Prospective Clinical Research Report

Journal of INTERNATIONAL MEDICAL RESEARCH

Journal of International Medical Research
48(10) 1–9

DOI: 10.1177/0300060520962943
journals.sagepub.com/home/imr
SAGE

Maximum voluntary molar bite force in subjects with malocclusion: multifactor analysis

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Abstract

Objective: This study was performed to determine the maximum voluntary molar bite force (MVMBF) in relation to age, sex, lip competency, midline shifting, dental and skeletal malocclusion, overjet, overbite, and crowding.

Methods: One hundred Saudi patients with orthodontic malocclusion aged 14 to 25 years (51 male and 49 female patients) were investigated in this cross-sectional study. The baseline MVMBF on the right and left side was evaluated in all patients before commencing any orthodontic treatment. The MVMBF was registered with a portable occlusal force gauge in the first molar region during maximal clenching.

Results: The MVMBF significantly varied with respect to all nine confounding variables. The MVMBF significantly increased with an age of >18 years, male sex, right-side lip competency, no midline shift, dental and skeletal Class I malocclusion, normal overjet, normal overbite, and mild crowding.

Conclusion: All nine variables examined in the present study significantly influenced the MVMBF.

Keywords

Bite force, malocclusion, fixed orthodontic treatment, confounding variables, lip competency, midline shift, cross-sectional study

Date received: 5 May 2020; accepted: 3 September 2020

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Introduction

In routine dental practice, clinicians encounter a variety of patients with various types of malocclusion. Extensive research is being performed to examine the bite force in patients with different problems and elucidate the effects of different methods of oral rehabilitation on the bite force to increase the accuracy of diagnosis and treatment planning. The bite force is a valuable indicator of the efficacy of the masticatory apparatus. According to Fontijn-Tekamp et al.,[1] the bite force is a measure of masticatory performance. In addition, the maximum voluntary molar bite force (MVMBF) may vary according to age and sex[2,3] as well as height and facial morphology.[3,4]

Notably, studies focusing on the actual relationship between the bite force and these variables have produced inconsistent results.[5,6] The MVMBF is associated with the efficiency of the masticatory system[7] and may impact the development of masticatory function during dental development.[8] Hence, its measurement could serve as an important screening method. The findings to date, particularly in relation to the MVMBF, are quite variable.[9] Such vast variations are attributed to differences in the test populations (ethnic groups) or to disparities in the devices and methodologies employed in these previous studies.[10] However, Tortopidis et al.[11] indicated that several other patient-specific factors, such as the pain threshold, dentition status, and strength of the muscles involved in mastication, might influence the MVMBF. The degree of jaw opening may also substantially influence the MVMBF.

Studies have been performed to evaluate the MVMBF in pre-orthodontic children with a unilateral crossbite[12] and in patients with different facial types to determine the effect of the type of functional occlusion and the influence of premature contacts and parafunctional habits.[13] Studies have also focused on patients with Class I normal occlusion and different types of malocclusions[14] to examine the effects of sex, body mass index, morphological occlusion, and jaw function evaluated using the number of occlusal contacts, overjet, overbite, maximal mouth opening, mandibular deflection during opening, sagittal slide between the retruded contact position and the intercuspal position, and number of dental restorations.[5] Moreover, research has been performed to compare patients with normal occlusion and different Angle malocclusions, to analyze the frequency of occurrence of each type of occlusion, and to identify any disparities between force and body mass index-associated bite force.[15] In another study, whether appliance type affects changes in MVMBF and the number of occlusal contacts during retention, controlling for sex, age, and body mass index.[5]

Both investigators and clinicians would benefit from objective data regarding stabilization of the MVMBF. Reference values of such data for different age groups could be used to objectively evaluate the occlusion of patients with orthodontic problems (either evaluation of various malocclusion conditions or prospective evaluation during different treatment phases). This is the first-in-human study to evaluate the MVMBF in relation to nine different confounding variables in orthodontic patients.

