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# Relationship between chewing side preference and handedness and lateral asymmetry of peripheral factors

*Jordi Martinez-Gomis* *, *Mar Lujan-Climent, Sara Palau, Josep Bizar, Juan Salsench, Maria Peraire*

*Department of Prosthodontics, Faculty of Dentistry, University of Barcelona, Spain*

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ABSTRACT

*Objective:* To determine whether chewing side preference is related to handedness and lateral asymmetry of occlusal characteristics, muscular force and temporomandibular disorders (TMD) in a dentate population.

*Design:* One hundred and seventeen dentate adults participated in this cross-sectional study. Static and dynamic occlusal characteristics were determined at the maximal intercuspal position and at the lateral excursions by scanning interocclusal records and analysing them using image software. Unilateral maximum bite force and finger–thumb grip force were measured by means of a gnathodynamometer. TMD were assessed according to the Research Diagnostic Criteria for TMD. Chewing side preference and masticatory laterality were determined by observing the jaw's movement while each subject chewed silicone. Asymmetry or side difference of the variables was calculated. Correlation between side difference variables and masticatory laterality was studied using Spearman correlation coefficient.

*Results:* Fifty-nine subjects chewed on the right, 15 on the left and 43 chewed on both sides. There was no relationship between preferred chewing side and handedness, lateral asymmetry of TMD or side difference in finger–thumb grip force. Significant and positive correlations were observed between masticatory laterality and side differences in bite force and side differences in occlusal contact area at intercuspal position ($P < 0.01$).

*Conclusions:* Chewing side preference in a dentate population is related to lateral asymmetry of bite force and asymmetry of occlusal contact area at the intercuspal position but not to handedness.





## 1. Introduction

Mastication is one of the main functions of the stomatognathic system.[1] Although mastication may occur bilaterally, it is assumed that the majority of people chew more on a particular side, i.e. they have a preferred chewing side.[2–5] Some studies did not find any significant differences between the proportions of children or adults who preferred to chew on the left- or right side.[2,3,6,7] However, other studies have suggested that more adults prefer the right side.[8–11]

It has been postulated that the preferred chewing side is centrally determined and related to a preference for using the hand, eye, ear and foot of the same side.[10] In contrast, other authors suggested that preference for chewing on a particular

* *Corresponding author at:* Campus de Bellvitge, Universitat de Barcelona, C/Feixa llarga s/n, 08907 L'Hospitalet de Llobregat, Spain. Tel.: +34 934035555; fax: +34 934035558.
E-mail address: jmartinezgomis@ub.edu (J. Martinez-Gomis).

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side may be related to some peripheral factors.[3,12] However, there is no agreement on whether peripheral factors such as occlusion,[3,13–16] the most efficient side for chewing[17,18] or temporomandibular disorders (TMD)[3,19–22] influence the preferred chewing side. Other factors that have been related with preferred chewing side are bilateral asymmetry in bite force at submaximal clenching level,[14] the ability to move the jaw laterally[23,24] and facial asymmetry.[19]

Several types of test food have been used to determine chewing side preference. Chewing gum was used in most studies,[2,4,7,9,10,13,14,25] although carrots,[3,16] almonds[18] and other foods have also been used.[11,26,27] It is known that the size, texture and hardness of the bolus affects muscle activity and the chewing cycle.[5,11,15,26–28] Although most studies of masticatory performance use tablets of a silicone impression material,[29,30] no studies have assessed chewing side preference using this standardised test food.

Since the main factors determining the preferred chewing side are unknown, the aim of this study was to determine whether handedness or lateral asymmetry of occlusal characteristics, muscular force or temporomandibular disorders are related to the chewing side preference using silicone as a test food in a population with a full or near-full complement of natural teeth.

