Tooth Size patterns in Patients with Hypodontia and Supernumerary teeth

AH Brook[1], RC Griffin[1], RN Smith[1], GCTownsend[1,2], G Kaur[1], GR Davis[3] and J Fearne[3]

[1]International Collaborating Centre in Oro-facial Genetics and Development, University of Liverpool, School of Dental Sciences, Daulby Street, Liverpool L69 3GN, UK

[2]School of Dentistry, University of Adelaide, SA 5005, Australia

[3]Centre for Oral Growth and Development, Queen Mary's School of Medicine and Dentistry, Turner Street, Whitechapel, London E1 2AD, UK

Corresponding author: Alan Brook, School of Dental Sciences, Edwards Building, University of Liverpool, Daulby Street, Liverpool L69 3GN, UK

Ph: +44 (0)151 706 5119

Fax: +44 (0)151 706 5809

Email: a.h.brook@liverpool.ac.uk

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: Anomalies of tooth number may not be isolated conditions but may have wider associations in the development of the dentition including tooth size. This study aimed to examine links between hypodontia, supernumerary teeth and crown size, considering the effect on the development of the whole dentition and so increase understanding of the aetiology of these conditions.

Methods and Results: The patients, who were all of European ancestry, were 60 young adults (30 males and 30 females) with hypodontia and 60 age and sex matched controls together with 60 young adults (39 males and 21 females) with supernumerary teeth and 60 age and sex matched controls. Hand measurements of mesiodistal and buccolingual dimensions were made of the teeth on dental study models using Mitutoyo electric callipers. The mean value of two measurements was used and intra-operator and inter-operator reliability determined. Patients with hypodontia had smaller teeth than the control group and this difference was statistically significant ($p<0.05$) for all teeth except the MD dimensions of 13, 23, 24 and 44. The difference in size was greatest for the BL dimensions in hypodontia patients. Further, the greater the number of missing teeth the smaller the tooth size. The hypodontia patients also showed higher variability in tooth dimensions than the control group. Patients with supernumerary teeth had larger teeth than the controls, with the greatest differences in the MD dimensions. In both hypodontia and supernumerary patients the differences in tooth size were generalised throughout the dentition.

Conclusions: In anomalies of tooth number the size of teeth is also involved. In patients with hypodontia and supernumerary teeth the crown size of the whole dentition is affected. These findings are compatible with a multifactorial aetiology of these conditions.

Keywords: Hypodontia, supernumerary teeth, tooth size patterns

Introduction

Interplay between genetic, epigenetic and environmental influences during the process of odontogenesis can lead to a range of anomalies of tooth number and size, including hypodontia, supernumerary teeth, microdontia and megadontia. Previous studies have reported co-occurrence of hypodontia and microdontia (1-8) and of supernumerary teeth and megadontia (1, 9), suggesting that these conditions may have similar aetiologies. This study seeks to investigate the link between hypodontia and supernumerary teeth and the size of the other teeth in the dentition of affected individuals. In particular, comparisons are made within and between groups to determine whether there are any trends or patterns discernible in the crown size of other teeth, for example between the sexes, between mesiodistal and buccolingual dimensions, between maxillary and mandibular teeth, and between different tooth types, e.g. incisors, canines, premolars and molars.

For the purposes of this study, hypodontia is defined as the congenital absence (or agenesis) of one or more teeth, while supernumerary teeth are defined as extra teeth present in addition to the normal human dental formula. The reported incidence of the two conditions varies between studies, depending upon the population analysed and the methods and definitions applied in the study (10). Both conditions show an uneven distribution between the sexes, with hypodontia more common in females and supernumerary teeth more common in males (1). For hypodontia, apart from the third molars, which are frequently missing, the most commonly missing teeth are lateral incisors and second premolars (11). Hypodontia is more commonly bilateral than unilateral (12), with the absence of a tooth significantly increasing the chance that its antimeric and vertical neighbours are also missing (13). The most common location for single supernumerary teeth is the maxillary incisor region (14) and for multiple supernumerary teeth is the premolar region (15), followed by the molar and then the anterior regions of the dentition (16). Supernumerary teeth tend to occur singly or bilaterally, with only 4.6% of cases involving 3 or more supernumerary teeth (16).

Both hypodontia and supernumerary teeth are considered to have a multifactorial aetiology (1). While family studies and twin studies have indicated a substantial genetic component in the occurrence of the two conditions (17, 18), the variable expression of hypodontia and supernumerary teeth in monozygotic twins (19) indicates that other factors play a role in the expression of these traits. This reflects the fact that hypodontia and supernumerary teeth are both complex genetically heterogeneous traits (20).

