

# Maximum Voluntary Bite Force Generated by Individuals with Healthy Dentition and Normal Occlusion



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**OBJECTIVE:** masticatory muscles work coordinately along with bones and teeth in these jaws to generate occlusal bite force. The amount of force varies from person to person. This study was performed to measure the amount of bite force to associated with demographics like age and gender so that we may compare it with prosthodontically rehabilitated dentition which may help us in the treatment plan.

**METHODOLOGY:** Bite force was recorded with an Occlusal Bite force meter (GM-10 Nagano Keiki Japan). A sample of 204 Pakistani individuals who are aged between 13 to 40 years and divided into three age groups: I (13-20years), II (21-30 years), III (31-40 years) is recorded. A mean of three left sided and a mean of three right sided maximum voluntary bite forces were calculated and a final mean of the two were taken to find out the Mean Maximum Voluntary Bite force.

**RESULTS:** Mean Maximum Voluntary Bite Force was calculated as  $533.42 \text{ N} \pm 185.44 \text{ N}$ , whereas Males have Mean MVBF  $635.23 \text{ N} \pm 179.86 \text{ N}$  and Females have Mean MVBF  $431.61 \text{ N} \pm 125.82 \text{ N}$ . Mean Maximum Voluntary Bite force with respect to age; group I is  $476.11 \text{ N} \pm 181.27 \text{ N}$ , group II is  $550.93 \text{ N} \pm 191.83 \text{ N}$ . MVBF of group 3 is  $573.21 \text{ N} \pm 171.18 \text{ N}$ .

**CONCLUSION:** Mean MVBF with standard deviation was calculated as  $533.42 \text{ N} \pm 185.44 \text{ N}$ , with males having bite force significantly higher than the females. In all the groups, gender was significantly associated with MVBF. The bite force is also positively correlated with age.

**KEYWORDS:** Bite force, Human Bite force, bite force gauge, maximum bite force

**HOW TO CITE:** Nawaz MS, Yazdanie N, Hussain S, Moazzam M, Haseeb M, Hassan M. Maximum voluntary bite force generated by individuals with healthy dentition and normal occlusion. J Pak Dent Assoc 2020;29(4):199-204.

**DOI:** <https://doi.org/10.25301/JPDA.294.199>

*Received: 30 October 2019, Accepted: 21 June 2020*

## INTRODUCTION

The masticatory system is a functional unit composed of the teeth along with their supporting structures, both upper and lower jaws, temporomandibular joints, muscles involved directly or indirectly in mastication

(including the muscles of the lips and tongue); and the vascular and nervous systems supplying these tissues. Masticatory muscles more importantly Masseter, Temporalis and Medial Pterygoid are primarily involved in the closure of jaws.

All these units of masticatory system work in harmony to generate a force by moving the mandible, which then helps in the mastication of individual. This force which brings the mandible in occlusion for mastication is called Occlusal bite force.<sup>1</sup> Maximum voluntary bite force (MVBF) is the maximum strain of the maximum force produced by the mandibular elevator muscles by their contraction through the occlusal surfaces of mandibular teeth against the occlusal surfaces of maxillary teeth.<sup>1-3</sup>

Occlusal bite force is frequently used to evaluate masticatory function because it reflects the maximum

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voluntary contraction of the masticatory muscles.<sup>2</sup> MVBF magnitude is influenced by age, gender, face form, occlusion, periodontal and gingival problems, missing teeth, pulp related problem, jaw muscle cross-sectional area, temporomandibular disorders and craniofacial morphology.<sup>1-6</sup>

The first reports of human bite force measurements are found in 17th century however with the passage of time different mechanical devices were being used for bite force measurements up till mid-20th century when these mechanical devices were gradually taken over by electronic equipment.<sup>2</sup> Highest MVBF is in first molar region. Unilateral measurements of MVBF in the molar region averages between 300 and 600 N in healthy adults with natural teeth.<sup>3</sup> In children and adolescent from 7 to early twenties the average increase in bite force is 23 N per year while from 26 to 41 correlation between bite forces gradually diminishes and then bite forces decrease after the age of 45 years.<sup>7,8</sup> Generally there has been a gradual decrease in average bite force with the time, white western population have less average bite force than eastern population which in turn have less average bite force than Black African. The rural area people generally have higher average bite force than urban area.<sup>7</sup> One major known cause of this is the type of food. Softer food consuming populations have lesser average bite force.<sup>1,2,7</sup>