## 2. Materials and methods

### 2.1. Subjects

One hundred and seventeen young adults (83 women and 34 men) with natural dentition participated in this cross-sectional study. Their ages ranged from 19.8 to 47.9 years with a median of 22.2. Subjects with fewer than 24 natural teeth, those undergoing active orthodontic treatment, or those suffering orofacial pain from disorders other than TMD were excluded. One hundred of the subjects were randomly selected from volunteer students and staff at the University of Barcelona's Faculty of Dentistry (Spain) and had participated in a previous investigation.[31] Seventeen other subjects with signs and/or symptoms of TMD were selected from the same target population. Subjects were fully informed and signed an informed consent form approved by the local ethics committee (Code 03/06). All experiments were carried out in accordance with the principles of the Helsinki Declaration.

Data were collected from each subject in the following chronological order: anthropometric assessments and Research Diagnostic Criteria for TMD (RDC/TMD) exploration and questionnaire, masticatory test to determine chewing side preference, occlusal registrations, and muscular force measurements. Once these measurements had been made, the subjects were questioned about their handedness and their preference for right- or left-side chewing.

### 2.2. TMD diagnosis

All subjects were examined clinically by the same trained dentist and answered the Spanish version of the RDC questionnaire for TMD.[32,33] The clinical examination included the measurement and accompanying pain of maximum opening, protrusion and laterotrusion, palpation and auscultation of the temporomandibular joints (TMJs), and palpation of the masticatory muscles. RDC/TMD has two components: Axis I contains an algorithm for clinical diagnosis and Axis II assesses mandibular function, psychological status and level of TMD-related psychosocial disability. For Axis I portion of the interview, the questionnaire mainly assessed self-report data on TMD pain over the preceding month or a history of a mouth opening limitation. Following the RDC/TMD algorithms, all subjects were assigned as non-TMD or, by diagnosis, to one of the three main groups (Group I myofascial pain; Group II TMJ disc displacement; Group III TMJ arthralgia/osteoarthritis/osteoarthrosis). Multiple diagnoses per single subject were also possible. Each main group was divided into two or three subgroups which were mutually exclusive. A diagnosis of myofascial pain was not taken into account in this study, as its symptoms are usually bilateral. The affected side was noted for Groups II and III.

### 2.3. Muscular force measurements

A bite-force transducer (gnathodynamometer, Technical University of Catalonia, Barcelona, Spain) was used to measure unilateral bite forces (Fig. 1). In order to protect the teeth, both sides of the transducer tips were covered with 1-mm thick rubber plates attached with cyanoacrylate and covered with a latex finger cot. The vertical height of the bite fork was 20.5 mm. This device was calibrated with loads from 0 to 1200 N by means of a compression test machine at the Department of Materials Science and Metallurgy of the Technical University of Catalonia (Barcelona, Spain). Maximum bite force was measured for four different regions: between the first molars on the right- and left sides and between the first premolars on both sides. Subjects were encouraged to bite as hard as possible on the transducer for a few seconds. The bite-force measurements were recorded three times and order was changed for each test. The highest bite-force value was selected for each region.

The finger–thumb grip force of each hand was also measured by a similar procedure, using the bite-force transducer to assess the subject's general muscle strength and to study the lateral asymmetry of the hand force as a quantitative parameter related to handedness.

**Fig. 1 – Measurement of unilateral bite force at the first right premolar using the transducer (gnathodynamometer).**



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### 2.4. Occlusal characteristics

Several static and dynamic occlusal characteristics were recorded because the majority of them have been related to masticatory performance or TMD.[31] The anteroposterior relationship of the upper and lower canines and first molars at the maximal intercuspal position (ICP) was evaluated using Angle's classification for both sides. The transverse or buccolingual relationship of the upper and lower posterior teeth was assessed for the left- and right side and classified into two groups: "no posterior crossbite" and "unilateral or bilateral crossbite". The number of lower posterior teeth in the crossbite for each side was also assessed.

