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Contact for Manuscripts

Rebecca L. George
Western Carolina University
E-mail address: rgeorge@wcu.edu
Website: journal.dentalanthropology.org

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Evaluation of Three Non-Metric Traits in Maxillary Central Incisors for Population and Sex Estimations: A Cross-Sectional Study using the Turner-Scott Dental Anthropology System

Jayasankar P. Pillai[1,*], Girish Parmar[1], Rajesh Babu[2], J.M. Vyas[2]

[1] Govt. Dental College and Hospital; Ahmedabad, India

[2] National Forensic Sciences University; Gandhinagar, India

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ABSTRACT The expressions of non-metric traits are commonly used for population or ancestry estimation. This present study explored the role of dental non-metric data from Gujarat state in India for population and sex estimation. The three non-metric traits namely, labial curvature, shoveling, and *tuberculum dentale* traits in permanent maxillary central incisors in distinct population subgroups from different geographical and community backgrounds were compared. The dental traits in right and left central incisors of 1299 school children, with a mean age of 13.97 years ± 1.70 were examined and recorded using the Turner-Scott standard dental anthropology plaques. There was no significant difference in the distribution of all three traits between sides. There was a significant difference in the overall distribution of the traits between the different population subgroups (p<0.001). Nearly 21% of the overall population was correctly classified district-wise using the non-metric dental traits in the maxillary central incisor. Only the shoveling trait showed significant gender differences in the study population. Using the discriminant function, 75% of the girls and 29%of the boys were correctly classified. The percentage of correct prediction of sex based on the discriminant function ranged from 57.9% to 70.9% in all the districts.

Forensic profiling plays an integral part in the human identification process. Parameters like age, sex, and ancestry are some of the important components of forensic profiling. The potential unique characteristics or personal information of an individual can also be derived by properly analyzing the dental structures. Furthermore, teeth are known to vary morphologically between and within populations and the sexes (Scott and Turner, 2008). Particularly, dental non-metric traits have shown affinities and variations among different population groups (Scott and Turner, 1997; Vargiu et al., 2009). The teeth, thus, can be used to provide an estimate of the ancestry and sex of an unidentified individual. Dental non-metric traits show different degrees of expression among different populations (Turner, 1991; Kelley and Larsen, 1991; Jernvall and Jung, 2000). This grading system places the trait expression into an ordinal scale based on the extent of expression of the traits (Turner, 1991). The frequencies of expressions of such traits are used to distinguish the population variations (Edgar, 2013; Lukacs, 1987). The most commonly studied traits in the tooth are cusp number, cusp size, groove patterns, root length, and number. Genetic and environmental influences have also been hypothesized to play an important role in the phenotypic manifestation of dental traits (Townsend et al., 2009).

For sex estimation, odontometric measures also have proved to be a more reliable method than the tooth morphologic parameters (Nagpal et al., 2017). Among the non-metric traits, the canine distal accessory ridge has shown a significant sex difference (Pilloud and Scott, 2020). The unique dental features and the evidence of dental treatments

*Correspondence to:
Jayasankar P. Pillai
Govt. Dental College and Hospital
Ahmedabad, India
Email: jppillaigdch@gmail.com

on teeth have their role in human identification or linking the accused to the victim or the crime. There are instances where the single incisor tooth has been used as an exhibit from the crime scene and sent for forensic odontology investigations like age and sex estimations. Though the expressions of non-metric traits have no role in age estimation, they play a significant role in estimating the ancestry and sex of the unidentified decedent. Thereby, dental traits help in generating the biological profile of the deceased.

According to G. Richard Scott and Christy Turner, only a few traits like shovel-shaped incisors, Carabelli's cusp, and lower molar cusp number have been characterized on a worldwide scale. However, in some geographic locations like India, dental morphologic traits have not been studied in detail (Scott et al., 2018). The application of dental non-metric traits in forensic human identification cases is very limited. However, from research and anthropological points of view, dental traits are being explored to study population variation. Such population-based studies in Gujarat, a state in the western part of India are also lacking. The principal author (JP), having more than 25 years of experience in teaching dental anatomy and histology in Gujarat observed variations in maxillary central incisors of his students who represent different parts of Gujarat. In the maxillary central incisor, the labial curvature, shoveling, and *tuberculum dentale* are the easily identifiable traits. The present population-based study was designed to explore the variations in the expression of these three traits among the eight geographically distinct populations using the standard Turner-Scott/Arizona State University Dental Anthropology System (ASUDAS). Another objective of the study was to explore the variations in these traits between sexes. There is hardly any study examining the expressions of these non-metric traits used for population and sex estimation, especially in this part of India. Hence, the present study was conducted to generate the population-based data from eight different districts of Gujarat and to explore the differences in the expression between populations and sexes.

Materials and Methods

One thousand two hundred and ninety-nine school children from eight different districts of Gujarat in the age group of 10 to 17 years were examined from August to November 2019 in their respective schools. The study subjects included 620 (47.7%) boys and 679 (52.3%) girls. The institutional ethical committee's approval was obtained before the start of the study (IEC/ GDCH/S.2/2019). The necessary permissions from the school authorities of the respective districts were obtained for this study. All the students were residents of Gujarat since birth and were basically of Gujarati origin in terms of their surname/family name and mother tongue. The clinical evaluation of the children was performed by the principal investigator (JP) using mouth mirrors and probes under good illuminations and the supervision of their respective class teachers. The ASUDAS plaques of three traits in the maxillary central incisors were used as standards (Figure 1).

The extent of labial curvature, the prominence

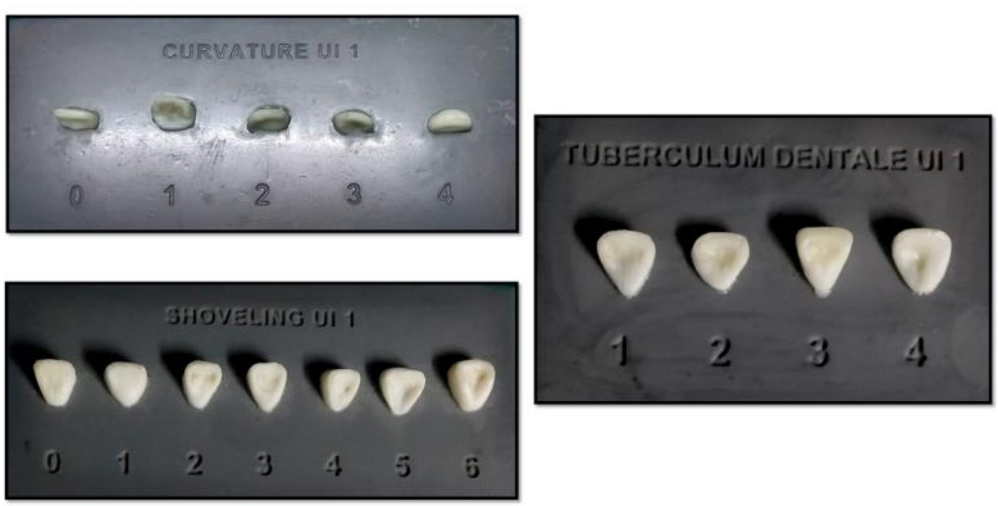

Figure 1. Non-metric traits in the permanent maxillary central incisor in the ASUDAS.

of mesial and distal marginal ridges, and the extent of projection of cingulum on the lingual surface of the maxillary central incisor were the morphological parameters used in the study. There are 5 scores of labial curvature (score 0-4) and 7 scores for grading the expression of shoveling in upper central incisors according to the ASUDAS plaques. For grading *tuberculum dentale*, there are 4 scores (Score 1-4) The grading of the traits were noted in the prescribed proforma and then entered in the Microsoft Excel sheet. The intra-observer error in grading the traits was tested before the start of the study by the same author (JP) with a subsample of 50 dental students in his institute.

Statistical analysis

The data were analyzed using the Statistical Package for the Social Sciences (SPSS) software (version 23; SPSS, Inc., Chicago, USA). The intra-observer error in grading the traits was tested using the Cohen's Kappa coefficient of agreement. The descriptive statistics included mean, standard deviation, and frequency distribution in percentages. The Wilcoxon Signed-Rank test was used to test the difference in the expression of the traits between sides. The Spearman correlation coefficient was used to correlate the expressions of traits between right and left central incisors. The nonparametric Kruskal-Wallis was used to test the difference in the expression of the trait among the eight districts' populations. The independent samples Mann-Whitney U test was used in assessing the graded data between sexes. The discriminant function analysis (DFA) using the traits as independent or predictor variables and the population groups as dependent or grouping variables was carried out using the Canonical discriminant function. The prior probabilities were set to compute from group sizes and using the within-group covariance matrix. The level of significance was set at $p \leq 0.05$ for all statistical analyses.

Results

Sample characteristics

The study included a sample of 1299 Gujarati school students aged 10 to 17 years from 8 districts of Gujarat (Figure 2). The mean age of the sample was 13.97 years ± 1.70. The Cohen's Kappa coefficient ranged between 0.84 to 0.96 for all the three traits when testing the intra-observer variations in grading the traits in the subsample. This result revealed an almost significant intra-observer agreement in grading the traits (Landis and Koch, 1977). The frequency distribution of the scores of the three non-metric traits in the overall sample is shown in Table 1. The labial surface of incisors was slightly curved and not exactly straight (Score 1) in around 82% of the overall cases. The shoveling was absent in 36.5% of the overall sample and 37% of the cases the *tuberculum dentale* trait was absent and the cingulum was smooth. There was no significant difference in the expression of the traits between right and left central incisors (see Table 1). There was also excellent intra-trait correlation between the right and left sides with the Spearman correlation coefficient ranging between 0.995 to 0.998. Hence, the data of one of the sides (right side), was considered for further analysis. The distribution of the samples according to the scores in all eight districts is shown in Table 2. The independent samples Kruskal-Wallis test revealed a significant difference in the distribution of the scores of all the three traits across the districts (see Table 2). The results of the pair-wise comparison of the expression of the traits between the districts are shown in Figure 3. This figure shows which of the two districts significantly differ from each other (yellow line) concerning the expression of the traits. Among the three traits studied, only the shoveling trait showed a significant difference in its expression between boys and girls. More boys were showing the expression of this trait than girls. (Table 3).

Discriminant function analysis

The discriminant function that best separates or discriminates between the groups is reported here. The discriminant function to classify the district-wise population using the dental non-metric traits in maxillary central incisors revealed a canonical correlation of 0.333 with a variance of 69.7%. There was a significant relationship between the discri-

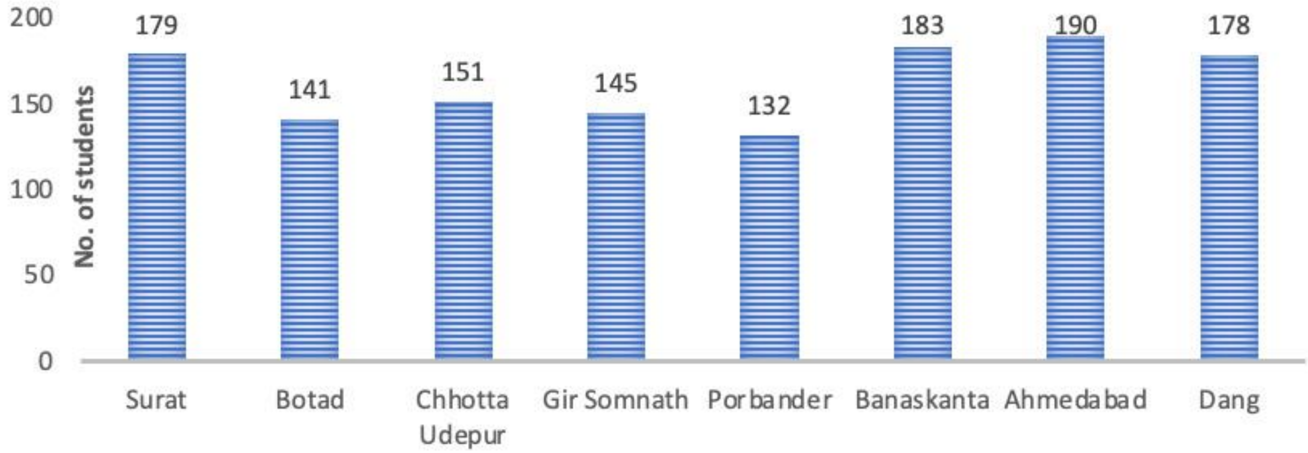

Figure 2. Graph showing the district-wise frequency distribution of the study subjects.

