Chewing side, bite force symmetry, and occlusal contact area of subjects with different facial vertical patterns

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Abstract: Craniofacial dimensions influence oral functions; however, it is not known whether they are associated with function asymmetry. The objective of this study was to evaluate chewing side preference and lateral asymmetry of occlusal contact area and bite force of individuals with different craniofacial patterns. Seventy-eight dentate subjects were divided into 3 groups according to the VERT index as follows: (1) mesofacial, (2) brachyfacial and (3) dolichofacial. Chewing side preference was evaluated using jaw tracking equipment, occlusal contact area was measured by silicon registration of posterior teeth, and bite force was measured unilaterally on molar regions using 2.25 mm-thick sensors. Statistical analysis was performed using ANOVA on Ranks, Student's *t*-test, and Mann-Whitney tests at a 5% significance level. Mesofacial, brachyfacial, and dolichofacial subjects presented more occlusal contact area on the left side. Only dolichofacial subjects showed lateral asymmetry for bite force, presenting higher force on the left side. No statistically significant differences were found for chewing side preference among all groups. Within the limitations of this study, it can be concluded that craniofacial dimensions play a role in asymmetry of bite force. ClinicalTrials.gov ID: NCT01286363.

Descriptors: Bite Force; Dental Occlusion; Face; Mastication.

Introduction

Basic jaw opening and closing movements during mastication are centrally determined and adjusted by receptors found in the periodontium, the temporomandibular joints, the tongue, mucosa, tendons, and muscle spindles of elevator muscles, all of which play an important role in chewing.[1] Therefore, differences in jaw rotation between short- and long-faced subjects could lead to alterations of muscular force axes and to different stimulation of muscle spindles of elevator muscles.[2]

It has been reported that the masticatory muscles of dolichofacial subjects are less efficient in generating bite force at a particular point on the lever arm, due to reduced mechanics when compared to brachyfacial subjects.[3,4] If bite force is considered to be a key determinant of masticatory function,[5] then it would be expected that mastication would also be affected by craniofacial morphology.[6]

Reduced masticatory function is also related to smaller occlusal contact area.[7] During growth, the musculature of the neck attached to the

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mandible must lengthen in synchrony, otherwise there is a tendency for a rotational growth pattern and a possible drift of posterior mandibular teeth in compensation,[8] as may be found in dolichofacial subjects. In adults, it has been reported that cervical muscles play a role in the exertion of bite force. Lower activity of these muscles has been associated with smaller occlusal contact area,[9] suggesting an indirect association between craniofacial dimension and occlusal contact area.

In order to achieve good food manipulation and transport, tongue and other tissue movements must be facilitated during mandibular movements for repositioning of mandibular teeth during sequential chewing strokes,[10] suggesting that wide, bilateral chewing cycles are related to better masticatory performance.[11] Unilateral chewing is found to be present in 45% to 97%[12-14] of the population, and is associated with centrally controlled factors, such as handedness,[12] unilateral signs of temporomandibular disorders, asymmetrical loss of antagonist contact, and presence of removable partial dentures.[13] In a dentate population, chewing side preference was present in almost half the subjects, and was associated with lateral asymmetry of bite force and occlusal contact area.[14] However, no studies concerning either occlusal or functional asymmetry in individuals with different facial highs has been found in the literature.

It has been reported that dolichofacial subjects need greater muscular effort during mastication as compared to meso- and brachyfacial subjects.[6] This may cause functional overloading of weaker masticatory muscles, and may lead to more masticatory and cervical muscle tenderness in long-faced individuals.[15]

Different craniofacial vertical dimensions lead to mechanical differences in masticatory parameters,[3,4,7] which may be of great importance for rehabilitation treatment planning, as the particularities of each facial pattern can interfere with the prosthesis prognosis. The purpose of this study was to verify whether subjects with different craniofacial morphologies present chewing side preference for mastication and lateral asymmetries of bite force and occlusal contact area.

Methodology

The research protocol (number 059/2004) was approved by the Ethics Committee of Piracicaba Dental School, State University of Campinas and all participants signed a written informed consent. Students and staff of Piracicaba Dental School, and individuals seeking dental treatment at the same institution were evaluated. Seventy-eight healthy dentate subjects (39 males and 39 females) with a mean age of 23.5 years-old were selected to participate in this study according to the following inclusion criteria: subjects must present no facial deformities, no severe malocclusion (anterior open bite, cross-bite), no history of signs or symptoms of temporomandibular disorder, no history of parafunctions, no history of maxillofacial surgery or jaw injuries, and no orthodontic treatment concluded in the last 2 years.

