Journal section: Orthodontics
Publication Types: Review

doi:10.4317/jced.61285
https://doi.org/10.4317/jced.61285

CBCT vs panoramic radiography in assessment of impacted upper canine and root resorption of the adjacent teeth: A systematic review and meta-analysis

Mariela Peralta-Mamani [1], Cássia-Maria-Fischer Rubira [1], José López-López [2], Heitor-Marques Honório [3], Izabel-Regina-Fischer Rubira-Bullen [1]

[1] Department of Surgery, Stomatology, Pathology and Radiology - Bauru School of Dentistry, University of São Paulo. Alameda Octávio Pinheiro Brisola, 9-75, Vila Universitária, ZIP CODE: 17012-901, Bauru- SP, Brazil
[2] Oral Health and Masticatory System Group-IDIBELL / Faculty of Medicine and Health Sciences (School of Dentistry) / Odontological Hospital University of Barcelona, University of Barcelona, Campus Bellvitge, Carrer de la Feixa Llarga, s/n, 08907 L'Hospitalet de Llobregat, Barcelona, Spain
[3] Department of Pediatric Dentistry, Orthodontics and Public Health, Bauru School of Dentistry, University of São Paulo. Alameda Octávio Pinheiro Brisola, 9-75, Vila Universitária, ZIP CODE: 17012-901, Bauru- SP, Brazil

Correspondence:
Bauru School of Dentistry- University of São Paulo (FOB-USP)
Department of Surgery, Stomatology, Pathology and Radiology
Alameda Octávio Pinheiro Brisola, 9-75
Vila Universitária
Zip code: 17012-901
Bauru- SP / Brazil
marielaperalta@alumni.usp.br

Received: 05/12/2023
Accepted: 08/01/2024

Peralta-Mamani M, Rubira CMF, López-López J, Honório HM, Rubira-Bullen IRF. CBCT vs panoramic radiography in assessment of impacted upper canine and root resorption of the adjacent teeth: A systematic review and meta-analysis. J Clin Exp Dent. 2024;16(2):e198-222.

Article Number: 61285 *http://www.medicinaoral.com/odo/indice.htm*

eMail: jced@jced.es
Indexed in:
Pubmed
Pubmed Central® (PMC)
Scopus
DOI® System

Abstract

Background: The IC may cause reabsorption of adjacent teeth; therefore detailed assessment of its position would enhance decision-making in the clinical workflow. The objective was to compare cone-beam computed tomography (CBCT) and panoramic radiography (PR) in assessing the position of the impacted upper canine (IC) and root resorption of adjacent teeth.

Material and Methods: Pubmed, EMBASE, Science Direct, Web of Science, and SCOPUS databases were searched for studies published before August 2023. Studies that evaluated IC by using both imaging methods were included. For statistical analysis, the Comprehensive Meta-Analysis software (Biostat; Englewood, NJ) was used, $p \leq 0.05$.

Results: A total of 17 articles were included, with 877 patients (average age of 17.6 years) and 1,115 ICs. The most frequent mesio-distal location of the IC was in sectors 3 and 4. The meta-analysis was performed with eleven studies. CBCT was more accurate in determining the labio-palatal position compared with PR ($p<0.001$) (CI 95%; 60% in labial position, 0.254-0.542, OR:0.398; 56% in palatal position, 0.350-0.533, OR:0.441; 78% in mid-alveolus position, 0.188-0.234, OR:0.221). For IC angulation to the midline, CBCT showing a smaller and more accurate angle than PR ($p<0.001$) (CI 95%, 18.008-33.686). IC angulation to the occlusal plane and lateral incisor, there was smaller angle in PR compared to CBCT ($p<0.001$) (CI 95%, 51.292-65.934; CI 95%, 30.011-55.954). With PR, fewer cases of root resorption of teeth adjacent to the IC were visualized compared with CBCT (86% less) ($p<0.001$) (CI 95%, 0.089-0.186; OR value: 0.138; n=1049).

Conclusions: CBCT showed statistically significant differences compared to PR in the assessment of IC position and root resorption of adjacent teeth. CBCT provided clinically relevant information that may contribute to diagnosing and planning IC treatment when PR was not sufficient.

Key words: *Canine teeth, tooth, impacted, panoramic radiography, Cone-beam computed tomography, systematic review, meta-analysis.*

Introduction

The upper canine is the tooth most frequently retained in the maxilla after the third molar and is followed in frequency by the second premolars and central incisors (1,2). In the etiology of impacted canines (IC), multiple factors are considered responsible, among them genetic factors that play a significant role both locally and systemically. The canine will not break out correctly if it deviates from its normal eruption path. This can be caused by a lack of space for tooth eruption or the absence of the lateral incisor. The latter cause is explained by orientation theory, which proposes that the lateral incisor serves as a guide for canine eruption. Other local factors that play a critical role in IC include discrepancies between arch length and tooth size, failed root resorption in the deciduous canine, early loss of the deciduous canine or permanent lateral incisor, dilaceration of the root, and variation in the time of permanent lateral incisor root formation (3-6).

Complications in patients with impacted upper canines include external root resorption in adjacent teeth due to their ectopic position, ankylosis of the affected tooth, and formation of cystic lesions. Because of these complications, early diagnosis of IC and its effects on adjacent structures is essential (7-9).

There are several options for diagnostic imaging of IC, including panoramic radiography (PR) and Cone-beam computed tomography (CBCT). PR images correspond to a two-dimensional aspect of a three-dimensional structure and, hence, have the potential to lead to errors of interpretation of IC due to image distortion and overlap of anatomic structures, factors that are the major limitations of this exam (10). Whereas CBCT allows 3D images to be reformatted without distortions. These characteristics have led to an increase in requests for CBCT. However, dentists should consider the costs and benefits of CBCT before exposing patients to ionizing radiation (11).

To the best of our knowledge, there are no recent systematic reviews that have compared PR and CBCT and reported summarized data on the position of the impacted canine and rate of resorption of adjacent teeth found in the two exams. This information is especially important to clinicians before clinical decision-making in cases of patients with IC.

In the case of IC, CBCT can lead to changing the treatment plan initially decided, based on conventional radiographs (4). This is because CBCT provides more detailed 3D images that include visualization of the resorption of adjacent teeth, of which the lateral incisor is the most commonly affected tooth (9,12,13). Therefore, the study was motivated to provide information obtained from imaging exams commonly used in dentistry that would help clinicians to reach an adequate diagnosis and perform treatment of the impacted upper canine, by establishing its precise location in relation to the adjacent structures. Thus, the aim of this study was to compare CBCT with PR used for the purpose of assessing the position of the impacted upper canine and resorption of adjacent teeth. Therefore, the null hypothesis of this study was that in patients with IC, there is no statistically significant difference in the assessment of its position and resorption of adjacent teeth through PR and CBCT.

Material and Methods

-Protocol and Registration

This systematic review was conducted according to the Preferred Reporting Items of Systematic reviews and Meta-Analyzes (PRISMA) guidelines (14). Registration was made with PROSPERO, an international database of systematic reviews registered in the area of health and social assistance and developed and managed by the National Institute for Health Research (NIHR) at York University, United Kingdom. The registration number obtained for this systematic review was CRD42016051645 and is available in full on the PROSPERO website: www.crd.york.ac.uk/PROSPERO/.

-Eligibility criteria

Inclusion criteria

The studies selected met the criteria established by the PECO strategy: Participants: patients with IC; Exposure: CBCT; Control: PR; and Outcome: assessment of position of the impacted upper canine and resorption of adjacent teeth. Thus, the search question of this study was: in patients with retained upper canines, is there a difference in CBCT compared with PR for assessing the position of the impacted upper canine and resorption of adjacent teeth?

All cross-sectional studies that assessed the position of ICs and resorption of adjacent teeth using PR and CBCT were included. Any parameter for evaluating the position was considered (labio-palatal position, mesio-distal position, vertical position, angulation with respect to the lateral incisor, midline or occlusal plane). Studies with ICs in any position, both labial and/or palatal or mid-al-

veolus, were included. All studies included participants with impacted maxillary canines (unerupted teeth within the maxillary bone), unilateral or bilateral, with or without the presence of the predecessor canine.

Exclusion criteria

Review articles, clinical cases, or case series were excluded. Studies were excluded if their sample was of lower canines or other unerupted teeth, if they evaluated the upper canine only with CBCT or PR but not both, or if the planning of orthodontic treatment was based on questionnaires, and studies that were not from living humans (typodont and skulls). Studies whose participants had cysts or tumors around impacted canines, a history of dental trauma, ectopic canines, previous orthodontic treatment, evaluation after orthodontic treatment, syndromes, and craniofacial anomalies were excluded.

-Exposure and Control

PR images were used as a control as they allow 2D visualization of anatomical structures and present the least risk to patients. CBCT images were considered the exposure/test condition due to their more detailed 3D assessment of the impacted canine position in the maxilla and the increased risk to patients through ionizing radiation exposure.

-Information sources and Search

The identification of the included studies was based on a search strategy for each electronic database: PubMed, EMBASE, Web of Science, SCOPUS, LIVIVO, and Virtual Health Library (VHL). The search strategy included any study that evaluated IC through PR and CBCT, the strategy was made with indexed words (MeSH) and terms related to the IC, CBCT, and PR. The terms were combined and related through Boolean operators (AND / OR) for use in each bibliographic database. There was no restriction on language or date of publication. The databases search are in Supplement 1 (http://www.medicinaoral.com/medoralfree01/aop/jced_61285_s01.pdf).

Gray literature was searched to include any additional work that met the eligibility criteria. The reviewers performed a manual search and reference lists of all selected studies and searched for theses and dissertations in OpenGrey, ProQuest, Brazilian digital library of theses and dissertations (BDTD-IBICT), and Google Scholar to find eligible works. Studies published until August 2023 were included.

-Study selection

All studies collected from the different databases uploaded to Endnote Web software (www.myendnoteweb.com), where they were stored in a single folder and organized and verified to remove duplicated references. In addition, a manual search was performed to check that there were no duplications.

All study titles and abstracts were identified independently. The selection of the studies was performed by two calibrated reviewers (M.P.M. and C.M.F.R.), for determined the eligibility of studies based on the criteria described above. For potentially eligible studies, the full text was read and the studies were coded alphabetically and placed in a folder to facilitate further analysis. The discrepancy between the two reviewers about the eligibility of studies in both phases was resolved by discussing it with the third reviewer (I.R.F.R.B.).

-Data extraction and Data items

The papers that met the inclusion criteria were examined independently by two reviewers (M.P.M. and C.M.F.R.). Data extraction was performed by these reviewers and any discrepancies were resolved by discussion with the third reviewer (I.R.F.R.B) until reached a mutual agreement.

For each of the selected studies, their main characteristics extracted for the synthesis of results using a standardized form in Microsoft Office Excel (Microsoft® Office). The information extracted included: first author, year of publication, geographic region, sample number, age and sex of the population, details of exposure (CBCT) and control (PR), examiners, methods used in CBCT/PR (Tables 1-2 cont.-1), measurements made of the studies and results (Tables 3-5). Only the information available in the articles was considered.

