Variability and patterning in permanent tooth size of four human ethnic groups.

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This paper has been submitted for consideration for inclusion in a Supplement to Archives of Oral Biology. This Supplement arises from a series of papers given at an International Workshop on Oral Growth and Development held in Liverpool on November 26-28, 2007. The papers to be submitted consist of a series of review and new concept papers to be followed by papers outlining new work in each of the areas covered by the reviews.

Abstract

Aims: Dental dimensions vary between different ethnic groups, providing insights into the factors controlling human dental development. This paper compares permanent mesiodistal crown diameters between four ethnic groups, highlighting patterns of tooth size between these groups and considers the findings in relation to genetic and environmental influences.

Methods and Results: Mesiodistal crown dimensions were recorded using standardised manual measurements on dental casts derived from four different human populations: Southern Chinese; North Americans of European ancestry; Modern British of European ancestry and Romano-British. Analyses based on double determinations showed that measurements in all study samples were reliable to an accuracy of 0.1mm. The Southern Chinese sample was found to have the largest teeth overall, whereas the Romano-British sample generally displayed the smallest mesio-distal crown dimensions ($p<0.001$). However, the Modern British sample had the largest maxillary central incisors, mandibular central and lateral incisors, and mandibular canines, while the North American sample had the largest maxillary first and second molars. Comparisons of coefficients of variation for teeth within each class showed that the later-forming teeth displayed greater variation in mesio-distal size than the earlier-forming teeth.

Conclusion: The different patterns of tooth size observed between the study samples are thought to reflect differences in the relative contributions of genetic, and environmental influences to dental development between the four populations. For example, it is proposed that major environmental insults during the early life of Romano-Britons, including recurrent illnesses, poor nutrition and excessive lead ingestion, contributed to the reduction in size and greater variability of their later-forming teeth. Using a standardized methodology, significant differences in mesio-distal crown diameters have been demonstrated between four human ethnic groups. There were also distinct differences in the patterns of crown size between the groups, with the later-forming teeth in each type generally showing greater size variation.

Key words: tooth size patterns, genetic and environmental factors

Introduction

Teeth can provide evidence about the nature and extent of diversity between human populations (1) and variations in dental crown size have been reported between different populations (2). Numerous factors can contribute to variation in tooth size and these may be described broadly as genetic, epigenetic and environmental influences (3, 4, 5). Previous studies have confirmed the presence of sexual dimorphism within the human dentition (6-8) and examples of ethnic differences and geographic variability in tooth size have been documented (2).

A strong genetic contribution to variation in tooth size has been shown but environmental factors may also play a role (3, 9). For example, low birth weight has been linked to a reduction in the mesiodistal width of deciduous teeth (5, 10, 11). Alvesalo (7) has shown that there is sexual dimorphism displayed in the dentition, with males tending to have larger teeth than females (9), reflecting X chromosome linkage with the Y chromosome also having an impact. For example, both 47,XXY males and 47,XYY males have larger teeth than 46,XY males (6, 8).

Hanihara and Ishida (12) argue for the clustering of tooth dimensions of world populations into three groups, termed microdontic, mesodontic and megadontic. They propose that the smaller tooth dimensions in western Eurasian populations are related to the lower impact of natural selection on tooth size in these populations over the last few millennia, associated with cultural changes in food preparation practices in these groups following the adoption of agriculture. Given the strong heritability of dental dimensions (3), it seems likely that genetic differences both between and within populations also contribute to diversity. Analysis of other populations, both living and historic, should help to clarify these issues further.

This study aims to compare dental crown size between four human populations from different geographical regions and time periods in order to determine:

1. Whether there are any overall differences in permanent mesiodistal crown diameters between the groups.
2. Whether the patterns of the mesio-distal diameters in each group are compatible with current understanding of the morphogenetic field concept (13).
3. Whether the patterns of variability in mesio-distal diameters for different tooth types were different between the groups.

Materials and Methods

Mesio-distal dental crown dimensions were compared between a Southern Chinese group, a North American group of European ancestry, a Modern British group of European ancestry and a Romano-British group.

The Southern Chinese data were collected from 50 male and 50 female Cantonese speaking dental students aged 19-24 years, at the Prince Phillip Dental Hospital, Hong Kong. The students all came from Hong Kong and their parents and grandparents from the surrounding southern provinces of China. The North American data were obtained from the study of Moorrees et al. (2). The data set consisted of 91 male and 93 female North American children of European ancestry, who were examined longitudinally from the age of 3 until the age of 18. The measurements from the permanent dentition are used here. The Modern British data were derived from 30 males and 30 females aged 12-20 years from Sheffield, England. All subjects were of European ancestry. The data on the Romano-British population were derived from the excavated skeletal remains of the Poundbury cemetery, Dorset, UK in use during the period 200-400 AD, and now housed in the Natural History Museum, London. They travelled to the UK to form part of the supporting network for the Roman Legions, but their exact origin is not known as many were recruited on route from other countries. It is also uncertain as to their future, but many would have fully integrated into the population and remained there with their families.

The skeletons were aged and sexed by the Museum staff. For this study 30 male and 30 female skulls with complete permanent dentitions were selected from the mixed juvenis/adultus group (14-24 years). Ethical approval was gained for this study.