The weight (kg) and height (m) of the subjects who agreed to participate in this study were measured (Welmy, Santa Bárbara D'Oeste, Brazil) to control anthropometric data. Cephalometric exams were performed for all participants using the standard protocols and the same radiographic unit (Macrotec Indústria e Comércio de Equipamentos Ltda., São Paulo, Brazil). The cephalograms were processed (Macrotec Indústria e Comércio de Equipamentos Ltda, São Paulo, Brazil) and analyzed by digital cephalometric analysis software (Radiocef v.4.0, Radio Memory Ltda, Belo Horizonte, Brazil). The VERT Index was used to determine the facial vertical pattern of the subjects, who were divided into 3 groups (for each group, n = 26) according to the facial type:

1. mesofacial (VERT Index between −0.49 and + 0.49),
2. brachyfacial (VERT Index > 0.5) and
3. dolichofacial (VERT Index < − 0.5).[16]

Cephalometric analysis and classification of the subjects by facial pattern were performed by a single operator. Two additional, different operators who were blinded for facial pattern collected the bite force and occlusal contact data.

Bite force

A transducer composed of two sensors (HBM, São Paulo, Brazil) was used and the signs were registered, amplified and analyzed by Catman Easy (HBM, São Paulo, Brazil) software. The sensors measured 12 mm (diameter) and 0.25 mm (thick); FSR Nº 151 (Interlink Electronics Inc., Camarillo, USA), and were protected on both sides with a metal device measuring 1 mm thick, constituting a system that measured 2.25 mm thick. The sensors were positioned unilaterally on the first molar region by the operator and subjects were instructed to occlude the teeth and bite as hard as they could during a 7-second period (Figure 1). After a 2-minute interval for release, the procedure was repeated for the other side. The order of sides on which the test was performed was randomized.

Occlusal contact area

Addition silicone (Bosworth Company, Skokie, USA) occlusal registrations of the posterior teeth (molars and premolars) were obtained bilaterally[17] using plastic frames (Bosworth Company, Skokie, USA). Subjects were asked to close their teeth into the maximum intercuspal position and instructed to maintain that position until complete setting of the silicone had occurred.[18] The registration was carefully removed from the subject's mouth and prepared for image analysis.[18]

Each occlusal registration was digitized using a desktop scanner (Hewlett Packard Development Company, Barueri, Brazil); registrations were placed with the mandibular occlusal surface facing downward.[17] Adobe Photoshop CS3 software (Adobe Systems Inc., San Jose, USA) was used to transform the image to greyscale, invert, and adjust the images. Pieces of the same addition silicone of known thickness as measured with a digital caliper (Digimess Instrumentos de Precisão Ltda., São Paulo, Brazil) were analyzed by the Image Tool software (University of Texas Health Science Center, San Antonio, USA) and used to establish the relationship between silicone thickness and each of the 256 gray shades (Figure 2). The same software was used to manually trace the occlusal contact areas of posterior teeth of 3× magnified images. Traced occlusal contact areas were automatically calculated by the software by the frequency distributions of pixels corresponding to each of 256 gray shades.[17] For the purposes of this study, it was considered that occlusal contact areas presented as regions of the impression material that were less than 50 μm thick, while regions near the contact area measured from 50 μm to 350 μm thick;[17] hence, areas of silicone thickness up to 350 μm were assessed.[18]

Determination of preferred chewing side

To determine whether the subjects presented bilateral or unilateral (right or left) mastication, a 3D jaw-tracking device (Myotronics-Noromed Inc.,

Figure 1 - Bite force sensor positioned unilaterally on the first molar region.

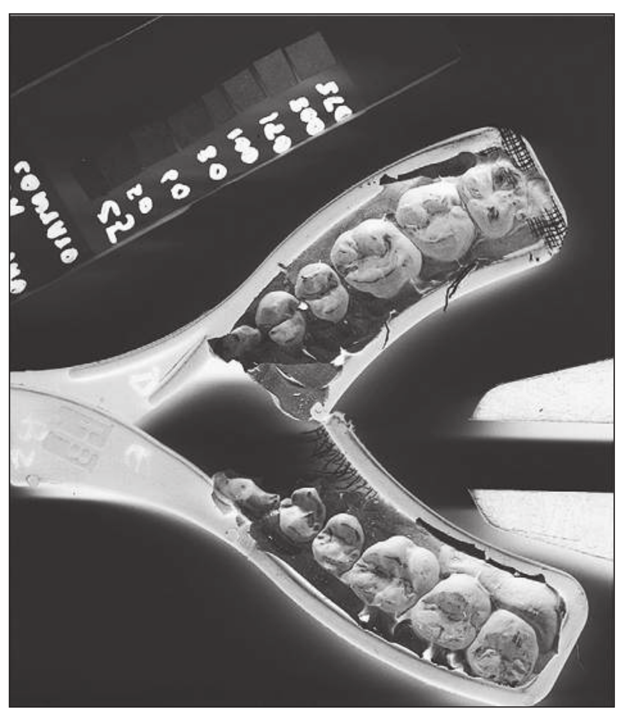

Figure 2 - Transformed to grayscale and inverted image of silicon record used to establish silicon thickness.