Table 1. Table showing the frequency distribution of the scores of the three traits in permanent maxillary central incisors on both sides.

Traits	Score	Right		Left		Wilcoxon Signed Rank test Sig.*
		n	%	n	%	
Maxillary Incisor Labial Curvature (UI1LC)	**0**	96	7.4	96	7.4	0.317
	1	1068	82.2	1069	82.3	
	2	127	9.8	126	9.7	
	3	8	0.6	8	0.6	
Maxillary Incisor Shovel shape (UI1SS)	**0**	471	36.3	467	36.0	0.257
	1	550	42.3	555	42.7	
	2	278	21.4	277	21.3	
Maxillary Incisor *Tuberculum Dentale* (UI1TD)	**0**	488	37.6	487	37.5	0.655
	1	719	55.4	720	55.4	
	2	88	6.8	88	6.8	
	3	4	0.3	4	0.3	

*Significant at p<0.05

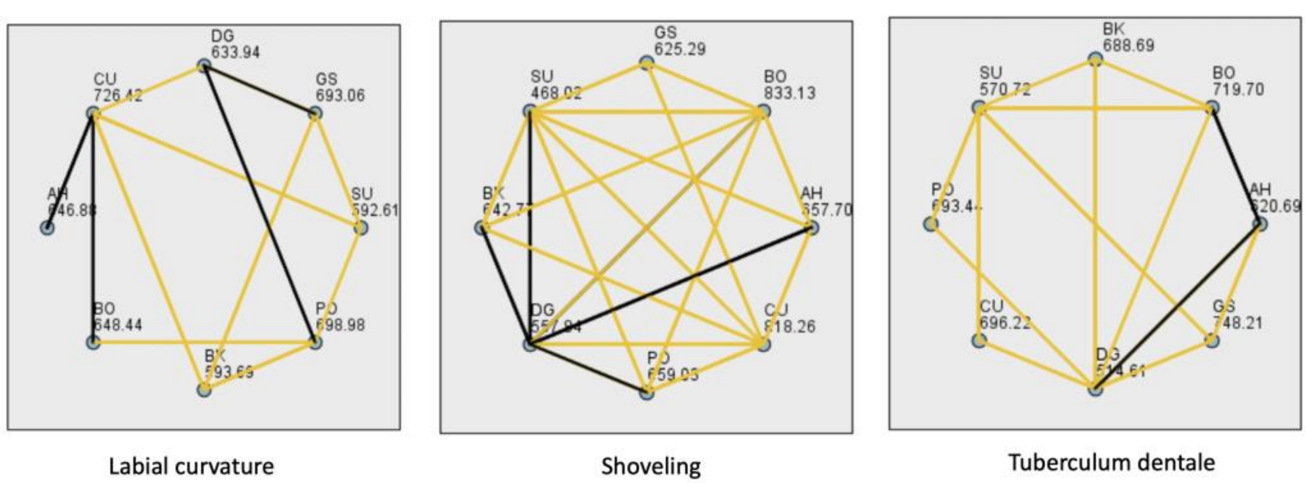

Figure 3. Figure showing the results of the pair-wise comparisons of the district populations for all the three traits. The yellow lines show significant difference (adjusted by Bonferroni correction) and the black lines represent the insignificant difference between the pairs of districts and the nodes represent the mean rank values, according to the independent Kruskal-Wallis test.

Table 2. Table showing the district-wise distribution of the scores of expressions of the three traits in maxillary central incisors.

District Code	Score	UI1 LC (Rt.)		UI1 Shoveling (Rt.)		UI1 *Tuberculum Dentale* (Rt.)	
		n	%	n	%	n	%
ST	0	25	14.0	109	60.9	87	48.6
	1	141	78.8	56	31.3	85	47.5
	2	13	7.3	14	7.8	6	3.4
	3	0	0.00	0	0.0	1	0.6
BO	0	9	6.4	15	10.6	38	27
	1	119	84.4	78	55.3	91	64.5
	2	13	9.2	48	34	12	8.5
	3	0	0.00	0	0	0	0
CU	0	13	8.6	25	16.6	46	30.5
	1	102	67.50	69	45.7	93	61.6
	2	28	18.50	57	37.7	12	7.9
	3	8	5.30	0	0	0	0
GS	0	7	4.80	62	42.8	32	22.1
	1	116	80.00	49	33.4	101	69.7
	2	22	15.20	34	23.4	12	8.3
	3	0	0.00	0	0	0	0
PO	0	5	3.80	51	38.6	48	36.4
	1	107	81.10	46	34.8	63	47.7
	2	20	15.20	35	26.5	19	14.4
	3	0	0.00	0	0	2	1.5
BK	0	28	15.30	68	37.2	57	31.1
	1	139	76.00	77	42.1	113	61.7
	2	16	8.70	38	20.8	13	7.1
	3	0	0.00	0	0	0	0
AH	0	8	4.20	59	31.1	81	42.6
	1	169	88.90	99	52.1	95	50
	2	13	6.80	32	16.8	13	6.8
	3	0	0.00	0	0	1	0.5
DG	0	1	0.60	82	46.1	99	55.6
	1	175	98.30	76	42.7	78	43.8
	2	2	1.10	20	11.2	1	0.6
	3	0	0.00	0	0	0	0
Chi-Square		43.084		135.815		68.400	
df.		7		7		7	
Sig.*		0.000		0.000		0.000	

*Significant at $p<0.05$

Table 3. Table showing the frequency distribution of the scores of the three traits in permanent maxillary central incisors in boys and girls.

Traits	Score	Boys (n=620)		Girls (n=679)		Mann-Whitney U test Sig.*
		n	%	n	%	
Maxillary Incisor Labial Curvature (UI1LC)	**0**	41	6.6	55	8.1	0.502
	1	514	82.9	554	81.6	
	2	63	10.2	64	9.4	
	3	2	0.3	6	0.9	
Maxillary Incisor Shovel shape (UI1SS)	**0**	174	28.1	297	43.7	0.000
	1	301	48.5	249	36.7	
	2	145	23.4	133	19.6	
Maxillary Incisor *Tuberculum Dentale* (UI1TD)	**0**	227	36.6	261	38.4	0.171
	1	338	54.5	381	56.1	
	2	51	8.2	37	5.4	
	3	4	0.6	0	0	

minant function and the grouping variables (Wilks Lambda = 0.843; $c^2 = 221.293$ *df=21, p<0.001).* The inter-trait correlation revealed a 27.6% correlation between shoveling and *tuberculum dentale* and a weak correlation between labial curvature and *tuberculum dentale* (8.1%). Between labial curvature and shoveling the correlation was 18.6%. The shoveling trait revealed a maximum discriminating power (94.4%) followed by *tuberculum dentale* (49.2%) and labial curvature (40.4%). Only 21.3% of the overall population was correctly classified using this function. The percentage of correct classification was maximum for the Surat district (Table 4).

The discriminant function for classifying sex based on the variables also revealed a significant relationship between the discriminant function and the grouping variables with a canonical correlation of 0.132. (Wilks Lambda= 0.983, $c^2 = 22.764$ *df=3, p<0.001).* The shoveling trait has more discriminant power followed by the *tuberculum dentale* trait (Table 5). The classification statistics revealed 53.2% of the original cases were correctly classified. The percentage of correct classification was more for girls (75.1%) when compared to boys (29.2%). The district-wise results of the discriminant function analysis in sex estimation using the three traits revealed an overall correct classification in the range of 57.9% to 70.9%. However, the function was significant only for three districts (Table 6).

Discussion and Conclusions

The present study observed the expression of three different non-metric traits in the permanent maxillary central incisors in eight different geographic locations in Gujarat. Gujarat is a state in western India with a population of nearly 67 million. The population is diverse based on caste, culture, tradition, occupation, geography, etc. The Gujarati population in the present study represents the ancestral North Indian gene that appears to be much more diverse than other South Asian populations (Silva et al., 2017). This study is the first of its kind in India which was conducted in a large population using the ASUDAS to discriminate the population subgroups based on the expression of non-metric traits in the tooth and also on sex estimation. However, as there are possible biases in recording the traits, the estimation of population just based on teeth is difficult and has to be undertaken very cautiously (Acharya and Sherawat, 2021). In the present study, around 82% of the population had slight curvature (score 1), a trait which is characteristic of Asian and Asian-derived populations. A study on labial curvature among 20 worldwide populations has shown that moderate curvature was seen in Europeans and American Indians (Nichol et al., 1984). The study also showed that

Table 4. The results of the discriminant function analysis performed to discriminate the populations based on the non-metric trait parameters in maxillary central incisors.

Varia-bles	Unstandardized coefficients	Standardized coefficients	Absolute size of correlation	Constant	Wilks Lambda	Sig.	% of correct classification		
							District	**%**	**Overall %**
UI LC	0.528	0.229	0.404				ST	58.10	
UI SS	1.179	0.834	0.944	-1.839	0.843	0.000	BO	30.50	21.30
UI TD	0.413	0.244	0.492				CU	21.20	
							GS	5.50	
							PO	0.00	
							BK	20.20	
							AH	0.00	
							DG	29.80	

Table 5. The results of the discriminant function analysis performed to discriminate the sex based on the non-metric trait parameters in maxillary central incisors.

Varia-bles	Unstandard-ized coefficients	Standard-ized coeffi-cients	Absolute size of correlation	Con-stant	Centroids		Wilks Lambda	Sig.	% correct classification		
					M	**F**			**M**	**F**	**Overall**
UI LC	-0.285	-0.126	0.094	-0.943	0.139	-0.127	0.983	0.00	29.20	75.10	53.20
UI SS	1.343	0.992	0.990								
UI TD	0.136	0.082	0.367								

Table 6. The results of the discriminant function analysis in sex estimation using the traits parameter in all the districts.

District	Eigenvalue	Canonical correlation	Wilks Lambda	Chi-Square	Sig.	% of correct classification		
						M	**F**	**Overall**
1	0.221	0.425	0.819	35.038	0.000	60.5	80.6	70.9
2	0.019	0.135	0.982	2.522	0.471	16.4	93.0	63.1
3	0.030	0.17	0.971	4.304	0.23	74.4	36.2	57.0
4	0.094	0.293	0.914	12.72	0.005	30.2	84.8	64.8
5	0.049	0.216	0.954	6.117	0.106	15.4	93.5	70.5
6	0.012	0.109	0.988	2.160	0.540	75.5	43.5	60.7
7	0.006	0.079	0.994	1.171	0.760	100.0	0.0	57.9
8	0.049	0.216	0.953	8.326	0.040	80.4	30.9	57.90

labial curvature does not exhibit sexual dimorphism. This finding is similar to the results of the present study. The shoveling trait in the incisors is a characteristic dental feature of North Asian and North/South American populations. It is very commonly seen in the Native American populations, South East Asians, and derived populations like Polynesians and Micronesians (Nichol et al., 1984). Grades of shoveling may be observed in both upper and anterior teeth. In the present study, this trait was observed in 64% of the study population. In the Tamil population in Southern India, the shoveling trait was present in 8% of the population (Shrivastav et al., 2018). However, that study did not grade the expression of traits as done in the present study. The same trait in a study on the Malayalee population showed a frequency of 6.7% (Uthaman et al., 2015). There is a clear-cut genetic demarcation between the Kerala population and the Gujarati population (D'Cuna et al., 2017). However, in another study on the Kerala population, the shoveling trait was observed in 69.12% of the population which was similar to the results of the present study (Baby et al., 2017). In the Bangalore population study, the shoveling of incisors was observed in 65.7% of the population and double shoveling in 66.6%. The shoveling of incisors was noted comparatively lower in the south Indian population, while 81% of East Indian and 85% of West Indian population showed shoveling of incisors (Nagaraj et al., 2015*).* A study by Lukacs and Pal (2013) demonstrated weak incisal shoveling in the early Holocene foragers in the mid-Ganga plains in North India. The district-wise comparisons showed a significant difference among all the districts except the Chottaudepur district. The expression of *tuberculum dentale* is more common in upper lateral incisors (20% - 50%).

