RESEARCH

A cross-sectional survey to determine the ages of emergence of permanent teeth of Caucasian children of the Colchester area of the UK

IN BRIEF

- Provides data to allow comparisons of contemporary tooth emergence data with historical records.
- Comparisons can be made with data acquired recently from elsewhere in Europe and the rest of the world.
- The data provide assistance in making dental interventions at the correct stage in a child's dental development.
- Further exploration of this data collection system may be beneficial.

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Objective To determine the ages of emergence of permanent teeth of Caucasian children of the Colchester area of the UK. **Methods** Emergence data for all permanent teeth except third molars was collected from 12,395 children between four and 15 years of age, in the Colchester area of the UK between April 1998 and July 2001. A simple, robust, easy-to-follow experimental protocol was devised to provide reliable data collection. **Results** The ages of emergence of the permanent teeth in this study which covered the period 1998-2001 in this Colchester population are later than earlier studies conducted throughout the twentieth century. **Conclusion** If confirmed, the results of this study would suggest that contemporary children's dental development is retarded which may have implications for their general health. The type of study reported here may have long-term value in rapidly identifying trends in children's development of public health importance.

INTRODUCTION

There is a general assumption that children are growing faster and maturing earlier. The age of menarche, frequently used as an indicator of maturation, is generally getting lower at a rate of about four months per decade. Between 1850 and 1950 the age of menarche decreased from 17 years to 13.5 years.[1] These changes are probably due to nutritional and socio-economic changes, because where there has been no change in the diet or lifestyle of a community, the age of menarche has not altered over periods of at least 50 years.[2]

Dental age correlates closely with chronological age in the developing child.[3] Research has shown[4,5] that chronological age is more closely related to dental age than skeletal, somatic or sexual maturity indicators. This is probably because teeth develop and emerge in a protected environment and their development proceeds even to the detriment of the development of other systems. Studies over the last century[6-8] have shown that over this period children's teeth were emerging progressively earlier than may have been expected with the improvement in community health.

The research described here was undertaken to investigate whether, as is widely assumed within the dental profession and elsewhere, a secular trend towards earlier maturation has continued to the present day in the UK. It is important to determine whether reports of earlier development[9] are supported by large scale, scientific studies so that the timing of dental health care initiatives, dental treatment and orthodontic treatment can be optimised. In addition, the study would provide contemporary data to allow accurate forensic odontological age assessments. As teeth are indicators of chronological age and the overall health of a child, this study was expected to give an indication of the overall health of Caucasian children in the Colchester area of the UK.

METHODS

Colchester is a town of 142,515 people situated about 80 km North East of London. The 1991 Census[12] listed the population of Colchester as being composed of 97.7% Caucasian and 2.3% non-Caucasian. This community was selected as the subject of this study because access to children through the schools via the Community Dental Service of the Essex Rivers Health Authority was possible. The data collected were based on dental examinations, undertaken between 3 April 1998 and 11 July 2001, on 12,395 children attending schools in the Essex Rivers Health Authority Area. The records of 219 children (1.77% of the total sample), of whom 105 were boys and 114 girls, who had had teeth removed (for trauma, decay, orthodontic reasons, major systemic illness or genetically inherited disorders) were not included in the final data set. In addition, the records of the 406 (3.26% of total sample) non-Caucasian children (210 boys and 195 girls) were excluded. The final size of the Caucasian population studied was therefore 11,770. This was 26.7% of the children attending school in the Essex Rivers Health Authority Area during the academic year 2001-2002.

A simple, robust, reproducible and reliable protocol for standardised data collection, and statistical analysis was developed, tested and used as described in detail by Elmes.[10] Examiners recorded the presence or absence of permanent teeth in the mouth of each child. If any part of the tooth was present in the oral cavity it was deemed to have emerged.

