Craniofacial morphology, occlusal traits, and bite force in persons with advanced occlusal tooth wear

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The aim of this study was to investigate the dentofacial structure, the occlusal traits, and the bite force in subjects with advanced occlusal wear. The material comprised 54 adults, 30 men ($\bar{x}$ = 40 years, range 16 to 61) and 24 women ($\bar{x}$ = 28 years, range 18 to 47), most of whom had a full or near-full complement of natural teeth, and the presence of occlusal wear. Craniofacial structure was studied on lateral cephalograms. Occlusal traits were examined on study casts, these serving also for an evaluation of occlusal wear to be carried out by using an ordinal scale. Bite forces were recorded at differing force levels (maximum biting, "biting as when chewing" and "light biting") and occlusal positions. Although maximum bite force and endurance time did not differ significantly between men and women, the level of bite force was high compared with other samples. The craniofacial structure of the sample was characterized by a deviation in the vertical direction, a small angle between the mandibular-palatal planes and a small gonial angle, as compared with Swedish adult norms. No significant differences were found in anteroposterior relationships between persons with advanced wear and normal standards. The results support the hypothesis that functional hyperactivity of the masticatory system imposed increased stress on the bony structures of the craniofacial complex with possible influences on its structure. (AM J ORTHOD DENTOFAC ORTHOP 1995;107:286-92.)

Clinical studies have shown a correlation between bite force, or cross section of the masticatory muscles, and facial structure.[1-7] Subjects with a strong bite force, or a well-developed masticatory musculature, had a more anteriorly inclined mandible, a smaller anterior and greater posterior facial height, as well as a smaller gonial angle, in contrast to those with a weak bite force; the latter possessed a longer anterior and shorter posterior facial height, and a larger gonial angle.

Animal experimental models have been used for the purpose of elucidating the relationship between craniofacial structure and muscle function. These models were based on altering masticatory function by removing the masticatory muscles,[8-10] disrupting the occlusion,[11-13] or changing the consistency of food.[14-17] The skeletal changes induced by an alteration of muscle function indicate that masticatory muscle function has a significant influence on craniofacial growth. Although the results of these studies illustrate the basic mechanism of bone remodeling and its relationship with muscle function in experimental animals, their application in human being is not necessarily valid.

Bite force has been demonstrated to be associated with occlusal wear and related to dentoalveolar structure.[18-20] Our interest therefore was focused on a group of persons with extensive occlusal wear, one possible cause of which may be the increased activity generated by the masticatory muscles, such as in bruxism, on the dental hard tissues; an increased stress on the bony structures of the craniofacial region in such persons would also be reasonable to assume. Thus the aim of this study was to examine more closely the relationship, if any, between dentofacial structure, occlusal traits, and bite force in persons with advanced occlusal wear.

SUBJECTS AND METHODS

The 54 subjects comprising the present sample are part of a group of 59 previously reported[20]; 5 of the 59 subjects had not had cephalograms taken, and were

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Table I. Ordinal scale used for grading severity of occlusal wear

0	No visible 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 adjacent tooth surface. Occlusal/incisal structure changed in shape with height reduction of crown.
3	Extensive wear into dentin. Larger dentin area (>2 mm^2) exposed occlusally/incisally and/or adjacent tooth surface. Occlusal/incisal structure totally lost locally or generally. Substantial loss of crown height.
4	Wear into secondary dentin (verified by photographs).