-Risk of bias of individual studies

We used the Appraisal tool for cross-sectional studies (AXIS tool) (15). The quality analysis was conducted through the use of 20 questions in the AXIS tool (about introduction, methods, results, discussion, and other) which were based on the following study aspects: quality of reporting, study design quality and possible introduction of biases. The reviewers assigned each guiding question one of three options: yes, no, do not know. Two reviewers (M.P.M. and C.M.F.R.) independently assessed the methodological quality of each study using the AXIS tool and any unresolved disagreement between the reviewers was resolved by a discussion with the third author (I.R.F.R.B.) (Table 6-6 cont.-2).

-Summary measures

Any type of prevalence outcome measurement of the IC position (labio-palatal position, mesio-distal position, vertical position, angulation with respect to the lateral incisor, midline, or occlusal plane), and resorption of the teeth adjacent to the IC was considered. In the case of the IC angulation, measures such as mean and standard deviation of the angulation in relation to the lateral incisor, occlusal plane, and midline were also considered.

-Synthesis of results

A narrative synthesis and meta-analysis were carried out on some variables that had sufficient quantitative data. In order to reduce the heterogeneity between the studies, the results were separated according to the IC position considered by each study: labial-palatal, mesio-distal, vertical, and/or angulation of the IC. The result on the

Table 1: Details of included studies (in alphabetical order).

First Author / Year	Sample number	Age and sex	Exposition and control	Examiners	Measurements in PR/ classification	Measurements in TCFC / classification	Resorption of teeth adjacent
Akkuc *et al*., 2021	30 patients 35 impacted canines	6 to 16 years/ NR	PR: Planmeca Proline XC. CBCT: NewTom 5G	Two pediatric dentists were trained and calibrated	Canine angulations: - To the lateral incisor - To the midline	1 and Incisor root resorption	Lateral incisors CBCT: 33.3%
Alfaleh and Al Thobiani, 2021	47 patients 60 impacted canines	19.8 ± 6.8 years/31 female, 16 male	PR: OP100, ORTHOPHOS XG 3, Conventional PRs digitized. CBCTs: Iluma CBCT, Carestream CS 9300 CBCT, GALILEOS Comfort PLUS	A examiner was trained and supervised by an oral and maxillofacial radiologist (15 years of experience)	The MDP of the IC with regard to the MLI: sector method of Lindauer et al. I, II, III, IV.	Canine location: labial, mid-alveolus, palatal Incisor root resorption	Central incisors CBCT: 37.9% Lateral incisors CBCT: 89.7%
Alqerban *et al*., 2011	60 patients 89 impacted canines	Range: 6,3 to 28,9 years Mean: 13,2±4,2 years/37 females, 23 males	PR: Cranex Tome CBCTa: 3D Accuitomo (n=30). CBCTb: Scanora 3D (n=30).	2 groups of examiners: 3 experienced dental practitioners and 8 postgraduates (mean age of 27 years)	Width of canine crown Width of canine follicle Canine angulations: - To the lateral incisor - To the midline - To the oclusal plane. Interval of exams: 2 weeks	to 3 Canine location: palatally, bucally, in the line of the arch. Severity of incisor root resorption: No, slight, moderate and severe. Location of resorption: apical, middle and cervical third.	Lateral incisors: CBCT-Accuitomo: 53.9% PR: 29.4% CBCT-Scanora: 50.9% PR: 30.7% Central incisors: CBCT-Accuitomo: 15.1% PR: 13% CBCT-Scanora: 4.9% PR: 5.5%
Alqerban *et al*., 2013	32 patients 39 impacted canines (17R, 22L)	25±14 years/ 19 females, 13 males.	PR: Veraviewepocs 2D® CBCT: 3D Accuitomo	6 examinators: 4 orthodontists and 2 oral surgeons.	IC crown position in the sagittal plane: palatal, buccal or in line with the arch. IC crown position in the axial plane respect to the occlusal plane: high, medium or low. Contact between IC and adjacent teeth: Yes or No. Resorption in lateral incisors. Linear measurements: Canine crown width	1, 2, 3, 4 and 5	Lateral incisors PR: 11.5% CBCT: 18%
Andresen *et al*., 2022	99 patients 156 impacted canines	11.2 ± 1.6/ 57 female, 42 male	PR: Planmeca Romexis CBCT: Accuitomo-170 and Veraviewepocs 3D R100	Two experienced maxillofacial radiologists	Canine cusp tip according to the lateral and central incisor. Canine position: inclination to the midline Resorption in lateral incisors: definitely present, probably present, probably not present, definitely not present.	3: Resorption: presence, localized in the root (apical 1/3, middle 1/3, cervical 1/3) and extension (cementum layer, half of dentine, inner half of dentine, pulp involvement).	Lateral incisors: PR: 40.4% CBCT: 80.1%

Table 1 cont.: Details of included studies (in alphabetical order).

Ardakani *et al.*, 2021	40 patients 40 impacted canines	18.2 ± 6.55 years/ 32 females, 8 males	PR: ProMax dental X-ray unit CBCT: ProMax 3D	A maxillofacial radiologist.	IC crown position in the axial plane respect to the occlusal plane: high, medium or low. Intersection of the occlusal line and longitudinal axis of IC. Intersection of the cervical line (line traced in the most anterior and inferior region of the images of the cervical vertebra 2) and longitudinal axis of IC. Root resorption of lateral incisors	4: Absence of resorption; Loss of natural contour of the root; Loss of <50% of dentin; Loss of >50% of dentin without pulp involvement; and Pulp involvement. Categorized in apical third, middle third, and cervical third.	Lateral incisors: PR: 27.5% CBCT: 55%
Botticelli *et al.*, 2011	27 patients 39 impacted canines	11,8 years (mean)/ 17 females, 10 males.	PR: Digora Optime System CBCT: NewTom 3G scanner	8 dentists: 3 at the beginning of orthodontics course, 2 with a moderate experience and 3 orthodontics with >5 years of experience.	Canine position: inclination to the midline Root resorption of lateral incisors	1 and 2	Lateral incisors: PR: 11.5% CBCT: 19.8% Agreement of PR and CBCT: 82%
Björksved *et al.*, 2018	58 patients 64 palatally impacted canines (6 bilateral)	13,2 years (SD 1,7). 13,3 years (SD 1,5) / 21 males; 13,4 years (SD 1,2). 37 females	PRa: Cranex Tome or Scanora equipment PRb: Orthophos XG5 equipment CBCTa: Morita Accuitomo 170 CBCTb: i-CAT unit	One radiologist	Canine cusp tip according to sectors: I, II, III, IV, V. Canine long axis Angle to midline	1 and 2	-
Haney *et al.*, 2010	18 patients 30 impacted canines (6R,5L, 7R+L)	16,9±5,8 years. Range: 12.3 to 34.6 years. /12 female e 6 male.	PR: Hitachi MercuRay, CBCT: CBCT scans (Hitachi MercuRay)	The maxillary dentitions were segmented by 1 postgraduate student of Orthodontics. 7 examinators: 4 orthodontists, 3 oral surgeons.	Mesio-distal tip canine position. Labio-palatal position Root resorption of lateral incisors	1, 2 and 3	Agreement of PR and CBCT: 63%
Jung *et al.*, 2012	63 patients 73 impacted canines (10R+L; 53 unilaterally) Two groups: <15 years and > 15 years	18.4±10.6 years. Range: 10-56 years/28 male, 35 female.	PR: Proline XC CBCT: DCT Pro	2 oral and maxillofacial radiologist	Mesio-distal position of the canine tip: Alessandri et al. method, sectors 1, 2, 3, 4, 5 in relation to the adjacent incisors.	Labio-palatal position: labial, mid-alveolus and palatal. Root resorption of incisors in cross-sectional reformatted images: Yes or No.	Adjacent incisors: CBCT: 30.1%

Table 1 cont.-1: Details of included studies (in alphabetical order).

Lai *et al.*, 2014	60 patients 72 impacted canines (12R+L, 34R)	17,3 years Range: 8.7 to 70.2 years/18 male, 42 female.	PR: Dell 380 Precision workstation CBCT: 3D Accuitomo	PR: 10 experienced specialists, 5 orthodontists and 5 oral surgeons CBCT: 1 orthodontist	Labio-palatal position: labial, median, palatal. Root resorption of incisors and/or second premolars: Yes or No. - Degree of resorption: no resorption, slight, moderate and severe.	1 and 2	Lateral incisors: PR: 13.4% CBCT: 34.7% Central incisors: PR: 3.1% CBCT: 6.9% First premolar: PR: 7.2% CBCT: 9.7% Second premolar: PR: 1.4% CBCT: 1.4%
Ngo *et al.*, 2018	64 patients 88 impacted canine Two groups: <15 years and >15 years	16,4 ± 8,1 years/27 Male (17,5 ± 11,6 years) 37 Female (15,6 ± 3,9 years).	PR and CBCT: iCAT FLX machine CBCT with: Dolphin software version 11.7	2 Orthodontics Residents	Mesio-distal position: Alessandri method. 1, 2, 3, 4, 5 sectors in relation to the adjacent incisors.	Labio-palatal position (cross-sectional, classified as labial, mid-alveolus, palatal) Resorption of maxillary incisors (resorption or no resorption)	Adjacent incisors: CBCT: 44.3%
Sarıkır *et al.*, 2017	60 patients 69 impacted canine	28,4 ± 14,4 years/43 female, 17 male	PR: Morita Veraviewepocs 2D CBCT: Promax 3D®	2 researchers with at least 2 years of experience	Labio-palatal position (labial, palatal) Root resorption of lateral incisor Canine angulations: - To the lateral incisor - To the midline - To the oclusal plane.	1, 2 and 3	Lateral incisors PR 23.2% CBCT: 62.3%
Simić *et al.*, 2023	64 patients 80 impacted canines	16.3 ± 4.3 years (12 to 33)/41 female, 23 male	NR	NR	Root resorptions in adjacent teeth: grade of Ericson and Kurol (no resorption, slight resorption, moderate resorption, severe resorption) and localization (cervical middle or apical 1/3 of root)	1 and Labio-palatal position of the IC: labial, mid-alveolus and palatal	Lateral incisors: PR: 17.5% CBCT: 36.3% Central incisors: PR: 7.5% CBCT: 23.8% First premolar: PR: 0% CBCT: 6.3%
Sosars *et al.*, 2020	88 patients 106 palatally impacted canines	16.8 ± 6.1 years (11 to 44 years) /61 female, 27 male	PR: Kodak 8000 CBCT: i-CAT Next Generation unit	Two examiners	Canine angulation to midline Vertical distance of the canine crown from the occlusal plane Mesio-distal position of canine cusp tip: Cernochova modified	Canine angulation to midline Canine angulation to the oclusal plane and distance Resorption of the adjacent teeth: severity (with or without pulp involvement)	Lateral incisors CBCT: 80.4% Central incisors CBCT: 24.3% First premolars CBCT: 12.1%

Table 1 cont.-2: Details of included studies (in alphabetical order).

