A study of bite force, part 1: Relationship to various physical characteristics

Stanley Braun, DDS, MME; Hans-Peter Bantleon, PhD; William P. Hnat, PhD; Josef W. Freudenthaler, DDS; Michael R. Marcotte, DDS, MSD; Baxter E. Johnson, DDS, MS, FACD

Clinicians have long been interested in bite force with regard to its potential influence on the development of the masticatory complex. Investigators have speculated that dental eruption is influenced by occlusal forces and have theorized that the supereruption of posterior teeth results in a clockwise rotation of the mandible with a related openbite and an abnormal vertical dimension.[1,2] Finn[3] reported that the maximum molar region bite force in individuals of normal facial appearance is approximately twice that of dolichofacial subjects (569 N versus 294 N; 1 Newton = 102 grams = 0.225 lbs), while brachyfacial types had even greater values. However, it is important to consider that changes of facial proportions may be the result, and not the cause, of altered bite forces .

Throckmorton et al.[1] demonstrated that bite force reflects the geometry of the jaw's lever system. The adductor muscles of the mandible appear to have a greater mechanical advantage when the ramus is more vertical and the gonial angle relatively acute. As the gonial angle increases, the mechanical advantage of the muscles is lessened, resulting in less force perpendicular to the occlusal plane. This finding implies that bite force may be a reflection of form.

Orthodontists have also been concerned with bite force because vertical forces are often produced in the process of treating malocclusions,

Abstract

A new device for measuring and recording bilateral bite force in the molar/premolar region has been developed. Because this new device is elastic and conforms to the occlusal surfaces of the teeth, and because the sensing element is relatively comfortable, it is believed that experimental subjects are less reluctant to register true maximal forces than in earlier studies. Potential correlations of maximum bite force to gender, age, weight, body type, stature, previous history of orthodontic treatment, presence of TMJ symptoms (jaw motion limitation, clicking with pain, or joint pain), or missing teeth were studied in a sample of 142 dental students. The mean maximum bite force of the sample was found to be 738 N, with a standard deviation of 209 N. The mean maximum bite force as related to gender was found to be statistically significant, while the correlation coefficients for age, weight, stature, and body type were found to be low. Even so, all data scatterplots exhibited relatively positive relationships. Correlations of maximum bite force to an earlier history of orthodontic treatment or to the absence of teeth were not found. Subjects reporting TMJ symptoms did not exhibit a significantly different maximum bite force than subjects without symptoms.

Key Words

Bite force • Instrumentation • Age • Gender • Stature • Weight • Relationships

Submitted: May 1994 **Revised and accepted:** October 1994 Angle Orthod 1995;65(5):367-372.

Downloaded from http://meridian.allenpress.com/doi/pdf/10.1043/0003-3219(1995)065<0367:ASOBFP>2.0.CO;2 by guest on 05 August 2020