therefore excluded. Thirty were men ($\bar{x} = 40$ years, range 16 to 61 years) and 24 women ($\bar{x} = 28$ years, range 18 to 47 years), most of them with full or near-full complement of natural teeth, the criteria for selection being the presence of definite clinical signs of occlusal wear. A standard clinical examination was performed that included a functional evaluation of the masticatory system. Impressions were taken to fabricate dental casts for an analysis of occlusal traits and for a detailed evaluation of the degree of occlusal/incisal wear. The relationship between the upper and lower jaws were recorded in the intercuspal position. Severity of wear was graded with an ordinal scale (Table I). As previously described, and on the basis of a full or near-full (excluding third molars) complement of teeth in the sample, it was considered reasonable to assign a mean occlusal wear index to each of the casts. This was obtained by dividing the sum of the scores for both arches by the number of teeth present. The rationale for transforming the scores from the ordinal scale into a mean value index has been discussed previously.[20] Intraoral photographs were used to determine grade 4 wear, which corresponded to "wear into secondary dentin" (Table I). Bite force was measured by means of an interocclusal metal fork-like device incorporating strain gauges; for ease of occluding the teeth, the bite fork was coated with soft rubber. The bite fork was connected to a Speedomax Recorder (Leeds & Northrup, London, U.K.), paper speed was 20 cm/minute and the maximum pressure, which could be recorded, was 980 N. The equipment was calibrated by using known loads. Biting was performed at different force levels and occlusal positions: maximum biting, "biting as when chewing," and "light biting," and in each of the second premolar, canine and incisor regions. Each biting activity was repeated twice, and the mean value was recorded. Maximum bite force was performed in any position considered best by the subject.[21] For statistical purposes, the recordings from submaximal biting ("biting as when chewing" and "light biting") were transformed into a mean value for each person; left and right canines and premolar groups had separate means assigned. Endurance time was measured as the time for which the subject could maintain the maximum bite force until exhaustion. Any reported symptoms during the endurance test (pain, tiredness) were recorded.[22]

Lateral cephalograms were taken to study the craniofacial structure. The reference points and lines used in the cephalometric analysis were based on those introduced by Björk[23] and are shown in Fig. 1. The results obtained from the cephalometric analysis of the sample were compared with normal mean standards for the facial skeleton of healthy Swedish adults, based on 50 women and 101 men.[24] The latter comprised the control group, and its choice was considered justified on the basis that unnecessary exposure to ionizing radiation for a new control group was unjustified.

The collection of clinical data was, in the majority of cases, carried out by one of the examiners (T.H.), whereas the cephalometric measurements and the analysis of the occlusal traits were carried out by another examiner (S.K.).

Statistical methods

Unpaired *t* test was used to assess differences in the cephalometric variables and between male and female subjects. Interdependence between age and variables was tested by linear correlation (Pearson). All statistical analyses were performed with the Statistical Package for Social Sciences (SPSS, Release 5, Chicago, Ill.) on an IBM 80386 DX personal computer.

RESULTS

Analysis of the dental casts showed that, in the anteroposterior relationship, 82% of the sample had Angle Class I occlusion, 16% Angle Class II, and 2% Angle Class III. Neither frontal nor lateral open bites were found among the persons examined, whereas, in the transverse direction, only one (less than 2%) subject had a lateral crossbite. The frequency of crowding (≥ 2 mm per quadrant) was 9%.

The median number of teeth per person subjected to examination for occlusal or incisal wear was 27, within a range of 19 to 28. The mean wear dentition index, for the sample, corresponded to 1.70 (SD = 0.47, range = 0.96 to 3.05), for men only to 1.90 (SD = 0.51, range; 0.96 to 3.05), and for women only to 1.45 (SD = 0.28, range, 1.07 to 2.27), the difference between the male and female subjects being significant ($p \leq 0.001$). In both the male and the female groups, a pattern emerged whereby, in both arches, anterior teeth exhibited significantly greater wear than did posterior teeth.[20]

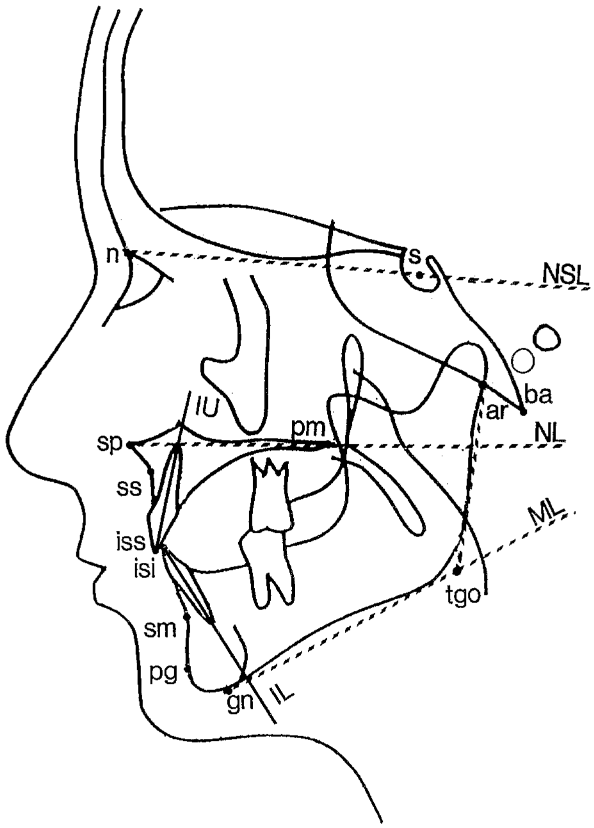

Fig. 1. Cephalometric reference points and planes used in this study.