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Table 1 Comparison of median ages of emergence 1912–2001

Tooth	(Boys+Girls)		Boys			Girls		
FDI Code	1912[6]	1998–2001 (n)	1925[7]	1976[8]	1998–2001 (n)	1925[7]	1976[8]	1998–2001 (n)
17	>12.00	12.67 (1,238)	12.33	11.9	12.8 (601)	12.07	11.3	12.4 (637)
16	6.15	6.66 (8,740)	6.34	6.2	6.77 (4,518)	6.12	5.9	6.5 (4,222)
15	10.73	12.01 (1,833)	10.89	11.4	12.25 (884)	10.72	11.2	11.78 (949)
14	9.82	11.06 (2,770)	9.96	10.4	11.25 (1,355)	9.77	9.9	10.85 (1,415)
13	11.66	11.74 (2,020)	11.73	11.4	11.98 (940)	11.2	10.6	11.39 (1,080)
12	8.52	8.44 (6,166)	8.81	8.3	8.66 (3,081)	8.37	7.8	8.24 (3,085)
11	7.35	7.3 (7,817)	7.42	7.2	7.42 (4,016)	7.2	6.2	7.17 (3,801)
41	6.35	6.47 (8,959)	6.49	6.2	6.6 (4,604)	6.23	5.9	6.36 (4,355)
42	7.51	7.61 (7,397)	7.72	7.3	7.76 (3,768)	7.5	7	7.4 (3,629)
43	***	10.57 (3,215)	10.8	10.5	11 (1,470)	9.4	9.9	10.29 (1,745)
44	10.5	10.94 (2,892)	10.86	11.4	11.19 (1,400)	10.36	10.8	10.71 (1,492)
45	11.79	12.1 (1,751)	11.8	12	12.21 (844)	11.21	11.7	11.87 (907)
46	5.93	6.59 (8,791)	6.24	6.1	6.76 (4,524)	5.95	5.9	6.46 (4,267)
47	11.79	12.15 (1,618)	11.86	11.4	12.26 (786)	11.52	11.3	11.95 (832)

(***data inadequate for E_{50} calculation, n = number of subjects)

Two teams of people collected the data. Dr Elmes was a member of both teams. The first team comprised the researcher, the Community Dental Officer and his dental nurse, and the second comprised the researcher and her dental nurse. The Community Dental Officer had been trained and assessed for standardisation of examination through BASCD, but Dr Elmes had not.

A study was undertaken to assess the consistency of procedures undertaken during dental examinations. During the first three days of data collection, the first and every subsequent fiftieth child was examined by both dentists. Each child was examined separately, and then jointly, and the data from both examiners, from both examinations, was compared. At the end of three days, 550 children had had a dental examination and 12 joint examinations had been undertaken. On each and every occasion identical data had been collected. This showed that the two examiners were collecting the data in a consistent fashion so the joint examinations were discontinued. Subsequently, whenever there was any question as to the presence or absence of a tooth, both dentists examined the child's mouth, collected the data and agreed a joint interpretation of the data. This was then recorded. This process continued throughout the data collection period. The dental data for the children at primary schools were recorded on modified NHS record card continuation sheets.

The data were initially recorded onto paper forms but to facilitate storage and analysis the data were transferred to an IBM-PC compatible computer (Packard Bell Platinum with Pentium II processor) into the database package, Microsoft Access. A data entry form was carefully designed to mimic the appearance on screen of the manual data collection form to minimise the likelihood of errors in transcription. Additional calculated fields on the form were the age of the child at the time of examination and quadrant totals. (Quadrant total fields were produced by adding together all the teeth in a single quadrant of the mouth; if the deciduous tooth and its permanent successor were present only the permanent tooth was recorded.) By comparing the quadrant totals shown by the computer to the actual number of teeth on the paper form it was possible to undertake a second check on the tooth entry fields. These calculated fields allowed a direct comparison of ages and numbers of teeth to be made. The data were entered into the Microsoft Access forms in batches of approximately 100. After each batch, the entry in the Access form was visually checked against the original paper record to make sure that the entry was correct and that the quadrant totals corresponded with the expected figures.

Once the whole data entry was completed an independent assessor compared approximately 3,000 data entry cards, randomly removed from the storage boxes with the original paper record charts. No errors were found confirming the accuracy of the data collection. To facilitate data handling and analysis, data was transferred electronically from Microsoft Access to the Statistical Package for Social Sciences (SPSS) program, Version 12 for MS Windows, with which statistical analyses were performed.

As a final validation check 200 specific records were examined separately in both programs, to check that they were identical, and a further 50 records were randomly selected for examination. The records examined were identical in both cases.

Data were placed in six-month age bands and actual life tables recording the

Table 2 Classification of tooth emergence patterns 1925-2001

Tooth	Boys	Girls
17	A	A
16	A	A
15	B	B
14	B	B
13	B	A
12	C	C
11	A/C	C (1925 time = 2001 time)
41	A	A
42	A	C
43	A	B
44	D	D
45	B	B
46	A	A
47	A	A

Key (01>25>76) = A, (01>76>25) = B, (25>01>76) = C, (76>10>25) = D

percentage of children having each tooth for each age band were generated. The median age of emergence,[6-8] E_{50}, calculated by interpolation, was chosen as the measure of central tendency. The largest sub-set of the data for a specific tooth was 8,959 for tooth 41 (FDI code) for all the children, and the smallest sub-set of the data was 601 boys for tooth 17.