The purpose of this study was to record the mean voluntary bite force of healthy individuals and associate it with demographic of the patients like age and gender. It will help us in planning treatment during prosthodontic rehabilitation of the patients. The mean voluntary bite force value of healthy patients with natural dentition will be a reference to compare with prosthesis given during the dental rehabilitation process. Since bite force varies with racial, geological and environmental effects along with the preference of food people eat, it has not been recorded in the local population. This study will determine the base line MVBF for local population.

## METHODOLOGY

Informed consent was granted from subjects or their parents/guardians. The study was approved by the ethical review board of the Fatima Memorial College of Medicine and Dentistry, Lahore.

Table 1 shows the Sample size which is 204, divided in three groups on the basis of age having 68 in each. Each group of age was further subdivided into two groups on the basis of gender comprising of 34 males and 34 females. The subjects had a neutral occlusion (Class I molar relationship) with balanced facial profiles, a symmetric appearance in the frontal view, harmoniously shaped competent lips, and absence of previous orthodontic treatment.

They had normal healthy teeth (intraoral examination revealed no caries, mobility, periodontitis or any pulp related pathology) and a full natural complement of teeth from 2nd molar to 2nd molar both in maxilla and mandible.

Subjects with craniofacial anomalies, systemic or local muscle or joint disorders, skeletal or dental malocclusions including minor rotations were excluded from the study. All the subjects were examined for canines and molars being in angle's class 1 relationship (neutral occlusion) in such a way that all molars are present (except third molars). The instrument used for measuring bite force was a portable occlusal bite force gauge (GM10; Nagano Keiki, Tokyo, Japan). The bite force gauge has a biting element and a hydraulic pressure gauge with a width of 17 mm and height of 5.4 mm which is made of a vinyl material. Disposable covering sleeves made of plastic are used for each patient (Figures 1). The device is cleaned with antiseptic wipes every time is being used for a measurement. The device displays bite force digitally on the display meter from 0 to 1000N with an accuracy  $\pm 1$  N.

The measurements were taken in such a way that the subjects seats comfortably in an unstrained position with back, head and neck being unsupported, looking forward in natural position. Measurement of maximum bite force was done unilaterally on both the left and right sides of the jaw in the 2nd pre molar and first molar region. The measurements were done three times on each side one by one with an interval of 3 minutes between each measurement as a rest period for muscle fatigue. Mean of each side was recorded separately and later an average of both the means were taken to record MVBF as under

$$Lo = (L1 + L2 + L3)/3$$

$$Ro = (R1 + R2 + R3)/3$$

$$MVBF = (Lo + Ro)/2$$

None of the subjects experienced any discomfort or pain during biting on the instrument.

## RESULTS

Total number of subjects included in the study at its inception were 204. None of the subject were lost during the study. The data was entered in SPSS 18 and analysis was carried out. Graph 1 shows the frequencies assorted bite forces of all the subjects.

Table 1 shows the age group and gender wise distribution of study participants. Table 2 shows Mean Maximum Voluntary Bite Force which was calculated as  $533.42 \text{ N} \pm 185.44 \text{ N}$ . whereas Males had Mean MVBF  $635.23 \text{ N} \pm 179.86 \text{ N}$  and Females had Mean MVBF  $431.61 \text{ N} \pm 125.82 \text{ N}$