Ucar *et al*., 2017	46 patients, 46 palatal or buccal impacted canines	16 males (19.53 ± 6.66 years) 30 females (19.44 ± 5.77 years)	PR: NR. CBCT: NewTom 5G, 3D reconstructions assessed by Mimics 14.01 image analysis software.	One orthodontist	The MDP of the IC with regard to the MLI: sector method of Lindauer et al. I, II, III, IV. The angle between the long axis of the IC and horizontal line (line drawn above both condyles). Divided into 3 groups: 0-30º, 30º-60º, 60º-90º.	Assess to root volumes of the MLIs. Assess to resorption of the MLI: difference in volumes on both MLIs. IC location	Evaluated amount of root resorption of maxillary lateral incisors
Wriedt *et a*l., 201*2*	21 patients 29 impacted canines (13L, 16R)	NR	PR: NR CBCT: Accuitomo, Morita	2 dentists analyzed CBCT. 26 dentist: 10 orthodontists, 8 dental surgeons, 8 general dentist. Analyzed first PR and second CBCT.	Canine angulation to midline: grade 1 (0-15º), grade 2 (16-30º), grade 3 (31-45º), grade 4 (>46º). Vertical position in relation to central incisor. NR Mesio-distal position of the cusp, in relation to lateral incisor: sectors 1, 2, 3 and 4 (1 mesial to MLI, 2 and 3 half of the MLI, 4 distal to MLI). NR Mesio-distal position of the apex, in relation to premolars: sector 1 (mesial to 1º premolar), 2 (1º premolar) and 3 (2º premolar).	Labio-palatal position Root resorptions in lateral incisors	Adjacent incisors: CBCT: 43%

Abbreviations: L (left), R (right), SD (standard deviation), IC (impacted canine), (MDP) mesio-distal position, (MLI) maxillary lateral incisor, PR (panoramic radiography), vs (versus), CBCT (cone-beam computed tomography), NR (not reported)

Table 2: Specifications of image acquisition in panoramic radiography and CBCT.

First author / Year of publication	Especifications Panoramic radiography	Especifications Cone-beam computed tomography
Akkuc *et al*., 2021	Planmeca Proline XC (2009; Helsinki, Finland). - Exams taken on the same day	NewTom 5G (VERONA, ITALY) 0.125 mm, 0.25 mm voxel size
Alfaleh and Al Thobiani, 2021	OP100 (Instrumentarium Corporation Imaging Division, Tuusula, Finland); ORTHOPHOS XG 3 (Sirona Dental Systems GmbH, Wals bei Salzburg, Austria); Conventional PRs were digitized (Epson Perfection V700 Photo Scanner, America, Inc. CA, USA).	- Iluma CBCT (IMTEK Imaging, 3MCompany, OK, and USA). Large FOV, voxel size: 0.29 mm. - Carestream CS 9300 CBCT (Carestream Dental LLC, Atlanta, USA), voxel size: 0.09 to 0.5 mm, adjustable FOV. - GALILEOS Comfort PLUS 3 (Sirona Dental Systems GmbH, Wals bei Salzburg, Austria), large FOV, voxel size: 0.25 to 0.125 mm. OnDemand3DTM software, (OnDemand Software, version 1.0, Cybermed Inc., Seoul, South Korea).
Alqerban *et al*., 2011	Digital PR Cranex Tome® (Soredex). 65 kV 15 mA 15 s - Interval of exams: 2 weeks	Group 1: 3D Accuitomo-XYZ Slice View Tomograph® (J. Morita, Kyoto, Japan) (n=30). 80 kV 3 mA 18 s 3 x 4 cm FOV 0.125 mm Voxel size Group 2: Scanora® 3D (Soredex, Tuusula, Finland) (n=30). 85 kV 15 mA 3.7 seconds 7,5 x 10 cm FOV 0.2 mm Voxel size
Alqerban *et al*., 2013	Veraviewepocs 2D® (J. Morita, Kyoto, Japan). Image acquisition parameters were not reported. - Interval of exams: 6 weeks	3D Accuitomo-XYZ Slice View Tomograph® (J. Morita). Image acquisition parameters were not reported.
Andresen *et al*., 2022	Digital PR Planmeca Romexis (Planmeca, Helsinki, Finland). - Interval of exams: 6 months	- Accuitomo-170 at DCD (J. Morita MFG. CORP, Tokyo, Japan) 80–90 kV 5.5–10 mA 5,4, 9.4 or 17.5 s 4 x 4 cm or 6 × 6 cm FOV 0.08 mm or 0.125 mm Voxel size - Veraviewepocs 3D R100 at OHCE (J. Morita MFG. CORP, Tokyo, Japan). 0–90 kV 5–10 mA 9.3 or 9.4 s 4 × 4 cm and 8 × 8 cm FOV 0.125 mm voxel size

Table 2 cont.: Specifications of image acquisition in panoramic radiography and CBCT.

Ardakani *et al*., 2021	ProMax dental X-ray unit (Planmeca, Helsinki, Finland). 110 kVp 10.65 s	ProMax 3D CBCT system (Planmeca, Helsinki, Finland), full field of view. Romexis software 4.6.2R. 66 kVp 9 mA 16 s
Botticelli *et al*., 2011	Digora Optime System (Soredex, Tusuula, Finland). Image acquisition parameters were not reported.	NewTom 3G scanner (Quantitative Radiology s.r.l., Verona, Italy). Image acquisition parameters were not reported.
Björksved *et al*., 2018	Digital PR Dental Education Center in Orebro: Cranex Tome or Scanora equipment (Soredex, Orion Corp, Helsinki, Finland). Cranex: 66 kV 10 mA 15 or 19 s Scanora: 66 kV 13 mA 13 s Public Dental Health Service in Eskilstuna: Orthophos XG5 equipment (Sirona, Bensheim, Germany). 64 kV 8 mA or 69 kV 15 mA 14.1 s	Dental Education Center in Orebro: Morita Accuitomo 170 dental CBCT scanner (J Morita Mfg Corp, Kyoto, Japan). 85 kV 5-7 mA 17.5 s 6 x 6 cm FOV 0.08 mm Voxel size Public Dental Health Service in Eskilstuna: i-CAT unit (Imaging Sciences International, Hatfield, Pennsylvania). 120 kV 5 mA 8.9 s 16 x 3.8 cm FOV 0.3 mm Voxel size
Haney *et al*., 2010	Hitachi MercuRay Image acquisition parameters were not reported.	CBCT scans (Hitachi MercuRay, Hitachi Medical Technology, Tokyo, Japan). CBWorks Software (CyberMed, Seoul, Korea). Image acquisition parameters were not reported.
Jung *et al*., 2012	Proline XC (Planmeca, Helsinki, Finland). Image acquisition parameters were not reported.	DCT Pro (Vatech Co. Hwasung, Republic of Korea). 90 kV 4 mA 24 s 20 x 19 cm FOV 0.4 mm Voxel size
Lai *et al*., 2014	Digital PR Dell 380 Precision workstation (Dell SA, Geneva, Switzerland) PR had been performed by the referring dentists (300 dpi and higher). Image acquisition parameters were not reported.	3D Accuitomo XYZ Slice View Tomograph (Morita Corp., Kyoto, Japan). 80 kV 5 mA 17.5 s 4 x4 or 6 x 6 or 8 x 8 cm FOV 0.08 mm Voxel size

Table 2 cont.-1: Specifications of image acquisition in panoramic radiography and CBCT.

Ngo *et al*., 2018	Digital PR iCAT FLX (Imaging Sciences International, LLC, Hatfield, Penn) 94 kVp 20 s 5 mA	iCAT FLX (Imaging Sciences International, LLC, Hatfield, Penn) 120 kVp 17.8 s 5 mA 23 x 17 cm FOV 0.30 mm voxel size
Sarıkır *et al*., 2017	Morita Veraviewepocs 2D (Morita, Kyoto, Japan) 60–80 kVp 1–10 Ma 0.5 mm focal spot 7.4 s	Promax 3D® (Planmeca, Helsinki, Finland) 90 kVp 12 mA 8 × 8 cm, 5 × 8 cm, and 5 × 4 cm FOV 13.85 s 0.4 × 0.4 × 0.4 mm voxel size
Simić *et al*., 2023	NR - Interval of exams: 2 months	NR
Sosars *et al*., 2020	Kodak 8000 (Carestream, Croissy-Beaubourg, France). 80 kV 10 mA 13.8 s - Interval of exams: 3 weeks	i-CAT Next Generation unit (Imaging Sciences International, Hatfield, Pa). 120 kV 5 mA 0.4-mm voxel size 20 s
Ucar *et al.*, 2017	Image acquisition parameters were not reported.	NewTom 5G (QR, Verona, Italy) kVp and mA not reported 3.6 s 0.30 mm Voxel size 13 cm FOV
Wriedt *et al*., 2012	Not reported.	Accuitomo (Morita, Japan) 120 kVp 17.8 s 5 mA 4 x 4 cm FOV 0.30 mm Voxel size

Abbreviations: FOV (Field of view), s (seconds), mA (milliamps), kVp (Kilovoltage peak), PR (panoramic radiography)

Table 3: Data from studies that assessed the labio-palatal position of impacted canine, represented in percentages (%).

Articles	**Impacted canine**	**CBCT (%)**					**PR (%)**					**Agreement among CBCT and PR (%)**	***p*-value**
		Labial	**Palatal**	**Mid-alveolus**	**Apical**		**Labial**	**Palatal**	**Mid-alveolus**	**Apical**	**NS**		
Botticelli *et al.*, 2011	Crown	73.1	26.9	-	-		50.9	49.1	-	-	-	68	0.001
	Apex	43.9	56.1	-	-		26.6	73.4	-	-	-	65	0.001
Wriedt *et al.*, 2012	Crown	28.9	40.9	-	30.2		27.3	42	-	23.7	7	53.7 LP 78.2 PP 70.4 AP	-
Alqerban *et al.*, 2011 – Scanora	Crown	44.2	34.0	21.8	-		20.6	42.7	36.7	-	-	-	-
Alqerban *et al.*, 2011 - Accuitomo	Crown	38.7	39.2	22.1	-		19.3	45	35.7	-	-	-	-
Alqerban *et al.*, 2013	Crown	20.2	61.4	18.4	-		26.2	64.4	9.4	-	-	-	0.002
Alfaleh and Al Thobiani, 202*1*	Crown	28.3	55	16.7	-		-	-	-	-	-	-	-
Andresen *et a*l., 202*2*	Crown	66.7	23	10.3	-		-	-	-	-	-	-	-
Ardakani *et a*l., 202*1*	Crown	17.5	82.5	-	-		-	-	-	-	-	-	-
Jung *et al.*, 2012	Crown	41.1	27.4	31.5	-		-	-	-	-	-	-	-
Lai *et a*l., 201*4*	Crown	40.3	44.4	15.3	-		-	-	-	-	-	-	-
Ngo *et al.*, 2018	Crown	26.1	65.9	8	-		-	-	-	-	-	-	-
Haney *et al.*, 2010	-	-	-	-	-		-	-	-	-	-	84	-
Sarıkır *et al.*, 2017	Crown	33.3	66.7	-	-		98.6	1.4	-	-	-	-	0.05
Simić *et a*l., 202*3*	Crown	23.8	72.5	2.8	-		-	-	-	-	-	-	-
Mean	Crown	37.1	49.2	16.3	-		40.5	40.8	27.3	-	-	70.9	-

Abbreviations: PR (panoramic radiography), CBCT (cone-beam computed tomography), NS (No statement), LP (labial position), PP (palatal position), AP (apical position).