Kent, USA) was used as the subject sat in a dental chair with the Frankfort plane parallel to the ground. An electromagnetic field was created around the subject's face by placing the device, which captures the signal of a magnet temporarily bonded (GC America Inc., Alsip, USA) to the buccal face of the mandibular incisors. For this reason, subjects could not be wearing a pacemaker. Mandibular movements were recorded during mastication of 3.4 g of a rubber-based artificial test material (Heraeus Kulzer, Hanau, Germany) for 15 chewing cycles. The jaw-tracking device was set at Scan 3 mode. Each chewing stroke was first evaluated vertically, after being broken into three phases: open, closed and occlusal. A slice level was determined as vertical displacement of 0.7 mm below maximum intercuspation position. Tracing above the slice level and below maximum intercuspation was determined as the occlusal phase. Each chewing cycle was identified from the starting time of an opening phase (the end of a previous occlusal phase) until the end of the next occlusal phase, as previously described.[19] After identification, chewing strokes were analyzed laterally and each cycle was determined as right, left or bilateral according to the lateral position during the occlusal phase of a given stroke. To present unilateral mastication or a preferred chewing side, the participant was required to perform 80% of the strokes coinciding on one side,[20] i.e., twelve out of fifteen chewing strokes.

Statistical analysis

Normal and equal variance tests were performed using SigmaPlot software (v. 11.0, Systat Software Inc., Chicago, USA): to analyze homogeneity of the sample, concerning weight, height, and age of meso-, brachy-, and dolichofacial subjects. ANOVA one-way and ANOVA on Ranks methods were used.

To analyze the type of chewing (uni- or bilateral) among meso-, brachy-, and dolichofacial subjects, ANOVA on Ranks was performed. Analysis of asymmetry of occlusal contact area and bite force was performed between right and left sides for each facial pattern using Student's *t*-test. Data of mesofacial subjects for bite force, and data of meso- and dolichofacial subjects for occlusal contact area were subjected to logarithmic transformation before performing parametric tests.

Additionally, analysis of correlation between maximum bite force (MBF) and occlusal contact area (OCA) was assessed using the Pearson Correlation Coefficient as follows:

1. MBF and OCA of the right side within each facial pattern separately;
2. MBF and OCA of the left side within each facial pattern separately;
3. MBF and OCA of the right side regardless of facial pattern (all groups – general right side);
4. MBF and OCA of left side regardless of facial pattern (all groups – general left side);
5. Bilateral MBF and OCA (sum of right and left sides) regardless of facial pattern (all groups – bilateral general).

All analyses were assessed at a 5 % significance level.

Results

A homogeneous distribution between meso-, brachy- and dolichofacial subjects was observed with regard to weight, height, and age ($p > .05$).

No statistical difference was found among groups ($p > .05$) with regard to chewing side preference, although more dolichofacial subjects tended to present unilateral chewing (Table 1).

Concerning craniofacial morphology, meso-, brachy-, and dolichofacial subjects presented different values of occlusal contact area for each chewing side, with larger measurements on the left side. For bite force, only dolichofacial individuals demonstrated higher force on the left side (Table 2).

A significant positive correlation between maximum bite force and occlusal contact area was observed for right ($r^2 = 0.341$) and left ($r^2 = 0.273$) sides

Table 1 - Distribution of chewing type in subjects with different facial vertical patterns. Absolute and relative (%) values.

Type of chewing	Mesofacial	Brachyfacial	Dolichofacial
Bilateral	18 (69.2%)	18 (69.2%)	13 (50.0%)
Unilateral			
• Right	4 (15.4%)	4 (15.4%)	8 (30.8%)
• Left	4 (15.4%)	4 (15.4%)	5 (19.2%)

Table 2 - Lateral asymmetry of OCA (mm^2) and bite force (Kgf) between subjects with different facial vertical patterns.

