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Occlusion time, occlusal balance and lateral occlusal scheme in subjects with various dental and skeletal characteristics: A prospective clinical study

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Abstract

Objectives: To analyse occlusion time, occlusal balance and lateral occlusal scheme in subjects with various dental and skeletal characteristics.

Methods: A total of 132 subjects (50 males and 82 females) seeking orthodontic treatment were included in this prospective study. Using the T-Scan III version 7.0 (Tekscan Inc, South Boston, MA, USA), the occlusion time, occlusal balance and lateral occlusal schemes were recorded and compared with gender, Angle's occlusal classification, overjet, overbite, space analysis, skeletal and transverse relations. ANOVA, *t* test and contingency tables analyses were performed. Statistical significance was set at $P < .05$.

Results: Occlusion time was significantly shorter in subjects with balanced occlusion (0.18 seconds, $P < .001$), Class I normal occlusion (0.35 seconds, $P = .028$) and Class I skeletal profile (0.37 seconds, $P = .002$). Occlusion time was significantly longer in subjects with decreased overjet (0.60 seconds, $P = .003$). There were significant associations between the distribution of occlusal balance and Angles' classes of occlusion, skeletal relationship, overjet, overbite and space analysis ($P < .05$). Lateral occlusal schemes were only associated with Angle's classes of occlusion and skeletal relationship ($P < .05$).

Conclusions: Patients with Class I occlusion showed the least occlusion time, the most balanced occlusion and a higher frequency of canine guidance. Nonetheless, potentially balanced occlusion and group function were highly prevalent in all groups; therefore, ideal occlusion must be considered an ideal to inspire and aim for, but cannot be considered an essential requirement of every dental treatment.

KEYWORDS
Angle classification, balanced dental occlusion, canine guidance, lateral occlusal scheme, occlusal analysis, occlusal time

1 | INTRODUCTION

Different occlusal features can affect the number, the position and the magnitude of teeth contacts.[1,2] In turn, the contacts between the teeth can influence different aspects of both static and dynamic dental occlusion.[3] Measurement of occlusal balance and tooth contact is often unreliable. Qualitative occlusal measures are habitually used because they are inexpensive and feasible. They encompass articulating paper, articulating silk, articulating film, metallic shim stock film and high spot indicators.[4,5] The main limitations of the use of these materials are the subjective evaluation, the incapacity to identify the time during which the teeth come in contact and the load applied on the contacts, the presence of saliva and the thickness of the film.[6-8]

An objective method to evaluate both static and dynamic dental occlusion is the T-Scan (Tekscan Inc). The T-Scan provides real-time data for the accurate evaluation of several features of dental occlusion and removes the operators' subjective perception of paper marks; in addition to that, T-Scan measurements are not influenced by the presence of saliva.[2,6,7,9-11]

Based on the mentioned data, the aim of this study was to analyse occlusion time (OT), occlusal balance and lateral occlusal scheme in subjects with different dental and skeletal Classes of occlusion, and to compare the effect of gender, overjet, overbite, space analysis and crossbite. OT, occlusal balance and lateral occlusal scheme were assessed by the use of the T-Scan.

2 | MATERIALS AND METHODS

This prospective clinical study recruited patients seeking orthodontic treatment at the Faculty of Dentistry of King Abdulaziz University by asking them to voluntary participate in this study. The inclusion criteria were as follows: (a) all permanent teeth present not including the third molars and (b) normal temporomandibular joint function. Exclusion criteria were the following: (a) history of temporomandibular disorders and/or oro-facial pain, (b) history of parafunctional habits, (c) history of muscle disorders, (d) presence of functional shift, (e) developmental dental or skeletal anomaly or facial asymmetry, (f) psychological inability to cooperate, (g) previous orthodontic treatment, (h) severe periodontal disease and (i) extensive fixed prosthetic dental work. The research was approved by the Research Ethics Committee (No. 024-15) of the Faculty of Dentistry, King Abdulaziz University (Jeddah, Saudi Arabia). The study protocol was explained to those who agreed to participate, and signed consent was obtained from each patient.

A priori power analysis was conducted using G*Power3 with a medium effect size ($d = 0.30$), and an alpha of 0.05. to achieve a power of 0.80. The required sample to test the difference between the means of two independent groups using a two-tailed test was 128 participants. For ANOVA, a total sample of 76 was required and a total of 122 participants were required for contingency tables analysis.[12] Thus, a total of 132 patients were included in the study. Subjects were divided into 4 groups based on Angle's classification of occlusion; patients with Class I normal occlusion serving as controls.