Measurement of the occlusal contact area at ICP was described in an earlier study.[31] Briefly, occlusal registrations (Occlufast Rock, Zhermack S.p.A. Badia Polesine, Italy) at ICP were obtained from all subjects and scanned (HP Scanjet 5370C, Hewlett-Packard Co., Palo Alto, CA, USA) (Fig. 2). The software program UTHSCSA Image Tool (V 3.0, University of Texas Health Science Center, San Antonio, TX, USA) was used to analyse the occlusal registrations. Calibration was performed using a known distance measured with a digital calliper (Absolute, Vogel Germany GmbH & Co., Kevelaer, Germany). A relationship between each of the 256 grey levels and the thickness of the occlusal registration was also established. Pixel densities were calculated for an interocclusal distance of 200 $\mu$m and the occlusal contact area was measured on the left- and right sides. The number of teeth in contact was determined for both sides. An interocclusal distance of 50 $\mu$m or less counted as contact.

To determine the dynamic occlusal characteristics, silicone-based occlusal registrations were obtained from each subject in two jaw positions: a right lateral excursion at 1.5 mm intercuspal distance from the incisal point and a left lateral excursion at 1.5 mm intercuspal distance from the incisal point. Interocclusal registrations were scanned and analysed following the

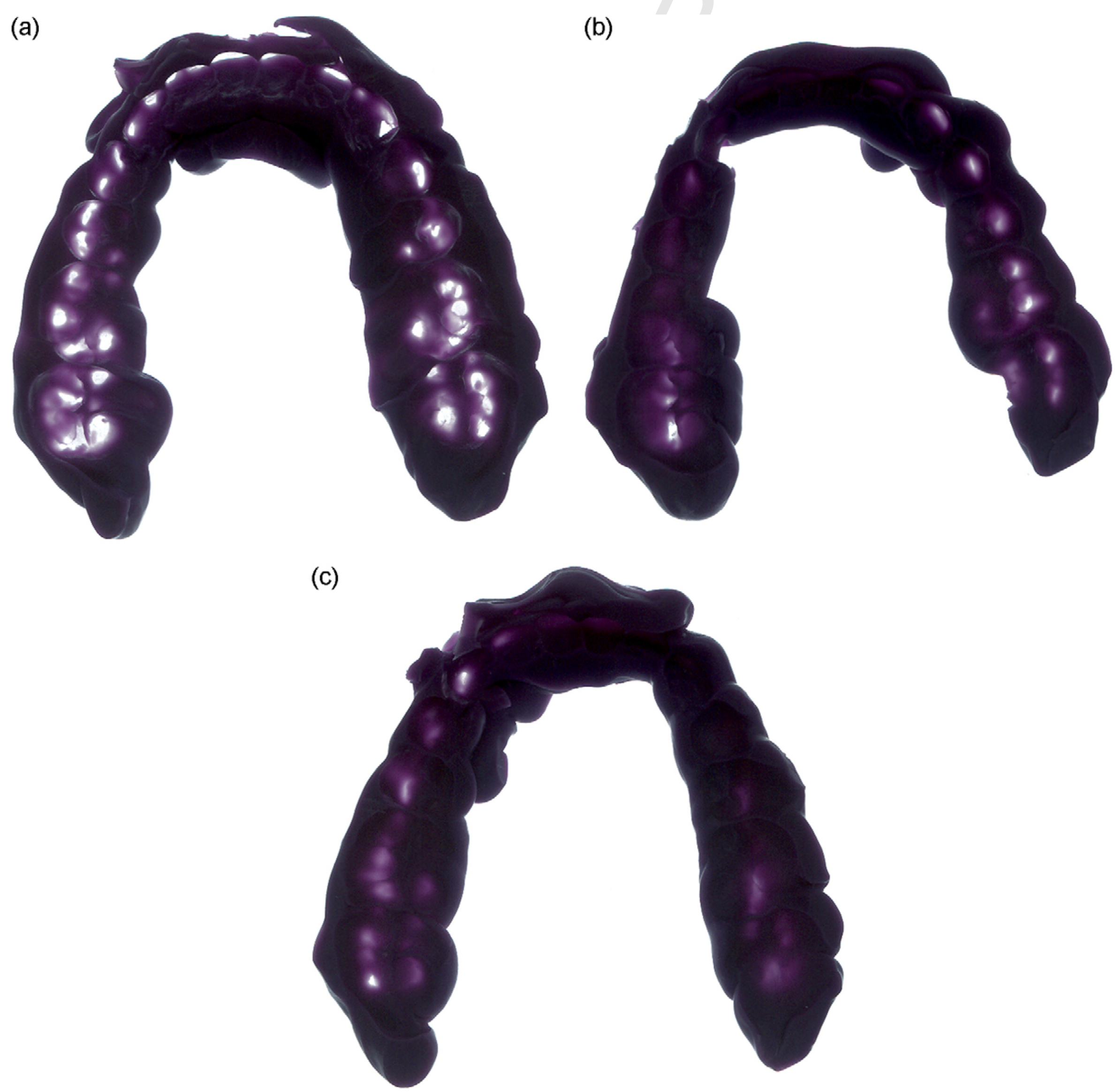


**Fig. 2 – Silicone-based occlusal registrations obtained at intercuspal position (A) and a right (B) and left (C) laterotrusion at a 1.5-mm intercuspal distance from the incisal point.**

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same procedure as ICP registration to determine the occlusal contact area and the number of teeth in contact for both sides (Fig. 2). The type of dynamic occlusion pattern was assessed on both the working and non-working sides for both lateral excursions of 1.5 mm from ICP at 50 μm thickness. Lateral dental guidance was classified as anterior protected articulation (the contact of one or more incisors without posterior contact), canine protection, group function and not defined.[34,35] Subjects were assigned a contact pattern for the non-working side for each laterotrusion: ‘‘absence of non-working side occlusal contacts’’, ‘‘presence of non-working side occlusal contacts’’ or ‘‘presence of non-working side interferences’’.[35]