In each group, study models were constructed from alginate impressions. All subjects had a full complement of teeth and any teeth with extensive caries, hypoplasia, loss of approximal tooth tissue, partial eruption or marked supragingival calculus were not included in the analysis. Measurements of the permanent teeth from all groups were performed on dental casts using hand held digital calipers (Mitutoyo Corp – Japan), with the beaks sharpened to allow greater accuracy. Brook was trained in this methodology by P. K-J Yen who was an investigator on the North American study (2). Brook then calibrated the operators in the subsequent studies. This ensured that all the studies used a standardised methodology.

Mesiodistal (MD) crown width was defined as the greatest distance between the contact points of the approximal surfaces of the dental crown, with the calipers parallel to the occlusal and buccal surfaces (15). Where the tooth was rotated or adjacent teeth were not present, the measurement was taken between the points where contact with the neighboring tooth would normally occur.

The authors note that with modern techniques and approaches such as 2 dimensional and 3 dimensional imaging and analysis, the variables could be assessed more accurately and reliably. These techniques also facilitate the use of additional variables such as surface area.

Each tooth was measured on two separate occasions and the mean value of the measurements was used. Different recording sheets were used on each occasion to ensure no access to the previous measurements. If there was a discrepancy greater than 0.4mm between the recordings, the measurements were discarded. No data were obtained on the maxillary and mandibular second molar teeth for the Modern British population.

Since there was no statistically significant difference for each individual tooth type between the findings from right and left sides, the measurements for both sides were pooled in these results. For each population the intra- and inter-operator reliability was determined from the repeat measurements and analysed by paired t-tests.

The mean values of the four groups were compared pair-wise using the SPSS statistical software package for Analysis of Variance (ANOVA). The level of difference between groups was automatically given when significant.

Results

Reliability testing across the four ethnic groups showed similar results, indicating that each set of data were reliable to 0.1mm and that valid comparisons between the groups could be made. Moreover, the standard deviations for dental dimensions in each ethnic group were similar within each tooth type (Figs 1-4).

The combined MD crown diameters for the Southern Chinese sample were largest overall compared with the other three groups, while those of the Romano-British sample were the smallest (Table 1). The MD dimensions for all four populations are shown in Figs 1-4, and the significance and variance outputs for group comparisons for each tooth type are shown in Table 2. While the Southern Chinese had the largest size for the majority of tooth types, the Modern British had the largest maxillary central incisors, mandibular central and lateral incisors, and mandibular canines. The North Americans had the largest maxillary first and second molars (Figure 5). This varying pattern of tooth size is illustrated in Figs 6 and 7.

Comparison of coefficients of variation between the first and second teeth of each tooth type, e.g. upper central incisor vs. upper lateral incisor, showed the later forming teeth usually demonstrated greater variation (Table 3).

Discussion

Our finding of significant differences in tooth size between the four ethnic groups studied, with Southern Chinese having generally larger mesiodistal crown dimensions, is consistent with previous reports (16). The larger mesiodistal dimensions observed in the Southern Chinese are likely to reflect genetic and environmental differences between this group and the other three considered here. A synthesis of data on dental dimensions from different populations worldwide (12) has indicated that western Eurasian populations tend to have the smallest teeth, with indigenous Australians, Melanesians, Micronesians, sub-Saharan Africans and native Americans tending to have large teeth. East and Southeast Asian populations were found to be intermediate in tooth size between these groups. The data presented here for the three modern populations match this pattern.

Hanihara and Ishida (12) have suggested that the distribution of tooth sizes observed in their study may be due to the impact of agriculture on the operation of natural selection on tooth size, with the use of agriculture reducing the effects of natural selection. This hypothesis is not supported by the data for the Romano-British population included in the present study, which showed smaller mesiodistal dimensions than were observed in any of the modern populations. Although Hanihara and Ishida (12) also included measurements from the same Romano-British population, they did not compare the data from this population with data from modern European populations. If the smaller tooth size in western Eurasian populations was due to a longer history of agriculture in these populations, then it would be expected that the Romano-British population would have larger teeth than both the modern British and North American populations. Instead, it is possible that genetic differences between the Southern Chinese and the British and North American populations may be contributing to the differences observed.

We propose that the systematically smaller mesiodistal tooth width seen in the Romano-British population is associated with specific environmental causes. Although only young individuals were included in this study, it is possible that a limited amount of tooth wear may have occurred even in these young individuals, and that this may have contributed to the smaller tooth size of this population. Hillson (17) identified a series of factors affecting tooth wear. These include masticator forces, non-chewing parafunctional activities, use of teeth as tools, and the nature of the diet. A tough fibrous diet requiring prolonged mastication, and the abrasivity of food consumed, could potentially contribute to tooth wear, as seen in the older cohorts of this population (18). However, evidence from defects of enamel development suggests that this group experienced recurrent illnesses, high lead ingestion and poor nutrition (19), a conclusion consistent with the archaeological evidence for health within this population (20). Moreover, these Romano-Britons also had a higher frequency of hypodontia and microdontia than Modern Britons (21). As these anomalies are associated with small tooth size (9), this suggests that the smaller Romano-British tooth size is largely developmental in origin and that major environmental factors may well have influenced tooth development in this ethnic group.

Patterns can also be detected within the dentition between the four populations. Although the Southern Chinese population has the largest mesiodistal dimensions for most of the dentition, there are some exceptions to this trend (Fig 5). These included the maxillary central incisor, mandibular central and lateral incisors and mandibular canine, which are largest in the Modern British population, and the first and second molar, which are largest in the North American population. The extent of the differences in tooth dimensions varied from tooth to tooth, as shown graphically in Figs 6 and 7. The overall pattern is seen to follow the morphogenetic field concept as recently revised by Townsend et al (13) with later-forming teeth in each tooth type being smaller and more variable (Figs 1-4, 6, 7). The values of coefficients of variation (Table 3) also showed that these later-forming teeth tended to be more variable in M-D diameter.