T-Scan III version 7.0 (Tekscan Inc) was used. Participants were seated in an upright position and were instructed to bite the sensor. To adjust the sensitivity of the device and ensure reproducibility, the sensor was inserted into the subject's mouth with the midline indicator of the plastic support between the upper central incisors. Participants were asked to perform a chewing act before recording to insure sensor adaptation to the occlusal surface. The sensitivity of the device was adjusted according to the manufacturer's instructions to obtain no more than 3 pink peaks at maximum intercuspation in the 3D mode.[13] Three consecutive recordings were taken, and their average values were recorded. Occlusal time (OT) recorded the time span from the first tooth contact to maximum intercuspation.[14] Hence, OT evaluated how fast the entire dentition reaches the occlusion status.

The occlusal balance was assessed using the T-scan force trajectory graph and categorised the individuals into three groups: (1) balanced, when the terminal movement of the trajectory was located in the white circle; (2) potentially balanced, when the terminal movement of the trajectory lied in the grey circle; and (3) not balanced, when the terminal movement was located outside the grey circle (Figure 1).

The lateral occlusal scheme was categorised as canine guidance, group function or both if the right and left sides did not match.[15-17]

The skeletal relations were assessed using lateral cephalometric radiographs. Based on the angle formed by points A, Nasion and B (ANB angle), patients were classified as Class I, II or III. VistaDent OC™ version 4.2.40 (Dentsply Sirona) was used for cephalometric analysis.

Dental occlusion was categorised according to Angle's molar classification as Class I normal occlusion, Class I, Class II and Class III malocclusions. Overjet was categorised into three groups: decreased (<2 mm), average (2-3 mm) and increased (>3 mm). Overbite was categorised into three groups: decreased (<10%), average (10%-40%) and increased (>40%). Transverse discrepancy (crossbite) was categorised into normal, unilateral crossbite, bilateral crossbite, single tooth crossbite and buccal (Brodie) bite. Crossbite was recorded when the cusps of the maxillary canines, buccal cusps of premolars and molars occluded lingually to the cusps of mandibular canines, buccal cusps of premolars and molars.[18] Buccal crossbite (Brodie) was recorded when the cusps of the maxillary canines, palatal cusps of premolars and molars occluded buccal to the buccal cusps of mandibular canines, premolars and molars. The skeletal profile was categorised as Class I (ANB 0-4 degrees), Class II (ANB >4 degrees) and Class III (ANB <0 degrees).

One trained investigator performed all the recordings to avoid any interexaminer variations. Cronbach's alpha was used to test intra-examiner reliability. T-scan measurements of 10 randomly participants were repeated after 2 weeks using the same protocol by the same examiner. The results of the Cronbach's alpha for all variables were >0.87, which indicated good to excellent reliability.

2.1 | Statistical analysis

Statistical Package for Social Sciences version 20 (SPSS; IBM Corporation) was used. The Shapiro-Wilk test showed that the data were approximately normally distributed. Data were tabulated, frequency and percentages were calculated for nominal and categorical outcomes, and for continuous variables means and standard