### 2.5. Masticatory test

Chewing side preference was evaluated using a standardised test food (Optosil P Plus, Heraeus Kulzer GmbH, Hanau, Germany). Tablets of Optosil (5 mm thick, 20 mm diameter) were made following Albert et al.[30] and were cut into quarters. Each subject chewed three quarter tablets (2 g) for 20 cycles. The trial was repeated five times. An operator observed the side towards which the jaw moved while closing for each masticatory cycle. Therefore, each cycle was classified as right-, left- or no-side. For each trial, a subject who chewed 11 or more cycles on the right side was considered a right chewer and was assigned +1 point. A subject who chewed 11 or more cycles on the left side was considered a left chewer and was assigned −1 point. A subject who did not chew 11 or more cycles on any side was considered a bilateral or central chewer and was assigned 0 points. The sum of the five values from the five trials ranged from −5 to +5. This value gives an idea of masticatory laterality (negative values means left chewers) and consistency.

### 2.6. Data analysis

The reliability and agreement of the main parameters were tested in nine subjects 2–4 weeks after the first measurements were taken. Their intraclass correlation coefficients ranged from 0.87 to 0.97.[31] The diagnoses of TMD for all these nine subjects from both examinations were in agreement. Furthermore, the observation method for assessing chewing side preference was compared with a video recording technique in 17 individuals. The five trials of these 17 subjects were recorded by a video camera (Sony HDR-UX7E, Japan) and masticatory laterality was evaluated using a slow-speed playback mode of these registrations following the same criteria. The intraclass correlation coefficient between visual and video methods was 0.98 (95% CI 0.94–0.99). Therefore, the visual observation method was considered valid for assessing the preferred chewing side.

Qualitative variables were converted into dichotomous variables (0 = absence and 1 = presence). New variables called ‘‘side difference’’ were calculated for each parameter as the difference between right-hand-side values and left-hand-side values. In cases of dynamic occlusion, the new variables were calculated as the difference between the values obtained from a right laterotrusion and those from a left laterotrusion. Therefore, a positive value for a side difference of quantitative variables signifies that the right-side value is higher than the left-side one. Side differences of qualitative parameters have three categories (+1; 0; −1), a positive value means that this variable is present on the right side but not on the left side, a 0 value means that this variable is absent or present on both sides and a negative value means that this variable is present on the left side but not on the right side.

