neck pain known as cervicalgia due to the pressure on the nerves and muscles contained in the surrounding structures (155). Other symptoms including tinnitus, otalgia, and trigeminal neuralgia are linked to the presence of elongated SP (155). Moreover, the elongated SP process could lead to more serious consequences like transient ischemic attack or stroke because of its proximity and compression on the carotid artery (156). The etiopathogenesis of Eagle's syndrome is attributed to different theories including congenital elongation of the styloid process and the calcification of the stylohyoid ligament (157). Furthermore, previous tonsillectomy is linked to some extent to the occurrence of Eagles' Syndrome (157). Several types of calcifications have been described in literature including outline calcification, complete, partial, and nodular. Regarding morphology, it is also reported that there are different types of morphology that include uninterrupted, pseudoarticulated, and segmented (158). OPG depicting bilateral elongated styloid process (Figure 48). Schematic illustration and corresponding image representation of the different morphologic patterns of the elongated styloid process (Figure 49). Schematic illustration and corresponding images of the different calcification types (Figure 50).

Figure 48. OPG depicts bilateral elongated styloid process. Adapted from (HOUB)

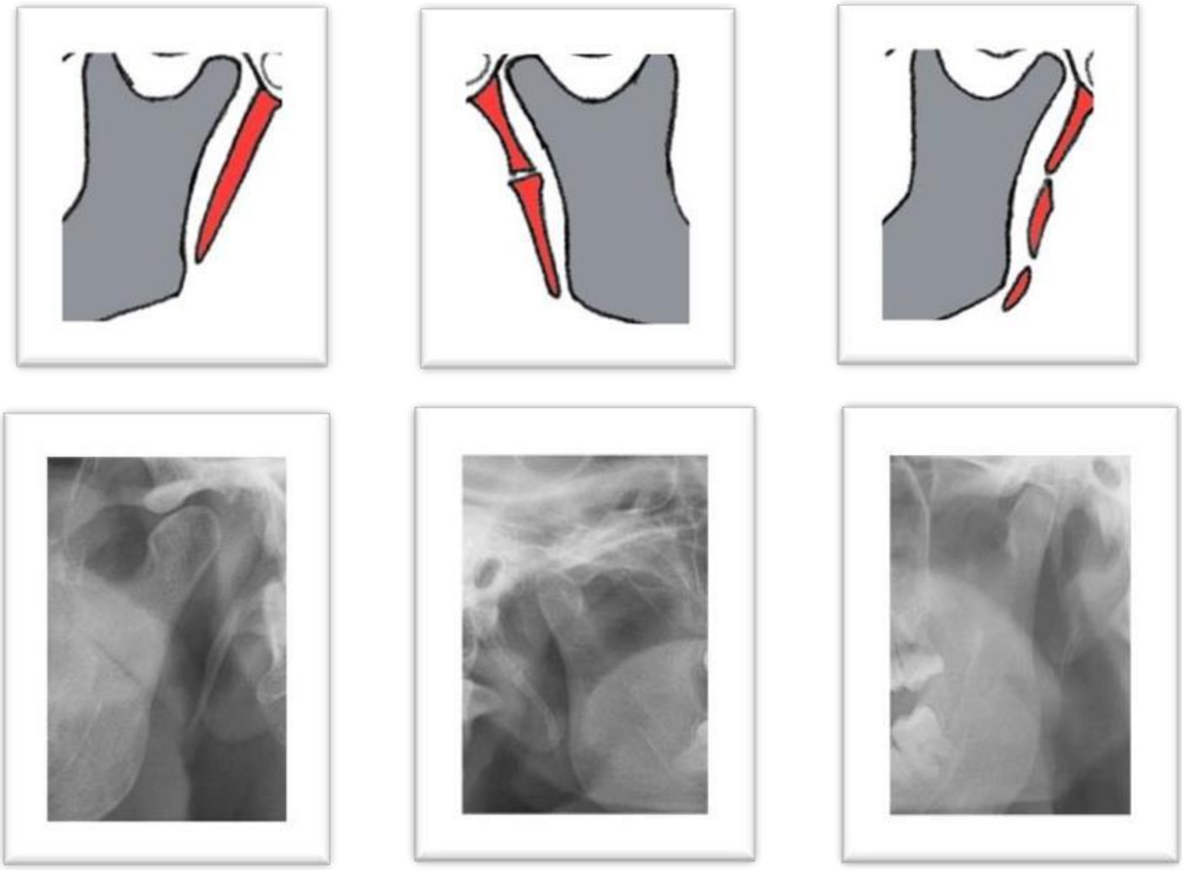

Figure 49. Schematic illustration and corresponding image representation of the different morphologic patterns of the elongated styloid process. Images adapted from (HOUB). Images are published in the article derived from this thesis project "Assiri Ahmed H, Estrugo-Devesa A, Roselló Llabrés X, Egido-Moreno S, López-López J. The prevalence of elongated styloid process in the population of Barcelona: a cross-sectional study & review of literature. BMC Oral Health. 2023 Sep 19;23(1):674. doi: 10.1186/s12903-023-03405-0."

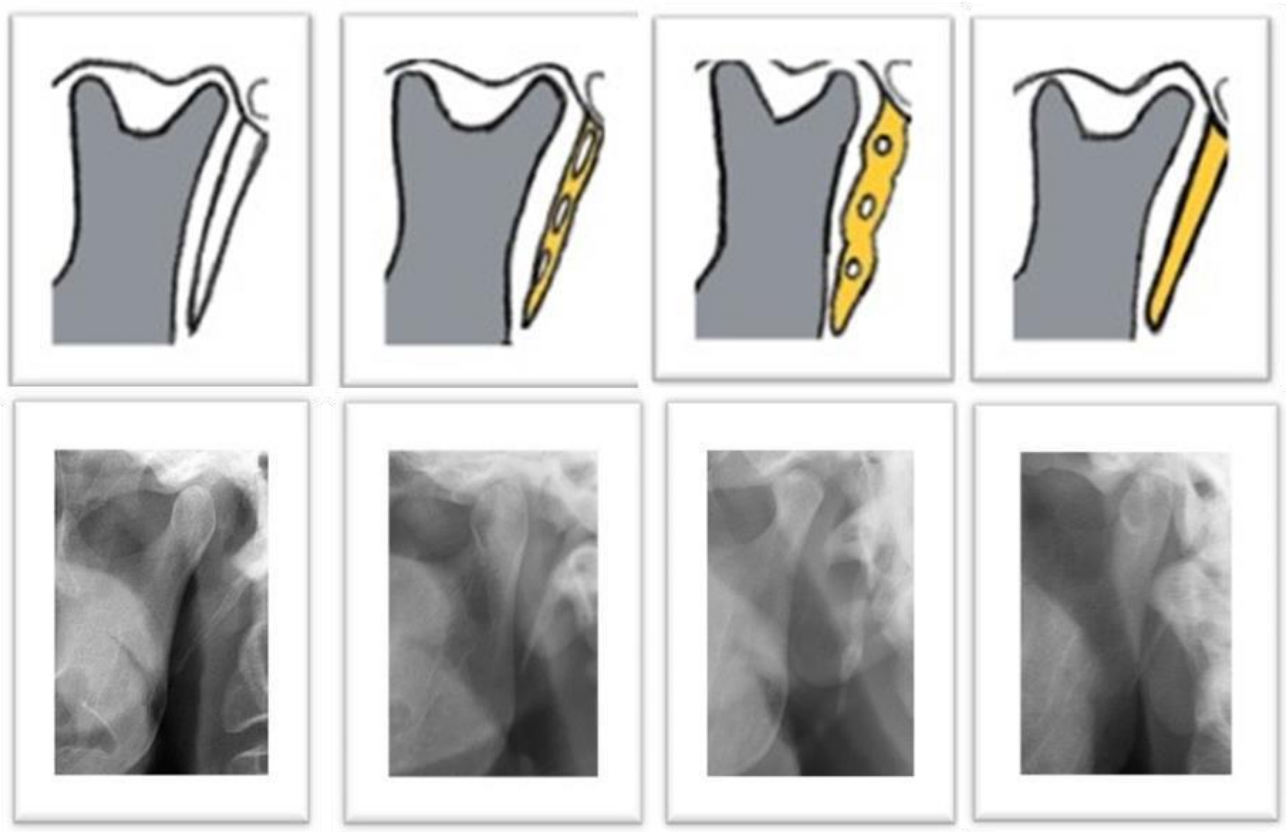

Figure 50. Schematic illustration and corresponding images of the different calcification types. Images adapted from (HOUB). Images are published in the article derived from this thesis project "Assiri Ahmed H, Estrugo-Devesa A, Roselló Llabrés X, Egido-Moreno S, López-López J. The prevalence of elongated styloid process in the population of Barcelona: a cross-sectional study & review of literature. BMC Oral Health. 2023 Sep 19;23(1):674. doi: 10.1186/s12903-023-03405-0."

1.12.2 Calcified Carotid atheroma (CCA)

It is well known that atherosclerosis is one of the diseases affecting individuals. In arterial walls, fat substances and cholesterol accumulate to form atheroma in some circumstances. Atheroma can occur in the wall of common artery near its bifurcation to form risk factor for cardiovascular diseases like stroke. Cerebrovascular stroke can be caused when the blood circulation to the brain is disrupted. Occasionally, such calcification is noticed on panoramic radiography. Patients must be alerted about the presence of these incidental findings as it might lead to life-threatening consequences. Risk factors of developing carotid atheroma include diabetes mellitus, cardiovascular disease, chronic renal disease, and alcoholism (159). OPG depicting carotid atheroma (Figure 51).

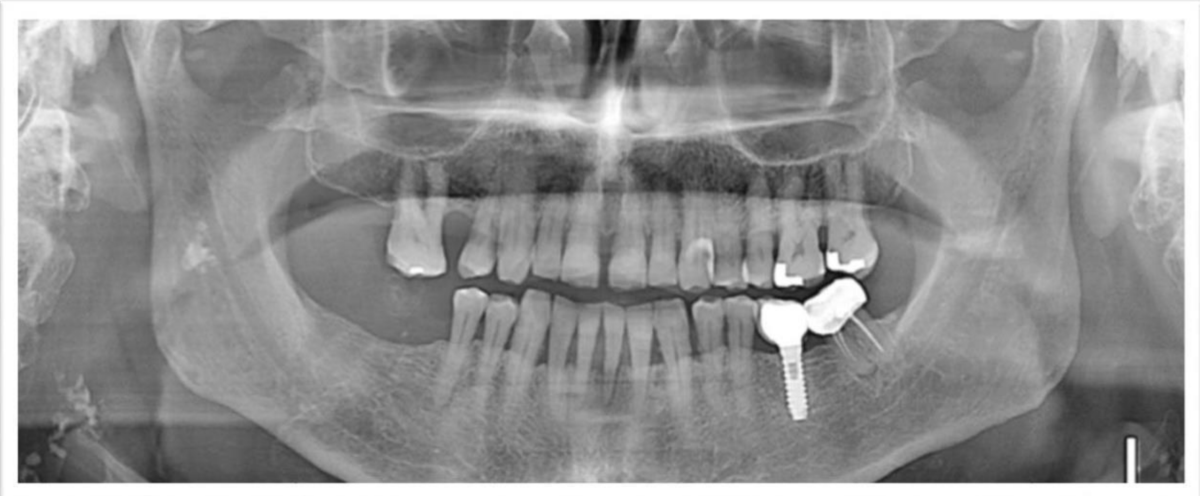

Figure 51. OPG depicting carotid atheroma (yellow arrow). Image adapted form (HOUB)

1.12.3 Salivary glands' stones (Sialoliths)

The formation of calcified structures within salivary glands, either the parenchyma or the ductal system, are regarded as salivary gland calculi or sialolith (160). It is more frequent in the submandibular glands accounting for 80% while in parotid, sublingual, and minor salivary glands represent 5-20%, 1-2% respectively (161,162). It is more dominant in males then females and occur mostly from third to sixth decades of age (163). Several reasons cause the sialolith to be more frequent in submandibular gland compared to the other gland. The submandibular gland (Wharton's duct) is anatomically wider in diameter and longer than the other gland's ducts**.** Since the salivary gland secretions contain more contents of calcium and phosphates, it makes the formation of calculi more in this gland (164). It can be shown coincidentally on panoramic radiography superimposed on the posterior mandible or inferiorly adjacent to the border of the mandible in either a single or multiple form. Usually, it measures between 1 mm to 1 cm. Therefore, large size salivary stones are rarely seen. Generally**,** the sialoliths of parotid glands occur as small multiple calculi (165). The etiology of the formation of salivary stones remains ambiguous. However, it is hypothesized that numerous factors such as gland's ducts irregularities, obstruction, saliva components, and presence of infections could exacerbate sialolith formation. Regarding diagnosis, it can be identified through clinical examinations. Nevertheless, the need for diagnostic imaging such as conventional radiography, ultrasonography, magnetic resonance imaging, or CBCT could be supportive to reach definitive diagnosis (166). Unusual size of submandibular gland sialolith superimposed on the posterior right of the mandible presented in the OPG (Figure 52) (167). On some occasions, the salivary gland stones are formed in larger sizes which can be identified by panoramic radiography (Figure 53). CBCT can be made for further accurate diagnosis and for the three-dimensional visualization (Figure 54. A, B, &C).

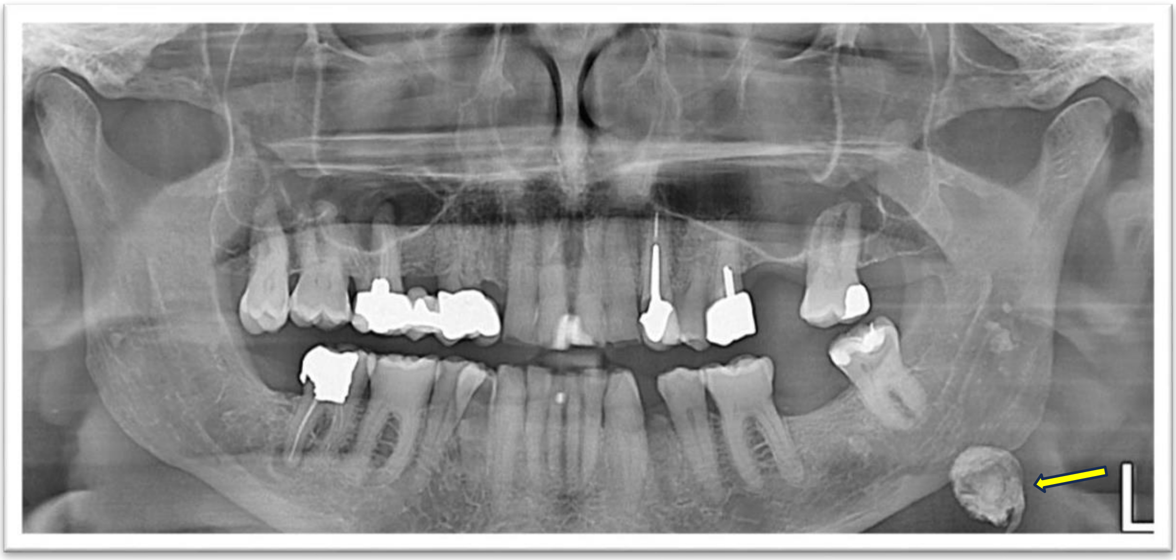

Figure 52. OPG depicting large size sialolith inferior to the border of the mandible on the left side (yellow arrow). Adapted from (HOUB)

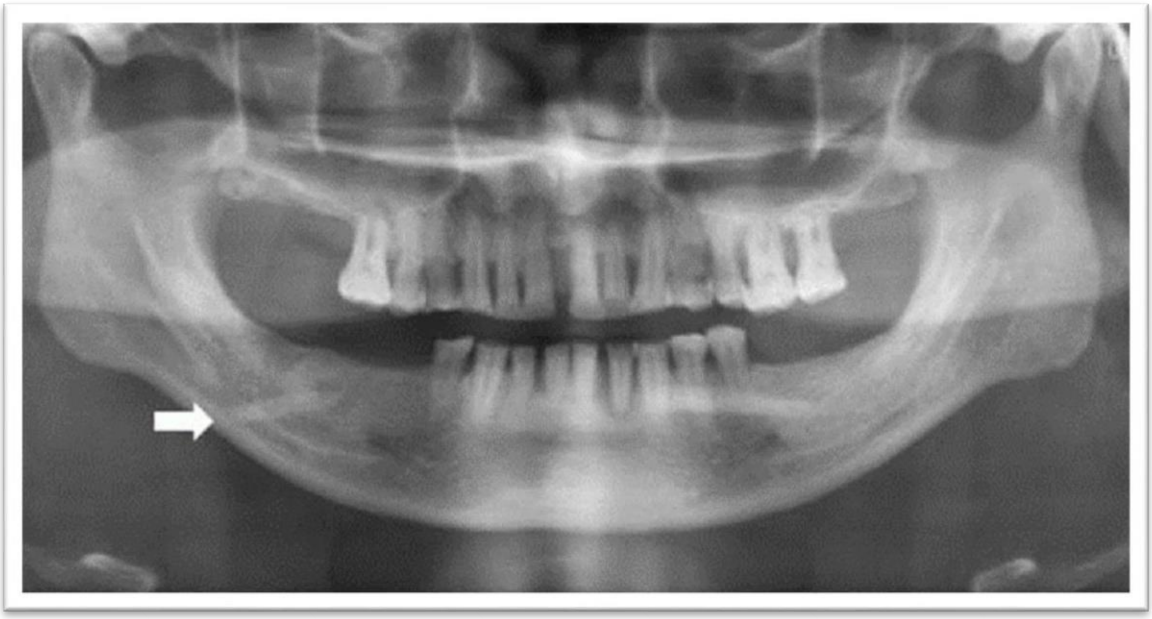

Figure 53. Unusual size of submandibular gland sialolith superimposed on the posterior right of the mandible (white arrow). Adapted from: Ser HP, Lazim NM et al. (167)

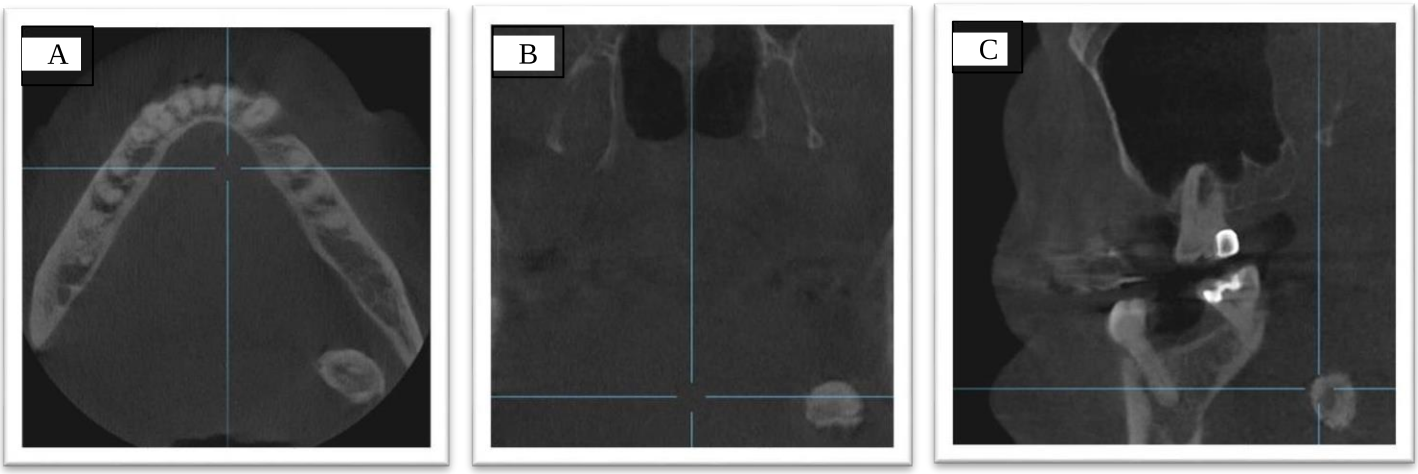

Figure 54. A). axial CBCT section. B). Coronal CBCT section. C). Sagittal CBCT section depicting the content, size, and location of the sialolith. Images adapted from (HOUB)

1.12.4 Tonsilloliths

The presence of calcified content with the tonsillar crypts most often the palatine crypt is regarded as tonsillolith. The etiology of the formation of tonsillolith is linked to the repeated occasions of inflammatory process of the tonsils. Upon occurrence of inflammation, fibrosis of the opening of the tonsillar crypts takes place (168). The debris and bacterial structure accumulate leading to the formation of retention cysts. Subsequently, the deposition of salt contents and minerals derived from the saliva results in calcifications that can be seen occasionally on panoramic radiography (169). It is noticed as a small or multiple irregular radiopaque structure projected on the mandibular ramus. On some occasions, tonsillolith can be seen bilaterally and multiple. The differential diagnosis of tonsilloliths can include varieties of abnormalities such as osteoma, idiopathic osteosclerosis, sialolithiasis, phlebolith, cysticercosis, calcified lymph nodes, carotid calcification, long hamular process, stylohyoid ligament calcification, or osteoma cutis and foreign body (170). OPG depicting multiple tonsilloliths on the right side, and unilateral on the left side of the mandible posteriorly (Figure 55).

Figure 55. OPG depicts multiple tonsilloliths on the right side, and unilateral on the left side of the mandible posteriorly. Image adapted from. Munhoz L et al. (171)

1.12.5 Phleboliths

Phlebolith is defined as the calcification found within vascular tissue associated with hemangioma or malformation of such vessels. It may develop in response to injury or blood flow stagnation (171). When seen on panoramic radiography, phlebolith usually appears in single or multiple round or oval radiopaque structures that measure more than 0.5 cm. It can be differentiated from the sialolith by its appearance in which there is radiolucent center (172). Sialolith is often elliptical or elongated following the anatomic configuration of the gland's duct. When noticed, it is critical to conduct a thorough examination to avoid any possible risk of bleeding and life threats conditions (167). OPG depicting multiple phleboliths on the posterior region of the right side of the mandible (Figure 56).

Figure 56. OPG depicting multiple phleboliths on the posterior region of the right side of the mandible. Image adapted from (HOUB)

1.12.6 Mandibular canal variation

The mandibular canal is located on the posterior of the mandible. It originates in the mandibular foramen and descends in anteroinferior direction following the configuration of the bone and ends at the opening of the mental foramen. It carries the mandibular nerve, artery, and vessels. It provides sensory innervation to the posterior teeth, alveolar bone, and gingiva. The anatomical variation of the canal can occur during the period of embryogenic development (173). Several classification methods based on panoramic radiography have been described in the literature (174–176). However, the most recent classification of bifid mandibular canal was described by Naitoh's et al. (177) in which he subcategorizes the bifid canal into four types using CBCT. To elaborate, the clinical significance behind the awareness of anatomical variation is to avoid the potential risks of nerve injury and difficulty achieving proper anesthesia before surgical intervention. Schematic diagram depicting different types ofmandibular canal variations (Figure 57).

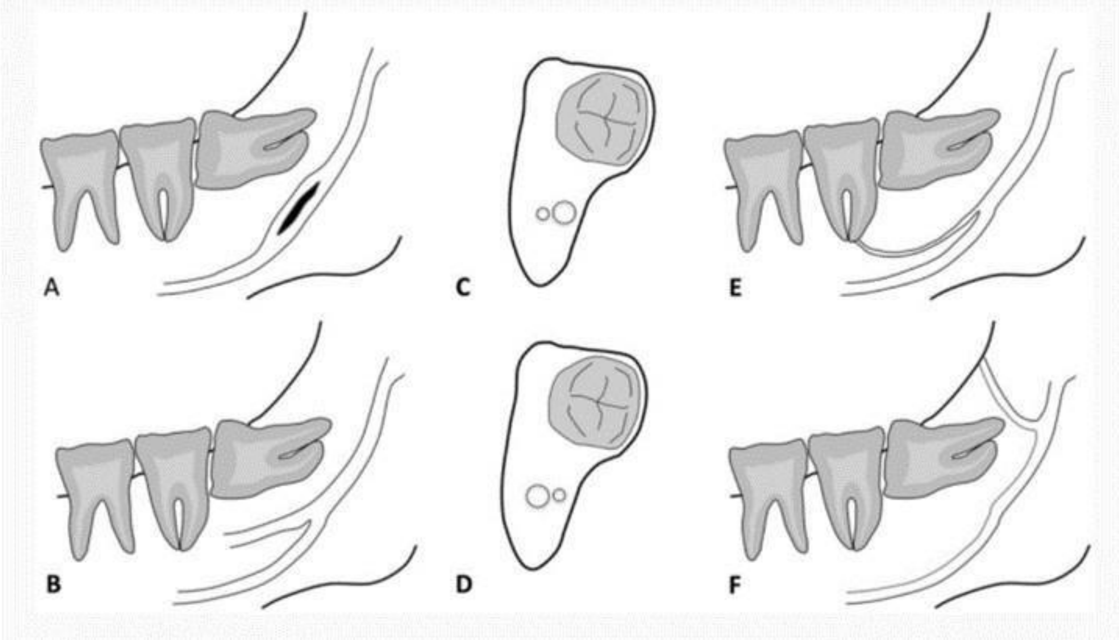

Figure 57. Schematic diagram depicting the different types of mandibular canal variations: A). The forward canal included with confluence or without confluence. B). The canal bifid without confluence. C, D). Buccolingual orientation of the bifid canal. E). The dental branch is oriented to the apex of the root. F). Retromandibular branch. Adapted from Valenzuela-Fuenzalida et al. (173)

1.12.7 Supernumerary teeth

Supernumerary teeth (hyperdontia) are defined as those teeth that are an addition in number to the normal series of permeant or primary dentations. It can occur in any parts of the jaws either unilaterally or bilaterally in a single or multiple form and can be noticed in either maxillary jaw or mandible or even both (178). Supernumerary teeth can be classified based on location and morphology. According to their location, supernumeraries may be categorized into four types: Mesiodens, paramolar, distomolar, and parapremolar. Paramolar is a supernumerary tooth adjacent to the molarteeth either platally/lingually or buccally. Distomolar is the one that is located distally to third molar and can be also regarded as fourth molar. Parapremolar is a supernumerary tooth located adjacent to premolar teeth. Mesiodense is the most frequent surpernumerary rooth takes place in the anterior of maxilla named (mesiodens)accounting for 80% and located in the incisor region of the maxillary dentitions (179,180). In addition, supernumerary teeth can be categorized into two types concerning morphology, rudimentary or supplemental. Rudimentary teeth (dysmorphic) describe teeth which appear in an abnormal shape and smaller size, including conical, tuberculate, and molariform types. On the other hand, supplemental teeth (eumorphic) are supernumeraries that attain a normal shape and size mimicking a particular tooth the normal dentition (179,180). Regarding the prevalence of supernumerary teeth, it is reported that it ranges between 0.1-3.8% In permanent dentition, it is more frequent in males than females (181). OPG depicts supernumerary teeth in the molar region of upper right region of the maxilla (distomolar) (Figure 58). Another OPG demonstrates two supernumerary teeth located in the premolar molar region (Figure 59).

Figure 58. OPG depicts supernumerary teeth in the molar region of upper right region of the maxilla (Distomolar). Adapted from (HOUB)

Figure 59. OPG depicts supernumerary teeth in the premolar molar region of mandible. Adapted from (HOUB)

1.12.8 Dense bone island (DBI) or enostosis

Dense bone island or ensostosis is defined as a radiopaque bone condensation that appears as an elliptical or irregular in shape. It is coincidentally noticed on panoramic radiography as a localized with a variable size and separated from the normal surrounding bone by smooth or irregular borders, and usually measuring less than 2 cm. In the literature, it has been named enostsois, idiopathic osteosclerosis, focal osteosclerosis, dense bone island, or periapical osteopetrosis (182). When it presents as a large mass, it does not cause any bony expansion, neither displacement nor resorption of the nearby teeth (183). It is more frequent in the mandible 89.3%–100% particularly molar-premolar region of than although one author reported unusual location and size of DBI in the anterior of maxilla (184). Concerning the radiographic appearance DBI, it is like osteoma. Therefore, multiple idiopathic osteosclerosis could be a sign of Gardener's syndrome known also as familial multiple polyposis syndrome should be. It is primarily characterized by adenomatous intestinal polyps which have the risk of transformation into malignancy (185). OPGs and CBCT depicting (DBI) in the canine and molar region of mandibular left region (Figure 60, 61 & 62) (186).