Methods

In 2014, de Araújo et al.[15] found that the mean MVMBF was 372.2 ± 133.8 and 265.1 ± 105.9 N in patients with normal occlusion and class III malocclusion, respectively. According to these values, the calculated Cohen's d and effect-size r were 0.887 and 0.405, respectively.[15] The software used in that study was G*Power software version 3.0.10 with power of 80%, α of 0.05, and effect size (d) of 0.4.[15] The total sample in the present cross-sectional study was determined to be 102. Only patients with a full complement of permanent teeth were included in the study. Patients with disorders of the temporomandibular joint, neurologic diseases, missing or restored permanent first molars, or chronic illnesses were not included in the study. After obtaining ethical clearance from the Institutional Ethics Committee of Jouf University, Sakaka, Saudi Arabia (LCBE 1-19-9/39), 100 patients (51 male and 49 female patients) aged 14 to 25 years from the specialist orthodontic clinic at the College of Dentistry, Jouf University, Sakaka, Saudi Arabia were included in the study. Written consent was obtained from all volunteers; in case of minor patients, consent was obtained from both the patient and his or her legal guardian after explaining the procedure and nature of the study.

All patients were divided into various groups based on data in their routine orthodontic records, such as their history and clinical examination findings, model analysis, orthopantomographs, and lateral cephalometric radiographs. The patient distribution and group splitting among all nine confounding are shown in Table 1. This study explored the MVMBF of the right and left sides in relation to sex (male and female), age (<18 and >18 years), lip competency (competent and incompetent),[16] midline shifting (shift and no shift),[16] dental malocclusion (Class I, II, and III Angle molar occlusion), skeletal malocclusion (Class I, II, and III ANB values), overjet (normal, increased, and decreased), overbite (normal, increased, and decreased),[18] and crowding (mild, moderate, and severe).[16]

Table 1. Patient distribution and confounding variables.

Variables	Groups	N = 100
Age, years	<18	49
	>18	51
Sex	Female	49
	Male	51
Lip competency	Competent	52
	Incompetent	48
Midline shift	No shift	37
	Shift	63
Dental malocclusion	Class I	41
	Class II	29
	Class III	30
Skeletal malocclusion	Class I	44
	Class II	29
	Class III	27
Overjet	Normal	36
	Increased	33
	Decreased	31
Overbite	Normal	42
	Increased	27
	Decreased	31
Crowding	Mild	43
	Moderate	25
	Severe	32

Bite force measurement

A portable occlusal force gauge (GM10; Nagano Keiki, Tokyo, Japan) was used to measure the MVMBF in the permanent first molar region in this study. This device has a hydraulic pressure gauge and a biting element enclosed in a plastic tube.[17,18] The registered bite force is displayed on the digital screen of the device in Newtons. The sensitivity and reliability were investigated and approved by Sakaguchi et al.[18] The patients were trained to bite as hard as they could after placing the device on the first molar on one side, and the MVMBF was evaluated. This was repeated on the other side to complete the process of recording the bite force. The procedure was repeated three times in every participant on each side with a time gap of 3 minutes to prevent any influence of muscle fatigue, and the arithmetic means of all measurements were calculated. The mean values calculated for both sides were regarded as the patient's MVMBF.

After each recording, the latex finger cots were changed and the device was sterilized with 70% isopropyl alcohol.

Statistical analysis

IBM SPSS Statistics for Windows, Version 22.0 (IBM Corp., Armonk, NY, USA) was used for the statistical analyses. Measurements were repeated after a 2-week interval in 20 randomly selected patients to confirm the reliability and tested using the intraclass correlation coefficient. The Shapiro–Wilk test revealed a normal data distribution; therefore, a paired-sample *t* test, independent-sample *t* test, and one-way analysis of variance with multiple comparisons by the Bonferroni post-hoc test were used. The level of statistical significance for all tests was set at $p < 0.05$.

Results

The intraclass correlation coefficient ranged from 0.86 to 0.98.

The results of the paired *t* test comparison are presented in Table 2. There were significant disparities in the MMVBF among all nine confounding variables. The MVMBF was significantly higher on the right than left side at >18 years of age (508.94 ± 69.97 vs. 469.12 ± 89.06 N, respectively; $p = 0.001$). It was also higher on the right than left side in male patients (486.08 ± 116.9 vs. 464.77 ± 99.41 N, respectively). The MMVBF was greater in patients with lip competence, no midline shift, Class I malocclusion, skeletal Class I malocclusion, normal overjet, normal overbite, and mild crowding ($p < 0.05$ for all).

