

Assessment of the relationship between maximum occlusal force and median mandibular flexure in adults: A clinical trial study

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Abstract

Aim: The narrowing of the mandible during opening and protrusion movements is defined as median mandibular flexure (MMF). MMF is caused by the attachment of mandibular muscles; therefore, it can be assumed that a greater amount of maximum occlusal force (MOF) may cause more flexion and could affect the survival of dental and implant restorations. The purpose of this study was to evaluate any relationship between MOF and MMF in a sample of adults.

Settings and Design: *In vivo* – comparative study.

Materials and Methods: In this descriptive, cross-sectional, nondirectional study, a sample of 90 volunteers were recruited (45 men and 45 women). MOF was measured by applying the strain gauge receptor to the first molar region, and MMF was measured by calculating the variation in the intermolar distance by a digital caliper with an accuracy of 0.01 mm using an impression and resulted in the stone cast during the maximum opening and closed-jaw positions. The body mass index (BMI) also was calculated.

Statistical Analysis: Data were analyzed using the SPSS software (version 23) inferential and descriptive statistics, linear regression, and Pearson correlation coefficient. $P < 0.05$ was considered statistically significant.

Results: There was no statistically significant relationship between MOF and MMF ($P = 0.78$), but there was a significant association between MOF and BMI ($P < 0.001$, $r = 0.475$) and gender.


Conclusion: Although MOF and MMF are both important and effective factors in the success of prosthetic restorations, one cannot be expected by the other and both should be considered in the treatment plan separately.

Keywords: Bite force, body mass index, mandibular flexure, masticatory muscles

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INTRODUCTION

The process of mastication is an essential function for the survival of dentate organisms and has long been a subject of the study in the dental literature.^[1] Mandibular shape changes during different degrees of movement, due to the force of the attached muscles and ligaments during the movement of mandible and mastication.^[2] Median mandibular flexure (MMF) occurs during the opening and protrusive movement.^[3,4] The lateral pterygoid muscle is the most effective muscle in MMF.^[5,6] In a study conducted by McDowell and Regli,^[7] making intraoral metal splinting and reporting an MMF of about 0.5 mm in protrusion and 0.4 mm in the wide opening at the second molar region. MMF in prosthetic treatments can increase stress in abutments, fixed prostheses, and removable prostheses, thereby causing distortion and pain during function, breakage of implant screws, loosening of prosthesis cement, and porcelain fracture.^[2] The bending of the mandible can also affect the stability of the lower denture.^[5] Bending in the opening of mouth begins only after the mouth opens over 28% of the maximal mouth opening and then increases linearly with a rise in the mouth opening.^[5,8,9] Thus, MMF can be minimized by preventing protrusion or wide mouth opening during the impression.^[5] The mean bending of the mandible is greater in people with clenching. Koriath and Hannam^[10] showed that MMF ranged from 0.46 to 1.6 mm depending on the severity of the clenching. Furthermore, MMF can be affected by the other physical properties of the mandible, such as bone density, muscle strength, and age.^[11]

The nonmasticatory functional activity of the muscles is often mentioned as a factor causing the inconsistency and failure of prosthetic treatments.^[12] Maximum occlusal force (MOF) can be considered an indicator of muscle activity and muscle strength.^[13] Parafunctional habits such as clenching can increase MOF, and muscle dystrophy could decrease the bite force.^[14] The mean MOF obtained in men is higher than that of women, which is probably due to the higher average body mass index (BMI) in men than in women.^[13] It can be seen from the above studies that BMI and muscle strength affect MMF and MOF, and thus those with a higher MOF can be expected to have higher MMFs. However, few studies have explored the exact relationship between MOF and MMF, and the contradictory results from previous studies in this regard require further studies. This study aimed to evaluate the relationship between MMF and MOF in completely dentate. The null hypothesis of the study was that there would be no significant relationship between MMF and MOF.

