Craniofacial morphology and tooth wear: A longitudinal study of orthodontic patients

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Abstract: Previous research has suggested that a relationship exists between craniofacial morphology and tooth wear. The primary objective of this study was to determine whether an individual's craniofacial morphology during childhood is related to the degree of tooth wear that occurs in that same individual's adult dentition. Pretreatment orthodontic records taken during the mixed dentition (T_1) and follow-up records taken an average of 20 years later (T_2) were available for 165 orthodontic patients. Incisal/occlusal tooth wear was measured on a tooth-by-tooth basis from T_1 and T_2 casts using a four-category scoring system. Measures of craniofacial morphology were made from the T_1 lateral cephalometric radiograph. Multiple regression analysis indicated that adult wear was associated with the T_1 cephalometric measures of ANB ($p = 0.017$) and the interaction between ramal height and sex ($p = 0.039$). These results suggest that the craniofacial morphology observed during childhood has a small but significant relationship to adult tooth wear.

Key Words: Cephalometric, Bruxism, Dental attrition, Occlusal wear, Occlusion

Individuals with significant tooth wear have been described as having a characteristic craniofacial morphology.[1-5] Cephalometric analyses of these individuals have reported a reduction in lower anterior facial height, a more horizontal mandibular plane angle relative to both the palatal plane and the cranial base, a more acute gonial angle, greater posterior facial height, and a more obtuse interincisal angle.[1-4,6,7] This pattern of cephalometric characteristics affects the vertical proportions of the face and results in these individuals having a "rectangular" facial appearance in profile.[2,8] The diagnostic importance of recognizing variations in the vertical dimension of the face was emphasized by Sassouni[9] and is critical in distinguishing long-face[10] and short-face[11] patterns.

One possible explanation for the relationship between tooth wear and craniofacial morphology is the common influence of muscle activity. There is an association between increased tooth wear and an individual's ability to produce greater levels of bite force,[2,3,12,13] although this is not a universal finding.[14] Muscular forces also affect the growth of the craniofacial complex.[15,16] For example, individuals with myotonic dystrophy have weakened craniofacial musculature and exhibit craniofacial growth typical of a long-face pattern.[17] Research on the relationship between craniofacial form and bite force has suggested that bite force is lower in individuals with facial proportions typical of a long-face pattern, and higher in those with short-face characteristics.[3,12,18-23] It is important to note, however, that there is considerable variability in these associations, and thus Hannam and Wood[24] caution that a simple relationship between craniofacial morphology and the ability to produce occlusal forces is unlikely due to the complexity of the biomechanically relevant variables.

Recent work by Knight and colleagues[25] found that the degree of tooth wear observed during the mixed dentition is correlated with the degree of tooth wear that occurs in that same individual as an adult. They suggested that there are likely to be some relatively consistent individual characteristics that contribute to this association. The purpose of this study was to determine whether an individual's craniofacial morphology during childhood (T_1) might be associated with the degree of tooth wear that occurs in that same indi-

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vidual as an adult (T_2). Lateral cephalometric radiographs taken prior to the start of orthodontic treatment and taken again more than 10 years after completion of treatment were available for cephalometric analysis. The cephalometric data were collected on a group of orthodontic patients that Knight and colleagues[25] had already evaluated using a categorical scoring system to assess each tooth's wear.

Materials and methods

Sample

The sample consisted of orthodontic records obtained from a sample originally used by Knight and colleagues.[25] Stone dental casts and lateral cephalometric radiographs made before treatment (T_1) and a minimum of 10 years postretention (T_2) were available from the long-term postretention collection at the University of Washington. These patients were treated in the Department of Graduate Orthodontics and/or in the private practices of departmental faculty.

The original sample was selected based on several inclusion criteria set forth by Knight and colleagues,[25] including the following: (1) at least one deciduous tooth was present, (2) stone dental casts were free of any obvious distortion and showed the occlusal/incisal edges of all teeth, and (3) dental radiographs (bitewing, periapical and/or panoramic) were available. A subset of this sample was selected based on the following additional inclusion criteria: (1) cephalograms were present at T_1 and T_2; (2) cephalograms were free of any obvious distortion, and were clearly dated and identifiable; (3) cephalograms had all necessary dental, skeletal, and soft tissue landmarks visible.

