A RADIOGRAPHIC STUDY OF THE CALCIFICATION AND ERUPTION OF THE PERMANENT TEETH IN INUIT AND INDIAN CHILDREN

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ABSTRACT

The purpose of this multidisciplinary study is to determine the mean age and range of variation for the calcification and eruption of the permanent teeth in Native Canadian populations, and to determine whether there are significant differences between these populations and other North American Native and North American White populations.

As more Canadian Inuit and Indian patients seek comprehensive dental treatment, including orthodontics, the recognition of significant genetic and environmental differences in the development of the permanent dentition could facilitate the timing and the type of dental treatment selected. As well, variations in the timing of calcification and eruption of the teeth are extremely relevant to the identification and the assessment of age and sex of skeletal material, for both anthropological and forensic purposes. At the present time, all skeletal remains are compared to Caucasian standards of dental development, particularly gingival emergence.

Panoramic data for this cross-sectional study was obtained from several clinical sources in Manitoba. All of the permanent teeth were studied, using twelve stages of calcification modified from Nolla (1960) and Moorrees et al. (1963). As well, four stages of eruption were considered, modified from Massler and Schour (1941).

The mean age for each calcification score was found to be younger in both the Inuit and Indian samples, compared to studies of White populations, for all teeth except the premolars and second molars. Calcification occurs earlier in Inuit females than males in certain

teeth. Indian females were clearly advanced in calcification over Indian males. A Dental Calcification Index was calculated using Nevile's (1973) formula in order to derive a dental age from the mean ages of calcification for each subject. A high correlation was found between the dental age and the chronological age.

The results of this study show that while there are slight genetic differences resulting in earlier eruption of certain teeth, particularly in the Inuit sample, the primary cause of differences in the timing of eruption is the premature loss of the deciduous teeth. There is also a significant time lag between the mean age of alveolar and gingival emergence for each sample, which varies for each tooth. Thus, clinical standards for gingival emergence do not accurately predict the mean age of alveolar emergence. An Eruption Index has been developed to more accurately predict age in skeletal material from the age of alveolar emergence.

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Numerous studies have been done on the development and eruption of the permanent teeth in North American Caucasian children. Most of this work has been done in the United States (Logan & Kronfeld, 1933; Massler & Schour, 1941; Carlson, 1944; Garn & Lewis, 1955, 1957, 1958, 1960, 1963, 1972; Moorrees, 1959; Shumaker, 1960, 1974; Nolla, 1960; Bradley, 1961; Knott & Meredith, 1966). Work has also been done at the Burlington Orthodontic Research Centre by Posen (1965) and Feasby (1971, 1981), also with Caucasian samples. Lo and Moyers did a study in Toronto (1953) but the ethnic origin of their sample was not defined. More recently Perreault (1974) and Masson (1980) have looked at the timing of gingival emergence in French-Canadian children.

Of the studies surveyed, those that considered differences in males and females found that permanent teeth generally erupt earlier in females than in males (Steggerda & Hill, 1942; Lo & Moyers, 1953; Moorrees, 1957; Nolla, 1960; Carr, 1962; Posen, 1965; Knott & Meredith, 1966). The sequence of eruption was also found to differ between males and females, according to Steggerda & Hill (1942), Moorrees (1957) and Knott and Meredith (1966). As well, the sequence of calcification, emergence through the alveolar process, and clinical emergence through the gingiva, do not always correlate (Garn & Lewis, 1957; Knott & Meredith, 1966). The main discrepancy occurs with regard to the premolars and second molars, particularly where the deciduous molars have been lost prematurely (Posen, 1965).

The only studies on the dental eruption of North American Native populations have been the work of: Hrdlicka (1908) and Dahlberg & Menegaz-Bock (1958) on the Pima Indians; Steggerda & Hill (1942) who compared four populations: Whites (Dutch), Negroes (southern rural U.S.A.), Navajo (reserve), and Maya (Yucatan); Garn and Moorrees (1951) on emergence in Aleut children; Mayhall et al. (1977) on Cree and Ojibwa Indians (Northern Ontario); and Mayhall et al. (1978) on the Inuit (Foxe Basin).