The results of the independent t test comparison are presented in Table 3, and the results of the one-way analysis of variance are presented in Table 4. The maximum MMVBF was observed on the right side in patients without a midline shift (527.39 ± 97.262 N). The MVMBF was significantly related to malocclusion among all confounding variables and was generally higher on the right side, in male patients, and in patients aged >18 years. The MVMBF was lower in patients with Class III malocclusion (both dental and skeletal type) (Table 3).

Discussion

This study was performed to identify the significant variances of the MVMBF with respect to different malocclusions, aesthetic outcome-related factors, and junctures of multiple confounding variables. The aim was to ascertain the existence of a relationship between the MVMBF and malocclusion within a sample of the Saudi population. No such studies in which nine confounding and frequently diagnosed variables are investigated have been previously conducted in this population.

Malocclusion refers to abnormalities in the alignment of the teeth and relationship between the maxillary and mandibular teeth. It may not only result in a poor facial appearance but can also lead to debilitating functional defects. Poor oral hygiene resulting in periodontitis is one of the most common diseases associated with malocclusion. In addition, malocclusion may affect speech, digestion, temporomandibular joint function, and respiration. Different types of malocclusions have been identified, defined, and classified. In this study, the most common types of malocclusion that are encountered in daily practice were investigated to explore the disparities in the MVMBF.

In this study, we observed significant differences in the MVMBF relative to the different sexes. These findings are consistent with the outcomes of studies conducted by Palinkas et al.,[19] Braun et al.,[8] Bakke,[2] and Varga et al.[5] It is generally understood that the occlusal bite force is greater in men than in women, on the right than left side, and in

Table 2. Comparison between left and right sides in each subgroup.

Variables	Groups	Side	Mean	SD	95% CI Lower	95% CI Upper	p value
Age, years	<18	Left	265.041	199.318	−67.231	−8.565	0.012
		Right	302.939	195.930			
	>18	Left	469.118	89.063	−63.048	−16.599	0.001
		Right	508.941	69.986			
Sex	Female	Left	269.571	198.852	−86.312	−28.014	0.000
		Right	326.735	195.270			
	Male	Left	464.765	99.413	−43.644	1.016	0.061
		Right	486.078	116.900			
Lip competency	Competent	Left	387.615	187.903	−81.502	−33.229	0.000
		Right	444.981	172.343			
	Incompetent	Left	349.083	179.038	−46.344	8.636	0.174
		Right	367.938	177.757			
Midline shift	No shift	Left	495.838	83.630	−48.697	−14.385	0.001
		Right	527.378	97.262			
	Shift	Left	294.698	186.196	−70.763	−15.618	0.003
		Right	337.889	178.277			
Dental malocclusion	Class I	Left	477.878	132.246	−37.754	−2.392	0.027
		Right	497.951	133.264			
	Class II	Left	379.241	179.387	−115.515	−32.416	0.001
		Right	453.207	157.243			
	Class III	Left	210.700	131.683	−70.487	9.153	0.126
		Right	241.367	134.083			
Skeletal malocclusion	Class I	Left	451.682	112.198	−57.603	−2.079	0.036
		Right	481.523	96.285			
	Class II	Left	328.586	196.275	−77.475	−4.525	0.029
		Right	369.586	213.149			
	Class III	Left	278.111	210.597	−87.531	−15.136	0.007
		Right	329.444	199.041			
Overjet	Normal	Left	458.861	104.326	−70.453	−8.214	0.015
		Right	498.194	71.300			
	Increased	Left	326.394	187.771	−71.773	−3.864	0.030
		Right	364.212	208.367			
	Decreased	Left	310.387	214.321	−73.105	−5.863	0.023
		Right	349.871	193.210			
Overbite	Normal	Left	440.333	142.403	−59.177	−21.156	0.000
		Right	480.500	139.958			
	Increased	Left	211.667	115.028	−105.592	−11.297	0.017
		Right	270.111	139.523			
	Decreased	Left	409.774	202.917	−56.677	16.483	0.271
		Right	429.871	190.600			
Crowding	Mild	Left	452.023	120.873	−56.824	−6.013	0.017
		Right	483.442	113.592			
	Moderate	Left	237.160	156.252	−112.196	−44.764	0.000
		Right	315.640	158.021			
	Severe	Left	360.813	213.393	−55.709	19.772	0.339
		Right	378.781	221.543			

SD, standard deviation; CI, confidence interval.