	OCA		Bite force	
	Right	Left	Right	Left
Mesofacial	46.8 ± 5.8	75.7 ± 8.6*	23.4 ± 13.0	26.5 ± 13.0
Brachyfacial	53.7 ± 10.4	90.4 ± 17.8*	31.0 ± 10.4	36.6 ± 10.2
Dolichofacial	37.5 ± 8.9	60.0 ± 15.2*	16.1 ± 8.4	21.1 ± 10.2*

OCA = Occlusal Contact Area *Difference between right and left sides for each group and variable $p < .05$.

separately, as well as when variables of both sides were summed (bilateral; $r^2 = 0.360$); i.e., the stronger the bite force, the larger the occlusal contact area unilaterally or bilaterally when groups were analyzed together (Table 3).

Table 3 - Pearson correlation coefficient of maximum bite force and occlusal contact area (r^2).

	Right	Left	Bilateral
Mesofacial	–0.219	–0.209	–0.232
Brachyfacial	0.215	0.212	0.255
Dolichofacial	–0.002	–0.201	–0.126
Mesofacial+brachyfacial +dolichofacial	0.341*	0.273**	0.360***

*$p = 0.002$; **$p = 0.017$; ***$p = 0.001$.

Discussion

Bite force,[4] occlusal contacts, type of chewing and craniofacial dimensions are reported as important factors that can influence oral functions;[6,11] however, the relationships among these factors have yet to be studied.

It has been reported that dentate subjects with no malocclusion and unilateral mastication present different values of bite force and occlusal contact area between right and left sides, suggesting that these peripheral factors are involved in the mechanism of chewing side preference rather than central factors, once the type of chewing was not associated to handedness.[14] Since balanced bilateral mastication has been suggested to be associated with more effective mastication,[11] it is possible that lateral asymmetric forces and contacts may promote unbalanced oral functions.

No studies relating the type of mastication to craniofacial vertical morphology have been found in the literature. The present study evaluated this relationship both directly and indirectly, by means of asymmetry of bite force and occlusal contact area. Meso-, brachy-, and dolichofacial individuals presented asymmetry in occlusal contact area, showing larger values on the left side. Asymmetry of bite force was found only in dolichofacial subjects, with higher bite force exerted on the left side. Despite this finding, analysis of type of mastication in subjects with different facial vertical patterns found no differences among groups. However, a tendency for there to be a relationship between long-faced subjects and unilateral chewing is suggested by the data, given that 50% of the dolichofacial group presented chewing side preference, as opposed to meso- and brachyfacial groups, of whom 30.8% were unilateral chewers. This may be explained by the weaker masticatory muscles found in long-faced individuals,[15] suggesting that weaker muscles could also present a tendency for unbalanced functions.

Although there were no significant differences between type of mastication and distinct craniofacial morphologies, it should be noted that dolichofacial subjects presented greater chewing preference on the right side when compared to mesofacial and brachyfacial individuals. As already pointed out, all subjects, regardless of facial pattern, exhibited greater occlusal contact area on the left side. Similar asymmetry occurred in long-faced individuals for bite force. It was expected that individuals with these asymmetries would show a preference for the left side during mastication, as stated by Martinez-Gomis *et al.*,[14] who used the same artificial material for chewing as in this study. However, the authors of the Martinez-Gomis study conducted the evaluation of chewing side preference by observation of mandibular movements. The present study used kinesiographic analysis, which seems to be the most reliable technique, as it is able to detect unidentified cycles and very small lateral movements that may not be detected by visual methods.[21] It may be suggested that central factors play a major role in the determination of chewing side preference[12] of dentate and healthy subjects; however, central factors such as handedness and footedness were not evaluated in the present study.

Masticatory function is predicted by a number of parameters, including bite force[5] and occlusal contact area[7], that suggest that the higher the bite force and the larger the occlusal contact area, the more efficient the mastication. Thus, it would be expected that the above-mentioned variables are positively correlated to improved mastication. In the present study, when the correlation between bite force and occlusal contact area was analyzed both unilaterally and bilaterally in the total sample (n = 78) rather than group by group, significant results were observed. The same correlation could not be detected for unilateral analysis of groups evaluated separately. Sample size for analysis within groups (n = 26) may have not been sufficiently large to show a significant correlation.

There are still many questions that need to be answered with regard to the predictors and the mechanisms involved in mastication. It is of great value to understand the needs of patients during rehabilitation treatments, as a variety of information is important in order to make effective decisions. For this reason, specific functional characteristics of people with different facial morphology and chewing side preference are significant and need further clinical investigations.

Conclusion

In the terms under which this study was conducted, it can be concluded that lateral symmetry of bite force is affected by craniofacial vertical pattern.