Figure 60. OPG depicting (DBI) in the canine and molar region of mandibular left side (yellow arrow). The one periapical to the molar could be considered as a condensing osteitis as a differential diagnosis. Image adapted from (HOUB)

Figure 61. OPG depicts multiple diffuse bone islands around the impacted mandibular second premolar (white arrow), and the rest of dense bone islands distributed through both jaws. Adapted from Koh et al. (186)

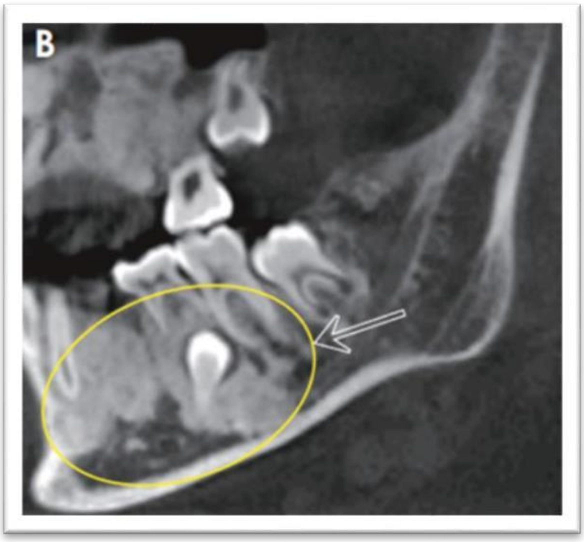

Figure 62. The Sagittal section of CBCT of the same patients depicting the dense bone islandsadjacent to the left impacted mandibular second molar (white arrow). Adapted from Koh et al. (186)

To elaborate of the literature, Vaseemuddin et al. (187) analyzed 410 panoramic radiographies for the purpose of reporting the incidence of different findings. They pointed out that the prevalence rate of incidental findings is 50%. The elongated styloid process is the most frequent finding representing 25% of the images with incidental findings. Likewise, Ghassemzadeh et al. (188) performed their studies on a wide spectrum of 2307 panoramic radiography. It is speculated that elongated styloid process is also the most noticed incidental finding. It manifests in about 48.2% of the studied images. Thus, several incidental findings can be seen in a panoramic radiography including carotid artery calcification (carotid atheroma), salivary glands' stones (sialoliths), tonsilloliths, idiopathic bony sclerosis (called enostosis or dense bone island), phleboliths, residual cysts, and temporomandibular joint changes.

1.13 Other findings noticed on OPG

1.13.1 Klemetti index

It is an index that was previously proposed and developed for the purpose of osteoporosis assessment based on the integrity of the inferior mandibular border noticed on panoramic radiography (189)**.** OPG depicting the area where Klemetti index (Figure 63). Schematic illustration of the integrity of the mandibular inferior border upon which the Klemetti index is correlated for the different classes (c1, c2, or c3). (Figure 64).

Figure 63. OPG depicting the area where Klemetti index quantified on the image. Adapted from Jose López-López et al. (189)

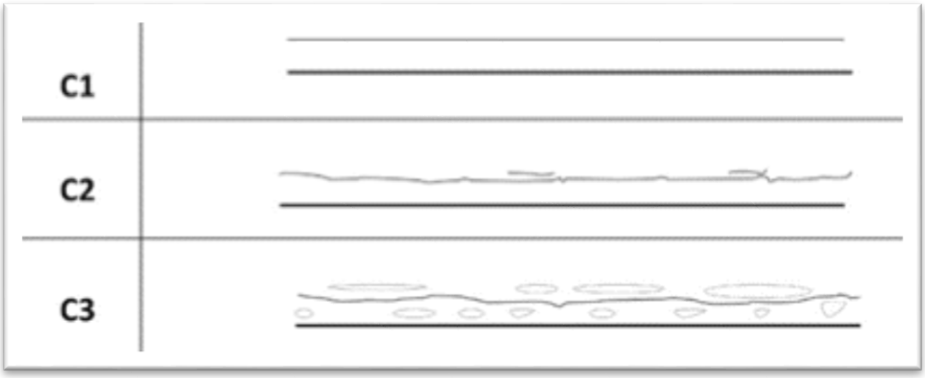

Figure 64. Schematic illustration of the integrity of the mandibular inferior border upon which the Klemetti index is correlated for the different classes (c1, c2, or c3). Adapted from. José López-López et al. (189)

1.13.2 Osteoporosis

Osteoporosis is a disease affecting the bone tissue characterized by reduced bone mass and changes in the microarchitectures of the bone tissue. It generally affects females in their middle age period. Therefore, it is considered as the major cause of bone fracture in this type of individual. It has been reported that it is highly prevalent in Europe and in Spain particularly. Several measures have been advocated to diagnose osteoporosis that range from x-ray absorptiometry to the use of panoramic radiographic through quantifying different indexes such as mandibular cortical width and mental index. Early diagnosis and preventive measures are paramount to further prevent consequences of osteoporosis (190). Images depict an algorithm that is based on nine points manually labelled in each image for determining osteoporosis (Figure 65).

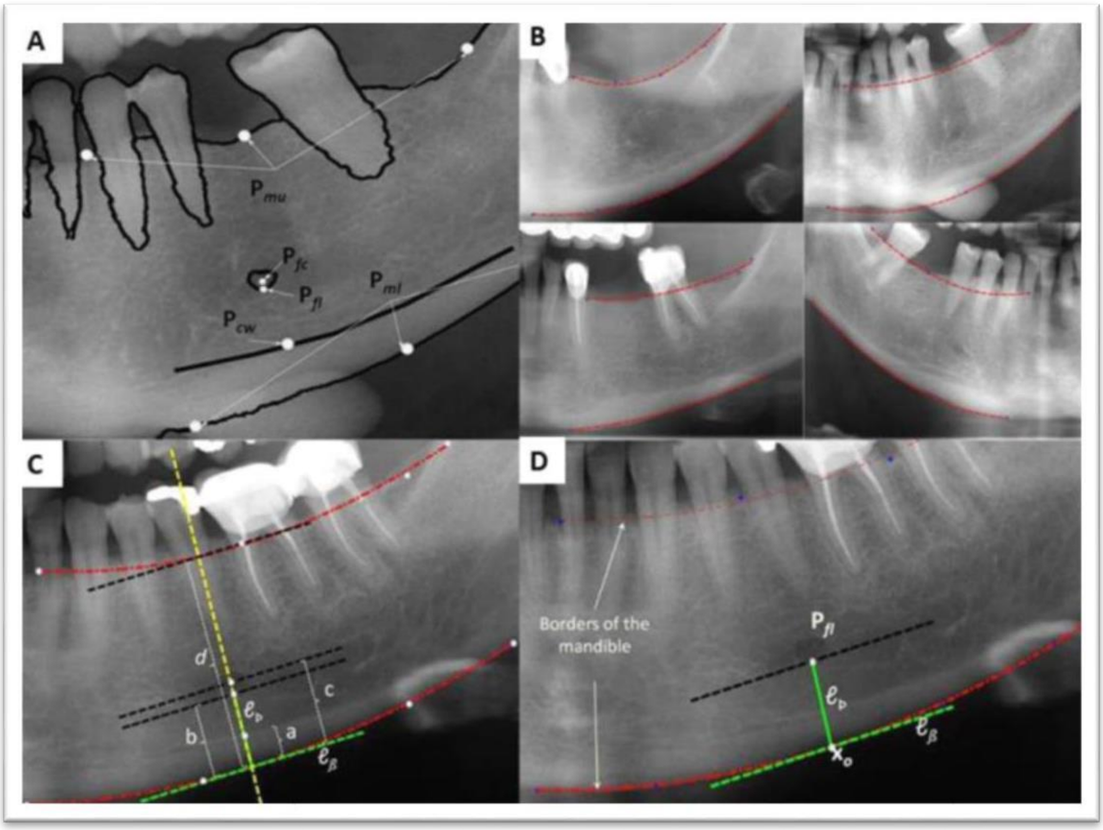

Figure 65. Images depict an algorithm that is based on nine points manually labelled in each image. Adapted from José López-López et al. (190)

1.14 Review of literature

As previously elaborated on, panoramic technique remains the most frequently and routinely used for radiographic diagnosis of maxillofacial structures due to its affordability and ease of use (191). Tooth impaction including mandibular third molar is among the findings screened by panoramic imaging. OPG could provide an insight about the proximity to the adjacent inferior alveolar nerve and guides the clinician whether to proceed with the intervention or to consider priorly the use of CBCT for further planning and decision making. Likewise, several studies have investigated the pathologies associate with mandibular third molar impactions specially, the effects on the neighboring second molar that include distal caries, bone lass, and external resorption (192–195). Regarding the bone loss assessment distal to the second molar, Dias et al. (125) have investigated the bone loss on the distal surface of the second molar by comparing panoramic radiographies to the CBCT images on a sample of 70 patients. They indicated that bone loss is manifested in 62.9% on OPG compared to 80% on CBCT. On panoramic radiography, they relied on the integrity of the alveolar bone crest to justify the presence or absence of bone loss. They furtherly classified the bone loss severity based on the level of loss from the coronal one third of the second molar up to the apical one third into slight, moderate, or severe. Another study performed by Matzen et al. (196) compared the pathological findings seen on panoramic radiography and CBCT that include the occurrence of marginal bone loss onthe distal surface of the second molar. On panoramic radiography, they consider bone loss to be evident when it exceeds 3 mm. Similarly, Gupta eta la. (127) investigated theoccurrence of periodontitis adjacent to lower second molar in the presence of impactedthird molar on panoramic radiographies and found it accounts for 39%. They indicated that horizontal bone loss occurs more than vertical bone loss. The vertical bone loss was more seen with the mesioangular impaction. Aside from that, they did not actually specify the method of measurement of bone loss on panoramic images. Tai et al. (197) performed their study on panoramic radiography to report on the association of mandibular third molar impaction with the dental and periodontal lesions in the adjacent mandibular second molar. The distal bone loss analyzed in relation to the second molar accounts for 35.30% for being more common with the mesioangular impaction. They classify the bone loss severity in relation to the distal aspect of the second molar for which the most severe form manifests includes the total distal aspect of the distal root and the furcation area. The mild form of bone loss is <2/3 the distal root length. Savitri et al. (198) described pathological abnormalities that is associated the molar impaction of horizontal and mesioangular lower mandibular third molar impaction using panoramic images. They reported that the interalveolar bone between the third and second molar loss is the most common pathology for being most frequent with the horizontal impaction in comparison to the mesioangular type. Ye et al. (194) evaluated the pathology related to mandibular impacted third molar and mandibular second molar. Marginal bone loss distal to lower second molar was regarded as a pathology and accounts for 14.81%. It was the third most common pathology in their subjects after pericoronitis and dental caries. Altan et al. (199) assessed the impact of different angulation of impacted mandibular third molar on the presence of different pathologies using panoramic radiographies. The bone loss on the distal surface of mandibular second molar accounted for 4.9%. Likewise, El-Khateeb et al. (200) investigated also the pathology associated with impacted third molars. They reported that distal to lower second molar, the loss of lamina dura and widening of periodontal ligaments are the most frequent pathological changes. On Yemeni population, Shumar et al. (201) has investigated the occurrence of different pathologies in impacted third molars. Accordingly, they concluded that in case of lower third molar impaction, the distal bone loss related to the second molar is manifested in about 6.8% of the study's participants. We could refer from the previously published studies that they used panoramic radiographies to report on the prevalence of impaction and the condition of associated pathologies including marginal bone loss on the distal aspect of lower second molar. However, the linear measurement was not explicitly explained. Therefore, the measurements of bone loss on panoramic radiography in our study are valuable regarding the usefulness of panoramic radiography technique as it is still the most radiographic technique for diagnosis in dentistry.

1.15 Justification

The mandibular third molar is considered the most frequently impacted tooth in the oral cavity; hence most oral surgery processes are in relation to this type of impaction. This tooth can exert complications on the surrounding tooth and bone that can result in dental caries or periodontal defects. The impaction position makes the area inaccessible to cleaning which contributes to the accumulation of food, plaque formation and bacterial colonization. The progression of this process would result in periodontal pocket formation and hence bone loss. To avoid the possible complication of the impaction on the second molar, surgical intervention represents a logical management. However, the bone status after extraction can lead to periodontal defects or an improvement of bone on the distal aspect depending on the type of impaction, surgical difficulty, participating factors like smoking and bad oral hygiene, and the severity of preexisting periodontal health around 2^{nd} molar. It seems that the periodontal condition on the distal aspect of the second molar have the potential to improve. Since mandibular third molar is the most frequently impacted tooth that requires surgical intervention, Since the presence of impaction of the mandibular third molar may exert adverse effects on the adjacent mandibular second molar in terms of bone loss, among other factors, we decided to investigate the condition of the bone using a panoramic radiograph. To have an insight into the presence of different pathological, abnormal, anatomical variations in the oral cavity, OPG is used routinely in dental practice and shows impaction and other dental problems. Compared to CBCT, it is considered affordable, lower dose, and lower cost. Therefore, we use it to assess the bone status distal to the mandibular second molar.

HYPOTHESIS

2. Hypothesis

2.1 Hypothesis

Impaction of the lower third molar causes bone loss distal to the second molar, therefore there will be bone gain distal to the second molar after extraction of the impacted third molar.

2.2 Null hypothesis

considers that the impaction of the third molar causes bone loss distal to the second molar, however, there will be no bone gain distal to the second molar after extraction of the impacted third molar.

OBJECTIVES

3. Objectives

3.1 Primary objective

To determine and evaluate the distal bone loss of the second lower molar associated with the impaction of the third molar in patients with extracted and non-extracted teeth and to analyze its evolution after the extraction of the third molar in patients with extracted teeth.

3.2 Secondary objectives

1. Relate the results with gender.
2. Relate the results with age.
3. Relate the results with the type of impaction of the third molar.
4. Relate the results with the systemic pathology of the patients.
5. Relate the results with periodontal disease.
6. Relate the results between smokers and non-smokers.
7. Investigate the different incidental findings found in panoramic radiographies.
8. Correlate the type of impaction with the temporomandibular joint changes.
9. The occurrence of impaction with respect to sides.
10. The prevalence of impaction according to Winter’s classification.
11. The prevalence of impaction according to Pell & Gregory (depth level).
12. The most prevalent inferior alveolar canal shape.
13. Inferior mandibular canal visibility with respect to molars region.
14. The canal proximity to the impacted mandibular third molar.
15. Describe radiolucent and radiopaque lesions noted on panoramic radiogrpahies.
16. Describe maxillary sinuses changes.
17. Describe the prevalence of condyle’s shape.
18. Elaborate on panoramic radiographies’ use for assessing bone loss.

METHODOLOGY

4. Methodology

4.1 Design of study

The design of this study is a retrospective cohort of patients visiting HOUB who have impacted third molars. Patients are collected by simple random sampling. X-rays of patients attending the hospital will be obtained randomly to indicate (study group); those with radiographs before and after extraction of impacted lower third molar with clearly documented history, and (control group); those who have gone to other dental treatments and have an impacted lower third molar without extraction. The OPG radiographs of the patients were divided into a study group and a control group.

4.2 Place of study

The study is conducted in the faculty of Odontology, Department of Odontostomatologia and the university Dental Hospital of Barcelona (HOUB). The patient's data are collected randomly by simple randomization from the patient's archived panoramic images. The study protocol was approved by the ethical committee of (HOUB) on 28/09/2022 under the protocol number 2022-032-1.

4.3 Study subjects

Patients are collected by simple random sampling. X-rays of patients who come to the hospital will be obtained randomly to indicate those who have x-rays before and after removal of the impacted lower third molar, and Those who have undergone other dental treatments and have a lower third molar impacted. The patients' OPG radiographs were divided into a study group and a control group:

4.3.1 Study group

The patients in this group are those who come to extract their impacted lower third molar, two x-rays are taken. One before the extraction, and the other taken at least 3-6 months later as the patient would come for other dental reason that necessitates OPG, considering the essential time for bone healing and remodeling is 3 months which is regarded as the cut-off period for periodontal healing (202,203). Measurement of bone loss is performed on both radiographs and the mean difference is compared (Figure 66).

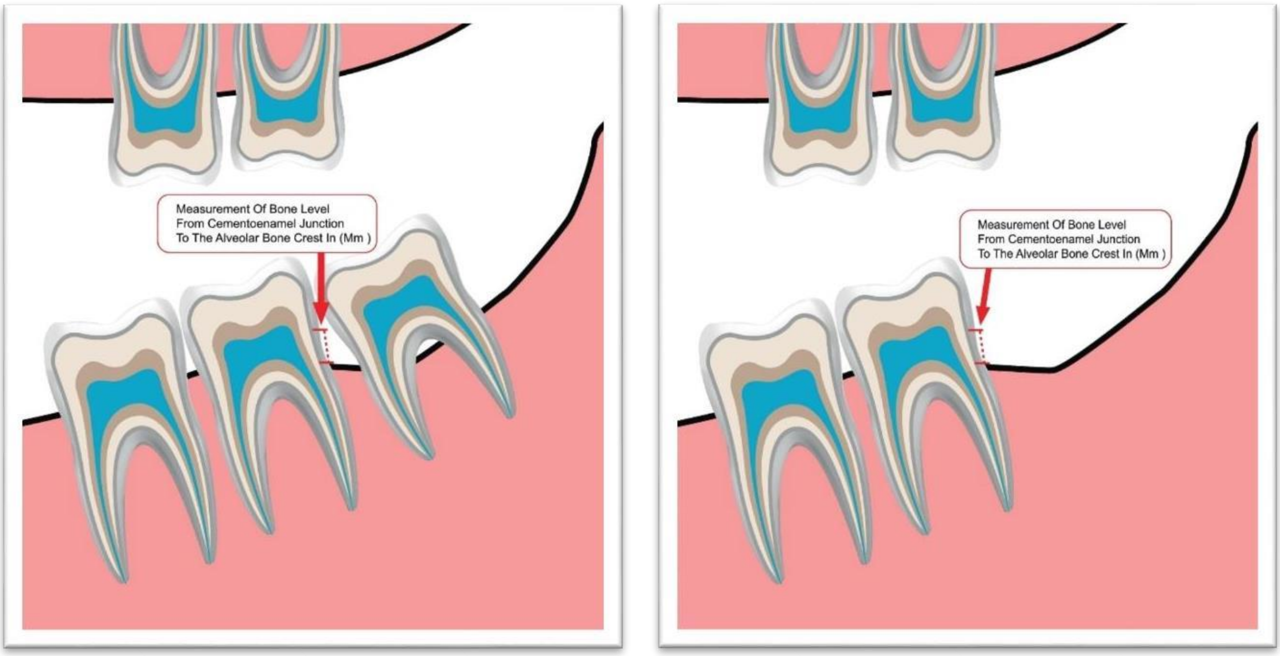

Figure 66. Measurements of the bone level from cementoenamel junction downward to the level of the alveolar bone crest of the study group (extraction group)

4.3.2 Control group

Control cases are those patients who come to the dental clinic for any dental reason and have an OPG performed that shows the presence of partial or complete impaction of the lower third molar, but the impacted tooth is not extracted. This group is selected based on age, sex, and type of impaction from the archived data of patients matching the study group. Thus, a control panoramic view is performed to assess the oral status and the evolution of this non-extracted third molar at least 3-6 months later. Since our goal is to assess bone change in extracted versus non-extracted, the goal for patients who do not have an extraction is to have a follow-up panoramic radiograph 3-6 months after their visit to assess oral status, history, and the condition of the bone distal to the second molar. Signed informed consent will be obtained from the patient prior to taking the follow-up panoramic radiograph. Measurement of the bone from the cementoenamel junction to the bone crest is performed using the Romexis software measurement tool according to Faria et al. (203). Calibration for all radiographs is performed first, and then measurements are performed. Intra-observer agreement within one month interval measures is performed using the Kappa test (204). Control cases are those patients who come to the dental clinic for any dental reason and an OPG is performed that shows the presence of impaction partial or complete of the lower third molar, but the impacted tooth is not removed. A control overview is performed to evaluate the oral state and the evolution of this third molar not extracted at least 3-6 months later (Figure 67).

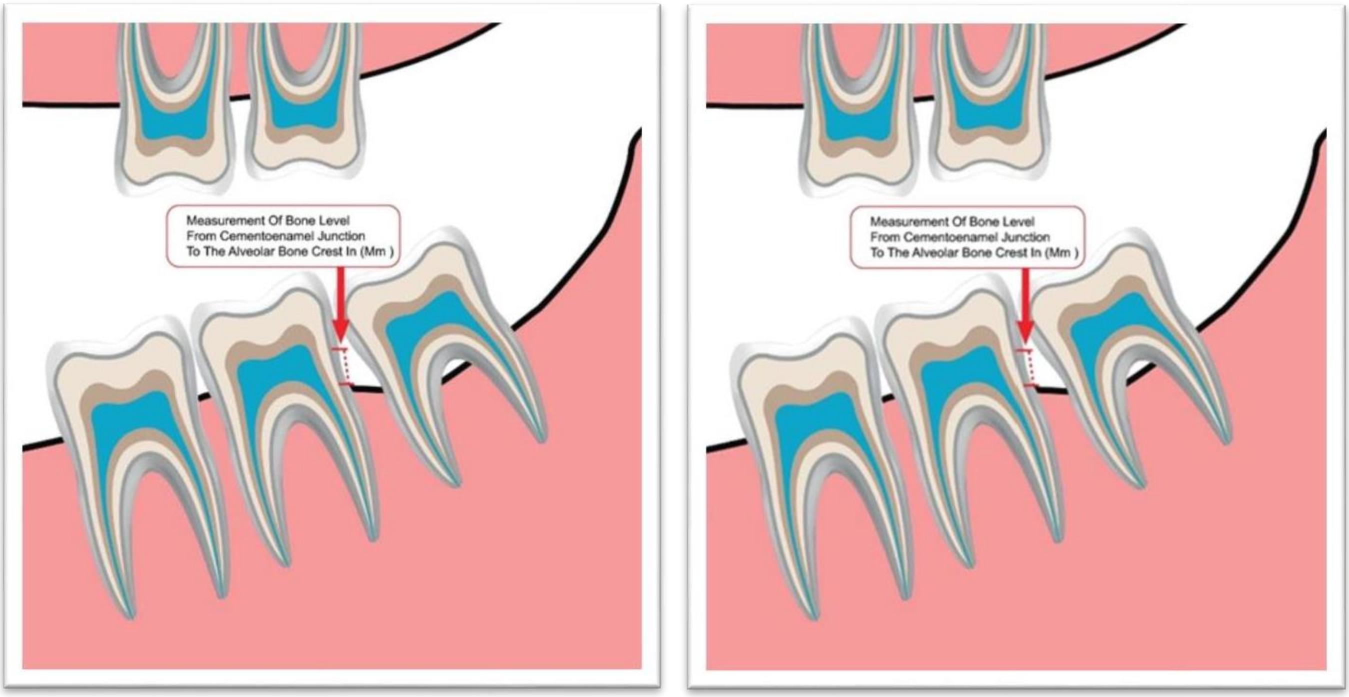

Figure 67. Measurements of the bone level from cementoenamel junction downward to the level of the alveolar bone crest of the control group (non-extraction group)

4.4 Patient's OPG selection

The patients' archived images are selected according to the predefined inclusion and exclusion criteria according to simple randomization method. A total of 12,000 panoramic radiographic images were retrieved consecutively from the archived data in the dental hospital within the period June 2018 to August 2022. A sample of 640 radiographies are randomly selected from the total number of radiographs according to the simple randomization method, and only 400 are regarded suitable for the analysis while 120 are found to be for patients under 18 years old. 160 archived (OPGs) of 80 patients that meet the inclusion criteria and match the purpose of the thesis objectives were randomly selected for this retrospective study case control study. Then, the participants were assigned into two groups (40 = each): the study group, wherein the bone level distal to the mandibular second molar was measured before and after the extraction of the IMTM, and the control group, in which the bone level was measured twice within a period of 3-6 months without the extraction of the IMTM.

4.5 Inclusion criteria

- Patients older than 18 years.
- Patients having radiographic images before and after impacted third molar extraction.
- The study group had to have their molar extracted.
- Control cases do not have extractions of the impacted lower third molar for different reasons.
- Presence of lower second molar.

4.6 Exclusion criteria

- Patients who do not have an impacted lower third molar.
- Patients who have had their lower second molar extracted or who have lost it or who have agenesis of the same.
- Patients who do not have an OPG image after extraction of the impacted lower third molar.

- Patients under 18 years of age.
- Patients who do not have informed consent transfer images for studies.
- Patients receiving chemotherapy, radiotherapy or bisphosphonate treatment for head and neck tumors.
- Patients who have systemic diseases that affect bone remodeling.
- Patients who have a large subgingival to distal restoration of the mandibular second molar.

4.7 Sample size

The sample is calculated based on the study by Faria et al. 2012 (203).

• Average initial depth of the pocket: 5.70 +- 3.80

• Average depth of the pocket after extraction: 3.77 +- 2.86

• Average difference: 1.93 +- 2.46

• Methods: ANOVA, repeated measures, within factors

• Effect size: 0.57 (calculated effect size is based on Cohen)

Cohen's d is a measure of the effect size as a standardized mean difference. Thus, the results of the d Cohen can be interpreted as:

1. Small effect = 0.2 – 0.5

2. Medium effect = 0.5 – 08

3. Long effect = > 0.8

In this research, the effect size calculation based on Cohen d is as follows:

Pooled SD = √ ((SD12 + SD22) ⁄ 2)

√ ((3.802 + 2.862) ⁄ 2) = √ (11.3098) = 3.36

Cohen's d = (M1 – M2) ⁄ SDpooled

(5.70 – 3.77) ⁄ 3.36 = 0.57

• Alpha error: 0.05

• Power: 80%.

Number of groups to compare: 2 Number of measurements: 2

Total sample size: 24, so there will be 12 patients for each group. However, we intend to increase the number of patients for the power of the study.

4.8 Study variables

Variable	Type of variable
Demographic data	
Age	Nominal
Gender	Nominal
Clinical history-related data	
Reason for consultation	Nominal
Smoking status	Nominal
Periodontal status	Nominal
Systemic diseases	Nominal
Third molar impaction-related data	
Impacted tooth	Nominal
Impaction status of (IMTM)	Nominal
Impaction side	Nominal
Winter's classification	Nominal
Pathology on 2nd molar	Nominal
Pell & Gregory classification by depth	Nominal
Pell & Gregory classification by anteroposterior space available	Nominal
Bone level adjacent to 2nd molar before extraction (SG)	Numerical
Bone level adjacent to 2nd molar after extraction (SG)	Numerical
Bone level difference before and after extraction	Numerical
Bone level interpretation before and after extraction	Nominal

Bone level adjacent to lower second molar (baseline of CG)	Numerical
Bone level adjacent to lower second molar (follow up CG)	Numerical
Bone level difference between baseline and follow up (CG)	Numerical
Bone level interpretation between baseline and follow up (CG)	Nominal
Inferior alveolar nerve canal shape	Nominal
Inferior alveolar nerve canal shape visibility at 3rd molar region	Nominal
Inferior alveolar nerve canal shape visibility at 2nd molar region	Nominal
Inferior alveolar nerve canal shape visibility at 1st molar region	Nominal
Inferior alveolar nerve canal proximity to 3rd molar roots	Nominal
OPG-related findings	
Mandibular cortical width (MCW) before extraction in (SG)	Numerical
Mandibular cortical width (MCW) after extraction in (SG)	Numerical
Mandibular cortical width difference	Numerical
Mandibular cortical width interpretation	Nominal
Mandibular cortical width (MCW) at baseline image in (CG)	Numerical
Mandibular cortical width (MCW) of follow up image in (CG)	Numerical
Mandibular cortical width (MCW) difference	Numerical
Mandibular cortical width interpretation	Nominal
Klemetti index	Nominal
Radiolucent changes	Nominal
Radiopaque changes	Nominal
Maxillary sinus findings	Nominal
Tempromandibular joint changes (TMJ)	Nominal
Shape of the condyle	Nominal
Incidental findings	Nominal

Table 10. A summary of the study variables

4.8.1 Demographic data

4.8.1.1 Age

is retrieved from patient records and date of birth is anonymous. Patients will be divided according to their age into three groups:

- The first group: 18-28

- The second group: 29-39

- The third group: 40-50

- The fourth group: ≥ 51

4.8.1.2 Gender

The sex of the patient is determined according to whether it is female or male. Any of the two genders is represented by a number, since they are considered nominal variables. If any other gender, such as binary, etc., was recorded in any of the medical records, it would be presented as either, female, or male.