In conclusion, using a standardized methodology, significant differences in M-D crown dimensions have been demonstrated between ethnic groups. There were varying patterns of tooth size between the groups and the later-forming teeth in each tooth type were smaller and showed greater variation. These differences reflect different contributions of genetic and environmental influences to tooth size variability within and between human populations.

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Figure legends

Figure 1. Mesiodistal crown dimensions of permanent maxillary teeth in males of four different ethnic groups (means and standard deviations shown).

Figure 2. Mesiodistal crown dimensions of permanent mandibular teeth in males of four different ethnic groups (means and standard deviations shown).

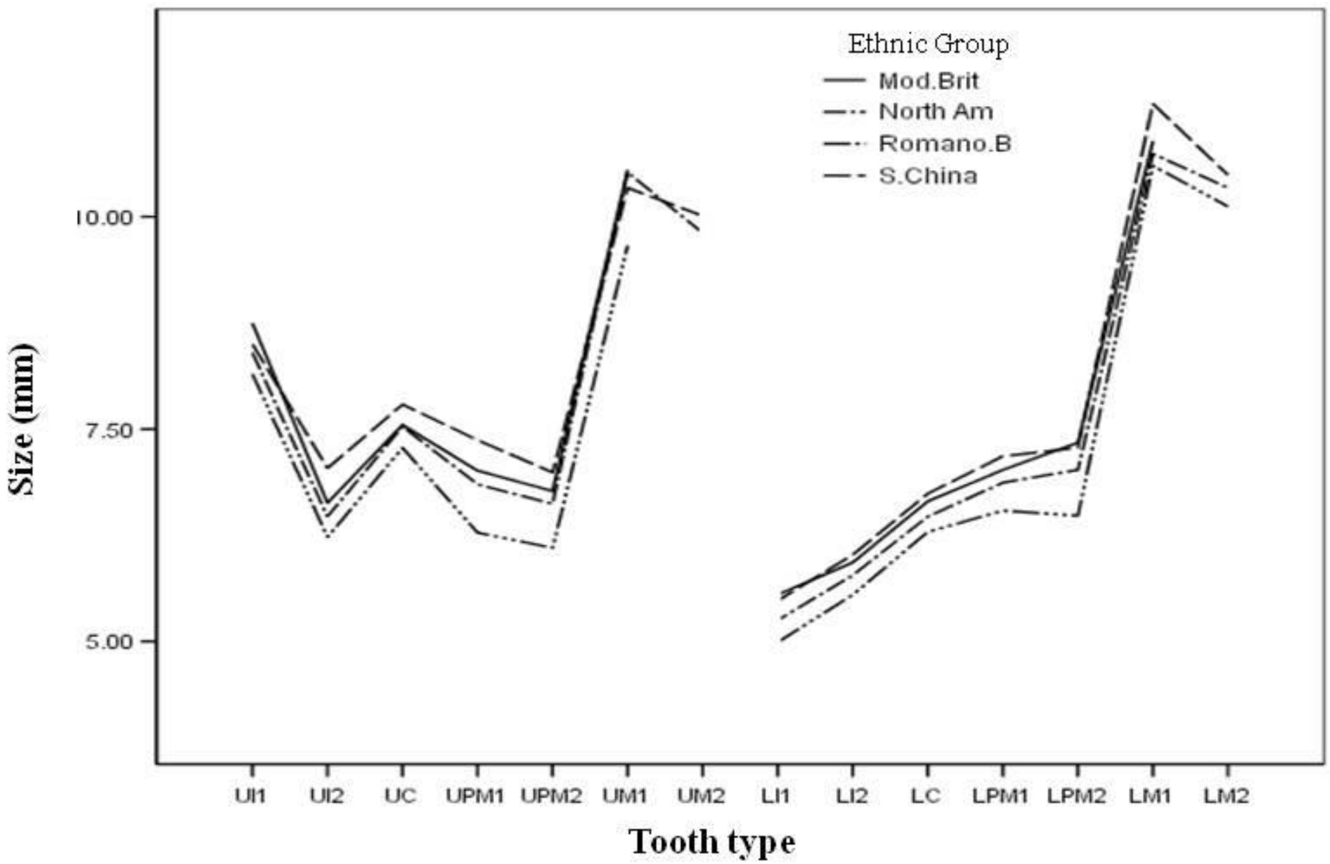
Figure 3. Mesiodistal crown dimensions of permanent maxillary teeth in females of four different ethnic groups (means and standard deviations shown).