There is a growing body of evidence to suggest that there is a link between anomalies of tooth number and the size of the remainder of the dentition. This is supported by the observed reduction in tooth size in unaffected relatives of hypodontia patients (18), which indicates that this link is at least partly due to genetic effects. Furthermore, it has been found that teeth adjacent to missing or supernumerary teeth sometimes show abnormal development and an altered morphology (8). Such observations suggest that there is a link between the causes of hypodontia and supernumerary teeth and the determinants of tooth size and shape in affected individuals but it is still unclear whether this effect is manifested consistently throughout the dentition and whether certain teeth or tooth dimensions are affected more than others.

Brook (1) has proposed a model that brings together the various genetic and environmental components of variation in hypodontia and supernumerary tooth occurrence and tooth size. The model posits a continuous normal distribution of tooth size and number, with an anomaly occurring when the genetic and environmental influences on an individual place them past the threshold for that particular type of anomaly. It accounts for the multifactorial and polygenic aetiology of these developmental defects of the dentition and for the variation in prevalence of the various anomalies in different populations and between males and females. The location of the thresholds for microdontia and hypodontia on the lower tail, and for supernumerary teeth and megadontia on the upper tail of the distribution reflects the proposal that these conditions are linked. The model has received support from studies of both modern and Romano-British populations (8, 21).

This study therefore aims to determine whether there are any discernible patterns or trends evident in the dental crown sizes of remaining teeth in patients with hypodontia, or of other teeth in patients with supernumeraries, in order to improve our understanding of the aetiology of these two conditions.

Materials and Methods

Two comparative studies were conducted using same methodology, one focussing on hypodontia and the other on supernumerary teeth. The studies measured the mesiodistal (MD) and buccolingual (BL) dimensions of the permanent teeth of patients with hypodontia or supernumerary teeth and of patients with normal dentitions, to identify the relationship between tooth size and these two anomalies of tooth number.

MD and BL measurements were obtained from dental casts of 240 individuals, of whom 60 displayed hypodontia, 60 showed supernumerary teeth and 120 possessed a normal dentition. Two sets of controls were used to allow age and sex matching of the hypodontia and supernumerary patient groups, who had different compositions by age and sex.

For the hypodontia study, 30 males and 30 females with missing permanent teeth (excluding 3rd molars), with ages between 8 and 20 years, were selected for study (H group). The control group for the hypodontia study was also comprised of 30 males and 30 females, aged 12-20 years and with no missing permanent teeth (excluding 3rd molars) (C(H) group). All individuals in the hypodontia study were of European ancestry.

For the investigation of supernumerary teeth, 39 males and 21 females were selected who were of European ancestry and aged between 7-30 years (S group). The control group was sex, race and age matched to the supernumerary group (C(S) group).

Teeth with carious lesions or restorations, teeth associated with defects on the study models, and teeth which were not completely erupted or were primary teeth were all excluded from the study. For the H and C(H) groups, third molars were also not included in the study.

Measurements were made from study models by hand using a modified Mitutoyo electronic calliper (with extended points for easier access to landmarks), after training in the measurement technique by an experienced investigator. Orthopantograms were used to confirm that the absence of any missing teeth was developmental and not due to extraction. Measurements were obtained systematically under standardised conditions, from the upper left quadrant to the upper right quadrant, then from the lower left quadrant to the lower right quadrant. The accuracy of the Mitutoyo callipers was 0.01 mm. As used on study models for measurement of MD and BL dimensions, the expected accuracy of measurement based on that reported in previous studies was ±0.1 mm. Each tooth was measured twice, on different occasions, and the mean value of the 2 measurements was used. Measurements were rechecked if there was a discrepancy of greater than 0.4 mm. The H and C(H) groups were measured by one observer, and the S and C(S) groups were measured by another observer, using the same method.

The MD distance was measured as the greatest distance between the contact points on the approximal surfaces of the tooth crown, as defined by Moorrees and Reed (22), with callipers held parallel to the occlusal and buccal surfaces. Where teeth were rotated or had no adjacent tooth, dimensions were obtained by measuring between the points where the contact with the neighbouring tooth would normally be. The BL distance was measured as the greatest distance between the labial and lingual surfaces of the tooth crown in a plane perpendicular to that in which the MD was measured, as defined by Moorrees (23).

For the H group, the position of the missing teeth and the total number of teeth missing were also recorded. For the S group, the position of the supernumerary tooth, number of supernumerary teeth present and an adjacency value to show the number of teeth between each tooth and the supernumerary tooth were also recorded.

Intra-operator repeatability was determined by measuring the MD and BL dimensions of either 10 upper and lower casts (for the H study) or 5 upper and lower casts (for the S study) twice according to the method described above and repeating these measurements on a different occasion. A lower number of casts were measured a second time in the supernumerary study, as the hypodontia study had been undertaken as the first investigation and it had been found that remeasuring 5 upper and 5 lower casts was sufficient for determining reliability and obtaining significant differences. Inter-operator reproducibility was determined by comparing the measurements of MD and BL dimensions for either 10 upper and lower casts (for the H study) or 5 upper and lower casts (for the S study) obtained by the main examiner and by a second examiner. Reliability was assessed by testing the statistical significance of any differences observed using paired t-tests.