Table 4: Data from studies that assessed the mesio-distal position of canine cusp tip, represented in percentages (%).

Articles		PR (%)					CBCT (%)					Agreement among CBCT and PR
	Method: Alessandri *et al*., 2009/Lindauer *et al*. 1992	**Sector 1/I**	**Sector 2/II**	**Sector 3/III**	**Sector 4/IV**	**Sector 5/V**	**Sector 1/I**	**Sector 2/II**	**Sector 3/III**	**Sector 4/ IV**	**Sector 5/V**	
	Corresponding area	Deciduous canine	½ distal - LI	½ mesial - LI	½ distal - CI	½ mesial - CI	Deciduous canine	½ distal - LI	½ mesial - LI	½ distal - CI	½ mesial - CI	
Alfaleh and Al Thobiani, 2021	Method: Lindauer	14.5	9.1	20	56.4	-	-	-	-	-	-	-
Ucar *et al*., 2017	Method: Lindauer	23.9	26.1	26.1	23.9		-	-	-	-	-	-
Jung *et al*., 2012	Method: Alessandri	19.2	17.8	13.7	24.7	24.7	-	-	-	-	-	-
Ngo *et al*., 2018	Method: Alessandri	11.4	25	30.7	14.8	18.2	-	-	-	-	-	-
Björksved *et al*., 2018	Method: Alessandri *	-	7.8	43.8	45.3	3.2	1.6	31.3	42.2	23.4	1.6	0.36 Kappa
Botticelli *et al*., 2011	-	-	-	-	-	-	-	-	-	-	-	64 %
Haney *et al*., 2010	-	-	-	-	-	-	-	-	-	-	-	79 %
Mean	Method: Lindauer + Alessandri	17.3	17.3	26.3	34.3	-	-	-	-	-	-	-
Mean	Method: Alessandri	15.3	16.9	29.4	28.3	15.4	-	-	-	-	-	-
Mean	Method: Lindauer	19.2	17.6	23.1	40.2	-	-	-	-	-	-	-

Abbreviations: PR (panoramic radiography), CBCT (cone-beam computed tomography), ½ (half), LI (lateral incisor), CI (central incisor), * (statistically significant difference).

Table 5: Impacted canine angulation with respect to the lateral incisor, midline, occlusal plane and condyles.

Articles	Canine angulation to	PR	CBCT		Agreement among CBCT and PR (%)	p-value
Alqerban *et al*., 2011	Lateral incisor (Mean° and SD°)	33.38 ±18.19	Scanora: 31.58 ±14.40	Accuitomo: 30.30 ±17.93	-	Scanora: 0.0795 Accuitomo: 0.1412
	Occlusal plane (Mean° and SD°)	55.80 ±18.11	Scanora: 62.43 ±9.04	Accuitomo: 63.09 ±12.27	-	Scanora: 0.0010 Accuitomo: 0.0101
	Midline (Mean° and SD°)	24.07 ±17.05	Scanora: 14.52 ±12.33	Accuitomo: 25.45 ±13.88	-	Scanora: 0.4341 Accuitomo: 0.0001
Sarıkır *et al*., 2017	Lateral incisor (Mean° and SD°)	57.26 ±25.00	83.41 ±56.23	-	-	0.00
	Occlusal plane (Mean° and SD°)	45.99±28.20	49.79±19.35	-	-	0.00
	Midline (Mean° and SD°)	47.08±18.52	34.68±17.50	-	-	0.00
Akkuc *et al*., 2021	Lateral incisor (Mean° and SD°)	39.62 ±13.81	34.31 ±16.84	-	-	0.01
	Midline (Mean° and SD°)	35.11 ±13.29	27.43 ±12.87	-	-	0.001
Ardakani *et al*., 2021	Occlusal plane (Mean° and SD°)	52.98 ±16.76	-	-	-	-
	Cervical line (Mean° and SD°)	52.61 ±16.90	-	-	-	-
Andresen *et al*., 2022	Midline (Median and Interquartile range)	26.7 (21.2)	-	-	-	-
	Occlusal plane (Median and Interquartile range)	57.6 (18.0)	-	-	-	-
Björksved *et al*., 2018	Midline (Mean° and SD°)	34.8 ±8.7	27.9 ±7.9	-	-	0.01
Wriedt *et al*., 2012	Midline (%)	Grade 3 (31°-45°): 31 Grade 2 (16°-30°): 27.6 Grade 4 (>45°): 27.6 Grade 1 (0°-15°): 13.8	-	-	-	-
Ucar *et al*., 2017	Condyles (%)	60°-90°: 39.2 30°-60°: 36.9 0°-30°: 23.9	-	-	-	-
Botticelli *et al*., 2011	Midline	-	-	-	74	0.05

Abbreviations: PR (panoramic radiography), CBCT (cone-beam computed tomography), SD (standard deviation), % (percentage)

Table 6: Risk of Bias Assessment. The answer to each question may be as follows: yes, no, do not know (15).

Questions		Articles																
		Akkuc *et al.*, 2021	Alfaleh and Al Thobiani, 2021	Alqerban *et al.*, 2011	Alqerban et al., 2013	Andrensen *et al.*, 2022	Ardakani *et al.*, 2021	Botticelli *et al.*, 2011	Björksved *et al.*, 2018	Haney *et al.*, 2010	Jung *et al.*, 2012	Lai *et al.*, 2014	Ngo *et al.*, 2018	Sarıkır *et al.*, 2017	Simić *et al.*, 2023	Sosars *et al.*, 2020	Ucar *et al.*, 2017	Wriedt *et* al,. 2012
	Introduction																	
1	Were the aims/ objectives of the study clear?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
	Methods																	
2	Was the study design appropriate for the stated aim(s)?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
3	Was the sample size justified?	Yes	No	No	No	Yes	Yes	No	No	No	No	No	No	Yes	No	No	Yes	No
4	Was the target/ reference population clearly defined? (Is it clear who the research was about?)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
5	Was the sample frame taken from an appropriate population base so that it closely represented the target/reference population under investigation?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Table 6 cont.: Risk of Bias Assessment. The answer to each question may be as follows: yes, no, do not know (15).

6	Was the selection process likely to select subjects/participants that were representative of the target/reference population under investigation?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
7	Were measures undertaken to address and categorise non-responders?	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
8	Were the risk factor and outcome variables measured appropriate to the aims of the study?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
9	Were the risk factor and outcome variables measured correctly using instruments/ measurements that had been trialled, piloted or published previously?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
10	Is it clear what was used to determined statistical significance and/or precision estimates? (e.g. p-values, confidence intervals)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	No

Table 6 cont.-1: Risk of Bias Assessment. The answer to each question may be as follows: yes, no, do not know (15).

11	Were the methods (including statistical methods) sufficiently described to enable them to be repeated?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes
	Results																	
12	Were the basic data adequately described?	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No
13	Does the response rate raise concerns about non-response bias?	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
14	If appropriate, was information about non-responders described?	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
15	Were the results internally consistent?	No	Yes	Yes	Yes	Yes	Do not know	Yes	Yes	Do not know	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Do not know
16	Were the results presented for all the analyses described in the methods?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Do not know	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Do not know
	Discussion																	
17	Were the authors' discussions and conclusions justified by the results?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
18	Were the limitations of the study discussed?	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No	No	No	No	Yes

Table 6 cont.-2: Risk of Bias Assessment. The answer to each question may be as follows: yes, no, do not know (15).

	Other																				
19	Were there any funding sources or conflicts of interest that may affect the authors' interpretation of the results?	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	Do not know
20	Was ethical approval or consent of participants attained?	Yes	Yes	Do not know	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Do not know	Yes	Yes	Yes	Yes

resorption of teeth adjacent to the IC was according to the type of tooth: lateral incisor, central incisor, or premolars.

To perform the meta-analysis, the Comprehensive Meta-Analysis software (Biostat; Englewood, NJ, USA) was used. The level of significance was 5%. The random effects model (16), and the Restricted maximum-likelihood was used as how random-effects estimator. The heterogeneity found in the meta-analysis of IC angulation to the midline, occlusal plane, lateral incisor was high. The heterogeneity of resorption of the lateral incisor and premolars adjacent to the IC was high, whereas in central incisor, it was low. In the meta-analyzes of labial-palatal position, there was low heterogeneity in mid-alveolus position, whereas it was high in labial and palatal positions.

Results

-Study selection

A total of 635 studies were collected after applying the initial search strategies in databases. After excluding the repeated records, 407 articles remained. In the gray literature, 782 records were found and only 5 studies were potentially eligible. After submitting the articles to the eligibility criteria, twenty six studies were selected for full reading, twenty one from the databases and five from the gray literature. In total nine studies were excluded: one because the image analysis was not in the same patient (17), one because the CBCT was compared with the panoramic reconstruction (18), two because the analyzes only used CBCT (9,19), one because it only reported data from the agreement of examiners about the location of the impacted canine and resorption of adjacent teeth (20), one because assessed the agreement between examiners for initial orthodontic evaluation, answering questionnaires (21), one study because it was performed on typodonts (22), one study because it was performed on deceased human skulls (23), and one because evaluated after orthodontic treatment (24). After these exclusions seventeen articles were considered eligible for this study (9,12,13,25-38) (Fig. 1).

-Study characteristics

The publication period for the ten included studies was from 2010 to 2023 and the studies were carried out in Leuven, Belgium (12,28), Aarhus, Denmark (13), Eskilstuna, Sweden (30), Busan , Republic of Korea (26), Bern, Switzerland (9), San Francisco, USA (25), New York, USA (31), Kayseri, Ankara, Malatya, Turkey (29,32,38) and Rhineland Palatinate, Germany (27), Riga, Latvia (37), kosovska Mitrovica, Serbia (36), Rafsanjan, Iran (35), Bergen, Norway (34), Riyadh, Saudi Arabia (33) (Table 1-1 cont.-2).