Of Knight and colleagues'[25] original sample of 223 possible subjects, 36 cephalometric radiographs were either unavailable, distorted, unclearly dated/identified, or unreadable. Of the remaining 187 subjects, 22 lacked complete data for statistical analysis, leaving the 165 subjects used in the present study.

Evaluation of stone dental casts

A 4-point ordinal scoring system for dental wear[25-28] was used to evaluate individual tooth wear. The scoring categories were as follows: 0 = no obvious wear facets in enamel, occlusal/incisal structure intact; 1 = marked wear facets in enamel, occlusal/incisal structure altered; 2 = wear into dentin, dentin exposed occlusally/incisally and/or occlusal/incisal structure changed in shape; 3 = extensive wear into dentin, greater than 2 mm^2 of exposed dentin, significant occlusal/incisal structure lost locally or generally. A detailed description of the methodology used to measure tooth wear is given in Knight et al.[25]

Evaluation of cephalograms

Cephalometric measurements were made from conventional dental and skeletal landmarks traced onto acetate paper from the original lateral cephalometric radiograph by one investigator (JRA). A total of 20 landmarks were identified on each film (Figures 1 and 2), and from these reference points and planes, 5 linear measurements, 10 angular measurements, and 1 ratio were determined. These 16 cephalometric measurements were grouped into (1) vertical measures, (2) anteroposterior measures, (3) mandibular plane measures, and (4) dentoalveolar measures (Table 1). Angular measurements were recorded to the nearest 0.5 degree and linear measurements to the nearest 0.5 mm without correction for enlargement.

Error of the method

Reproducibility of the linear and angular measurements was assessed. Of the total residual sample of 165 subjects, approximately 15% (27 subjects) were randomly selected to be reevaluated by the same investigator a minimum of 1 week after the initial measurement session. The second evaluation was done without any knowledge of the subjects' identities or of the previous measures. The cephalometric radiographs were retraced, and the cephalometric variables were remeasured. The measurement error was calculated using Dahlberg's Equation:[29] S_x = square root of ΣD^2 / 2N, where D is the difference between the repeat measures and N is the number of subjects reevaluated. For the cephalograms that were measured twice, the average of the two measurements was used in the subsequent statistical analyses.

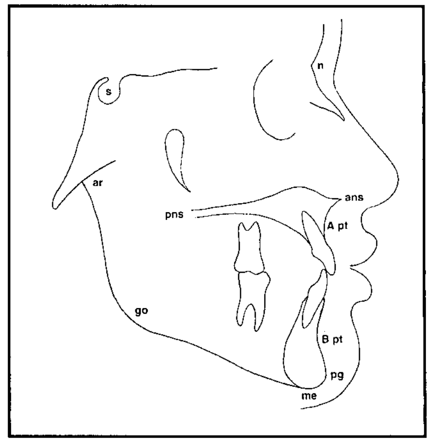

Figure 1
Cephalometric reference points

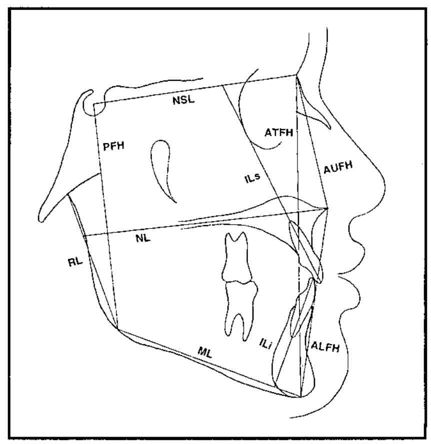

Figure 2
Reference planes derived from cephalometric landmarks

Table 1
Descriptive statistics for the sample during the mixed dentition (T_1) and the adult dentition (T_2)