Comparisons of mean values for MD and BL dimensions of the four groups were analysed using SPSS. As the data for H and C(H) groups were normally distributed, comparisons were made using analysis of variance. However, due to the different recording procedure used by the supernumerary tooth observer it was not possible to apply analysis of variance to these results, and instead the data were compared using simple t-tests. Regression analyses were used to investigate the relationship between the number of missing teeth and tooth dimensions and F tests were used to compare the variances of the different groups. The level of significance was set at p=0.05.

<u>Results</u>

High levels of intra-operator repeatability were seen for both observers, with no statistically significant difference between the two sets of measurements (Table 1). The inter-operator reproducibility for the supernumerary study was found to be acceptable for both BL and MD dimensions (Table 1). However, for the hypodontia study, the MD measurements made by the first operator were significantly different from those obtained by the second observer (Table 1). This variation in measurement error should be taken into account when interpreting the results. The BL measurements showed an acceptable level of inter-operator agreement, and showed no statistically significant difference between the two sets of measurements (Table 1). In all cases, the observed difference between the means of the two sets of measurements was relatively small in comparison to the size of the measurements being undertaken.

All MD and BL dimensions in females showed significantly smaller teeth in the H group, except for the MD dimensions of 13, 23, 24, and 44 (Table 2). The percentage reduction in the tooth dimensions of the female hypodontia patients ranged from 2.1 % to 11.1 % in the MD dimension and from 5.1 % to 12.0 % in the BL dimension. Likewise, all MD and BL dimensions in males showed a significant reduction in the H group over those in the C(H) group, apart from the MD dimensions of 14 and 41, and the MD dimensions of 15 where there was an increase in the H group (Table 3). The percentage reduction in the tooth dimensions of the male hypodontia patients ranged from 5.3 % to 13.9 % in the MD dimension and from 4.3 % to 15.5 % in the BL dimension.

The variances of the MD dimensions of the lower first molar, lower second premolar and upper central incisor were higher for the H group than for the C(H) group for both males and females, although this difference did not reach statistical significance for all measurements of these teeth. For females, the variances of the MD dimensions of the upper first molar and upper second premolar were also higher for the H group than for the C(H) group, while for males the variances of the MD dimensions of the upper canine and upper first premolar were higher for the H group. For the BL dimensions, the variances for the upper first molar, upper first and second premolars and upper central incisor were higher for the H group than the C(H) group in both males and females, and the variance for the upper canine was lower in the H group. In addition, the variance for the lower canine was higher for females in the H group, and the variance in the lower first molar, lower second premolar and lower central and lateral incisors was higher for males in the H group than those in the C(H) group.

It was possible to detect several patterns in the tooth size in hypodontia patients compared to controls (Tables 2 and 3). The percent differences in BL dimensions were greater for all teeth than those in the MD dimension, except for the upper first molar (for both males and females), the lower central incisor (for females) and the lower first molar (for males). The teeth of the lower jaw were also more severely affected in the BL dimension than the teeth of the upper jaw.

Certain teeth within the dentition were also more severely affected by the difference in tooth dimensions than others. In the MD dimension, the upper lateral incisor and lower central incisor showed the greatest percentage difference, with the upper first molar and lower canine also markedly smaller in MD dimension in females but not in males. For the BL dimension, the lower central incisor was among the most strongly affected, with the lower canine and lower first premolar in females and the upper lateral incisor and lower lateral incisor in males also considerably smaller in the BL dimension than controls.

Differences were also observed between males and females within the hypodontia group. Males tended to show a greater level of reduction in the BL dimensions of anterior teeth. In the MD dimension, males tended to show a greater difference in the posterior dentition and a lesser difference in the anterior dentition.

As the number of missing teeth increased, for both males and females there was a general trend for MD and BL dimensions to be smaller. However, this difference was not statistically significant ($p>0.05$ for male BL, male MD, female BL, female MD). In contrast, when the data for males and females were pooled, the difference in tooth size reached statistical significance for the BL dimension ($p<0.05$). The smaller tooth size in the MD dimension also approached statistical significance ($p=0.065$) when the male and female datasets were analysed together. The differences in dimensions of teeth between those with adjacency less than two, and those with adjacency more than two did not reach statistical significance (simple t-test, $p>0.05$ for MD and BL dimensions).