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References

1. Bosman F, Van der Bilt A, Abbink JH, Van der Glas HW. Neuromuscular control mechanism in human mastication. J Texture Stud. 2004 Jun;35(2):201-21.
2. Miralles R, Dodds C, Manns A, Palazzi C, Jaramillo C, Quezada V, *et al*. Vertical dimension. Part 2: the changes in electrical activity of the cervical muscles upon varying the vertical dimension. Cranio. 2001Jan;20(1):39-47.
3. Throckmorton GS, Finn RA, Bell WH. Biomechanics of differences in lower facial height. Am J Orthod. 1980 Apr;77(4):410-20.
4. García-Morales P, Buschang PH, Throckmorton GS, English JD. Maximum bite force, muscle efficiency and mechanical advantage in children with vertical growth patterns. Eur J Orthod. 2003 Jun;25(3):265-72.
5. Hatch JP, Shinkai RSA, Sakai S, Rugh JD, Paunovich ED. Determinants of masticatory performance in dentate adults. Arch Oral Biol. 2001 Jul;46(7):641-8.
6. Gomes SG, Custodio W, Faot F, Del Bel Cury AA, Garcia RC. Masticatory features, EMG activity and muscle effort of subjects with different facial patterns. J Oral Rehabil. 2010 Nov;37(11):813-9.
7. Lujan-Climent M, Martinez-Gomis J, Palau S, Ayuso-Montero R, Salsench J, Peraire M. Influence of static and dynamic occlusal characteristics and muscle force on masticatory performance in dentate adults. Eur J Oral Sci. 2008 Jun;116(3):229-236.
8. Ranly DM. Craniofacial Growth. Dent Clin North Am. 2000 Jul;44(3):457-70.
9. So K, Komiyama O, Arai M, Kawara M, Kobayashi K. Influence of occlusal contact on cervical muscle activity during submaximal clenching. J Oral Rehabil. 2004 May;31(5):417-22.
10. Mioche L, Hiiemae KM, Palmer JB. A postero-anterior videofluorographic study of the intra-oral management of food in man. Arch Oral Biol. 2002 Apr;47(4):267–80.
11. Wilding RJ, Lewin A. The determination of optimal human jaw movements based on their association with chewing performance. Arch Oral Biol. 1994 Apr;39(4):333-43.
12. Nissan J, Gross MD, Shifman A, Tzadok L, Assif D. Chewing side preference as a type of hemispheric laterality. J Oral Rehabil. 2004 May;31(5):412-6.
13. Diernberger S, Bernhardt O, Schwahn C, Kordass B. Self-reported chewing side preference and its associations with

occlusal, temporomandibular and prosthodontic factors: results from the population-based Study of Health in Pomerania (SHIP-0). J Oral Rehabil. 2008 Aug;35(8):613-20.
14. Martinez-Gomis J, Lujan-Climent M, Palau S, Bizar J, Salsench J, Peraire M. Relationship between chewing side preference and handedness and lateral asymmetry of peripheral factors. Arch Oral Biol. 2009 Feb;54(2):101-7.
15. Sonnesen L, Bakke M, Solow B. Temporomandibular disorders in relation to craniofacial dimensions, head posture and bite force in children selected for orthodontic treatment. Eur J Orthod. 2001 Apr;23(2):179-92.
16. Ricketts RM, Roth RH, Chaconnas SJ, Schulhof RJ, Engle GA. Orthodontic Diagnosis and planning. Denver: Rocky Mountain Data System; 1982. 269 p.
17. Owens S, Buschang PH, Throckmorton GS, Palmer L, English J. Masticatory performance and areas of occlusal contact and near contact in subjects with normal occlusion and malocclusion. Am J Orthod Dentofacial Orthop. 2002 Jun;121(6):602-9.
18. Gurdsapsri W, Ai M, Baba K, Fueki K. Influence of clenching level on intercuspal contact area in various regions of the dental arch. J Oral Rehabil. 2000 Mar;27(3):239-44.
19. Yoshida E, Fueki K, Igarashi Y. Association between food mixing ability and mandibular movements during chewing of a wax cube. J Oral Rehabil. 2007 Nov;34(11):791-9.
20. Varela JMF, Castro NB, Biedma BM, da Silva Domínguez JL, Quintanilla JS, Muñoz FM, *et al*. A comparison of the methods used to determine chewing preference. J Oral Rehabil. 2003 Oct;30(10):990-4
21. Paphangkorakit J, Thothongkam N, Supanont N. Chewing-side determination of three food textures. J Oral Rehabil. 2006 Jan;33(1):2-7.