The expression of ridge form of *tuberculum dentale* varies in size and number. There are 7 scores (Score 0-6) for grading the expression of *tuberculum dentale* (Edgar, 2017). However, in the ASUDAS, only 4 sores (score 1-4) were considered. The expressions of these three traits significantly differed among the populations. The study populations analyzed in the present study represented different geographical and community backgrounds. The present study also applied DFA to estimate population based on the three traits. The overall per cent of correct classification is only 21.3%. This is because only one tooth (i.e., the central incisor) is being considered here. Similar functions using multiple teeth may also be attempted in the future.

The present study also applied DFA to estimate sex based on the three variables. Among the three traits, shoveling was found to be more powerful in estimating sex and also the population. It was also observed in the present study that the females were more correctly classified than the males. Just based on the visual examination of the teeth, it may not be possible to exactly estimate the sex of an individual (Radlanski, 2012). Sex estimation accuracy rate of 53-65% was earlier reported using the shape analysis of upper arch incisors and canine (Horvath et al., 2012). However, odontometric parameters may be useful in some cases. Perhaps, a few traits like Carabelli's cusp and canine distal accessory ridge have shown evidence of sexual dimorphism (Pilloud and Scott, 2020). Carabelli's trait and the molar cusp number traits have shown an accuracy in the range of 70.2%- 74.8% in sex estimation in children (Adler et al., 2012).

In the present study, only the permanent maxillary central incisor tooth was considered and its three characteristic traits were used as independent variables to explore their role in population and sex estimations. Though there is a potential role of non-metric traits in sex estimation, it needs to be applied very carefully because there is always a possibility of subjective error in grading the traits. This mandates a need for intensive training for handling the standard plaques and identifying the expression grades accurately. In India, the dental curriculum needs to focus on dental anthropological aspects for the undergraduate and postgraduate students, by incorporating practical training on grading the traits using dental models and clinical subjects. Such exercise may minimize the inter-observer grading errors and increase the scope of application of the non-metric traits in population-based studies and sex estimation. Also, there is a need to incorporate dental morphology details including the non-metric trait details during the recording of the post-mortem dental findings during the dental autopsy procedures.

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Morphogenetic Fields and Variation in Deciduous Tooth Crown Size

John R. Lukacs*

Department of Anthropology, University of Oregon

Keywords: coefficient of variation; tooth size; deciduous dentition; primary teeth; odontometry

ABSTRACT Does variation in deciduous tooth crown size and variation agree with expectations predicted by morphogenetic fields (MGF) as documented for morphometric attributes of permanent teeth? Published literature on deciduous tooth crown size permits analysis of a large dataset. Are expectations of MGF theory evident in size and patterns of variation within and between deciduous tooth classes? Thirty-five reports of deciduous tooth crown size have a global distribution, are ethnically diverse, and geographically widespread. Analysis centers on mesiodistal (MD) and buccolingual (BL) dimensions, crown areas (CA), coefficients of variation (CV) and rank order of variability across populations and dental arcades. Mean crown size, CAs and CVs follow expectation: a) udi1is larger and less variable than udi2, b) a gradual decline in mean CVs from dc to dm2 is evident, c) in rank order of decreasing CV dm2 is the least variable, and incisors are most variable. The udi1 and dm2s exhibit attributes of key teeth. In size, measures of variability, and rank order variation across teeth, results are consistent with expectations based on MGFs in permanent teeth. This confirms the likely existence of morphogenetic-like fields in deciduous teeth during dental development. The diverse groups and different modes of analysis ensure confidence in the results that may have value for clinical purposes and evolutionary studies.

This study analyzes variation in deciduous tooth crown dimensions within the context of morphogenetic developmental fields. Do patterns of variation in deciduous odontometic data conform to expectations predicted by morphogenetic fields (MGF) in a manner analogous to morphometric variation in permanent teeth? Morphogenetic developmental fields have been proposed to explain morphometric attributes of meristic dental elements in the post-canine teeth of mammals (Butler, 1939). The concept was initially adapted to explain variation in expression of morphological attributes of the permanent dentition of modern humans by Dahlberg (1945, 1950, 1951). More recently the morphogenetic field concept in the human dentition has been integrated with clone and homeobox code models of dental development to better understand anomalies of tooth number and size (Townsend et al., 2009). A field-like mechanism proposed to predict the size of mammalian and hominin teeth is known as the inhibitory cascade, an activator–inhibitor mechanism that affects relative tooth size (Evans et al., 2016; Kavanaugh et al., 2016). Analysis of patterns of variability in crown dimensions of permanent teeth in humans and non-human primates were summarily critiqued by Kieser (1990), who reviewed approaches to odontometric variability giving attention to evidence of developmental and occlusal influences, group variation theory, and coefficients of variation. He concluded that the exact causes for patterns of metric variability in permanent teeth are poorly understood. Analyses of deciduous dental variability are far fewer with significant assessments by Harris (2001; Harris and Lease, 2005) for mesiodistal data and by Riberio et al. (2012) for mesiodistal (MD) and buccolingual (BL) diameters, crown height, and intercuspal distances of same-sex mono- and

*Correspondence to:
John Lukacs
University of Oregon
E-mail: jrlukacs@uoregon.edu

di-zygotic twin pairs. An atlas depicting the development and eruption of deciduous and permanent dental elements clarifies the ontogenetic relationship of the two dentitions (AlQahtani et al., 2010; https://www.qmul.ac.uk/dentistry/atlas/).

Interestingly, Dahlberg (1945, 1951) did not define fields within the primary dentition and, without any comment, he added a premolar field to Butler's (1939) three-field paradigm for permanent teeth (Townsend et al., 2009: S35). This observation was reiterated seven years later, "Neither Butler nor Dahlberg commented specifically on the application of dental field theory to the deciduous dentition" (Hemphill, 2016). While generally correct, these comments overlook the many instances in which patterns of metric variation in deciduous tooth crown dimensions have been interpreted to be consistent with expectations of morphogenetic field theory. This opinion may be stated simply with little elaboration, for example, "The variability in the MD and BL measurements follows the field concept" (Axelsson & Kirveskari, 1984: 343). Before this, Hanihara (1974) used factor analysis to identify influences controlling variation in deciduous tooth crown size in four groups (Japanese, Australian aboriginals, Native American Pima, and Caucasians) and found three factors influencing size and shape. The tendency for the second molar to be less variable in size than the first in a Dominican sample was noted to be in accord with the field concept which considers deciduous second molars as anterior members of a molar tooth field and therefore particularly stable in their morphology (Garcia-Godoy et al., 1985). Farmer & Townsend (1993: 681) note that although distinct morphogenetic fields have not been defined in the deciduous dentition, South Australian children of European descent appeared to show a gradient of decreasing size variability from anterior to posterior, with the second deciduous molar being particularly stable. Gradients in variation of deciduous tooth measures of recent children from Spitalfields Cemetery, London show the greatest variability in anterior teeth and stability in second molar teeth (Liversidge and Molleson, 1999), in accord with the MGF concept. That the second deciduous molar is the key (most stable) tooth in the molar field is supported by stability in size variation and asymmetry of dm2 in the Spitalfields sample and by expression of the protostylid noted by Dahlberg (1950). The differential patterning of coefficients of variation (CV) in deciduous teeth of male Japanese singletons and twins is almost the same as in the permanent dentition, suggesting the existence of three MGFs in the deciduous dentition (Mizoguchi, 1998). Though exceptions exist, this assessment is based on the presumption that the pattern of CVs reflects the extent of MGF control of crown size. The validity of Dahlberg's field hypothesis for the deciduous dentition requires further research into local environmental factors and concrete variables including inducing substances and homeobox genes (Mizoguchi, 1998). While reports of deciduous tooth crown size (DTCS) allege that observed variation is consistent with MGF theory, these reports are few in number, population-specific, and include exceptions. A wider review of data is essential to determine the degree to which the field concept applies broadly and consistently to DTCS in ethnically and geographically diverse populations.

Materials

This analysis emanates from original research on deciduous dental attributes in prehistoric and living samples from India and Indonesia. These studies included variability in crown dimensions (Lukacs 1981, 2016, 2019, 2022; Lukacs et al., 1983; Lukacs and Kuswandari, 2022), non-metric dental morphology (Lukacs and Walimbe, 1984; Lukacs and Kuswandari, 2009, 2013), developmental enamel defects (Lukacs, 1991; Lukacs and Walimbe, 1998; Lukacs et al., 2001a, 2001b), and diachronic change in deciduous dental traits (Lukacs and Walimbe, 2005; Lukacs, 2007). Collectively this research gives deeper insight into biological relationships and health in otherwise understudied regions of the world. The recent re-analysis of Indonesian DTCS and inter-group variation in sex dimorphism in the deciduous dentition led to this study (Lukacs and Kuswandari, 2022). This study is designed to determine if patterns of deciduous dental variation within and between populations are consistent with MGFs in a manner analogous to developmental fields in the permanent dentition.

A search of the scientific literature (Anthrosource, Medline, Web of Science) revealed the rapidly increasing growth of reports on DTCS among widespread populations. The thirty-five samples in this study have a global distribution, are ethnically diverse, and geographically widespread (Table 1). Criteria for selecting studies to include in this analysis focused on the presence of: descriptive odontometric statistics including CV or data from which CV could be computed (mean, standard deviation), a protocol ensuring reliability of tooth crown measurement methodology (repeat measures, evaluation of measurement error), and broad geographic and ethnic distribution of study samples. Studies that did not present data by sex and/or were based on small samples were excluded, such as Moss and Chase's (1966) analysis of Liberian children (n= 21), for example. Indigenous and modern samples from all continents are included. Four Indigenous groups include the Bunun (Taiwan); Pima (native North America), San, Kalahari (South Africa), and Warlpiri Yuendumu (central Australia). Though global in origin, samples are unevenly distributed with a bias toward East Asia (China, Japan; n=8) and Europe (n=6), and underrepresentation of other groups (middle East, South America). A shortcoming not evident from this list is that crown dimensions are not reported for all teeth in all groups (see Table 1). For example, incisor dimensions were not included in Adler and Donlon's (2010) analysis of Australians of European descent, and only measurements for deciduous molars were reported for the Indian (Puducherry; Sujitha et al., 2021) and Spanish (Madrid; Barberia et al., 2009) samples. Buccolingual dimensions of incisor and canine teeth were not part of Kaul and Prakash's (1984) description of Jat odontometrics. Yet more commonly, BL dimensions are not reported at all or especially for anterior teeth, thus precluding computation of

Table 1. Global distribution and data source of samples included in study (n = 35)

Region	Location	Group	Data	Data Source
Africa (n=4)	AfroAmerican	Tennessee	all	Vaughn & Harris, 1992
	sub-Saharan	Kalahari San	all	Grine, 2009
	sub-Saharan	South Afr Black	all	Grine, 1986
	sub-Saharan	Nigerian	all	Egibobo et al., 2010
American (n=5)	EuroAmerican	Burlington White	all	DeVito, 1988
	EuroAmerican	Michigan White	all	Black, 1978
	Native	Pima	all	Alvrus, 2000
	Dominican	mulatto	all	Garcia-Godoy et al., 1985
	South	Colombian	MD	Botero et al., 2015
Asia – East (n=9)	Chinese	Taiwan 1	all	Tsai, 2000
	Chinese	Taiwan 2	all	Liu et al., 2000
	Indigenous	Taiwan 3	MD	Lee, 1978
	Japan	Japan 1970	MD	Makiguchi et al., 2018
	Japan	Japan 2000	MD	Makiguchi et al., 2018
	Japan	various	MD	Ooshima et al., 1996
	Japan	Nagoya	all	Yamada et al., 1986a, b
	Japan	Tokyo	all	Tsutsumi et al., 1993
	Korea	south	all	Baik et al., 2002
Asia - South (n=4)	India	Puducherry	inc	Sujitha et al., 2021
	India	Gujarat	all	Lukacs et al., 1983
	India	Jat	inc	Kaul & Prakash, 1984
	India	Wardha	all	Chaudhury et al., 2011
Asia - Southeast (n=2)	Indonesia	Malay	all	Lukacs & Kuswandari, 2022
	Vietnam	native	all	Huynh et al., 2020
Australia (n=4)	Indigenous	Warlpiri-Yuendumu	all	Margetts & Brown, 1978
	European	southern White	all	Farmer & Townsend, 1993
	Melanseia	Nasioi	all	Bailit et al., 1968
	Sydney	white	inc	Adler & Donlon, 2010
Europe (n=6)	Iceland	modern	all	Alexsson & Kirveskari, 1984
	London	Spitalfields	all	Liversidge & Molleson, 1999
	Poland	Medieval	all	Zadzinska et al., 2008
	Portugal	NMNH, Lisbon	all	Cardoso, 2010
	Spain	Granada	all	Viciano et al., 2013
	Spain	Madrid	inc	Barberia et al., 2009
Middle East (n=1)	Jordan	Irbid	all	Hattab et al., 1999

compound variables like Crown Area (MD x BL). Mesiodistal dimensions are clinically relevant to issues of spacing and occlusion and some reports comprise only MD data. Examples include, Colombian (Medellin; Botero et al., 2015), Japanese (Ooshima et al., 1996), Javanese (Kuswandari and Nishino, 2004), and the Indigenous Bunun of Taiwan (Lee, 1978). Hence, MD crown dimensions were selected for a worldwide analysis of temporospatial variations and sex dimorphism by Harris (2001, Harris and Lease, 2005: 594); BL measurements were less frequently and consistently reported.