Variable	T_1 Method error	T_1 assessment $\bar{x}$ (SD, range) Male (N = 60)	T_1 assessment $\bar{x}$ (SD, range) Female (N = 105)	T_2 assessment $\bar{x}$ (SD, range) Male (N = 60)	T_2 assessment $\bar{x}$ (SD, range) Female (N = 105)
Age		10.0 (1.3, 7.2-13.1)	9.8 (1.6, 6.7-14.6)	30.4 (5.6, 20.6-46.4)	29.7 (5.3, 20.1-48.9)
Occlusal measures					
Angle Class I (%)		40.0	44.8	81.7	77.1
Overjet (mm)		6.8 (3.5, -4.7-13.2)	6.3 (3.0, -2.8-14.4)	3.3 (1.2, 0.7-6.4)	3.5 (1.5, 1.2-10.6)
Overbite (mm)		4.2 (2.0, -3.5-7.4)	3.7 (2.0, -3.4-8.3)	3.0 (1.4, -1.6-5.3)	3.3 (1.1, 0.0-5.7)
Openbite yes (%)		28.3	35.2	13.3	14.3
Tooth wear scores					
All teeth		0.7 (0.3, 0.0-1.4)	0.5 (0.3, 0.0-1.3)	0.9 (0.4, 0.0-1.9)	0.8 (0.4, 0.1-1.6)
L-CDE wear scores		1.5 (0.6, 0.0-3.0)	1.3 (0.7, 0.0-2.4)		
Vertical facial height measures					
Ant. total facial height, *N-Me* (mm)	0.4	112.1 (6.4, 101.0-128.5)	107.6 (5.9, 94.0-122.5)		
Ant. upper facial height, *N-ANS* (mm)	0.5	50.1 (6.7, 43.0-95.5)	48.1 (3.5, 38.5-58.0)		
Ant. lower facial height, *ANS-Me* (mm)	0.4	64.6 (4.8, 55.5-75.5)	61.2 (4.4, 51.0-72.0)		
Post. ramal height, *Ar-Go* (mm)	0.9	40.5 (3.2, 32.5-47.5)	39.8 (3.5, 32.5-49.5)	51.7 (5.9, 40.0-69.0)	44.0 (4.0, 31.5-54.0)
Post. facial height, *S-Go* (mm)	0.8	69.4 (4.5, 61.5-80.5)	67.4 (4.3, 56.0-78.0)		
ATFH/PFH ratio, *N-Me/S-Go*		1.6 (0.1, 1.4-1.9)	1.6 (0.1, 1.4-1.9)		
Anteroposterior measures					
SNA	0.5	79.6 (4.2, 69.5-89.5)	80.7 (3.3, 70.5-89.5)		
SNB	0.4	74.7 (3.9, 64.0-83.5)	75.9 (3.4, 68.0-85.0)		
SNPg	0.4	75.8 (4.0, 66.0-86.0)	77.0 (3.5, 69.0-87.0)		
ANB	0.4	4.9 (3.1, -6.0-12.0)	4.8 (2.3, 0.0-9.5)	2.3 (2.5, -9.5-6.0)	3.5 (2.3, -1.5-10.0)
Mandibular plane measures					
MnPl-SN, ML/NSL (°)	0.7	36.3 (5.4, 26.3-49.3)	35.2 (4.7, 25.0-44.5)		
MnPl-PalPl, ML/NL (°)	1.3	28.8 (5.4, 13.5-40.0)	27.8 (4.8, 16.5-38.5)		
MnPl-RamPl, ML/RL (°)	0.9	131.9 (6.0, 114.5-145.5)	130.8 (5.3, 118.0-149.5)		
Dentoalveolar measures					
Interincisal angle, ILs/ILi (°)	3.2	130.2 (11.8, 101.5-160.0)	128.9 (12.1, 95.5-165.5)		
Mn 1/Mn plane, ILi/ML (°)	1.7	91.1 (7.3, 77.5-109.5)	92.6 (6.7, 75.0-112.0)		
Mx 1/SN, ILs/NSL (°)	2.7	101.8 (8.7, 81.5-119.5)	102.7 (8.3, 76.5-122.5)		