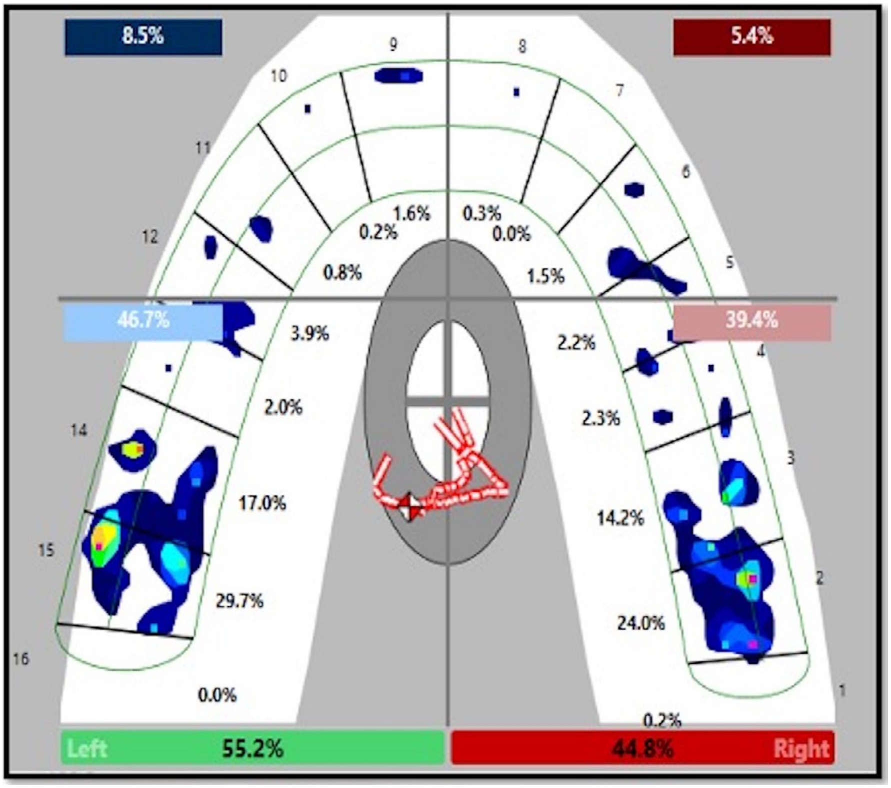

FIGURE 1 T-scan overview showing force trajectory (red line in the middle circle)

deviation were calculated. One- and two-way ANOVA and Tukey's HSD post hoc tests were performed to assess occlusion time differences between groups. Contingency tables analyses were performed to study associations. The significance level was set at $P < .05$.

3 | RESULTS

A total of 132 patients were recruited. There was no significant age difference between males (21.3 ± 5.2 years) and females (21.1 ± 4.7 years), $P = .76$. A two-way ANOVA was conducted to assess the effect of occlusal balance and gender on occlusion time. No statistically significant main effect was found for gender ($P = .258$); however, a statistically significant main effect was found for occlusal balance ($P = .008$). Still, there was no significant interaction between the effects of gender and bite in occlusion time ($P = .129$). Contingency tables analyses showed that there were no significant differences between males and females in the distribution of Angle's occlusal classifications, skeletal profile, overjet, overbite, transverse skeletal relations and lateral occlusal scheme relationships ($P > .05$). Therefore, data of male and female subjects were pooled together in all analyses.

3.1 | Occlusion time

Table 1 shows the comparisons of OT (seconds) within the studied variables. One-way ANOVA shows a significant difference in OT between the bite balance groups ($P < .001$). Subjects with balanced bite had a statistically significant shorter occlusion time than those with potentially balanced and unbalanced bites ($P < .001$). One-way ANOVA was also conducted to evaluate the OT between Angle's classes of occlusion, and a significant main effect was found ($P = .028$). There was a difference only between the occlusion time of subjects with Class I normal occlusion and subjects with Class III malocclusion (0.35 seconds and 0.52 seconds, respectively, $P = .036$). No statistical differences were found between subjects belonging to the other Classes of dental occlusion ($P > .05$). OT was also statistically different between different skeletal profiles ($P = .002$). Patients in skeletal Class III had longer OT than patients in skeletal Class I ($P < .001$) and Class II ($P = .013$). OT in subjects with decreased overjet was significantly longer compared with subjects with an average and increased overjet ($P = .005$ and $P = .001$, respectively).

One-way ANOVA did not show a significant difference in OT among the remaining studied variables (Table 1).

3.2 | Occlusal balance

Contingency tables analyses were conducted to study the association between occlusal balance and the studied variables. As can be shown in Table 2, there was a significant association between Angle's classes of occlusion and occlusal balance ($P = .008$). The percentage of patients with a balanced occlusion was higher among subjects with Class I normal occlusion and Class I malocclusion, 38.5% and 32.4%, respectively. While the percentage of patients with an unbalanced occlusion was higher among subjects with Class III malocclusion (42%) compared to subjects with Class I normal occlusion (3.8%),