Methods

Multiple methods were used to determine if DTCS and patterns of variability meet expectations of MGFs as defined in permanent teeth. Two levels are used to evaluate variability in deciduous tooth dimensions: intra-population and inter-population. First, differences in linear dimensions, ratios, and crown areas of adjacent teeth were evaluated within populations. Data came from individual reports of tooth crown size or were calculated from reported mean values. Analysis within each population compares variability in DTCS by tooth across dimensions (MD, BL) and arcades (maxilla, mandible). Second, inter-population assessment of coefficients of variation for linear dimensions (MD & BL, mm) and crown areas (CA = MD x BL, mm^2) were calculated and assessed. The summary data: mean MD and BL (linear), CV (index) and, and CA (area) from all studies were evaluated for normality using the Shapiro-Wilk (1965) test before computing means across all groups.

The CV is a relative measure of variability that indicates the size of a standard deviation in relation to the mean. A standardized, dimensionless measure, a CV allows you to compare variability between disparate groups and traits. The CV is occasionally referred to as the relative standard deviation. CVs are often used to analyze mammalian odontometric variation as reviewed by Polly (1998). The CVs were taken directly from published reports on deciduous tooth crown dimensions. Since two positively correlated linear dimensions contribute to overall crown size, Crown Area (CA) was computed from reported data for each tooth (CA = mean MD * mean BL; in mm^2) and the CVs of mean CAs across populations were examined. If CVs were not given in a study, they were calculated from mean values and standard deviations for each linear dimension (MD and BL) of each maxillary and mandibular tooth. If standard deviation was not included among descriptive statistics in a report it was calculated from the standard error (CV = std error * $\sqrt{n}$), then the CV was determined. To be clear, mean CVs of linear dimensions (MD, BL) were computed across populations and have an associated standard deviation. However, since CAs are a product of mean MD and mean BL of each dental element in each population there's no way to obtain a mean CV (and standard deviation) for each CA across all populations. Hence the CVs of the mean CA values were assessed for relative variability using Forkman's (2009) F test. Differences in mean CV across populations were evaluated by first applying a test for normality (Shapiro-Wilk), to each variable and if normal, an F-test for equality of variances was conducted before the t-test was run ($\alpha = 0.05$). If data failed the normality test a Mann-Whitney rank-sum test for differences in median values was used with 25% and 75% confidence values. Tooth crown size databases were created and stored in Excel (Microsoft Office 365 ProPlus), statistical analysis was conducted in Excel data analysis and in SAS-PC (ver. 9.3), graphics were prepared using SigmaPlot for Windows (ver. 11.0). Statistical significance of differences in CV were evaluated using Forkman's (2009) approximate F test for equality of CVs in MedCalc (v.20.144; Belgium; www.Medcalc.org).

The CVs for a set of measurements within a population, say MD dimension of maxillary teeth, were ranked from one to five in order of decreasing CV from most to least variable tooth. The tooth with the largest CV was ranked one (most variable), the tooth with the lowest variability was ranked five, the least variable, or the most stable tooth in the set. This procedure was followed independently by jaw and dimension for each tooth in each population resulting in four sets of rankings for each data set (MD-maxilla, MD-mandible; BL-maxilla, BL- mandible). The relative frequency of ranks across all groups was determined for each tooth and dimension to identify patterns of variability, based on CVs, throughout the dental arcade. Which teeth exhibit greater variability? Which teeth are most stable? Can patterns of variability be identified and do they follow expectations of MGFs in permanent teeth? If MGFs, as described for permanent teeth, are expressed in the deciduous dentition, observed patterns of deciduous crown size and variability should reveal a series of specific expectations (Table 2). These are described below.

Morphogenetic fields in deciduous incisor teeth

The concept of dental morphogenetic fields when

Table 2. Crown size and variability expectations for deciduous tooth types based upon the MGF theory as described for permanent dentition (Butler, 1939; Dahlberg, 1945, 1951)

Arcade	Expectations: deciduous teeth		Basis for Expectations: permanent teeth
	Size	Variability	
Maxilla	$di^1 > di^2$	$di^1 < di^2$	I^1 is a polar tooth, larger and less variable than I^2
	$dm^1 > c > di^2$	$dm^1 < c < di^2$	based on tooth position and development
	$dm^1 < dm^2$	$dm^1 > dm^2$	M^1 developmentally more stable than M^2 or M^3
			dm^2 and M^1 are developmentally closely related with both arising from the same dental lamina with developmental timing that overlaps but with dm^2 initiation preceding M^1
Mandible	$di_1 < di_2$	$di^1 > di^2$	I_1 is smaller and more variable than I_2
	$dm^1 > c < di^2$	$dm^1 < c < di^2$	based on tooth position and development
	$dm_1 < dm_2$	$dm_1 > dm_2$	same reasons as for maxilla

applied to the pattern of metric variation in permanent incisors has several components and is different for upper and lower incisor teeth (Dahlberg, 1945, 1951). Initially, the description of MGFs applied to human permanent teeth focused on morphometric attributes of Native Americans in a comparative perspective. In upper incisors: the central incisor is the key or polar tooth and is larger and more stable (less variable) than the lateral incisor. By contrast, lower permanent incisors exhibit a reversed morphogenetic field, opposite that expressed in upper incisors. In MD size the ldi1 is smaller and less stable (more variable) than ldi2, which is the polar tooth and is larger and less variable. After assessing variability in incisor crown size, patterning of coefficients of variation is evaluated across the deciduous dental arcade.

Results

A brief description of the data used in this analysis precedes presentation of results. Sample sizes varied across dental elements and studies, but mean sample sizes (n) varied from 80 to 106 for MD (34 studies) and from 50 to 75 for BL dimensions (29 studies). Sample sizes for mean crown dimensions, mean CVs, and mean CAs analyzed in this analysis represent means across studied groups (e.g. interpopulation) from which data were derived. Shapiro-Wilk tests of normality revealed the majority of variables match a pattern expected if drawn from a population with a normal distribution; 90% of sample means (8/10 - MD, 9/10 - BL, 10/10 CA) passed, and 80% of coefficients of variation passed (6/10 - MD_CV, 9/10 - BL_CV, And 10/10 - CA_CV) with $\alpha = 0.05$. Thus, skewness and kurtosis are unlikely to impact this analysis of deciduous dental variability.

Results are presented in two sections. The first focuses on patterning of variability in incisor teeth. The second addresses the results of three different approaches to patterns of variability in deciduous tooth crown metrics. Is the pattern of metric variation observed in the deciduous dentition concordant with expectations based on MGFs in permanent incisors? Analysis of results focused initially on incisor teeth because reversed fields have been described for upper and lower permanent incisors. In relative MD and BL size, the observed pattern is that udi1 exhibits attributes of a polar or key tooth. Table 3 shows that in size the udi1 is larger and less variable, has a lower SD and CVs than udi2 in both dimensions. By contrast, mandibular incisors reveal a mixed pattern, not fully consistent with field theory expectations. The lateral incisor is significantly larger in MD and BL dimensions than the central incisor as expected ($p<0.0001$), and consistent with expectation, ldi2 is less variable than ldi1 in BL dimension. Yet in MD diameter the lower lateral incisor is more variable than ldi1, an observation inconsistent with MGF patterning in permanent lower incisors. The pattern of odontometric variation in size and variability of deciduous upper incisors follows expectations based on the description of morphogenetic fields in permanent maxillary incisor teeth. In mandibular incisors the size differential is consistent with field expectations - lateral incisors are significantly greater in MD and BL dimension than centrals, however, ldi2 is less variable than ldi1. However, CV is greater for the MD dimension of ldi2 than ldi1, an unexpected result not compatible with reduced variation expected of a polar or key tooth.

Table 3. Mean crown dimensions (n, mean, sd, min, max) and mean coefficient of variation ($\bar{x}$CV, sd) across populations (males only; see Fig. 1)

Variable	n	Mean	sd	$\bar{x}$CV	sd	min	max
			mesiodistal				
udi1	31	6.59	0.28	**6.32**	1.14	5.80	7.35
udi2	31	5.38	0.25	6.78	1.22	4.91	6.00
udc	32	6.83	0.20	5.93	0.93	6.48	7.41
udm1	34	7.40	0.29	6.16	1.28	6.69	8.25
udm2	34	9.22	0.41	**5.40**	1.27	8.58	10.55
		F=0.6354;			*p=0.2060*		
ldi1	31	4.21	0.22	7.50	1.42	3.86	4.97
ldi2	31	4.69	0.17	**7.89**	1.80	4.25	5.01
ldc	32	5.94	0.18	6.26	1.69	5.68	6.48
ldm1	34	8.12	0.25	5.62	1.24	7.43	8.54
ldm2	34	10.16	0.35	**4.93**	1.45	9.39	10.89
		F=0.3919;			*p=0.0098*		
			buccolingual				
udi1	25	5.04	0.21	7.07	1.60	4.48	5.47
udi2	25	4.76	0.25	**8.10**	1.76	3.87	5.24
udc	26	6.03	0.28	7.61	1.64	5.39	6.61
udm1	29	8.65	0.34	5.52	1.62	7.73	9.17
udm2	29	9.95	0.3	**5.00**	1.20	9.44	10.65
		F=0.3825;			*p=0.0158*		
ldi1	25	3.83	0.18	**7.91**	1.86	3.53	4.33
ldi2	25	4.28	0.19	7.35	1.62	3.95	4.75
ldc	26	5.52	0.21	7.08	1.39	5.13	6.05
ldm1	29	7.33	0.42	6.41	1.73	6.17	7.98
ldm2	29	9.09	0.37	**5.18**	1.65	8.54	10.02
		F=0.4303;			*p=0.0336*		

N = sample size; SD = standard deviation; CV = CV for mean for all samples; min = minimum; max = maximum; **Bold =** largest and smallest CV by dimension and arcade; F=test for equal CVs, *p*-value, α=0.05

Variability in deciduous teeth across the arcade: metric and rank analyses

To determine if patterns of deciduous odontometric variability follow expectations predicted by patterns documented by MGFs in permanent teeth (see Table 2), three analyses were conducted. The first examines the expression mean CVs by tooth and dimension across the arcade and across populations. The second investigates relative size of mean CAs and their associated CVs. The third quantifies the rank order of CVs from di1 to dm2 by jaw and dimension across populations.