Statistical analysis

Descriptive statistics for age, tooth wear, and occlusal characteristics (Angle class, overjet, overbite, and openbite, which was defined as lack of incisor contact) were determined at T_1 and T_2 (Table 1). A descriptive analysis of tooth wear was done for the primary and permanent dentition at T_1 and for the permanent dentition at T_2 as described by Knight and colleagues.[25] A descriptive analysis of tooth wear was performed for each tooth, as well as for subgroups of teeth as detailed below. At T_1 the subgroups of teeth were: (1) primary maxillary canines, first molars and second molars (U-CDE); (2) primary mandibular canines, first molars and second molars (L-CDE); (3) permanent maxillary central and lateral incisors (U-1,2); (4) permanent mandibular central and lateral incisors (L-1,2); (5) permanent maxillary first molars (U-6); and (6) permanent mandibular first molars (L-6). As in previous research,[25,28] means of individual tooth wear scores were used as an index of tooth wear. At T_2, the whole-mouth mean wear score was used. This score represents an index of dental wear for an individual and is derived by summing the ordinal scores for all of the teeth and dividing by the number of teeth assessed. Descriptive statistics were also calculated for each of the cephalometric parameters at T_1.

To assess the factors associated with tooth wear at T_1, multiple regression analysis was used. The unit of analysis was tooth subgroup (previously defined). The starting point for this analysis was the statistical model presented by Knight and colleagues,[25] which included all tooth subgroups, sex, age, overbite, and the following interactions: age × sex, age

× subgroup, and overbite × subgroup. A subset of the original 16 cephalometric variables was selected for inclusion in this analysis based on correlations between variables. Those measures that were highly correlated with others (i.e., were redundant) were omitted. Thus, eight of these cephalometric variables [vertical facial height (N-Me, Ar-Go, S-Go); anteroposterior (NSL/A, NSL/B); mandibular plane (ML/NSL, ML/RL); and dentoalveolar (ILs/ILi)] were added individually to the model, and each was tested for statistical significance at $p = 0.05$. Correlation between multiple wear scores on the same subject was adjusted for by using generalized least squares estimation with restricted maximum likelihood estimation of variance and correlation parameters.[30] Residual analysis was performed to verify that the assumptions of this analysis were met. Likelihood ratio tests were used to assess the significance of the factors in the model.

To determine if cephalometric measures at T_1 were associated with mean occlusal wear in the adult permanent dentition at T_2, Pearson correlation coefficients were used. A multiple regression model was also used with the whole mouth mean wear score at T_2 as the dependent variable. The variables found to be predictive of T_2 tooth wear by Knight and colleagues[25] were included as independent variables (L-CDE, sex, age T_1, age T_2, and the interactions: age T_1 × sex and age T_1 × L-CDE). The eight previously described cephalometric measures at T_1 were included in this model. This approach was used to search for cephalometric predictors that would account for variation in adult tooth wear over and above that explained by the predictors found by Knight and colleagues.[25] After the elimination of nonsignificant variables, all pairwise interactive effects were added to the model. The statistical significance of model effects was assessed using the F-test, based on the error sums of squares with significance level $p = 0.05$.

Table 2
Multiple regression model relating cephalometric and other variables measured in mixed dentition (T_1) to wear in the adult dentition (T_2) (N = 165, $R^2 = 0.42$)

Variable	Coefficient	SE	t	p
Intercept	-0.362	0.713	-0.51	0.61
Sex (0 = male; 1 = female)	-1.312	0.710	-1.85	0.066
T_2-age	0.024	0.005	4.90	<0.0001
T_1-age	0.009	0.040	0.22	0.82
L-CDE	0.956	0.265	3.62	0.0004
L-CDE × T_1-age	-0.061	0.026	-2.38	0.018
L-CDE × sex	0.134	0.086	-1.56	0.12
PRH	-0.005	0.014	-0.32	0.75
ANB	0.025	0.010	2.42	0.017
PRH × sex	0.036	0.017	2.08	0.039

Cephalometric measurements taken at T_1 that were associated with tooth wear at T_2 were measured on the cephalometric radiographs in adulthood (T_2). The T_2 values of these cephalometric variables were added to the multiple regression model for adult tooth wear.

