Examining the relationship between skull size and dental anomalies

• Joseph R. Krecioch •

Army Environmental Command, US Army, Ft Sam Houston, Texas, USA

Address for correspondence:
Joseph R. Krecioch, M.A., M.Sc.
Army Environmental Command, US Army
Ft Sam Houston
Texas, USA
E-mail: joseph.r.krecioch.civ@mail.mil

Bull Int Assoc Paleodont. 2014;8(2):224-232.

Abstract

This study, reporting the results of a 2012 Master's dissertation, of 131 skulls from 6 Classical to Medieval populations in Macedonia and England examined the relationship between craniometric variables and dental anomalies of shape, number, and position. Standard craniometric landmarks were measured and dental anomalies of shape, number, and position were recorded and tested for associations using SPSS. Rotations were the most common anomaly and were associated significantly with reduced mandibular robustness, as well as smaller facial height and width, and shorter cranial height. Congenitally absent M3 was associated with reduced facial height. Among the most interesting findings is that dental anomalies were more prevalent in population samples with generally small skulls (i.e., normal, non-anomalous skulls).

Keywords: Anthropology; Paleopathology; Paleodontology; Skull; Dental arch

Introduction

Among the major trends of anthropological research over the past decades has been the focus on the reduction of skeletal robustness in the masticatory complex as humans have progressed from a hunter-gatherer diet to the refined diet provided by agriculture (1,2,3). Additionally, the phylogenetic growth, globularization, and reduction of alveolar prognathism characteristic of the human skull is at least partially driven by the expansion of the braincase and flexure of the cranial base to allow bipedalism; these features are believed to be under stronger genetic control than features of the face, an idea supported by a number of recent studies (4,5,6,7). The importance of climatic, environmental, dietary, and other extrinsic factors in the development of the adult human face has been appreciated since at least Boas' 1912 study of craniometric difference between Europeans and their American immigrant counterparts (8). By the 1960s, Moss's Functional Matrix Hypothesis (FMH) took full account of the "functional demands of soft tissue" in shaping the skeletal elements of the face (9). A significant postulate of the FMH is that facial bone growth is spurred on by a genetic plan, but each element is shaped by the activities of neighboring elements and associated musculature, as well as other, possibly epigenetic and genetic, factors (10). This feedback activity allows the jaws to grow to maintain functional efficacy (9, 10, 11, 12).

The epidemiologic transition theory of occlusal disorder explains the hypothesized increase in occlusal disorders as a result of the transition to the softer diet of agriculture, in which highly-genetically controlled teeth erupt into environmentally-controlled, reduced jaws (1, 13, 14, 15). As a "disease of civilization" (1), occlusal disorders in modern society have been described as "so common as to be almost normal" (16), and have been also attributed to other modern environmental and behavioral conditions ranging from mouth-breathing to ethnic mixing (16, 17).

This study tested several implications of the epidemiological transition theory: First, that premodern archaeological populations should indicate lower prevalence of orthodontic anomalies; second, that sizes of craniofacial or masticatory elements should show reductions from premodern to modern times; and finally, that orthodontic anomalies should be associated with such reductions in jaw sizes.

Materials and Methods

Sixteen standard craniometric landmark measurements, as described by Howells (18), Buikstra and Ubelaker (19), and Bass (20), summarized in Table 1, were taken from the complete or near-complete skulls utilizing digital sliding and spreading calipers. Measurements were recorded and converted into indices (described in 20) including the unique indices MAXBCDL ([MAXB*100]/BCDL), FB1 ([BCDL*100]/ZYB), and FB2 ([FMT*100]/BCDL)(described in 21) in order to gain insight into relative dimensions of orofacial structure. Dentitions were visually inspected for dental anomalies, including crowding, rotations, transpositions, ectopic eruptions, agenesis, and supernumeraries. Data was collected onto paper recording forms and later entered into an SPSS 18.0 database.