Descriptive statistics for mean CVs for males are presented in Table 3. Mean crown dimensions (n, mean, sd, min, max) and mean coefficients of variation ($\bar{x}$CV, sd) across populations are provided. Figure 1 provides a graphic representation of data that allows easy visualization of differences in CV by tooth and dimension. Results for females exhibit the same pattern as males and are not presented. The overall result follows expectations in that dental elements exhibit a gradation of decreasing variability (or increased stability) from anterior to posterior elements of the dentition (from di2 to dm2). More specifically: a) the upper central incisor (udi1) is less variable, than the upper lateral incisor (udi2) in MD and BL dimensions, b) all second molars (dm2) have lower mean CVs than first molar teeth in upper and lower arcades, and c) the lower lateral incisor (di2) is more stable (lower CV) than the central incisor (di1) in BL dimension. The relative amount of variability in anterior (incisors) and posterior (molars) teeth were tested with an assessment of significant differences in mean CV. The largest $\bar{x}$CVs in a dental quadrant (bold values) are consistently found in incisor teeth and the smallest $\bar{x}$CVs (bold values) occur in dm2s. In three of four comparisons (see Table 3) the difference between largest and smallest $\bar{x}$CVs were found to be significant using Forkman's (2009) F-test: ldi2_MD *vs.* ldm2_MD (F=0.3919, p=0.0098); udi2_BL *vs.* udm2_BL (F=0.3825, p=0.0158), and ldi1_BL *vs.* ldm2_BL (F=0.4303, p=0.0336). However, this difference is non-significant in one quadrant (udi2_MD *vs.* udm2_MD; F=0.6354, p=0.2060). These observations are all consistent with expectations of MGF as described for permanent teeth. The only exception is in the MD dimension of the lateral incisor (di2) which has a greater mean CV than the central incisor (di1). These results show that for maxillary and mandibular molars, dm2s consistently exhibit lower $\bar{x}$CVs than dm1s. Most comparisons of mean CVs are consistent with MGF expectations with one exception.

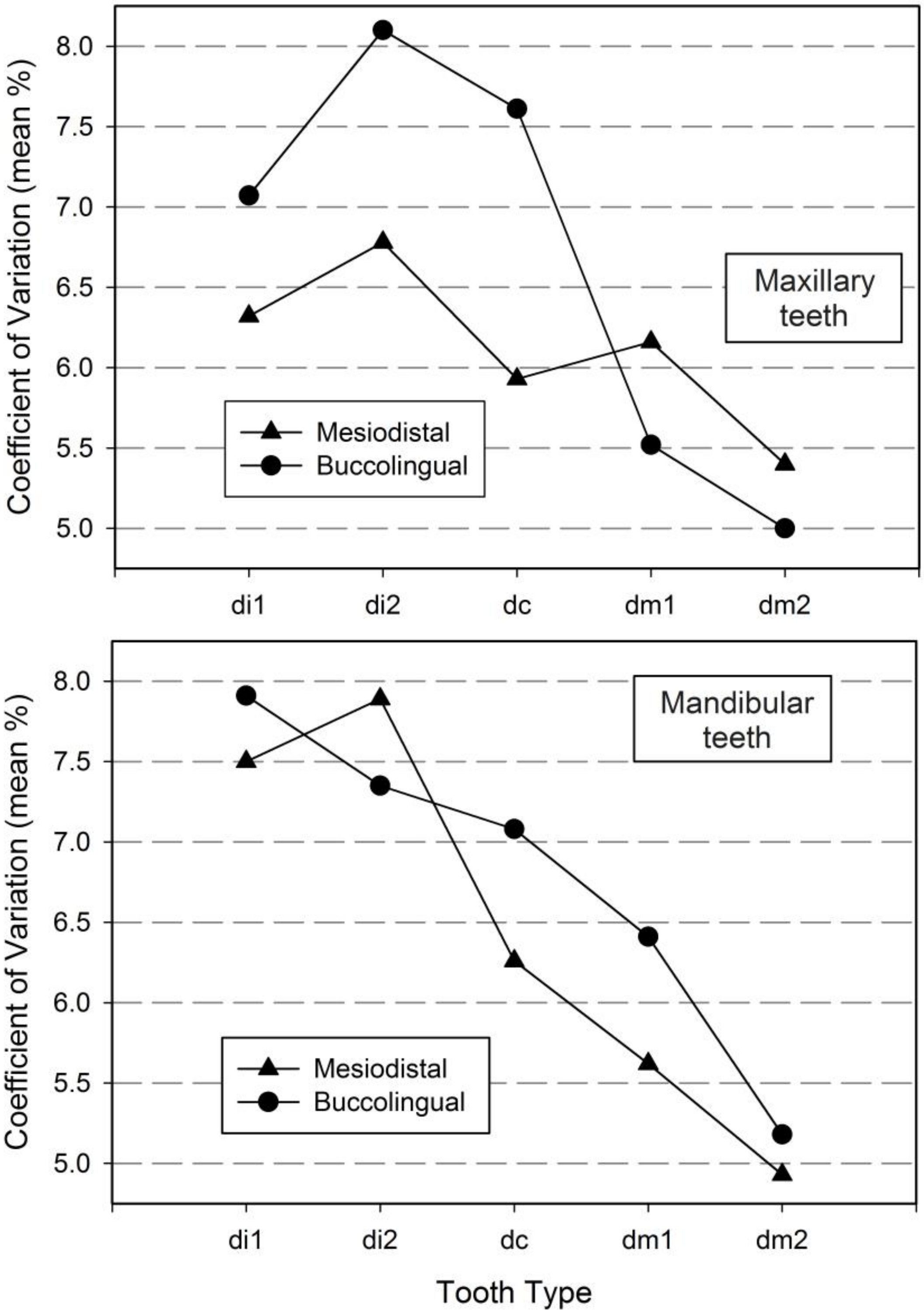

Figure 1. Mean Coefficients of Variation (CV) for mean tooth crown size (maxillary - upper panel, mandibular - lower panel, mesiodistal - MD and buccolingual - BL; see Table 3).

The second approach focuses on variability in CAs across the dental elements. Covariation of MD and BL dimensions varies among elements of the dental arcade, hence CA (mm²) provides an approximate overall estimate of tooth size. For this reason, CVs for each mean CA were calculated and plotted. The results include mean CAs, associated CVs, and descriptive statistics (Table 4, Figure 2). Are key teeth less variable? Do they have lower CVs than non-key dental elements? In four comparisons of adjacent teeth, (upper and lower incisors; upper and lower molars) prospective key teeth have lower CVs than non-key teeth, thus exhibiting patterns of variation consistent with field theory expectations. The CV comparisons consistent with field theory include: udi2 > udi1, ldi1 > ldi2, udm1 > udm2, and ldm1 > ldm2. An F test for significant differences between largest and smallest CVs (Forkman, 2009) shows that incisors (udi2, ldi1) are more variable than second molars (udm2, ldm2) (see Table 4). The CV for crown area of the udc is intermediate between values for upper incisors and upper molars, while the CV for ldc falls between the lower incisors and dm2.

The third analysis examines the rank of relative variability in CV for each tooth by dimension and by jaw across populations. Results are presented graphically for MD (Figure 3) and BL (Figure 4) dimensions. Data are presented in summary form in Table 5 and raw data by population in Table 6. Note that not all ranks were observed for all teeth. The BL dimension of maxillary teeth and second molar teeth exhibit fewer than five ranks; ranks not observed are omitted from figures. For example, in the upper BL dimension (see Figure 4, top panel) three ranks (1, 2, 3) were observed and plotted for udi2, and only two ranks (4, 5) were present and graphed for the BL dimension of udm2. Ranks not observed are omitted from the figure and not plotted are indicated by a double dash (--). Close examination of Figures 3 and 4 reveals several patterns: a) ranks one through three have a high frequency in both dimensions (MD, BL) in central and lateral incisors, upper and lower, b) rank five (least variable) has the highest frequency in second molars and is evident in both jaws and both dimensions, c) the first molar is more variable than the second molar with a greater number of ranks observed and with rank 4 attaining highest frequencies, and d) canines display a pattern of ranked variation intermediate between incisor and molar teeth. Rankings of coefficients of variation (CV) by di-

Table 4. Mean Crown Areas ($\bar{x}$CA) and coefficients of variation (CV) across populations (males only; see Fig. 2)

Tooth	n	$\bar{x}$CA	CV	sd	min	max
			maxilla			
di1	25	33.28	8.16	2.71	26.92	40.20
di2	25	25.70	**9.07**	2.33	19.00	31.44
dc	25	41.22	7.20	2.97	36.77	48.98
dm1	25	64.26	5.33	3.42	58.03	70.30
dm2	22	89.55	**5.15**	4.62	81.00	97.29
F=3.0852				*p=0.0113*		
			mandible			
di1	25	16.21	**8.86**	1.44	14.01	19.53
di2	25	20.13	7.30	1.47	17.48	23.80
dc	25	32.88	6.48	2.13	29.55	38.18
dm1	25	59.89	6.56	3.93	50.90	67.11
dm2	22	91.02	**5.46**	4.97	81.51	99.99
F=2.6209				*p=0.0291*		

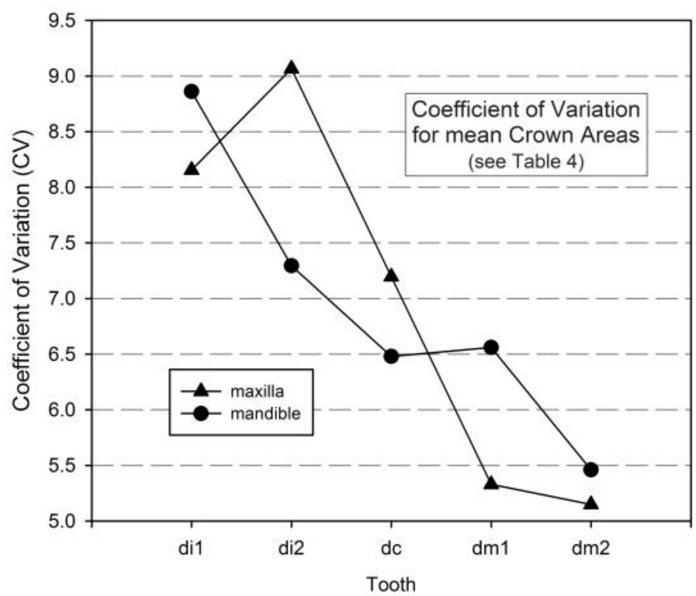

Figure 2. Coefficients of Variation for mean tooth crown areas (CAs; see Table 4).

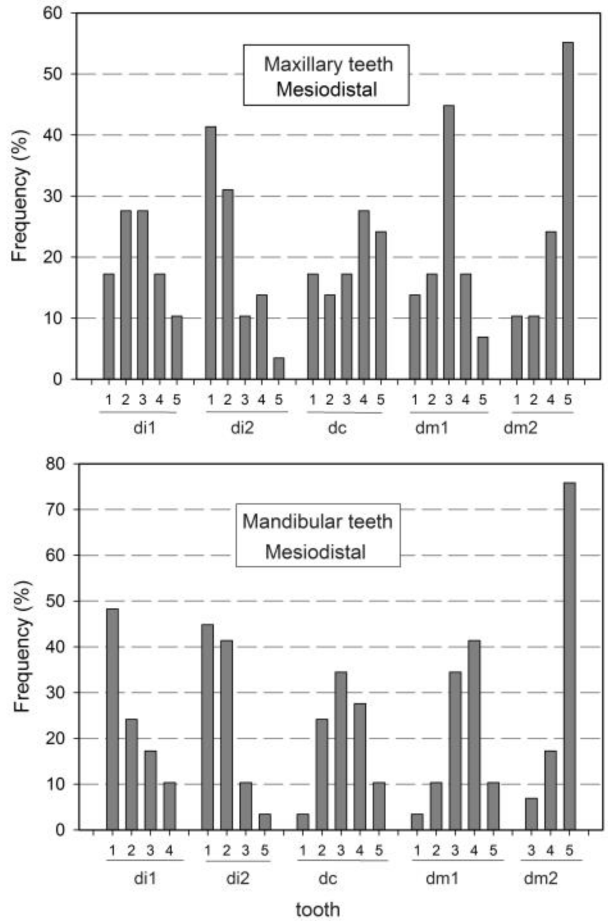

Figure 3. Histogram of CVs in rank order from most (rank 1) to least (rank 5) variable: Mesiodistal dimension (maxillary - upper panel; mandibular - lower panel; see Table 5).

