A study of bite force, part 2: Relationship to various cephalometric measurements

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In part 1 of "A study of bite force," we examined the relationship of maximum human bite force to gender and to various characteristics, including weight, height, body type, previous history of orthodontic treatment, the presence of TMJ symptoms, and the absence of teeth.[1] In this paper, part 2, we examine the potential relationship of maximum human bite force to various cephalometric measurements.

Ringqvist[2] examined maximum posterior unilateral bite force in a small sample of females and determined that the mandibular size (Ar - Pg), mandibular plane angle, and mandibular/palatal plane angle correlated significantly with maximum bite force. Proffit et al.[3] measured posterior unilateral occlusal force in adults with normal vertical dentofacial proportions and adults with vertical dysplasia of the long face type and found that long-face individuals exhibited approximately 50% less bite force than those of normal dentofacial proportions.

Garner and Kotwal[4] found incisive bite force correlated with dental overbite in both males and females. Denzinger[5] evaluated various cephalometric measurements, including ANB, ANS-Gn, MP-FH, and interincisal angle relative to incisive bite force and found that correlations lacked statistical significance.

These earlier studies reported a wide range of values and correlations to cephalometric patterns. As pointed out in part 1,[1] this may be due to differences in instrumentation design, size, technique, whether measurements were made unilaterally or bilaterally, degree of mandibular opening, as well as individual tissue tolerance, comfort, pain threshold, anxiety, mental attitude, head posture, and conditions during the test itself.[6-10] Hagberg,[11] in an extensive review of the literature, tabulated the wide range of maximum bite forces determined by various investigators.

Abstract

Maximum bilateral bite force, determined in 129 dental students, was evaluated with regard to six skeletal and eight dental measurements acquired from conventional lateral cephalometric radiographs. Statistically significant correlations for three of the skeletal measurements were found. Maximum bite force increased with regard to decreasing mandibular plane/palatal plane angle and to decreasing mandibular plane angles. Maximum bite force increased with an increasing ratio of posterior facial height to anterior facial height. Significant statistical correlation for only one of the eight dental measurements was found: maximum bite force related directly with increasing maxillary and/or mandibular dentoalveolar heights, an unexpected finding.

Key Words

Bite force • Facial type • Cephalometric correlations • Dental correlations

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Table 1
Cephalometric measurements

Measurements	Study sample Mean	Study sample SD	Dentofacial Planner sample Mean	Dentofacial Planner sample SD
Skeletal				
ANB	2.2°	2.8°	3.9°	2.1°
Y Axis	58.9°	6.4°	59.4°	3.8°
MP/PP	22.1°	5.9°	28.0°	2.0°
MPA	21.7°	6.3°	21.3°	3.9°
Wits Appraisal	0.7 mm	4.2 mm	-1.1 mm	2.0 mm
PFH/AFH	68.7%	5.8%	62.0%	1.0%
LFH/TFH	52.9%	2.7%	–	–
Dental				
IMPA	93.6°	7.6°	90.0°	10.0°
1|1 – NF	109.4°	8.0°	111°	4.7°
Interincisal angle	134.9°	11.7°	127.1°	9.7°
Occlusal plane angle	6.5°	4.5°	9.3°	3.8°
Overjet	3.6 mm	1.6 mm	2.5 mm	2.5 mm
Overbite	4.1 mm	2.1 mm	2.5 mm	2.0 mm
6|6 – NF	23.5 mm	6.7 mm	26.2 mm	2 mm
6|6 – MP	35.7 mm	3.9 mm	35.8 mm	2.6 mm

Table 2
Correlation of skeletal measurements with maximum bite force

Skeletal Measurements	Correlation Coefficient (r)	Regression Equation (F = maximum bite force)
ANB°	-0.0647	ANB = -3.7×10^{-4} (F) + 2.959
Y Axis°	-0.127	Y axis = -25.3×10^{-4} (F) + 61.357
Wits appraisal (mm)	-0.0129	Wits = -2.6×10^{-4} (F) + 1.139
LFH/TFH (%)	0.11	LFH/TFH = 14×10^{-4} (F) + 51.86

The purpose of this study (part 2) is to use the improved instrumentation described in part 1,[1] which eliminates or significantly reduces the deficiencies cited above, to more accurately determine potential correlations between various skeletal and dental measurements as related to maximum human bite force.