The overall MD dimensions of the S group were significantly larger than those of the C(S) group, when the data from males and females were combined. When males and females were analysed separately, the MD dimensions from individuals in the S group were larger than those from the C(S) group, but the difference was not statistically significant. The BL dimensions were generally greater in the S group than in the C(S) group, but again his difference was not statistically significant. The disparity in BL and MD dimensions between the two groups was greater for the females than for the males. In spite of the overall tendency for increased tooth size in individuals with supernumerary teeth, when comparisons were undertaken by tooth type, only the lower second premolar showed a statistically significant difference in MD dimension ($p<0.05$; Table 4). In addition, several teeth showed a smaller crown size in the S group, namely 32, 42 in the MD dimension, and 11, 21, 37, 47, 36, 46, 35, 45, 32, and 42 in the BL dimension. However, in other teeth the increase in tooth dimensions was substantial, with percentage increases of up to 6.0 % in the MD dimension (in 37, 47) and up to 6.2 % in the BL dimension (in 33, 43).

There was no consistent pattern in the percentage differences in tooth dimensions between the MD and BL dimensions for each tooth in the S group. However, the posterior maxillary teeth were more strongly affected by the increase in BL dimensions than those of the mandible. The largest increases in tooth size were seen in the MD dimensions of the lower second molar and lower second premolar, and in the BL dimensions of the upper and lower canines.

The presence of supernumerary teeth appeared to be linked to greater MD dimensions throughout the dentition. No statistically significant relationship was observed between adjacency to the supernumerary tooth and MD or BL tooth dimensions.

Discussion

Patients with hypodontia had smaller tooth sizes in comparison to the control group. This finding is consistent with previous studies which have shown a link between hypodontia and tooth size in hypodontia patients (1, 6) and even in the unaffected relatives of hypodontia patients (18), indicating that part of this link may be genetically determined. For patients with hypodontia, crown size differences appear to be more marked in the BL dimension than in the MD dimension, confirming the findings of previous studies of hypodontia and tooth size (2). In addition, female hypodontia patients showed less difference in the size of their canines relative to their controls than male hypodontia patients. It is possible that this lesser difference in the canines is related to the smaller size of normal female canines relative to normal male canines. Males generally showed a greater percentage difference in BL dimensions in the anterior dentition and in the MD dimensions in the posterior dentition, with a smaller percentage difference in MD dimensions in the anterior dentition. The reasons for this trend are unclear at present.

The presence of hypodontia does not just affect the size of the tooth, but it appears to also influence the level of variability in tooth dimensions. The tooth dimensions of the hypodontia patients generally showed a higher variability than those of the control group. No obvious pattern in variability was evident between different tooth dimensions or teeth, with both earlier-developing and later-developing teeth affected. This seems to suggest that the magnitude of the impact of missing teeth on the MD and BL dimensions of the formed teeth is variable. This variability may reflect the impact of differing environmental conditions, the different severity of hypodontia or the varying amounts of buffering of the individual against environmental impacts.

For hypodontia, the teeth showing the greatest difference in tooth dimensions in both males and females are the lower central incisor (for both MD and BL dimensions) and the upper lateral incisor (for MD dimensions). For supernumerary teeth, the greatest increases in tooth dimensions are seen in the lower second molar and the lower second premolar (for MD dimensions) and in the canines (for BL dimensions). This suggests that these teeth may be more susceptible to disturbances during development than the other teeth in the dentition. Such a finding is consistent with the theory of morphological fields (24), which proposes that the earliest forming teeth in each part of the dentition are the least variable in morphology. As the lower central incisor, upper lateral incisor, lower second premolar and lower second molar are not key teeth in their respective fields (24), under the morphological field theory they would be expected to show greater variation from the norm, as is observed here.

The coefficients of variation observed in the unaffected individuals also show a pattern which supports the morphogenetic field theory, with first molars appearing to show a particularly low level of variability, and the upper lateral incisor showing a higher level of variability than the upper central incisor. For the hypodontia patients, the coefficients of variation tend to be higher than those of unaffected individuals, with this trend most consistently observed in the first molars (for MD and BL dimensions) and the upper incisors (for BL dimensions). The pattern of coefficients of variation within the dental arch is similar in hypodontia patients to that observed in unaffected individuals, except in the female lower incisors where the trend is reversed. This indicates that in spite of the higher variability in the MD and BL dimensions of hypodontia patients, the distribution of this variability in the dentition is similar to that found in unaffected individuals, and to that predicted by morphogenetic field theory.

The extent of the difference in tooth size appeared to be linked to the number of missing teeth. Although this was not statistically significant when males and females were considered separately, this is presumably due to the smaller sample size when the sexes were treated independently. The susceptibility of the results to sample size suggests that the relationship between tooth size reduction and the number of missing teeth may not be strong, in contrast to the findings of Garn and Lewis (6) and Schalk-van der Weide (25), who observed a strong relationship between these two measures. However, both these studies limited their populations to patients with severe cases of hypodontia, with at least six teeth missing. The removal of minor cases of hypodontia from their studies may have enhanced the strength of the relationship between the number of missing teeth and tooth size reduction. It appears that when less severe cases are also considered, the relationship is not as strong. This may be because these individuals are not as far past the threshold proposed by Brook (1) for hypodontia occurrence, and therefore will not show as great a difference in tooth size from the average size for their sex.