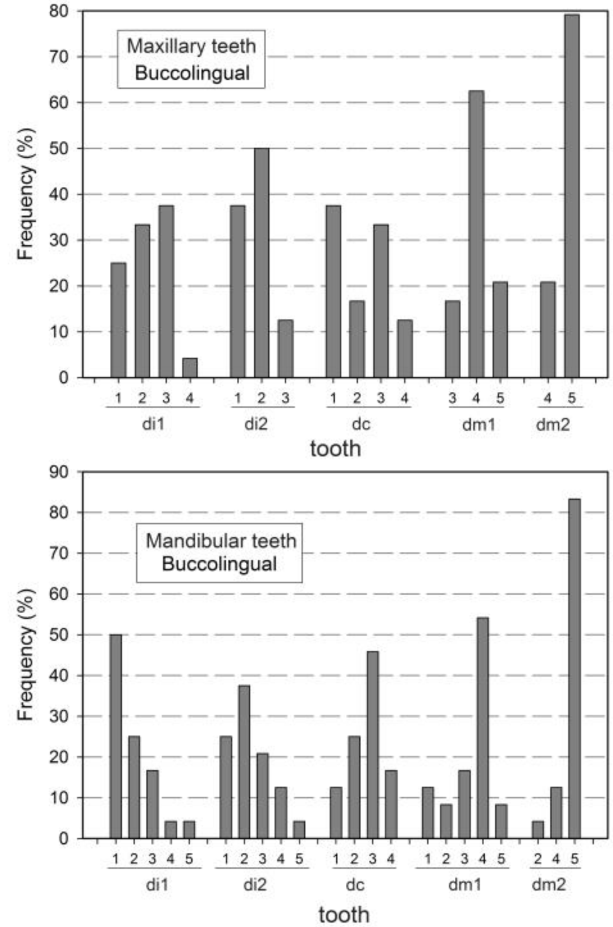

Figure 4. Histogram of CVs in rank order from most (rank 1) to least (rank 5) variable: Buccolingual dimension (maxillary - upper panel; mandibular - lower panel; see Table 5).

Table 5. Frequency (f, %) by rank order of CVs for MD and BL dimensions across populations (raw data by population, Table 6)

	di1		di2		udc		udm1		udm2	
rank	f	%	f	%	f	%	f	%	f	%
	Mesiodistal					maxillary				
1	5	17.24	12	41.38	5	17.24	4	13.79	3	10.34
2	8	27.59	9	31.03	4	13.79	5	17.24	3	10.34
3	8	27.59	3	10.34	5	17.24	13	44.83	--	--
4	5	17.24	4	13.79	8	27.59	5	17.24	7	24.14
5	3	10.34	1	3.45	7	24.14	2	6.90	16	55.17
					mandibular					
1	14	48.28	13	44.83	1	3.45	1	3.45	--	--
2	7	24.14	12	41.38	7	24.14	3	10.34	--	--
3	5	17.24	3	10.34	10	34.48	10	34.48	2	6.90
4	3	10.34	--	--	8	27.59	12	41.38	5	17.24
5	--	--	1	3.45	3	10.34	3	10.34	22	75.86
	Buccolingual					maxillary				
1	6	25.00	9	37.50	9	37.50	--	--	--	--
2	8	33.33	12	50.00	4	16.67	--	--	--	--
3	9	37.50	3	12.50	8	33.33	4	16.67	--	--
4	1	4.17	--	--	3	12.50	15	62.5	5	20.83
5	--	--	--	--	--	--	5	20.83	19	79.17
					mandibular					
1	12	50.00	6	25.00	3	12.50	3	12.50	--	--
2	6	25.00	9	37.50	6	25.00	2	8.33	1	4.17
3	4	16.67	5	20.83	11	45.83	4	16.67	--	--
4	1	4.17	3	12.50	4	16.67	13	54.17	3	12.50
5	1	4.17	1	4.17	--	--	2	8.33	20	83.33

Table 6. Rank order of tooth variability (Coefficient of Variation) by tooth, jaw and dimension (1=largest CV, 5=smallest CV; males only).

jaw	maxilla										mandible									
dimension	mesiodistal					buccolingual					mesiodistal					buccolingual				
source \ tooth	di1	di2	dc	dm1	dm2	di1	di2	dc	dm1	dm2	di1	di2	dc	dm1	dm2	di1	di2	dc	dm1	dm2
Africa_S, Black	1	2	3	4	5	2	1	4	3	5	4	1	2	3	5	2	1	4	3	5
Africa, Kalahari	2	1	4	3	5	1	2	3	4	5	3	1	2	4	5	1	2	3	4	5
AmBlack, TN	3	5	4	2	1	1	2	4	3	5	2	1	3	4	5	1	5	4	3	2
AmWhite, Burl	2	1	4	3	5	3	2	1	4	5	1	2	4	3	5	2	3	1	4	5
AmWhite, MI	3	1	4	2	5	2	1	3	4	5	1	2	3	4	5	1	2	4	3	5
Australia, Warlpiri	3	1	5	2	4	1	2	3	4	5	2	1	4	3	5	3	1	2	4	5
Australia, White	2	1	3	4	5	2	1	3	4	5	1	2	4	3	5	2	1	3	4	5
Dominican	2	3	1	4	5	3	2	1	4	5	3	1	2	4	5	1	2	3	5	4
Iceland	2	1	4	3	5	3	1	2	4	5	2	1	3	4	5	3	1	2	4	5
Japan_1970	5	1	4	3	2	--	--	--	--	--	1	2	4	3	5	--	--	--	--	--
Japan_2000	5	4	2	3	1	--	--	--	--	--	1	2	4	3	5	--	--	--	--	--
Japan, Nagoya	3	1	5	2	4	2	1	4	3	5	1	2	5	3	4	3	2	1	5	4
Japan_Ooshima	1	2	4	3	5	--	--	--	--	--	1	2	3	4	5	--	--	--	--	--
Java, Malay	4	2	1	3	5	3	2	1	4	5	1	2	4	3	5	1	2	3	4	5
India, Gujarat	4	1	5	3	2	4	2	1	3	5	1	2	4	5	3	5	3	2	1	4
India, Jat	1	2	4	3	5	--	--	--	--	--	1	2	3	4	5	--	--	--	--	--
India, Wardha	2	3	1	4	5	1	2	3	4	5	1	3	2	4	5	1	2	3	4	5
Jordan	4	1	2	3	5	2	1	3	4	5	2	1	3	4	5	1	3	2	4	5
Korea, South	4	3	1	2	5	3	2	1	4	5	2	1	5	3	4	1	2	3	4	5
London, Spital	1	2	3	5	4	3	2	1	5	4	1	5	3	2	3	2	4	3	1	5
Pima, NNA	3	2	5	1	4	2	3	1	5	4	1	2	3	4	5	1	4	2	3	5
Melanesia-Nasioi	3	4	5	1	2	3	1	2	5	4	2	1	3	4	5	2	1	3	4	5
Nigeria	4	2	5	3	1	1	2	3	5	4	3	1	2	4	5	2	1	3	4	5
Poland	2	4	3	1	5	2	3	1	4	5	4	3	1	2	5	4	3	2	1	5
Spain, Granada	2	1	3	5	4	3	1	2	5	4	3	1	2	5	4	3	2	1	4	5
Taiwan 1	3	2	1	4	5	3	1	2	4	5	1	2	4	3	5	1	4	3	2	5
Taiwan 2	1	2	5	3	4	1	2	3	4	5	3	1	2	5	4	1	2	3	4	5
Taiwan 3	5	1	2	3	4	--	--	--	--	--	2	3	5	1	4	--	--	--	--	--
Vietnam	3	4	2	1	5	2	3	1	4	5	4	1	3	2	5	1	3	4	2	5

mension (MD and BL) and by jaw exhibit patterns consistent with the hypothesis that deciduous dental variation is mediated by MGF-like mechanisms during development.

Discussion

The conclusion to Kieser's (1990: 88) chapter on odontometric variability states that, "Dental dimensional variability emerges as a complex phenomenon and will probably require a complex synthesis of ideas for its explanation." The multitude and diversity of hypotheses make some models unfalsifiable using variability statistics (from Butler and Dahlberg's fields, Waddington's epigenetic canalization, Osborn's clones, Pengilly's functional relations, and Grigerich's occlusal complexity). These observations relate to the more thoroughly documented variability observed in the permanent dentition, "The honest answer at the moment is that we do not know the exact cause for the observed patterning of odontometric variability in man" (Kieser, 1990: 88).

This investigation of odontometric variability in deciduous teeth yields insight into important yet unresolved issues. The data presented here for patterns of variability in deciduous tooth crown dimensions are mainly in agreement with predictions based on morphogenetic fields as described for permanent teeth. The pattern of variability in deciduous dentition differs in several ways from that described for permanent teeth: a) three fields -- not four -- are sufficient to explain patterns observed, b) incisor variability follows expectation, with one exception, c) second molars are larger and more stable than first molars, and d) a canine field is implied by variability intermediate between incisor and molar teeth.

Though the findings documented in this report have merit they do not allow confirmation of one or another cause for the observed patterning of variability. We can see that deciduous tooth crown variability adheres to patterns of variation predicted by MGFs to explain variability in permanent teeth. The number of samples and their global and ethnic diversity gives these results a broad empirical base, yet several questions remain. The lower lateral incisor MD is more variable than the central, a deviation from expectation. Does this result suggest that lower incisors do not fully adhere to the reversed MGF of lower incisors in permanent teeth? Additional unanswered questions center on patterns of variability across the transition from deciduous to permanent teeth. Is the deciduous second molar more, or less, stable than the first permanent molar? Which is the key or polar tooth in the molar MGF? How does variability in deciduous molars compare with that of their succedent permanent premolar teeth?

A final question regards causality. Mizoguchi (1998), Farmer and Townsend (1993), Kieser (1990), and others point to the timing of dental development as a potential explanation for the observed patterning of variability. Several studies propose that the time a tooth spends in the pre-calcification, or soft tissue stage of development is a potential explanation. Deciduous incisors are longer in pre-calcification and more variable in crown dimensions, while molars have less time in the soft tissues stage and are more stable odontometrically. Differences in form and development between dm1, dm2 and M1 are notable. Deciduous teeth and the permanent first molar are derived from the same primary dental lamina (Bailey, 2014, 2017), and Butler (1956, 1967) noted these differences are to some extent adaptive. "Dm2 has a much shorter period of function than M1, and it operates in a smaller mouth and shorter jaw. It is a deciduous tooth, whereas M1 is a permanent tooth. From a morphogenetic point of view, however, the two teeth belong to the same series, and their differences may be ascribed to position within the series" (Butler, 1967: 1259). Thus, "…it is tempting to see the deciduous second molar and permanent first molar as representing different stages of the same ontogenetic process" (Bailey et al., 2014: 112). In this analysis dm2 is odontometrically the least variable tooth in the deciduous dentition and its development is closely linked to M1 suggesting that dm2 is the polar or key tooth of the meristic molar series (dm2 thru M3) (Smith et al., 1987, 1997).

Conclusions

Patterns of odontometric variability in deciduous tooth crown size are largely consistent with expectations described for permanent teeth. This correspondence is evident in results from three different analyses and is based on a large and diverse sample of populations. Independent studies of metric variation in deciduous tooth crown measurements have interpreted results consistent with the dental morphogenetic field concept. These studies now have further validation and confirmation from the results reported here. Further analysis of deciduous tooth crown variability in relation to morphogenetic field theory is in progress using statistical procedures for meta-analysis and multivariate methods (e.g., principal components analysis).