Graph 1: Maximum voluntary bite force gender wise

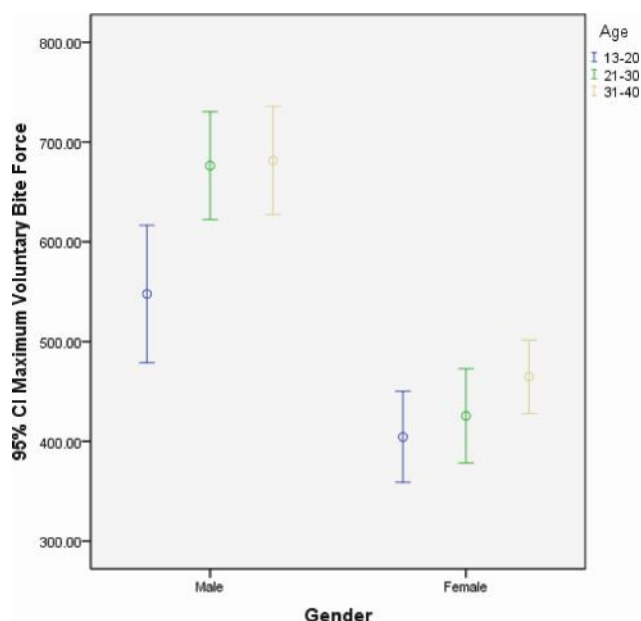


Table 1: Age group and gender wise distribution of study participants

Group	Age group	Male	Female	Total
Group No 1	13 – 20 years	34	34	68
Group No 2	21 – 30 years	34	34	68
Group No 3	31 – 40 years	34	34	68
Total	13-40 years	102	102	204

Table 2: Comparison of Age, Gender and Mean MVBF. Levene test for degree of freedom (df), Pearson correlation (R) for correlation of age and bite force, unstandardized coefficient beta from regression analysis.

Group	Gender		Total Mean MVBF	t	df	R value	Unstandardized coefficient beta
	Mean MVBF Male	Mean MVBF Female					
1 (13 – 20 years)	547.78 N ± 197.54 N	404.44 N ± 130.66 N	476.11 N ± 181.22 N	3.5*	57.2	0.632	60
2 (21 – 30 years)	676.34 N ± 154.83N	425.53 N ± 135.39 N	550.93 N ± 191.83 N	7.11*	66	0.306	26.4
3 (31 – 40 years)	681.57 N ± 155.52N	464.85 N ± 105.42 N	573.21 N ± 171.18 N	6.72*	58	0.43	2.4
4 (13-40years)	635.23 N± 179.86 N	431.69N ± 125.82N	533.42N ±185.44N	9.35*	180	0.276	6.174

\*Significant (p<0.05)

Mean Maximum Voluntary Bite force with respect to age; Group 1 Mean MVBF for group 1 was 476.11 N ± 181.27 N. (males of group 1 is 547.78 N ± 197.54 N and females of group 1 was 404.44 N ± 130.66 N).

MVBF of group 2 was 550.93 N ± 191.83 N. (males in group 2 was 676.34 N ± 154.83 N and females in group 2

was 425.53 N ± 135.39 N).

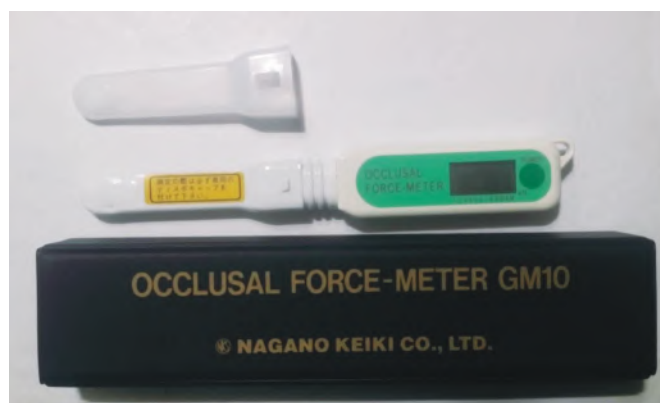
MVBF of group 3 is 573.21 N ± 171.18 N. (males group 3 was 681.57 N ± 155.52 N and females group 3 was 464.85 N ± 105.42 N).

The table 2 showed the values of t test at 95% confidence interval where p<0.05 and the MVBF of males in each of the respective age group was significantly higher than females. Levene test showed higher degree of freedom of independent variable also MVBF was positively related to age, as the age increased, the bite force increased. The regression analysis revealed that standardized coefficient beta is 0.276 while the unstandardized coefficient beta was 6.174.