TABLE 1 Comparisons of occlusion time (seconds) within the studied variables

	N	Mean	SD	P value
Occlusal Balance				
Balanced	35	0.18	0.04	<.001[a]
Potentially Balanced	72	0.39	0.08	
Not Balanced	25	0.83	0.21	
Dental Occlusal Relationship				
Class I normal occlusion	26	0.35	0.17	.028[a]
Class I malocclusion	37	0.37	0.22	
Class II malocclusion	38	0.42	0.27	
Class III malocclusion	31	0.52	0.27	
Skeletal Relationship				
Class I	68	0.37	0.20	.002[a]
Class II	39	0.42	0.27	
Class III	25	0.56	0.27	
Overjet				
Decreased	17	0.60	0.28	.003[a]
Average	62	0.41	0.22	
Increased	53	0.37	0.23	
Overbite				
Decreased	18	0.54	0.28	.072[a]
Average	52	0.41	0.22	
Increased	62	0.39	0.25	
Space analysis				
Crowding	59	0.44	0.28	.109[a]
Adequate	45	0.38	0.17	
Spacing	28	0.46	0.26	
Crossbite				
No	103	0.44	0.25	.091[b]
Yes	29	0.34	0.21	
Lateral Occlusal Scheme				
Canine Guidance	30	0.35	0.24	.153[a]
Group Function	56	0.45	0.45	
Both	46	0.43	0.43	
Right lateral Occlusal Scheme				
Canine guidance	50	0.37	0.22	.067[b]
Group function	82	0.45	0.25	
Left lateral Occlusal Scheme				
Canine guidance	56	0.39	0.24	.269[b]
Group function	76	0.44	0.25	

[a]ANOVA.
[b]*t* test.

Class I and II malocclusions (13.5 and 15.8, respectively). However, patients with potentially balanced occlusion were the most numerous in all Classes of occlusion.

There was a significant association between balanced occlusion and skeletal profile ($P < .001$). Balanced occlusion was present in 35.3% of the subjects with skeletal Class I, 23.1% of the subjects with skeletal Class II and 8% of the subjects with skeletal Class III. A significant association between occlusal balance and overjet was also found ($P = .002$). Almost 53% of the patients with increased overjet showed unbalanced occlusion, while 34% of the patients with decreased overjet had a balanced occlusion. A significant association was also found between occlusal balance and overbite ($P = .012$). About 27% of patients with average overbite showed a balanced occlusion, while 44.4% of patients with open bite had an unbalanced occlusion. The results also showed that there was a significant association between occlusal balance and space analysis ($P = .034$). Balanced occlusion was found more frequently in patients with no spacing or crowding; however, patients with potentially balanced occlusion were the most numerous in all groups. No significant association was found between occlusal balance and the presence of crossbite ($P = .271$).

3.3 | Lateral occlusal scheme

Table 3 shows the results of the contingency tables analyses evaluating the association between the lateral occlusal scheme and the studied variables. The association between the lateral occlusal scheme and Angle's occlusal classification was significant ($P = .045$). The percentage of patients with canine guidance was higher in the group with Angle's Class I occlusion compared to the group with Class II or III malocclusions, 34.6%, 15.8% and 9.7%, respectively. Group function was more prevalent in subjects with Angle's Class II and Class III malocclusions, 50 and 55%, respectively. In addition, there was an association between the lateral occlusal scheme and skeletal profile ($P = .049$). The percentage of patients with canine guidance was higher in the group with skeletal Class I compared to the group with skeletal Class III, 32.4%, and 8%, respectively. No association was found between the lateral occlusal scheme and overjet, overbite, space analysis and crossbite ($P > .05$).

4 | DISCUSSION

The present study investigated the association between three occlusal features (OT, occlusal balance and lateral occlusal scheme) and gender, Angle's occlusal classification, overjet, overbite, space analysis, skeletal and transverse relations. OT, occlusal balance and lateral occlusal scheme were measured by the use of the T-Scan III version 7.0.

The results show that OT was significantly shorter in subjects with balanced occlusion, Class I normal occlusion and Class I skeletal

TABLE 2 Distribution (%) of occlusal balance among the different studied variables

	Balanced (n = 35)	Potentially Balanced (n = 72)	Not Balanced (n = 25)	*P* value
Dental Occlusal Relationship				
Class I normal occlusion (n = 26)	10 (38.5)	15 (57.7)	1 (3.8)	.008[a]
Class I malocclusion (n = 37)	12 (32,4)	20 (54.1)	5 (13.5)	
Class II malocclusion (n = 38)	9 (23.7)	23 (60.5)	6 (15.8)	
Class III malocclusion (n = 31)	4 (12.9)	14 (45.2)	13 (41.9)	
Skeletal Relationship				
Class I (n = 68)	24 (35.3)	37 (54.4)	7 (10.3)	<.001[a]
Class II (n = 39)	9 (23.1)	24 (61.5)	6 (15.4)	
Class III (n = 25)	2 (8.0)	11 (44.0)	12 (48.0)	
Overjet				
Increased (n = 53)	1 (5.9)	7 (41.2)	9 (52.9)	.002[a]
Average (n = 62)	16 (25.8)	36 (58.1)	10 (16.1)	
Decreased (n = 17)	18 (34.0)	29 (54.7)	6 (11.3)	
Overbite				
Increased (n = 62)	2 (11.1)	8 (44.4)	8 (44.4)	.012[a]
Average (n = 52)	14 (26.9)	29 (55.8)	9 (17.3)	
Decreased (n = 18)	19 (30.6)	35 (56.5)	8 (12.9)	
Space analysis				
Crowding (n = 59)	14 (23.7)	31 (52.5)	14 (23.7)	.034[a]
Adequate (n = 45)	14 (31.1)	29 (42.9)	2 (4.4)	
Spacing (n = 28)	7 (25.0)	12 (42.9)	9 (32.1)	
Crossbite				
No Crossbite (n = 103)	24 (23.3)	58 (56.3)	21 (20.4)	.271[b]
Cross bite (n = 29)	11 (37.9)	14 (48.3)	4 (13.8)	