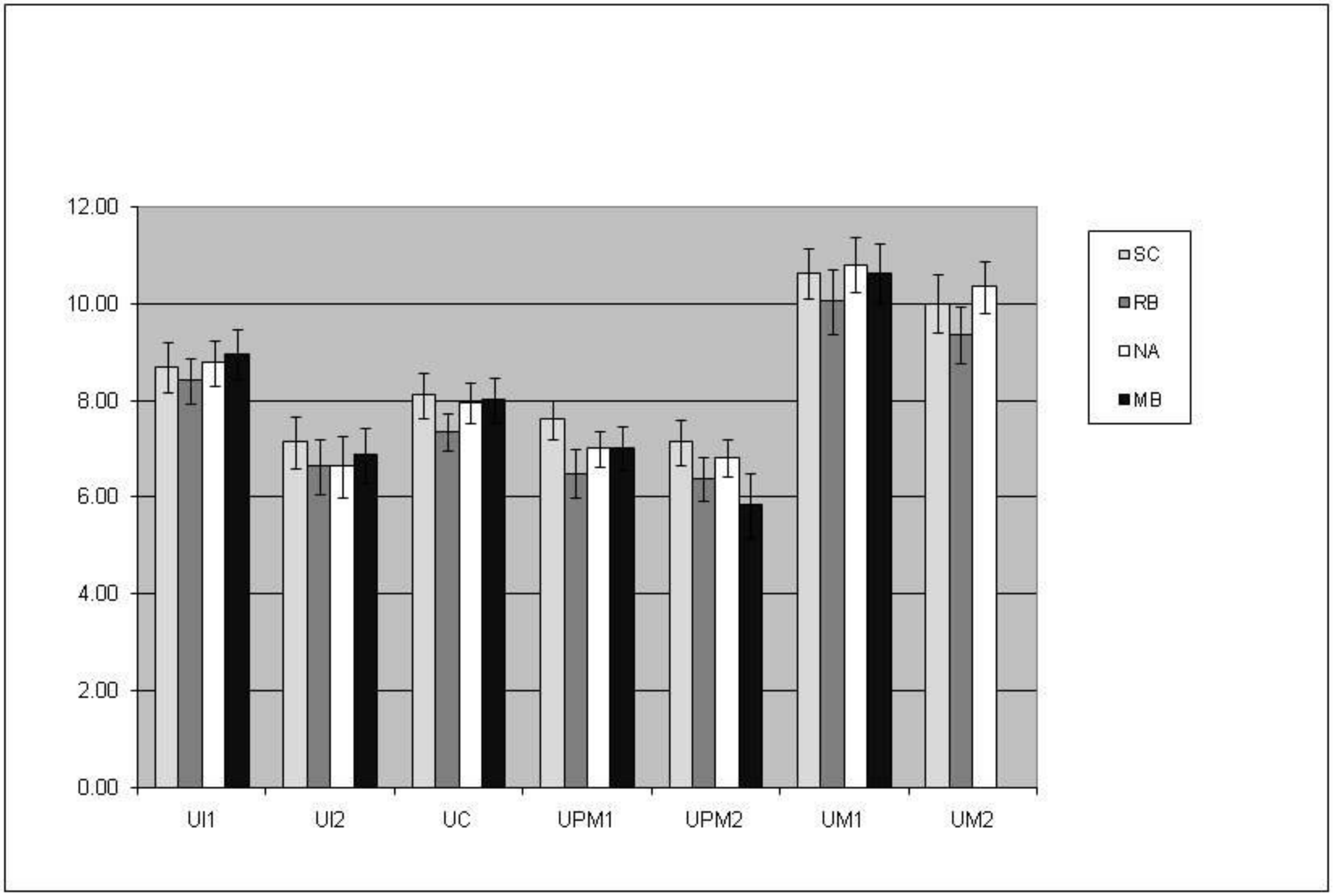
Figure 4. Mesiodistal crown dimensions of permanent mandibular teeth in females of four different ethnic groups (means and standard deviations shown).

Figure 5. Comparison of tooth size between four ethnic groups: number of times tooth size in each group was significantly larger than in the other three groups is shown on the y axis (see Table 2).

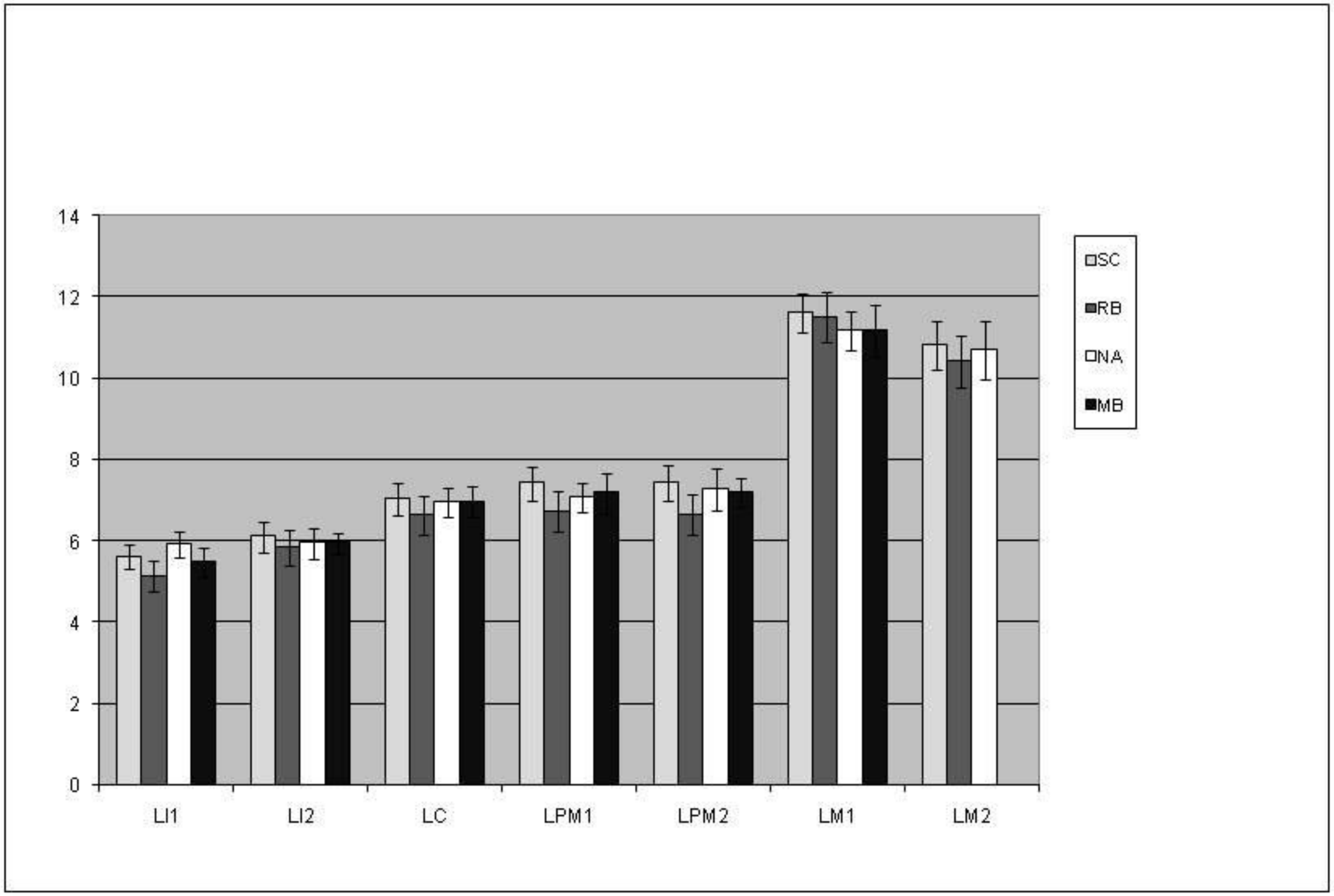
Figure 6. Comparison of mean tooth size per tooth type between different ethnic groups (males).