Materials and methods

Cephalometric radiographs were taken of 129 dental students who had participated in the study of bite force, part 1.[1] Radiographic landmarks were digitized using the Dentofacial Planner (Dentofacial Software, Inc, Toronto, Ontario, Canada) computer program. One operator digitized all of the cephalometric landmarks to insure measurement reliability. Additionally, 25 cephalograms were randomly selected and digitized a second time by the same operator. Variation in the measurements obtained was less than 0.05%. The cephalometric measurements used in this study are listed in Table 1. These measurements were also compared with a larger population of the same age group to insure that the test subjects were not of atypical facial morphology. Maximum bite force values obtained in part 1[1] are correlated with respect to the cephalometric measurements presented in Table 1.

Results

Skeletal correlates

Scatterplots of the skeletal cephalometric measurements, listed in Table 1, reveal that the distribution of the data with respect to each of the measurements is good across the range. All of the relationships are linear. Graphical inspection of all scatterplots indicate that all the assumptions of the statistical models employed (namely linear correlation and linear regression) were clearly met.[12]

The correlation of maximum bite force to the measurements ANB, y-axis, Wits appraisal, and the ratio of lower facial height to total facial height are not statistically significant. Correlation coefficients and regression equations related to these data are shown in Table 2.

The correlation of maximum bite force to the mandibular plane/palatal plane angle is inverse and is statistically significant ($r = -0.276$, $P < .001$). The correlation of maximum bite force to the mandibular plane angle is also inverse, with a correlation coefficient of -0.304 ($P < .001$). The correlation of maximum bite force to the ratio of posterior facial height to anterior facial height is direct, with a correlation coefficient of 0.33, ($P < .001$). Scatterplots of these three relationships are presented in Figures 1, 2, and 3, respectively.