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Morphological and Metric Description of a Rare Mesolithic Deciduous Tooth from Trail Creek Caves, Alaska

Verner Alexandersen[1], Lasse Vinner[2], Charlotte Primeau[1,3*]

1 Laboratory of Biological Anthropology, Department of Forensic Medicine, University of Copenhagen, Frederik V's Vej 11, 2100 Copenhagen, Denmark
2 Lundbeck GeoGenetics Centre, Globe Institute, University of Copenhagen, Østervoldgade 5-7, 1350 Copenhagen, Denmark
3 Warwick Manufacturing Group (WMG), University of Warwick, England, UK

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ABSTRACT A human deciduous maxillary central incisor from Trail Creek Caves, Seward Peninsula, Alaska, is described. The tooth from ancient Beringia is radiocarbon dating to 8085 ±40 BP. The tooth is compared to the incisors from the deciduous dentition of USR1 from the Upward Sun River site in central Alaska dating to ca. 11,500 (cal) BP. Genetic analysis of the Trail Creek child and the USR1 child showed that they both belonged to an ancient eastern Beringian population that remained isolated in present-day Alaska during the late Pleistocene and early Holocene. The tooth was measured using a sliding calliper and the morphology of the tooth described directly from macroscopic evaluation as well as from a 3D surface scan. Based on tooth development, the age of the Trail Creek child corresponds to an age of 1-1.5 years. The sex of the child is determined as female from the genetic analysis. The tooth was expected to show the characteristic shovel-shape of Native Americans but was without marked shovel-shape. The variability of shovel-shape in maxillary deciduous and permanent incisors is discussed and it is suggested that the trait shovel-shape in a deciduous dentition is more reliably recorded on the maxillary lateral incisors than the central incisors.

This is a morphological and metric description of a deciduous maxillary central incisor excavated from the archaeological site Trail Creek Cave 2 on the Seward Peninsula in western Alaska by Helge Larsen in 1949 and 1950 (Larsen, 1968). The tooth stored at the National Museum in Copenhagen was the only human skeletal remain among thousands of animal bones retrieved from excavation (Pasda, 2012). Pasda (2012) identified the tooth as a left I^1 (upper left permanent central incisor), instead of a left i^1 (upper left deciduous central incisor) and described it as a slightly worn tooth with the root not fully formed. The tooth derives from Cave 2, Section 4m, Layer III. The deciduous tooth is radiocarbon dated to 8085 ±40 BP, hence from early Holocene (Moreno-Mayar et al., 2018). The morphological examination was requested by the Centre for GeoGenetics in Copenhagen, Denmark prior to the destructive genetic analysis. Images of the tooth were provided before the root was cut for radiocarbon dating (Figure 1a and 1b). Additionally, a 3D surface scan was provided of the crown which could be digitally rotated and from where images could be extracted with different views of the tooth.

Within dental anthropology, tooth morphology can be related to regional populations (Hanihara, 1967; Scott and Turner, 1997). This applies to the deciduous as well as the permanent dentition. Most researchers today favour the hypothesis that Upper Palaeolithic populations of hunter-gatherer reached northeast Asia 30,000+ years before the last glacial maximum (LGM) (Pitulko et al., 2004). During the LGM the landmass between Asia and North America called Beringia became a refugium

*Correspondence to:
Charlotte Primeau
WMG
University of Warwick
Coventry, England, UK
E-mail: Charlie.primeau@warwick.ac.uk

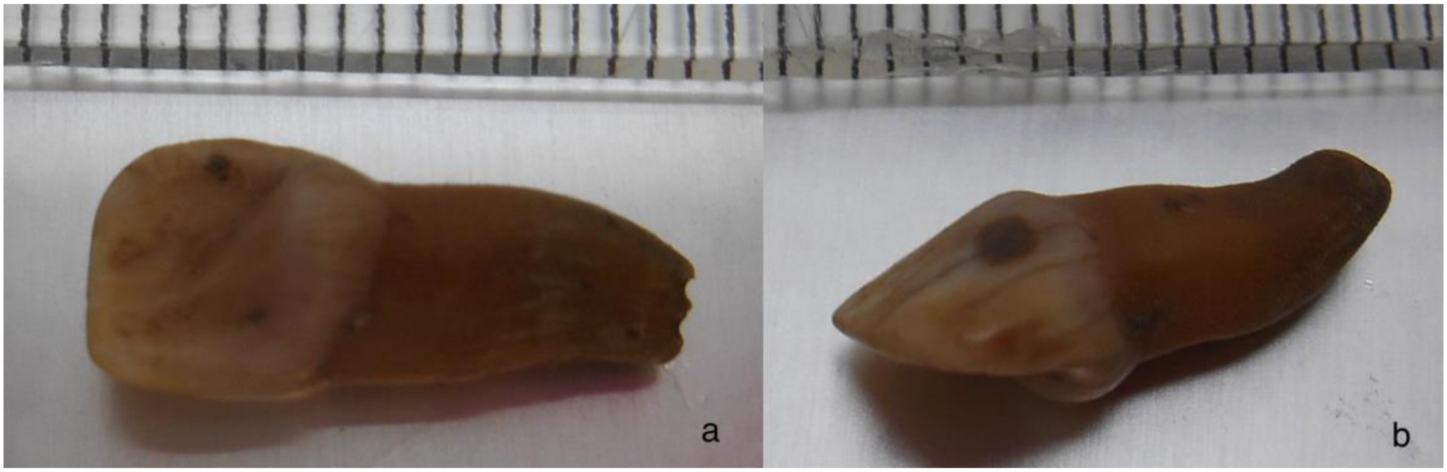

Figure 1. Images provided prior to this examination. 1a is the lingual surface seen from the mesial side. 1b is the facial surface seen from the distal side. Scale bars represent millimetres.

for Northeast Asian groups of hunters (ca. 20.000 – 15 thousand years ago). At the end of the LGM the hunters migrated along the coast and along land corridors into North America (Scott et al., 2016). These prehistoric Native Americans had their dentitions described by Turner (1983). He observed three fairly clear geographic clusters: 'Alaska interior-Northwest Coast mainly Na-Dene-speaking Indians; Arctic coast (Aleut-Eskimo) and all the rest of North and South America (Indian)'. All three clusters had a Sinodont dental pattern in their permanent dentitions. The anterior teeth in such a dental pattern have a high frequency of shovel-shape. It is the purpose of this examination to study the morphology of the Trail Creek incisor and compare with anterior teeth from another and more ancient Alaskan child (USR1, dated ca. 11,500 cal. years BP) (Potter et al., 2014). The hypothesis was that the Trail Creek tooth would show a Sinodont morphology, like USR 1 and other Native Americans. The genomes of the children from the Trail Creek and USR1 sites have been analysed by geneticists and the results are included in recent literature on the First Americans (Moreno-Mayar et al., 2018; Hoffecker et al., 2020, 2021).

Genetic analysis

The genetic analysis revealed the Trail Creek individual as female. Sequencing of ancient DNA recovered from the Trail Creek specimen was expanded to ~0.4× genomic depth of coverage, using Illumina high-throughput sequencing. The results of the genomic analyses were previously described in detail (Moreno-Mayar et al., 2018). In brief, initial multidimensional scaling analysis indicated genomic affinity between Trail Creek and another contemporaneous specimen (USR1) from the same region and showed similar proportions of Siberian and Native American genomic components. The mtDNA haplotype belonged to B2 (shared with USR2 -a low-coverage genome of a close relative to USR1), although different from the derived B2 variant found throughout other parts of the American continents (Moreno-Mayar et al., 2018). Furthermore, f3-statistical analysis suggested that Trail Creek (like USR1) are similarly related to other Native Americans. Finally, D-statistics and admixture graph-fitting, using qpGraph, supported a model in which the Trail Creek genome form a clade with USR1 to the exclusion of other known North- and South- Native Americans. The collective genetic evidence from Trail Creek and USR1, which also showed similar archaeological artefacts, support that the Trail Creek tooth came from an individual that belonged to an ancient metapopulation present in eastern Beringia. This population who remained isolated in present-day Alaska during the late Pleistocene and early Holocene were equally related to North- and South- Native American populations (Moreno-Mayar et al., 2018).

Age assessment of the child

The incisal edge of the crown was slightly worn, and the root formation not completed. From inspection of the provided photos (see Figure 1a and 1b) the root length was estimated to be 2/3 to 3/4 completed. The apical opening was wide and the root walls very thin (Stage F according to Liversidge and Molleson, 2004). The development of the tooth corresponds to an age of 1-1.5 years (AlQahtani et al., 2010, Figure 6, Liversidge and Molleson, 2004, Table 2).

Overall description of the Trail Creek tooth

The facial surface of the crown was flat without double-shovel and almost square with a mesiodistal breadth of 6.7 mm and a crown height of 6.6 mm (Figure 2a). The apical part of the root was bent in a facial direction as expected from deciduous maxillary incisors (see Figure 1b). The lingual surface of the crown had weakly developed marginal ridges on each side of a very shallow central fossa (Figure 2b). This corresponds to trace of shoveling in the terminology of Hanihara (1967) or Sciulli (1998). Of the two marginal ridges, the distal ridge is more distinct. The basal cingulum occupied the gingival half of the lingual surface. From this bulging eminence, there was an extension in the direction of the incisal edge (Figure 3a and 3b). This was observed on the scan, while it was indistinct from visual

Figure 2. The tooth at the time of examination. Figure 2a is the facial surface with the mesial edge to the left. Figure 2b is the lingual surface with the distal edge to the left. Scale bar represents millimetres.

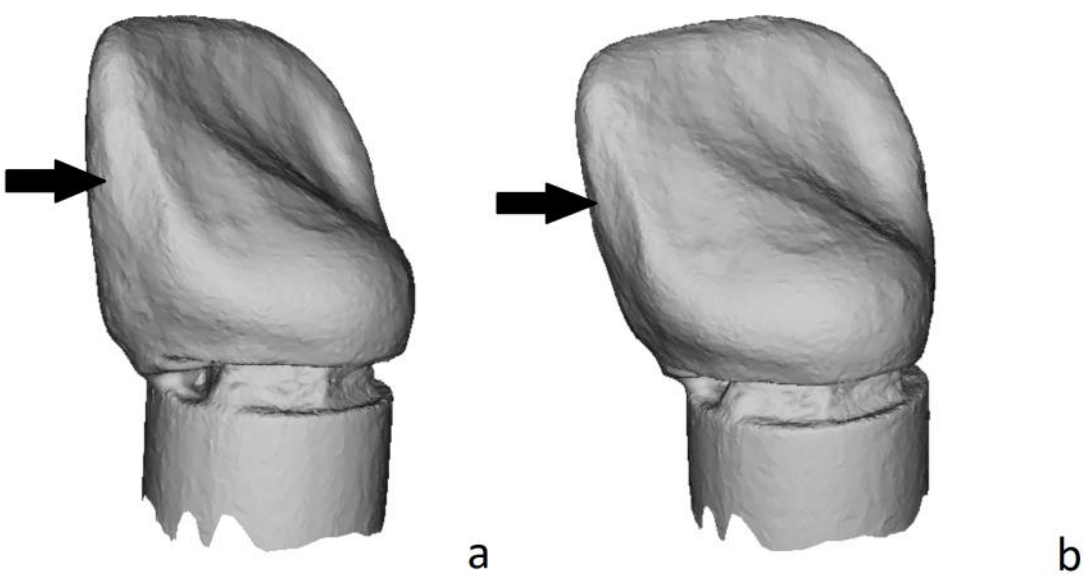

Figure 3. Scanning images of the deciduous central incisor crown showing the attritional facet (arrows). 3a is seen from the mesial side. 3b is seen from the lingual surface. 3D scanning was after the root was removed for radiocarbon dating, so tooth crown was mounted on a stance.

inspection or from the photograph (see Figure 2b). In Table 1, the results are presented with use of the terminology described by (Sciulli, 1998).

The 3-dimensional digital model created by surface scanning using a Trio scanner (3shape, Copenhagen) deserves further comment. The scanning images illustrated a small attritional facet visible on the mesial surface of the crown, caused by friction between the two central incisors (see Figure 3a and 3b). Hence the tooth had been erupted and in use for some time. The scanning images showed no visible microwear.

The mesial attritional facet visible on the scanning images was not apparent on the tooth when viewed directly. This imaging method was therefore a valuable addition to the macroscopic examination of the tooth. The facet was formed during a very short functional period from the eruption of the central incisors at circa 10 months of age to the death of the child at about 18 months of age (see above). It is important to note that enamel of deciduous teeth is not fully mineralized at the time of eruption (Nanci, 2013; Harris and Lease, 2005).

A larger brown discoloured spot was observed on the facial surface of the crown (see Figure 2a) and a minor spot on the lingual surface (see Figure 2b). These extrinsic discolorations are most likely due to absorption of pigment particles from the soil. The *post-mortem* cracks in the enamel are likewise stained by unknown material (see Figure 2a).