Cross-sectional observational studies whose samples were assessed using PR and CBCT of the same patient, to describe the position of the IC and resorption of ad-

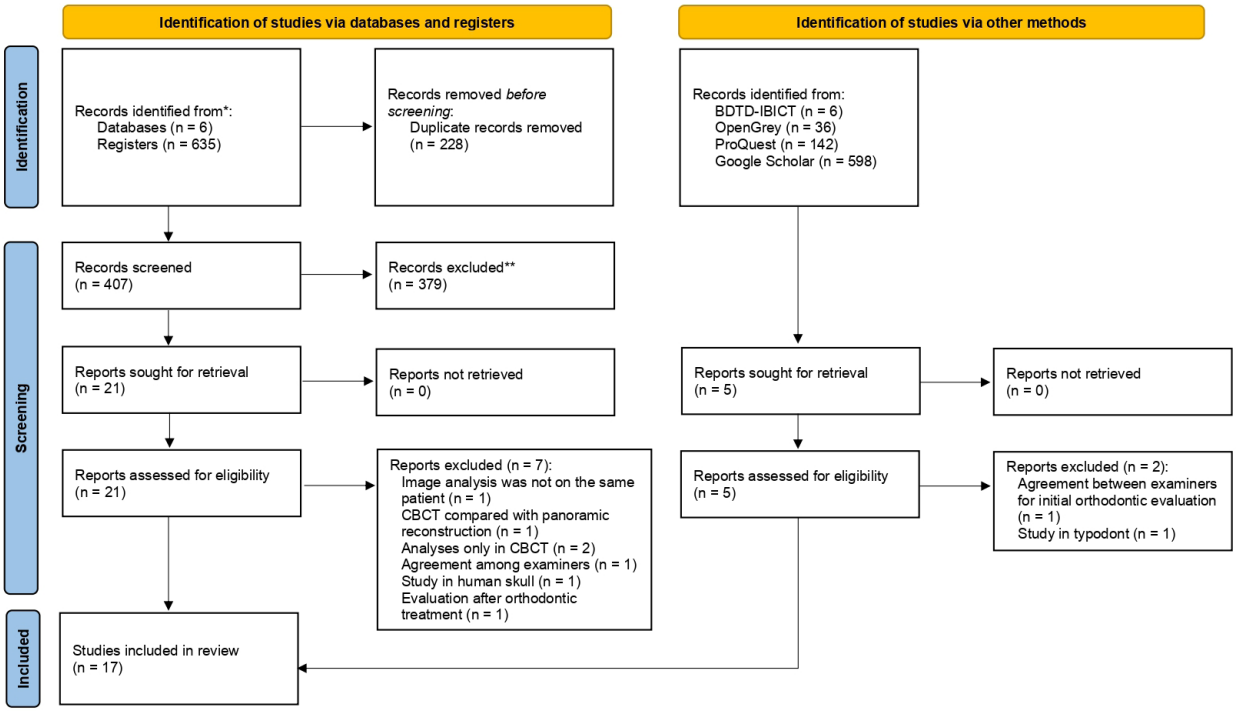

Fig. 1: Flowchart of study selection for qualitative and quantitative syntheses.

jacent teeth were included. In total, 877 patients were included in the seventeen studies, with a total of 1115 impacted upper canines. The mean age of patients was 17.6 years, there were 531 women and 295 men. One study not reported the age and gender of 21 patients (27). One study reported only the range of 6 to 16 years in 30 patients and did not report gender (32). Table 1-1 cont.-2 summarizes the descriptive characteristics of the seventeen studies.

-Risk of bias within studies

The quality assessments of the individual studies are listed in Table 6, 6 cont.-2. All studies included in this systematic review were cross-sectional studies. The studies adequately addressed the study design, the quality of the reporting of results, and the risk of bias. However, only five studies justified the sample size (29,32,34,35,38), two studies in the methodology did not report the type of statistical analysis used (27,36), one study did not describe the equipment used in RP and CBCT, image acquisition parameters, experience and number of examiners, images considered to perform the analyses (36), two studies did not report data on gender and mean age (27,36), two studies did not report RP acquisition data (27,29). One study was divided into 4 phases, in the fourth phase they proposed to compare PR and CBCT performed on the same day, however, the location of IC was not described in detail by sectors as described in the methodology, they only presented data of mean, SD, median, min, max (32). Four studies did not show results that were internally consistent (25,27,32,35). The limitations were not discussed in six studies (12,29,31,36-38) and in three studies it was not clear whether the study was ethically approved (12,27,36).

-Results of individual studies

The primary outcome was the position assessing of IC and resorption of adjacent teeth through panoramic radiography and CBCT.

Impacted upper canine position

The seventeen studies included in this review assessed IC position in the following ways:

• Labio-palatal position / sagittal plane, classified as labial, palatal or mid-alveolus (9,12,13,25-28,31,33-36,38)

• Mesio-distal position (13,25,26,29-31,33)

• Vertical position / axial plane, classified as grade 1, 2, 3, 4 (13) and high, medium, low (28)

• Angulation with respect to the lateral incisor, midline or occlusal plane (12,13, 27,29,30,32,34,35,38)

-Resorption of teeth adjacent to the impacted upper canine

Fifteen studies evaluated the occurrence root resorption of adjacent teeth (9,12,13,25-28,31-38). Root resorption of teeth adjacent to the IC was more frequently detected with CBCT (29.9%) than with PR (15.2%)

Eleven studies evaluated the resorption of lateral incisors. Three studies evaluated only with CBCT, finding 67.8% resorption (32,33,37). Eight studies compared both methods, finding greater reabsorption in CBCT (45.7%) compared to PR (22.8%) (9,12,13,28,34-36,38). Five studies evaluated the resorption of central incisors.

Two studies evaluated only with CBCT, finding 31.1% resorption (33,37). Three studies compared both methods, finding greater reabsorption in CBCT (12.7%) compared to PR (7.3%) (9,12,36).

Three studies evaluated resorption in first premolars. One of them evaluated only on CBCT, finding 12.1% reabsorption. Two studies compared both methods, finding greater reabsorption in CBCT (8%) compared to PR (3.6%) (9,36). A single study reported resorption in second premolars, finding 1.4% of cases with both exams (9).

Three studies evaluated resorption of the adjacent incisors on CBCT, presenting 30.1%, 43%, and 44.3% of resorption cases (26, 27, 31). The agreement of PR and CBCT evaluation respect to root resorption of adjacent incisors varied from 63% (25) to 82% (13).

-Labio-palatal position

Six studies evaluated the labio-palatal position of the IC (crown or apex) through CBCT and PR (9,13,25,27,28,38). Seven studies evaluated the labio-palatal position only by CBCT (9,26,31,33-36) (Table 3).

In one study, this was evaluated according to the concepts of horizontal amplification, which is determined by the position of the object within the image layer. If the crown of the IC was magnified in the image, it indicated the palatine position of the tooth. If the crown was narrow, it indicated the labial position of the tooth (28). The other study used only panoramic radiography for this evaluation, however, the authors did not specify the evaluation parameters (9).

In CBCT, the crown of the IC is most often found in the palatal position (49.2%), followed by the labial position (37.1%), and mid-alveolus position (16.3%). In PR, the IC labial and palatal position is the most frequent (40.5% and 40.8%), followed by the mid-alveolus position (27.3%). The labio-palatal position of the apex was determined in one study. With CBCT the palatal position of the apex occurred in 56.1% of cases and labial position occurred in 43.9%. In PR, palatal position of the apex occurred in 73.4% cases and labial position in 26.6% (13).

The agreement between PR and CBCT regarding the labio-palatal position of the IC was determined by three studies (70.9%) (13,25,27).

-Mesio-distal position

Seven studies evaluated the mesio-distal position of the IC through CBCT and PR (13,25,26,29-31,33). Two studies evaluated the agreement between PR and CBCT regarding the mesio-distal position. One study evaluated the position of canine cusp tip and classified it as mesial, distal or direct. Resulting in 79% agreement between exams (25). Another study evaluated the mesio-distal position of the apex, classified as Grade 1 (above the region of the canine), Grade 2 (above the first premolar) and Grade 3 (above the second premolar). In the PR exams, the IC position was most frequently found in the first premolar region and in the CBCT a larger spread was observed. There was a 64% agreement between the exams, with PR indicating less variation in the position of the IC apex ($p = 0.001$) (13) (Table 4).

Two studies evaluated the mesio-distal position of IC cusp tip using PR and by the sector method of Lindauer *et al*. (39): sector I (region distal to the lateral incisor), sector II (distal half of the lateral incisor), sector III (mesial half of the lateral incisor) and sector IV (region mesial to the lateral incisor). The result showed that the IC was more frequently found in sector II (26.1%) and sector III (26.1%), followed by sector I (23.9%) and sector IV (23.9%) (29). The other study showed that the UC was more frequently found in sector IV (56.4%), followed by sector sector III (20%), sector I (14.5%) and sector II (9.1%) (33).

Three studies evaluated the mesio-distal position of canine cusp tip (26,30,31) by the sector method of Alessandri *et al*. (40): sector 1 (corresponding to the deciduous canine-present or absent), sector 2 (the distal half of the lateral incisor), sector 3 (the mesial half of the lateral incisor), sector 4 (distal half of the central incisor) and sector 5 (mesial half of the central incisor to the midline). In the PR evaluation, the IC was found more frequently in sectors 3 (29.4%) and 4 (28.3%), followed by sectors 2 (16.9%), 5 (15.4%), and 1 (15.3%). One study evaluated the mesio-distal position through CBCT and PR, showing that PR classified the IC in higher sectorial values compared to the analysis with CBCT ($p < 0.01$; kappa 0.36) (30).

-Vertical position

The vertical position of the IC in relation to the axial plane or occlusal plane was evaluated in two studies (13,28). PR shows a higher position compared to CBCT. The first study classified the vertical position by Stivaros and Mandall method (41), respective to the adjacent upper incisor as grade 1 (below the cemento-enamel junction (CEJ), grade 2 (above the CEJ, but below the half way point of the root), grade 3 (half or more apical from the root, but below the apex) and grade 4 (above the apex). There were eight evaluators, resulting in a 66% agreement between PR and CBCT ($p = 0.013$), with PR showing a higher vertical position, being more apical to the lateral incisor (13). The second study assessed the vertical position in relation to lateral incisor root (LIR) and classified as high (apical third of LIR), medium (middle third of LIR), and low (coronal third of LIR). The results showed a statistically significant difference between PR and CBCT ($p = 0.005$). In PR there 51.7% of cases were classified as medium, followed by 30.3% high and 18% low. The CBCT saw 43.6% medium, followed by 29% high and 27.4% low (28).

-Canine Angulation

Nine studies analyzed the IC angulation through CBCT and PR (12,13,27,29,30,32,34,35,38] (Table 5).

Seven studies analyzed IC angulation to the midline (12,13,27,30,32,34,38). The average was 33.6° in PR and 26° in CBCT. One study found 74% agreement between the PR and CBCT ($p>0.05$) (13). Two studies measured only CBCT (27,34). Four studies that compared CBCT and PR found a statistically significant difference between measurements ($p<0.05$) (12,30,32,38).

Three studies evaluated IC angulation to the lateral incisor with two lines drawn along the long axis of the IC and lateral incisor. The average PR was 43.4° and the CBCT was 44.9°. Two studies found a statistically significant difference between CBCT and PR means ($p<0.05$) (32,38) and one study found no difference between the methods ($p>0.05$) (12).

Four studies evaluated the IC angulation to the occlusal plane, where two lines were drawn along the long axis of the IC and the occlusal plane. Two studies measured only CBCT, obtaining an angle of 52.98 to 57.6° (12,35). Two studies that compared CBCT (58.4°) and PR (50.9°) found a statistically significant difference between measurements ($p<0.05$) (12,38).

One study evaluated IC angulation to the line between both condyles only in PR, with two lines drawn along the long axis of the IC and a line drawn between superior points of both condyles (29).

-Synthesis of results

The meta-analysis was performed with eleven studies (9,12,13,27,28,30,32,34-36,38).