As with hypodontia, the effects on tooth size of supernumerary teeth were generalized to the whole dentition. The teeth of individuals with supernumerary teeth tended to be larger than those of the control group, particularly in the MD dimension. However, as this tendency was only statistically significant when data from males and females were pooled for analysis, it seems that this trend was not as strong as that observed in the hypodontia group. Again, there is evidence for the independent influence of MD and BL dimensions. However, for supernumerary teeth, it is the MD dimension that is most strongly affected by the presence of the dental anomaly, consistent with the findings of Khalaf et al. (9). Females with supernumerary teeth showed a greater increase in tooth size than males, consistent with the prediction of the model of Brook (1) that the tooth size of females who had reached the threshold for possessing supernumerary teeth would be further from the average tooth size for their sex than males with supernumerary teeth.

The largest percentage increases in tooth size in patients with supernumerary teeth were in the lower second molar and lower second premolar (both in the MD dimension) and in the canines (in the BL dimension). In the BL dimension, the posterior teeth of the upper jaw showed a greater increase in size than the posterior teeth of the lower jaw. This may be due to the longer period of time over which these teeth develop, with the canine and second molar having some of the longest periods of development in the dentition. Unfortunately, as the supernumerary tooth observer used a different recording procedure to the hypodontia observer, it was not possible to report standard deviations for the S group and the C(S) group by tooth type. As a result, this study was not able to investigate patterns in the variance and variability of changes in tooth dimensions within the S group.

No relationship was observed between adjacency and tooth size for either hypodontia or supernumerary teeth. Such a finding contradicts the results of Garn and Lewis (26) on hypodontia patients, who found that there were differential effects on tooth size reduction in individuals with tooth agenesis. However, their study focussed on third molar agenesis and cases of multiple agenesis, and thus is not as comprehensive in its scope as the current study. The inclusion of more varied and more minor cases of hypodontia in the present study may have made it more difficult to detect adjacency effects in the dentition. In particular, the absence of certain teeth may have a stronger influence on adjacent teeth than others. Due to the limited sample available for this study, it was not possible to test this theory with the current data.

In Tables 2 and 3 data are given for patients with hypodontia and controls in females and males, for left and right sides separately. No evidence was detected of a systematic asymmetry, and the results for individuals with supernumerary teeth and controls in Table 4 are given combined.

A link between the relative location of the supernumerary tooth and larger tooth dimensions has also been suggested for supernumerary teeth (9). The study of Khalaf et al. (9) of mesiodens supernumeraries showed a statistically significant effect for the upper incisors and lower lateral incisors. While the other teeth in the supernumerary patients were also larger than controls, this difference did not reach significance. In the present study, the effects of the position of the supernumerary tooth on tooth dimensions were tested throughout the dentition, and no pattern was observed. Indeed, the results of this study indicate that the influence of hypodontia and supernumerary teeth on tooth dimensions can be seen throughout the dentition and, in the case of hypodontia, that the strength of this effect is linked to the number of missing teeth. The findings of this study therefore support the theory of Brook (1), which posits that the dentition acts as a single developmental system.

The results of this study emphasise the importance of dental measurements in investigating the aetiology of dental anomalies. This study has focussed on MD and BL measurements, as these are the most commonly reported odontometrics. However, clinical observations indicate that the variation in tooth morphology resulting from hypodontia or supernumerary teeth is not just in size, but also in shape. This emphasizes the need for more detailed measurements of tooth dimensions and shape in order to better understand the aetiology of these defects. Such measurements could be achieved using 2D and 3D imaging methodologies (such as those used in 27), which are now beginning to be applied to the investigation of developmental defects of the dentition (e.g. 9). Further application of these new technologies to the study of the relationship between hypodontia and supernumerary teeth and tooth dimensions may help clarify the aetiological links between these conditions and the determination of patterning in the dentition.

Acknowledgements

We would like to thank Najeeb Kassim and Rajeshree Parekh for their help with collecting the measurements used in this study.

References

1. Brook A. A unifying aetiological explanation for anomalies of human tooth number and size. *Arch Oral Biol* 1984;**29**(5):373-378.

2. Schalk-van der Weide Y, Steen W, Beemer F, Bosman F. Reductions in size and left-right asymmetry of teeth in human oligodontia. *Arch Oral Biol* 1994;**39**(11):935-939.

3. Rune B, Sarnas K. Tooth size and tooth formation in children with advanced hypodontia. *Angle Orthod* 1974;**44**:316-321.