MATERIALS AND METHODS

In this descriptive, cross-sectional, nondirectional study, a convenience sample of 90 volunteers was recruited from the Dental School of the Isfahan University of Medical Science, Isfahan, Iran; the sample size was determined based on previous studies.^[3] By 90 samples, $d = 0.18$ and the age range was 18–30-year-old students, including 45 males and 45 females, were recruited by convenience sampling. The inclusion criteria comprised the presence of all teeth (excluding the third molar), age range 18–30 years, normal occlusion, and absence of root canal therapy of first molars at both sides of the arch. The exclusion criteria consisted of the history of maxillofacial surgery, mandibular trauma, orthodontic treatment in the past 2 years, active periodontal disease, teeth mobility, bone or musculoskeletal disorders, large scalp facial lesions, facial pain, and pregnancy.

The written consent forms were completed by the volunteers of the study after providing accurate information. All procedures performed were conducted following the ethical standards given in the 1964 Declaration of Helsinki as revised in 2013 and the study was approved by Institutional review board. All of the information obtained was confidentially analyzed. The height and weight of the samples were measured and recorded. BMI was calculated by the ratio of weight in kilograms to height squared in meters. To measure the bite force, a U-shaped transducer equipped with a strain gauge as used in previous studies (FLA-5–11, Tokyo Sokki Kenkyujo Co., Ltd., Tokyo, Japan).^[15] The machine was calibrated by the unique forces of the universal testing machine (K-21046, Walter-Bai Co., Lohningen, Switzerland). The metal head of the machine was covered with 2-mm-thick rubber pads that prevented tooth damage when applying the force. After placing the head on the occlusal surface of the first molar, the volunteers were asked to close their teeth to the transducer with a maximum strength of 5–10 s. Maximum values were recorded on the monitor of the device. Measurement was performed three times on each jaw side with a 1-min interval. The average bite force was calculated for each side, and the maximum number was used for the statistical analysis. MMF is due to the difference between the intermolar distance in the resting state and the maximal mouth opening. To make an impression by closed-mouth technique, the triple-tray technique (First Bite, Dentsply Sirona, Pennsylvania, United States) was used in the closed-mouth mode. In the maximum mouth opening, a disposable tray was used with short flanges to prevent interference with the buccal mucosa during maximal mouth opening. After confirmation of the

size and the absence of any interference, the impression was made with an appropriate amount of polyvinyl siloxane impression material (Panasil, Kettenbach GmbH and Co. KG, Eschenburg, Germany) [Figure 1].

Each impression was poured with Gypsum type III (Snow rock, Mungyo Gypsum and Engineering CO, Gimhae, Korea). On the occlusal surface of the first molar of a cast, an acrylic index was made so that the index would be placed on the surface of the first molar of the second cast without obvious error [Figure 2]. Each index had a hole to place the head of the digital caliper in. The distance between the two indexes was measured by a standard digital caliper (Guangli, Guilin Guanglu Measuring Instrument Co, Ltd., Guilin, China [Figure 3]). It was measured in millimeter in each case, and the difference between the two recorded, MMFs was calculated. The calculation of MMF in each case was done blindly by two researchers. In the case of a large difference, an experienced specialist was asked to perform the measurement. Data were analyzed by SPSS software Version 23.0. (IBM SPSS Statistics for Windows, Armonk, New York) using descriptive statistics, linear regression analysis, and Pearson correlation coefficient. $P < 0.05$ was considered statistically significant. The interexaminer bias was measured by correlation analysis.

RESULTS

The purpose of this study was to investigate the relationship between MMF and MOF in a sample of 90 dental students at Isfahan University of Medical Sciences, Isfahan, Iran (45 women and 45 men). The occlusal force in this study varied from 10.9 to 60.2 kg/N in women (106.8–590.3 N) and from 19.8 to 83 kg/N in men (194–814 N). The MMF range varied from -0.38 to -4.23 mm. Mean and standard deviation of MMF, MOF, height, weight, and BMI were calculated. The mean MMF in the studied population was 0.62 ± 0.42 in men and 0.72 ± 0.73 mm in women. The interexaminer correlation was 0.95. The Pearson correlation coefficient showed no significant correlation between mean MMF and mean MOF ($P = 0.78$, $r = -0.030$). However, this test showed a significant correlation between age and MMF ($r = -0.250$, $P = 0.01$), between height and MOF ($P < 0.0001$, $r = 0.506$), and between weight and MOF ($P < 0.001$, $r = 0.612$). Moreover, there was a significantly positive correlation between BMI and MOF ($r = 0.475$, $P < 0.001$) [Figure 4].