Table 3. Comparison of MVMBF between two groupings of confounding variables.

Independent *t* test for MVMBF

Variables	Groups	Side	Mean	SD	95% CI Lower	95% CI Upper	p value
Age, years	<18	Left	265.041	199.318	−264.939	−143.215	<0.001
	>18		469.118	89.063			
	<18	Right	302.939	195.930	−263.941	−148.064	<0.001
	>18		508.941	69.986			
Sex	Female	Left	269.571	198.852	−257.215	−133.172	<0.001
	Male		464.765	99.413			
	Female	Right	326.735	195.270	−222.919	−95.768	<0.001
	Male		486.078	116.900			
Lip competency	Competent	Left	387.615	187.903	−34.438	111.502	0.297
	Incompetent		349.083	179.038			
	Competent	Right	444.981	172.343	7.547	146.540	0.030
	Incompetent		367.938	177.757			
Midline shift	No shift	Left	495.838	83.630	136.800	265.479	<0.001
	Shift		294.698	186.196			
	No shift	Right	527.378	97.262	126.370	252.609	<0.001
	Shift		337.889	178.277			

MVMBF, maximum voluntary molar bite force; SD, standard deviation; CI, confidence interval.

younger than older individuals. The present study showed significant differences in the MVMBF relative to the different sexes. The MVMBF was significantly related to malocclusion with respect to all confounding variables. Such associations may be attributed to the deviation of the occlusion from normal (malocclusion). In general, occlusion is considered to have two important components: that at rest is referred to as the static component, and that when the mandible is functioning is referred to as the dynamic component. The relationship between the adjacent teeth of the same arch, their relationship with the teeth of the opposing arch, and the relationship of the teeth with the periodontium (supporting alveolar bone) when the mandible is at rest constitute the static component of occlusion.[20] The term "dynamic" refers to a persistent change in the position of an object, and "dynamic occlusion" refers to the inter-arch and intra-arch relationships between the teeth and the relationship of the teeth with the supporting bone when the mandible is functioning. In contrast to the current study, Sathyanarayana et al.[14] found that the sagittal morphology does not significantly affect the MVMBF value; consistent with the current study, however, they found a significant correlation with the vertical morphology. In agreement with the current study, de Araújo et al.[15] also found that the type of occlusion influenced the MVMBF. The authors reported that the number of occlusal contacts determined the chewing efficiency and that chewing was less efficient in patients with malocclusion than normal occlusion.[15] Therefore, it can be assumed from the findings of the present study that the patients with significantly lower bite force were those with Class III malocclusion and fewer occlusal contacts.

Thorough knowledge of the development of occlusion, mastication, and their influences on the growth and development

Table 4. Comparison of MVMBF among three groupings of confounding variables.