Figure 1
Instrumentation schematic

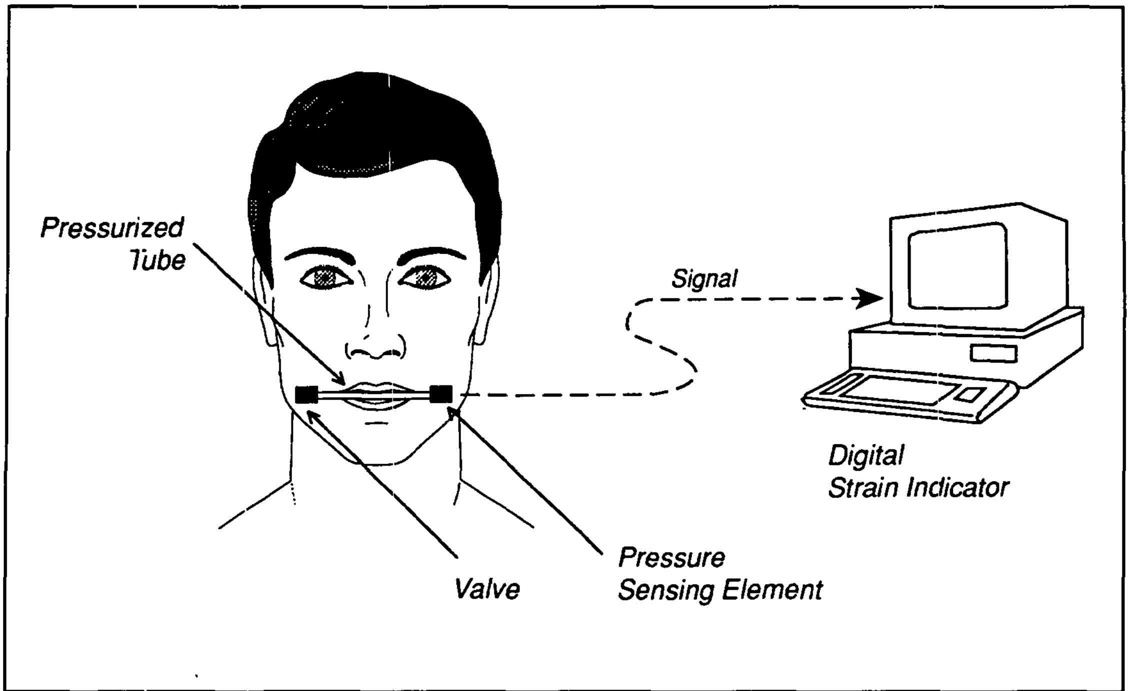

Figure 1

as in use of Class II elastics or tip back bends. Sometimes it is desirable that bite forces negate these orthodontic forces. It would therefore be advantageous to be able to forecast vertical bite forces in the patient who is to undergo orthodontic treatment. Additionally, the influence of bite force on the vertical stability of any treatment result is important. The new position of the dentition should be compatible with the dynamics of the muscular and occlusal forces in all planes. To this end, many investigators have attempted to evaluate maximum bite forces.

Proffit et al.[4] measured maximum unilateral bite forces in children who had normal facial patterns. Mean values ranged from 152 N at 6 mm molar separation to 171 N at 2.5 mm separation. The standard deviation for each of these values was 139 N and 188 N, respectively. Hellsing and Hagberg,[5] in a small adult sample, measured maximum unilateral bite force with the head in normal posture and reported a mean value of 272 N. Osborne and Mao,[6] also in a small sample, measured incisive bite forces and found the average to be 190 N in males and 50 N in females. In a study of orthognathic surgical patients prior to treatment, Dean et al.[7] found the mean bite force in the molar region to be 490 N in males and 402 N in females. Bakke et al.,[8] in a large sample (63 females and 59 males), found the mean bite force in the molar region to be 522 N in males and 441 N in females. These studies imply that bite force is gender-related.

There is a wide range of maximum bite force values as found by different investigators. This range is likely due to several factors: (1) location of the bite force transducer, i.e., unilateral, bilateral, posterior or anterior; (2) when the transducer material is made of metal, subjects may be reluctant to bite fully for fear of dental damage, pain, etc.; (3) size of the transducer may distract the condyles excessively; (4) lack of "give" or flexibility of the transducer element may contribute to a subject's reluctance to bite maximally; (5) dynamic responsiveness and accuracy of the transducer; (6) sensitivity of the teeth, muscles and TM joints.

The purpose of this study, the first of two, was to evaluate maximum human bite force as it correlates with gender, age, stature, weight and body type, as well as to determine any potential relationship between TMD signs and symptoms, absence of dental units or related to earlier orthodontic treatment (part 1). A second study (part 2) examined the relationship between maximum bite force and various cephalometric measurements.

Materials and methods

A transducer was designed for this study, taking into account the potential problems of earlier instrumentation cited above. The transducer consists of a sterilizable, fiber-reinforced, pressurized rubber tube connected to a pressure sensing element (Omega Model No. PX300-1KGV, Omega Engineering, Inc, Stamford, Conn). Pressure change is transformed into an electrical sig-

Downloaded from http://meridian.allenpress.com/doi/pdf/10.1043/0003-3219(1995)065<0367:ASOBFP>2.0.CO;2 by guest on 05 August 2020