The results of the *t*-test showed a significant difference between male and female patients in MOF, height, weight, and BMI. The frequency distribution of the studied samples in terms of MOF by sex is shown in

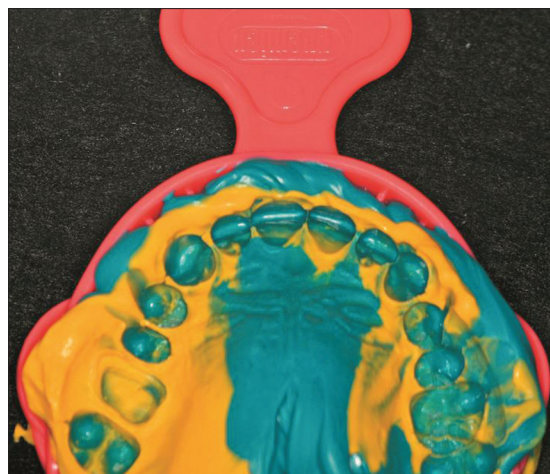


Figure 1: The triple tray used for the impression



Figure 2: Cast of the mandible with the acrylic index on the surface of the first molar



Figure 3: Measuring the distance between the two indexes by a standard digital caliper

Figure 5. The correlations obtained from the Pearson correlation coefficient between MOF, MMF, BMI, and age are presented in Table 1. Although the MMF was slightly higher in women than in men, the *t*-test showed no statistically significant difference between males and females ($P = 0.451$). No significant relationship was found in other cases.

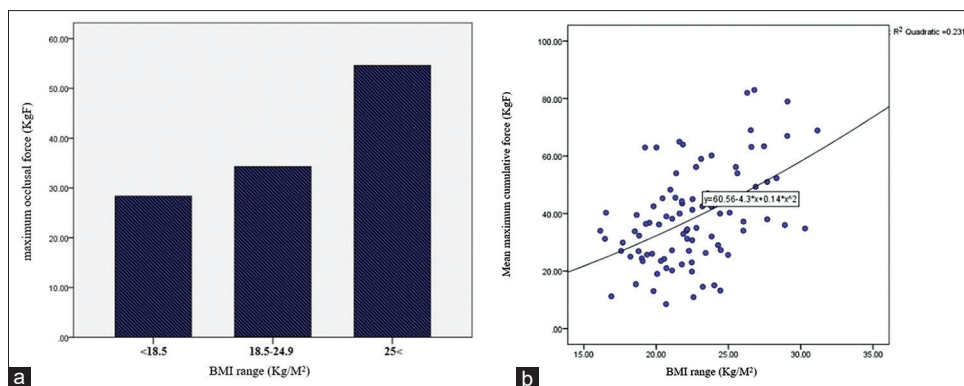


Figure 4: (a) Relationship between maximum occlusal force (Kgf) and body mass index (kg/m²). (b) Mean maximum cumulative force in the participants based on body mass index (kg/m²)

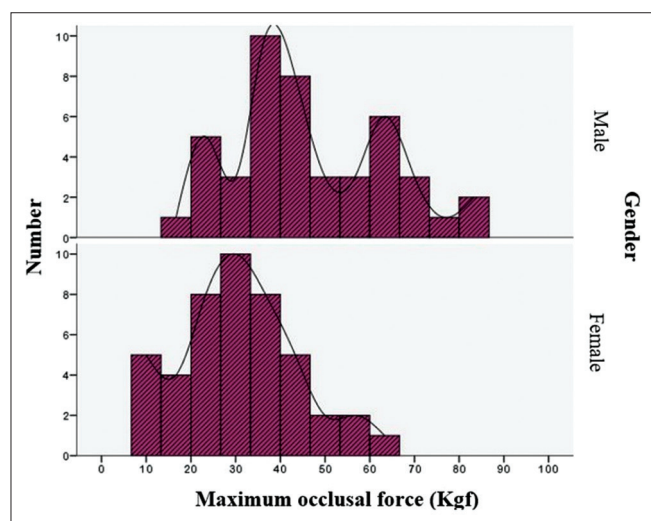


Figure 5: Frequency distribution of the studied samples based on the maximum occlusal force by gender