4.8.2 Clinical history-related data

4.8.2.1 Reason for consultation

The main complaint that motivates the patient to visit the dentist is determined from the clinical history. The complaints recorded and coded as:

Code1= dental pain

Code 2= dental caries

Code 3= cheek bite

Code 4= dental infection

Code 5= extraction of IMTM

Code 6= other dental extractions

Code 7= dental restoration

Code 8= endodontic treatment

Code 10= periodontal treatment

Code 11= prosthodontic treatment

Code 12=dental implant

Code 13= dental fracture

4.8.2.2 Systemic Disease

We investigated the systemic disease reported in the clinical history and coded as:

Code 0= not reported

Code 1= diabetes mellitus

Code 2= hypertension

Code 3= osteoporosis

Code 4= hyperthyroidism

Code 5= hypothyroidism

Code 6= other diseases

Code 7= diabetes and hypertension together

4.8.2.3 Smoking status

It is investigated whether the patients studied are smokers or non-smokers and coded as:

Code 1= smoker

Code 2= non-smoker

4.8.2.4 Periodontal status

The patients' images were evaluated in term of the present periodontal status and coded as:

Code 0= no evidence of periodontitis

Code 1= generalized periodontitis

Code 2= localized periodontitis

4.8.3 Third molar impaction-related data

4.8.3.1 Impaction Status

OPG images are analyzed for the presence of impaction, whether it is partial, complete, or both. Coded as:

Code 1= partial impaction

Code 2= complete impaction

Code 3= both types

4.8.3.2 Impacted tooth

Impacted teeth are found as mandibular third molar, maxillary third molar, canine, or premolar. Coded are assigned according to the presence of impaction as:

Code 1= canine

Code 2= premolar

Code 3= maxillary 3rd molar

Code 4= mandibular 3rd molar

Code 5= another supernumerary impaction

Code 6= maxillary and mandibular 3rd molars

Code 7= multiple impaction in addition to third molar

4.8.3.3 Impaction side

Impacted teeth can be found as right unilateral, left unilateral, or both sides. Coded assigned as:

Code 1= right unilateral IMTM

Code 2= left unilateral IMTM

Code 3= Both sides

4.8.3.4 Winter's classification

One of the classifications of the lower third molar is named after the Winter's classification. Different categories were screened and coded as:

Code 0= NA/absent

Code 1= upright (vertical)

Code 2= mesioangular

Code 3= distoangular

Code 4= horizontal

Code 5= Buccally tilted

Code 6= Lingually tilted

Code 7= Transverse

Code 8= Inverted

4.8.3.5 Pell & Gregory Classification

Another classification of the lower third molar is called the Pell & Gregory classification.

- Class A. The occlusal plane of the impacted tooth is at the same level as the occlusal plane of the 2nd molar. Coded as 1
- Class B. The occlusal plane of the impacted tooth is between the occlusal plane and the cervical margin of the 2nd molar. Coded as 2
- Class C. The impacted tooth is below the cervical margin of the 2nd molar. Coded as 3
- Class 1. There is sufficient space available between the anterior border of the ascending ramus and the distal aspect of the 2nd molar for the eruption of the 3rd molar. Coded as 1
- Class 2. The space available between the anterior border of the ramus and the distal aspect of the 2nd molar is less than the mesiodistal width of the crown of the 3rd molar. Denotes that the distal portion of the crown of the 3rd molar is covered by the bone of the ascending ramus. Coded as 2
- Class 3. The 3rd molar is totally embedded in the bone of the anterior border of the ascending ramus due to the absolute lack of space. It is obvious that class 3 teeth are more difficult to extract, since a relatively large amount of bone must be removed and there is a risk of damaging the nerve or fracturing the jaw. Coded as 3

4.8.3.6 Pathology on 2nd molar

The presence of IMTM can exert an effect on the adjacent second molar. Different pathologies that can be noticed are coded as:

Code 0 = no pathology detected

Code 1= dental caries

Code 2= bone loss

Code 3= external root resorption

Code 4= radiolucent change (lesion)

Code 5= dental caries & bone loss

Code 6= bone loss & external resorption

4.8.3.7 Bone loss distal to mandibular 2nd molar before extraction for study group in (mm)

Measured from cementoenamel junction to bone crest.

4.8.3.8 Bone loss distal to mandibular 2nd molar after extraction for study group, in (mm)

Measured from cementoenamel junction to bone crest.

4.8.3.9 Bone status difference

This represents the difference between the condition of bone before extraction and after extraction, labelled in (mm).

4.8.3.10 Bone status interpretation

The bone status difference is interpreted and coded as following:

Code 0= bone level does not measure due to the absence of the second molar

Code 1= bone gain

Code 2 = bone loss

Code 3= no change in bone level

4.8.3.11 Bone loss distal to mandibular 2nd molar at baseline for control group in (mm)

Measured from cementoenamel junction to bone crest.

4.8.3.12 Bone loss distal to mandibular 2nd molar after follow-up for control group, in (mm)

Measured from cementoenamel junction to bone crest.

4.8.3.13 Bone status difference

This represents the difference between the condition of bone before at baseline and after follow-up, labelled in (mm).

4.8.3.14 Bone status interpretation

The bone status difference is interpreted and coded as following:

Code 0= bone level does not measure due to the absence of the second molar

Code 1= bone gain

Code 2 = bone loss

Code 3= no change in bone level

4.8.3.15 Shape of inferior alveolar nerve canal

In the literature it is reported that there are different possible shapes of the nerve canal ranging from the line, elliptical, the spoon shaped to turning curve. Different shapes are coded as following:

Code 1= linear

Code 2= elliptical

Code 3= spoon shaped

Code 4= turning curve

4.8.3.16 Visibility of inferior alveolar nerve canals

It is intended to describe whether the canals containing the nerve are visible or not. Descriptive categories including clearly visible, approximately visible, and almost invisible were provided. We describe the visibility at three different regions: at 3rd molar, 2nd molar, and 1st molar regions. The coded as follow:

Code 1= clearly visible

Code 2= approximately visible

Code 3= invisible

4.8.3.17 Proximity of inferior alveolar nerve

The alveolar nerve canal is sometimes located near the roots of the impacted mandibular third molar. Therefore, we evaluate the proximity, and the numbers are given to represent the state. We categorize this condition as far from the duct, near the duct, or not applicable or difficult to determine. The coded as follow:

Code 0= impossible to determine

Code 1= distant from the canal

Code 2= close to the canal

4.8.4 OPG-related findings

4.8.4.1 Mandibular cortical width before extraction in study group (MCW)

The mandibular cortical width is measured on both sides of the mandible in the region of the canine premolars, the mean is calculated, and the results are expressed in millimeters (mm).

4.8.4.2 Mandibular cortical width after extraction in study group (MCW)

The mandibular cortical width is measured on both sides of the mandible in the region of the canine premolars, the mean is calculated, and the results are expressed in millimeters (mm).

4.8.4.3 MCW difference

The difference is calculated in mm.

4.8.4.4 MCW interpretation

To describe the measurement, we provided coded as follow:

Code 0= no change

Code 1= improved results

Code 2= negative results

4.8.4.5 Klemetti Index

Erosions of the lower border of the mandible and general integrity are evaluated according to the mandibular cortical index (KLEMETTI) (189). Three categories described for this index including:

- C1: The cortex margin is clear and sharp on both sides
- C2: Endosteal surface defects are crescentic
- C3: Cortical layer is extremely porous

The findings are coded as follow:

Code 1= C1

Code 2= C2

Code 3= C3

4.8.4.6 Radiolucent lesion

The maxilla and mandible were evaluated for the presence of any radiolucent changes that could be tooth-related radiolucent lesions or non-tooth-related radiolucent lesions. The changes are coded as follow:

Code 0= no observed changes

Code 1= changes of dental origin

Code 3= changes of non-dental origin

4.8.4.7 Radiopaque lesions

The presence of radiopacities within the mandible or maxilla or both is detected on OPG. Lesions are reported on whether they are idiopathic, condensation osteitis, neoplastic change, or mixed lesion. The changes are coded as follow:

Code 0= no observed changes

Code 1= idiopathic

Code 2= condensing osteitis

Code 3= neoplastic changes

Code 4= mixed changes

4.8.4.8 Maxillary sinuses

The presence of pathologies in the maxillary sinuses is evaluated and the different possible pathologies are reported, and our variables were determined as no pathology or impossible to assess, partial thickening, complete annihilation, or domed Opacity. The changes are coded as follow:

Code 1= no pathology or impossible to detect

Code 2= partial thickening

Code 3= complete obliteration

Code 4= dome-shaped changes

4.8.4.9 Tempromandibular joints (TMJ) changes

The joints are evaluated for different changes including flattening, osteophytes, and other possible changes. codes are provided to represent the different changes as follow:

code 0= no observed changes

code 1= flattening

code 2= erosion

code 3= osteophyte

code 4= sclerotic changes

4.8.4.10 Condyle's shape

We intend to describe whether there is change in the condyle shapes for both groups in our study. Therefore, different shapes have been described in the literature upon which we rely to describe the shapes off the condyles in our study. the possible noticed shapes are coded as follow:

code 1= oval

code 2= flattening

code 3= diamond

code 4= mixed

code 5= bifid

code 6= crooked finger

4.8.4.11 Incidental findings

Several incidental findings that can be noticed on OPG such as styloid process elongation, carotid atheroma, sialoliths, tonsilloliths, dense bone islands. Different coded are provide as follow:

Code 0= no observed incidental findings

Code 1= styloid elongation

Code 2= carotid atheroma

Code 3= tonsillolith

Code 4= sialolith

Code 5= phlebolith

Code 6= bifid mandibular canal

Code 7= supernumerary tooth

Code 8= styloid & carotid atheroma

Code 9= styloid & sialolith

Code 10= styloid & phlenolith

4.9 Study statistics

All data was collected in an Excel table from the Microsoft Office 365 suite and analyzed with the SPSS 27.0 program for Windows (SPSS, Chicago, Illinois, 2022). Our The aim is to measure the mean difference of measurements before and after extraction. in the study group, and then assess whether there is a statistically significant difference between the means of the two groups.

A descriptive analysis of the qualitative variables was carried out according to their frequency and percentage, and quantitative according to measures of central tendency and dispersion. The quantitative variables, depending on their normal distribution, studied according to the Kolmogorov-Smirnov ($p>0.05$), were defined according to mean and standard deviation. The possible associations of the main dichotomous variables with the variables qualitative tests were studied according to the chi-square test and its possible associations. Quantitative tests were studied according to the t-Student test or by default the non-student test. Mann-Whitney U parametric (if they did not meet the normality criteria). Based on the distribution of numerical variables:

In normal distribution we use the t-student for paired pairs for the group of Study to compare bone measurement in the initial set (radiographs before extraction) and the final set (the radiographs after extraction), and the t-student for independent samples between the study group and the control group. For the nonparametric distribution: The Wilcoxon test is used in the comparison of data for the study group, and the Mann-Whitney U test between the study group and the control group. The difference between the study group and between the study group and the control group. It was performed using the student's t test for paired observation. Significance Statistics are accepted at less than 5%. A value P less than 0.05. A one-way analysis of variance (ANOVA) was used to investigate differences regarding gender and age in both groups. A p-value of <0.05 was considered statistically significant. We used a generalized mixed regression model to estimate the effect of removal of the third molar in healing and improvement of bone in study group, and the non-removal in the control group in relation to the other clinical or confounding factors. The intra-examiner reliability was calculated using the Kappa test. On OPGs, the level of the bone was measured from the cementoenamel junction of the second molar to the level of the alveolar crest.

RESULTS

5. Results

5.1 Descriptive and bivariate analysis:

The descriptive analysis of the study's qualitative variables of the study group and control group are expressed in frequency and percentage. On the other hand, the qualitative variables are expressed, depending on the normal distribution, according to Kolmogorov-Smirnov (p-value <0.05) and described according to the mean and standard deviation.

5.1.1 Demographic data

5.1.1.1 Age

5.1.1.2 Gender

The sample of the study included 80 patients divided equally between study group and control group into 40 patients each. In the study group the mean age was 35.5 years with standard deviation of 15.45. In study group, the number of female participants is 25 accounting for 62.5%, and males are 15 patients representing 37.5%. In the control group, the mean age was 33.4 years with a standard deviation of 16.49. The number and frequency of female participants were 22 and 55% respectively while the male number and frequency were 18 and 45% respectively. Statistically, our findings illustrate no significant differences between either group with respect to age, age groups categories, and gender (*p*-values 0.57, 0.43, 0.36) respectively. (Figure 68 & Table 11).

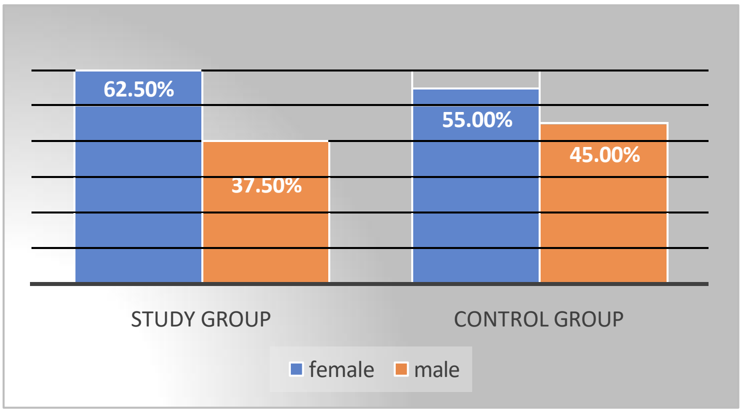

Figure 68. Distribution of gender in frequency / number of study and control groups

		Total sample	Study group (n=40)	Control group (n= 40)	p-value
Variables	*Mean* *SD*	34.5	35.5	33.48	0.57
		15.76	15.45	16.49	
Age categories					
18-28	*n (%)*	43 (53.8%)	18 (45%)	25 (62.5%)	0.43
29-29	*n (%)*	19 (23.8%)	12 (30%)	7 (17.5%)	
40-50	*n (%)*	4 (5%)	2 (5%)	2 (5%)	
≥51	*n (%)*	14 (17.5%)	8 (20%)	6 (15%)	
Gender	*Female (n)*	48	26	22	0.36
	(%)	60%	65.0%	55%	
	Male (n)	32	14	18	
	(%)	40%	35.0%	45%	

Table 11. Distribution of study & control group according to age and genders

5.2 Clinical history-related data

5.2.1 Reason for consultation

Regarding the reason for consultation, it is noticed that most of the patients of our sample visited (HOUB) for the reason of IMTM extraction; in study group 88%, and in control group 73%. No statistical difference between both groups (*p*-value 0.079). (Table 12).

5.2.2 Systemic diseases

Considering systemic diseases, our findings indicate that most of the patients did not report any systemic diseases; study group 68% and control group 58 %. The most prevalent systemic diseases noticed in the study group is diabetes mellitus accounting for 8% while hypertension is the most prevalent in the control group accounting for 10%. Overall, there are no statically significant differences between both groups (*p*-value 0.159). (Table 12).

5.2.3 Smoking status

Regarding the status of smoking, our data indicates that most of the patients in both groups are non-smokers; in the study group 73% and in control group 75%. Although representing less frequency in both groups, smokers are seen more in the study group accounting for 27.5%. In this regard, no statistical difference was reported between the groups (*p*-value 0.799). (Table 12).

5.2.4 Periodontal status

Concerning the presence of periodontal diseases, we encountered that the patients without radiographic evidence of such periodontal changes are more frequent in the study group accounting for 73%. On the contrary, the most prevalent periodontal status in the control group is the localized periodontitis accounting for 53%. The difference between study group and control group in terms of the occurrence and non-occurrence periodontal diseases is statistically significant (*p*-value 0.001). (Table 12).

Variables	**Visits motivation**	**Study group**		**Control group**		**Chi²**	***P*-value**
		N (40)	**F (%)**	**N (40)**	**F (%)**		
Reason of consultation	Dental pain	1	3%	4	10%	9.863	0.079
	Dental caries	1	3%	0	0%		
	Cheek bite	0	0%	0	0%		
	Dental infection	1	3%	0	0%		
	Extraction of MTMI	35	88%	29	73%		
	Other dental extraction	1	3%	7	18%		
	Dental restoration	0	0%	0	0%		
	Endodontic treatment	1	3%	0	0%		
	Periodontal treatment	1	3%	0	0%		
	Prosthodontic treatment	0	0%	0	0%		
	Dental implant	0	0%	0	0%		
	Dental fracture	0	0%	0	0%		
Systemic diseases	Diabetes mellitus	3	8%	0	0%	5.177	0.159
	Hypertension	2	5%	4	10%		
	Osteoporosis	0	0%	0	0%		
	Hyperthyroidism	0	0%	0	0%		
	Hypothyroidism	0	0%	0	0%		
	Other disease	8	20%	13	33%		
	Not reported	27	68%	23	58%		
	Diabetes & hypertension	0	0%	0	0%		
Smoking status	No	29	72.5 %	30	75%	0.65	0.799
	Yes	11	27.5 %	10	25%		
Periodontal diseases	Generalized periodontitis	5	13%	1	3%	13.574	0.001*
	Localized periodontitis	6	15%	21	53%		
	No evidence of periodontitis	29	73%	18	45%		

Table 12. Description of the clinical history-related data among the two groups

5.3 Third molar impaction-related data

5.3.1 Impaction status

Regarding the status of impaction, the results indicated that the most prevalent status of impaction is partial impaction accounting for 80% in the study group, and for 78% in the control group. Partial and complete impaction of the IMTM is noticed more in the control group compared to the study group; 18% and 10% respectively. The presence of only complete impaction is the least frequent as it is witnessed accountingfor 10% in the study group and 5% in the control group. The difference between both groups is not clinically significant (*p*-value 0.472). (Table 13).

5.3.2 Impacted tooth

Concerning the impacted tooth present in the study sample of both groups, our findings reported that the presence of both maxillary and mandibular third molar of at least two teeth represents most cases in study group 53%, and control group 60%. The presence of mandibular third molar regardless of being unilateral or bilateral accounts for 8% in the study group, and for 33.8% in the control group. Maxillary third molar impaction is seen more in the study group representing a frequency of 38%. Our statistical analysis reveals significant difference between both groups (*p*-value <0.001*). (Table 13).

5.3.3 Impaction side

As our study investigates the occurrence of IMTM whether to be present as a unilateral or bilateral, we found that the right unilateral IMTM occurs more in the study group 15% while it accounts for 8% in the control group. Bilateral IMTM is the most frequent among other occurrences accounting for 73% of the study group, and 75% of the control group. However, the statistical analysis indicates that there is no difference among both groups (*p*-value 0.509). (Table 13).

5.3.4 Winter's classification

We have investigated the occurrence of different types of impactions in accordance with winter's classification. Our findings display that the vertical type of impaction is the most prevalent on the right side for study and control group accounting for 45.7% and 48.5% respectively. On the other hand, mesioangular type is more prevalent in the study group accounting for 34.3%. The horizontal impaction appears more in the study group 14%. The least prevalent impaction type; distoangular and buccal tilted, are noticed only in the study group accounting for 1.3 % for both. Above all, the statistical analysis indicated that the differences between both groups with respect to the winter's classification of the right side of the patients (*p*-value 0.652). (Table 13).

With respect to the type of impaction on the left side, the findings reveal that the vertical type is the most frequent in both group accounting for 44.1% in study group, and 51.4% in the control group. Mesioangular impaction is the second most frequent with a percentage of 41.2% in the study group, and 27% in the control group. The horizontal type is the third most frequent type in both groups representing a percentage of 14.7% in the study group, and 21.6% in the control group. It is obvious that the distribution of the horizontal impaction for both groups is almost similar regardless of the side of impaction. Overall, the statistical difference concerning the type of impaction on the left side is not clinically significant (*p*-value 0.426). (Table 13).

To elaborate, the winter's classification of impaction in both groups indicates that the vertical type is more in control group (43.8%) compared to the study group (38.8%) regardless of the sides. On the other hand, the mesionangular inclination appears more in study group (32.5%) compared to the control group (25%). The findings reveal the horizontal impaction occurs more in the control group in comparison with the study group (12.5%). The statistical analysis shows that there is no significant difference among both groups (*p*-value 0.539). (Table 13).

5.3.5 Pell & Gregory classification according to depth level

Mandibular third molar impaction is further described according to Pell and Gregory positions. We have described the different positions relative to depth level according to right side, left, side, and the total in each group. Regarding the prevalence of this classification on the right side of the patients, our findings indicated that position B is the most prevalent in study group (57.5%) and control group (40%), hence it is more in study group compared to the control one. On the other hand, position A is the second most frequent in both groups and it appears more in control group (25%) to study one (20%). Position C is the least frequent in both groups accounting for 10% is study group, and 17.5% in the control. Statistical analysis shows that there is no significant difference with (*p*-value 0.452). (Table 13).

Regarding the prevalence of Pell and Gregory on the patient's left side, we noticed that the most prevalent position in the study group is position B (50%) while the most prevalent one in the control group is position A (37.5%). Position A is the second prevalent in the study group (20%) whereas position B is the second prevalent position in the control group (35%). Obviously, the least frequent position in both groups is Type C accounting for 15% in study group and for 20% in the control. Our statistical analysis states no significant differences between both groups with (*p*-value 0.215). (Table 13).

Overall, the distribution of the Pell and Gregory classification among groups regardless of the sides are reported. We found that the most prevalent impacted position is position B is the most prevalent in both groups and being dominant in the study group (53.8%) compared to the control (37.5%). Position A is considered the second most frequent occurring in both groups representing 20% in the study group and 31.3% in the control one. Therefore, position B is seen more in the study group while position A is predominant in the control. Regarding position C, it is the least position noticed and it is more frequent in control group (17.5%) compared to the study group (12.5%). Statistically, the difference between the groups is not significant (*p*-value 0.149). (Table 13).

According to the available space between the distal part of the second molar and the anterior border of the ramus on the patient's right side, our results indicate that the class 2 is more frequent in the study and control accounting for 55% and 50% respectively. Nevertheless, class classification occurs evenly in both groups with a percentage of 20%. Similarly, class 3 occurs at equal frequency of 12.5% in both groups. However, class c is the least frequent among the others in the right side for both groups. Statistical analysis has provided no significant difference with (*p*-value 0.934). (Table 13).

Regarding the occurrence of the classification on the patient's left side teeth, it is noted that class 2 is the dominant in both group accounting for 52.5% in the study group, and 50% in the control. Class 1 category occurs mor in the control compared to the study group representing 27.5% and 25% respectively. Although it is the least frequent classification, it seems that class 3 is predominant in the study group accounting for 12.5% compared to the control group at which it accounts for only 7.5%. Accordingly, our statistical analysis did not reveal any significant difference with (*p*-value 0.558). (Table 13).

5.3.6 Pell & Gregory classification according to the availability of the space

Considering the distribution of the classification based on the space available regardless of the sides, our findings reveal that the predominant classification in both groups is the class 2, and it is more prevalent in the study group with a percentage of 53.8% compared to the control in which it accounts for 50%. Similarly, class 1 is more frequent in the study group accounting for 22.5% while it represents 23.8% in the control. On the contrary, class 3 is the least frequent in both groups, and it is more prevalent in the control compared to study group with percentages of 13.8% and 10% respectively. Overall, our statistical analysis reveals no significant difference among the groups in all categories with (*p*-value 0.883). (Table 13).

5.3.7 Pathology on 2nd molar

Considering the possible pathology detected on the distal aspect of the second molar in the presence of mandibular third molar impaction on the patient's right side, our findings illustrated that the most frequently noticed pathological change is the bone loss representing 52.5% in the study group and 47.5% in the control. We noticed that the second most frequently noticed pathology in the study group is the condition of combination between the dental caries and bone loss. On the other hand, it is apparent that a combination of dental caries and bone loss is at equal frequency to the occurrence of bone loss and external resorption in the control group accounting for 2.5%. Dental caries is only noticed in the study group with only a percentage of 2.5%. On the contrary no dental caries detected in the control group specifically on the right side. A considerable percentage of teeth that do not reveal any sign of pathology in both groups accounting for 27.5% in the study group and 30% in the control. Teeth has been seen missing in 17.5% of the control group and 12.5% of the study group. Based on the statistical analysis, the findings do not reveal any significant difference of the pathology of patient's right-side teeth of both groups with (*p*-value 0.729). (Table 13).

With respect to pathology noticed on patient's left side, it is evident that bone loss is the most frequent in both groups and being more in study group 55% in comparison to the control one 35%. Apparently, the second most noticed pathology of both groups is the combination of bone loss dental caries and bone loss accounting for 5%. Dental caries has been noticed only in the control group at a frequency of 2.5% whereas no dental caries seen in the study group. Above all, there was no pathology detected in 22.5% of the study group and in 50% of the control on the left side of the patients. teeth on the left side were termed absent in 15% of the study group and in 7.5% of the control. Statistically, there was no significant difference among the groups regarding the pathology detected on patients' left side with (*p*-value 0.111). (Table 13).

Concerning the overall frequency of pathology detected on second molar in both groups regardless of the sides, the total number of OPGs investigated was 160 representing considering that there are two radiographies of the total sample that is 80 patients of the study group and control group together. It is apparent that the most frequently evident pathological change is bone loss accounting for 53.8% in the study group and 41.3% in the control. Interestingly, dental caries occurs at equal frequency of 1.3% in both groups, similarly, the presence of combined bone loss and external resorption manifested at even percentage of 1.3%. On the other hand, the combinations of dental caries and bone loss occurs in 5% of the study group whereas it occurs in 3.85% of the control. Pathological changes are not detected in 40 % for the control while not detected in 25% 0f the study one. Aside from that, teeth were absent in 13.8% of the study group and in 12.5% of the control. Consequently, the statistical analysis did not present any significant difference among the groups with (*p*-value 0.510). (Table 13).

5.3.8 Shape of inferior alveolar nerve canal

The most prevalent mandibular alveolar canal shape on the patient's right side is the turning curve (32.5%) in the study group, and (37.5%) in the control one. In the study group, it appears that the spoon-shaped canal and the elliptical ones ae distributed equally representing percentage of 25% and considered the second most prevalent shapes. On the other hand, the second most prevalent shapes in the control group are elliptical and linear shapes being distributed equally (27%). The least dominant shape in the study group is the linear shape accounting for 17.5 % whereas the spoon-shaped shape is the least frequent one in the control one. Statically, there is no significant difference (*p*-value 0.183). (Table 13).

Concerning the shape of the mandibular alveolar canal on the patient's left side, our analysis pointed out that turning curve shape is the predominant in the study group (37.5%) and in the control group (40%). The spoon-shaped canal is the second dominant in the study group (25%) whereas the elliptical shape is the second most prevalent in the control group (42.5%). The linear shape is distributed equally (15%) among the groups and considered the least frequent shape in the study group. On the other hand, the least frequent shape in the control group is the elliptical one with a percentage of 2%. The statistical analysis indicates that there is significant difference between the groups with a (*p*-value 0.02). (Table 13).

Considering the prevalence of the shape among groups regardless of the sides, our findings illustrate that the most frequent shape noticed in both groups is the turning curve shape accounting for 35% in the study group and 38.8% in the control one. On the contrary, the second most frequent shape in the study group is the spoon-shaped canal. The second dominant shape in the control group is the elliptical shape. It appears that the least common shape in the control is the spoon-shaped canal representing only 5% while the linear shape is the least frequent in the study group accounting for 16.3%. Interestingly, there is statistically significant difference among the groups regarding the overall canal shape in each sample with (*p*-value 0.004). (Table 13).

5.3.9 Visibility of inferior alveolar nerve canals

The visibility of the mandibular canal is described in the different regions including third molar region, second molar region, and first molar region for each side in both groups. Accordingly, our findings state that most of the mandibular canals of the patients' right side are clearly visible in both groups accounting for 87.5% in the study group and 85% in the control one. The invisible ones appear to be only in the study group accounting for only 5%. The statistical analysis states no significant differences among both groups on the right sides with (*p*-value 0.222). (Table 13). Similarly, the canal is clearly visible on the left side for the patients in both groups; in study group (80%) and (82.5%) for the control one. The canal is approximately visible in eth 20% of the study group, and in 17.5% for the control one. Statistically, there is no significant difference among the groups with (*p*-value 0.775). (Table 13).

Regarding the visibility of the canals at the third molar region among the groups regardless of the sides, our results indicate that most of the canals are clearly visible in both groups accounting for 83.8% at an equal frequency. Canals that are approximately visible are noticed more in the control group (16.3%) compared to the study group (13.8%). The invisible canals are found only in the study group accounting for only 2.5%. statistical analysis provided no significant difference among the groups concerning the visibility of caman at 3rd molar region (*p*-value 0.338). (Table 13).