A total of 131 male and female skulls were analyzed. Seventy-four skulls (47 male and 27 female) were from medieval to post-medieval England, located at the Biological Anthropology Resource Center at the University of Bradford. Fifty-seven skulls (29 male and 28 female), from the largely classical Marvinci and mostly medieval Demir Kapija collections at the Museum of Macedonia, Skopje, were analyzed. SPSS 18.0 was used to calculate the frequency and distributions of orthodontic anomalies, and to investigate relationships of craniometric variables to the distribution of these anomalies.

Results

Prevalence rates are indicated in Table 2. The general prevalence rate of anomalies was 72.5%. No statistically significant correlations exist between any anomaly and sex or population sample, although crowding occurred more frequently in males (27.6%) than females (18.2%). Fisher's exact tests indicate a correlation among males of rotations with crowding (p=0.032), and among English males rotations were correlated with ectopic eruptions (p=0.043). Further, prevalence of anomalies varied according to population sample, with crowding reaching nearly 50% in the Marvinci (Macedonia) sample, and rotation prevalence over 36% in the Chichester (England) sample; see table 3.

Mandibular variables were the most common craniometric landmarks associated with orthodontic anomalies by independent sample t-tests (at p=0.05). Bicondylar breadth, ascending ramus height, ascending ramus minimum breadth, and height of mandibular symphysis size reductions were all significantly associated with the presence of rotations. Minimum ramus breadth reduction was also associated with crowding, and congenitally absent teeth were associated with reduced bigonial breadth. Table 4 summarizes the details of craniofacial landmark associations.

Facial features also showed associations with anomalies. Facial height, facial width, maximum cranial length and cranial height reductions were all associated with rotations; reduced facial height was associated with congenitally absent M3. The only craniometric variables never showing a significant relationship to the expression of an anomaly were maximum cranial breadth (XCB), upper facial breadth (FMT), palatal breadth (PB), and maxilloalveolar breadth (MAXB). Indices featuring jaw dimensions were largely associated with dental anomalies; see table 5 for details.

Discussion

The prevalence rates of hyperdontia (supernumeraries), misshapen teeth, and ectopic eruptions and impactions all fell within the modern range of worldwide populations (22, 23, 24), as well as other archaeological populations (25). Rotations, the most common anomaly, were not generally associated with crowding, which is often assumed (26, 16).

While there is evidence of a general deterioration of dental health and increase in orthodontic deviance between modern and premodern populations, this study also indicated variation among the Classical and Medieval period population samples, suggesting that the variation may be due not only to the shift from the hunter-gatherer lifestyle to agriculture, but to more local environmental, health, and/or population (endogamy or mixing) disturbances. Crowding is regarded as a major concern for modern, Westernized populations, with prevalence of between 40% and 80% (27, 28), and many researchers have claimed that ancient and non-Westernized populations have little or no crowding (17, 27) or malocclusion (1). Other archaeological data, however, has indicated high levels of crowding, including a medieval London site (29), and a report of prevalence as high 100% in a French Copper Age site (27). The data here, particularly the significant difference in the rate of crowding between the Macedonian samples, Classical/Roman Marvinci (44.8%) and Medieval Demir Kapija (14.3%), resembles Vodanovic and colleagues' description of the Croatian transition period, between a Late Antique (26% crowding) and Early Medieval (7.19%) sample (25). This data also supports Valjanovska's description of a "deterioration" of general health during the Roman period of Marvinci (30). Crowding, along with rotations, has been hypothesized to result from decreases in jaw size (1, 31), but this data supports an etiology for rotations beyond a relationship with crowding; crowding in this study was not significantly associated with masticatory element reduction.

The size and shape of the mandible has long been attributed to environmental factors and is a key component in the proposed reduction of the masticatory apparatus as a result of the transition to the softer diet of agricultural and westernized populations (3, 32). Further, mandibular size is highly variable as well as sexually dimorphic (33); the data presented here supports this mandibular variability in relation to dental anomalies. Rotations are expressed more frequently as mandibular breadth widens relative to zygomatic breadth, and maxilloalveolar breadth broadens relative to mandibular breadth (see figure 1).