Results

Sample description

Demographic, occlusal, and cephalometric characteristics of the sample are presented in Table 1.

Error of the method

Of the 16 cephalometric measures considered, the angular measures in general had greater method error than the linear measures, but were acceptable. The specific method error of each measurement is shown in Table 1.

Cephalometric variables associated with tooth wear

Of the eight cephalometric variables analyzed at T_1, no significant effects were found on the wear of any tooth subgroups or on the whole-mouth mean wear at T_1. In the initial regression model for wear at T_2, three cephalometric variables were at least marginally significant: posterior ramal height (PRH), SNA, and SNB. Because the regression coefficients for SNA and SNB were similar in magnitude and of opposite sign, these variables were replaced with ANB (based on the relationship ANB = SNA-SNB). The final predictive model is shown in Table 2 ($R^2 = 0.42$). Two cephalometric variables were found to be associated with occlusal wear at T_2: the interaction between posterior ramal height and sex (PRH × sex, $p = 0.039$); and the anteroposterior discrepancy between the maxilla and the mandible (ANB, $p = 0.017$). Specifically, females with greater ramal height at T_1 had more tooth wear at T_2. Also, a larger ANB at T_1 corresponded to greater tooth wear at T_2. Statistically significant correlations were found between the T_1 and T_2 values for ANB ($r = 0.61$, $p < 0.0001$) and for PRH ($r = 0.33$, $p < 0.0001$). However, when these T_2 cephalometric variables were added to the multiple regression model shown in Table 2, they were not found to be related to adult wear ($p > 0.05$).

Discussion

The purpose of this study was to determine whether any craniofacial morphological characteristics present during childhood are related to the amount of tooth wear that octo the amount of tooth wear that occurs during adulthood. This hypothesis was based on the assumption that at least some of the craniofacial morphological characteristics that have been associated with adult tooth wear[1-3,6,7] may play a role in its development and are not simply a consequence of excessive wear. In the present study, two childhood (T_1) cephalometric measures were found to be related to the amount of tooth wear observed in adulthood (T_2). A positive relationship was found between the anteroposterior discrepancy between the maxilla and mandible (as measured by the ANB angle) at T_1 and the amount of tooth wear measured at T_2. The other significant association was between the height of the ramus (articulare to gonion in mm) at T_1 and the amount of wear at T_2, although this relationship was limited to females (females with greater T_1 ramal heights had increased wear at T_2). By themselves, the contribution of these cephalometric variables to the prediction of adult tooth wear is small, and the possibility exists that they could be false positive findings (i.e. Type I errors). Nonetheless, when these cephalometric variables were combined with other factors that were shown by Knight and colleagues[25] to be related to adult tooth wear, a model can be created (Table 2) that accounts for 42% of the variance observed in adult tooth wear.

At present, the mechanisms by which craniofacial form influences tooth wear are unknown. Tooth wear results from a variable combination of three different mechanisms: attrition, abrasion, and erosion.[4] Using longitudinal orthodontic records, Knight and colleagues[25] found that the degree of tooth wear present during childhood was predictive of the degree of tooth wear observed in adulthood. They suggested that an individual trait or characteristic present at both T_1 and T_2 might account for this association. For example, some individuals may be predisposed to greater dental attrition at T_1 and T_2 because of their propensity to generate greater occlusal forces during functional, and especially parafunctional (e.g., bruxing and clenching) tooth-to-tooth contacts. Thus, one hypothesis to account for the present cephalometric findings is that craniofacial morphological characteristics may influence the degree of occlusal force that an individual can generate, which in turn would affect the amount of attrition that occurs during function and parafunction. A prerequisite for this interpretation would be that the T_1 cephalometric measures associated with adult tooth wear (or the underlying factor(s) mediating that association) should be somewhat consistent over time. Indeed, the T_1 and T_2 measures of ANB and ramal height are significantly related within an individual, despite intervening orthodontic treatment.