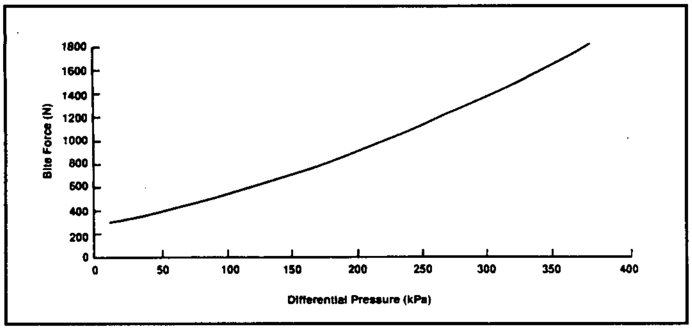

Figure 2

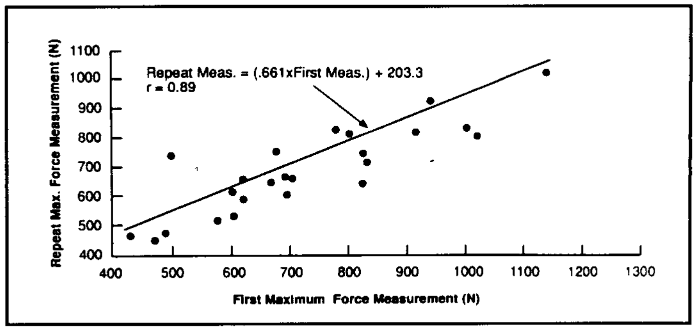

Figure 3

Figure 2
Calibration curve

Figure 3
Repetitive maximum bite force measurements

Table 1
Maximum bite force related to sex

Gender	n	Mean	Minimum	Maximum	Median	SD	Skewness
Male	86	814.0	417.0	1280.0	789.0	209.0	0.243
Female	56	615.0	342.0	914.0	596.0	138.0	0.351
Total sample	142	738.0	342.0	1280.0	710.0	209.0	0.549

nal and transferred to a digital strain indicator (Vishay/Ellis-20, Measurements Group, Inc, Raleigh, NC). A schematic of the instrumentation is seen in Figure 1. The benefit of this design is its rapid response while sensing bilateral biting forces. During its use the tubing is elastically deformed, conforming to the occlusal anatomy of the individual maxillary and mandibular teeth, thereby providing a more uniform force distribution. This deformation is important because it gives the test subject a degree of psychological security unlike the typical metal biting elements (even though covered by rubberized material) used in earlier studies. It is therefore more likely to yield a true representation of maximal bite force, because the mandible is minimally distracted.

The experimental sample consisted of 142 students (86 males and 56 females) from the University of Vienna Dental School, Vienna, Austria. The age range was from 26 to 41 years, with a mean of 32.4 years.

The measurement system was calibrated using an MTS Model 810 Universal testing machine. A known force was applied to typodont teeth occluding on the upper and lower surfaces of the tubing and the resulting tube-pressure change was recorded. Because there could be a variation in biting force signal output as related to the location of the teeth along the tube length, borders were marked on the tubing so that all experimental subjects bit within these limits to control experimental error. A calibration curve is seen in Figure 2.

Each subject was asked to bite with maximum bite force three times in succession, resting 2 or 3 seconds between each bite. The largest value was chosen as the maximum bite force. Each subject was standing with a relaxed head posture, keeping Frankfort horizontal approximately parallel to the floor. The transducer tubing was positioned across the arches in the maxillary first molar-second premolar area and maintained approximately parallel to Frankfort horizontal.

Measurement reliability was evaluated by repeating the maximum bite-force readings in 25 randomly selected subjects 24 hours following the initial bite force experiment. The results are shown in Figure 3. The correlation coefficient of 0.89 indicates 79% of the variability in the repeated measurement is predicted by the variability in the first measurement. The stability shown by this repeated sampling is sufficient to justify using the 142 bite force readings for further analysis.

Results

The maximum bite force as related to gender is tabulated in Table 1. When the Behrens-Fischer t'-test was applied, a P value of 0.0001 was obtained, indicating that the difference in mean value of 814 N for males and 615 N for females was statistically significant.

The maximum bite force distributions, regression equations, and correlation coefficients with regard to age, weight, and stature are seen in Fig-

Downloaded from http://meridian.allenpress.com/doi/pdf/10.1043/0003-3219(1995)065<0367:ASOBFP>2.0.CO;2 by guest on 05 August 2020