Incongruence in relative sizes of the maxilla to the mandible, and dimensions of the dental arches, has been reported as significant in the expression of dental anomalies and malocclusions (1, 14, 15, 34), and this study indicated associations of ectopic eruptions and rotations with variation in the maxilloalveolar index (MAI), the lower jaw breadth ratio (MAXBCDL), and the upper facial index/maxilloalveolar ratio (UFIMAI). Masticatory complex breadths were not as variable as lengths in this data, which is consistent with descriptions of early developmental modeling of palate length from infantile behavior such as suckling (35), and of the reported high heritability of bimaxillary breadth (36).

Not all anomalies were associated with reductions, however. Congenitally missing teeth (hypodontia) was mostly associated with longer cranial and palatal length, although absent third molars, as expected by the epidemiologic transition theory, were significantly associated with reductions in total facial height. Macedonian male skulls show increases in cranial and palatal length with rotations; it seems that incongruence rather than simply reduction may be related to the expression of dental anomalies.

Importantly, significant associations varied between sex and among population samples, but overall rotations show a pattern of expression among populations with generally reduced skulls (see figure 2). Rotations appear to be clustered among populations with low, broad skulls with relatively thin palates.

Conclusion

This study emphasizes the complex etiology for dental anomalies, as well as the multifactorial origin of human skull variation. In general, skeletal elements which have been determined in previous studies to be most heritable showed the least variation in this study, and the least association with orthodontic anomalies. The size and shape of the mandible has been thought for a long time to be the most environmentally-variable craniofacial element, and this study has indicated a clear association between mandibular gracility and orthodontic anomalies, particularly rotations.

The maxillary component, however, also showed distinct associations between dental anomalies and incongruence between length and breadth. The relationship of anomalies with maxillary/palatal length variation may indicate a threshold for highly-heritable breadth to environmentally-plastic length deviance in contributing to the disruption of dental eruption paths. The presence of rotations, ectopic eruptions, and impactions was most pronounced in skulls with relatively small mandibles and broad palates relative to thin faces, and rotations had higher prevalence rates in populations with relatively broad skulls and long, thin palates. This may imply a threshold of cranial reduction beyond which the likelihood of orthodontic anomalies is increased, and also supports the theory of strong genetic control of tooth size compared to the environmental plasticity of specific elements of cranial functional complexes.

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Measurement	Code	Landmarks
Maximum cranial length	GOL	g-op
Maximum cranial breadth	XCB	eu-eu
Cranial height	BBH	ba-b
Facial height	TFH	n-gn
Facial breadth	ZYB	zy-zy
Upper facial height	NPH	n-pr
Upper facial breadth	FMT	fmt-fmt
Maxilloalveolar length	MAXL	pr-alv
Maxilloalveolar breadth	MAXB	ect-ect
Palatal length	PL	ol-sta
Palatal breadth	PB	enm-enm
Bicondylar breadth	BCDL	cdl-cdl
Bigonial breadth	BGO	go-go
Height of ascending ramus	HAR	go-cdl
Min breadth of ascending ramus	MBAR	
Height of mandible at symphysis	HMS	gn-ini

Table 1. Cranial landmarks used in this study.

Anomaly	All (n=131)		Males (n=76)		Females (n=55)	
	Cases	Prevalence	Cases	Prevalence	Cases	Prevalence
Any anomaly other than crowding	64	48.9%	34	44.7%	30	54.5%
Supplemental Teeth	2	1.5%	2	2.6%	0	0
Rotations	36	27.5%	18	23.7%	18	32.7%
Reversals	2	1.5%	0	0	2	3.6%
Peg/Misshapen	4	3.1%	4	5.3%	0	0
Congenitally Absent	4	3.1%	2	2.6%	2	3.6%
M3 Absent	12	9.2%	7	9.2%	5	9.1%
Ectopic etc.	16	12.2%	9	11.8%	7	12.7%
Crowding	31	23.7%	21	27.6%	10	18.2%

Table 2. Prevalence rates of dental anomalies.