[a]ANOVA.
[b]*t* test.

profile; it was longer in subjects with decreased overjet. There were significant associations between the distribution of occlusal balance and Angles' classes of occlusion, skeletal relationship, overjet, overbite and space analysis. Lateral occlusal schemes were only associated with Angle's classes of occlusion and skeletal relationships.

OT describes the time from the first tooth contact to maximum intercuspation and evaluates how fast the entire dentition reaches complete occlusion. A long OT reveals unstable occlusion due to dental interferences; conversely, occlusion is considered to be stable when OT is less than 0.3 seconds.[14] Lee et al confirmed a relationship between dental occlusion and OT showing a decrease of OT when the peer assessment rating (PAR) index was low and the objective grading system (OGS) was high. The PAR index is a measure of pretreatment malocclusion obtained by evaluating the following variables: displacement, buccal occlusion, overjet, overbite and centre line. A high score indicates an unsatisfactory occlusal condition. The OGS was proposed by the American Board of Orthodontics for the assessment of post-treatment occlusal condition by evaluating the following variables: tooth alignment, vertical positioning of marginal ridges, bucco-lingual inclination of posterior teeth, occlusal relationship, occlusal contacts, overjet and interproximal contacts. A high score indicates achievement of a good occlusal condition.[14] This is in agreement with our results where the presence of a skeletal and dental Class I and a balanced occlusion were associated with a shorter OT.

OT was also shown to be dependent on tooth morphology and anterior guidance, being higher when the opening angle of the slopes of the cusps increases, and when the furrow angle of aperture between the cusps decreases.[19] In fact, subjects examined before and after prosthetic treatment of complete dentures showed changes of OT, with significant reduction after 3 months, in females. This was attributed to the difference of occlusal morphology between the old and the new dentures.[20] However, in the current study, no difference was found between genders.

Baldini et al revealed increased OT in patients with temporomandibular disorders, probably due to the presence of pain and dysfunction

TABLE 3 Distribution (%) of the lateral occlusal scheme among the different studied variables

	Canine guidance ((n = 30)	Group function (n = 56)	Both (n = 46)	*P* value
Dental Occlusal Relationship				
Class I normal occlusion (n = 26)	9 (34.6)	5 (19.2)	12 (6.2)	.045[a]
Class I malocclusion (n = 37)	12 (32.4)	15 (40.5)	10 (27.0)	
Class II malocclusion (n = 38)	6 (15.8)	19 (50.0)	13 (34.2)	
Class III malocclusion (n = 31)	3 (9.7)	17 (54.8)	11 (35.5)	
Skeletal Relationship				
Class I (n = 68)	22 (32.4)	22 (32.4)	24 (35.3)	.049[a]
Class II (n = 39)	6 (15.4)	20 (51.3)	13 (33.3)	
Class III (n = 25)	2 (8.0)	14 (56.0)	9 (36.0)	
Overjet				
Increased (n = 53)	10 (18.9)	26 (49.1)	17 (32.1)	.161[a]
Average (n = 62)	19 (30.6)	21 (33.9)	22 (35.5)	
Decreased (n = 17)	1 (5.9)	9 52.9)	7 (41.2)	
Overbite				
Increased (n = 62)	13 (21.0)	26 (41.9)	23 (37.1)	.067[a]
Average (n = 52)	17 (32.7)	19 (36.5)	16 (30.8)	
Decreased (n = 18)	0 (0.0)	11 (61.1)	7 (38.9)	
Space analysis				
Crowding (n = 59)	10 (16.9)	28 (47.5)	21 (35.6)	.083[a]
Adequate (n = 45)	12 (26.7)	13 (28.9)	20 (44.4)	
Spacing (n = 28)	8 (28.6)	15 (53.6)	5 (17.9)	
Crossbite				
No Cross bite (n = 103)	25 (24.3)	42 (40.8)	36 (35.0)	.672[b]
Cross bite (n = 29)	5 (17.2)	14 (48.3)	10 (34.5)	

[a]ANOVA.
[b]*t* test

that might affect the speed of mouth closing.[21] Generally speaking, a short OT indicates an adequate dental occlusion, without interferences and disease, and this was confirmed by our results.