4. Baum B, Cohen M. Agenesis and tooth size in the permanent dentition. *Angle Orthod* 1971;**41**:100-102.

5. Lavelle C, Ashton E, Flinn R. Cusp pattern, tooth size and third molar agenesis in the human mandibular dentition. *Arch Oral Biol* 1970;**15**:227-237.

6. Garn S, Lewis A. The gradient and the pattern of crown-size reduction in simple hypodontia. *Angle Orthod* 1970;**40**:51-58.

7. Keene H. Third molar agenesis, spacing and crowding of teeth, and tooth size in caries-resistant naval recruits. *Am J Orthod* 1964;**50**:445-451.

8. Brook A, Elcock C, Al-Sharood M, McKeown H, Khalaf K, Smith R. Further studies of a model for the etiology of anomalies of tooth number and size in humans. *Connect Tissue Res* 2002;**43**(2):289-295.

9. Khalaf K, Robinson D, Elcock C, Smith R, Brook A. Tooth size in patients with supernumerary teeth and a control group measured by an image analysis system. *Arch Oral Biol* 2005;**50**:243-248.

10. Brook A. Variables and criteria in prevalence studies of dental anomalies of number, form and size. *Community Dent Oral Epidemiol* 1975;**3**(6):288-293.

11. Vieira A, Meira R, Modesto A, Murray J. MSX1, PAX9 and TGFA contribute to tooth agenesis in humans. *J Dent Res* 2004;**83**(9):723-727.

12. Kirzioglu Z, Sentut T, Erturk M, Karayilmaz H. Clinical features of hypodontia and associated dental anomalies: A retrospective study. *Oral Diseases* 2005;**11**:399-404.

13. Kirkham J, Kaur R, Stillman E, Blackwell P, Elcock C, Brook A. The patterning of hypodontia in a group of young adults in Sheffield, UK. *Arch Oral Biol* 2005;**50**:287-291.

14. Brook A. Dental anomalies of number, form and size: their prevalence in British schoolchildren. *J Int Ass Dent Child* 1974;**5**:37-53.

15. Kalra N, Chaudhary S, Sanghi S. Non-syndromic multiple supplemental supernumerary teeth. *J Indian Soc Pedodontics Preventative Dent* 2005;**23**(1):46-48.

16. Rajab L, Hamdan M. Supernumerary teeth: Review of the literature and a survey of 152 cases. *Int J Paediatr Dent* 2002;**12**(4):244-254.

17. Miles A. Malformations of the teeth. *Proc Royal Soc Med* 1954;**47**:817-826.

18. McKeown H, Robinson D, Elcock C, Al-Sharood M, Brook A. Tooth dimensions in hypodontia patients, their unaffected relatives and a control group measured by a new image analysis system. *Eur J Orthod* 2002;**24**:131-141.

19. Gravely J, Johnson D. Variation in the expression of hypodontia in monozygotic twins. *Dent Pract Dent Rec* 1971;**18**:212-220.

20. Townsend G, Richards L, Hughes T, Pinkerton S, Schwerdt W. Epigenetic influences may explain dental differences in monozygotic twin pairs. *Aust Dent J* 2005;**50**(2):95-100.

21. Brook A, Smith J. Hypoplastic enamel defects and environmental stress in a homogeneous Romano-British population. *Eur J Oral Sci* 2006;**114**:370-374.

22. Moorrees C, Reed R. Correlations among crown diameters of human teeth. *Arch Oral Biol* 1964;**9**:685-697.

23. Moorrees C. The Aleut Dentition. Cambridge: Harvard University Press, 1957.

24. Butler P. Studies in the mammalian dentition - and of differentiation of the postcanine dentition. *Proc Zoological Soc* 1939;**107**:103-132.

25. Schalk-van der Weide Y. Oligodontia, a clinical, radiographic and genetic evaluation [PhD]: University of Utrecht; 1992.

26. Garn S, Lewis A. Effect of agenesis on the crown-size profile pattern. *J Dent Res* 1969;**48**(6):1314.

27. Brook A, Smith R, Elcock C, Al-Sharood M, Shah A, Karmo M. The measurement of tooth morphology: Development and validation of a new image analysis system. In: Mayhall J, Heikkinen T, editors. Proceedings of the 11th International Symposium on Dental Morphology. Oulu: Oulu University Press, 1998. p. 380-387.

Text tables

Table 1. Intra- and inter-observer reliability for the hypodontia and supernumerary tooth studies.

	Difference in means (mm)	
	Intra-observer	*Inter-observer*
Hypodontia observer		
MD	0.0015	0.0704*
BL	0.0073	-0.0324
Supernumerary tooth observer		
MD	0.05	0.04
BL	0.00	0.02

* p<0.05

Table 2. Tooth dimensions (mm) in female hypodontia patients and the female hypodontia control group.