Maximum bite force and endurance time did not differ significantly between men and women (Table II). When biting at submaximal levels ("biting as when chewing" and "light biting"), the male subjects possessed significantly higher forces than the female subjects at all levels and in all regions ($0.001 \geq p \leq 0.05$; Table II). Increased age was significantly correlated to a lower maximum bite force in both men ($r = -0.56$; $p \leq 0.01$) and women ($r = -0.47$; $p \leq 0.05$). In neither men nor women did endurance time show any significant correlation to maximum or submaximal bite forces.

The results of the cephalometric analysis showed no statistically significant difference in the anteroposterior skeletal relationship (s-n-ss, s-n-pg) between persons with advanced occlusal wear and the normal mean standards for the facial skeleton of healthy Swedish adults (Table III). However, the craniofacial structure of the study sample was characterized by a deviation in the vertical direction: A less steep mandibular plane (NSL/ML) and reduced mandibular-palatal plane angle (ML/NL) were found for the occlusal wear sample, which were statistically significant ($p \leq 0.05$ and $p \leq 0.02$, respectively) for the men. A small gonial angle (gn-tgo-ar) was also a statistically significant characteristic for both men and women of the occlusal wear sample ($p \leq 0.01$) (Fig. 2). No statistical differences could be found between the groups tested for the inclination of the upper and lower incisors (IU/NL and IL/ML). Some differences observed in the interincisal angle (IU/IL) were not statistically significant and may reflect the vertical changes between the upper and lower jaw.

DISCUSSION

The presence in the sample of an extensive degree of wear, which was positively correlated to increased bite force,[20] and the finding that the overall majority of the persons reported bruxism,[20] would justify the assertion that the group possessed a functional activity beyond that which would be considered normal. Notwithstanding the known existence of other etiologic influences on wear, the high-wear group making up the present sample, could reasonably be said to be one in which changes, if any, in the craniofacial skeleton may have been influenced by functional factors during early or late growth.

When testing bite force capacity, not only was maximum force recorded, but also the force at submaximal levels, i.e., to simulate the person's chewing and light biting forces. It is known that, when testing maximum bite force, the recording may be rendered unreliable on account of the subject's fear of fracturing fillings, or experiencing sensations of pain or discomfort. The rationale for recording forces at certain submaximal levels was thus to provide an additional method to evaluate the functional capacity of the masticatory system.[18] In the present study, age was inversely correlated to bite force, which is in agreement with a previous report.[25]

Maximum bite force (about 600 N) in the present selected high-wear sample was high compared with that found in more random samples[18,26,27] (about 400 to 450 N) by using the same recording technique. This finding, together with previous reports of a correlation between high bite force and the severity of tooth wear,[18-20] raises a question about the causal or consequential nature of the bite force used in contemporary populations. Within such populations, and particularly in those possessing extensive occlusal wear, the cause of wear is of a much more multifactorial nature[28] compared with that of earlier populations: in the latter, coarse and abrasive food, and the use of the

Table II. Mean ($\bar{x}$), standard deviation (*SD*), and range (*R*), of bite force (maximal and sub-maximal; *N*) and endurance time (*s*) in men and women (Independent samples *t* test)

	Men (n = 30)			Women (n = 24)			
	$\bar{x}$	SD	R	$\bar{x}$	SD	R	p≤
Maximum bite force	651	196	270-980	556	218	140-980	ns
Biting as when chewing							
Premolar	140	72	55-340	90	50	20-200	0.01
Canine	128	70	45-305	62	34	20-120	0.001
Incisors	113	53	40-230	60	31	20-150	0.001
Light biting							
Premolar	74	59	15-265	42	35	10-145	0.05
Canine	64	48	10-195	33	28	1-120	0.01
Incisors	61	41	10-160	31	23	1-90	0.01
Endurance time (s)	46	39	6-180	40	17	17-72	ns