## DISCUSSION

The aim of the study was to find out mean of maximum voluntary bite force in people with healthy dentition and normal occlusion. The device used for bite force measurement was occlusal bite force meter GM-10 Nagano keiki japan (figure 1). In working, design, manufacture and origin this device is similar to the devices used in many other studies.<sup>2,7-10</sup> The sensitivity and specificity of the device has

Figure.1: Occlusal bite force meter GM-10 Nagano Keiki Japan



been established by Sakaguchi et al.<sup>10</sup> The primary function of plastic covering sleeves was to maintain cross infection control. No damage to teeth was reported in this study. A 3-5-minute interval is necessary for the periodontal ligament to reestablish its hydration and recoil from the compression due to bite force and return to normal.<sup>12</sup> In order to minimize the machine and human error in recording procedure the bite force was recorded 3 times on left side and 3 times on right side, a total of six times. Mean of left side and right side were calculated separately and finally the total mean was calculated. interval of 3 minutes between consecutive readings was given as resting phase. This delay was to nullify any fatigue effect on the muscles of mastication. This is time was also necessary to bring any electromyographic (EMG)

activity to the normal level.<sup>8,13,14</sup>

The width of the transducer is 5.4mm and is made of vinyl material (Figure 2). The width of the plastic pad is 3mm. The transducer along with its vinyl covering and the plastic pads together were 5.4mm + 3.0 mm = 7.4 mm. As the part of the transducer where individual will bite is compressible so after teeth clenching on them for maximum bite forces, the plastic covering sleeves are depressed and the width is further reduced which falls in optimum range according to Manns et al. 15 and Paphangkorakit and Osborn.<sup>16</sup>

The sample selection was from 13 years because the end of 12 years is appreciated as the end of mixed dentition stage.<sup>17</sup> In mixed dentition stage various deciduous tooth are present which have occlusal surface area and periodontal surface area less than that of permanent teeth area as a result of which the MVBF generated by the subject can be influenced.<sup>6,16-18</sup>

Another reason for taking sample age from 13 years was that pubertal changes and hormonal influence takes place around this age. Under hormonal influence striated muscle development take place which affects the bite force. This is one of the main reasons why there is no gender difference in school children below 12 years and preschool children.<sup>2,18,19</sup>

Bite forces recorded during bilateral clenching are usually higher than unilateral clenching<sup>1,2,3,18,20</sup> while several authors have used unilateral method of determining MVBF.<sup>4,7,8,9,14</sup> Multiple readings on each side and its respective mean calculation as mentioned above greatly reduces the error in unilateral bite force calculation as compared to bilateral calculations.

Mean MVBF with standard deviation from age 13 to 40 years was calculated as 533.42 N ± 185.44 N (table 2) which is in accordance to Bakke et al<sup>3</sup> who mentioned the range of MVBF 300 - 600 N.

Bite force is a complex outcome of multiple factors,<sup>1-4,14,19,20</sup> therefore bite force is a unique feature of every human which varies from person to person and age to age. No two studies till date have reported exactly same bite force values. The disparity between different studies is from 189 ± 78 N by Sasaki et al<sup>21</sup> 1989 to 720 N by Gibbs et al in 1981. Gibbs et al<sup>22</sup> in 1986 discovered one individual who had a biting force of 4340 N (443 kg). This disparity in the bite force in this study and all the previous studies can be due to various intra human and inter human reasons one of them may be the global variation of food preference, food availability, urbanization, human races, environmental factors. The bite force calculated in our study is lower than Sathanarayana H P, Sridhar Premkumar S<sup>23</sup> with Adults (17-25years) who had a mean MVBF of 601.83 N with males having a value of 650.67 N and females it was 543

N. it was also different than study of Bonakdarchian M, Askari N Askari M<sup>4</sup> in a sample of 40 subjects with normal dentition with age range from 19 - 27 years the Mean MVBF was 631.12 N ± 235 N

The main reason of MVBF calculated in this study being less than that of few other studies may be attributed to the age group taken. In this study the age range is 13 - 40 while in above mentioned other studies the age range is smaller. Relatively younger age group is taken which have been proven to have higher average bite force values than older adults.<sup>1,2,8,14</sup>

The MVBF calculated in this study is greater than

- Palinkas M et al<sup>2</sup>, according to this study average MVBF in age 13-20 years MVBF is 341.5 N ± 27, from age 21-30 years MVBF is 288.5 N ± 24.5, from age 31-40 years MVBF is 264 N ± 21.5.