Dahlberg and Menegaz-Bock (1958) compared their results to Clement's study of British children (1953). They found that a similar pattern of eruption existed in the maxilla and mandible in both boys and girls, but that the anterior teeth of the Pima erupt later than do those of the English, and the posterior teeth erupt earlier. They felt that the differences may be genetically based, environmentally induced, or "due to some complex of environmental and hereditary factors" (1958:1136). Steggerda and Hill also found that the order of eruption appears to be the same in all populations, but that there are genetic differences in eruption time. The earliest eruption of teeth occurs in the Navajo, followed by the Negro, the Maya, with the latest time of eruption occurring in the White sample (1942:369). No published studies on the stages of dental calcification have been done for Native populations either in the United States or Canada.

Clinical Significance

As more Canadian Indian and Inuit patients seek comprehensive dental treatment, including orthodontics, it is imperative that their

dental development not be assumed to be identical to that of Caucasian children. If there are significant differences in the timing and sequence of eruption of the permanent teeth, particularly the canines, premolars, and second molars, this information could facilitate orthodontic treatment: preventive treatment such as space maintenance, limited interceptive treatment, and comprehensive treatment. If significant population differences do exist in the timing and sequence of dental calcification, as well as the timing and sequence of eruption, for Manitoba Native children, then the type of dental treatment selected at different ages may be altered. The population of Manitoba, in particular, is composed of so many ethnic groups that no single eruption standard is representative of the diversity that exists.

Anthropological and Forensic Significance

Anthropologists have long been interested in the physical characteristics of humans and how these characteristics differ between the many ethnic populations. Variations exist, not only between populations, but also between individuals within these populations. Variations in the formation and eruption of the teeth are extremely relevant in the identification and the assessment of age and sex of skeletal material. At present, all prehistoric remains are compared to the standards of dental development and eruption for North American White populations. No studies have been done in North America comparing the mean age of alveolar eruption to the mean age of gingival eruption. If standards for gingival eruption are applied to skeletal

material without taking into consideration the time interval between alveolar and gingival emergence, there will be a variable amount of error in predicting the age.

In summary then, the major aims of this investigation are:

1). To determine the mean and range of normal variation for the timing and sequence of eruption of the permanent teeth for Native populations in Manitoba and the Northwest Territories.

2). To determine the mean and range of normal variation for the timing and sequence of calcification of the permanent teeth for Native populations in Manitoba and the Northwest Territories.

3). To compare the timing and sequence of calcification and eruption in Native populations to the standards set for North Americal White populations.

4). To determine the differences in the timing and sequence of calcification and eruption males and females in Native populations compared to North American White populations.

5). To determine whether there are significant correlations between the sequence of calcification and the sequence of emergence through the alveolar bone and the gingiva.

DENTAL DEVELOPMENT

In 1929 Logan and Kronfeld began their notable histological and roentgenological investigation. The material consisted of the jaws of

30 infants and children aged up to 15 years. Logan and Kronfeld (1933) report the times of the initial calcification of permanent teeth, illustrated by histological sections and radiographs. The tables drawn up by Logan and Kronfeld lay out the chronology of the initial calcification of the deciduous and permanent dentitions, the completion of the crown and the termination of the calcification process as well as the eruption of the teeth. Apart from the fact that no idea of the range of variation or of sex differences could be obtained from such a small number of subjects, many of the subjects died from prolonged debilitating illnesses which could have affected the chronology of tooth development. Many contemporary references to tooth formation and its variation are derived from the studies of Logan and Kronfeld, but their ranges are unduly narrow owing to the extremely small sample investigated. Although Logan and Kronfeld did not claim to provide 'norms' in the usual sense, many later authors have unfortunately assigned this authoritative status to their findings, and these tables have found their way into a large portion of the literature up to the 1960's.