Table III. Cephalometric data by sex. Cephalometric norm values according to Sarnäs and Solow[24] (Independent-samples *t* test)

	Occlusal wear (male) n = 30				Norm (male) n = 101		Occlusal wear (female) n = 24				Norm (female) n = 50	
	$\bar{x}$	SD	R	p≤	$\bar{x}$	SD	$\bar{x}$	SD	R	p≤	$\bar{x}$	SD
s-n-ss°	83.0	5.0	75.1-92.7	ns	82.4	4.1	82.4	4.3	74.9-89.7	ns	81.5	3.6
s-n-pg°	83.0	5.0	74.4-94.3	ns	81.5	4.0	80.6	4.5	70.3-87.6	ns	79.7	3.3
NL/NSL°	6.6	3.3	0.4-14.0	ns	6.6	3.4	7.8	3.4	0.2-13.6	ns	7.5	2.7
ML/NSL°	26.1	6.9	9.1-40.8	0.05	29.3	6.7	30.1	6.4	19.3-46.5	ns	32.1	6.0
ML/NL°	19.5	6.1	7.9-37.8	0.02	22.7	6.3	22.3	5.5	10.8-36.5	ns	24.7	6.1
n-s-ba°	129.9	4.4	118-138	ns	129.3	5.2	131.3	5.4	120-141	ns	129.7	5.2
gn-tgo-ar°	118.8	6.4	108-134	0.01	123.0	7.3	120.3	6.9	111-138	0.01	126.0	7.1
IU/IL°	136.3	13.5	111-170	ns	134.0	10.9	133.8	11.1	115-157	ns	131.3	10.8
IU/NL°	110.6	9.9	89.4-124.5	ns	109.0	7.0	109.9	7.8	94.7-135.3	ns	109.3	7.4
IL/ML°	93.6	8.3	78.9-109.5	ns	94.4	7.4	94.0	8.4	74.1-106.3	ns	94.7	6.0

teeth as a tool, all of which required considerable amounts of masticatory force, were the main wear-contributing factors.[29] The training effect of increased muscle function on the masticatory muscles, due to parafunction or the effect of a higher tolerance level in the mechanism controlling masticatory muscle contraction, may, thus, be contributory causes of high bite forces.

The occlusal traits of the present sample, compared with those found in previous epidemiologic studies in Sweden,[30,31] showed a low frequency of orthodontic problems. No frontal open bite was found in the persons with advanced wear, whereas, in the epidemiologic studies, the prevalence of this malocclusion was 3% to 4%. In the transverse direction only one of the persons with advanced wear, i.e., less than 2%, had a lateral crossbite, whereas in the epidemiologic studies unilateral or bilateral crossbites were found in 20% of the men and in 27% of the women. A low frequency of crowding (≥ 2 mm per quadrant) was found among the persons with advanced wear, i.e., less than 9%, whereas in the epidemiologic studies it was found to vary from 21% to 43%. On the other hand, in the anteroposterior and vertical relationships no greater differences were observed between our sample and that found in the epidemiologic studies.

It has been observed that the frequency of occlusal variations and malocclusions have increased during recent centuries.[32,33] In this regard, it has been suggested that the absence of approximal wear (which produced space in the dental arches for erupting and migrating teeth in primitive people) is responsible for the greater frequency of