Comparative material from Alaska

For comparison with the Trail Creek tooth, it is relevant to mention the complete deciduous dentition of the young child from an Upward Sun River site (USR1) in central Alaska, reported in the paper by Potter et al. (2014). The nonmetric crown traits of the teeth belonging to USR1 were compared to a pooled prehistoric sample of Ohio Native Americans studied by Sciulli (1998) (see Table 1). The maxillary central incisors of USR1 showed only a trace of shoveling. The upper lateral incisors and the lower lateral incisors showed a higher grade of the trait shovel- shape than the upper central incisor and it was concluded that USR1 was a Native American child with a Sinodont-like deciduous dentition.

Discussion of shovel-shape in the deciduous dentition

Shovel-shape in the deciduous dentition was first classified by Hanihara (1963) and later followed up by Sciulli (1998) with the following definitions: 0: no shovel-shape, lingual surface smooth, 1: semi shovel-shape, slight elevation of marginal ridges, 2: shovel, marginal ridges easily seen, and 3: strong or marked shovel when marginal ridges are broad and high. A shovel-shaped incisor means grade 2 or 3 to most researchers. In Europeans and Western Eurasians, the maxillary incisors are usually without shovel-shape in

Table 1. Nonmetric crown traits for deciduous upper central incisors

Trait	Comparative sample			Individual USR1*		Trail Creek	
	N	Break-points**	%**	Status	Grade	Status	Grade
Shovel	163	2-3/0-3	77.3	Absent	1	Absent	1
Double Shovel	157	1-3/0-3	20.4	Absent	0	Absent	0
Interruption groove	161	1-4/0-4	0.0	Absent	0	Absent	0
Tuberculum dentale	155	1-4/0-4	11.6	Present?	1?	Absent	0

*Values for USR1 are from Potter et al., 2014.

** Comparative sample of 370 individuals from 26 prehistoric Ohio Valley populations (ca. 3000-350 BP), Sciulli, 1998.

grade 2 and 3 while it is common in East Asian populations and Native Americans and Inuit (Table 2).

Shovel-shape of maxillary incisors is often more distinct on the lateral than the central incisors in the same dentition (Sciulli, 1998). Lukacs and Kuswandari (2013) therefore recorded shovel-shape on maxillary lateral incisors in their study of Malayan children. In the permanent dentition shovel-shape is more common than in the deciduous dentition (Table 3). It does not follow from the lack of marked shovel-shape in the Trail Creek central incisor that shovel-shape also was missing on the upper lateral incisors.

The strength of correlation between deciduous and permanent incisors in the same individual has been studied by Saunders and Mayhall (1982). They studied individuals of European ancestry with a low frequency of marked shovel-shape. They found that absence or trace shoveling in the deciduous dentition also meant absence in the permanent successor but occasionally was absent followed by some degree of shovel in the permanent dentition (Table 4). Edgar and Lease (2007) likewise studied European Americans as children and adults. Hanihara´s and Sciulli´s descriptions were used for their recordings of deciduous teeth while the ASU dental anthropology system was used for the permanent teeth (Scott and Irish, 2017). Edgar and Lease (2007) expected high correlation between the two dentitions, but their null hy-

Table 2. Population frequencies for shovel-shape of deciduous maxillary central incisors

Population	N	Grade 0 and 1 (%)	Grade 2 and 3 (%)	Reference
Eskimo	16	50.0	50.0	Hanihara, 1966
Pima Indian	78	38.4	61.5	Hanihara, 1966
Pima Indian	53	49.1	50.9	Tocheri, 2002
Amerindian, Ohio	163	22.7	77.3	Sciulli, 1998
Japanese (Wajin)	124	23.4	76.6	Hanihara, 1963
Prehistoric Jomon	24	62.5	37.5	Kitagawa et al., 1995
Ainu	4	50.0	50.0	Kitagawa et al., 1995
Malay	129	93.0	7.0	Lukacs and Kuswandari, 2013
Australian Ab.	38	23.7	76.3	Hanihara, 1963, 1965
Amer. W/Danish	19	84.2	15.8	Present authors (unpublished)
American white	20	100.0	0.0	Hanihara, 1966
Jats	68	95.6	4.4	Kaul and Prakash, 1981
Inamgoan, Chalchol.	39	84.6	15.4	Lukacs and Walimbe, 1984

Grade 0 and 1: includes no shovel-shape and semi-shovel 1; Grade 2 and 3: marked shovel-shape. Grade 3 is rarely observed according to Hanihara (1963), who only found it in few American Indians. Lukacs and Kuswandari (2013) and Kitagawa et al. (1995), likewise observed no children with shovel grade 3, only with grade 2. The authors acknowledge that some of the terminology within this paper is no longer acceptable, but references as the originally presented to avoid confusion within the literature.

Table 3. Frequencies of the various expressions of shovel-shape in deciduous and permanent incisors

	Permanent I1 absent	Permanent I1 trace	Permanent I1 Semi-shovel	Permanent I1 Shovel-shaped
Deciduous i1 absent	76.6%	16.9%	1.5%	0.5%
Deciduous i1 trace	2.5%	2.5%	1.5%	0.0%

From Saunders and Mayhall (1982), Table 1, p.46, based on 650 children from Burlington, Canada. Ninety percent of all parents of these children had their ancestry traced to the British Isles or Continental Europe; the remainder was also of Caucasoid origin. The figures add up to 100% di1.

Table 4. Frequency distributions of shovel-shape in deciduous and permanent dentitions

Population	Permanent (I1and I2) % (N)	Deciduous (di1) % (N)
Eskimo	100.0 (21)	50.0 (16)
Pima Indian	99.1 (222)	61.6 (78)
Japanese Ainu	81.4 (97)	50.0 (4)
American whites	27.7 (83)	0.0 (20)

From Hanihara et al. (1975), Tables 3.5-1 and 2, page 258. Shovel-shape grade 2+3.

pothesis was nevertheless that there is not a strong significant correlation between trait expression in the deciduous and permanent teeth. Their results showed that correlations for maxillary incisors were non-significant supporting Saunders and Mayhalls (1982) results and the null hypothesis was likewise supported for all other types of incisors with one exception. Surprisingly the correlation for mandibular second incisor shoveling was significant, negating the null hypothesis. There is, however, a need for similar studies in populations with high frequency of shovel-shape where a higher inter-dentition correlation for shovel-shape possibly can be observed.

Tooth size

The mesiodistal and buccolingual crown diameters of the Trail Creek incisor were measured and compared to results from studies of archaeological skeletal material and plaster casts from modern living children. The tooth was measured with a Mitotoyo sliding calliper to an accuracy of 0.1 mm. Mesiodistal measurements can be made with the same precision near the incisal edges on actual teeth and casts. However, measurements of the buccolingual diameters require the basal cingulum to be fully exposed. This is the case for teeth in skeletal material or isolated teeth. In casts with teeth *in situ*, made from living individuals, the basal cingulum of the central deciduous incisor can be partly covered by gingiva. A minor unknown error in buccolingual crown sizes measured on plaster casts compared to skeletal material is thereby a possibility.

In Table 5, the size of very few central decid-

Table 5. Tooth size of the deciduous maxillary central incisor in archaeological material

	Mesiodistal diameter			Buccolingual diameter			
Population	N	($\bar{x}$)	SD	N	($\bar{x}$)	SD	Reference
Mesolithic							
Trail Creek	1	6.7	N/A	1	5.6	N/A	Present study
Mehrgahr 3 (Preceramic, <8000 BP)	8	7.1	0.43	9	5.58	0.2	Lukacs and Hemphill, 1991
Vedbæk (Denmark, 7500-7300 BP)	1	7.1	N/A	1	5.3	N/A	Alexandersen, 1976
Western Europe (Arene Candide, Ofnet, Muge, Hohlenstein, 8-5000 BP)	7	7.2	0.46	7	5.3	0.34	Frayer, 1978
Neolithic							
Mehrgahr 2 (Chalcolithic, 6500 BP)	4	6.83	0.39	4	5.38	0.46	Lukacs and Hemphill, 1991
Tell Leilan, Syria (4300-4200 BP, Bronze Age)	2	6.75	N/A	2	5.25	N/A	Haddow and Lovell, 2003
Ohio Indians (ca. 3000 BP)	24	6.5	0.41	24	4.8	0.33	Sciulli, 1990

uous incisors known from Mesolithic and Neolithic archaeological sites in Europe, Syria and Pakistan are presented. The Mesolithic period is here considered to begin after the Ice Age at about 11,500 BP, thus including the tooth from Trail Creek. The mesiodistal diameter of the tooth from Trail Creek is close to 1 standard deviation (SD) below the mean value for the two small Mesolithic samples while it is comparable to the few Neolithic Near East incisors. The buccolingual diameter of the Trail Creek tooth is within 1 SD of the mean values for the comparative Mesolithic samples.

The diachronic change in tooth size is very small, if existing at all, in the deciduous dentition as seen from Table 5. The archaic Native Americans from the Ohio Valley had smaller central deciduous incisors than the Trail Creek tooth, but the recent Pima Indians from Southern Arizona and the Asiatic Japanese and Taiwanese children had matching mesiodistal diameters although smaller buccolingual diameters. Recent Europeans have mesiodistal diameters comparable to the Alaskan tooth, but again smaller buccolingual diameters.

Table 6 show sizes of modern populations where sex is known, hence data are sex specific. In modern populations the smallest deciduous incisors occur in Europeans. The Trail Creek incisor fits among the modern Asiatic and New World samples represented in Table 5.

Conclusions

This metric and morphological examination has documented a rare deciduous left central incisor from Trail Creek Cave 2, Alaska, dated to 8085+/-40 BP. The age of the child corresponds to an age of 1-1.5 years based on incomplete development of the root. The lingual surface of the crown showed only a trace of shovel-shape and a prominent basal cingulum. Comparison with the central incisor from the USR1 child (Potter et al., 2014) showed that this incisor (USR1) also had minimum trace of shovel-shape. Several anterior teeth were available from the USR1 child and the lateral maxillary and mandibular incisors in this dentition showed a higher grade of shovel -shape and was characterized as a Sinodont dentition belonging to a Native American child.

Review of the literature has shown that shovel-shape occurs with a lower frequency in deciduous than in permanent maxillary inci-

Table 6. Tooth size of the deciduous maxillary central incisor in modern samples

Population	Mesiodistal diameter			Buccolingual diameter			Reference
	N	($\bar{x}$)	SD	N	($\bar{x}$)	SD	
Pima Native Indians, boys	22	6.83	0.49	23	5.20	0.35	Alvrus, 2000
Pima Native Indians, girls	22	6.81	0.28	22	5.06	0.49	
Japanese, boys	42	6.87	0.46	N/A	N/A	N/A	Mizoguchi, 1998
Taiwanese, boys	60	6.77	0.38	60	4.89	0.22	Tsai, 2000
Taiwanese, girls	57	6.62	0.42	57	4.78	0.36	
American white, boys	90	6.46	0.39	N/A	N/A	N/A	Meredith and Knott, 1970
American white, girls	90	6.32	0.42	N/A	N/A	N/A	
American white, boys	25	6.50	0.29	23	5.20	0.25	Alexandersen, 1969
American white, girls	18	6.31	0.50	17	4.95	0.41	
Jordanians, boys	34	6.54	0.39	43	4.95	0.33	
Jordanians, girls	40	6.46	0.32	31	4.87	0.27	Hattab et al., 1999
Icelanders, boys	20	6.49	0.45	29	5.08	0.26	Axelsson and Kirveskari, 1984
Icelanders, girls	18	6.43	0.45	20	5.01	0.30	
Australians, boys	28	7.34	0.47	N/A	N/A	N/A	
Australians, girls	10	7.15	0.46	N/A	N/A	N/A	Brown et al., 1980

sors of the given population. The trait shovel-shape occurs with a higher frequency on lateral than central incisors in the deciduous dentitions. It is also pointed out that the degree of shovel-shape is not necessarily the same in both dentitions of a given individual. Lack of strong correlation has been established for European Americans but there is need for a similar study in individuals of Native American origin. The mesiodistal crown diameter of the Trail Creek tooth was of modern size. The buccolingual diameter was large as expected considering the prominent basal cingulum.

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