The visibility of the canal at 2nd molar region on the right side of the patients indicate that most canals are clearly visible in both groups; (52. %) in the study group and (55%) in the control one. The canal is approximately visible in 42.5% of the study group while it is approximately visible in about 35% of the control. The findings illustrate that the canal is not visible in 10% of the control group whereas invisible in 5% of the study group. Consequently, there is no statistically significant difference among the groups with respect to right side visibility of the canal at second molar region (*p*-value 0.613). (Table 13).

Regarding the canal visibility at second molar region on the left side. We found that most of the canals in the study group are approximately visible 60% compared to the visible ones which account for 30%. However, the majority are clearly visible in the control group accounting for 52.5% compared to the approximately visible one that represents 32.5%. The data shows that 10% is not visible in the study group while 15% is not visible in the control group. Statistical analysis indicates that there is no significant difference among the groups with respect to the canal visibility at second molar region (*p*-value 0.047). (Table 13).

Regarding the visibility of the canal among the groups regardless of the sides at 2nd molar region, our data indicates that most of the canals on the control groups are clearly visible (53.8%) while most of the canals on the study groups are approximately visible accounting for 51.2%. canal is deemed more invisible in the control group with a frequency of 12.5% compared to the frequency of 7.5% in the study one. Statistical analysis provided insignificant difference among the groups with (*p*-value 0.074). (Table 13).

At 1st molar region of the right side, it appears that the visibility of the canal is clear and distributed equally among the groups with 50% in each one. It is approximately visible in 35% of the study group while approximately visible in around 27.5% of the control group. The frequency of invisibility is termed to be less in study group compared to the control one with a percentage of 15% and 22.5 % respectively. The statistical analysis indicates that there is no significant difference among the groups (*p*-value 0.619). (Table 13).

At the 1st molar region of the left side, our findings show that the visibility of the canal is distributed evenly among the groups accounting for a percentage of 35%. However, most of the canals on the left side are approximately visible and distributed equally among the groups with a proportion of 37.5%. This is different from the visibility on the right side in which most canals are clearly visible. The distribution of the invisible canals represents 27.5% in each group. Statistically, our analysis finds no significant difference (*p*-value 1.000). (Table 13).

Concerning the overall visibility at 1st molar region in each group regardless of the sides, our results indicate that most of the canals are visible and occur at an even frequency (42. %) for both groups. About 36.3% of the canals in the study group turned out to be approximately visible while it represents 32.5% of the control one. The invisible canals are noticed d more in the control group (25%) compared to the study one (21.3%). The statistical analysis reveals no significant difference among both groups (*p*-value 0.816). (Table 13).

5.3.10 Proximity of inferior alveolar nerve

Regarding the proximity of mandibular third molar to mandibular alveola nerve canal, our findings revealed that majority of the teeth in both groups are close to the canal; study group (77.5%) and control group (70%). The study group has shown a higher percentage (10%) of the teeth that are distant from the canal compared to those on the control group (7%). On the other hand, control group has 22% of images from which the proximity of the tooth to the canal is not clear or undeterminable compared to the images shown in study group 12.5%. The statistical analysis indicates no significant differences among groups regarding the proximity on the right side of the patients (*p*-value 0.487). (Table 13)

Concerning the proximity of the tooth to the canal on the left side, the data states that, in similarity the right side, the majority on the left side are close to the canal with a frequency of 82.5% in the study group compared to control group (67.5%). Nevertheless, both groups demonstrated a higher percentage of teeth that are distant from the canal compared to the right-side ones with a percentage of 12.5% in study group and 20% in the control group. On the left side, less frequency of proximity of the teeth that are unclear or unable to determine its proximity to the canal accounting for 5% in study group and 12.5% in the control one. The statistical difference among groups is not significant with (*p*-value 0.276). (Table 13).

Concerning the overall proximity in both groups regardless of the sides, our findings reveal that 80% of the teeth are close to the canal in the study group. Similarly, 64.8% of the control group teeth are deemed close to the canal. On the contrary, the teeth that are distant from the canal are seen mor in the control group (13.8%) in comparison to the study one (11.3%). Likely, we were unable to determine the proximity in the control group in 17.5% of the teeth while less frequency of the teeth that we are not able to determine its proximity in the study group accounting for 8.8%. Overall, the statistical analysis provided nonsignificant difference concerning the proximity of the impacted 3^{rd} molar to the canal (*p*-value 0.200). (Table 13).

Variables	Criteria	Study group N (40)	Study group F (%)	Control group N (40)	Control group F (%)	Chi2	*P*-value
Impaction status	Partial impaction	32	80%	31	78%	1.501	0.472
	Complete impaction	4	10%	2	5%		
	Both types	4	10%	7	18%		
Impacted tooth	Canine	1	3%	1	3%	23.20	<0.001*
	Premolar	0	0%	0	0%		
	Maxillary 3rd molar	15	38%	0	0%		
	Mandibular 3rd molar	3	8%	15	38%		
	Supernumerary impaction	0	0%	0	0%		
	Maxillary & mandibular 3rd molar	21	53%	24	60%		
	Multiple impactions + MTM	0	0%	0	0%		
Impaction side#	Right unilateral	6	15%	3	7.5%	1.350	0.509
	Left unilateral	5	12.5%	7	17.5%		
	Bilateral	29	72.5%	30	75%		
Right side impaction (Winter's classification)	Vertical	16	40%	16	40%	2.848	0.652
	Mesioangular	12	30%	10	25%		
	Distoangular	1	3%	0	0%		
	Horizontal	5	13%	7	18%		
	Buccal inclination	1	3%	0	0%		
	Lingual inclination	0	0%	0	0%		
	Transversal	0	0%	0	0%		
	Inverted	0	0%	0	0%		
	NA or absent	5	13%	7	18%		
Left side impaction (Winter's classification)	Vertical	15	40%	19	48%	2.830	0.426
	Mesioangular	14	35%	10	25%		
	Distoangular	0	0%	0	0%		
	Horizontal	5	13%	8	20%		
	Buccal inclination	0	0%	0	0%		
	Lingual inclination	0	0%	0	0%		
	Transversal	0	0%	0	0%		
	Inverted	0	0%	0	0%		
	NA or absent	6	13%	3	10%		
Winter's classification of the total sample#	Vertical	31	44.9%	35	50 %	4.073	0.539
	Mesioangular	26	37.7%	20	28.6%		
	Distoangular	1	1.4%	0	0%		
	Horizontal	10	14.5%	15	21.4%		
	Buccally tilted	1	1.4%	0	0%		
	Lingually tilted	0	0%	0	0%		
	Transversal	0	0%	0	0%		
	Inverted	0	0%	0	0%		
	NA or absent	9	11.3%	10	12.5%		
Pathology on right 2nd molar	Dental caries	1	2.5%	0	0%	2.810	0.729
	Bone loss	21	52.5%	19	47.5%		
	External root resorption	0	0%	0	0%		
	Radiolucent changes	0	0%	0	0%		
	Dental caries & bone loss	2	5%	1	2.5%		
	Bone loss & external resorption	0	0%	1	2.5%		
	No pathology detected	11	27.5%	12	30%		

	Not applicable due to tooth absence	5	12.5%	7	17.5%		
Pathology on left 2nd molar	Dental caries	0	0%	1	2.5%	8.950	0.111
	Bone loss	22	55%	14	35%		
	External root resorption	0	0%	0	0%		
	Radiolucent changes	0	0%	0	0%		
	Dental caries & bone loss	2	5%	2	5%		
	Bone loss & external resorption	1	2.5%	0	0%		
	No pathology detected	9	22.5%	20	50%		
	Not applicable due to tooth absence	6	15%	3	7.5%		
Total pathology on 2nd* (n=160)	Dental caries	1	1.3%	1	1.3%	4.275	0.510
	Bone loss	43	53.8%	33	41.3%		
	External root resorption	0	0%	0	0%		
	Radiolucent changes	0	0%	0	0%		
	Dental caries & bone loss	4	5%	3	3.8%		
	Bone loss & external resorption	1	1.3%	1	1.3%		
	No pathology detected	20	25%	32	40%		
	Not applicable due to tooth absence	11	13.8%	10	12.5%		
Right side classification by depth level (Pell & Gregory)	Position A	8	20%	10	25%	2.630	0.452
	Position B	23	57.5%	16	40%		
	Position C	4	10%	7	17.5%		
	NA or absent	5	12.5%	7	17.5%		
Left side classification by depth level (Pell & Gregory)	Position A	8	20%	15	37.5%	4.475	0.215
	Position B	20	53%	14	35%		
	Position C	6	15%	8	20%		
	NA or absent	6	15%	3	7.5%		
Total classification of Pell & Gregory (depth level) * (n=160)	Position A	16	20%	25	31.3%	5.338	0.149
	Position B	43	53.85%	30	37.5%		
	Position C	10	12.55%	15	18.8%		
	NA or absent	11	13.8%	10	12.5%		
Right side classification in relation to ramus width (Pell & Gregory)	Class 1	8	20%	8	20%	0.429	0.934
	Class 2	22	55%	20	50%		
	Class 3	5	12.5%	5	12.5%		
	NA or absent	5	12.5%	7	17.5%		
Left side classification in relation to ramus width (Pell & Gregory)	Class 1	10	25%	11	27.5%	2.072	0.558
	Class 2	21	52.5%	20	50%		
	Class 3	3	7.5%	6	15%		
	NA or absent	6	15%	3	7.5%		
Total classification of Pell & Gregory (space available) (n=160)	Class 1	18	22.5%	19	23.8%	0.657	0.883
	Class 2	43	53.8%	40	50%		
	Class 3	8	10%	11	13.8%		
	NA or absent	11	13.8%	10	12.55		
Right canal shape	Linear	7	17.5%	11	27.5%	4.849	0.183
	Elliptic	10	25%	11	27.5%		
	Spoon shaped	10	25%	3	7.5%		
	Turning curve	13	32.5%	15	37.5%		
Right canal visibility at 3rd molar region	Clearly visible	35	87.5%	34	85%	3.014	0.222
	Approximately visible	3	8%	6	15%		
	Invisible	2	5%	0	0%		
	Clearly visible	21	53%	22	55%		

Right canal visibility at 2nd molar region	Approximately visible	17	43%	14	35%	0.980	0.613
	Invisible	2	5%	4	10%		
Right canal visibility at 1st molar region	Clearly visible	20	50%	11	28%	0.960	0.619
	Approximately visible	14	35%	11	28%		
	Invisible	6	15%	18	45%		
Right canal proximity of 3rd molar	Unable to deremine	5	13%	9	23%	1.438	0.487
	Distant from the canal	4	10%	3	8%		
	Close to the canal	31	78%	29	73%		
Left canal shape	Linear	6	15%	6	15%	9.857	0.020*
	Elliptic	9	23%	17	43%		
	Spoon shaped	10	25%	1	3%		
	Turning curve	15	38%	16	40%		
Left canal visibility at 3rd molar region	Clearly visible	32	80%	34	85%	0.082	0.775
	Approximately visible	8	20%	7	18%		
	Invisible	0	0%	0	0%		
Left canal visibility at 2nd molar region	Clearly visible	12	30%	21	53%	6.125	0.047*
	Approximately visible	24	60%	13	33%		
	Invisible	4	10%	6	15%		
Right canal visibility at 1st molar region	Clearly visible	14	35%	14	35%	0.000	1.000
	Approximately visible	15	38%	15	38%		
	Invisible	11	28%	11	28%		
Left canal proximity of 3rd molar	Unable to determine	2	5%	5	13%	2.578	0.276
	Distant from the canal	5	13%	8	20%		
	Close to the canal	33	83%	27	68%		
Total of alveolar canal shape (n=160)	Linear	13	16.3%	17	21.3%	13.07	0.004
	Elliptic	19	23.8%	28	35%		
	Spoon shaped	20	25%	4	5%		
	Turning curve	28	35%	31	38.8%		
Total of canal visibility at 3rd molar region (n=160)	Clearly visible	67	83.8%	67	83.8%	2.167	0.338
	Approximately visible	11	13.8%	13	16.3%		
	Invisible	2	2.5%	0	0%		
Total of canal visibility at 2nd molar region (n=160)	Clearly visible	33	41.3%	43	53.8%	5.198	0.074
	Approximately visible	41	51.2%	27	42.5%		
	Invisible	6	7.5%	10	12.5%		
Total of canal visibility at 1st molar region (n=160)	Clearly visible	34	42.5%	34	42.5%	0.407	0.816
	Approximately visible	29	36.3%	26	32.5%		
	Invisible	17	21.3	20	25%		
Total of canal proximity (n=160)	Unable to determine	7	8.8%	14	17.5%	3.214	0.200
	Distant from the canal	9	11.3%	11	13.8%		
	Close to the canal	64	80%	55	64.8%		

Table 13. Descriptive and bivariate analysis of the impaction related variables.
*Statistically significant
Published results

5.4 OPG-related findings

5.4.1 MCW interpretation

Our findings indicate that there are equal percentage of the cases that have improvement or discrepancy of (MCW) in the study group. On the contrary, the control group demonstrated a higher frequency of cases that have discrepancy. Above all, the inconsistency between the measurements could be attributed to the inherited errors of OPGs and the difficulty of measurements reproducibility. The statistical analysis demonstrated no significant difference between the two groups (*p*-value 0.105). (Table 14).

5.4.2 Klemetti Index

Regarding the distribution of the different types of the Klemetti index, study groups have demonstrated higher frequency of (C2) (52.5%). Similarly, the control group shows more prevalence of (C2) (45%). On the other hand, the occurrence of (C3) is more prevalent in the control group accounting for 30% compared to the study group in which it represents only 15%. Statistical analysis revealed no significant difference among both groups (*p*-value 0.270). (Table 14).

5.4.3 Radiolucent changes

Considering the radiolucent changes, or analysis indicates that most of the cases has not revealed any radiolucent lesions in both groups; study group (92.5%) and control group (58%). Nevertheless, there are radiolucent changes that are related to teeth manifested more in the control group (15%) in comparison to the study group (7.5%). Thes statistical analysis depicts no significant difference among the groups with (*p*- value 0.241). (Table 14).

5.4.4 Radiopaque lesions

Concerning the presence of radiopaque changes, most of the cases in both groups have not shown any radiopaque changes with a percentage of 80% in the study group, and a percentage of 67.5% in the control group. Idiopathic changes occur more in the control group (27.5%) compared to the study one (17.5%). Condensing osteitis is also noticed more in the control group (5%) in comparison to the study one (2.5%). Statistically, the analysis shows no significant difference among the groups with (*p*-value 0.439). (Table 14).

5.4.5 Maxillary sinuses

The changes noticed in the right maxillary sinus of the patients has witnessed more cases that were impossible to evaluate clearly on OPG in both groups; 72.5% in study group and 60% in the control one. On the other hand, the partial thickening changes are seen more frequently in the control group (30%) compared to the study groups (25%). Similarly, the complete obliteration of the sinuses is noticed more frequently in the control (7.5%) to the study one (2.5%). Only one case has witnessed dome shaped change, and it was present in the control group. Statistically, there was no significant difference among the groups with (*p*-value 0.448). (Table 14).

Regarding the changes of the left maxillary sinuses. It is evident that most of the cases were unable to be described due to unclarity accounting for 72.5% in the study group and 65% in the control. Like the changes seen on the right-side sinuses, partial thickening occurs more in the control group (27.5%) in comparison to the study gone (25%). Additionally, complete obliteration occurs more in the control group with a frequency of 5%. Only one case has a dome shaped change which is in the left side of the control groups similarly to the right-side occurrence. Statistically, our results depict no significant difference among the groups with (*p*-value 0.672). (Table 14).

Overall changes of the maxillary sinuses in the groups regardless of the sides has revealed that most of both groups fell into the category of "no pathology or impossible to determine" representing 72.5% of the study group in comparison to 66.9% of the control one. Partial thickening of the sinuses is seen more in the control group accounting for 30% whereas it represents 25% of the study group. Similarly, the complete obliteration of the maxillary sinuses is noticed mor in the control group than study one with a frequency of 6.3% and 2.5% respectively. Even though it is the least frequent change, The dome-shaped change is seen only in the control group accounting for 2.5%. Statistically, our results depict no significant difference among the groups with (*p*-value 0.221). (Table 14).

5.4.6 Temprомandibular joints (TMJ) changes

Regarding TMJ changes, most of the cases did not demonstrate any obvious change. Flattening was seen more frequently in the study group accounting for 15% while flattening and erosion is distributed equally in the control group accounting for 7.5% for both. Sclerotic changes are noticed at even distribution among both groups accounting for 6%. Only one case of osteophyte was noticed in the control group. Statistically, our results depict no significant difference among the groups with (*p*-value 0.696). (Table 14).

Concerning the changes of the left TMJ, the results revealed no evident changes in either group representing most of the cases. Flattening occurs equally among study and control with a percentage of 7.5%. On the other hand, sclerotic changes are noticed more in the study (20%) in comparison to the occurrence in the control group (10%). Erosion and osteophytes are noticed more in the control group with a frequency for 7.5% and 5% respectively. Statistically, our results depict no significant difference among the groups with (*p*-value 0.470). (Table 14).

Concerning the overall TMJ changes regardless of the sides, we detected most of the changes are sclerotic changes accounting for 17.5% of the study group cases and to a less frequency in the control group 12.5%. Flattening and erosion are seen at an equal frequency in the control group representing 7.5%. flattening is seen more in the study group than in the control one at a percentage of 11.3%. Erosion is noticed at less frequency in the study group compared to the control one 5%. Osteophytes are seen only in the control group 1.9%. Above all, our analysis of both groups regarding TMJ changes has revealed no changes at all in a percentage of 66.3% and 68.3% of the study and control respectively. The Statistical analysis depicts no significant difference among the groups with (*p*-value 0.319). (Table 14).

5.4.7 Condyle' changes

Regarding the shape of the condyle of the right side of the patients, the findings revealed that the most noticed shape is the oval shape in both groups accounting for 37.5% in the study group and 57.5% in the control. Flattened shape is noticed in 15% of the study group cases while it was not seen in any case of the control. Mixed shape is the second most prevalent one that is revealed in both groups accounting for 25% in the study group and 20% in the control. Diamond shape is the least one noticed in the study group representing only 5% of the participant on the right side. Statistically, depict no significant difference among the groups with (*p*-value 0.112). (Table 14).

Regarding condyle's shape on the left side of the participants, it is apparently similar that the oval shape is the most prevalent in both groups accounting for 30% in the study group and for 52.5% in the control. The second most frequent shape in the study group is the mixed shape representing 20%. On the contrary, it is found that the diamonds shaped and crooked fingers are the second most frequent shapes in the control group as it occurs at an equal frequency 12%. The least frequent shape in the study group is the crocked finger shape accounting for only 5%. On the other hand, the least frequent shape in the control group is the bifid shape as it appears in 5%. The statistical analysis did not reveal any significant difference among the groups in relation to the shape of the condyle of the patient's left side (*p*-value 0.078). (Table 14).

With respect to the condyle's shape among study group and control group regardless of the sides, our analysis reveals that oval shape is the most frequent in both group and being more frequent in the control group (55%) in comparison to the study group (33.8%). The mixed shape is seen more frequent in the study group as it represents 22.5% and regarded as the second most frequent in the study group. On the other hand, the second most frequent shape notice in control group is the mixed shape accounting for 17.5%. interestingly, the diamond shape occurs at an even percentage among the two groups accounting for 10%. The bifid shape is the least frequent shape noticed in the control groups representing only 5%. On the other hand, crooked finger is the least shape noticed in the study groups as it appears only in 6.3%. The statistical analysis is off the data has revealed significant differences between the two groups (*p*-value 0.003). (Table 14).

5.4.8 Incidental findings

Concerning the analysis of the occurrence of the different incidental fining in the two groups, our findings illustrate that the elongated styloid process is the most frequently seen among the study group and control group accounting for 47.5% and 40% respectively. Carotid atheroma is noticed more in the study group at a frequency of 27.5% in comparison to the frequency in the control group (12.5%). Tonsillolith finding occurs only in the study group at frequency of 5%. Sialoliths and the combination of styloid and carotid atheroma are the least frequent findings noticed in the study group accounting for only 2.5%. On the other hand, supernumerary teeth, combination of styloid and sialolith, and combination of styloid and phlebolith occur at an even frequency of 2.5% in the control group and are considered as the least frequent incidental findings. OPG images that did not reveal any incidental finding are more in the control group accounting for 35% in comparison to those in the e study group representing 12.%. Above all, the statistical analysis of the results did not reveal any significant difference among both groups with respect to the occurrence of the different incidental findings (*p*-value 0.119). (Table 14).

Variables	**Criteria**	**Study group**		**Control group**		**Chi²**	**P-value**
		N (40)	**F (%)**	**N (40)**	**F (%)**		
Mandibular cortical width (MCW)	no change	2	5%	0	0%	4.516	0.105
	positive change (enhancement)	19	47.5%	13	32.5%		
	negative change (discrepancy)	19	47.5%	27	67.5%		
Klemetti index	c1	13	32.5%	10	25%	2.622	0.270
	c2	21	52.5%	18	45%		
	c3	6	15%	12	30%		
Radiolucent changes	No observed change	37	92.5%	34	85%	1.127	0.241
	Related to the teeth	3	7.5%	6	15%		
	Unrelated to the teeth	0	0%	0	0%		
Radiopaque changes	no observed changes	32	80%	27	67.5%	1.646	0.439
	idiopathic	7	17.5%	11	27.5%		
	condensing osteitis	1	2.5%	2	5%		
	neoplastic changes	0	0%	0	0%		
	mixed changes	0	0%	0	0%		
Right maxillary sinus findings	no pathology or impossible to evaluate	29	72.5%	24	60%	2.654	0.448
	partial thickening	10	25%	12	30%		
	complete obliteration	1	2.5%	3	7.5%		
	dome shape change	0	0%	1	2.5%		
Left maxillary sinus findings	no pathology or impossible to evaluate	29	73%	26	65%	1.545	0.672
	partial thickening	10	25%	11	28%		
	complete obliteration	1	3%	2	5%		
	dome shape change	0	0%	1	3%		
Total of maxillary sinus changes (n=160)	no pathology or impossible to evaluate	58	72.5%	49	66.9%	4.406	0.221
	partial thickening	20	25%	24	30%		
	complete obliteration	2	2.5%	5	6.3%		
	dome shape change	0	0%	2	2.5%		

Right TMJ changes	no change	26	65%	27	67.5%	2.219	0.696
	Flattening	6	15%	3	7.5%		
	Erosion	2	5%	3	7.5%		
	Osteophyte	0	0%	1	2.5%		
	sclerotic changes	6	15%	6	15%		
Right condyle shape	oval	15	37.5%	23	57.5%	8.916	0.112
	Flattened	6	15%	0	0%		
	Diamond	2	5%	3	7.5%		
	Mixed	10	25%	8	20%		
	Bifid	4	10%	2	5%		
	crooked finger	3	7.5%	4	10%		
Left TMJ changes	no change	27	67.5%	28	70%	3.552	0.470
	Flattening	3	7.5%	3	7.5%		
	Erosion	2	5%	3	7.5%		
	Osteophyte	0	0%	2	5%		
	sclerotic changes	8	20%	4	10%		
Left condyle shape	Oval	12	30%	21	52.5%	9.903	0.078
	Flattened	7	18%	1	2.5%		
	Diamond	6	15%	5	12.5%		
	Mixed	8	20%	6	15%		
	Bifid	5	13%	2	5%		
	crooked finger	2	5%	5	12.5%		
Total of TMJ changes (n=160)	no change	53	66.3%	55	68.3%	4.704	0.319
	flattening	9	11.3%	6	7.5%		
	Erosion	4	5%	6	7.5%		
	Osteophyte	0	0%	3	1.9%		
	sclerotic changes	14	17.5%	10	12.5%		
Total of condyle's shape (n=160)	oval	27	33,8%	44	55,0%	17.922	0.003*
	flattened	13	16.3%	1	1.3%		
	Diamond	8	10%	8	10%		
	mixed	18	22.5%	14	17.5%		
	bifid	9	11.3%	4	5%		
	crooked finger	5	6.3%	9	11.3%		
Incidental findings	styloid elongation	19	47.5%	16	40%	14.104	0.119
	carotid atheroma	11	27.5%	5	12.5%		
	Tonsillolith	2	5%	0	0%		
	Sialolith	1	2.5%	0	0%		
	Phlebolith	5	12.5%	0	0%		
	bifid mandibular canal	0	0%	0	0%		
	supernumerary tooth	0	0%	1	2.5%		
	no observed incidental findings	5	12.5%	14	35%		
	styloid and carotid atheroma	1	2.5%	2	5%		
	styloid and sialoliths	0	0%	1	2.5%		
	styloid and phleboliths	0	0%	1	2.5%		

Table 14. Descriptive and bivariate analysis of OPG relates variables

5.4.9 Elongated styloid process of the whole OPGs retrieved (published results)

In a published study of the thesis, we investigated 400 of the OPG that is suitable for analysis. Among them, 291 have elongated styloid process (ESP) either bilaterally or unilaterally which represents 72.75% while only 109 (27.25%) of the investigated radiographies do not show any evidence of ESP. The calculated intra-observer agreement was 0.54 which indicated a moderate level of agreement using the *Kappa test*. Our results revealed that 72.57% of the participants have ESP compared to 27% with non-ESP, and the difference is statistically significant with *a (p*-value of 0.0001). (Table15).

Data	Males	Females	Patients with ESP	Patients with non-ESP	Chi^2	*P*-value
Number	127	164	291	109	161.8	0.00000001
Frequency	43.64%	56.36%	72.75%	27.25%		

Table 15. Genders number and frequency in association with (ESP) versus (non-ESP). Table is published in the article derived from this thesis project "Assiri Ahmed H, Estrugo-Devesa A, Roselló Llabrés X, Egido-Moreno S, López-López J. The prevalence of elongated styloid process in the population of Barcelona: a cross-sectional study & review of literature. BMC Oral Health. 2023 Sep 19;23(1):674. doi: 10.1186/s12903-023-03405-0."

We noticed ESP is more prevalent in females compared to males. Also, regarding age, our data indicate that there is no clinically significant difference in elongation among the different age groups. (Table 16).

Participants			**Non- ESP**	**ESP**	**Chi^2**	**p-value**
Gender	Females	N	67	164	0.849	0.366
		%	29.0%	71.0%		
	Males	N	42	127		
		%	24.9%	75.1%		
Age groups	18-30	N	42	84	3.86	0.145
		%	33.3%	66.7%		
	31-60	N	46	151		
		%	23.4%	76.6%		
	>60	N	21	56		
		%	27.3%	72.7%		

Table 16. Gender & age groups related distribution. Table is published in the article derived from this thesis project "Assiri Ahmed H, Estrugo-Devesa A, Roselló Llabrés X, Egido-Moreno S, López-López J. The prevalence of elongated styloid process in the population of Barcelona: a cross-sectional study & review of literature. BMC Oral Health. 2023 Sep 19;23(1):674. doi: 10.1186/s12903-023-03405-0."

For the occurrence, the ESP occurs more bilaterally, and the difference is statistically significant (*p*-value of 0.0001). (Table 17).

Occurrence		**Non-ESP**	**ESP**	**Total**	**Chi²**	***p*-value**
Non	N	109	0	109	360.2	0.00000001*
	%	100%	0%	100.0%		
Unilateral	N	3	74	77		
	%	3.9%	96.1%	100.0%		
Bilateral	N	1	213	214		
	%	0.5%	99.5%	100.0%		
Total	N	109	291	400		
	%	27.3%	72.8%	100.0%		

Table 17. Occurrence of unilateral and bilateral (ESP). Table is published in the article derived from this thesis project “Assiri Ahmed H, Estrugo-Devesa A, Roselló Llabrés X, Egido-Moreno S, López-López J. The prevalence of elongated styloid process in the population of Barcelona: a cross-sectional study & review of literature. BMC Oral Health. 2023 Sep 19;23(1):674. doi: 10.1186/s12903-023-03405-0.”

Regarding the calcification pattern, the results signify that the partial calcification type occurs more in females than males with a statically significant difference (*p*-value 0.000). In addition, it occurs more in the age group 31–60 years with a statistically significant difference of *p*-value 0.000. Likewise, Type B is more frequent on the right side than the left side with a statistically significant difference (*p*-value of 0.000). (Table 18).