DISCUSSION

The null hypothesis was accepted. Although MOF and MMF are both important, one cannot be expected by the other and both should be considered in the treatment plan separately. The MMF is influenced by various factors such as symphysis bone width, bone density, mandibular length, and gonial angle.^[16] Chen *et al.*^[16] showed that the longer the mandible, the smaller the gonial angle, and the smaller the symphysis region were and the MMF was greater. Various studies have indicated a range of variations in the MMF, which may be due to the differences in the studied population. Many studies have also used a variety of methods to measure MMF. The amount of MMF has been reported to be lower *in vitro* studies than in *in vivo* studies.^[5,7,17,18] Different characteristics of the form of the face and other physiological factors such as arch shape and bone density in the studied population seem to be attributed to the amount of MMF.

Table 1: Relationship between median mandibular flexure, masticatory muscle force, age, and body mass index

	MMF (r/P)	MOF (r/P)	BMI (r/P)
MMF	-	-	-
MOF	-0.03/0.78	-	-
BMI	0.05/0.62	0.47/0.0	-
Age	-0.25/0.01	0.0/0.93	-0.06/0.53

MMF: Median mandibular flexure, MOF: Maximum occlusal force, BMI: Body mass index

As the lateral pterygoid is the main muscle at the posterior end of the mandible,^[2] it may be the cause of a smaller amount of MMF in the long-face individuals. Spronsen Van *et al.*^[19] found that long-face patients had lower cross-sectional areas of the masseter and medial pterygoid muscle. Custodio *et al.*^[20] showed that MOF, muscle activity, and MMF were associated with different forms of the face. Prasad *et al.*^[4] linked the MMF with a variety of face patterns, explaining that the maximum MMF levels would occur in the brachyfacials. Some studies have shown that individuals with a short face have the highest bite force.^[20] Different characteristics of the form of the face and other physiological factors such as arch shape and bone density in the studied population seem to be attributed to the bending rate of the mandible.

In the present study, the MMF range varied from -0.38 to -4.23 mm, which is wider than that of a similar study conducted by Canabarro Sde and Shinkai^[3] The mean MMF in the studied population was more than the mean reported by Canabarro *et al.* It may be due to the differences in the applied methods. Omar and Wise^[21] reported that the mean lateral flexure of the mandible in the horizontal plane was 0.073 ± 0.028 mm. As a corollary to the study, the mean medial flexure of the mandible in wide opening movements was found to be 0.093 ± 0.044 mm, which was consistent with earlier studies. Goodkind and Heringlake^[11] reported that the mean amounts of flexure were 0.0768 mm in the second molar region and 0.0316 mm in the first bicuspid region. Prasad *et al.*^[4] measured the MMF in three different

forms of the face. The mean MMF obtained in the mesoface group (with normal form) was consistent with the results of this study. Other studies have indicated a variable range of values in this regard.^[5,20] Considering the wide range of numbers obtained in various studies, it seems that the measurement of the MMF requires a standardized method with high accuracy as well as a broader systematic study among different populations by taking into account the physiological differences among societies. Abdel-Latif *et al.*^[6] showed that mandibular changes during the function were divided into four forms: bending-median, dorsoventral shear, corporal rotation, and posterior-anterior. Hylander also studied the effect of symphysis bone characteristics on these four patterns.^[22] The above patterns occur simultaneously during the opening and closing of the mouth, thus changing the distance between the molars in both maximal mouth opening and closed mouth is affected by all four patterns. In cases with a negative value of MMF, the intermolar distance is increased in the maximum open mouth relative to the closed mouth, which can be attributed to the dominance of other patterns of variation over the MMF. The extent of the changes resulting from these four patterns depends on the strength of the muscle and the position of the jaw.^[6] However, Abdel-Latif *et al.* indicated a simultaneous correlation between all four patterns of mandibular elastic change and masticatory muscle strength.^[6] Increased strain on masticatory muscle can increase the bone density in regions where flexural forces are applied to the mandible.^[23] The study of Chen *et al.*^[16] on the factors influencing mandibular flexural changes showed that an increase in bone density was one of the factors reducing the amount of MMF. Based on the results of this study, it can be concluded that the increase in dimensional changes due to increased muscle strength is almost neutralized by increasing the bone density. There was a negative correlation between age and MMF; the amount of MMF being decreased with a rise in the age of the participants. Studies have shown a positive relationship between age and bone density, especially in dentate individuals and a negative correlation between the number of teeth and bone density. As the age increases and the number of teeth decreases, the bone density decreases.^[24] Thus, the number of teeth probably affects MMF through bone density changes.^[11] Further, the reduced number of teeth is associated with decreased MOF.^[25] Therefore, all selected samples were completely dentate to eliminate the effect of this factor. Hence, it can be argued that increasing age has led to a decrease in MMF by increasing the bone density. Goodkind and Heringlake^[11] also considered the MMF to be a function of bone density, muscle strength, and age, which is in line with the results