RESULTS

The median ages of emergence for each of the 14 permanent teeth of all the children from three comparable studies (1912,[6] 1925,[7] 1976[8]) and the current study (1998-2001) are shown in Table 1. Since Lavelle[8] restricted his analysis to the right side of the mouth this was used as the basis for comparison of all the median ages. Elmes[10] confirmed earlier work by Clements *et al.*[11] which showed that there were no significant differences in the median ages of emergence of contra-lateral teeth, so no important information was lost by applying this restriction. The earliest study comparable with the current work was that of James and Pitts[6] in 1912. They considered boys and girls together. However, the studies in 1925[7] and 1976[8] treated the boys and girls separately. Therefore a direct statistical comparison between the 1912 data with the 1925 and 1976 studies was not possible. It was possible to characterise the E_{50} derived from the 1912 data as being earlier than, later than or within the range of the both the 1925 and 1976 boys and girls results. Only one tooth (lower right first permanent molar – FDI Code 46) was earlier, all others were in the range. This suggests that teeth were probably emerging at approximately the same time in 1925 as in 1912.

Comparing the 1912 combined data (Table 1) for boys and girls (n = 12, Mean = 9.00, Standard Deviation = 2.30) with the current (1998-2001) data (n = 12, M = 9.43, SD = 2.43) using the Wilcoxon Signed Ranks Test the differences in E_{50} were significant beyond the 0.01 level: p = 0.003 (two tailed).

A comparison of the 1925 data (Table 1) for boys (n = 14, M = 9.52, SD = 2.26) with the current data (n = 14, M = 9.95, SD = 2.44) using the Wilcoxon Signed Ranks Test, the differences in E_{50} were significant at the 0.01 level: p = 0.001(two tailed). A similar comparison of the 1925 data for girls (n = 14, M = 9.12, SD = 2.18) with the current data (n = 14, M = 9.53, SD = 2.36), the differences in E_{50} were significant at the 0.01 level: p = 0.002 (two tailed).

Comparing the 1976 data (Table 1) for boys (n = 14, M = 9.41, SD = 2.37) with the current data using the Wilcoxon Signed Ranks Test, the differences in E_{50} were significant at the 0.01 level: p <0.0001(two tailed). A similar comparison of the 1976 data for girls (n = 14, M = 8.96, SD = 2.36) with the current data, the differences in E_{50} were significant at the 0.01 level: p <0.0001 (two tailed).

For all teeth where a valid comparison can be made (Table 1) current (1998-2001) data (E_{50}) shows that teeth are emerging later over the period 1998-2001 than in 1912 (except for 11 and 12) and these differences are statistically significant.

Comparing boys (E_{50}) in the current study with the 1925 data all teeth (except 11 - emerges at same time and 12 - emerges earlier) emerge later in 1998-2001 than in 1925 (Table 1). For girls 11 teeth emerge later in the period 1998-2001 than in 1925 (11, 12 and 42 – emerge earlier).

For boys current data (E_{50}) shows that all 14 teeth except 44 are emerging later in 1998-2001 than in 1976 (Table 1). The same is true for girls except once again for 44 (Table 1). The statistical evidence supports the inference that teeth in general are emerging later in 1998-2001 than at any time in the twentieth century.

The results across all teeth are not identical. Some teeth seem to be largely unaltered in their emergence throughout the twentieth century. Others show considerable variability. The records show a different pattern at each time they were examined. To try to make sense of this complexity, the patterns were classified depending on the order in which a tooth emerged over 2001, 1976 and 1925. Using '>' to indicate later emergence a tooth which emerged latest in 2001, at a less late time in 1925 and earliest in 1976 would be written (01>25>76). This is pattern A. Similar patterns were identified, classified and displayed in Table 2.

Table 2 shows that there were only four patterns identified in the boys' and girls' data. For the maxilla the patterns for the molars (A) are different from the premolars (B) and the incisors (C). The canines of the girls and boys are different in the patterns observed (B for boys, A for girls). For the mandibular teeth the pattern is less clear. Four classes are needed, the extra one for tooth 44. The molar teeth have the A pattern and the second pre-molar B as for the maxilla. The first pre-molar has a unique pattern (D) and the other teeth at the anterior of the mouth for boys and girls together are 4A, one B and one C.