Eight studies (9,12,13,28,34-36,38) were eligible for the meta-analysis of root resorption of the teeth adjacent to the IC. The results showed that in PR there was 86% less chance of finding resorption of the teeth adjacent to the IC when compared with CBCT. Thus, CBCT detected a larger number of cases of resorption of teeth adjacent to the IC ($p<0.001$) (Confidence interval 95%, 0.089 - 0.186; heterogeneity: Q value 182.313; I2 91.772%; Tau squared 0.008; *P*-value 0.001; Odds Ratio [OR] value: 0.138; n=1049). In the analysis of subgroups, CBCT showed 78% more cases of lateral incisor resorption than PR ($p<0.001$) (Confidence interval 95%, 0.150 - 0.298; heterogeneity: Q value 38.665; I2 79.31%; Tau squared 0.010; *P*-value 0.001; Odds Ratio [OR] value: 0.224; n=584). CBCT showed 95% more cases of resorption of central incisor than PR ($p<0.001$) (Confidence interval 95%, 0.018 - 0.085; heterogeneity: Q value 4.254; I2 29.477%; Tau squared 0.000; P-value 0.235; OR value: 0.052). CBCT showed 97% more cases of premolars resorption than PR ($p=0.032$) (Confidence interval 95%, -0.002 - 0.062; heterogeneity: Q value 8.785; I2 65.85%; Tau squared 0.001; *P*-value 0.032; OR value: 0.032) (Fig. 2).

A meta-analysis of the IC position through PR and CBCT was performed in five studies (12,13,27,28,38). CBCT showed 60% more cases of labial position than PR ($p<0.001$) (Confidence interval 95%, 0.254 - 0.542; heterogeneity: Q value 279.387; I2 98.21%; Tau squared 0.032; *P*-value 0.001; Odds Ratio [OR] value: 0.398). Additionally, CBCT demostrated 56% more cases of palatal position than PR ($p<0.001$) (Confidence interval 95%, 0.350 - 0.533; heterogeneity: Q value 102.189; I2 95.107%; Tau squared 0.012; P-value 0.001; Odds Ratio [OR] value: 0.441). Moreover, CBCT exhibited 79% more cases of mid-alveolus position than PR ($p<0.001$) (Confidence interval 95%, 0.188 – 0.234; heterogeneity: Q value 1.502; I2 0%; Tau squared 0.000; P-value 0.472; Odds Ratio [OR] value: 0.221) (Fig. 3).

The IC angulation (to the midline, occlusal plane, lateral incisor) meta-analysis was carried out in four studies (12,30,32,38). A significant statistical difference was observed between PR and CBCT. For IC angulation to the midline, four studies revealed a substantial difference ($p<0.001$), with CBCT showing a smaller and more accurate angle than PR (Confidence interval 95%, 18.008 – 33.686; heterogeneity: Q value 249.364; I2 98.396%; Tau squared 76.834; P-value 0.001). In the meta-analysis of IC angulation to the occlusal plane, two studies indicated a smaller angle in PR compared to CBCT ($p<0.001$) (Confidence interval 95%, 51.292– 65.934; heterogeneity: Q value 25.141; I2 92.045%; Tau squared 38.274; P-value 0.001). Similarly, for IC angulation to the lateral incisor, three studies demonstrated a smaller angle in PR compared to CBCT ($p<0.001$) (Confidence interval 95%, 30.011– 55.954; heterogeneity: Q value 56.348; I2 94.676%; Tau squared 160.096; P-value 0.001) (Fig. 4).

Discussion

The initial assessment of ICs is often performed using PR images. However, this is often complemented with CBCT as this helps to recognize cases of IC with ankylosis (14.8%), dilaceration of the root (17.9%), resorption of adjacent teeth (14.8%) or odontoma (1.9%) (42). This complementary exam assists in diagnosis and is important in the preoperative analysis for orthodontists and surgeons, as they need precision in identifying the IC position to generate an appropriate treatment plan (6). This study used a systematic review to determine whether CBCT is better than PR at assessing the position of the unerupted upper canine and its effects on adjacent teeth.

Therefore, PR should be complemented with CBCT following the principle of As Low As Reasonably Achievable (ALARA) and As low as diagnostically acceptable (ALADA), according to European guidelines for radiation protection (43). To reduce the radiation dose, field-of-view (FOV) can be reduced. One study showed that the FOV required for IC was smaller than the smallest FOV offered by CBCT devices. Thus, reduced FOV to promote radiation safety is recommended (44).

CBCT was more effective than PR in assessing cases that are difficult to diagnose in the initial assessment of

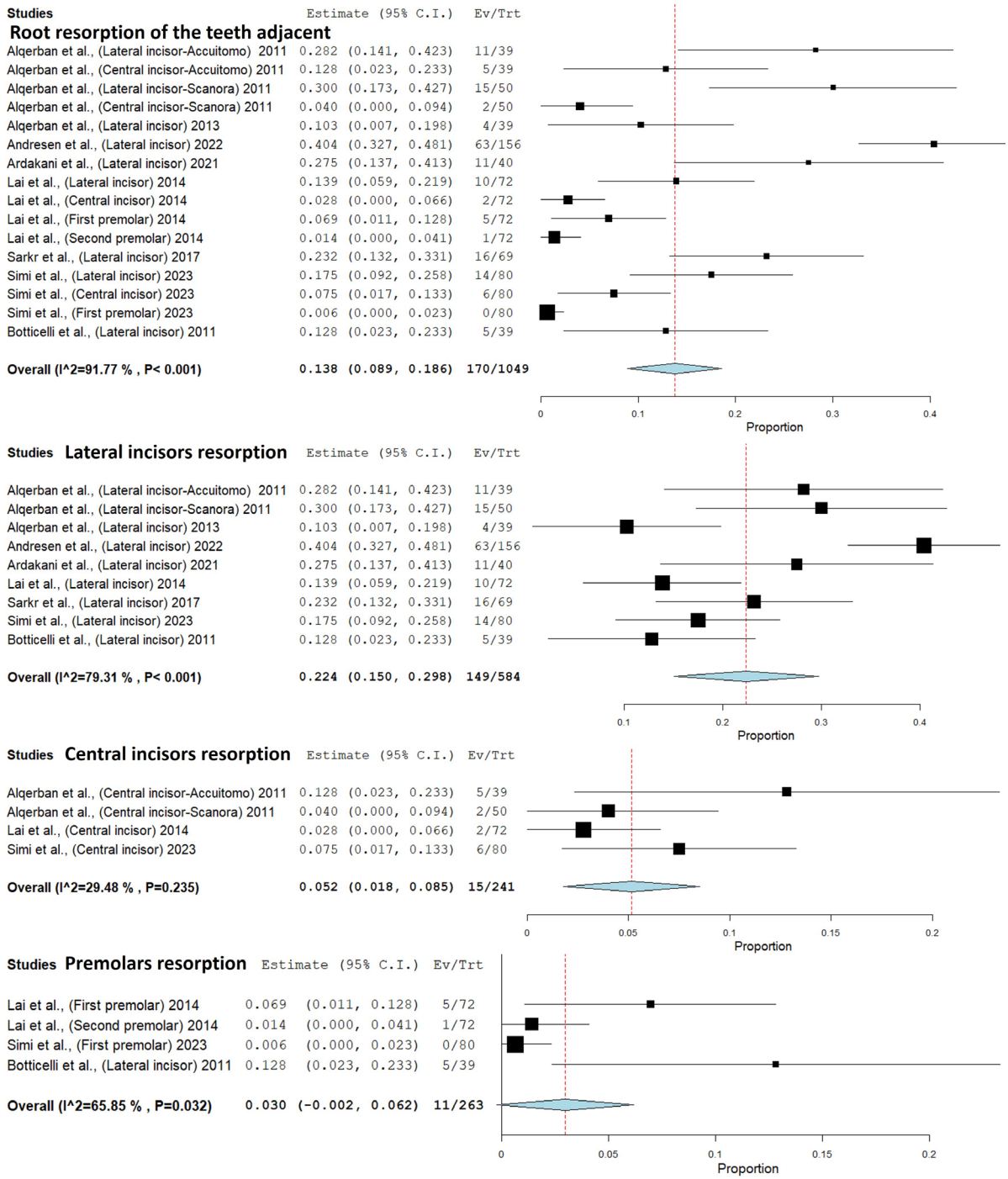

Fig. 2: Comparison between panoramic radiography and cone-beam computed tomography, in the number of cases detected with resorption of the teeth adjacent to the IC.

IC (45). The evaluation of IC by CBCT can provide more accurate angle measurements, linear measurements and better evaluation of cases with resorption of adjacent teeth (46). Our study agrees with these findings; the results showed that CBCT provided better results compared to PR with regards to identification of the IC location and resorption of adjacent teeth.

The presence of root resorption of teeth adjacent to the IC was detected in 15.2% of cases using PR and 29.9% using CBCT. The agreement between the exams was on average 72.5%. This result shows that CBCT detects more cases of root resorption, detecting almost double the cases seen with PR. Root resorption is more frequent when the IC is vertically above the apex of the lateral

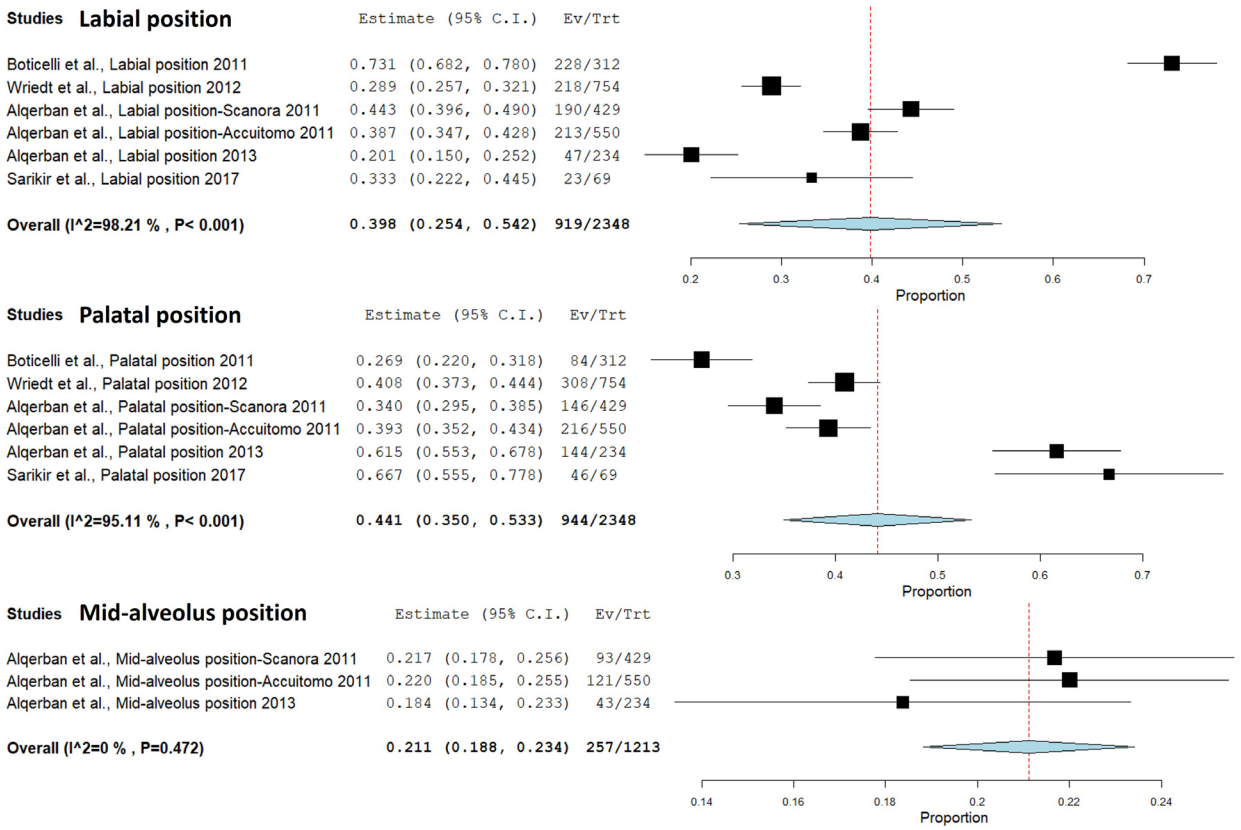

Fig. 3: Comparison of the labio-palatal position through panoramic radiography and cone-beam computed tomography.