Analysis of variance for MVMBF

Variables	Groups			Side	95% CI Lower	95% CI Upper	p value
Dental malocclusion	Class I	vs	Class II	Left	11.590	185.684	0.021
	Class I	vs	Class III		180.985	353.371	<0.001
	Class II	vs	Class III		75.117	261.966	<0.001
	Class I	vs	Class II	Right	−38.508	127.996	0.581
	Class I	vs	Class III		174.149	339.020	<0.001
	Class II	vs	Class III		122.489	301.192	<0.001
Skeletal malocclusion	Class I	vs	Class II	Left	24.571	221.621	0.009
	Class I	vs	Class III		72.870	274.271	<0.001
	Class II	vs	Class III		−59.685	160.635	0.801
	Class I	vs	Class II	Right	14.704	209.169	0.018
	Class I	vs	Class III		52.699	251.457	0.001
	Class II	vs	Class III		−68.573	148.856	1.000
Overjet	Normal	vs	Increased	Left	31.173	233.761	0.006
	Normal	vs	Decreased		45.490	251.459	0.002
	Increased	vs	Decreased		−89.121	121.135	1.000
	Normal	vs	Increased	Right	36.260	231.704	0.004
	Normal	vs	Decreased		48.971	247.676	0.001
	Increase	vs	Decreased		−87.080	115.762	1.000
Overbite	Normal	vs	Increased	Left	133.930	323.403	<0.001
	Normal	vs	Decreased		−60.381	121.499	1.000
	Increase	vs	Decreased		−299.208	−97.008	0.000
	Normal	vs	Increased	Right	115.881	304.897	<0.001
	Normal	vs	Decreased		−40.092	141.350	0.531
	Increase	vs	Decreased		−260.616	−58.903	0.001
Crowding	Mild	vs	Moderate	Left	114.332	315.394	<0.001
	Mild	vs	Severe		−2.109	184.530	0.058
	Moderate	vs	Severe		−230.347	−16.958	0.017
	Mild	vs	Moderate	Right	66.284	269.320	<0.001
	Mild	vs	Severe		10.425	198.896	0.024
	Moderate	vs	Severe		−170.883	44.601	0.470

MVMBF, maximum voluntary molar bite force; SD, standard deviation; CI, confidence interval.

of the orofacial muscles and facial skeleton as well as the possible etiological factors of abnormalities will help us understand the complicated nature of the development of normal and abnormal occlusion. A thorough understanding of the underlying physiological concepts makes it possible to predict that the occlusal bite force might be increased in a patient with Class II malocclusion with a deep bite, while the occlusal bite force might be considerably decreased in a patient with an open bite with excessive vertical growth. A similar concept can be seen in patients with normal bites and crossbites. Sonnesen et al.[12] found that the differences in the muscle function associated with unilateral crossbite led to a significantly smaller bite force in the crossbite group than in controls. In another study, the average

MVMBF was higher in patients with premature contacts than those without; it did not differ in patients with different types of functional occlusion or in the presence of parafunctional habits.[13] The current study showed alterations in the MVMBF related to midline shift. The midline can be deviated by an asymmetrical mandibular position, or midline deviation might be the reflex of intra-arch dental deviations and associated with differences in the dental occlusion between the right and left sides. More than an aesthetic problem, midline deviation can reveal mandibular functional deviation or intra-arch dental deviation with reflex on the intercuspation of teeth, leading to an asymmetrical relationship between the two sides. These problems should be taken into consideration when interpreting a patient's midline shift, and future studies on this topic are warranted.

A thorough understanding and comprehensive knowledge of the different types of malocclusion and their associated aesthetics-related problems will aid clinicians in establishing an ideal treatment plan. Recording the MVMBF is a simple, inexpensive chair-side procedure, and assessment of the MVMBF helps orthodontists to identify disturbances in the stomatognathic system and accordingly plan the type of mechanics to be employed. The bite force is the force generated during mastication, and it is a good measure of the status of the stomatognathic system. Measurement of the bite force helps to identify the presence of any derangement in this system due to any change in the occlusion, thus aiding in more accurate planning and the mechanics to be used. This study furthers new areas of research in this field, particularly the influence of the bite force on the development of malocclusion. A limitation of this study is the single ethnic group that was investigated; further studies involving different ethnic groups are needed to validate the results of this study. Additionally, because the results of this study revealed the influence of many confounding factors on the MVMBF, it would be desirable to examine each confounding factor after matching groups based on all other confounding factors to yield a clear conclusion about the examined factor. Long-term evaluation of prospective changes would be helpful to obtain confirmatory results.

Conclusion

In this study, the MVMBF was evaluated using a simple chair-side procedure in relation to age, sex, lip competency, midline shift, dental and skeletal malocclusion, overjet, overbite, and crowding. The MVMBF was significantly related to all nine variables. The findings of these relationships between the MVMBF and the various types of malocclusions assessed in this study will enable a better understanding of the etiology, manifestations, and treatments of such occlusions.

Declaration of conflicting interest

The authors declare that there is no conflict of interest.

Funding

The authors disclosed receipt of the following financial support for the research, authorship and/or publication of this article: This work was supported by the Deanship of Research, Jouf University (Research fund: 40/002).

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