Participants		Calcification pattern				ESP (N)	Chi^2	*P*-value
		Type A (N) (%)	Type B (N) (%)	Type C (N) (%)	Type D (N) (%)			
Gender	Male	(54) (23.58%)	(84) (36.68%)	(50) (21.83%)	(41) (17.90%)	229	540	0.000*
	Female	(31) (11.27%)	(127) (46.18%)	(45) (16.36%)	(72) (26.18%)	275		
Age group	18-30	(14) (9.33%)	(77) (51.33%)	(30) (20%)	(29) (19.33%)	150	22.61	0.000*
	31-60	(44) (17.60%)	(101) (40.4%)	(44) (17.60%)	(61) (24.40%)	250		
	>60	(27) (28.42%)	(25) (26.31%)	(21) (22.10%)	(22) (23.15%)	95		
Side of elongation	Right	(42) (16.15%)	(118) (45.38%)	(52) (20%)	(50) (19.23%)	260	514	0.000*
	Left	(45) (18.44%)	(97) (39.75)	(46) (18.85%)	(64) (26.22%)	244		

Table 18. ESP concerning calcification pattern. Table is published in the article derived from this thesis project "Assiri Ahmed H, Estrugo-Devesa A, Roselló Llabrés X, Egido-Moreno S, López-López J. The prevalence of elongated styloid process in the population of Barcelona: a cross-sectional study & review of literature. BMC Oral Health. 2023 Sep 19;23(1):674. doi: 10.1186/s12903-023-03405-0."

Moreover, our data reveal that morphological type 1 is more prevalent in males. In addition, it is more frequent in the age group 31–60 with a statistically significant difference of *p*-value 0.0001. This type is also more prevalent on the right side compared to the left side. (Table 19).

Participants		Morphology			ESP (N)	Chi^2	P-value
		Type 1 (N) (%)	Type 2 (N) (%)	Type 3 (N) (%)			
Gender	Male	(116) (50.65%)	(45) (19.65%)	(68) (29.69%)	(229)	3.15	0.187
	Female	(136) (49.45%)	(57) (20.72%)	(82) (29.81%)	(275)		
Age groups	18-30	(68) (45.33%)	(24) (16%)	(58) (38.66%)	(150)	35.3	0.0001*
	31-60	(108) (43.2%)	(62) (24.8%)	(80) (32%)	(250)		
	>60	(710 (74.7%)	(13) (13.68%)	(11) (11.75%)	(95)		
Side of elongations	Right	(123) (47.30%)	(55) (21.15%)	(82) (31.5%)	(260)	1.15	0.562
	Left	(127) (52.04%)	(48) (19.67%)	(69) (28.27%)	(244)		

Table 19. ESP concerning the morphology. are published in the article derived from this thesis project "Assiri Ahmed H, Estrugo-Devesa A, Roselló Llabrés X, Egido-Moreno S, López-López J. The prevalence of elongated styloid process in the population of Barcelona: a cross-sectional study & review of literature. BMC Oral Health. 2023 Sep 19;23(1):674. doi: 10.1186/s12903-023-03405-0."

*Statistically significant

5.5 Bone loss analysis distal to second molar

Based on the normal distribution of the variables, our results indicated a p-value <0.05 revealing non-normal distribution. Therefore, the Wilcoxon test was used to determine the statistical difference of the numerical value of bone level changes.

5.5.1 Comparison of the bone level measurement within groups with respect to the sides

5.5.1.1 Bone level distal to mandibular 2nd molar for study group

Bone loss distal to lower 2nd molar analysis was conducted for both groups. In the study group, the mean of the bone level is calculated on the right side and left side of the patient's teeth before and after extraction. The mean and standard deviation of the measurement in (mm) on the right side before extraction of the 3rd molar impaction was 3.02 ± 2.80 mm while after extraction of the 3rd molar was 2.48 ± 2.26 mm. The statistical analysis was performed using the Wilcoxon test and the p-value was 0.251 indicating no significant difference although the results reveal bone gain after extraction of 3rd molar on the right side.

On the left sided teeth, the mean and standard deviation of the bone level before extraction was 2.77 ± 2.21 mm whereas after extraction was found to be 2.07 ± 2.05 mm. Although the difference reveals bone gain after extraction, the statistical analysis performed using Wilcoxon test indicates no significant difference (*p*-value 0.06). (Table 20).

Side	**Before Extraction**	**After Extraction**	***P*-value**
	Mean *SD*	*Mean* *SD*	
Right side	3.02 ± 2.80	2.48 ± 2.26	0.251
Left side	2.77 ± 2.21	2.07 ± 2.05	0.06

Table 20. Bone level status before and after extraction with respect to right and left side in the study group.

5.5.1.2 Bone level distal to mandibular 2nd molar for control group

In the control group, the mean of the bone level is calculated on the right side and left side of the patient's teeth before and after extraction. On the right side, the mean and standard deviation of the bone level at baseline OPG was 2.69 ± 2.36 mm. On the contrary, the mean and standard deviation of the bone level after the second OPG was 2.89 ± 2.42 mm. The statistical analysis of the difference between the two means of the measurements was performed using the Wilcoxon test and revealed significant difference in favor of bone loss with (*p*-value 0.050)

On the left side, the mean and standard deviation at baseline radiography was 2.83 ± 2.45 mm whereas those after the second radiography was 3.24 ± 2.92 mm. The statistical analysis of the difference between the two means of the measurements was performed using the Wilcoxon test indicating significant difference in favor of bone loss with (*p*-value 0.0001). (Table 21).

Side	**Baseline**	**Follow-up**	***P*-value**
	Mean *SD*	*Mean* *SD*	
Right side	2.69 ± 2.36	2.89 ± 2.42	0.050
Left side	2.83 ± 2.45	3.24 ± 2.92	0.0001*

Table 21. Bone level status at baseline and after follow-up with respect to sides in the control group.

*Statistically significant

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5.5.1.3 Comparison of the bone level among the groups as a whole

The bone level measurements were calculated and reported in terms of mean and standard deviation among study group and control group as a total regardless of the sides. Therefore, our analysis has revealed that the mean and standard deviation in the study group before extraction was 3.00 ± 1.68 mm. On the other hand, the mean and standard deviation of the measurements after extraction was 2.63 ± 1.75 mm. Accordingly, the statistical analysis was performed using Wilcoxon test and revealed statistically significant difference in favor of bone gain in the study group (*p*-value 0.0001). (Table 22).

Regarding control group, the mean and standard deviation at the baseline radiography was 2.73 ± 1.75 mm while after the second radiography was found to be 3.01 ± 1.98 mm. The statistical analysis revealed significant differences in favor of bone loss (*p*-value 0.001). (Table 22).

Group	**Baseline bone level** **Mean** **SD**	**Bone level after extraction/ follow-up** **Mean** **SD**	***P*-value**
Study group	3.00 ± 1.68	2.63 ± 1.75	0.0001*
Control group	2.73 ± 1.75	3.01 ± 1.98	0.001*

Table 22. Bone level status among study group and control group sample regardless of the sides. (published results)

*Statistically significant

Both males and females experienced bone gain in the study group and bone loss in the control group. However, the differences in bone level changes were not statistically significant with respect to gender in the study group. Since the data were not normally distributed, the U Mann–Whitney test was performed, and provided no statistical difference between genders of the study group p-value 0.747. On the other hand, the control group witnessed bone loss and was higher in males compared to females, with a (p-value 0.034) with significant statistical difference. (Table 23).

Group	**Gender**	**Baseline BL[1]**	**Follow-up BL[2]**	**Bone change df (mm)[3]**	**p-value**
Study	Male	3.51 ± 1.89	3.27 ± 2.17	0.24 ± 1.29	0.747
	Female	2.73 ± 1.35	2.29 ± 1.41	0.44 ± 1.13	
Control	Male	3.64 ± 1.79	4.12 ± 2.11	−0.48 ± 0.66	0.034
	Female	1.97 ± 1.32	2.11 ± 1.3	−0.13 ± 0.31	

Table 23. Bone-level changes in the two groups based on gender. (Published results)
1 = bone loss measured before extraction in the study group and at baseline in the control group (non-extraction group); 2 = bone loss measured after extraction in the study group and at follow-up in the control group;
3 = bone-level difference between the two measurements.

Regarding the bone change among the two groups in relation to age; in the study group, patients between the ages of 29 and 39 years appeared to experience the highest bone gain after extraction compared to those in the other age groups. On the other hand, only those aged 40–50 years experienced bone loss after extraction (−1.20 ± 0.14 mm). In the study group, significant differences in bone-level changes were observed among the age groups after extraction ($p < 0.05$). Since the data were not normally distributed, a non-parametric Kruskal–Wallis test was performed and resulted in a p-value of 0.042, which indicates a statistically significant difference between the 29–39 age group and other groups. Additionally, the post hoc comparison with a Bonferroni test only shows statistical differences between the age groups of 29–39 years old and 40–50 years old. In the control group, all age groups presented bone loss at the follow-up evaluation; however, the differences in bone loss among the age groups were not statistically significant (p-value 0.794). (Table 24).

Group	Age groups	Baseline BL[1]	Follow-up BL[2]	Bone change df (mm)[3]	p-value
Study	18-28	2.48 ± 1.51	2.18 ± 1.57	0.29 ± 1.07	0.042
	29-39	3.25 ± 1.69	2.29 ± 1.51	0.96 ± 1.05	
	40-50	4.30 ± 3.53	5.50 ± 3.39	-1.20 ±0.14	
	≥51	3.51 ± 1.53	3.45 ± 1.44	0.05 ± 1.34	
Control	18-28	2.93 ± 1.94	3.19 ± 2.13	−0.26 ±0.53	0.794
	29-39	2.28 ± 1.32	2.45 ± 1.50	−0.17 ±0.25	
	40-50	2.20 ± 0.71	2.38 ± 0.46	−0.17 ±0.25	
	≥51	2.58 ± 1.72	3.16 ± 2.35	−0.57 ±0.69	

Table 24. Bone-level changes in relation to different age groups. (Published results).

5.6 Univariate and multivariate analysis of bone status of study group

Regarding the stratified analysis of the study group in which the third molar is extracted, we notice that although female patients witnessed more bone gain, it is not statistically significant (FEE 0.07, DE 0.4, *p*-value 0.86). In the adjusted multivariate model, the bone status of females is not associated with bone gain independent to other factors revealing no significant difference (FEE -0.49, DE 0.53 *p*-value 0.36).

With respect to age groups, the group of 29-39 years show more bone gain after extraction compared to reference group although not statistically significant (FEE 0.74; *p*-value 0.18). Regarding the adjusted multivariate model, the bone gain is less and independent to the confounding factors. It illustrated no statistically significant difference (FEE 0.19, DE 11.10, *p*-value 0.86)

Regarding smoking status, it is found that smokers witnessed bone loss after extraction compared to the non-smokers within the study group although not statistically significant (FEE -0.29, DE 0.43, *p*-value 0.5). In relation to other factors using the multivariate model, the bone loss after extraction in the smokers of the study group is maintained independently to the other confounding factors although not statistically significant (FEE -0.42, DE 0.56, *p*-value 0.45).

Regarding the presence of periodontal disease, patients with only localized periodontal diseases have shown more bone gain after extraction in comparison to those with generalized periodontitis although not statistically significant (FEE 0.57, DE 0.51, *p*-value 0.27). In relation to other factors, the multivariate models show that the bone gainin patients with localized periodontitis is maintained independently of the confounding factors although it is not statistically significant (FEE 0.35, DE 0.71, *p*-value 0.62).

With respect to winter's classification of the IMTM, all the types demonstrated bone loss after extraction compared to the reference one showing that the distoangular inclination demonstrated more bone loss after extraction although not statistically significant (FEE -1.24, DE 1.47, *p*-value 0.4). In the adjusted multivariate model, we notice that all types demonstrated bone gain after extraction except mesioangular impaction independently to other confounding factors. Although the mesioangular impaction witnessed bone loss, the difference with other's is not statistically significant (FEE -0.32, DE 0.77, *p*-value 0.67).

Regarding the depth level of the IMTM based on Pell & Gregory, position A is termed to have bone loss after extraction in comparison to the reference position although the difference is not statistically significant (FEE -0.22, DE 0.43, *p*-value 0.6). Position C witnessed bone gain after extraction in comparison to the reference position although also the difference is not statistically significant (FEE 0.65, DE 0.5, *p*-value 0.6). In the adjusted multivariate model, our analysis indicates that position A maintained bone loss independent of confounding factors. However, the results are not statistically significant (FEE -.0.31, DE 0.52, *p*-value 0.54). position C maintains the bone gain after extraction independent to the confounding factors and the difference is almost significant (FEE 1.70, DE 0.72, *p*-value 0.06).

We analyze the bone change after extraction in relation to the impaction classification based on the space available between the distal aspect of the MSM and the anterior border of the ascending ramus. We found that class 1 witnessed more bone gain after extraction in comparison to the reference group (class 2) and the change is not statistically significant (FEE 0.74, DE 0.41, *p*-value 0.08). Class 3 has also witnessed bone gain in comparison to class and the difference is not statistically significant (FEE 0.69, DE 0.55, *p*-value 0.21). In the adjusted multivariate model, we found that class 1 almost maintains the bone gain after extraction independent to the confounding factors, but the change is not statistically significant (FEE 0.73, DE 0.57, *p*-value 0.21). On the other hand, class 3 witnessed less bone gain after extraction independent to the confounding factors although not statistically significant (FEE 0.23, DE 0.9, *p*-value 0.79).

Corresponding to the TMJ changes with status of bone changes after extraction, our analysis demonstrates bone loss after extraction in cases of in cases of all TMJ changes. Bone loss after extraction is seen more in TMJ associated with erosions although not statistically significant (FEE -0.89, DE 0.85, *p*-value 0.29). In the adjusted multivariate model, our findings indicated that the bone loss is maintained and increased only in the cases of TMJ erosion regardless of the confounding factors, but the change is not statistically significant (FEE -1.51, DE 1.48, *p*-value 0.31).

Regarding the status of bone change in relation to the condyle shape after extraction of IMTM, our findings revealed that the cases of bifid shapes have the most bone loss but not statistically significant (FEE -0.37, DE 0.61, *p*-value 0.54). In the case of flattened condyle, we found more bone gain after extraction in comparison to the reference shape, but the difference is not statistically significant (FEE 0.08, DE 0.56, *p*-value 0.87). In the adjusted multivariate model, we detect improvement the bone loss although the cases of bifid condyle represent the most shape associated with bone loss regardless of the confounding factors. The difference in relation to the reference shape is not statistically significant (FEE -0.34, DE 0.74, *p*-value 0.65). Flattened shape is the one revealing bone gain in dependent to the confounding factors but without any statistical significance (FEE 0.73, DE 0.72, *p*-value 0.6). (Table 25).

Variables	Subcategories	Univariate analysis (fixed effect estimation)	Deviation error	P-value	Multivariate analysis (fixed effect estimation)	Deviation error	*P*-value
Gender	Females	0.07	0.40	0.86	-0.49	0.53	0.36
	Males	Reference	-	-	Reference	-	-
Age groups	18-28	0.01	0.5	0.98	-0.39	1.53	0.72
	29-39	0.74	0.55	0.18	0.19	1.10	0.86
	40-50	-1.47	0.95	0.13	-2.67	1.6	0.1
	> or = 51	Reference	-	-	Reference	-	-
Smoking status	smokers	-0.29	0.43	0.5	-0.42	0.56	0.45
	non-smokers	Reference	-	-	Reference	-	-
Periodontal status	Localized	0.57	0.51	0.27	0.35	0.71	0.62
	Generalized	0.07	0.65	0.9	-0.81	1.53	0.59
	No evidence	Reference	-	-	reference	-	-
Winter's classification	vertical	-1.08	0.54	0.05	0.24	0.79	0.76
	mesioangular	-0.91	0.55	0.1	-0.32	0.77	0.67
	distoangualr	-1.24	1.47	0.4	0.53	2.48	0.83
	horizontal	Reference	-	-	reference	-	-
	buccally tilted	-0.54	1.50	0.7	0.82	1.70	0.63
Pell & Gregory (depth level)	position A	-0.22	0.43	0.6	-0.31	0.52	0.54
	position B	Reference	-	-	reference	-	-
	Position C	0.65	0.5	0.6	1.37	0.72	0.06
Pell & Gregory (space available)	Class1	0.74	0.41	0.08	0.73	0.57	0.21
	class 2	Reference	-	-	Reference	-	-
	class 3	0.69	0.55	0.21	0.23	0.9	0.79
TMJ changes	no change	reference	-	-	Reference	-	-
	flattening	-0.06	0.58	0.91	-0.05	0.79	0.94
	erosion	-0.89	0.85	0.29	-1.51	1.48	0.31
	sclerotic changes	-0.58	0.48	0.23	-0.63	0.64	0.32
Condyle's shape	oval	Reference	-	-	Reference	-	-
	flattened	0.08	0.56	0.87	0.73	0.72	0.6
	diamond	0.07	0.63	0.91	0.3	0.76	0.69
	mixed	-0.36	0.5	0.47	-0.04	0.64	0.94
	bifid	-0.37	0.61	0.54	-0.34	0.74	0.65
	crooked finger	-0.27	0.71	0.7	0.26	0.79	0.74

Table 25. Univariate and multivariate analysis of the study group sample

5.7 Univariate and multivariate analysis of bone status of control group

Regarding the stratified analysis of the control group in which the third molar is not extracted, we notice that female patients witnessed more bone gain in comparison to male patients and the difference is statistically significant (FEE 0.39; DE 0.16 *p*-value 0.02). On the other hand, according to the adjusted multivariate model, the bone status of females witnessed almost no change independent to the confounding factors in comparison to males (FEE 0.002, DE 0.21, *p*-value 0.79).

In relation to age groups, the group of 29-39 years show less bone loss after evaluating the second OPG compared to reference group although not statistically significant (FEE 0.47; DE 0.32, *p*-value 0.15). According to the adjusted multivariate model, the status of less bone loss is independent to the confounding factors with almost statistically significant difference in comparison to the reference age group (FEE 0.65, DE 0.34, *p*-value 0.06).

Regarding smoking status, it is found that smokers witnessed bone loss compared to the non-smokers within the control group although not statistically significant (FEE - 0.08, DE 0.2, *p*-value 0.68). Based on the adjusted multivariate model, the bone loss inthe smokers is maintained independent to the confounding factors although not statistically significant (FEE -0.22, DE 0.22 *p*-value 0.32).

Regarding the presence of periodontal disease, patients with generalized periodontal diseases have shown more bone loss after in comparison to the reference group although not statistically significant (FEE -0.88; DE 0.63, *p*-value 0.16). according to the adjusted multivariate model, the bone loss is maintained but diminished independent to the confounding factors. The difference is not statistically significant (FEE -0.28, DE 0.66 *p*-value 0.66).

Considering the winter's classification of the IMTM, all the types demonstrated bone loss after compared to the reference one showing that the mesioangular inclination demonstrated more bone loss although not statistically significant (FEE -0.45, DE 0.59, *p*-value 0.44). In the adjusted multivariate model, we notice that all types demonstrated maintenance of bone loss independently to other confounding factors, and the mesioangular impaction is being the most associated with bone loss. However, the difference is not statistically significant (FEE -0.74, DE 0.7, *p*-value 0.29).

With respect to the depth of impaction, position B reveals the most bone loss in comparison to the reference although not statistically significant (FEE -0.37, DE 0.6, *p*-value 0.53). According to the adjusted multivariate model, the findings revealed slight improvement in the bone status and the position C is being the most revealing improvement independent to other confounding factors without significant statistical difference (FEE 0.15, DE 0.2, *p*-value 0.46).

Regarding space available between the distal aspect of the MSM and the anterior border of the ascending ramus. We found all the classes are associated with bone loss, and class 2 is the most among them without any significant difference in comparison to the reference one (FEE -0.55, DE 0.59, *p*-value 0.36). In the adjusted multivariate model, we found that class 1 and class 2 witnessed bone gain in comparison to the references (FEE 0.15, DE 0.18, *p*-value 0.41) and (FEE 0.55, DE 0.26, *p*-value 0.04) respectively. Therefore, the change of class 3 is statistically significant.

In relation to the TMJ changes with status of bone changes in control group, our analysis demonstrates bone loss only in cases of the presence of osteophytes (FEE - 1.33, DE 0.36, *p*-value 0.001) which is statistically significant. In the adjusted multivariate model, our findings indicated that the bone loss is present but diminished independent to the confounding factors. It is statistically significant (FEE -1.16, DE .41, *p*-value 0.008).

Regarding the status of bone change in relation to the condyle shape, our findings revealed that the cases of mixed shapes have the most bone loss which is statistically significant (FEE -0.61, DE 0.21, *p*-value 0.06).

In the adjusted multivariate model, the bone loss in case of mixed shapes is maintained although less, and it is statistically significant (FEE -0.54, DE 0.26, *p*-value 0.04). (Table 26).

Variables	Subcategories	Univariate analysis (fixed effect estimation)	Deviation error	P-value	Multivariate analysis (fixed effect estimation)	Deviation error	*P*-value
Gender	Females	0.39	0.16	0.02	0.002	0.21	0.99
	Males	Reference	-	-	Reference	-	-
Age groups	18-28	0.34	0.26	0.19	0.39	0.28	0.17
	29-39	0.47	0.32	0.15	0.65	0.34	0.06
	40-50	0.40	0.47	0.39	0.53	0.45	0.24
	> or = 51	Reference	-	-	Reference	-	-
Smoking status	smokers	-0.08	0.2	0.68	-0.22	0.22	0.32
	non-smokers	Reference	-	-	Reference	-	-
Periodontal status	Localized	-0.30	0.17	0.08	-0.09	0.22	0.68
	Generalized	-0.88	0.63	0.16	-0.28	0.66	0.66
	No evidence	Reference	-	-	Reference	-	-
Winter's classification	vertical	-0.12	0.6	0.84	-0.45	0.67	0.51
	mesioangular	-0.45	0.59	0.44	-0.74	0.7	0.29
	horizontal	-0.33	0.61	0.59	-0.71	0.69	0.3
	buccally tilted	Reference	-	-	Reference	-	-
Pell & Gregory (depth level)	position A	-0.31	0.61	0.61	0.04	0.16	0.79
	position B	-0.37	0.6	0.53	Reference	-	-
	Position C	-0.14	0.62	0.81	0.15	0.2	0.46
	NA/absent	Reference	-	-	Reference	-	-
Pell & Gregory (space available)	Class1	-0.52	0.6	0.38	0.15	0.18	0.41
	class 2	-0.55	0.59	0.36	Reference	-	-
	class 3	-0.13	0.59	0.81	0.55	0.26	0.04*
	NA/absent	Reference	-	-	Reference	-	-
TMJ changes	no change	Reference	-	-	Reference	-	-
	flattening	0.16	0.27	0.55	0.2	0.37	0.59
	erosion	0.24	0.22	0.28	0.48	0.25	0.06
	osteophyte	-1.33	0.36	0.001	-1.16	0.41	0.008*
	sclerotic changes	0.32	0.22	0.16	0.29	0.25	0.26
Condyle's shape	oval	Reference	-	-	Reference	-	-
	flattened	-0.009	0.6	0.98	-0.53	0.64	0.41
	diamond	-0.04	0.25	0.84	-0.0005	0.28	0.99
	mixed	-0.61	0.21	0.006	-0.54	0.26	0.04*
	bifid	0.46	0.43	0.29	0.21	0.43	0.61
	crooked finger	-0.21	0.22	0.35	-0.16	0.24	0.51

Table 26. Univariate and multivariate analysis of the control group sample

5.8 Univariate and Multivariate analysis of bone status of the whole study sample

In relation to the bone status changes, the study group in which the IMTM is extracted shows significant bone gain in comparison to the controls who did not extract third molar with statistically significant difference (FEE 0.73, DE 0.21, *p*-value 0.0001). With respect to the adjusted multivariate model, the association is maintained, and it is independent of the confounding factors (FEE 0.79, DE 0.26, *p*-value 0.003) which is also statistically significant.

Regarding gender, female patients of the whole sample have more bone gain compared to males (FEE 0.32, DE 0.22, *p*-value 0.16) although it is not statistically significant. In the adjusted multivariate model, bone gain is maintained although less, and it is independent to confounding factors (FEE 0.28, DE 0.25, *p*-value 0.91) which is not statistically significant.

In relation to age groups, our findings reveal that the age groups between 29-39 have more bone gain in comparison to reference group (FE 0.73, DE 0.35, *p*-value 0.04) which is statistically significant. In the adjusted multivariate model, the association is maintained in all groups independent of the confounding factors and seems also statistically significant in the groups 29-39 (FEE 0.95, DE 0.45, *p*-value 0.03).

In relation to the smokers versus non-smokers of the whole study sample, our analysis indicated that the smokers demonstrated major bone loss in comparison to the non-smokers although not statistically significant (FEE -0.17, DE 0.57, *p*-value 0.50). In the adjusted multivariate model, it appears that the bone loss is maintained independent to confounding factors, but it is not statistically significant (FEE -0.41, DE 0.26, *p*-value 0.12).

Regarding the winter's classification of the impaction in the whole sample, our results indicate that the distoangular inclination demonstrated more bone loss in comparison to reference inclination (FE -0.33, DE 1.60, p-value 0.84) although it is not statistically significant. In the adjusted multivariate model, we notice that the bone loss of all types of Winter's classification is maintained independent of confounding factors, and the distoangular is being the most associated with bone loss although not statistically significant (FEE -1.69, DE 1.82, *p*-value 0.35)

With respect to the depth of impaction based on Pell & Gregory classification, our findings indicate that position A reveals the most bone loss in comparison to the reference although not statistically significant (FEE -0.25, DE 1.12, *p*-value 0.82). According to the adjusted multivariate model, the findings revealed slight improvement in the bone status and the position C is being the most revealing improvement independent to other confounding factors with almost statistical significance (FEE 0.54, DE 0.31, *p*-value 0.08).

Regarding the classification of the IMTM based on the available space between the anterior border of the ascending ramus and the distal aspect of the MSM, we found that class 2 is the most associated with bone loss though the results are not statistically significant (FEE -0.38, DE 1.11, *p*-value 0.72). In the adjusted multivariate model, our analysis depicts an improvement of bone status with class 1 and 3 in comparison to the reference. The improvement is seen more with class 1 which indicates statistically significant difference (FEE 0.57, DE 0.25, *p*-value 0.02).

Concerning the bone status association with the different changes of TMJ, we found that the bone loss is mostly associated with the occurrence of osteophytes changes in the TMJ, and the association is statistically significant in comparison to the reference one (FEE -1.71, DE 0.72, *p*-value 0.01). I the multivariate model, we noticed that the association with bone loss is maintained although improved. The difference is statistically significant for the association with osteophytes in comparison to the reference (FEE -1.60, DE 0.74, *p*-value 0.03).

In relation to the association of bone changes with the condyle shapes, the analysis revealed that the mixed condyle shape is the most associated with bone loss although not statistically significant (FEE -0.36, DE 0.27, *p*-value 0.19). According to the multivariate model, we found that that the is maintained independent with the confounding factors and not statistically significant (FEE -0.42, DE 0.31, *p*-value 0.17). (Table 27).