	English (n=74)				**Macedonian** (n=57)	
	Blackfriars (n=17)	**Box Lane** (n=9)	**Chichester** (n=36)	**Hickleton** (n=12)	**Demir Kapija** (n=28)	**Marvinci** (n=29)
Supernumeraries	0	1 (11.1%)	1 (2.8%)	0	0	0
Rotations	2 (11.8%)	1 (11.1%)	13 (36.1%)	4 (33.3%)	6 (21.4%)	10 (34.5%)
Reversals	0	0	0	0	0	2 (6.9%)
Misshapen	1 (5.9%)	1 (11.1%)	2 (5.6%)	0	0	0
Hypodontia	0	1 (11.1%)	1 (2.8%)	1 (8.3%)	0	1 (3.4%)
M3 absent	2 (11.8%)	2 (22.2%)	3 (8.3%)	0	3 (10.7%)	2 (6.9%)
Ectopic etc	1 (5.9%)	2 (22.2%)	3 (8.3%)	2 (16.7%)	2 (7.1%)	6 (20.7%)
Crowding	2 (11.8$)	2 (22.2%)	7 (19.4%)	3 (25.0%)	4 (14.3%)	13 (44.8%)

Table 3. Cases and prevalence of anomalies by population sample.

Variable	Anomaly	Mean, Females (mm)		Mean, Males (mm)		Significance		
Vault		Absent	Present	Absent	Present	*std. error*	*t value*	*p=*
GOL	Rotation	177.36	173.18	183.04	180.63*	1.690	2.260	0.026
BBH	Rotation	128.08	124.91	134.60	129.85	1.989	2.195	0.031
	Hypodontia	127.24	124.50	133.00	148.00	(M) 6.219	-2.412	0.020
	Crowding	125.04	135.29	133.66	132.38	(F) 3.644	-2.813	0.008
Face		Absent	Present	Absent	Present	*std. error*	*t value*	*p=*
TFH	Rotation	107.79	106.76	116.24	111.67	1.979	2.492	0.015
	M3 Absent	107.69	100.50	115.56	103.50	4.316	2.407	0.019
ZYB	Rotation	126.96	125.17	134.26	131.46	1.485	2.313	0.023
NPH	Ectopic etc	65.18	60.00	68.63	67.63	(F) 2.213	2.339	0.024
MAXL	Hypodontia	49.93	51.00	52.87	60.00	(M) 3.304	-2.158	0.037
	Ectopic etc	49.89	52.00	53.57	49.40	(M) 1.507	2.767	0.009
PL	Rotation	48.50	45.87	49.74	49.36*	(F) 1.240	2.124	0.040
Mandible		Absent	Present	Absent	Present	*std. error*	*t value*	*p=*
BCDL	Rotation	121.25	115.13	124.39	120.15	1.579	3.676	0.000
HAR	Rotation	67.39	64.53	70.30	67.86	1.085	2.913	0.004
MBAR	Rotation	30.46	29.20	32.19	30.36	0.614	2.958	0.004
HMS	Rotation	28.15	26.29	30.89	29.43	0.867	2.376	0.019

Table 4. Significant metric mean differences, anomalies present and absent, by craniofacial landmarks. * Macedonian male skulls with rotations, however, showed an increase in GOL, from an average of 181.86mm to 183.17mm with rotations, and with PL, from 48.15mm to 50.00mm.

Anomaly	Index	Mean		Significance		
		Absent	Present	*std. error*	*t value*	*p=*
Rotation	CBHI	91.64	88.62	1.38148	2.187	0.032
	MAXBCDL	0.48	0.51	0.01196	2.418	0.019
	FB1	0.94	0.91	0.01039	2.529	0.014
	FB2	0.86	0.90	0.01828	2.123	0.038
Hypodontia	CDLGO	0.83	0.74	0.0405	2.243	0.028
	UFIMAI	0.45	0.56	0.04510	-2.504	0.016
Ectopic, etc	MAXALV	114.08	123.79	4.69967	2.066	0.043
	UFIMAI	0.46	0.42	0.01969	2.170	0.035
Crowding	CLHI	72.42	75.04	1.03576	2.532	0.013
	CBHI	89.92	93.17	1.46071	2.221	0.029
	ZYGFMT	0.82	0.79	0.00728	3.154	0.002
	FB2	0.88	0.84	0.01364	2.582	0.012

Table 5. Significant differences of indices by anomaly.