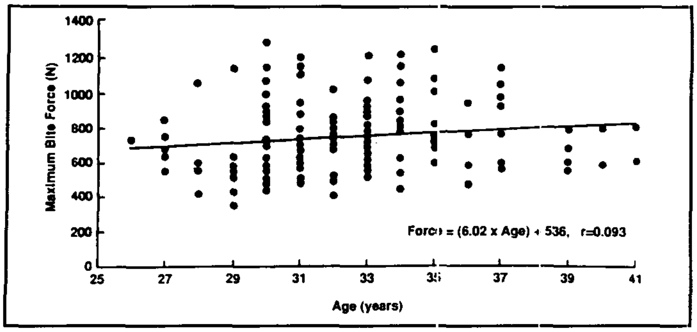

Figure 4

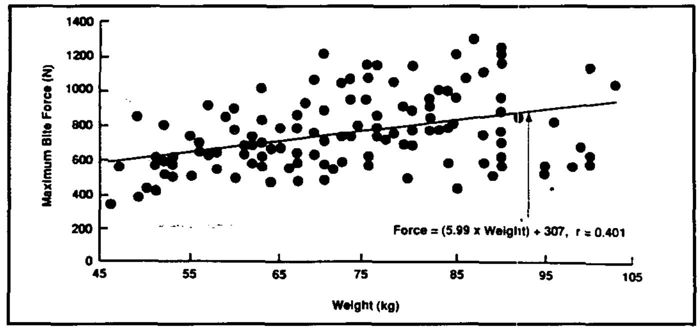

Figure 5

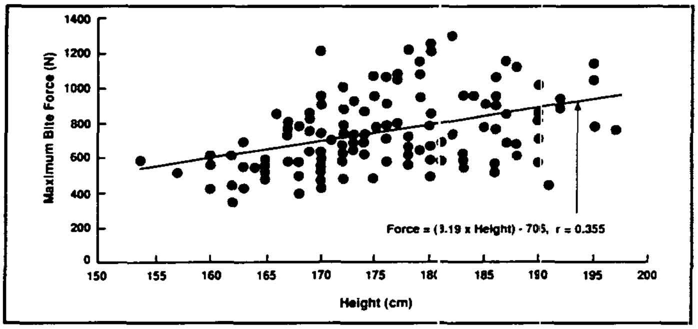

Figure 6

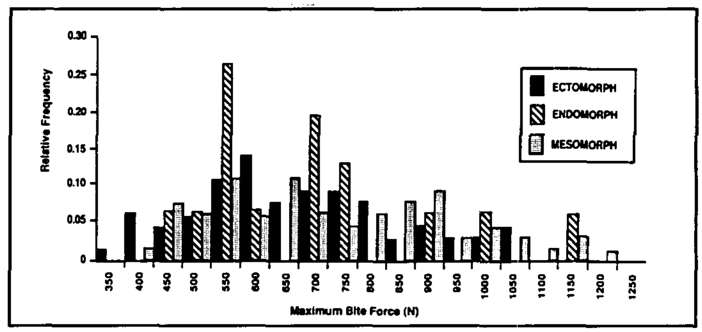

Figure 7

Figure 4
Maximum bite force related to age

Figure 5
Maximum bite force related to weight

Figure 6
Maximum bite force related to stature

Figure 7
Maximum bite force related to body type

ures 4, 5, and 6, respectively. The correlation coefficients for age, weight, and stature are all low. The relationship of weight to maximum bite force exhibited the largest correlation coefficient of these three subsets (r= 0.401). Although predictability is low, it should be noted that the scatterplots exhibited consistent, slightly positive relationships to age, weight and stature.

The relationship between body type (ectomorph, mesomorph and endomorph) to maximum bite force is statistically normal and relatively symmetrical, although the mesomorphs are slightly positively skewed, as seen in Figure 7. The central tendency for the ectomorphs and mesomorphs is in the range of 492 to 725 N. Because of the small number of endomorphs in the sample (15), this distribution is skewed. It is expected the distribution of this group would be similar to the others if there were a larger number in this subset.

Mean maximum bite-force comparisons were made with respect to a history of previous orthodontic therapy, the presence of TMD signs and symptoms, or the absence of teeth. These are illustrated in Table 2. A version of the Behrens-Fisher t′-test, with the Welch df correction, was used to analyze the data because the sample sizes were unequal.[9] There was no statistically significant difference between the means of maximum bite force in subjects having a history of earlier orthodontic therapy or the presence of TMD symptoms or missing natural teeth when compared with normal.

Discussion

The mean maximum bite force of 738 N measured in this study is greater than that determined by earlier investigators. This outcome is likely attributable to the transducer deforming during maximum biting as opposed to a hard metal substance that would not compress to any degree. This difference tends to lessen the reluctance of subjects to bite maximally because of concerns of dental fracture and/or pain. The fact that measurements were made bilaterally rather than unilaterally may also be important. The subjects were all dental students and this may have been a contributing factor to the larger maximum bite force values.

Maximum bite force did correlate with gender, in agreement with the findings of Dean et al.[7] and Bakke et al.,[8] although the percentage difference between sexes was greater in this study (25% versus 18% and 16%, respectively).

Maximum bite force did not correlate well with age. This finding is not surprising in that the sample consisted of adults between the ages of 26 to 41. The maximum bite force range for this age group is 342 N to 1280 N.