Variables	Subcategories	Bone status (gain or loss) means & SD.	Univariate analysis (fixed effect estimation)	Deviation error (DE)	P-value	Multivariate analysis (fixed effect estimation)	Deviation error (DE)	P-value
Group category	Study group	0.45 ± 0.15	.73	0.21	0.001*	0.79	0.26	0.003*
	Control group	-0.29 ± -0.15	Reference	-	-	Reference	-	-
Gender	Females	0.199 ± 0.14	0.32	0.22	0.16	0.28	0.25	0.91
	Males	-0.125 ± 0.18	Reference	-	-	Reference	-	-
Age groups	18-28	-0.02 ± 0.14	0.09	0.31	0.767	0.49	0.41	0.24
	29-39	0.61 ± 0.22	0.73	0.35	0.04	0.95	0.45	0.03*
	40-50	-0.69 ± 0.50	-0.57	.57	0.32	-0.30	0.63	0.63
	> or = 51	-0.12 ± 0.27	Reference	-	-	Reference	-	-
Smoking status	Smokers	- 0.05 ± 0.22	-0.17	0.25	0.50	-0.41	0.26	0.12
	Non-smokers	0.11 ± 0.13	Reference	-	-	Reference	-	-
Periodontal status	Localized	-0.099 ± 0.19	-0.26	0.23	0.27	0.12	0.28	0.12
	Generalized	0.15 ± 0.46	-0.005	0.48	0.99	0.42	0.64	0.5
	No evidence	-	Reference	-		Reference	-	-
Winter' classification	Vertical	0.008 ± 0.15	-0.13	1.14	0.91	-0.84	1.22	0.49
	Mesioangular	0.04 ± 0.18	-0.09	1.14	0.94	-1.21	1.24	0.33
	Distoangualr	-0.19 ± 1.13	-0.33	1.60	0.84	-1.69	1.82	0.35
	Horizontal	0.29 ± 0.25	0.15	1.16	0.90	-1.04	1.25	0.41
	Bucclly tilted	0.30 ± 1.13	0.16	1.59	0.92	-0.68	1.64	0.68
	NA/absent	-	Reference	-	-	Reference	-	-
Pell & Gregory (depth level)	Position A	-0.10 ± 0.18	-0.25	1.12	0.82	-0.10	0.24	0.66
	Position B	0.058 ± 0.14	-0.09	1.11	0.93	Reference	-	-
	Position C	0.39 ± 0.24	0.24	1.13		0.54	0.31	0.08*
	NA/absent	-	Reference	-	-	Reference	-	-
Pell & Gregory (space available)	Class1	0.26 ± 0.20	-0.02	1.12	0.98	0.57	0.25	0.02*
	Class 2	-0.09 ± 0.14	-0.38	1.11	0.72	References	-	-
	Class 3	0.40 ± 0.27	0.11	1.11	0.91	0.54	0.37	0.15
	NA/absent	-	Reference	-	-	Reference	-	-
TMJ changes	No change	-	Reference	-	-	Reference	-	-
	Flattening	0.27 ± 0.33	0.14	0.35	0.68	0.005	0.43	0.99
	Erosion	-0.90 ± 0.37	-0.21	0.38	0.56	0.004	0.42	0.99
	Osteophyte	-1.64 ± 0.71	-1.77	0.72	0.01*	-1.60	0.74	0.03*
	Sclerotic Changes	-0.004 ± 0.27	-0.13	0.29	0.65	-0.19	0.30	0.52
	Oval	-	Reference	-	-	Reference	-	-
	Flattened	0.58 ± 0.46	0.35	0.38	0.97	-0.05	0.41	0.89
	Diamond	0.31 ± 0.44	0.07	0.34	0.81	-0.04	0.35	0.9

Condyle's shape	Mixed	-0.12 ± 0.39	-0.36	0.27	0.19	-0.42	0.31	0.17
	Bifid	0.24 ± 0.46	0.013	0.39	0.97	-0.32	0.4	0.43
	Crooked finger	-0.10 ± 0.31	-0.23	0.34	0.49	-0.25	0.34	0.47

Table 27. Univariate and multivariate analysis of the whole sample of the whole sample

DISCUSSION

6. Discussion

Several studies used panoramic radiography to estimate the status of bone distal to the mandibular second molar. However, the majority focused on the overall estimation after extraction of impacted mandibular third molar (205–207). A study conducted by Krausz et al. (205) designed their retrospective study according to the split mouth method where study group was the extraction site while the control groups was the non- extracted third molar of the same patients. To our knowledge, our study is the first to compare the extraction patients versus non extraction patients with respect to the bone changes on the distal aspect of the second molar.

6.1 Demographic data

6.1.1 Age

6.1.2 Gender

With respect to the age of the patients, it is well-known that the mandibular third molar erupts between the age of 17 up to 25 (14,15). However, the impaction can be predicted and that would continue for life if left unmanaged (200). In our study we included patients from 18 up to more than 51 years old. This is comparable and supported by the previously published study by Krausz et al. (205) in which they included patients from the age of 20 years up to 60 years old. In addition, our age span of the participants agrees with the age span of the study reported by Hatem et al. (51). In which they described the pattern of impaction among Libyan populations. Overall, the patients in our study were grouped into 4 age groups to assess the changes of the bone status among these different categories. Regrading gender groups, the pattern of impaction, we detected heterogeneity in the frequency of the distribution of females and males. However, we were restricted to the inclusion and exclusion criteria which makes it difficult to include equal frequency of both genders in our study. Above all, we found a study performed to assess the effect of the IMTM extraction on the periodontal status of MSM reported by Singh et al. (208). The sample of their study was 106 which seem comparable to ours although more participants included. The distribution of males and females was 46.22% and 53.77% respectively. it can be noticed that the distribution is different from to our total sample distribution of females and males which was around

60% and 40% respectively. Additionally, the study reported by Passarelli et al. (209) described the influence of surgical extraction on the periodontal status of the MSM. Their sample was almost close to our sample in which they included 89 participants. However, the gender distribution was more homogenous than ours.

6.2 Clinical history

6.2.1 Reason of consultation

Impacted mandibular third molar is among the different dental complaints that motivate patients to seek dental care. Hence, it represents around 18% of dental extractions compared to other dental extractions. In our sample, it is revealed that the extraction of mandibular third molar is the most common reason for consultation. This would be explained by the fact of being the most frequently impacted among other teeth. Generally, in literature, we found that the most common reason for seeking dental visits is dental pain that might or might not originate from the IMTM (210,211). This is different from the motivation of the dental visit reported in our sample in which we found the dental pain is the second most common reason preceded by the extraction of third molar. However, this can be linked to the fact that we primarily search for patients who have mandibular third molar impaction.

6.2.2 Systemic diseases

Although it is suggested in the literature that some endocrinal disturbances might contribute to the occurrence of tooth impaction, the association with systemic diseases such as diabetes, hypertension and other common diseases is not clear whether it exerts a potential effect on the occurrence of impaction (212,213). This unclarity could be explained in our study samples in which we found only 8% of the patients demonstrating diabetes mellitus in the study group. Additionally, we did not find any patients with diabetes mellitus in the sample of the control group. Similarly, our data is supportive to the non-association between the hypertension and the status of impaction in which we found only 7.4% in the study group and 4% in the control group demonstrating hypertension. Therefore, it could be anticipated that diseases affecting general growth, bone remodeling, hormonal disturbances, and genetic diseases that could have to the possible occurrence of the tooth impaction (212,213).

6.2.3 Smoking status

Regarding the smoking status, our findings illustrated that most of the participants in the study and control group are smokers. Smoking habits contribute to the worsening of the general oral health status which can lead to periodontal diseases and manifestation of bone loss. Therefore, it is considered as factor that can worsen the presence of bone loss in impacted teeth regardless of the status of impaction (214).

6.2.4 Periodontal diseases

Based on Kaveri et al, the presence of impacted third molar can adversely affect the status of periodontium especially on the distal aspect of MSM (215). It agrees with our findings in which we found considerable frequency of localized periodontitis especially on the distal aspect of the MSM. In addition, it was reported in the literature that even the visible erupted third molar would exert an effect on the periodontal status and found that it is 1.5 times associated with the increase of periodontal pockets (216).

6.3 Third molar impaction-related data

6.3.1 Impaction status

Concerning the station of IMTM whether it is partially, completely, or both types, our analysis reported a higher frequency of partial impaction. It agrees with data reported by Obuekwe ON and Enabulele JE in which they conducted their study on 151 of Nigerian population. They have found that about 73.5% of their samples are partially impacted mandibular third molar (217). On the contrary, our records are different from those reported by Alfadil et al. (49) in which he found that the most common status of impaction is the complete boney impaction in both mandibular and maxillary third molar.

6.3.2 Impacted tooth

Regarding the different impacted teeth noticed in our sample, we found that the presence of both maxillary and mandibular third molar impaction is prevalent. This is in accordance with the literature in which the most prevalent impacted teeth are the mandibular third molar followed by maxillary third molar, and maxillary canine (218). Additionally, our findings are in accordance with those reported by Chu et al. (219) in which they stated that the mandibular third molar is the most prevalent impacted tooth succeeded by maxillary third molar and followed by maxillary canine.

6.3.3 Impaction side

In their study, Prajapati et al. (220) reported more prevalence of IMTM on the right side 63.5% compared to the left side 36.5%. It is different from our findings which reveal predominance of bilateral impaction compared of being either right or left. One other study conducted on Bosnian population by Šečić et al. (221) who revealed only 15.6% of the impacted teeth were bilateral mandibular third molar. Thus, it is contradictory to our results of both groups that show bilateral dominance. On the other hand, Zaman et al. (48) performed their studies on wide spectrum of sample in Saudi Arabia. Considering the occurrence of impaction, they found bilateral impaction is more prevalent than unilateral impaction representing 7.52% which corresponds to the bilateral dominance in our findings, especially the IMTM.

6.3.4 Winter's classification

Classification of IMTM based on Winter's categorization is applied in many studies reporting pattern of impaction. In this regard, our findings disagree with study reported by Alsaegh et al. (222) who pointed out the mesioangular impaction is the most prevalent angulation of IMTM in their sample. Similarly, a study of the pattern of impaction conducted on Indian population by Padhye et al. (223) indicated that the mesioangular angulation is the predominant one. On east Baltic population, Jarón et al. (52) indicated that the mesioangular impaction pattern dominates the other noticed patterns in their study. Correspondingly, mesionagular impaction is the most prevalent pattern seen when investigating the data of Libyan population (51). On the contrary, it is found that the vertical pattern of impaction occurs more than the other patterns in Eritrean population which agrees with our records (224). Similarly, Al-Dajani et al. (225) agree with our findings which indicated a dominance of the vertical pattern. Additionally, it is found that the vertical type is the most prevalent base on the analysis reported by Yilmaz et al. (226) on Turkish population which is also in accordance with our sample's results.

6.3.5 Pell & Gregory classification

With respect to the classification proposed by Pell & Gregry based on the depth level of IMTM, our findings of the total sample of both the study group and control group witnessed higher prevalence of position B which is in accordance with the findings reported by Primo et al. (63) who reported higher incidence of the position B category. On the contrary, our findings differ from that reported by Yilmaz et al. (226) in which they revealed higher prevalence of position C in IMTM. Furthermore, our results contradict the findings reported by Xavier et al. (227) in which they reveal a higher incidence of position A. The study reported by Zaman et al. (48) speculated also that the predominant position based on Pell & Gregory depth level is position A, which is different from our findings. According to their analysis, Primo et al. (63) stated that the mesioangular and horizontal impaction possess the most potential risk to the adjacent structures in association with position A of depth level. According to the classification of the IMTM impaction in relation to the space available between the anterior wall of the ascending ramus and the distal aspect of the MSM, our data revealed that the most dominant class is class 2 in the total sample. This agrees with the data reported by Alsaegh et a. (222) in which they stated a higher occurrence of class 2. Additionally, our records are supported by the previously reported studies by Hatem et al. (51), Jarón et al. (52), and Padhye et al. (223) in which all of them presented predominance of class 2 position in relation to the ramus of the mandible. It can be assumed that the variation between demographic population in terms of reported impaction pattern is attributed to either methodology or statistical analysis performed.

6.3.6 Pathology on 2nd molar

Since the presence of lower third molar impaction bear a potential risk of different of pathological process on the adjacent tooth, bone and soft tissue, our results indicated that the most noticed pathological changes on the adjacent structures are the bone loss manifested on the distal aspect of MSM. These findings are termed in disagreement with the data reported by AlKhateeb et al. (228) in which they stated that the most prevalent pathological condition in their sample is the distal caries on the MSM. Similarly, Oyebunmi et al. (229) documented that the most prevalent pathology associated with IMTM is the dental caries followed by pocket formation on the distal aspect of MSM. Apart from that, it is illustrated by Ye et al. (194) that the soft tissue impaction is mostly associated with pericoronitis which was not described in our study since it is solely focused on panoramic analysis rather than clinical assessment. In Iranian population, Sahibzada et al. (230) have investigated a wide spectrum of panoramic radiography containing about 2832 mandibular third molar and found that dental caries is the most incited pathological change on panoramic radiography exerted by the occurrence of impaction.

6.3.7 Shape of inferior alveolar nerve canal

The determination of the shape and course of the inferior alveolar nerve canal is paramount as it plays an important role in overcoming the possible nerve injury during removal of the IMTM or placement of dental implant in the molar region (231). In this aspect, the most prevalent shape of the inferior alveolar nerve canal reported in our sample is the turning curve shape which differs from the study reported by Liu et al. (232). They conducted their investigation on a sample of 386 panoramic radiography and regarded the shape of elliptic arc as the most prevalent while this shape is the third most prevalent in our sample preceded by the turning curve and spoon shaped canal. In the study conducted by Derafshi et al. (225); they performed their investigational study on panoramic radiography, and regarded the shapes of the canal as right, angled, curved, or spoon shaped. Accordingly, they found that the most prevalent is the curved shape which could be in accordance with our findings that regarded the most prevalent as a turning shape.

6.3.8 Visibility of inferior alveolar nerve

Identification of the course of the inferior alveolar canal nerve canal and its related course is regarded important in the planning for removal of the impacted third molar and consideration of the dental implant placement in the molar region (233). Regarding the visibility of mandibular canals on panoramic radiography, it could differ from patient to patient and from one region to another within the jaws (234). Jung et al. (234)

has addressed this task and found that the canal is visible more at the first molar region in comparison to the second and third molar regions. Their findings are in accordance with ours in which we found more frequency of the visible canal in third molar region compared to the other molar regions.

6.3.9 Proximity of inferior alveolar nerve

As the inferior alveolar nerve canal is possibly prone to injury upon planning of surgical removal of IMTM, the identification of its proximity to the impacted tooth is critical (235). Our findings with respect to the potential proximity to the IMTM have revealed that most of the cases have canals that are in considerable proximity to the impacted tooth. These findings are in accordance with the study performed by Deshpande et al. (236) in which they indicated that the approximately (61.8%) surpass the upper border of the canal. In this regard, there are several indicators that can be followed when evaluating the proximity of the canal on panoramic radiography (86,237). These signs were followed upon analysis of the panoramic radiography of our study.

6.4 OPG related-data

6.4.1 MCW interpretation & Klemetti index

Determination of mandibular cortical width (MCW) is paramount to predict the mineral density of the mandible. Many indexes have been proposed in literature and one of them is the mental index (MI) which we use in our study. We calculated the meaning of the width of the cortical border and our findings of witnessed changes after taking the second x-ray with the specified period (3-6) months on both groups (238). Although we found these changes after taking the second x-ray, these changes could be related to the measurements limited reproducibility of panoramic radiography in quantifying the mental index. However, these measurements consider the screening of bone minerals in osteoporotic and osteopenia patients. Therefore, correlation between the status of the mandibular cortex and the presence or extraction of impacted third molar could controversial or irrelated. Apart from that, the descriptive classification of the integrity of the bone using Klemetti index could provide a prospective about the status of bone. In our study we were curious to investigate that index (190). Our findings showed that the C1 classification is the most prevalent which indicates better integrity of bone quality.

6.4.2 Radiolucent & radiopaque changes

OPG has been a useful tool in identifying the different radiolucent and radiopaque changes which are of odontogenic and non-odontogenic origins. Our findings indicate that the most noticeable radiolucent change in the studies sample is of odontogenic origin particularly carious lesions, periodontal and periapical inflammatory process. This is in accordance with the study reported by Yunus et al. (239) in which they investigated the soft and hard tissue lesions utilizing periapical and panoramic radiography. They found that the most noticeable lesions are periodontal and periapical lesions accounting for 37% among other detected lesions. Additionally, they found that other radiopaque lesions such as idiopathic osteosclerosis, cement osseous dysplasia and condensing osteitis which is comparable to our findings providing that the most prevalent radiopaque lesions are idiopathic osteosclerosis followed by condensing osteitis.

6.4.3 Maxillary sinus findings

Assessment of maxillary sinus situation is particularly important when suspecting a pathological process or planning for dental implant placement (240). It is claimed that the evaluation of those sinuses utilizing panoramic radiography is potentially applicable supporting the clinical examination (241). In this regard, our analysis revealed that the most noticed change in the maxillary sinus is the partial thickening. It is in accordance with Mathew et al. (241) in which they investigated the sinuses' findings on panoramic radiography and indicated that the mucosal thickness is the most change seen. However, they have conducted their study on elderly people aged above 50 years which is different from m the age span in our study. It seems that limited changes of the sinuses could be identified on the sinuses because of the overlap of the structures on the images produced by OPG.

6.4.4 TMJ changes and condyle's shape

The presence of IMTM and its removal is potentially a contributing factor to the occurrence of TMJ disorders or changes (242). Our findings have revealed that the most noticed changes on OPGs were the sclerotic changes although considerable percentage of OPGs did not reveal any changes providing that the OPG could be not accurate in identifying details of TMJ. To some extent, it is in accordance with the study reported by Bhardwaj et al. (243) in which they found considerable prevalence of TMJ changes and disorders with the different types of impactions of IMTM. In this regard, we understand that studies correlating the different types of impaction, type of surgical intervention, and the prevalence of TMDs is still scares and point of interest considering the clinical symptoms and radiographical analysis. With respect to the condyle shapes we found that the oval shape is the most prevalent in both the extraction group and non-extraction group. Our sample findings agree with the study performed by Shaikh et al. (242) in which they stated also a quite prevalence of oval shape of the condyle. Apart from that, we have not found any study that correlates the shape of the condyle with extraction of IMTM or the different types of impaction.

6.4.5 Incidental findings

In the first part of the incidental findings, we investigated those findings in the sample of the extraction group and non- extraction group which represent (80) patients with (160) OPGs. Therefore, we found that the elongated styloid process (ESP) is the most prevalent followed by calcified carotid atheroma (CCA). These findings are in accordance with the study performed on a wide spectrum of sample by Ghassemzadeh et al. (188) in which they stated the ESP is the most prevalent followed by CCA. The second part of the incidental findings analysis is to investigate the occurrence of the ESP in the whole sample of the study which represents 400 OPGs from which we randomly select the 80 participants of the study group and control group. For the prevalence of the elongated styloid process in our sample, we found that it manifests in 72.5% of the study's participants. This agrees with the results reported by Ferrario et al. (149) and Kursoglu et al. (244) whom they regarded prevalence as more than 70% of their populations. Concerning gender distribution of the ESP, our study stated that the elongation is more in females 164 (56.36%) than in males 127 (43.64%). It agrees with the study published by Omami et al. (245), and Vieira et al. (246), Ferrario et al.

(149), Roopshari et al. (247). Additionally, the estimated difference between females and males is not clinically significant in the studies of Ferrario et al. (149) and Roopashri et al. (247). Our findings regarding gender predilection disagree with those reported by AlZarea et al. (141), Rai et al. (248), and Sokler et al. (249) who declared more prevalence in favor of males. Statistically, our results are following the study conducted by Gokce et al. (250) on the Turkish population which indicates no clinical significance of elongation between males and females. Regarding the occurrence, our sample reveals that bilateral elongation is the most frequently noted in males and females of all age groups. This is contradictory to the findings reported by Hettiarachchi et al. (251) in which they indicated 26% unilateral elongation and only 11% of bilateral elongation of their sample. On the other hand, it agrees with the studies documented by Vieira et al. (246), Sakhdari et al. (252) and Alsweed et al. (253) for which they postulated more occurrence of bilateral elongation. Regarding the occurrence, we found that bilateral ESP is more prevalent than unilateral ESP. Our data agree with Ferrario et al. (149), and Zaki et al. (254). Our study is also following Gosh and Dubey et al.
(255) whom they reported bilateral elongation in about 57% of their sample. Similarly, our findings are following Zokaris et al. (256) whom they reported more prevalent bilateral occurrences than unilateral ones. However, they focused their studies on young individuals rather than older ones. Concerning the calcification pattern described by Langlais et al. (158); our findings indicated that partial calcification type B is the most prevalent among genders of all age groups. Our findings on calcification patterns are different from the other conducted studies on a different population. These studies are those of Shaik et al. (257) and More and Asrani et al. (258), Shah et al. (259) in which they determined that the outline calcification pattern type A is the most prevalent in their population. In addition, our finding is different from the data reported by Khashyab et al. (260) in which they indicated the complete calcification type D is the most common in their sample without any significant difference between the type and pattern in both the right and left sides. About the distribution of morphology, we noticed that the uninterrupted Type1 is the most common morphological type among all age groups in both genders. This is following More and Asrani et al. (258) who similarly indicated that uninterrupted elongation is more prevalent among other types. Likewise, Shaik et al. (257) reported that uninterrupted elongation is the most prevalent regardless of the side's occurrence. Considering the manifestation of Eagle's syndrome, our data indicated the appearance of the syndrome's symptoms in women more than men. It

consequently agrees with data reported by Keur et al. (261), Liu et al. (262), and Yavuz et al. (263). Therefore, our results demonstrate a prevalence of 9.6% which is within the worldwide prevalence of 4–10.3%. We can speculate from the literature that the variation in the elongation of the styloid process as well as morphology and calcification pattern is unclear and could be linked to differences of ethnicity origins or the factors related to the diagnostic method being used. Additionally, the variations in the different studies could be related to the variations in defining a starting point from which the elongation is measured. In our study, we measured the elongation according to Ilgüy et al. (147) which initiated the measurements at a point where the styloid process emerges from the temporal bone. However, some studies measure the length at a point at the line that connects the mastoid to the nasal spine (151,264,265).

It seems that the demographic variables of ESP are not consistent. Some studies indicated ESP is proportional to the aging process (266,267). Concerning gender, Hamedani et al. (268) indicated that females with low bone density show an ESP as twice as normal ones. Even some studies that were conducted in the same country of India demonstrated different prevalence. Bagga et al. (269) claimed that the higher prevalence in their sample compared to those performed by Phulambrikar et al. (270) and More and Asrani et al. (258) is related to a combination of various factors including lifestyle, race, and dietary intakes. The population is known for chewing hard foods and carrying heavy kinds of stuff on their head that could aggravate the elongation and ossification of ligaments of SP. Another reason for the variability between different studies is related to the method of measurement. Some studies measure the elongation at the point of origin from the temporal bone which is the method we performed and presented similar results of ESP. Other studies consider the measurement at the line that connects the nasal spine to the mastoid process (149,257,265).

6.4.6 Bone change of study group and control group

In the present study, the bone level changes in the mandibular second molar (MSM) were compared between patients who underwent extraction of the IMTM and those who did not. The bone level was measured from the cementoenamel junction to the level of the bone crest, as described by Faria et al. (203). In dental practice, identifying bone loss in the presence of an IMTM is essential to assessing the overall prognosis and planning the appropriate treatment strategy. Despite the possible limitations of the OPG, clinicians continue to rely on it for interventional decisions (205). In the current study, the second OPG was available for patients from both groups because they had revisited the hospital and taken the OPGs for other dental needs. No significant differences in bone loss were observed among patients in the different age groups, although it appeared to be more pronounced in those aged ≥51 years in the control group. This finding differs from those reported by Dias et al. (125) wherein statistically significant differences in the severity of bone loss were seen among participants <50 years old. Interestingly, our findings demonstrated bone loss in the 40–50 age group among the patients in the study group. Furthermore, our results agreed with those in the study by Fernandes et al. (271) which indicated an association between age and the change in the status of the alveolar crest. In the current study, a higher degree of bone loss was observed among males than females, but the difference was not statistically significant. Similar findings were reported by Dias et al. (125) wherein no significant difference in the severity of bone loss distal to the MSM was noted between males and females using panoramic radiography. It should be emphasized that several factors, such as smoking habits, impacted positioning, and maintenance of proper oral hygiene, can potentially worsen periodontal conditions on the distal aspect of the MSM (272). Therefore, if the impaction is not managed, bone changes in the form of bone loss may occur. Despite variations in the IMTM inclination type and other contributing risk factors among individuals, our findings revealed bone loss in patients who did not undergo extraction of the IMTM after evaluating their follow-up OPGs.

Bone improvement and gain distal to the MSM were observed after the extraction of the IMTM in the study group. These findings agree with those reported by Passarelli et al (209) wherein an overall improvement in the periodontal status was observed following surgical extraction of the IMTM. The removal of such teeth provides better access for cleaning, leading to overall improvement. Similarly, Krausz et al. (205) reported significant improvements in the bone on the distal aspect of the MSM after the extraction of an IMTM. These improvements were evaluated clinically and radiographically using an OPG. Additionally, they noticed mild bone loss in the control group despite variations in contributing factors, such as the degree of oral hygiene maintenance, which aligns with our findings in the control group. Furthermore, Montero et al. (273) indicated an overall improvement in the periodontal health status adjacent to the MSM after the removal of the IMTM. On the contrary, Kan et al. (207) pointed out the formation of periodontal defects on the distal aspect of the MSM after removing the IMTM.

Several studies have investigated the different patterns of IMTM in various demographic samples (225,274–276). In the present study, the vertical type of impaction was found to be the most prevalent, followed by the mesioangular type. Alsaegh et al (222) reported a higher prevalence of mesioangular impaction than other types in the Arab Emirati population. Similarly, Eshghpour et al. (277) claimed a higher predominance of mesioangular impaction in the Iranian population. Prajapati et al. (278) conducted investigations on the Indian population and reported that the mesioangular inclination dominated the other patterns, such as vertical, horizontal, and distoangular. Awareness of the different inclination patterns would indicate the need to remove the IMTM and aid in determining the necessary surgical method.

The current study revealed a higher number of individuals with bilateral impaction, which is different from the study conducted by Alsaegh et al. (222) wherein a comparable distribution of unilateral and bilateral impaction was reported. However, several studies have shown considerable variations in the occurrence of bilateral and unilateral events among different populations, including Saudi Arabian, Singaporean, Chinese, and Libyan populations (21,48,51). Bilateral impaction was predominant in these studies. It should be highlighted that the intra-examiner agreement was used instead of the inter-examiner agreement when assessing the OPGs. This decision was made because the assessment was performed concurrently between the observers, resulting in only one single outcome. Thus, the intra-examiner calculation was considered sufficient. To investigate the reproducibility of the OPG in estimating bone loss on the distal aspect of the MSM, a Kappa test was calculated. Based on the outcome mean, we assigned descriptive categories for the status of bone change, whether it is bone loss, bone gain, or no change of bone, to report the intra-examiner agreement. These descriptive categories were assigned to translate the quantitative measurements on panoramic radiography because of difficulties in reproducing the quantitative measures. Consequently, our Kappa results indicated a substantial agreement of 0.68. This study has some limitations. The reproducibility of panoramic radiograph in terms of quantitative measures is questionable due to inherited limitations. However, we used this method to assess the bone loss distal to the MSM in cases of an IMTM owing to its routine use in clinical practice and the expected occurrence of such pathologic conditions. Furthermore, our study solely focused on the radiographic findings without considering the clinical parameters that may contribute to the periodontal status of the patients. Thus, further studies using alternative radiographic techniques and a larger sample size are required to validate the findings of the current study.

CONCLUSION

7. Conclusions

In response to the primary objective:

The bone changed distal to the second molar in the study group (extraction group) witnessed bone gain while the bone changes distal to second molar in the control group (non-extraction group) witnessed bone loss.

In response to the secondary objectives:

1. In study group (extraction group), female patients witnessed more bone gain than males. Likewise, the male patients of the control group (non-extraction group), witnessed more bone loss than females.

2. In the study group (extraction group), patients aged 29-39 witnessed more bone gain than other groups. In the control group (non-extraction group), patients ages 29-39 demonstrated less bone loss compared to other groups.

3. In the study group (extraction group), all types of impactions witnessed bone gain except the mesioangular type. In control group (non-extraction group), bone status maintains bone loss with all types of impactions.

4. Most of the study samples did not demonstrate a considerable frequency of systemic pathology.

5. In the study group (extraction group), patients with localized periodontitis demonstrate more bone gain after extraction compared to those with generalized periodontitis without statistical significance. In the control group,

bone loss corresponds more to the presence of the generalized periodontitis.

6. In the study group, smokers demonstrated more bone loss versus non-smokers. Similarly, smokers demonstratedmore bone loss compared to nom-smokers in the control group.

7. The most prevalent incidental findings are the elongated styloid process followed by the calcified carotid atheroma.

8. Most of the sample's panoramic radiographies did not reveal changes in temporomandibular joints regardless of the different impaction types.

9. The occurrence witnessed in the sample is the bilateral impaction.

10. The most prevalent type of impaction is the vertical type according to Winter's classification.

11. The most prevalent type of Pell & Gregory (depth level) is position B and according to the space available is class 2.

12. The most prevalent inferior alveolar canal shape in the sample is the turning curve.

13. Most of the canals are clearly visible in the third molar region while approximately visible in the second and first molars regions.

14. Most of the canals are located close to the impacted mandibular third molar.

15. Most panoramic radiographies did not reveal any radiolucent or radiopaque lesions other than the ones related to the impacted mandibular third molars.

16. Panoramic images of the maxillary sinuses are not often accurate for revealing all pathological changes.

17. The most prevalent condyle shape is the oval shape.

18. Panoramic radiography is considered practical in the descriptive of presence or absence of bone changes although not reproducible in quantifying the changes when it is measured in millimeters.

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ANNEXES

9. Annexes

9.1 Articles

Articles related to the thesis:

1- "The prevalence of elongated styloid process in the population of Barcelona: a cross-sectional study & review of literature." Assiri Ahmed H, Estrugo-Devesa A, Roselló Llabrés X, Egido-Moreno S, López-López J. The prevalence of elongated styloid process in the population of Barcelona: a cross-sectional study & review of literature. BMC Oral Health. 2023 Sep 19;23(1):674. doi: 10.1186/s12903-023-03405-0.