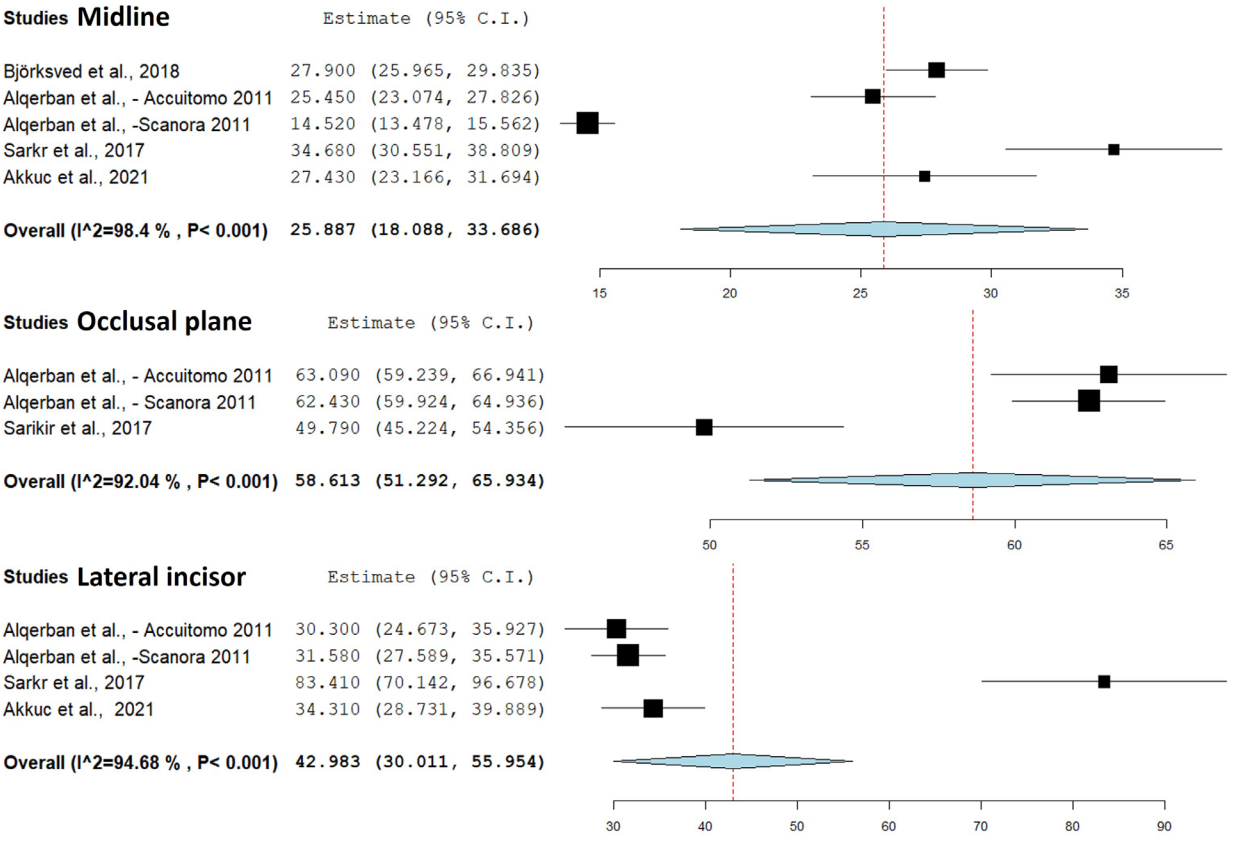

Fig. 4: Comparison of the IC angulation to the midline, occlusal plane, and lateral incisor through panoramic radiography and cone-beam computed tomography.

incisor root and close to midline (19). When this pathology is present, it can affect the treatment plan, if the reabsorption is very severe, tooth extraction would be indicated. Therefore, in these cases CBCT can contribute to accurate and timely diagnosis, and thus allow clinicians to carry out an appropriate treatment (6).

Regarding the labiopalatal position of the IC crown, in the evaluation of CBCT in two studies, they found that the IC was found most commonly in the labial position (57.1%) (13,26). However, this result differed from the findings of our study that found that IC was found most commonly in the palatal position (49.2%), followed by the labial position (37.1%), and mid-alveolus position (16.3%). In RP, the palatal and vestibular position was found with similar frequency (40.8% and 40.5%), and a higher frequency of mid-alveolar cases compared to CBCT (27.3%). The agreement between PR and CBCT on average was 70.9%. Therefore, CBCT appears to be more effective in evaluating the IC position. This result is due to the overlap of structures in the PR.

In the mesio-distal position of the IC, only one study evaluated the position of the apex of the IC, being more frequently found in the first premolar region (13). Five studies determined that the cusp tip of IC is most frequently found in sectors 3 and 4. Therefore, the position of the IC crown was commonly found in the sectors corresponding to the central and lateral incisor (26,29-31,33). Due to this, these are the teeth that present the more cases of root resorption. Furthermore, the agreement between CBCT and PARA was 71.5%. This shows that CBCT is better at evaluating the mesio-distal position of the IC.

Furthermore, the angulation of the IC with respect to the midline is greater when evaluated with the PR compared to CBCT (12,30,32,38). The angulation of the IC with respect to the occlusal plane and lateral incisor is greater with the CBCT compared to the PR (12,32,38). A study showed that the agreement between the methods was 74% in relation to the midline (13). This result provides valuable insights into the diagnostic capabilities of these imaging modalities. This discrepancy in angulation measurements highlights the importance of carefully considering the imaging technique employed, as it can significantly influence the assessment of IC positioning.

In the vertical position of IC, one study found that PR shows a higher position, than CBCT (more apical to the lateral incisor) (13). The other study found more commonly a medium position (middle third of lateral incisor) in both exams (CBCT and PR) (28).

One study compared the effective radiation dose in 10-year-old patients with impacted canines who underwent 2D (PR) and 3D (CBCT) exams, using a thermoluminescent dosimeter system and dosimetric film. The findings showed that the ProMax3D and NewTom5G tomographs resulted in an effective dose of 88 µSv and 170 µSv; while PR resulted in a 4.1 µSv dose (47). This result showed that CBCT generated a higher effective radiation dose when compared with PR. However, 2D scans provided limited IC diagnostic information, due to distortions, superimpositions, and magnification, resulting from the different distances between X-ray source, object, and film (48). These factors can lead to inaccurate and unreliable measurements that can be mitigated by using measurements taken in vertical dimensions, which are more reliable than the horizontal types (49,50). In this study, the mean age of the patients was 17.6 years. CBCT would be a complementary diagnostic tool, in view of the patient's age. However, this is not a general guideline throughout the entire process of dental development. PR alone is frequently sufficient as a diagnostic tool and CBCT is required only in specific circumstances. CBCT can be requested when resorption of teeth adjacent to the IC is suspected. In such cases, this exam will assist in surgical and orthodontic planning.

There were some limitations to this systematic review. We minimized the bias between the studies included and extracted the utmost homogeneity among them, by using adequate eligibility criteria. Additionally, we selected all studies that evaluated CI by means of PR and CBCT, which used similar methods in children, adolescents, and young adults. The majority of variations among results of the studies occurred due to the various ages of the populations, the number of men and women, sample size, and classification of IC positions. The diversity in the latter classifications, including vertical position (13,28), prevented the authors from including all studies in the meta-analysis.

High heterogeneity was observed in the meta-analysis of angulation to the midline, occlusal plane, and lateral incisor, as well as in the resorption of the lateral incisor and adjacent premolars adjacent to the IC, and in labial and palatal positions. In contrast, the analyses of central incisor resorption and mid-alveolus position indicated low heterogeneity. This variability could be attributed to differences in study populations, methodologies, 2D image quality, and parameters used in CBCT evaluation. Four studies reported the results of resorption according to the number of examiners (8, 26, 11 or 6 examiners) (12,13,27,28).

Seven studies evaluated the position of the IC only on CBCT (9,26,31,33-36). Therefore, they were not included in the meta-analysis. However, they were included in the narrative synthesis. In the other studies that evaluated the labiopalatal position on PR, complementary periapical radiographs, cephalometric radiograph, or study casts were also used (13,25,27). The association of PR with complementary resources could be more reliable than using PR alone to assess the labio-palatal position of the IC. Whereas analysis with the use of CBCT showed the exact position of the IC.

We recommend that further studies use comprehensive and standardized classifications (labial, palatal, mid-alveolus position of IC and mesio-distal position in grades 1 to 4) (41), that report in detail the measurements, thereby allowing comparisons among the results. Furthermore, the authors must justify the sample and report the equipment used (PR and CBCT).

In conclusion, within the limits of the data available for this systematic review, the null hypothesis initially formulated was rejected; CBCT images showed statistically significant differences when compared with PR in the assessment of IC, relative to the mesiodistal and labio-palatal position, angulation to the midline, occlusal plane, lateral incisor, and root resorption of adjacent teeth. CBCT provided clinically relevant information that could contribute to the diagnosis and planning of IC treatment when PR was not sufficient.