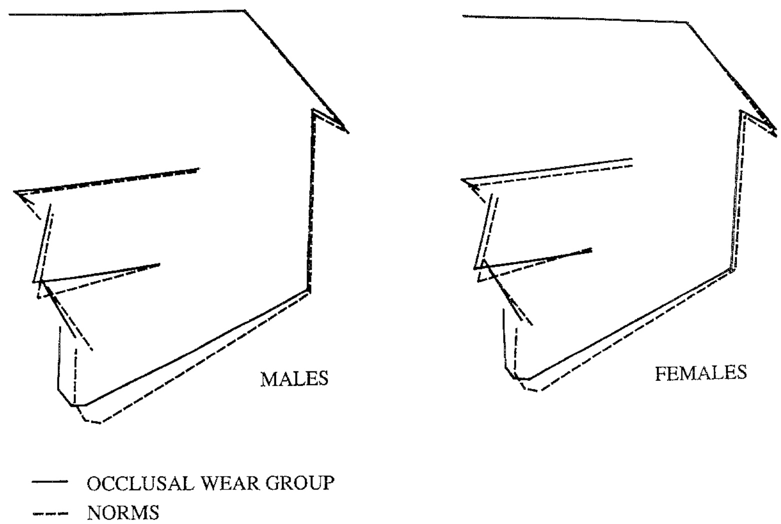

Fig. 2. Mean facial diagrams of men and women in occlusal wear sample and cephalometric norm values, according to Solow and Sarnäs.[24]

space-related malocclusions in contemporary populations.[34] Another reason for the increase in the prevalence of malocclusions in more recent population groups is the change in dietary habits over the past few hundred years, and the consequently reduced demand on masticatory activity; the resultant decrease in condylar growth, with a tendency toward a posterior rotation of the mandible, could contribute to the increased frequency of Class II malocclusion in modern man.[35] Furthermore, reduced masticatory function under animal experimental conditions caused decreased transversal dimensions of the dental arch breadth. This could be an explanation to the greater frequency of space-related malocclusions.[15] Taking into account the relatively short time period over which these drastic morphologic changes have occurred, the likelihood of an environmental basis for the changes, as opposed to a genetic one, is considered to be strong.[35] In contrast, the low frequency of features of malocclusion found in the present sample shows a similarity to that of earlier populations.

Our findings in the cephalometric analysis are in agreement with those found by Krogstad and Dahl.[36] The reduced mandibular-palatal plane angle in the occlusal wear sample and specially in men, may be explained by the assumption that the rate of the dental wear exceeds the rate of compensatory tooth eruption and dentoalveolar bone growth[37] causing an anterior rotation of the mandible with reduction of the lower anterior facial height.[38] However, this explanation contradicts the findings of studies on skull materials and on certain contemporary nonWestern population groups, e.g., Australian aborigines and Eskimos with extensive wear, where the loss of vertical dimensions after wear of the teeth was compensated for by tooth eruption and vertical growth of the alveolar bone.[29,39,40]

The other significant cephalometric finding in our sample was the small gonial angle of the mandible found in both men and women. This finding reflects the local effect of the excessive function of the masticatory muscles on the region of their insertion.[41] The facial structure of our sample is reminiscent of medieval skulls studied by Mohlin et al.[32] The characteristic facial structure in the medieval skulls was found to comprise a small intermaxillary angle, a small gonial angle and broad jaws. The severity of wear of the teeth in medieval skulls suggests an excessive function of the masticatory muscles, a factor which could, in turn, have influenced facial structure. Since the degree of wear in many of our subjects could be compared with that found in the medieval skulls, it may reasonably be suggested that a similar function—wear—facial structure interrelationship to that of the medieval material accounted for the observations made in the present sample.

This contrasts with most contemporary populations, but conforms with that of all primitive societies in which extensive occlusal and approximal wear seem to have been the norm,[29] and the process of "wearing in" started early during the deciduous dentition[34]; other features of the developing primitive facial skeleton were a compensatory growth to improve the vertical facial dimensional deficit accompanying wear, and an anterior rotation of the mandible that, together with an uprighting of the incisors, manifested in an "edge-to-edge" bite early in life.[29,42]

The results of this study complement those of a previous investigation on patients with an altered and reduced muscle function caused by myotonic dystrophy.[26] A high incidence of malocclusions (Angle Class II, anterior open bite, lateral crossbite, and crowding) was found among these patients. Their craniofacial structure showed a vertical aberration characterized by a large angle between the mandibular and palatal planes and a steep mandible; that is, the exact opposite picture to that presented by patients with excessive wear and the likely presence of a high level of muscle function.

On the basis of our previous findings on the etiologic factors, and covariation thereof, in a similar group,[20] and the findings in this study, the functional theory[16,35] is supported: In particular, the interdependence between muscle function, occlusal wear, and dentofacial structure has been shown to be significant in the present sample, and the relationship differs little from that seen in earlier populations. A clinical application lending support to the functional theory has been tried in children with skeletal anterior open bite.[43,44]

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