In assessing age from dentitions that are immature, use is commonly made of a chart prepared by Schour and Massler (1941), published in slightly modified form by the American Dental Association and reproduced in many textbooks. This chart, like many charts and tables of its kind, is based to a large extent upon the observations made by Logan and Kronfeld (1933) and Kronfeld (1935a,b,c). In practice, however, the Schour and Massler chart appears to give useful and reasonably reliable results (Brauer and Bahador, 1942; Miles, 1958; Gray and Lamons, 1959). Its use is, however, virtually limited to ages below

15 years because no stages of growth of the third molars are recorded for the ages between 15 and 21 years.

Review of the earlier literature relating to tooth formation reveals that the technique, material and methods used to do not give a correct picture of continued growth and development. It was not until the 1950's that studies began to appear that were based on new procedures, and no longer copied old tables, because deficiencies had been detected in them. One noteworthy longitudinal research project was started in the United States as early as 1930, under the direction of Dr. H.C. Stuart at the Forsyth Dental Infirmary, Harvard University, which dealt with the development of healthy Boston children. From this material several papers have been published since the mid-1950's that deal with tooth development. Another important longitudinal study was undertaken around the same time at the Fels Research Institute in Ohio, which has produced a number of reports on dental development, by Garn and colleagues.

The Stuart material was used by Gleiser and Hunt (1955) to produce a notable study on the calcification, eruption and decay of the permanent mandibular first molar. In their investigation of the calcification process, Gleiser and Hunt were the first to divide tooth formation into 15 developmental stages. They described in detail the stages of growth of the first molar in radiographs of 25 girls and boys, taken at six month intervals from birth onwards. The mean values given by Gleiser and Hunt for the early stages of formation of the first permanent molar are several months later than those depicted on the Schour and Massler chart, and the data of Garn et al. (1959) put these stages slightly later still. These discrepancies are not gross,

however, especially when the whole dentition is being assessed.

A similar, but larger and more extensive longitudinal study by Garn et al. (1959) has provided data relating to all the permanent mandibular molars and premolars. Being based on a study of 225 children, and presented with particularly good statistical treatment, this study shows, virtually for the first time, the range of variation that exists. For instance, the 50th percentile value for the age of apical closure of the first permanent molar in girls was 10.4 years, and the 5th and 95th percentiles were 9.0 and 11.4 years respectively. These workers modestly issue the warning, however, that the size of their population sample falls short, though not grossly, of the number necessary for the establishment of a system of reliable 'norms' (1959:146). It is worthy of note that Garn et al. (1959) found that the chronology of tooth development was slightly less variable than that of osseous development among the same group of subjects.

A smaller but similar longitudinal study by Fanning (1961), as well as providing data comparable to, but by no means in complete agreement with, that of Garn et al. (1959), has added information about the chronology of resorption of the roots of the deciduous teeth. Using the same material, Moorrees et al. (1963) supplemented the foregoing findings by reporting on the formation of the permanent mandibular teeth, with the exception of the incisors, between the ages of 0 to 21 years, and on the upper and lower incisors from the fourth year of life onward.

In her longitudinal study, Nolla (1960) depicts tooth development from the ages of 2 to 17 years by means of graphs and tables. She concludes that the type of growth displayed by each tooth is the same,

and that few developmental differences existed between the right and left sides for teeth of the same type (1960:265).

Since among the permanent teeth the first molar begins to form first, the development of this tooth has been studied most. Many researchers have observed the process of calcification to have started from the tip of the mesio-buccal cusp, to continue from the disto-buccal, then the mesio-lingual and finally the disto-lingual cusp (Kronfeld, 1935a; Gleiser and Hunt, 1955; Butler, 1967). There are distinctly slower and faster stages in tooth calcification. Carlson (1944), from radiographs; Kronfeld (1935a), from histological sections; and Gleiser & Hunt (1955) and Moorrees et al. (1963), from radiographs; have noted that the initial calcification becomes more rapid before the completion of the crown. "The rate of tooth development is not constant when judged from the mean interval between stages. For instance, the formation of the second quarter of the mandibular canine and premolar roots required 1.3 years for the second premolar in females and 2.3 years for the canine in males. The fourth quarter root of these teeth was formed in only 0.7 and 0.6 years respectively" (1963:1496-1497). Schour and Massler (1940a) reported that when the root development is half completed, the calcification is accelerated to its maximum. Haavikko (1970) also found that, when the duration of the different stages of root formation are compared, there is a greater length of time between the stages of crown completion and one-quarter root development for all teeth, and that the remaining three-quarters of root formation appear to progress more rapidly than the first (1970:143).