Tooth	Control						Hypodontia patients						
	Mean (R)	Std. Dev (R)	CV (R)	Mean (L)	Std. Dev (L)	CV (L)	Mean (R)	Std. Dev (R)	CV (R)	Mean (L)	Std. Dev (L)	CV (L)	% difference
Mesiodistal													
16,26	10.55	0.51	4.8	10.75	0.61	5.7	9.76*	0.71	7.3	9.82*	0.79	8.0	-8.1
15,25	6.77	0.48	7.1	6.77	0.53	7.8	6.21*	0.67	10.8	6.40*	0.61	9.5	-6.9
14,24	7.01	0.50	7.1	7.06	0.55	7.8	6.64*	0.65	9.8	6.83	0.45	6.6	-4.3
13,23	7.55	0.57	7.5	7.63	0.50	6.6	7.44	0.56	7.5	7.42	0.43	5.8	-2.1
12,22	6.63	0.75	11.3	6.74	0.65	9.6	6.07*	0.95	15.7	6.28*	0.61	9.7	-7.6
11,21	8.75	0.56	6.4	8.64	0.63	7.3	8.29*	0.63	7.6	8.12*	0.76	9.4	-5.6
36,46	10.89	0.50	4.6	10.90	0.59	5.4	10.33*	0.78*	7.6	10.50*	0.68	6.5	-4.4
35,45	7.34	0.52	7.1	7.22	0.46	6.4	6.84*	0.85*	12.4	6.75*	0.81*	12.0	-6.7
34,44	7.02	0.57	8.1	7.06	0.46	6.5	6.72	0.53	7.9	6.73*	0.57	8.5	-4.5
33,43	6.65	0.46	6.9	6.73	0.52	7.7	6.11*	0.47	7.7	6.28*	0.48	7.6	-7.4
32,42	5.93	0.43	7.3	5.91	0.42	7.1	5.62*	0.43	7.7	5.62*	0.51	9.1	-5.1
31,41	5.55	0.70	12.6	5.93	0.37	6.2	5.10*	0.45*	8.8	5.11*	0.62*	12.1	-11.1
Buccolingual													
16,26	11.23	0.43	3.8	11.26	0.43	3.8	10.61*	0.64*	6.0	10.56*	0.87*	8.2	-5.9
15,25	9.35	0.56	6.0	9.28	0.62	6.7	8.65*	0.76	8.8	8.75*	0.75	8.6	-6.6
14,24	8.95	0.54	6.0	8.98	0.49	5.5	8.52*	0.77	9.0	8.50*	0.78	9.2	-5.1
13,23	7.81	0.67	8.6	7.84	0.67	8.5	7.42*	0.50	6.7	7.32*	0.62	8.5	-5.8
12,22	6.40	0.74	11.6	6.38	0.69	10.8	5.89*	0.87	14.8	5.78*	0.72	12.4	-8.7
11,21	7.12	0.56	7.9	7.11	0.58	8.2	6.60*	0.93*	14.1	6.62*	0.80	12.1	-7.1
36,46	10.61	0.47	4.4	10.62	0.51	4.8	10.03*	0.50	5.0	10.06*	0.46	4.6	-5.4
35,45	8.54	0.75	8.8	8.49	0.58	6.8	7.96*	0.49	6.2	7.73*	0.85	11.0	-7.9
34,44	7.86	0.84	10.7	7.94	0.70	8.8	7.06*	0.60	8.5	7.14*	0.64	9.0	-10.1
33,43	7.05	0.62	8.8	7.27	0.55	7.6	6.15*	1.07*	17.4	6.45*	1.04*	16.1	-12.0
32,42	6.32	0.55	8.7	6.34	0.48	7.6	5.72*	0.46	8.0	5.68*	0.49	8.6	-10.0
31,41	6.09	0.56	9.2	6.07	0.44	7.2	5.53*	0.51	9.2	5.39*	0.66*	12.2	-10.2

* p<0.05 when mean dimension was compared with control group

** p<0.05 when the variance was compared with that of the control group

Table 3. Tooth dimensions (mm) in male hypodontia patients and the male hypodontia control group.