The normal distribution fit of the data was tested by means of a Kolmogorov–Smirnov test. Comparisons between right chewers, left chewers and bilateral chewers were performed using analysis of variance or the Kruskal–Wallis *H*-test and the Mann–Whitney *U*-test, as appropriate. Spearman rank correlation coefficients were calculated to evaluate the bivariate correlation between side difference variables and masticatory laterality. Statistical analysis was performed using the SPSS program (version 15.0 SPSS Inc., Chicago, IL, USA) and *P*-values below 0.05 were considered significant.

## 3. Results

Ten subjects (8.5%) were left-handed. Nearly half of the subjects were observed to have a preferred chewing side (PCS) on the right, 12.8% on the left and 36.8% had no preferred chewing side. When subjects were questioned about their preference for right- or left-side chewing, 59% of them stated they chewed on the right, 17% on the left and 23.9% stated they did not have a preferred chewing side. There was agreement between the observed and declared preferred chewing side in 80.3% of subjects, with a Cohen's kappa value of 0.67 ($P < 0.001$). There was no relationship between the diagnosis of any group of TMD and unilateral chewing ($P > 0.05$, chi-square).

The differences between maximum bite force on the right first molar and left first molar were significantly more negative in left chewers than right chewers or subjects without a preferred chewing side ($P = 0.006$; ANOVA, Duncan test). Similarly, right chewers exhibited more bite force on the right-side first premolar than on the left-side first premolar ($P < 0.001$; ANOVA, Duncan test) (Fig. 3). Subjects who chewed

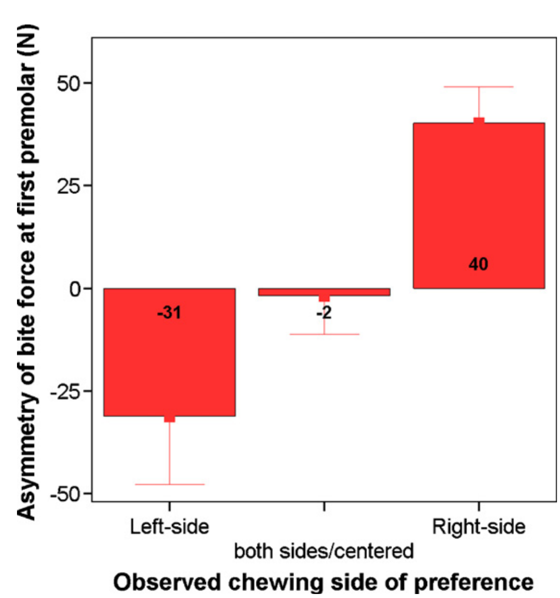


**Fig. 3 – Asymmetry or side difference of bite force at first premolar for the different preference chewing side groups.**

on their left side had more occlusal contact area at ICP on the left side than on the right side (Fig. 4). No significant relationship was observed between the preferred chewing side and handedness or side difference in finger–thumb grip force.

Consistency of chewing side preference in the five mastication trials was analysed by masticatory laterality, whose values ranged from −5, for a consistent left chewer, to +5, for a consistent right chewer. Positive and significant correlations were observed between masticatory laterality and lateral differences in bite force and in occlusal contact area (Table 1). No significant correlation was observed between masticatory laterality and asymmetry in the Angle class, presence of crossbite, and the type of dynamic occlusion (Table 2). The interrelation between variables that were significantly associated with masticatory laterality is shown in Table 3. Asymmetry in occlusal contact area at ICP was related to asymmetry in bite force only in the first premolar region.

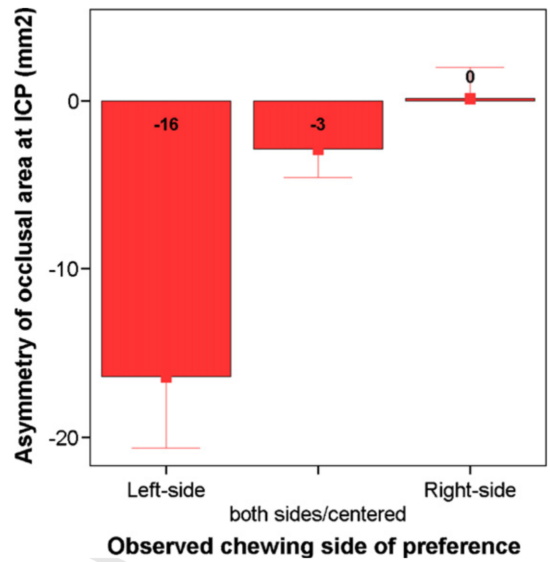


**Fig. 4 – Asymmetry or side difference of occlusal contact area for left chewers, right chewers and bilateral chewers.**