2- "Mandibular Third Molar Impaction and Bone Change Distal to the Second Molar: A Panoramic Radiographic Study". Ahmed HA, López-López J, Egido-Moreno S, Llabrés XR, Hameed M, Estrugo-Devesa A.J Clin Med [Internet]. 2024;13(3). Available from: https://www.mdpi.com/2077-0383/13/3/906

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RESEARCH Open Access

The prevalence of elongated styloid process in the population of Barcelona: a cross-sectional study & review of literature

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Abstract

Background Styloid process (SP) is a cylindrical bony projection that originates from the inferior part of the petrous temporal bone just anteriorly to the stylomastoid foramen. Several nerves, muscles, and ligaments are related closely to the (SP). It is considered elongated when the measurement exceeds 30 mm. The overall prevalence of the styloid process is between 3.3% to 84.4%. The elongation of the styloid process (ESP) is associated with the manifestation of Eagle's Syndrome (ES) which is characterized by various types of pain in the head and neck region such as headache, tinnitus, otalgia, and trigeminal neuralgia. Eagle's syndrome occurs in 4–10.3% of individuals with an elongated styloid process (ESP). The objective of the study is to determine the prevalence of (ESP) in the patients who were treated in the Dental Hospital University of Barcelona (HOUB), to review the literature to spot the light on the different demographic data worldwide.

Methods The archived panoramic image in the University of Barcelona dental Hospital were consecutively retrieved to investigate the prevalence of (ESP). Of all digital panoramic radiographs (OPG), 400 met the inclusion criteria and were furtherly analyzed. The results are correlated with the participant's gender, age, and occurrence. Age is subcategorized into three groups. A chi-square test is used to measure the significant differences and the *P*-value is set at < 0.05 for the level of significance.

Results Among the included 400, we found 291 demonstrating (ESP). The prevalence of (ESP) which exceeds 30 mm is 72.75%. It is found that the most common morphological type is type 1 which is regarded as the uninterrupted (ESP) regardless of gender and age group. Concerning the calcification pattern, the most prevalent is the partial calcified (ESP) despite genders and age groups.

Conclusion (OPG) is a sufficient tool for the screening of the elongated styloid process. Regarding the prevalence, our results are considered higher than previously reported prevalence in different populations using (OPG) radiography tool. A study on a wider spectrum of the Spanish population is recommended to further investigate the correlation between the elongated styloid process and the occurrence of Eagle's syndrome.

Keywords Styloid process, Elongated styloid process, Eagle's syndrome, Panoramic radiography

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Background

The styloid process SP is a cylindrical bony projection that originates from the inferior part of the petrous temporal bone just anteriorly to the stylomastoid foramen [1]. The 'styloid' is a term derived from the Greek word 'Stylos' which refers to pillar [2]. Embryologically, this apophysis develops from the Reichert's cartilage of the second pharyngeal arch [3]. It is subjected to ossification from the third trimester of pregnancy through the first ten years of life. Regarding its location, it is positioned laterally in the neck between the internal and external carotid arteries and the internal jugular vein. Several nerves including the glossopharyngeal, facial, accessory, hypoglossal, and vagus are located near the SP [4]. Regarding anatomic structure, the distal part of the styloid process is considered the origin of various muscles including the stylohyoid, stylopharyngeus, and styloglossus. In addition, the stylomandibular ligament and the stylohyoid ligaments emerge from part of the styloid process and are inserted into the ramus of the mandible and the lesser horn of the hyoid bone respectively [5]. The muscles attached to the SP are known as Riolan's bouquet [6]. He has described the muscle of the styloglossus, stylopharyngeus, and stylohyoid as red flowers whereas the stylomandibular and stylohyoid ligaments as white flowers [6]. These structures contribute to the movement of the oropharyngeal complex. Considering the function of Ronal's bouquet, the styloglossus is an extrinsic muscle of the tongue in addition to the genioglossus, hyoglossus, and palatoglossus. Styloglossus contributes to the retraction and side elevation movement of the tongue. On the other hand, the stylohyoid muscle acts to elevate the hyoid bone during the process of swallowing. The stylopharyngeus muscle elevates and widens the pharynx during swallowing besides larynx elevation [5]. Concerning the function of the ligaments, the stylohyoid ligament connects the SP to the hyoid bone and acts to elevate it. The stylomandibular ligament is attached to the medial side of the mandible and functions to limit the maximum opening and protrusion of the mandible [7]. ESP is defined as the condition at which the SP exceeds 30 mm when measured from the emergency point in the temporal bone down to the tip of the process [2, 8, 9]. Regarding the prevalence of elongated styloid process ESP, several studies have investigated the elongation of the styloid process in different populations. The prevalence ranges between 3.3 to 84.4% (Table 1) [2, 3, 8–43].

From the radiographic point of view, there have been varieties in the methods used for the evaluation of the styloid process elongation that ranges from orthopantomography OPG to the most advanced technology of cone beam computed tomography (CBCT) and computed tomography (CT) [45–47]. Nonetheless, OPG is an extraoral imaging technique that depicts the jaws and the surrounding structures in a two-dimensional view. Due to its cost-effectiveness and ease of use, it is considered by most practitioners as the first line of radiographic diagnosis modality for the dentomaxillofacial complex [48–52]. It provides a general perspective on pathological change in the maxilla and mandible. Therefore, OPG aids to distinguish abnormal changes and observe normality. In addition, the state of teeth impaction, dental anomalies, incidental findings, malocclusions, and abnormalities of the structures surrounding the jaws are illustrated using OPG [53]. Consequently, the elongation of the styloid process unilaterally or bilaterally can be addressed via the orthopantomography technique. The elongation of the styloid process is potentially linked to the occurrence of craniofacial and cervical pain; a status described by the American Otolaryngologist Watt. W. Eagle and termed as Eagle's Syndrome [54]. It is characterized by episodes of pharyngeal pain referred to different areas of the cervicofacial area [47]. It is reported in the literature that approximately 4–10.3% of individuals with elongated SP would develop this type of pain manifestation [47]. Although Eagles' syndrome has no specific behavior or pain symptoms, patients present with dysphagia and general head and neck pain known as cervicalgia due to the pressure on the nerves and muscles contained in the surrounding structures [55]. Other symptoms including tinnitus, otalgia, and trigeminal neuralgia are linked to the presence of elongated SP [55]. Moreover, the elongated SP process could lead to more serious consequences like transient ischemic attack or stroke because of its proximity and compression on the carotid artery [56]. The etiopathogenesis of Eagle's syndrome is attributed to different theories including congenital elongation of the styloid process and the calcification of the stylohyoid ligament [57]. Furthermore, previous tonsillectomy is linked to some extent to the occurrence of Eagles' Syndrome [57].

To our knowledge, the status of styloid process elongation in the Spanish population is not yet described. Accordingly, our main objective is to determine the prevalence of the elongated styloid process in the patients treated at the Dental Hospital University of Barcelona HOUB. The secondary objectives are to review the literature to spot the light on the different demographic data worldwide.

Methods

Study design

The present study is regarded as a retrospective descriptive cross-sectional of the archived panoramic radiographs available for the patients treated in the Dental Hospital of the University of Barcelona

Table 1 Demographic data concerning the prevalence of elongated styloid process using OPG

Study	Year	Demographic population	Participants	ESP > 30 mm
Al Zarea et al. [2]	2017	Saudi Arabian	198	44%
Vieira et al. [3]	2015	Brazilian	736	43.89%
Kaufman et al. [8]	1970	American	484	28%
Goldstein & Scopp [10]	1973	American	554	22.2%
Gossman & Tarsitano [11]	1977	American	4200	4%
Correl et al. [12]	1979	American	1771	18.2%
O'Carroll et al. [13]	1984	American	479	35.3%
Monsour and Young et al. [14]	1986	Australian	1200	21.1%
Keur et al. [15]	1986	Australian	1135	30%
Ferrario et al. [16]	1990	Italian	286	84.4%
Bozkir et al. [17]	1999	Turkish	200	4%
MacDonald-Jankowski et al. [18]	2001	Londoners & Chinese (HK)	1662	7.8–8.6%%
Scaf et al. [19]	2003	Brazilian	166	12.6%
Kursoglu et al. [20]	2005	Turkish	55	83.6%
Ilguy et al. [9]	2005	Turkish	860	3.7%
Radfar et al. [21]	2008	Iranian	1000	22%
Gokce et al. [22]	2008	Turkish	698	7.7%
Balcioglu et al. [23]	2009	Turkish	227	3.3%
More & Asrani et al. [24]	2010	Indian	500	19.4%
Öztaş et al. [25]	2012	Turkish	2000	67.5%
Bagga et al. [26]	2012	Indian	2706	52.1%
Shaik et al. [28]	2013	Saudi Arabian	1162	63.2% M; 36.8%F
Alpoz et al. [29]	2014	Turkish	1600	28.8%
Chabikuli et al. [30]	2016	South African	147	69%
Sakhdari et al. [31]	2017	Iranian	500	17.7%
Rai et al. [32]	2017	West Indian	987	27.3%
Gracco et al. [33]	2017	Italian	600	31%
Mathew et al. [34]	2017	Indian (Kerala)	100	35%
Hettiarachchi et al. [35]	2019	Sri Lankan	100	29%
Zokaris et al. [36]	2019	Greek	805	30%
Sharma et al. [37]	2019	Nepalese	1061	57.5% R; 42.3% L
Sridevi et al. [38]	2019	Indian	500	55.8%
Asutai et al. [39]	2019	Turkish (East Aegean)	3678	7.01%
Aoun et al. [40]	2020	Lebanese	489	15.5%
AlSweed et al. [41]	2021	Saudi Arabian	2010	21%
Swapna et al. [42]	2021	Saudi Arabian	300	27.3%
Chen et al. [43]	2022	Taiwanese	593	41.5% R; 36.2% L
Roopashri et al. [44]	2012	Indian	300	35.6%

HOUB, Spain between June 2018 to December 2022. The ethical approval for the study was provided by the ethics committee of HOUB and approved under protocol number 32/2022. The radiographic images are obtained through a simple randomization method and retrieved consecutively from the archived images for analysis.

Sample size calculation

To identify the sample size needed for this study, the following formula is used (z statistic) * (z statistic) * P * (1-P)/ (precision $^{2)}$ [56] where: i.-P = expected prevalence of condition (obtained from previous research); ii.-Precision = how much variation in prevalence is acceptable = prevalence - least expected prevalence = allowed error (5–10%); iii.-Standard normal variate (alpha error) known as (z value or z statistic) = 1.96 for confidence interval 95%; iv.-Based on a previous sample size of the study conducted by Gracco et al. [33], our calculation would be as following: $(1.96)^2 * 0.27 * (1-0.27)/ (0.05)^2 = 302.87 = 303$. So, the minimum number of patients that we would include in our study is 303 patients. The sample of 640 images was randomly selected from the total number of radiographs according to the simple randomization method. SP length is measured following Ilgüy et al. [9] the calcification pattern, and morphology types are recorded following Langlais et al. [58]. Additionally, the hospital records of the patients demonstrating ESP were reviewed to identify the possible symptoms matching the ES manifestations including cervicalgia, dysphagia, otitis, migraine, unexplainable chronic pain, and facial muscular pain [59].

The inclusion and exclusion criteria in our study were set as follows: The inclusion criteria include i.- panoramic image free of distortion and errors and ii.- panoramic radiographs for patients > 18 years old. Concerning exclusion criteria, radiographic images that have errors, distortion, or cuts are excluded. Regarding the quality of analyzed images, only images that depicts both styloid processes with adequate quality are considered. OPG images were acquired using a Planmeca ProMax® x-ray unit manufactured by (Planmeca Oy, 00880 Helsinki, Finland) equipped with a digital sensor Planmeca Dimax 3. The measurement tool is performed by the software Planmeca Romexis®. The images were taken based on the manufacturer's recommendations about the standards of exposure. The Kilovoltage value kV ranges from 64–70 kV and the milliamperage value mA ranges from 7–14 mA based on whether the patient is an adult female, small male, adult male, or large adult male. Well-trained oral radiology doctoral students conducted the investigation twice at the one-month interval and the intra-examiner reliability was calculated using *the Kappa* test. An example of the panoramic image depicting the bilateral elongation of the styloid process (Fig. 1).

Statistical analysis

For analysis, the data obtained were entered into the excel package 2022. Results and the correlations between genders, age groups, side of elongations, and elongation in mm were analyzed using the Statistical Package for Social Sciences SPSS version 22. In this cross-sectional study, we have applied the Chi-square test to measure the significant differences, and *p*- the value is set at < 0.05 for the level of significance. *The Kappa* test is calculated for intra-observer agreement within one-month intervals [60].

Results

The panoramic radiographs of the patients treated in the dental hospital of the University of Barcelona from June 2018 up to December 2022 were collected. A total of 12,000 panoramic radiographic images were retrieved consecutively from the archived data in the dental hospital. A sample of 640 radiographies are randomly selected from the total number of radiographs according to the simple randomization method, and only 400 met the inclusion criteria while 120 are found to be for patients under 18 years old. Accordingly, there are no data for participants under 16 years old in our study. In addition, about 80 radiographies are disregarded as the radiographic images are distorted whereas 10 images were excluded as the patients fail to provide consent to perform the analysis. Similarly, about 30 radiographies were disregarded due to unclear observation of the styloid process. Accordingly, all 400 radiographies are screened completely without any missing data or images.

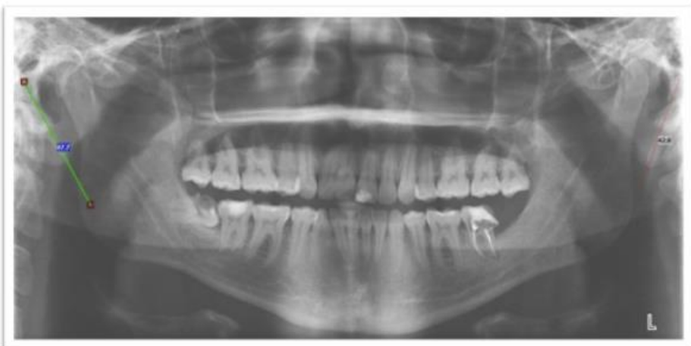


Fig. 1 Radiographic illustration of bilateral ESP on digital panoramic radiography with measurements using the Romexis software tool. Image from HOUB

Measurements of the lengths of styloid processes were conducted on diagnostically acceptable images [58]. According to Ilguay et al. [9], we measured the elongated styloid process starting from the point of origin in the tympanic plate up to the tip of the process using the measuring tool in OPG. SP is considered elongated when it is equal to, or it exceeds 30 mm [9]. In addition, the morphology of the elongated processes was evaluated based on Langlais' classification as a type of 1 = uninterrupted, type 2 = pseudo-articulated, and type 3 = segmented [58] (Fig. 2).

The calcification pattern was described and regarded as type A = calcified outlines, type B = partially calcified, Type C = nodular, type D = completely calcified according to Langlais et al. [59] (Fig. 3).

Among the included 400 images, 291 have elongated styloid process either bilaterally or unilaterally which represents 72.75% while only 109 (27.25%) of the investigated radiographies do not show any evidence of ESP. The calculated intra-observer agreement was 0.54 which indicated a moderate level of agreement using the *Kappa* test.

Our results revealed that 72.57% of the participants have ESP compared to 27% with non-ESP, and the difference is statistically significant with *a p*-value of 0.0001 (Table 2).

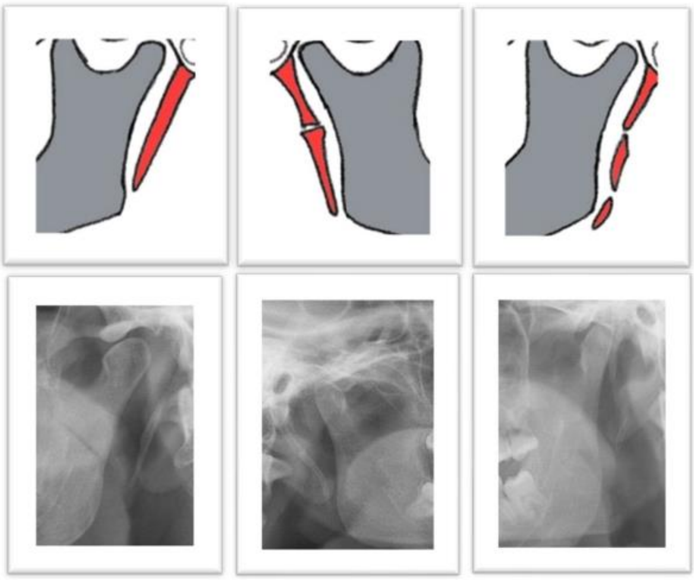
We noticed ESP is more prevalent in females compared to males. Also, regarding age, our data indicate that there is no clinically significant difference in elongation among the different age groups (Table 3).

For the occurrence, the ESP occurs more bilaterally, and the difference is a statistically significant *p*-value of 0.0001 (Table 4).

Regarding the calcification pattern, the results signify that the partial calcification type occurs more in females than males with a statically significant difference *p*-value of 0.000. In addition, it occurs more in the age group 31–60 with a statistically significant difference of *p*-value 0.000. Likewise, Type B is more frequent on the right side than the left side with a statistically significant difference *p*-value of 0.000 (Table 5).

Moreover, our data reveal that morphological type 1 is more prevalent in males. In addition, it is more frequent in the age group 31–60 with a statistically significant difference of *p*-value 0.0001. This type is also more prevalent on the right side compared to the left side (Table 6).

On the other hand, we noticed that many patients demonstrated symptomatic ESP. These patients represent approximately 9.6% of all patients with ESP. The symptoms are more prevalent in females 64.28% compared to males 35.71%. Statistically, there is no significant difference in gender. Regarding age, the symptoms are more frequent in the group aged 31–60 years old. However, there are no statistically significant differences between the age groups.



1(a) 1(b) 1(c)

Fig. 2 Diagram & radiographic illustration of morphologic types of ESP. **a** Uniterrupted. **b** Pseudo-articulated. **c** Segmented. Drawings by the author HA, images from HOUB

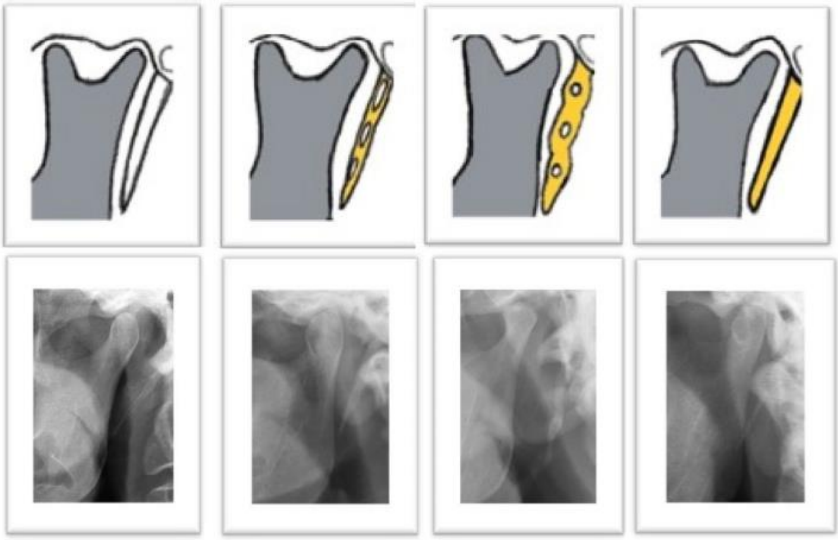


Fig. 3 Illustration of ESP calcifications. **a** Outline calcification. **b** Partially. **c** Nodular. **d** Completely calcified. Drawings by the author HA, images from HOUB

Table 2 Genders number and frequency in association with (ESP) versus (non-ESP)

Data	Males	Females	Patients with ESP	Patients with non-ESP	Chi²	*P*-value
Number	127	164	291	109	161.8	0.00000001*
Frequency	43.64%	56.36%	72.75%	27.25%		

* Statistically significant difference

Table 3 Gender & age groups related distribution

Participants		Non- ESP	ESP	Chi²	*P*-value
Gender					
Females	N	67	164	0.849	0.366
	%	29.0%	71.0%		
Males	N	42	127		
	%	24.9%	75.1%		
Age groups					
18–30	N	42	84	3.86	0.145
	%	33.3%	66.7%		
31–60	N	46	151		
	%	23.4%	76.6%		
>60	N	21	56		
	%	27.3%	72.7%		

Discussions

Generally, the styloid process is considered one of the incidental findings that are encountered in patients during routine dental examinations using panoramic radiography. In our study, we performed the measurements and investigations on digital OPG. This diagnostic technique is affordable and can be easily performed and interpreted [61]. Aside from exposing patients to a lower radiation dose, this method is much more cost-effective than CT [42]. Since digital panoramic radiography is commonly prescribed in dental practice including a styloid process elongation analysis. We decided to use this diagnostic modality in the present study. For the prevalence of the elongated styloid process in our sample, we found that it manifests in 72.5% of the study's participants. This agrees with the results reported by Ferrario et al. [16] and Kursoglu et al. [20] whom they regarded prevalence as more than 70% of their populations. Concerning gender distribution of the elongated SP, our study postulates that the elongation is more in females 164 (56.36%) than in males 127 (43.64%). It is following the study published by Omami et al. [62], and Vieira et al. [3], Ferrario et al. [16], Roopshari et al. [44]. Additionally, the estimated difference between females and

Table 4 Occurrence of unilateral and bilateral (ESP)

Occurrence		Non-ESP	ESP	Total	Chi²	*P*-value
Non	N	109	0	109	360.2	0.00000001*
	%	100%	0%	100.0%		
Unilateral	N	3	74	77		
	%	3.9%	96.1%	100.0%		
Bilateral	N	1	213	214		
	%	0.5%	99.5%	100.0%		
Total	N	109	291	400		
	%	27.3%	72.8%	100.0%		

* Statistically significant difference

Table 5 ESP concerning calcification pattern

Participants	Calcification pattern				ESP (N)	Chi²	*P*-value
	Type A (N) (%)	Type B (N) (%)	Type C (N) (%)	Type D (N) (%)			
Gender							
Male	(54) (23.58%)	(84) (36.68%)	(50) (21.83%)	(41) (17.90%)	229	540	0.000*
Female	(31) (11.27%)	(127) (46.18%)	(45) (16.36%)	(72) (26.18%)	275		
Age group							
18–30	(14) (9.33%)	(77) (51.33%)	(30) (20%)	(29) (19.33%)	150	22.61	0.000*
31–60	(44) (17.60%)	(101) (40.4%)	(44) (17.60%)	(61) (24.40%)	250		
>60	(27) (28.42%)	(25) (26.31%)	(21) (22.10%)	(22) (23.15%)	95		
Side of elongation							
Right	(42) (16.15%)	(118) (45.38%)	(52) (20%)	(50) (19.23%)	260	514	0.000*
Left	(45) (18.44%)	(97) (39.75)	(46) (18.85%)	(64) (26.22%)	244		

* Statistically significant difference

males is not clinically significant in the studies of Ferrario et al. [16] and Roopashri et al. [44]. Our findings regarding gender predilection disagree with those reported by AlZarea et al. [2], Rai et al. [32], and Sokler et al. [63] who declared more prevalence in favor of males. Statistically, our results are following the study conducted by Gokce et al. [22] on the Turkish population which indicates no clinical significance of elongation between males and females. Regarding the occurrence, our sample reveals that bilateral elongation is the most frequently noted in males and females of all age groups. This is contradictory to the findings reported by Hettiarachchi et al. [35] in which they indicated 26% unilateral elongation and only 11% of bilateral elongation of their sample. On the other hand, it agrees with the studies documented by Sakhdari et al. [31], Vieira et al. [3], and Alsweed et al. [41] for which they postulated more occurrence of bilateral elongation.

Regarding the occurrence, we found that bilateral ESP is more prevalent than unilateral ESP. Our data agree with Ferrario et al. [16], and Zaki et al. [64]. Our study is also following Gosh and Dubey et al. [65] whom they reported bilateral elongation in about 57% of their sample. Similarly, our findings are following Zokaris et al. [36] whom they reported more prevalent bilateral occurrences than unilateral ones. However, they focused their studies on young individuals rather than older ones.

Concerning the calcification pattern described by Langlais et al. [58], our findings indicated that partial calcification type B is the most prevalent among genders of

Table 6 ESP concerning the morphology

Participants	Morphology			ESP (N)	Chi^2	*P*-value
	Type 1 (N) (%)	Type 2 (N) (%)	Type 3 (N) (%)			
Gender						
Male	(116) (50.65%)	(45) (19.65%)	(68) (29.69%)	(229)	3.15	0.187
Female	(136) (49.45%)	(57) (20.72%)	(82) (29.81%)	(275)		
Age groups						
18–30	(68) (45.33%)	(24) (16%)	(58) (38.66%)	(150)	35.3	0.0001*
31–60	(108) (43.2%)	(62) (24.8%)	(80) (32%)	(250)		
> 60	(710 (74.7%)	(13) (13.68%)	(11) (11.75%)	(95)		
Side of elongations						
Right	(123) (47.30%)	(55) (21.15%)	(82) (31.5%)	(260)	1.15	0.562
Left	(127) (52.04%)	(48) (19.67%)	(69) (28.27%)	(244)		

* Statistically significant difference

all age groups. Our findings on calcification patterns are different from the other conducted studies on a different population. These studies are those of Shaik et al. [28] and More and Asrani et al. [24], Shah et al. [66] in which they determined that the outline calcification pattern type A is the most prevalent in their population. In addition, our finding is different from the data reported by Khashyab et al. [27] in which they indicated the complete calcification type D is the most common in their sample without any significant difference between the type and pattern in both the right and left sides.

About the distribution of morphology, we noticed that the uninterrupted Type1 is the most common morphological type among all age groups in both genders. This is following More and Asrani et al. [24] who similarly indicated that uninterrupted elongation is more prevalent among other types. Likewise, Shaik et al. [28] reported that uninterrupted elongation is the most prevalent regardless of the side's occurrence.

Considering the manifestation of Eagle's syndrome, our data indicated the appearance of the syndrome's symptoms in women more than men. It consequently agrees with data reported by Keur et al. [15], Liu et al. [67], and Yavuz et al. [68]. Therefore, our results demonstrate a prevalence of 9.6% which is within the worldwide prevalence of 4–10.3%.

We can speculate from the literature that the variation in the elongation of the styloid process as well as morphology and calcification pattern is unclear and could be linked to differences of ethnicity origins or the factors related to the diagnostic method being used. Additionally, the variations in the different studies could be related to the variations in defining a starting point from which the elongation is measured. In our study, we measured the elongation according to Ilgüy et al. [9] which initiated the measurements at a point where the styloid process emerges from the temporal bone. However, some studies measure the length at a point at the line that connects the mastoid to the nasal spine [16, 28, 69].

It seems that the demographic variables of ESP are not consistent. Some studies indicated ESP is proportional to the aging process [29, 70]. Concerning gender, Hamedani et al. [71] indicated that females with low bone density show an ESP as twice as normal ones. Even some studies that were conducted in the same country of India demonstrated different prevalence. Bagga et al. [26] claimed that the higher prevalence in their sample compared to those performed by Phulambrikar et al. [72] and More and Asrani et al. [24] is related to a combination of various factors including lifestyle, race, and dietary intakes. The population is known for chewing hard foods and carrying heavy kinds of stuff on their head that could aggravate the elongation and ossification of ligaments of SP. Another reason for the variability between different studies is related to the method of measurement. Some studies measure the elongation at the point of origin from the temporal bone which is the method we performed and presented similar results of ESP. Other studies consider the measurement at the line that connects the nasal spine to the mastoid process [16, 28, 69].

Limitations

It would not be ignored that there is possibly some limitation to our study. A larger sample size would provide more information about the estimated prevalence as well as the morphologic and calcification patterns. However, based on the sample size calculation, it is estimated that the minimum number that we could have in our study to reach reliable information is 303 patients.

Indeed, using the most advanced three-dimensional technique; CBCT would provide more details specially the degree of angulation in medial and lateral directions. Above all, this study provides valuable knowledge of the anatomical variations of the status of the styloid process which guides clinicians from different specialties to diagnose Eagle's syndrome. Yet, the accurate diagnosis of ESP must be assisted by CBCT as it provides details in three-dimensional aspects [73].

In addition, this study is conducted on patients visiting the dental hospital of the university of Barcelona in which the patients are mostly coming from the residential area of Baix Llobregat.