References

1. Al-Zoubi H, Alharbi AA, Ferguson DJ, Zafar MS. Frequency of impacted teeth and categorization of impacted canines: A retrospective radiographic study using orthopantomograms. Eur J Dent. 2017;11:117-121.
2. Peck S, Peck L, Kataja M. The palatally displaced canine as a dental anomaly of genetic origin. Angle Orthod. 1994;64:249-56.
3. Sarica I, Derindag G, Kurtuldu E, Naralan ME, Caglayan F. A retrospective study: Do all impacted teeth cause pathology? Niger J Clin Pract. 2019;22:527-533.
4. Bjerklin K, Ericson S. How a computerized tomography examination changed the treatment plans of 80 children with retained and ectopically positioned maxillary canines. Angle Orthod. 2006;76:43-51.
5. Chung DD, Weisberg M, Pagala M. Incidence and effects of genetic factors on canine impaction in an isolated Jewish population. Am J Orthod Dentofacial Orthoped. 2011;139:e331-5.
6. Hamada Y, Timothius CJC, Shin D, John V. Canine impaction - A review of the prevalence, etiology, diagnosis and treatment. Semin Orthod. 2019;25:117-123.
7. Ericson S, Kurol J. Incisor resorption caused by maxillary cuspids. A radiographic study. Angle Orthod. 1987;57:332-346.
8. Liu DG, Zhang WL, Zhang ZY, Wu YT, Ma XC. Localization of impacted maxillary canines and observation of adjacent incisor resorption with cone-beam computed tomography. Oral Surg Oral Med Oral Pathol Oral Radiol Endod. 2008;105:91-98.
9. Lai CS, Suter VG, Katsaros C, Bornstein MM. Localization of impacted maxillary canines and root resorption of neighbouring teeth: a study assessing the diagnostic value of panoramic radiographs in two groups of observers. Eur J Orthod. 2014;36:450-6.
10. Bender IB. Factors influencing the radiographic appearance of bony lesions. J Endod. 1982;8:161-70.
11. Rodrigues MGS, Alarcón OMV, Rocha ECJF, Capelozza ALA. Cone-beam computed tomography: Formation of the image, indications and selection criteria. Odontol Clín-Cient. 2010;9:115-118.
12. Alqerban A, Jacobs R, Fieuws S, Willems G. Comparison of two cone beam computed tomographic systems versus panoramic imaging for localization of impacted maxillary canines and detection of root resorption. Eur J Orthod. 2011;33:93-102.
13. Botticelli S, Verna C, Cattaneo PM, Heidmann J, Melsen B. Two- versus three-dimensional imaging in subjects with unerupted maxillary canines. Eur J Orthod. 2011;33:344-9.
14. Page MJ, Moher D, Bossuyt PM, Boutron I, Hoffmann TC, Mulrow CD, et al. PRISMA 2020 explanation and elaboration: updated guidance and exemplars for reporting systematic reviews. BMJ. 2021;372:n160.
15. Downes MJ, Brennan ML, Williams HC, Dean RS. Development of a critical appraisal tool to assess the quality of cross sectional studies (AXIS). BMJ Open. 2016;6:e011458.
16. Borenstein M, Hedges LV, Higgins JP, Rothstein HR. A basic introduction to fixed-effect and random-effects models for meta-analysis. Res Synth Methods. 2010;1:97-111.
17. Maverna R, Gracco A. Different diagnostic tools for the localization of impacted maxillary canines: clinical considerations. Prog Orthod. 2007;8:28-44.
18. Pico CL, do Vale FJ, Caramelo FJ, Corte-Real A, Pereira SM. Comparative analysis of impacted upper canines: Panoramic radiograph Vs Cone Beam Computed Tomography. J Clin Exp Dent. 2017;9:e1176-e1182.
19. Cuminetti F, Boutin F, Frapier L. Predictive factors for resorption of teeth adjacent to impacted maxillary canines. Int Orthod. 2017;15:54-68.
20. Tsolakis AI, Kalavritinos M, Bitsanis E, Sanoudos M, Benetou V, Alexiou K, et al. Reliability of different radiographic methods for the localization of displaced maxillary canines. Am J Orthod Dentofacial Orthop. 2018;153:308-314.
21. Pittayapat P, Willems G, Alqerban A, Coucke W, Ribeiro-Rotta RF, Souza,PC, et al. Agreement between cone beam computed tomography images and panoramic radiographs for initial orthodontic evaluation. Oral Surg Oral Med Oral Pathol Oral Radiol. 2014;117:111-9.
22. Serrant PS, McIntyre GT, Thomson DJ. Localization of ectopic maxillary canines is CBCT more accurate than conventional horizontal or vertical parallax? J Orthod. 2014;41:13-8.
23. Alqerban A, Jacobs R, Souza PC, Willems G. In-vitro comparison of 2 cone-beam computed tomography systems and panoramic imaging for detecting simulated canine impaction-induced external root resorption in maxillary lateral incisors. Am J Orthod Dentofacial Orthop. 2009;136:764.e1-11;discussion 764-5.
24. Bouwens DG, Cevidanes L, Ludlow JB, Phillips C. Comparison of mesiodistal root angulation with posttreatment panoramic radiographs and cone-beam computed tomography. Am J Orthod Dentofacial Orthop. 2011;139:126-32.
25. Haney E, Gansky SA, Lee JS, Johnson E, Maki K, Miller AJ, Huang JC. Comparative analysis of traditional radiographs and cone-beam computed tomography volumetric images in the diagnosis and treatment planning of maxillary impacted canines. Am J Orthod Dentofacial Orthop. 2010;137:590-7.
26. Jung YH, Liang H, Benson BW, Flint DJ, Cho BH. The assessment of impacted maxillary canine position with panoramic radiography and cone beam CT. Dentomaxillofac Radiol. 2012;41:356-60.
27. Wriedt S, Jaklin J, Al-Nawas B, Wehrbein H. Impacted upper canines: examination and treatment proposal based on 3D versus 2D diagnosis. J Orofac Orthop. 2012;73:28-40.
28. Alqerban A, Hedesiu M, Baciut M, Nackaerts O, Jacobs R, Fieuws S, et al. Pre-surgical treatment planning of maxillary canine impactions using panoramic vs cone beam CT imaging. Dentomaxillofac Radiol. 2013;42:20130157.
29. Ucar FI, Celebi AA, Tan E, Topcuoğlu T, Sekerci AE. Effects of impacted maxillary canines on root resorption of lateral incisors: A cone beam computed tomography study. J Orofac Orthop. 2017;78:233-240.
30. Björksved M, Magnuson A, Bazargani SM, Lindsten R, Bazargani F. Are panoramic radiographs good enough to render correct angle and sector position in palatally displaced canines? Am J Orthod Dentofacial Orthop. 2019;155:380-387.
31. Ngo CTT, Fishman LS, Rossouw PE, Wang H, Said O. Correlation between panoramic radiography and cone-beam computed tomography in assessing maxillary impacted canines. Angle Orthod. 2018;88:384-389.
32. Akkuc S, Duruk G, Duman S. Evaluation of impacted canines' localization and adjacent lateral incisors' root resorption with orthopantomography and cone-beam computed tomography. Oral Radiol. 2021;37:476-486.
33. Alfaleh W, Al Thobiani S. Evaluation of impacted maxillary canine position using panoramic radiography and cone beam computed tomography. Saudi Dent J. 2021;33:738-744.

34. Andresen AKH, Jonsson MV, Sulo G, Thelen DS, Shi XQ. Radiographic features in 2D imaging as predictors for justified CBCT examinations of canine-induced root resorption. Dentomaxillofac Radiol. 2022;51:20210165.
35. Ardakani MP, Nabavizadeh A, Iranmanesh F, Hosseini J, Nakhaei M. Relationship of angulation of maxillary impacted canines with maxillary lateral incisor root resorption. Pesqui Bras Odontopediatria Clín Integr. 2021;21:e0164.
36. Simić S, Nikolić PV, Pavlović J, Vukićević V, Vujačić A. Root resorption of adjacent teeth due to maxillary impacted canines-comparative analysis of the findings on cone beam computed tomography and panoramic imaging. Vojnosanitetski pregled 2023;80:136-142.
37. Sosars P, Jakobsone G, Neimane L, Mukans M. Comparative analysis of panoramic radiography and cone-beam computed tomography in treatment planning of palatally displaced canines. Am J Orthod Dentofacial Orthop. 2020;157:719-727.
38. Sarıkır Ç, Alkurt MT, Değerli Ş, Altunkaynak B, Peker İ. Comparison of panoramic radiography and cone-beam computed tomography for qualitative and quantitative measurements regarding localization of permanent impacted maxillary canines. Acta Odontol Turc. 2017;34:1-7.
39. Lindauer SJ, Rubenstein LK, Hang WM, Andersen WC, Isaacson RJ. Canine impaction identified early with panoramic radiographs. J Am Dent Assoc. 1992;123:95-97.
40. Alessandri BG, Zanarini M, Danesi M, Parenti SI, Gatto MR. Percentiles relative to maxillary permanent canine inclination by age: a radiologic study. Am J Orthod Dentofacial Orthop. 2009;136:486.e1-6;discussion 486-7.
41. Stivaros N, Mandall NA. Radiographic factors affecting the management of impacted upper permanent canines. J Orthod. 2000;27:169-173.
42. Grisar K, Piccart F, Al-Rimawi AS, Basso I, Politis C, Jacobs R. Three-dimensional position of impacted maxillary canines: Prevalence, associated pathology and introduction to a new classification system. Clin Exp Dent Res. 2019;5:19-25.
43. European Commission. Radiation protection 172. Cone beam CT for dental and maxillofacial radiology. In: Evidence Based Guidelines. 2012 http://www.sedentexct.eu/files/radiation_protection_172.pdf
44. Pakbaznejad Esmaeili E, Ilo AM, Waltimo-Sirén J, Ekholm M. Minimum size and positioning of imaging field for CBCT scans of impacted maxillary canines. Clin Oral Investig. 2020;24:897-905.
45. Eslami E, Barkhordar H, Abramovitch K, Kim J, Masoud MI. Cone-beam computed tomography vs conventional radiography in visualization of maxillary impacted-canine localization: A systematic review of comparative studies. Am J Orthod Dentofacial Orthop. 2017;151:248-258.
46. Dağsuyu İM, Kahraman F, Okşayan R. Three-dimensional evaluation of angular, linear, and resorption features of maxillary impacted canines on cone-beam computed tomography. Oral Radiol. 2018;34:66-72.
47. Kadesjö N, Lynds R, Nilsson M, Shi XQ. Radiation dose from X-ray examinations of impacted canines: cone beam CT vs two-dimensional imaging. Dentomaxillofac Radiol. 2018;47:20170305.
48. Ladeira DB, Cruz AD, Almeida SM, Bóscolo FN. Influence of the intergonial distance on image distortion in panoramic radiographs. Dentomaxillofac Radiol. 2012;41:417-21.
49. Devlin H, Yuan J. Object position and image magnification in dental panoramic radiography: a theoretical analysis. Dentomaxillofac Radiol. 2013;42:29951683.
50. Abdinian M, Soheilipour F, Nazeri R, Ghorbanizadeh S. Investigation of the magnifi cation of digital panoramic radiographs in different regions of the jaws. SRM J Res Dent Sci. 2016;7:10-6.

Ethics

This article does not contain any studies with human participants or animals performed by any of the authors.

Source of Funding

This study was supported by the Coordenação de Aperfeiçoamento de Pessoal de Nível Superior – Brasil (CAPES) - Finance Code 001. CAPES Scholarship/Sandwich Doctoral Program Abroad – PDSE/ Process nº {88881.188448/2018-01}.

Authors' contributions

MPM and IRFRB contributed to the study conception. MPM, IRFRB, and HMH contributed to the design. Data acquisition were performed by MPM and CMFR. MPM, CMFR, JLL, and IRFRB contributed to data analysis and interpretation of data. Statistical analysis was performed by HMH. The manuscript was written by MPM and all authors reviewed it critically. All authors approved the final manuscript and agreement with all aspects of the work.

Conflict of Interest

The authors declare that they have no conflict of interest.