## 4. Discussion

The results of this cross-sectional study confirm that although bilateral chewing is common, many people appear to have masticatory laterality while chewing a hard food, in agreement with other studies.[3,5,26] In this study, most subjects preferred to chew on the right side, as was found by other authors.[10,11] Peripheral factors such as side differences in occlusal contact area and in bite force showed a positive and significant correlation with masticatory laterality.

The fact that only few asymmetrical parameters were correlated with masticatory laterality and the lack of agreement observed in other studies on whether central or peripheral factors influence the preferred chewing side[3,13–22] means that a complex interplay of factors affects the selection of chewing side preference. Most subjects preferred to chew on the right side, hence chewing side preference might be affected by central regulation, although handedness or lateral difference in finger–thumb grip force were not significantly related to masticatory laterality in the present study.

The side on which more bite force can be exerted and more occlusal contact area exists was more likely to be used to chew. However, due to the cross-sectional design of this study, we cannot demonstrate whether an increase in occlusal contact area and bite force on one side is the result or the cause of preferring this side for chewing. Longitudinal studies are needed to clarify the cause–effect of these correlations. Although masticatory efficiency in one study tended to be better on the preferred side, no significant correlation was found between chewing side preference and chewing efficiency.[18] The present study did not test the masticatory efficiency on each side. However, as bite force and occlusal contact area at ICP can explain 41% of the variation in masticatory performance,[31] and lateral differences in these parameters were positively correlated with masticatory laterality, side efficiency could affect the chewing side preference.

Whereas in some studies unilateral chewing has been correlated with TMD,[20–22] in another study TMD signs or symptoms were not correlated with chewing side preference.[3] In the present study, no relationship was observed between the side of chewing preference and the side of unilateral

**Table 1 – Mean of side difference quantitative variables and its Spearman rank correlation with masticatory laterality.**

| Asymmetry | Mean (S.D.) | Correlation with masticatory laterality Rho (P-value) |
|---|---|---|
| Maximum laterotrusion (mm) | 0.8 (2.1) | −0.05 (0.60) |
| Bite-force molar (N) | −22.9 (87.2) | 0.31 (0.001) |
| Bite-force premolar (N) | 15.6 (69.9) | 0.40 (<0.001) |
| Finger–thumb grip force (N) | 7.9 (9.8) | −0.03 (0.72) |
| Intercuspal position | | |
| Posterior teeth in crossbite (num) | −0.2 (1.6) | −0.03 (0.72) |
| Occlusal contact area at 200 μm (mm²) | −3.1 (14.4) | 0.23 (0.01) |
| Occlusal teeth in contact (num) | 0.1 (1.1) | 0.05 (0.58) |
| Laterotrusion | | |
| Occlusal contact area at 50 μm (mm²) | −0.2 (2.5) | 0.03 (0.76) |
| Occlusal teeth in contact (num) | −0.1 (2.0) | 0.06 (0.51) |

S.D., standard deviation.

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**Table 2 – Distribution and percentage of qualitative variables and Spearman rank correlation between asymmetry of these variables and masticatory laterality.**