No other studies used the terminal movement of the T-scan force trajectory graph to evaluate occlusal balance; therefore, a direct comparison of our results was not possible. However, although assessed differently, Mizui et al reported that subjects with normal tooth alignment showed complete left-right occlusal balance compared to patients with temporomandibular disorders.[22] No further information on subjects' occlusion was given; therefore, it is difficult to make a comparison with our findings. Goto et al measured occlusal balance using pressure-sensitive sheets put between the teeth. They found that patients with skeletal mandibular asymmetry showed a balance shift towards the deviated side, while no difference between the right and the left side was seen in controls without craniofacial anomalies.[23]

While it seems logical that all the features that characterise ideal occlusion, such as dental and skeletal Class I, average overjet and overbite, adequate spacing and absence of crossbite show the highest percentage of balanced occlusion, in the present study patients with potentially balanced occlusion were the most numerous in almost all groups. This seems to suggest that a perfectly balanced dental occlusion is ideal to inspire and aim for, but it is not frequently seen in reality.

Our results show an association between lateral guidance and both dental and skeletal Classes of occlusion, with Class I occlusion subjects displaying a higher prevalence of canine guidance; however, such association was not reported by other studies, where different findings were described. No other studies evaluated the lateral occlusal guidance using the T-Scan III, and other methods have been used. Al-Nimri et al evaluated static and dynamic dental occlusion using intraoral examination and a shimstock. They assessed the occurrence of canine, balanced and group function at 0.5 mm and 3 mm lateral excursion, and their findings are very interesting. At 0.5 mm lateral excursion, only subjects with Class I dental occlusion showed canine guidance. Nevertheless, canine guidance was not the most prevalent lateral occlusal scheme. At 3 mm lateral excursion, 70% of the subjects with bilateral Class II dental occlusion and 37% of the subjects with bilateral Class I dental occlusion showed canine guidance.[16] This was also reinforced by another study where a significant association was found between Class II malocclusion and the presence of canine guidance.[24] However, this trial studied 14- to 17-year-old children, while our sample included subjects with a mean age of about 21 years (21.3 ± 5.2 years for males, 21.1 ± 4.7 years for females), and the prevalence of canine guidance has been shown to decrease with age.[25] As tooth wear develops on the canines, the angle of guidance lessens and more posterior contacts become recruited.[25] A different trial studied the relationship between the presence of unilateral posterior crossbite and lateral guidance angle. They found that such angle was lower on the side of the crossbite, and higher on the opposite side. Although no distinction was made between canine and group function, the fact that group function can be established after wearing of the canines suggests that unilateral crossbite might be associated to the presence of group function, compared with the opposite side where no crossbite was present.[26] This would be in partial agreement with the present study, because, although non-significant, a tendency towards a higher prevalence of group function in subjects with unilateral crossbite was detected. However, group function was the most frequent lateral guidance in both groups.

The limitations of the current study are mainly due to the fact that, although the sample size of the total sample was calculated, the numbers were not equally distributed among the categories, with some groups including only a few patients. Furthermore, the use of occlusal indicators necessarily modifies tooth contacts; consequently, measurements of the variables assessed might not identify real occlusion.[27,28]

5 | CONCLUSIONS

Patients with Class I occlusion showed the least occlusion time, the most balanced occlusion and a higher frequency of canine guidance. Nonetheless, potentially balanced occlusion and group function were highly prevalent in all groups; therefore, ideal occlusion must be considered an ideal to inspire and aim for, but cannot be considered an essential requirement of every dental treatment.

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CONFLICT OF INTEREST

The authors state that they have no conflict of interest to declare.

AUTHORS' CONTRIBUTION

All authors contributed to the conception and design of the research. Data collection was performed by MAA. KHZ and MM performed the data tabulation and statistical analysis. AAA, MAA and KAT verified the analytical methods. MM and KHZ were involved in data interpretation. All authors contributed to drafting the manuscript, revision and proof reading.

PEER REVIEW

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