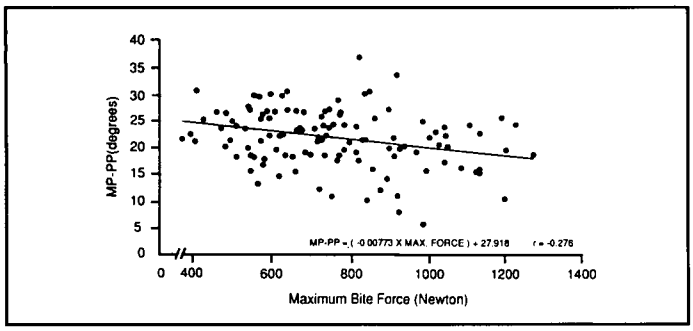

Figure 1

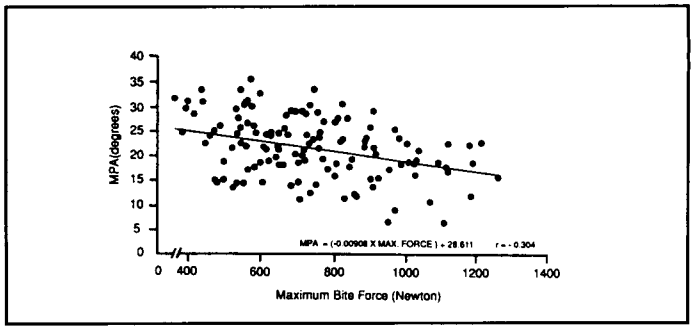

Figure 2

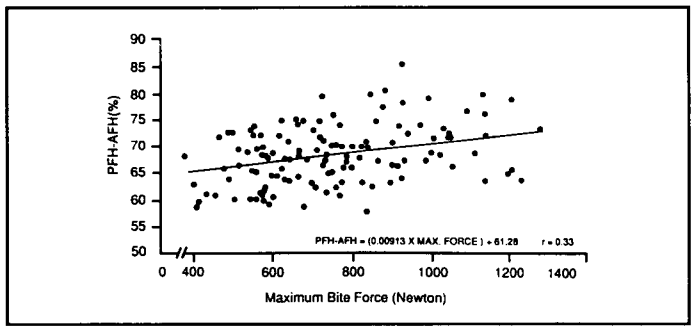

Figure 3

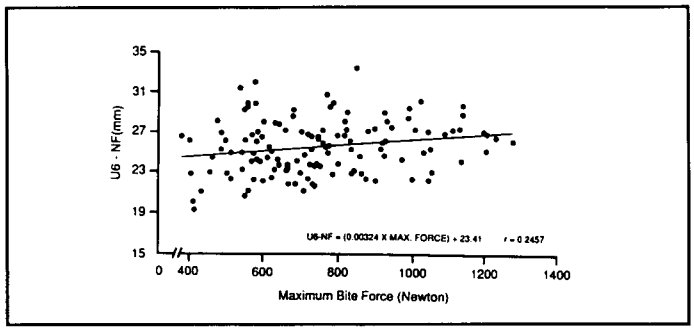

Figure 4

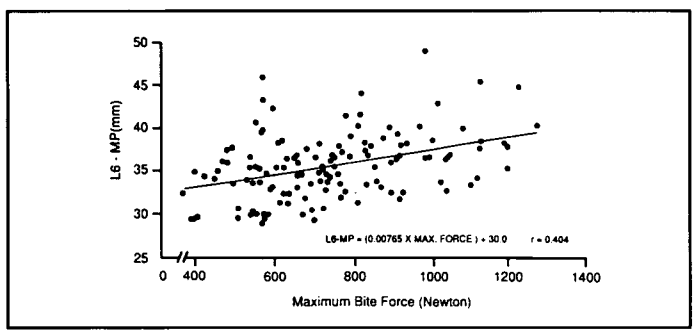

Figure 5

Figure 1
Maximum bite force vs. mandibular plane/palatal plane angle
Figure 2
Maximum bite force vs. mandibular plane angle
Figure 3
Maximum bite force vs. posterior facial height/anterior facial height ratio
Figure 4
Maximum bite force vs. maxillary posterior dentoalveolar height
Figure 5
Maximum bite force vs. mandibular posterior dentoalveolar height

Dental correlates

As in the case of the skeletal cephalometric measurements, all the dental relationships relative to maximum bite force are linear and the scatterplots indicated that all of the assumptions of the statistical models employed—linear correlation and linear regression—were met. The correlation coefficients for all the dental measurements relative to maximum bite force are not statistically significant, except for the relationship between maximum bite force and maxillary and mandibular dentoalveolar heights. These latter correlations are statistically significant: $r = 0.246$ ($P < .005$), in the case of the maxillary posterior dentoalveolar height, and $r = 0.404$ ($P < .001$), in the case of the mandibular posterior dentoalveolar height. Scatterplots of these two relationships are presented in Figures 4 and 5, respectively. A tabulation of correlation coefficients of the remaining dental measurements to maximum bite force is presented in Table 3.

Discussion and conclusions

Correlation of decreasing maximum bite force to increases in mandibular plane angle and to increases in the mandibular/palatal plane angle supports the widely held concept that subjects exhibiting a long face syndrome tend to bite with diminished force.[13] The correlation of maximum bite force to an increased ratio of posterior facial height to anterior facial height supports the notion that "square-jaw" individuals exhibit a greater maximum bite force capability than those of normal facial proportions.[14] Correlation of bite force to anterior-posterior skeletal measures are low, indicating that maximum bite force is not directly dependent on these measurements.

Contrary to conventional understanding, greater posterior dentoalveolar heights were found to correlate significantly with increasing maximum bite force.[3] These isolated skeletal variables may not be a reliable indicator of maximum bite force. As a consequence of this unex-

Table 3
Correlation of dental measurements with maximum bite force

Dental Measurements	Correlation Coefficient (r)	Regression equation (F = maximum bite force)
IMPA°	0.158	IMPA° = 58.5 x 10^{-4} (F) + 89.259
1|1 - NF°	-0.0087	1|1 - NF° = -3.4 x 10^{-4} (F) + 109.84
Interincisal angle°	0.0396	Interincisal angle = 22.33 x 10^{-4} (F) + 132.97
Overjet (mm)	0.0137	OJ = 1.1 x 10^{-4} (F) + 3.60
Overbite (mm)	0.0418	OB = 4.47 x 10^{-4} (F) + 3.726
OP Angle	-0.1417	OP = -31.1 x 10^{-4} (F) + 8.805