DISCUSSION

The pattern seen in the eruption times of the set of teeth for each single year represents the effects of the (unknown) factors which control tooth eruption. The patterns over time give the response of the individual tooth to different controlling factors of different strengths at different times. Classifying the patterns enables the identification of similarities in the responses over time of single teeth. The patterns shown are consistent with the determinants of tooth eruption being the grouping of the teeth into incisors, canines, molars and pre-molars particularly for the maxilla. Parner *et al.*[17] have claimed that the biological process underlying the development of the dentition is based on the innervation. In particular the maxillary teeth are controlled by the naso-palatine nerve to the incisors, maxillary nerve to canines/pre-molars, palatine nerve to molars. The patterns in this study given the very limited number of times sampled are strikingly in accord with this. The mandibular teeth are controlled by the inferior alveolar nerve with a common bundle of nerve branches. In the current study the mandibular teeth show a greater pattern variation than the maxillary as would be expected on this hypothesis. These data can therefore be interpreted to support the proposition that innervation controls tooth emergence times.

Comparison of surveys conducted over an historical period of almost a century must be treated with caution. There may be unrecorded variation in recording methods, selection of subjects and data analysis. In all surveys the examination method and the recording protocols were simple and unlikely to lead to significant errors. In all surveys the populations were heterogeneous but all used large numbers of subjects (4,000 or more). No evidence of systematic errors could be detected in the survey results. The same measure was used in all surveys.

It is important to stress that although the sample size for the current survey was comparatively large, these results represent the findings in a small geographical area. Further studies using the same methodology are needed from other areas of the UK to confirm that these results apply nationally. Lavelle (1976) took samples from populations in Birmingham, Sheffield, Gloucester and Biddulph. The children from Biddulph showed the latest tooth emergence. Comparing these data for the girls, 12 out of 14 teeth emerged later in the current study. The two teeth that emerged later in the Biddulph data were 44 (difference 0.09 years) and 45 (difference 0.03 years). For the boys 13 out of 14 teeth emerged later in the current study. The one tooth that emerged later in the Biddulph results was 11 (difference 0.08). These results suggest that geographical variation in tooth emergence across the English population may not be large and is very unlikely to explain the magnitude of the changes observed in the current study.

The reasons for these results if they are confirmed cannot be due to genetic factors due to the timescales involved, but must arise from the environment. Thus the explanation must be that some material is ingested, absorbed or inhaled or a dietary trend of some kind has become established in the population which has led to these changes.

Previous work has shown the importance of diet in the development of children. Teeth of the children in Registrar-General's Social Classes I and II emerged up to seven months earlier than the teeth of the children in Registrar-General's Social Class III.[12] Malcolm and Bue[13] in New Guinea showed that the teeth of the children who had a better balanced diet emerged earlier than children with a poorly balanced diet. Billewicz and McGregor[14] in The Gambia showed that of the children within a single age band those with more teeth tended to be heavier and taller. They concluded that 'This seems to suggest that long term under nutrition may have some influence on the eruption of permanent teeth'. The same was found by Garn, Lewis and Keresky[16] with white children in Ohio ('it is clear that taller and heavier children are advanced dentally'). They also refer to the difficulty in general of detecting these effects in well-nourished populations. These results suggest that diet is an important factor in the time of emergence of children's teeth and that the better the diet the earlier their teeth emerge. As the age of emergence of children's teeth in the Colchester area, sampled between 1998 and 2001, was later in comparison with earlier samples of the British population, a possible explanation is that this may reflect poorer nutritional status of contemporary children compared with previous generations.

CONCLUSIONS

The study reported here provides supporting evidence for the role of innervation determining the timing of the emergence of permanent teeth. Studies over the last century[6-8] have shown that over this period children's teeth were emerging progressively earlier, a secular trend which may have been expected with the improvement in community health. Teeth of children among the sample studied in 2001 were emerging later than at any time in the twentieth century. As teeth are considered to be good indicators of the maturity of children these data do not support the commonly held view that children are in every respect maturing earlier. The results reported here, if confirmed, may be early indications of possible problems with child development in the UK. The type of study reported here may have long-term value in rapidly identifying trends in children's development of public health importance.

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