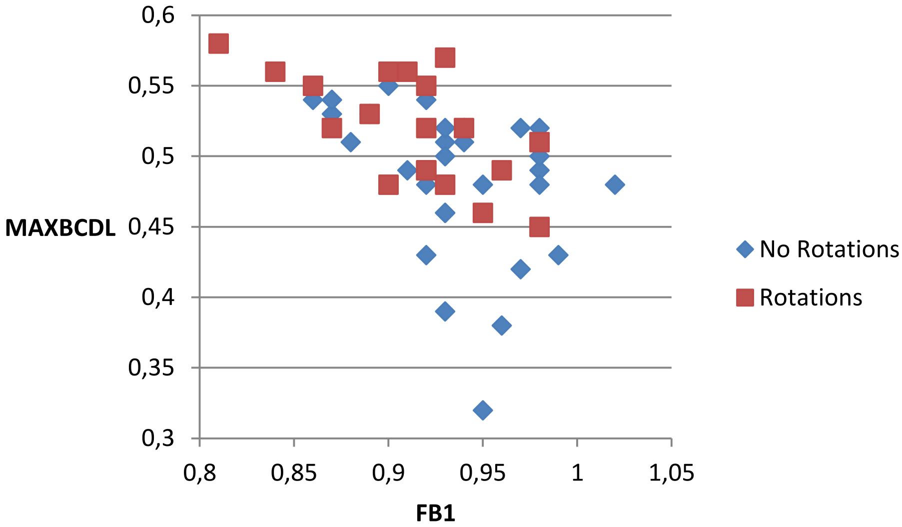

Figure 1. Scatterplot of jaw breadth index (MAXBCDL) and Facial Breadth (FB1), skulls with and skulls without rotations. See text.

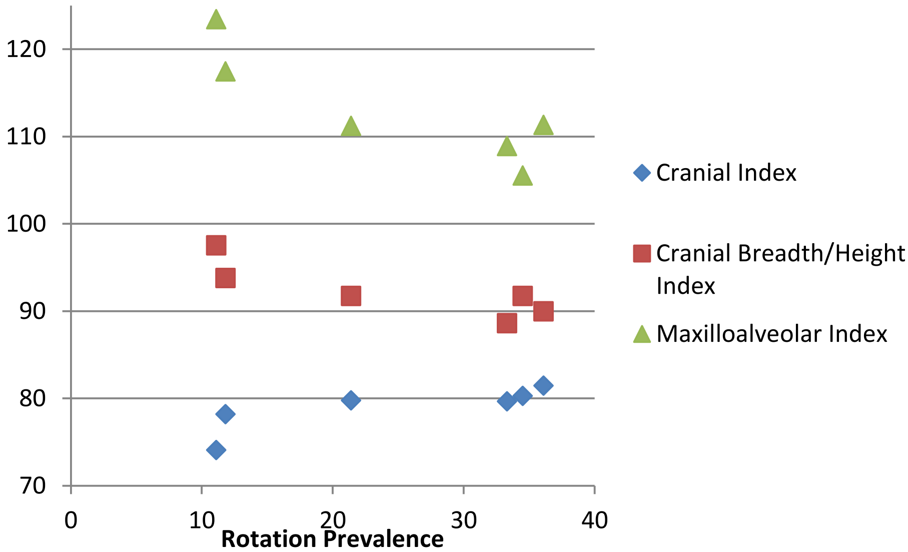

Figure 2. Scatterplot indicating higher cranial indices, and lower maxilloalveolar and cranial breadth/height indices in populations with higher prevalence of rotations.