Table 4
Correlation coefficients of dentoalveolar height with various cephalometric measurements

Measurement	PFH/AFH%	MP/PP°	MPA°
6|6 - NF	0.0057	0.1769	0.0815
6|6 - MP	0.1487	0.0378	0.010
Sum of above	0.099	0.0585	0.0319

pected finding, subjects of this study were re-evaluated to determine if those exhibiting greater posterior dentoalveolar heights also tended to exhibit a greater ratio of posterior facial height to anterior facial height, or tended to display diminished MP/PP angles, or exhibited a smaller mandibular plane angle. The correlation coefficients of each of these measures with regard to posterior dentoalveolar height are presented in Table 4. These were all found to be low, indicating a lack of a significant relationship between these independent variables to posterior dentoalveolar heights.

Correlation of maximum bite force with various dental linear and angular cephalometric measurements was found to be low. Dental overbite, believed to correlate to maximum bite force, is not supported by the findings of this study.[15] It is interesting to note that patients in the past who wore the Milwaukee type brace, which causes a relatively constant occlusal force, exhibited splaying of the incisors and an increased overbite.[16] Maximum bite force occurs relatively infrequently and likely does not have the same effect as a relatively constant applied force. Perhaps normal daily functioning bite force has a greater potential effect on the dentition than infrequently applied maximum bite force.

We may also reflect as to whether differences in bite force play a primary role in determining the ultimate facial morphology or merely reflect the mechanical advantage of the musculature in different facial types.

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References

1. Braun S, Bantleon HP, Hnat WP, Freudenthaler JW, Marcotte MR, Johnson BE. A study of bite force; part 1. Angle Orthod 1995;65(5):367-372.
2. Ringqvist M. Isometric bite force and its relation to dimensions of the facial skeleton. Acta Odont Scand 1973; 31:35-42.
3. Proffit WR, Fields HW, Nixon WL. Occlusal forces in normal and long-face adults. J Dent Res 1983; 62:566-70.
4. Garner LD, Kotwal NS. Correlation study of incisive biting forces with age, sex and anterior occlusion. Proceed IADR Abstracts 1972; 53.
5. Denzinger FW. A study of the correlation of incisal biting force and cephalometric patterns. (Thesis.) Indianapolis, Indiana: Indiana University School of Dentistry 1971.
6. Pruim GJ, de Jongh HJ, ten Bosch JJ. Forces acting on the mandible during bilateral static bite at different bite force levels. J Biomech 1980; 13(9): 755-763.
7. Fields HW, Proffit WR, Case JC, Vig KWL. Variables affecting measurements of vertical occlusal force. J Dent Res 1986; 65(2): 135-138.
8. Garret FA, Angelone L, Allen WI. The effect of bite opening, bite pressure and malocclusion on the electronic response of the masseter muscles. Am J Orthod 1964; 50:435-444.
9. Archer S, Vig P. Effects of head posture on intraoral pressure in classes I, II and III adults. Am J Orthod 1985; 87:311-318
10. Daly P, Preston CB, Evans WG. Postural response of the head and bite opening in adult males. Am J Orthod 1982; 82:157-160.
11. Hagberg C. Assessments of bite force: a review. J Craniomandib Disord: Facial and Oral Pain, Vol I (3) 1989; 162-169.
12. Zar JH. Biostatistical Analysis. 2nd Edition. Englewood Cliffs; Prentice-Hall 1984: Ch 7-9.
13. Ingervall B, Helkimo R. Masticatory muscle force and facial morphology in man. Archs Oral Biol 1978; 23: 203-6.
14. Ingervall B, Thilander B. Relation between facial morphology and activity on the masticatory muscles. J Oral Rehab 1974; 1:131-147.
15. Kotwal NS. A study of the correlation of incisive biting forces with age, sex, in centric occlusion. (Thesis.) Indianapolis, Indiana: Indiana University School of Dentistry, 1971.
16. Graber TM, Chung DDB, Aoba JT. Dentofacial orthopedics verses orthodontics. J Am Dent Assoc 1967; 75:1145.