This aspect is a limitation and studies that include a broader Spanish population would be interesting. Though the *Kappa* result agreement indicates a moderate level, the results were interpreted by a well-trained doctoral student who specializes in oral radiology interpretation. The retrospective nature of this work has an intrinsic risk of information and detection bias. It is suggested to emphasize their control in future prospective studies as well as analysis of possible confounding factors and potential differential diagnoses.

Conclusion

OPG is a sufficient tool for the screening of ESP. Regarding the prevalence, our results are considered higher than most of the previously reported prevalence in different populations using OPG. Mostly, ESP should be considered an asymptomatic entity and should be detected coincidentally during routine dental diagnosis. However, dentists must be aware of cases present with craniofacial pain associated with ESP. Consequently, A study on a wider spectrum, assisted by both OPG and CBCT, of the Spanish population is recommended to further investigate the correlation between the elongated styloid process and the occurrence of Eagle's syndrome.

Abbreviations

OPG	Orthopantomography
CBCT	Cone beam computed tomography
CT	Computed tomography
ESP	Elongated styloid process
Non-ESP	Non-elongated styloid process
SP	Styloid process
HOUB	University of Barcelona Dental Hospital
kV	Kilovoltage
mA	Milliamperage
SPSS	Statistical package for social sciences

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Authors' contributions

HA contributed to the collection of the data and writing the manuscript. AED contributed to the follow up of the manuscript preparation and correction of possible encountered errors. JLL contributed to the review the manuscript, guiding the necessary corrections, and approval of the final manuscript. SEM contributed to the statistical analysis. XRL contributed to the follow up the research process.

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Availability of data and materials

The datasets used and/or analyzed during the current study are available from the corresponding author upon reasonable request.

Declarations

Ethics approval and consent to participate

The study was approved by the ethical committee of the University of Barcelona Dental Hospital (HOUB) under the number 32/2022. An informed consent form was obtained for each participant. All methods were carried out by relevant guidelines and regulations of the declaration of Helsinki [74].

Consent for publication

Not applicable (NA).

Competing interests

The authors declare no competing interests.

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Mandibular Third Molar Impaction and Bone Change Distal to the Second Molar: A Panoramic Radiographic Study

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Abstract: Background: The mandibular third molar is the most frequently impacted tooth. An impacted mandibular third molar (IMTM) can have negative consequences on the adjacent mandibular second molar (MSM), such as bone loss. An IMTM can be identified using orthopantomography (OPG). Our objective is to compare changes in bone level distal to the mandibular second molar (MSM) in patients with an extracted IMTM versus non-extracted IMTM using OPG. **Methods:** In this retrospective case–control study, 160 orthopantomograms (OPGs) of 80 patients who attended Dental Hospital of the University of Barcelona (HOUB) were randomly selected. Participants were stratified into a study group and control group. **Results:** Males and females experienced bone gain in the study group and bone loss in the control group. However, the difference in bone-level change was not statistically significant regarding gender in the study group. Within the study group, the age group of 29–39 years demonstrated significant (p-value = 0.042) bone gain after extraction compared to other age groups. However, the control group demonstrated bone loss in all age groups in which the difference is not statistically significant (p-value 0.794). **Conclusions:** Bone improvements distal to the MSM were observed after the extraction of an IMTM compared to when an IMTM was not extracted.

Keywords: impacted mandibular third molar; bone loss; mandibular second molar; panoramic radiography

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1. Introduction

The term "erumpere", which means "to erupt", refers to the movement of a developing tooth from its non-functional position to its corresponding functional and anatomical position in the dental arch [1]. However, for several reasons, some teeth fail to undergo this physiological process, leading to partial or complete tooth impaction [1]. An unerupted tooth is defined as one that remains embedded within the jawbone, is covered by gingival tissue, and may be partially or entirely covered by bone. Nevertheless, such a tooth is expected to erupt and come into occlusion based on clinical and radiographic findings [2]. A partially erupted tooth is defined as one that does not fully erupt into its normal position but can still be seen in the oral cavity. The term "tooth impaction" signifies that a tooth is obstructed from fully erupting into the oral cavity due to the blockage of the eruption path or a lack of space [3]. The third molars, followed by the maxillary canines, are the most frequently impacted teeth that are routinely encountered in dental practice [3]. The frequency of mandibular third molar impaction is influenced by factors such as facial skeleton, gender, age, and ethnic group [4]. Breik and Grupor [4] reported a higher incidence of mandibular third molar impaction in individuals with a dolichofacial pattern (vertical growth; facial axis angle, <87) and in females (43%) compared to males (45%). On the contrary, Padhye et al. [5] observed a higher prevalence of third molar impaction in males (51.77%) than in females (48.33%). The study by KalaiSelvan et al. [6] reported a prevalence of 45.8% in the Tamil population, while Prajapati et al. [7] reported a higher prevalence of impacted mandibular third molars (IMTMs) among females aged 21–30. A study by Selene Barone et al. [8] reported a statistically significant correlation between the Gonial angle and the position of the mandibular third molar. They observed that with a progressive decrease in the Gonial angle, a higher incidence of IMTMs was observed ($p < 0.05$). The worldwide prevalence of impacted third molars is 24% [9].

Systemic local reasons and craniofacial development contribute to tooth impaction. Systemic conditions, such as nutritional deficiencies, vitamin D insufficiency, anemia, rickets, Down's syndrome, genetic factors, endocrine disturbances, and various syndromes and infectious diseases, play a significant role in tooth impaction [9]. Local factors and craniofacial development that can hinder eruption and lead to impaction include a premature loss of deciduous teeth, traumatic conditions, ankylosed teeth, inflammatory and pathological conditions, Gonial angle and an insufficient space in the dental arch [1,8,9].

Different imaging modalities, including conventional radiography and advanced three-dimensional imaging, are used in dental practice. The initial screening of oral-cavity-related abnormalities is performed using periapical and panoramic radiography. Intraoral periapical radiography is used whenever it is possible to position a radiographic sensor inside the oral cavity. This technique provides a sharp and detailed image of the impacted tooth and its relation to the inferior alveolar canal [10]. The tube-shift technique can be used to determine the relationship between a tooth and the inferior mandibular nerve [10]. However, due to the difficulties associated with positioning the device, panoramic radiography is more convenient to use [11]. An orthopantomogram (OPG) provides the advantage of being able to view the structures of the mandible, maxilla, and facial bone in a single broad image. It is beneficial for identifying different pathological conditions, assessing carious and fractured teeth, detecting dental anomalies, and determining the presence of impacted teeth and pathologies [2]. However, there are several drawbacks linked to the panoramic radiographic technique, including overlapping, magnification, blurred images, metal artifacts, and errors related to patient positioning and image acquisition [11]. Therefore, the need for more accurate three-dimensional diagnosis has led to the introduction of cone-beam computed tomography (CBCT). CBCT is considered superior to conventional panoramic radiography because it provides a three-dimensional view of structures [12]. However, the routine use of CBCT in dental practice is controversial and limited to patients' needs since it produces higher radiation doses than conventional dental radiography [12]. The radiation doses resulting from a full field-of-view dental CBCT scan are reported to be 4–42 times higher than the doses from an OPG [13]. Thus, it is necessary to implement the ALADA (as low as diagnostically acceptable) concept, which has replaced the previous ALARA (as low as reasonably acceptable) concept, to control the use of CBCT [14]. In this study, IMTM was the primary predictor variable and bone loss in the adjacent MSM was the outcome variable. The null hypothesis was that there is no difference in bone in the adjacent MSM, regardless of the extraction of the IMTM.

Hence, this study aimed to compare changes in the bone level between patients who underwent the extraction of an IMTM and those who did not. The findings were also analyzed in relation to the gender and age of the patients. Additionally, the pattern of impaction in the study sample was examined.

2. Materials and Methods

2.1. Study Description

This retrospective case–control study utilized archived panoramic radiographic images of patients who visited the Dental Hospital of the University of Barcelona (HOUB) from June 2018 to August 2022. A total of 1000 OPGs were randomly selected. Among them, 400 were deemed error-free and suitable for analysis. Based on the study characteristics, 160 OPGs were selected to perform the measurements; these OPGs were from 40 patients representing the study group and 40 patients representing the control group. Ethical approval for this study was obtained from the ethics committee of HOUB (protocol number: 2022-032-1).

2.2. Study Description

The patients were selected using a simple random sampling technique, and the sample size was calculated based on Cohen's concept, as described in a study conducted by Faria et al. [15]. The minimum determined sample size for each group was 24; however, 80 patients (40 in each group) were included in this study to enhance validity. The patients were divided into two groups based on whether they underwent an extraction (study group) or non-extraction (control group) of the IMTM. The patients in the study group were individuals who came to the clinic to have their impacted lower third molar extracted. Two X-rays were taken for evaluation, one before the extraction and the other at least 3–6 months later, given that the time necessary for bone healing and remodeling is three months. This period is considered the cut-off period for periodontal healing [16]. The measurement of bone loss was performed using both radiographs, and the mean difference was compared.

The control group consisted of patients who visited the dental clinic for various dental issues and underwent an OPG, which showed the presence of either partial or complete impaction of the lower third molar. However, in this group, the impacted tooth was not extracted. A control panoramic image was performed at least 3–6 months later to assess the oral condition and the evolution of this non-extracted third molar. Since our goal was to examine bone changes in patients with and without extraction, those who did not undergo extraction should have a follow-up panoramic radiograph 3–6 months after their visit. This would help to evaluate their oral status, history, and the condition of the bone distal to the second molar.

2.3. Inclusion and Exclusion Criteria

The inclusion criteria for this study were as follows: patients older than 18 years; availability of images depicting the presence of an IMTM; availability of undistorted panoramic images without errors or overlapping; availability of radiographs taken before and after the extraction of the IMTM, with a clearly documented history for the study group; and the presence of a second molar adjacent to the impacted mandibular third molar. The exclusion criteria included images demonstrating an absent or extracted mandibular third molar; patients who had previously undergone chemotherapy, radiotherapy, or bisphosphonate treatment for head and neck tumors; individuals with incomplete records; and those with an incomplete formation of the third molar roots.

2.4. Measurement Method

The panoramic images were obtained using a Planmeca ProMax® X-ray unit (Planmeca Oy, 00880 Helsinki, Finland), which was equipped with a digital sensor called Planmeca Dimax 3. The measurement was performed using the Planmeca Romexis® software (Fadente distribution, Badalona, Barcelona, Spain, updated November 2023). Images were taken based on the manufacturer's recommendations at 64–70 kV and 7–14 mA, depending on the patients' gender and age. The recommended settings varied for adult females, small adult males, and large adult males. Well-trained doctoral students from the Oral Radiology Department conducted the measurement twice, with a two-month interval between each session. The intra-examiner reliability was calculated using the Kappa statistic [17]. Using the obtained OPGs, the level of the bone was measured from the cementoenamel junction of the second molar to the level of the alveolar crest for the study group before (Figure 1A) extraction and after extraction (Figure 1B).

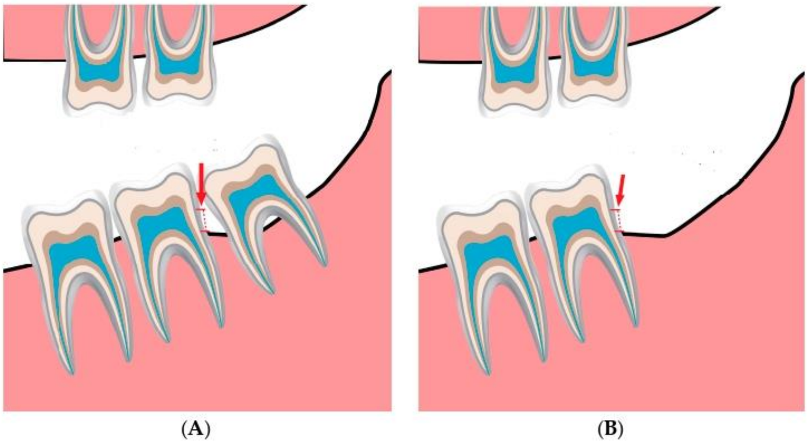

Figure 1. (**A**). The bone level is measured from the cementoenamel junction (red arrow and dotted line) of the second molar downward until the alveolar bone crest before the extraction in the study group. (**B**). The bone level is measured from the cementoenamel junction (red arrow and dotted line) of the second molar downward until the alveolar bone crest after extraction to identify the amount of bone change.

Similarly, bone changes in the control group were measured at baseline (Figure 2A) and after a period of 3–6 months (Figure 2B).

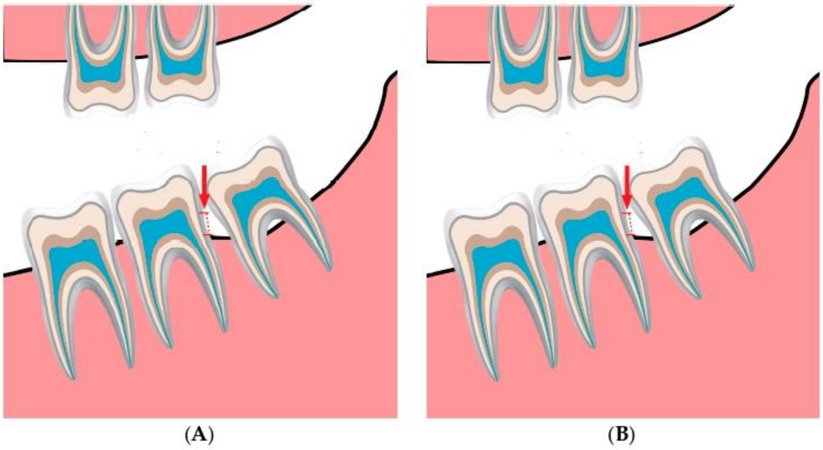

Figure 2. (**A**). The bone level is measured from the cementoenamel junction (red arrow and dotted line) of the second molar downward until the alveolar bone crest in the baseline in the control group. (**B**). The bone level is measured again from the cementoenamel junction (red arrow and dotted line) of the second molar downward until the alveolar bone crest after following up, in which the patients undergo panoramic radiography for other dental tasks, and within a period of 3–6 months to identify the amount of bone change in the control group.

2.5. Statistical Analysis

The data were imported into an Excel sheet (Microsoft® Excel® for Microsoft 365 MSO, Version 2307, Microsoft corporation, Washington, DC, USA) for descriptive analysis. All statistical analyses were performed using IBM SPSS Statistics for Windows, version 26 (IBM Corp., Armonk, NY, USA). A chi-squared test was performed to identify differences between the variables. Quantitative variables were expressed as the mean and standard deviation. Since the data were not normally distributed with respect to age and gender, a Wilcoxon test was performed to determine statistical differences in bone-level changes between the two groups. A one-way analysis of variance (ANOVA) was used to investigate differences with respect to gender and age in both groups. According to normality distribution, the U Mann–Whitney test was performed to report statistical significance with respect to the genders among the two groups. The Kruskal–Wallis test was used to report the statistical difference between the groups with respect to the different age groups. A p-value of <0.05 was considered statistically significant.

3. Results

The mean ages of the patients in the study and control groups were 35.5 ± 15.45 and 33 ± 16.49, respectively. Females and males accounted for 62% and 37.5% of the patients in the study group, respectively, and 55% and 45% of the patients in the control group, respectively. Furthermore, the patients were divided into four subgroups based on age: 18–28, 29–39, 40–50, and ≥51.

3.1. Comparison of Bone Levels among the Groups

The bone-level measurements were calculated and reported as the mean and standard deviation for both the study and control groups. The values in the study group before and after extraction were 3.00 ± 1.68 and 2.63 ± 1.75, respectively, indicating a statistically significant difference in favor of bone gain ($p < 0.0001$). In the control group, the value of the baseline radiography was 2.73 ± 1.75, whereas the value of the second radiography was 3.01 ± 1.98, revealing a statistically significant difference in favor of bone loss ($p < 0.001$) (Table 1). The Kappa values were interpreted as follows: low agreement (<0), very slight agreement (0–0.19), slight agreement (0.2–0.39), moderate agreement (04–0.59), substantial agreement (0.6–0.70), and almost perfect agreement (0.8–1) [17] (Table 1).

Table 1. Comparison of bone-level changes between the study group and the control group.

Group	Baseline Bone Level Mean SD *	Bone Level after Extraction/Follow-Up Mean SD	p-Value
Study group	3.00 ± 1.68	2.63 ± 1.75	0.0001
Control group	2.73 ± 1.75	3.01 ± 1.98	0.001

* SD, standard deviation.

3.2. Comparison of Bone Levels between Genders

Both males and females experienced bone gain in the study group and bone loss in the control group. However, the differences in bone level changes were not statistically significant with respect to gender in the study group (Table 2). Since the data were not normally distributed, the U Mann–Whitney test was performed, and provided no statistical difference between genders of the study group p-value 0.747. On the other hand, the control group witnessed bone loss and was higher in males compared to females, with a p-value 0.034.

Table 2. Bone-level changes in the two groups based on gender.

Group	Gender	Baseline BL [1]	Follow-Up BL [2]	Bone Change df (mm) [3]	p-Value
Study	Male	3.51 ± 1.89	3.27 ± 2.17	0.24 ± 1.29	0.747
	Female	2.73 ± 1.35	2.29 ± 1.41	0.44 ± 1.13	
Control	Male	3.64 ± 1.79	4.12 ± 2.11	−0.48 ± 0.66	0.034
	Female	1.97 ± 1.32	2.11 ± 1.3	−0.13 ± 0.31	

[1] = bone loss measured before extraction in the study group and at baseline in the control group (non-extraction group); [2] = bone loss measured after extraction in the study group and at follow-up in the control group; [3] = bone-level difference between the two measurements.

3.3. Bone-Level Changes among the Two Groups Based on Age

In the study group, patients between the ages of 29 and 39 years appeared to experience the highest bone gain after extraction compared to those in the other age groups (Table 3). On the other hand, only those aged 40–50 years experienced bone loss after extraction (−1.20 ± 0.14 mm). In the study group, significant differences in bone-level changes were observed among the age groups after extraction ($p < 0.05$; Table 3). Since the data were not normally distributed, a non-parametric Kruskal–Wallis test was performed and resulted in a p-value of 0.042, which indicates a statistically significant difference between the 29–39 age group and other groups. Additionally, the post hoc comparison with a Bonferroni test only shows statistical differences between the age groups of 29–39 years old and 40–50 years old.

Table 3. Bone-level changes in relation to different age groups.

Group	Age Group	Baseline BL	Follow-Up BL	Bone Change df (mm)	*p*-Value
Study	18–28	2.48 ± 1.51	2.18 ± 1.57	0.29 ± 1.07	0.042
	29–39	3.25 ± 1.69	2.29 ± 1.51	0.96 ± 1.05	
	40–50	4.30 ± 3.53	5.50 ± 3.39	−1.20 ±0.14	
	≥51	3.51 ± 1.53	3.45 ± 1.44	0.05 ± 1.34	
Control	18–28	2.93 ± 1.94	3.19 ± 2.13	−0.26 ±0.53	0.794
	29–39	2.28 ± 1.32	2.45 ± 1.50	−0.17 ±0.25	
	40–50	2.20 ± 0.71	2.38 ± 0.46	−0.17 ±0.25	
	≥51	2.58 ± 1.72	3.16 ± 2.35	−0.57 ±0.69	

In the control group, all age groups presented bone loss at the follow-up evaluation; however, the differences in bone loss among the age groups were not statistically significant (p-value 0.794; Table 3).

3.4. Pattern of Impaction

Based on Winter's classification, the number of IMTMs in this study was 139 out of a total sample of 160. This accounted for 82.28%. Vertical impaction was the most prevalent (41.24%), followed by mesioangular impaction (28.75%) and horizontal impaction (16.62%). No statistically significant difference in the occurrence of different types of impaction was observed in the current study (p-value 0.539; Table 4). As the data were not normally distributed, Kruskal–Wallis test is performed and provided a p-value 0.794, which indicates no statistical differences between the age groups. Since there is no statistical difference, there was no need to conduct the pos hoc test.

Table 4. Distribution of the impaction pattern according to Winter's classification.

Classification	Inclination	Study Group		Control Group		Total Sample		*p*-Value
		(N)	(F)	(N)	(F)	(N)	(F)	
Winter's classification	Vertical	31	44.9%	35	50%	66	41.25%	0.539
	Mesioangular	26	37.7%	20	28.6%	46	28.75%	
	Distoangular	1	1.4%	0	0%	1	1.25%	
	Horizontal	10	14.5%	15	21.4%	25	16.62%	
	Buccally tilted	1	1.4%	0	0%	1	1.25%	
	Total	69	86.25%	70	87.5%	139	82.28%	

3.5. Impaction Side

In both groups, most of the patients demonstrated bilateral impaction, which accounted for 73.8% of the total sample. In the study group, unilateral impaction on the right side was more prevalent than unilateral impaction on the left side (15% and 12.5%, respectively). By contrast, unilateral impaction on the left side was more prevalent than unilateral impaction on the right side in the control group (17.5% and 7.5%, respectively).

No statistically significant difference regarding the side of impaction was observed between the two groups (p-value = 0.509; Table 5).

Table 5. Distribution of impaction type in relation to the side of impaction in the two groups.

	Occurrence	Study Group		Control Group		Total Sample		p-Value
		(N)	(F)	(N)	(F)	(N)	(F)	
Impaction side	Right	6	15%	3	7.5%	9	11.3%	0.509
	Left	5	12.5%	7	17.5%	12	15%	
	Bilateral	29	72.5%	30	75%	59	73.8%	

4. Discussion

Mandibular third molar impaction is one of the most common dental problems encountered in daily dental practice. Surgical removal of an impacted tooth can result in various consequences, which have been reported to occur in 0 to 30% of patients. These complications include pain, trismus, swelling, prolonged bleeding, dry socket, postoperative infection, and paresthesia resulting from an injury to the inferior alveolar nerve [18]. Since pain, swelling, and trismus are among the most common complications of IMTM surgery, Antonelli et al. [19] performed split-mouth randomized clinical trials, in which they investigated the significance of the preoperative prednisone (25 mg/os) administration on such postoperative complications, mainly facial swelling. They compared the use of prednisone in one group with a placebo group at different time intervals and using different methods, including Bollus 3D Face APP for swelling, a visual analog scale for pain, and the calibration of the incisal distance for trismus. According to their outcomes, the preoperative administration of prednisone could improve the overall postoperative complication of third molar surgery, including the facial swelling compared to the placebo group. Their findings are an agreement with those reported by Tiigimae-Saar et al. [20] who stated that the administration of preoperative prednisone contributes to the reduction in edema.

In the present study, the bone level changes in the mandibular second molar (MSM) were compared for patients who underwent extraction of an IMTM and those who did not. The bone level was measured from the cementoenamel junction to the bone crest, as described by Faria et al. [15]. In dental practice, identifying bone loss in the presence of an IMTM is essential for assessing the overall prognosis and planning an appropriate treatment strategy. Despite the possible limitations of OPGs, clinicians continue to rely on them for making interventional decisions [21]. In the current study, a second OPG was available for patients from both groups because they revisited the hospital and OPGs were taken for other dental needs. No significant differences in bone loss were observed among patients in different age groups, although bone loss appeared to be more pronounced in those aged $\geq$ 51 years in the control group. This finding differed from those reported in the study by Dias et al. [22], wherein statistically significant differences in the severity of bone loss were seen among participants < 50 years old. Interestingly, our findings demonstrated bone loss in the age group of 40–50 years among the patients in the study group. Furthermore, our results agreed with those reported in the study by Fernandes et al. [23], indicating an association between age and a change in the status of the alveolar crest. In the current study, a higher degree of bone loss was observed among males than females, but the difference was not statistically significant. Similar findings were reported in the study by Dias et al. [22], wherein no significant difference in the severity of bone loss distal to the MSM was noted between males and females using panoramic radiography. It should be emphasized that several factors, such as smoking habits, impacted positioning, and a lack of maintenance of proper oral hygiene, can potentially worsen periodontal conditions on the distal aspect of the MSM [24,25]. Therefore, if an impaction is not managed, bone changes in the form of bone loss may occur. Despite variations in IMTM inclination type and other contributing risk factors among the patients in this study, our findings revealed bone loss in patients who did not undergo extraction of the IMTM after an evaluation of their follow-up OPGs. Bone improvement and gain distal to the MSM were observed after the extraction of the IMTM in the study group. These findings aligned with those reported by Passarelli et al. [26], who observed an overall improvement in their patients' periodontal status following the surgical extraction of an IMTM. The removal of an impacted tooth provides better access for cleaning, thus leading to overall improvement. Similarly, Krausz et al. [21] reported significant improvements in the bone on the distal aspect of the MSM after the extraction of an IMTM. These improvements were clinically and radiographically evaluated using an OPG. Additionally, they noticed mild bone loss in the control group despite variations in the contributing factors, such as the degree of oral hygiene maintenance, which aligned with our findings in the control group. Furthermore, Montero et al. [27] indicated an overall improvement in the periodontal health status adjacent to the MSM after the removal of an IMTM. On the contrary, Kan et al. [28] pointed out the formation of periodontal defects on the distal aspect of the MSM after removing an IMTM. Several studies have identified different patterns of IMTMs in different demographic samples [29,30]. In the present study, the vertical type of impaction was found to be the most prevalent, followed by the mesioangular type. Alsaegh et al. [31] reported a higher prevalence of mesioangular impaction compared to other types in the Arab Emirati population. Similarly, Eshghpour et al. [32] found a higher prevalence of mesioangular impaction in the Iranian population. Prajapati et al. [7] conducted an investigation in the Indian population and reported that mesioangular inclination was more common than the other patterns, including vertical, horizontal, and distoangular inclinations. A greater awareness of the different inclination patterns indicates the need to remove IMTMs and aids in determining the necessary surgical method. The current study revealed a higher number of individuals with bilateral impaction, which was different from the study conducted by Alsaegh et al. [31], wherein a comparable distribution of unilateral and bilateral impactions was reported. However, several studies have reported considerable variations in the occurrence of bilateral and unilateral impaction events among different populations, including Saudi Arabian, Singaporean, Chinese, and Libyan populations [33,34]. Bilateral impaction was found to be predominant in these studies. It should be highlighted that intra-examiner reliability was used instead of inter-examiner reliability when assessing the patients' OPGs. This decision was made because the assessment was performed concurrently between the examiners, resulting in only one single outcome. Thus, the calculation of the intra-examiner reliability was considered sufficient. To investigate the reproducibility of using OPGs to estimate bone loss on the distal aspect of the MSM, a Kappa test was calculated. Based on the mean of the outcomes, we assigned descriptive categories for the status of bone level changes, including bone loss, bone gain, or no changes in bone level, to report the intra-examiner reliability. These descriptive categories were assigned to translate the quantitative measurements based on panoramic radiography because of the difficulties in reproducing such quantitative measures. Consequently, our Kappa results indicate a substantial agreement of 0.68 between the examiners.

This study has some limitations. The reproducibility of a panoramic radiograph in terms of quantitative measures is questionable due to the inherent limitations of such a method. However, we used this method to assess bone loss distal to the MSM in cases with an IMTM due to its routine use in clinical practice and the expected occurrence of such pathologic conditions. Furthermore, our study solely focused on the radiographic findings without considering clinical parameters, such as those obtained via clinical probing. Thus, further studies correlating findings based on OPGs with three-dimensional imaging, such as cone-beam computed tomography and clinical probing, and the use of a larger sample size are required to validate the findings of the current study. Although a larger sample size could provide more valid findings, our sample size calculation indicated that a total of 24 patients in each group was sufficient for performing the statistical analysis; we increased this number based on the available OPGs that met the inclusion criteria to increase the validity of the evidence. Overall, a larger sample is still advisable to enhance the validity of studies. In addition, the absence of findings from clinical probing is a considerable limitation of our study.

A strength of this study is that it provides clear evidence about the status of bone level changes in subjects who underwent the extraction of an impacted mandibular third molar compared to those who did not. Hence, the findings could guide clinicians in devising a proper management strategy for this tooth, taking into consideration whether to use OPG alone or combine it with other advanced imaging modalities such as CBCT.

5. Conclusions

An increase and improvement in the bone level distal to the mandibular second molar was observed after the extraction of an IMTM when compared to the control group. The findings of this study suggest that, taking into account the routine use, affordability, and convenience of OPG, this method may be beneficial for visualizing a patient's bone status after the extraction of an impacted molar.

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Informed Consent Statement: Patient consent was waived because we only reviewed the radiographic images of the patients anonymously, and there was no intervention or investigation on humans directly.

Data Availability Statement: All relevant data are provided within the article.

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