- Al-Saadi D K and Al-Mulla A A<sup>9</sup>, according to them in Iraqi people the MVBF is 392.81 N ± 54.7. The studies<sup>2,14</sup> with lesser bite force than this study are based on the Brazilian, Iraqi respectively and the studies<sup>4,13</sup> with higher bite force than this study are based on Iranian and Indian population. The results are more comparable to studies<sup>4,13</sup> the reason may be the regional variation as per Hallak Regalo SC et al<sup>7</sup> the type of food being consumed in one particular region.<sup>1,2,7</sup>

The bite force of males and females are mentioned in table 2. The mean MVBF of males are 635.23 ± 179.86 N and the mean MVBF of females is calculated as 431.61 ± 125.82 N. Males have bite force highly significant than females. Males have highly significant MBVF in each of the group 1, 2 and 3 than females of the same group. This is in accordance with most of the studies.<sup>1-4,7-9,14,19,21</sup>

The reason for males having more bite force is attributed to various factors like males having more masseter muscle mass than females, males have higher bone density than females, the periodontal surface area of males is more than females, jaw design mechanics of males is more productive of higher forces than females and hormonal variations in females also effect bite force.<sup>1,2,6,11,14,15,19,20</sup>

Pearson coefficient relation R values as in table 2 indicate that bite force in correlation to age and unstandardized coefficient B reveals that MVBF increases 6.174 units/year. In age group 1 according to R value bite force is much strongly correlated to age than other age groups and according to unstandardized coefficient beta in age group 1 bite force increases by 60 units/years. The R value decreases to 0.306 and 0.43 in group 2 and group 3 respectively which shows that the correlation decreases as the age increases also unstandardized coefficient beta shows that average increase in bite force per year decreases from 60 units in age group 1 to 26.4 in age group 2 and 2.4 in age group 3. Similar results

are predicted by other studies as well<sup>1,2,7,8,9,22</sup> this strong correlation of age with bite force in teen age is mainly due to the pubertal growth and hormonal influence under which bone and muscle mass increases.<sup>1,2,7,8,13,15,19</sup>

In case of male there is a significant increase in MVBF from age group 1 to age group 2 but the increase in MVBF from age group 2 to age group 3 is not that significant. This can once again be explained by the pubertal growth of the male in teen age creating an increase in Mean MVBF<sup>8,12,14,20</sup> (table 2).

In case of female if we analyze the age groups then we can find that there is a steady increase in MVBF from age group 1 2 and 3. (Graph 1). This increase in MVBF is of small value i.e. from minimum to maximum value only 60 N bite force was increased. This increase can be explained by the gradual increase in muscle mass with age or this can be due the randomized sampling or to inherent error of this study which is the variation in urban and rural population. The urban population has increased bite force values than rural population<sup>1,2,7,14</sup> and this factor was not controlled in the study. Some subjects might be inducted in the sample as they are born and brought up in rural area and now migrated to urban areas for education, jobs, marriage etc.

#### LIMITATIONS AND FUTURE IMPLICATIONS

Although every effort possible was done to calculate bite force but it's very hard to end up with a universally acceptable value of MVBF. The age groups we presented are large and stratification of groups is only age and gender based ignoring other factors. Further research is needed with a relatively large sample size and larger age range. Larger sample size should be distributed in smaller age groups such that a better understanding of variation of MVBF with age can be done. Rural and urban population statistics should be evaluated. Dietary habits and parafunction should be taken into account. Hormonal analysis and pubertal growth indicators must be taken in account to access their effect on MVBF. The skeletal and dental classes should be taken in account to find out the values MVBF in different skeletal and dental patterns. Masseter muscle mass can be evaluated with ultrasonography and its effect must be cordially related to MVB.

#### CONCLUSION

Results of this study show that MVBF is clearly gender related with MVBF of males being significantly higher than females. MVBF is age dependent. There is strong correlation of bite force in young individuals both males and females but this correlation decreases as the age increases.

#### CONFLICT OF INTEREST

There is no specific conflict of interest related to this study

#### FUNDING

No external funding was utilized for this study.

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