Previous research on subjects with high dental wear has found a positive association between posterior facial height and degree of tooth wear.[6] In the present study, the only cephalometric measure of vertical facial dimension at T_1 that was associated with wear at T_2 was a measure of posterior facial height (i.e., ramal height). One possible explanation for this observation is that a greater posterior facial height has been associated with an individual's ability to generate stronger occlusal forces.[12,18,20-22,31] Thus, for individuals prone to excessive tooth wear via attrition (e.g., bruxism), the ability to produce greater occlusal forces may result in increased wear. The present study found that the association between ramal height at T_1 and tooth wear at T_2 only existed for females. Interestingly, Ingervall and Minder[31] found a significant correlation between facial form and bite force for girls but not for boys. Kiliaridis and Kälebo[32] also found a correlation between masseter muscle thickness and facial morphology for women, but not for men. Specifically, women with thinner masseter muscles had a longer face in proportion to facial width.

Other measures in the vertical dimension of the face have been associated with excessive dental wear. For example, a reduced lower anterior facial height is often reported.[1,2,6] However, this change in facial morphology may be a consequence of the loss of occlusal vertical dimension due to a rapid rate of tooth wear that allows anterior rotation of the mandible.[2,4,6] In this situation, the reduction in lower anterior facial height is a consequence of tooth wear, not a cause, and therefore would not be expected to be a T_1 predictor of tooth wear at T_2.

The positive relationship between the ANB angle at T_1 and the amount of tooth wear measured at T_2 was surprising. In general, cephalometric research evaluating the relationship between craniofacial form and excessive tooth wear typically reports differences in the vertical, not the anteroposterior, dimension. (For a recent example, see the work of Kiliaridis and colleagues.[3]) Similarly, research examining the association between craniofacial morphology and maximum bite force typically reports a relationship between vertical, not anteroposterior, cephalometric measures. (For a recent example, see the work of Throckmorton and colleagues.[21]) Although speculative, one explanation for this finding may be a relationship between the initial severity of the ANB angle and the quality of the occlusion at T_2. The research described in this study is unusual in that all the subjects included in the sample were treated orthodontically. Therefore, most achieved a reasonable immediate posttreatment occlusion. However, patients with severe initial anteroposterior skeletal discrepancies may be at increased risk for occlusal relapse. Poor occlusal relationships may not allow the immediate disarticulation of tooth surfaces on excursive movements of the mandible and thus may put more teeth at risk for wear. A similar argument may be made to explain why more wear is associated with a lesser amount of overbite.[25,33,34]

There are likely to be additional factors at T_1 that were not measured in this study that, when added to the model shown in Table 2, might improve the strength of the association with tooth wear at T_2. For example, the current analysis of the relationship between craniofacial morphology and tooth wear was limited to measures in the vertical and anteroposterior dimensions. Yet research has suggested that craniofacial morphological characteristics measured in the transverse dimension (e.g., intergonial width, intercondylar width, width of the dental arches) may be related to the strength of occlusal forces and to tooth wear.[12] Other individual factors that could be measured at T_1 and that might be related to the development of T_2 tooth wear include: (1) salivary characteristics,[7,28] (2) bite force,[2,35] and (3) bruxism.[36]

Another longitudinal study relating cephalometric and occlusal measures in childhood (T_1) to occlusal wear in adulthood (T_2) should be conducted on a different sample of patients to validate the model presented in this study. It would also be valuable to identify a sample of high wear adults who had previous orthodontic treatment and whose initial pretreatment records are available. In this way, the utility of the present model could be better generalized to the group of high wear individuals who present clinical problems. Improving our ability to identify individuals who are at risk for excessive tooth wear may be beneficial, since orthodontic retention schemes are available to protect tooth surfaces.

Conclusion

The results of this study suggest that the craniofacial morphology observed during childhood has a small but significant relationship to adult tooth wear.

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