Figure 7.Comparison of mean tooth size per tooth type between different ethnic groups (females).


Ethnic Group
Mod.Brit
North Am
Romano.B
S.China
10.00
7.50
5.00
Size (mm)
UI1
UI2
UC
UPM1
UPM2
UM1
UM2
LI1
LI2
LC
LPM1
LPM2
LM1
LM2
Tooth type



SC = South Chinese, RB = Romano Britain, NA = North American, MB = Modern Britain



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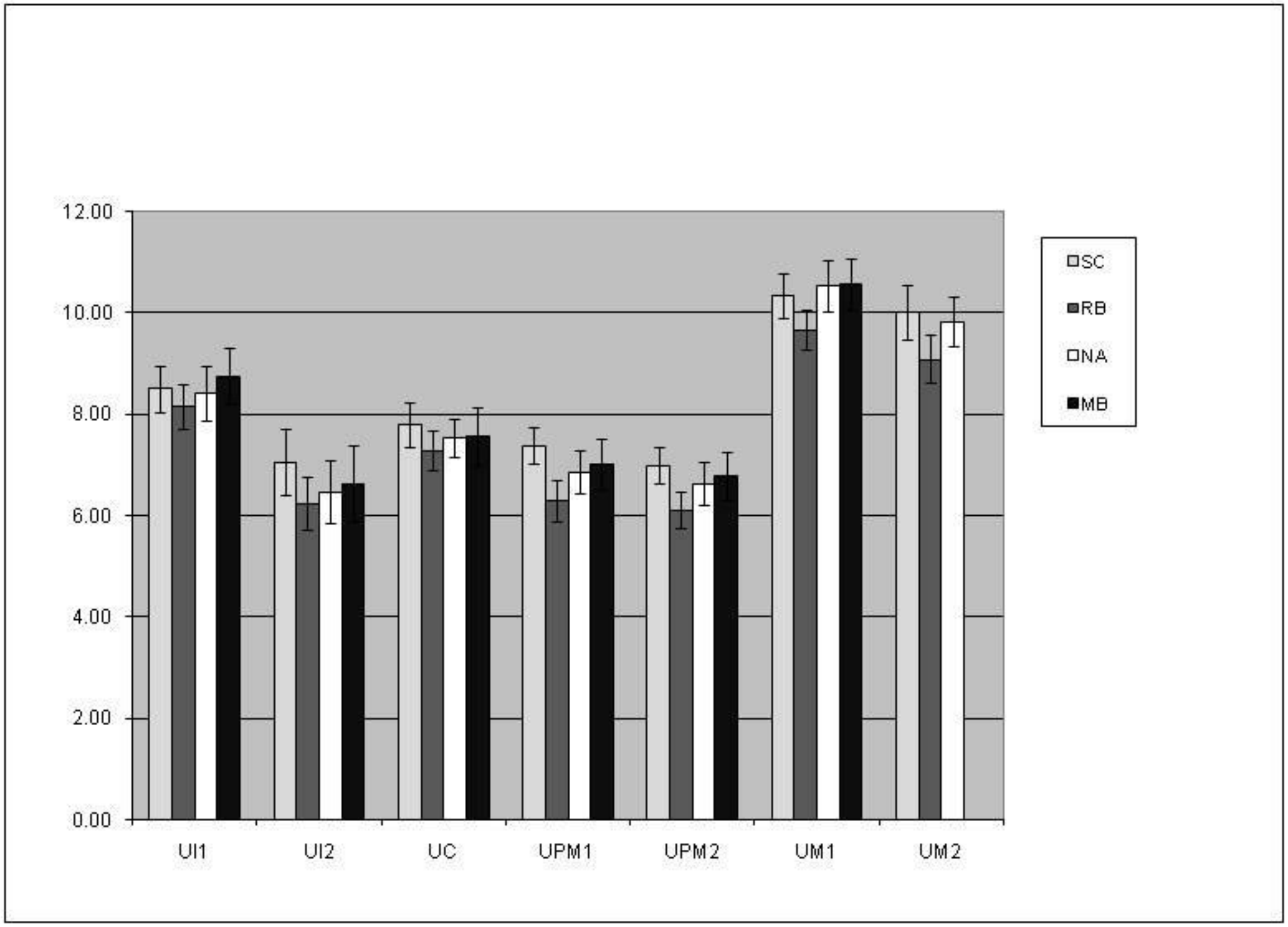
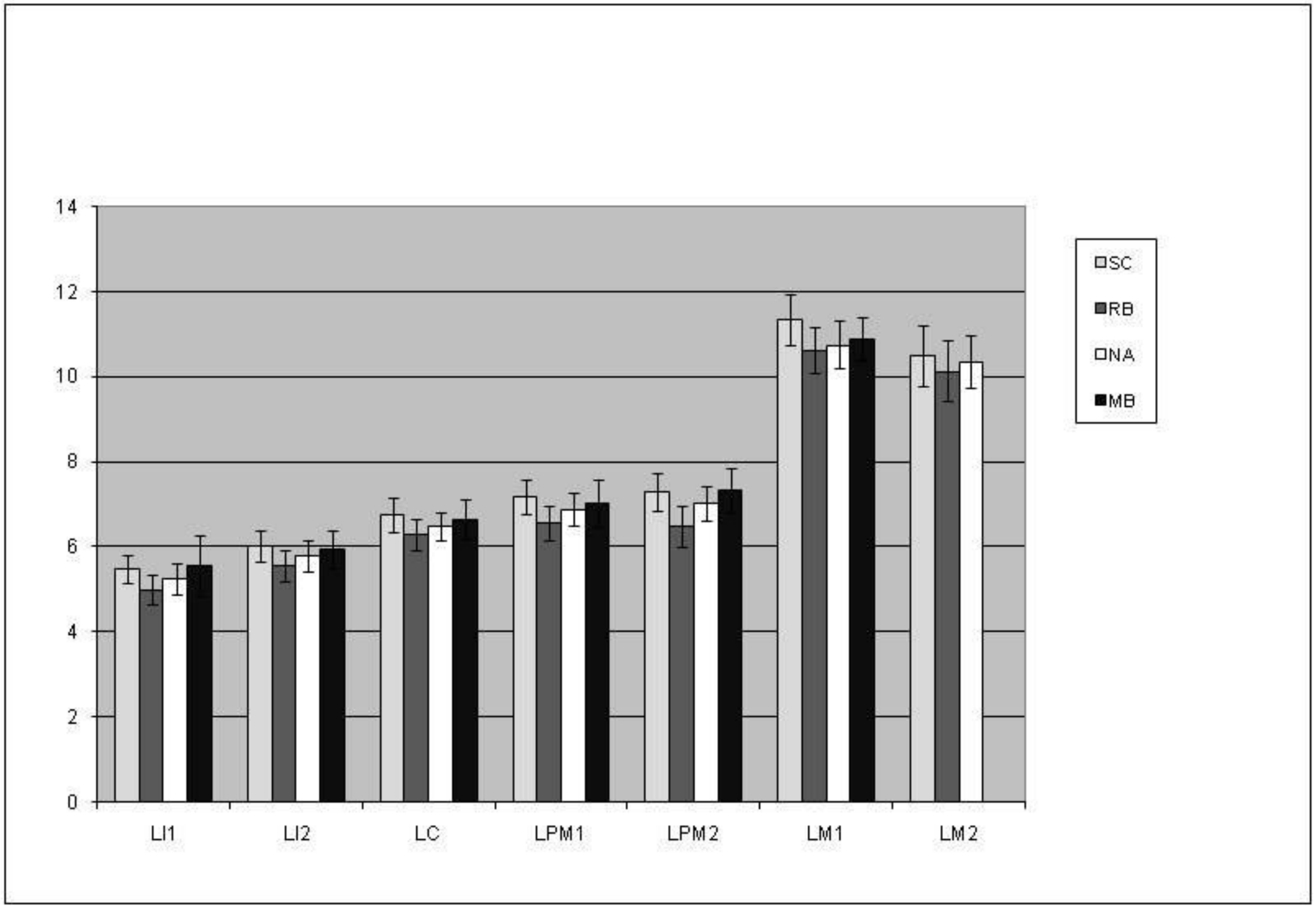
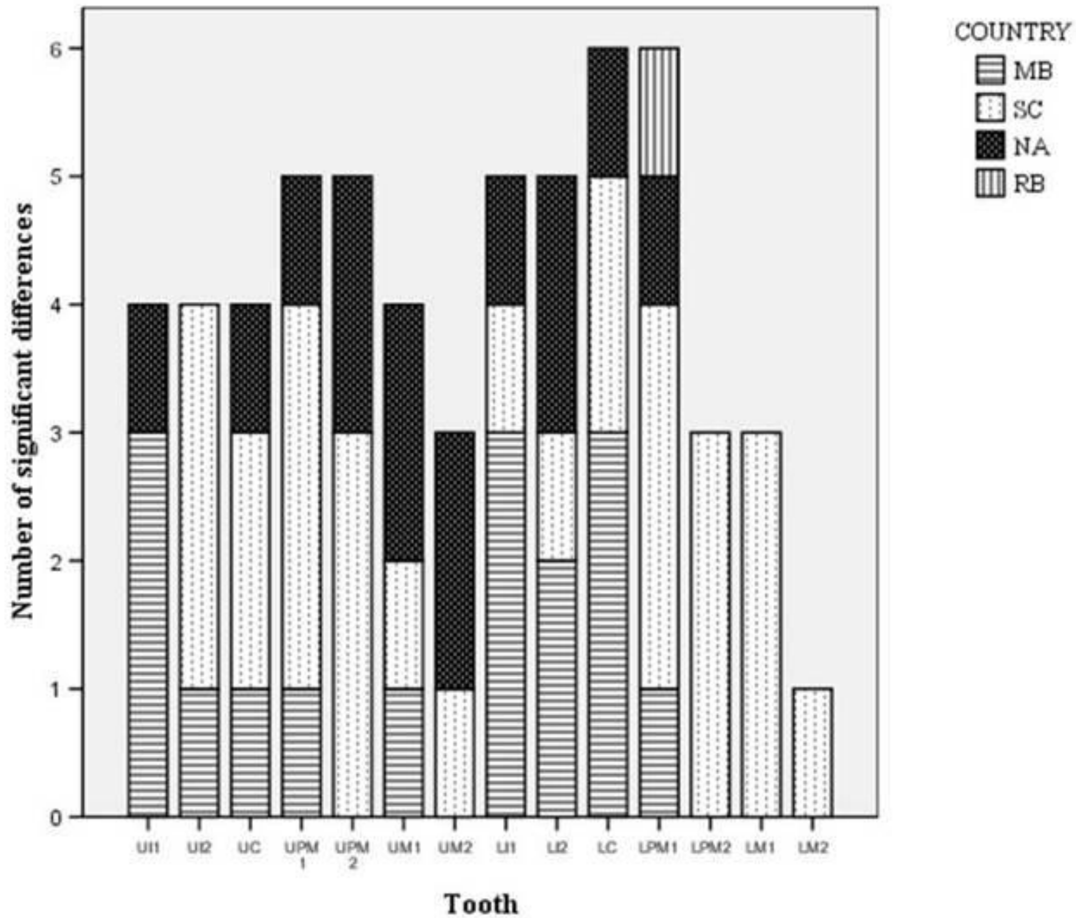