| | Presence only on left side N (%) | Presence bilaterally or absent N (%) | Presence only on right side N (%) | Correlation with masticatory laterality Rho (P-value) |
|---|---|---|---|---|
| Disc displacement of TMJ (%) | 18 (15.4) | 81 (69.2) | 18 (15.4) | 0.12 (0.19) |
| Arthralgia of TMJ (%) | 4 (3.4) | 111 (94.9) | 2 (1.7) | −0.02 (0.87) |
| Handedness (%) | 10 (8.5) | 0 (0) | 107 (91.5) | 0.08 (0.41) |
| Angle class I (%) | 6 (5.1) | 104 (88.9) | 7 (6.0) | 0.15 (0.10) |
| Angle class II (%) | 7 (6) | 105 (89.7) | 5 (4.3) | −0.11 (0.23) |
| Angle class III (%) | 0 (0) | 116 (99.1) | 1 (0.9) | −0.16 (0.09) |
| Presence of crossbite (%) | 8 (6.8) | 104 (88.9) | 5 (4.3) | −0.01 (0.94) |
| Anterior protected-articulation (%) | 7 (6) | 104 (88.9) | 6 (5.1) | −0.11 (0.23) |
| Canine protection (%) | 16 (13.7) | 90 (76.9) | 11 (9.4) | −0.02 (0.83) |
| Group function (%) | 24 (20.5) | 69 (59) | 24 (20.5) | 0.18 (0.06) |
| Non-defined group (%) | 16 (13.7) | 79 (67.5) | 22 (18.8) | −0.12 (0.21) |
| Absence non-working contacts (%)[a] | 19 (16.2) | 78 (66.7) | 20 (17.1) | −0.05 (0.57) |
| Presence non-working contacts (%)[a] | 25 (21.4) | 70 (59.8) | 22 (18.8) | 0 (0.98) |
| Presence non-working interferences (%)[a] | 6 (5.1) | 103 (88) | 8 (6.8) | 0.10 (0.30) |

[a] Related to left- or right laterotrusion.

arthrogenous pain or disc displacement of the TMJ. This lack of relationship may be due to the fact that subjects were selected from a general population. As this was not a case–control study, the TMD symptoms were not severe enough for the subject to seek treatment. Moreover, only seven subjects presented arthralgia (six unilaterally). Therefore, there may be a lack of statistical power.

There is no agreement on whether central regulation or peripheral factors influence the preferred chewing side, or what such peripheral factors may be.[3,13–22] The discrepancies in the literature can be explained by differences in the study population, in the methods for determining the preferred chewing side and in the type of test food used. Most studies were performed with young adults with natural dentition,[2,9,11,26] others studies were carried out with children,[7] teenagers[21] or elderly people.[10] Since the notion of preferred side of mastication has no universal definition,[15] some methods determined which side the food was mostly chewed on,[2,4,7,10] others assessed the side the jaw moved to in the closing phase of mastication,[9,11,18,25,26] and a few studies used a questionnaire to assess the preferred chewing side by means of the subjects' perceptions.[20,21,36]

Several types of test food have been used to determine chewing side preference and chewing gum was used in most studies.[2,4,7,9,10,13,14,25] In the present study, tablets of silicone impression material were used to assess the chewing side preference, as this material has minimal taste and smell and can be prepared following a standardised protocol.[30] Moreover, it was found that muscle activity while chewing this silicone corresponds to chewing a natural food.[37] Although masticatory movement was found to be more stable when masticating chewing gum than peanuts or crispy bread,[30] people usually chew gum for entertainment. However, the aim of chewing a hard food is to breakdown the food, which probably requires using the preferred side for chewing.

The study of chewing side pattern aids understanding of the neural control of chewing and the design of prosthodontic restoration. A central goal of prosthodontics is to stabilise the occlusion and restore or improve oral function, i.e. chewing capability.[1] Restoration of missing dental units on the preferred side would improve masticatory efficiency.[10] However, it still unknown whether prosthodontic restoration on the non-preferred side would improve masticatory performance. Clinical studies are needed to evaluate the improvement in masticatory performance on patients' non-preferred sides.

**Table 3 – Spearman's rank correlation coefficients among side difference variables.**

| | 1 | 2 | 3 |
|---|---|---|---|
| 1. Masticatory laterality | | | |
| 2. Bite-force, molar | 0.31*** | | |
| 3. Bite-force, premolar | 0.40*** | 0.44*** | |
| 4. Occlusal area at ICP | 0.23** | 0.17 | 0.29*** |

ICP, intercuspal position.
** $P < 0.01$.
*** $P < 0.001$.

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