The notion that persons of larger body build, size and/or weight exhibit a greater bite force is not confirmed by this study. The best correlation is exhibited with regard to weight (r = 0.401), indicating only 16% variability in maximum bite force is predicted by weight. This outcome agrees with an earlier study by Lindhom and Wennström.[10]

Downloaded from http://meridian.allenpress.com/doi/pdf/10.1043/0003-3219(1995)065<0367:ASOBFP>2.0.CO;2 by guest on 05 August 2020

Table 2
Maximum bite force related to history of orthodontic treatment, TMD symptoms, or missing teeth

	Mean	Number	SD	SEM	Skewness	Max	Min	P
Prior orthodontic treatment								
No	757.0	89	22.0.	23.3	0.458	1280	418	
Yes	706.0	53	186.0	186.0	0.60	1192	342	>0.05
TMD symptoms								
No	745.0	117	203.0	303.0	0.674	1280	418	
Yes	706.0	25	235.0	235.0	0.238	1136	342	>0.05
Missing teeth								
No	765.0	81	214.0	214.0	0.451	1280	388	
Yes	702.0	61	198.0	198.0	0.654	1138	342	>0.05

Findings regarding a history of earlier orthodontic therapy or limited missing natural teeth may be expected, while the finding regarding subjects having TMD symptoms is unexpected. Perhaps the latter is explained by the notion that TMD-symptom severity is an important factor. One may speculate that a discomfort threshold must be reached for the maximum bite force to be affected. One may also speculate that the condyles had been distracted sufficiently by the tubing to release any disc malposition, allowing each subject's maximal bite force to not be significantly different than that of subjects not reporting TMD symptoms.

Any subject with limitation in jaw motion, clicking with pain, or joint pain alone was considered as having TMD signs or symptoms.

None of the subjects in this sample exhibited more than the absence of one tooth in any one quadrant. All subjects with absent teeth posteriorly had fixed or removable prostheses in place. Third molars were excluded.

Acknowledgments

The authors are indebted to Dr. John M. Yancy, Professor of Biostatistics, School of Dentistry, University of Louisville, for his guidance and analysis of the experimental data.

Author Address

Stanley Braun, DDS, MME
Clinical Professor
7940 Dean Road
Indianapolis, IN 46240
(317) 845-8780

S. Braun, clinical professor, Vanderbilt University and the University of Illinois.

H.-P. Bantleon, professor, Universitätsklinik für Zahn-Mund-und Kieferheilkunde, Vienna, Austria.

W.P. Hnat, associate professor, mechanical engineering, J. B. Speed Scientific School, University of Louisville, Louisville, Kentucky.

J.W. Freudenthaler, university professor, Universitätsklinik für Zahn-Mund-und Kieferheilkunde, Vienna, Austria.

M.R. Marcotte is in private practice in Bristol, Connecticut.

B.E. Johnson, Chairman, Department of Orthodontic, Pediatric and Geriatric Dentistry, School of Dentistry, University of Louisville, Louisville, Kentucky.

Downloaded from http://meridian.allenpress.com/doi/pdf/10.1043/0003-3219(1995)065<0367:ASOBFP>2.0.CO;2 by guest on 05 August 2020

References

1. Throckmorton GS, Finn RA, Bell WH. Biomechanics of differences in lower facial height. Am J Orthod 1980;77:410-20.
2. Proffit WR, Fields HW, Nixon WL. Occlusal forces in normal and long faced adults. J Dent Res 1983;62:566-71.
3. Finn RA. Relationship of vertical maxillary dysplasia, bite force and integrated EMG. Ann Arbor, MI, Abstracts and Conference on Craniofacial Research, University of Michigan Center of Human Growth and Development, 1978.
4. Proffit WR, Fields HW, Nixon WL. Occlusal forces in normal and long faced children. J Dent Res 1983;62:571-74.
5. Hellsing E, Hagberg C. Changes in maximum bite force related to extension of the head. European J Orthod 1990;148-53.
6. Osborne JW, Mao J. A thin bite force transducer with three-dimensional capabilities. Archives of Oral Biology 1993;38:139-44.
7. Dean JS, Throckmortön GS, Ellis EE, Sinn DP. A preliminary study of maximum voluntary bite force and jaw muscle efficiency in pre-orthognathic surgery patients. J Oral Maxillofac Surg, 1992;50:1284-88.
8. Bakke M, Holm B, Jensen L, Michler L, Moller E. Unilateral, isometric bite force in eight 68-year-old women and men related to occlusal factors. Scand J Dent Res 1990;98:149-58.
9. Zar JH. Biostatistical Analysis. 2nd Edition. Englewood Cliffs: Prentice-Hall 1984: 130-131.
10. Linderholm H, Wennström A. Isometric bite force and its relation to general muscle form and body build. Acta Odontol Scand 1970;28:679-87.

Downloaded from http://meridian.allenpress.com/doi/pdf/10.1043/0003-3219(1995)065<0367:ASOBFP>2.0.CO;2 by guest on 05 August 2020