SC = South Chinese, RB = Romano Britain, NA = North American, MB = Modern Britain



SC = South Chinese, RB = Romano Britain, NA = North American, MB = Modern Britain



SC = South Chinese, RB = Romano Britain, NA = North American, MB = Modern Britain

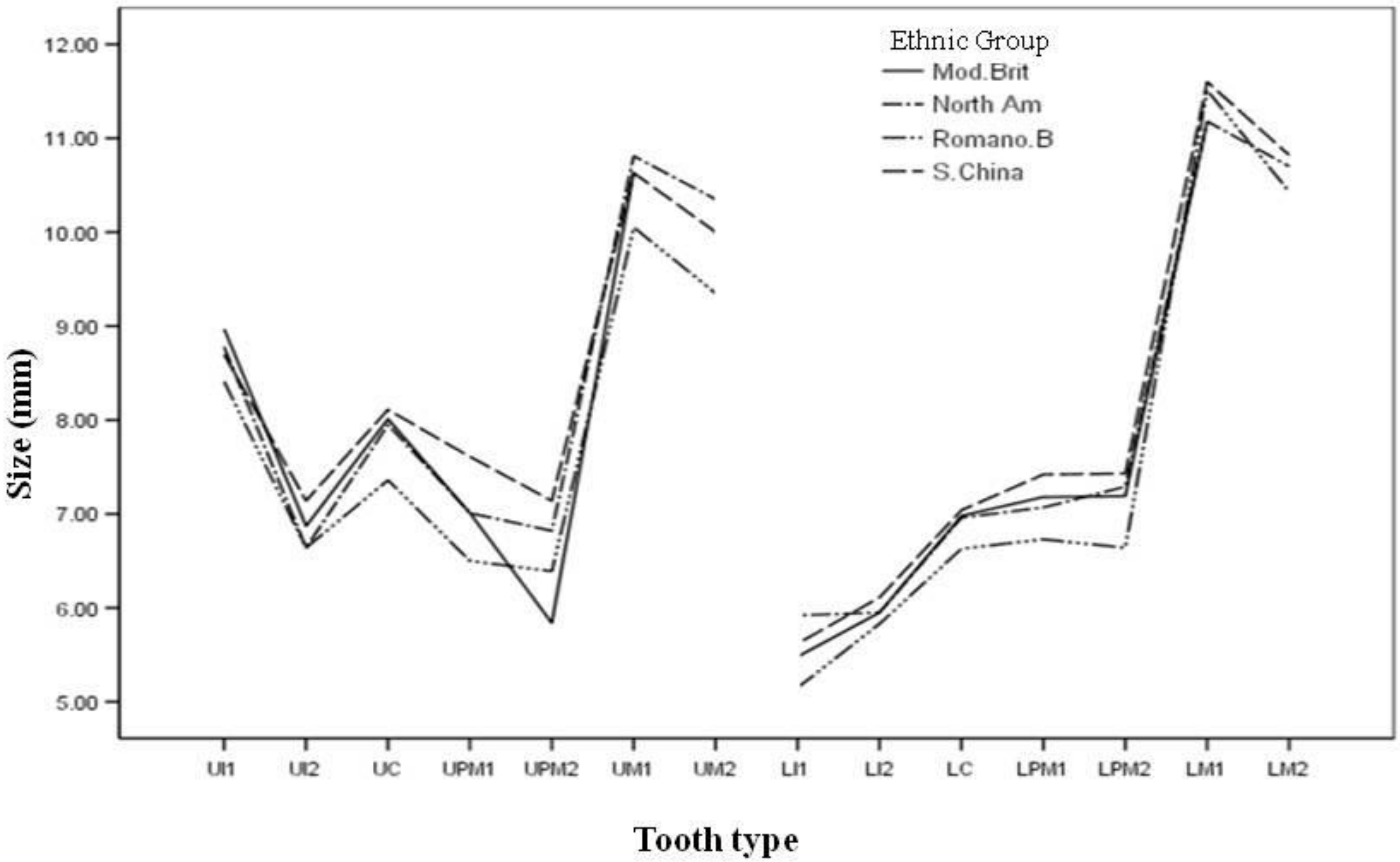

Ethnic Group
Mod.Brit
North Am
Romano.B
S.China
12.00
11.00
10.00
9.00
8.00
7.00
6.00
5.00
Size (mm)
UI1
UI2
UC
UPM1
UPM2
UM1
UM2
LI1
LI2
LC
LPM1
LPM2
LM1
LM2
Tooth type

Table 1. Sum of the mesiodistal crown diameters for all tooth types in different ethnic

ORIGIN	Males		Females		Overall Total
	Maxillary	Mandibular	Maxillary	Mandibular	
SC	49.3	45.2	48.0	44.0	186.5
MB	47.3	44.0	47.3	43.4	182.0
NA	48.1	44.4	46.4	42.1	181.0
RB	45.4	42.5	43.7	40.1	171.7

SC = South Chinese, MB = Modern Briton, NA = North American, RB = Romano Briton.

Table 2. Tooth size comparison between four ethnic groups: F values and significance levels. The first letter of the group with the larger teeth is indicated, together with the level of significance (* = 0.05, ** = 0.01, *** = 0.001or greater significance)

Significance and variance F outputs for all possible country comparisons per tooth type														
TOOTH	**UI1**	**UI2**	**UC**	**UPM1**	**UPM2**	**UM1**	**UM2**	**LI1**	**LI2**	**LC**	**LPM1**	**LPM2**	**LM1**	**LM2**
	Modern UK/Chinese													
Variance F	6.16	7.07	2.94	29.70	58.67	1.05	-	408.35	23.60	25.55	8.91	22.93	36.55	-
Level of significance	*U	**C		***C	***C			***U	***U	*** U	**C	***C	***C	
	Modern UK/Romano British													
Variance F	18.52	4.85	20.23	32.23	0.26	33.56	-	152.96	93.06	67.71	11.36	0.05	4.77	-
Level of significance	***U	*U	***U	***U		***U		***U	***U	***U	**U		*R	