Tooth	Control						Hypodontia patients						
	Mean (R)	Std. Dev (R)	CV (R)	Mean (L)	Std. Dev (L)	CV (L)	Mean (R)	Std. Dev (R)	CV(R)	Mean (L)	Std. Dev (L)	CV (L)	% difference
Mesiodistal													
16,26	10.64	0.62	5.8	10.73	0.64	6.0	9.92*	0.65	6.6	10.02*	0.82	8.2	-6.7
15,25	5.84	0.68	11.6	6.77	0.33	4.9	6.32*	0.68	10.8	6.48*	0.53*	8.2	1.5
14,24	7.01	0.45	6.4	7.06	0.45	6.4	6.69	0.67	10.0	6.69*	0.62	9.3	-4.9
13,23	8.01	0.47	5.9	7.94	0.38	4.8	7.59*	0.56	7.4	7.30*	0.53	7.3	-6.7
12,22	6.87	0.58	8.4	6.92	0.49	7.1	6.08*	0.68	11.2	5.79*	0.73	12.6	-13.9
11,21	8.97	0.52	5.8	8.97	0.66	7.4	8.48*	0.84*	9.9	8.44*	0.94	11.1	-5.7
36,46	11.18	0.64	5.7	11.29	0.53	4.7	10.53*	0.90	8.5	10.61*	1.06*	10.0	-5.9
35,45	7.19	0.36	5.0	7.24	0.43	5.9	6.78*	0.72*	10.6	6.88*	0.64	9.3	-5.3
34,44	7.18	0.49	6.8	7.22	0.47	6.5	6.74*	0.38	5.6	6.82*	0.49	7.2	-5.8
33,43	6.98	0.38	5.4	7.02	0.47	6.7	6.57*	0.46	7.0	6.49*	0.47	7.2	-6.7
32,42	5.95	0.26	4.4	6.04	0.45	7.5	5.68*	0.30	5.3	5.54*	0.58	10.5	-6.4
31,41	5.48	0.35	6.4	5.68	0.87	15.3	5.19	0.69*	13.3	5.00*	0.74	14.8	-8.7
Buccolingual													
16,26	11.57	0.43	3.7	11.51	0.46	4.0	10.98*	0.70*	6.4	11.11*	0.75*	6.8	-4.3
15,25	9.36	0.52	5.6	9.30	0.84	9.0	8.72*	0.93*	10.7	8.59*	1.00	11.6	-7.2
14,24	9.28	0.54	5.8	9.36	0.61	6.5	8.68*	0.94*	10.8	8.56*	0.96*	11.2	-7.5
13,23	8.16	0.78	9.6	8.06	0.64	7.9	7.54*	0.59	7.8	7.49*	0.37*	4.9	-7.3
12,22	6.56	0.62	9.5	6.51	0.65	10.0	5.72*	0.66	11.5	5.33*	0.88	16.5	-15.5
11,21	7.37	0.62	8.4	7.23	0.69	9.5	6.64*	0.89	13.4	6.75*	0.91	13.5	-8.3
36,46	10.85	0.33	3.0	10.78	0.44	4.1	10.26*	0.69*	6.7	10.36*	0.63	6.1	-4.7
35,45	8.55	0.61	7.1	8.63	0.47	5.4	7.90*	0.76	9.6	8.00*	0.73*	9.1	-7.5
34,44	7.90	0.67	8.5	8.09	0.46	5.7	7.28*	0.60	8.2	7.42*	1.03*	13.9	-8.1
33,43	7.31	0.64	8.8	7.46	0.69	9.2	6.48*	0.67	10.3	6.73*	0.64	9.5	-10.6
32,42	6.21	0.50	8.1	6.41	0.58	9.0	5.45*	1.11*	20.4	5.44*	1.12*	21.6	-13.7
31,41	6.14	0.54	8.8	6.15	0.52	8.5	5.16*	1.00*	19.4	5.40*	0.79*	14.6	-14.1

* $p<0.05$ when mean dimension was compared with control group

** $p<0.05$ when the variance was compared with that of the control group

Table 4. Tooth dimensions (mm) in patients with supernumerary teeth and the supernumerary tooth control group (data from males and females combined).

Tooth	Control	Supernumerary tooth patients	% difference
Mesiodistal			
17,27	9.40	9.54	1.5
16,26	9.73	9.87	1.4
15,25	6.34	6.44	1.6
14,24	6.70	6.82	1.8
13,23	7.57	7.79	2.9
12,22	6.79	6.97	2.7
11,21	8.69	8.83	1.6
37,47	9.81	10.40	6.0
36,46	10.76	10.76	0.0
35,45	6.74	7.13*	5.8
34,44	6.96	7.08	1.7
33,43	6.57	6.78	3.2
32,42	5.73	5.71	-0.4
31,41	5.19	5.29	1.9
Buccolingual			
17,27	10.83	10.97	1.3
16,26	11.08	11.10	0.2
15,25	9.23	9.30	0.8
14,24	9.09	9.18	1.0
13,23	7.49	7.78	3.9
12,22	6.08	6.24	2.6
11,21	6.81	6.72	-1.3
37,47	9.98	9.71	-2.7
36,46	10.44	10.42	-0.2
35,45	8.42	8.33	-1.1
34,44	7.86	7.86	0.0
33,43	6.57	6.98	6.2
32,42	5.72	5.56	-2.8
31,41	5.40	5.47	1.3

* $p<0.05$ when mean dimension was compared with control group