obtained in this study. Since some of the studies performed in this field have found no significant correlation between MMF and age,^[3] further studies on broader age ranges are required. The mean mandibular flexion in men and women showed that the MMF was slightly higher in women than in men. However, the difference between the two groups was not statistically significant. Loth and Henneberg^[26] reported a correlation between men and women in the severity of posterior ramus flexion, which might be due to bone strength differences in the two genders. Thus, it can be expected that gender changes the elastic form of the mandible. Participants in this study were young and had maximum bone density. Considering the decrease in bone density in middle-aged and aged people, especially in women at older ages, the effect of age and bone density on the degree of MMF in both genders are likely to be more pronounced.^[27] Prasad *et al.*^[4] found no significant difference between women and men in mean MMF, which confirms the results of this study.

To measure the MOF in patients, a strain gauge device was used in design and mechanism similar to other studies.^[3,4,28] The special design of the transducer reduced the effect of the reactive forces applied to the transducer head compared to larger devices used in some studies.^[25,29] In the study of Custodio *et al.*,^[20] the sensor of the device had a thickness of 2.5 mm, which is much smaller than that of the device used in this study. Due to less mouth opening, positioning of the sensor is facilitated, and consequently, less mandibular displacement has occurred, so the measured MOF is likely to be more reliable and closer to the maximum occlusal contact. However, the measurement accuracy of the device has not been compared in different recordings of MOF.

The statistical analysis revealed a significant correlation between anthropometric indices and BMI and MOF. A similar study by Canabarro Sde and Shinkai^[3] obtained similar results. Anthropometric variables can indirectly reflect the amount of muscle mass and muscle strength. As the body height, weight, and BMI were higher, the maximum bite force was increased. However, there was no significant relationship between anthropometric and BMI indices and MMF. As these indices have been associated with MOF, this can be an indication of a lack of correlation between MMF and MOF. As the bite force values were higher in men than in women in the previous studies,^[11,30] the number of male and female participants in the present study was considered equal to control the effect of gender on the results of the study. As with other studies, the results of the present study showed that MOF strongly correlated with gender and its level was significantly higher in men than in women, which can be due to higher anthropometric

indices and BMI, more muscle diameter and attachment site, and broader type 2 collagen fibers in men than in women.^[11,30,31]

The results of this study, compared to previous studies, showed a wider range of occlusal force variations, which could be due to a wider age range of participants in the study. The mean MOF was 310 ± 123.5 N in women and 455 ± 164.7 N in men, which is lower than those recorded in the study of Julien *et al.*^[32] Shinkai *et al.*^[30] also obtained a higher mean in their study. The reason for this difference is the unequal number of samples. Different devices record the bite force differently, which will be followed by different measurement accuracy. MMF values may be increased in older people, with a lack of posterior teeth, shorter symphysis, and lower bone density due to osteoporosis. Further studies are needed to investigate other unconfirmed factors such as muscle attachment, mandible form, face form, and bone density. The two limitations of this study were the limited age range and the only inclusion of dentate cases.

CONCLUSION

Although MOF and MMF are the effective factors in the success of prosthetic restorations, there was no significant correlation between these two factors and should be considered in the treatment plan separately.

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Conflicts of interest

There are no conflicts of interest.

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