	Modern UK/North American													
Variance F	6.22	1.95	0.19	0.76	17.36	0.36	-	342.99	1.92	58.12	0.32	1.73	0.74	-
Level of significance	*U				***N			***U		***U				
	Chinese/North American													
Variance F	0.02	33.70	10.73	89.67	32.22	5.41	0.49	0.68	42.12	9.51	30.71	31.59	92.72	1.22
Level of significance		***C	**C	***C	***C	*N			***N	**C	***C	***C	***C	
	Chinese/Romano British													
Variance F	0.01	39.16	68.38	230.73	112.27	48.19	52.43	26.50	23.82	33.49	73.09	38.45	16.99	8.51
Level of significance		***C	***C	***C	***C	***C	***C	***C	***C	***C	***C	***C	***C	**C
	Romano British/North American													
Variance F	8.67	1.18	35.50	51.91	38.02	67.75	69.63	27.49	51.39	14.17	20.53	3.90	15.28	3.23
Level of significance	**N		***N	***N	***N	***N	***N	***N	***N	***N	***N		***R	

Table 3. Comparison of the values of coefficient of variation for tooth size between mesial and distal teeth of each type.

ORIGIN	TOOTH TYPE					
	UI1 v UI2	**UPM1 v UPM2**	**UM1 v UM2**	**LI1 v LI2**	**LPM1 v LPM2**	**LM1 v LM2**
SC						
Male	6.0 v 7.4	5.3 v 6.6	5.0 v 6.0	5.3 v 6.1	5.7 v 5.9	4.1 v 5.1
Female	5.4 v 9.2	4.9 v 5.3	3.1 v 5.3	6.2 v 6.2	5.6 v 6.2	5.2 v 6.8
RB						
Male	5.7 v 8.4	7.5 v 7.0	6.6 v 6.3	7.2 v 7.4	7.6 v 7.5	5.3 v 6.0
Female	5.5 v 8.5	6.4 v 5.9	4.1 v 5.2	7.2 v 6.5	6.1 v 7.3	5.1 v 7.0
NA						
Male	5.2 v 9.5	5.4 v 5.4	5.2 v 5.1	5.2 v 6.4	5.0 v 7.1	4.2 v 6.6
Female	6.3 v 9.6	6.1 v 6.5	4.9 v 5.0	6.9 v 6.6	5.5 v 5.7	5.2 v 6.0
MB						
Male	5.8 v 8.4	6.4 v 11.6	---	6.4 v 4.4	6.8 v 5.0	---
Female	6.4 v 11.3	7.1 v 7.1	---	12.6 v 7.3	8.1 v 7.1	---

SC = South Chinese, RB= Romano Briton, NA = North American, MB = Modern Briton.