Sex Differences

When material can be sexed, allowance can be made for the fact that tooth development is very slightly but significantly more advanced in girls than in boys at all stages, even before puberty (Gleiser and Hunt, 1955; Garn et al., 1958). Garn et al. noted that the differences are of the order of 1 month in infancy, and 4 months at 9 years, and are slightly greater in respect to eruption than to tooth formation. These sex differences are, however, about three times less than those for osseous development over the same period so that, where material of unknown sex is concerned, estimates of age based upon the dentition are more likely to be correct than ones based upon osseous development. Sex differences amounting to about 3 percent for calcification are about the same as for the clinical eruption of teeth (5%). Both events thus represent smaller differences by sex than in bone development, where they amount to between 10 to 20 percent (1958:566).

Nolla (1960) observed that there were no significant differences in the rates of calcification in males and females, and that, on the average, there were no apparent differences in the general sequences of calcification between the sexes (1960:265).

Third Molars

The data published during the present century on the clinical eruption age of wisdom teeth give a wide range between 16 and 40 years. The most frequently reported age of gingival emergence for

wisdom teeth is the period between 17 and 21 years (Logan and Kronfeld, 1933).

The differences in the development of wisdom teeth between the sexes are not so clear as for the other teeth. Many researchers have detected no sex differences with respect to the emergence of the third molar (e.g. Steggerda and Hill, 1942). There are some researchers who have found boys to undergo an earlier eruption of this tooth than do girls (Fanning, 1962), and there are others whose observations place the girls first. On the other hand sex differences, though not marked ones, in the formation of the wisdom teeth have been noted by many researchers. According to Nolla (1960), girls experience the calcification process earlier. According to the findings of Demisch and Wartman (1956), girls are earlier in four of the six comparable calcification stages from the crypt to the initial root formation. By contrast, Garn et al. (1962a) observe that no significant sex differences occur during the entire period of development of the wisdom teeth "thus being unique among the teeth." (1962a:278)

Studies on the developmental age of the upper and lower wisdom teeth have reported the maxillary teeth to be more often earlier. However, calcification is observed by Demisch and Wartman (1956) to be generally symmetrical in 71 to 85 percent of the cases. The first radiographically visible calcification stage of a wisdom tooth occurs between the ages of six and thirteen years, the mean falling between nine and ten (Demisch and Wartman, 1956; Garn et al., 1962). At the age of 21 years, on the average, the root formation of the third molar is complete.

Genetic and Environmental Influences

Garn et al. (1960) compared three stages of calcification for all the teeth in sibling pairs and monozygotic and dizygotic twins in order to determine whether, and to what extent, tooth development shows evidence of genetic control. Their results show very low correlations between the sibling pairs and the dizygotic twins, but very high correlations (0.91) between the monozygotic twins. From these results Garn et al. conclude that the rate of tooth development is largely, though not entirely, under genetic control (1960:174). Nanda and Chawla (1966) conclude, on the other hand, that the retardation in root development seen in tropical zones is intimately related to nutritional status and environmental conditions and that the differences observed were not genetic but due to differences in nutritional status and health standards (1966:850).

Correlations of Tooth Formation to other Developmental Phenomena

The concept of physiological age is based upon the degree of maturation of different tissue systems. Several biological ages have been developed: skeletal age, morphological age, secondary sex character age, and dental age. These criteria can be applied separately or together to assess the degree of physiological maturity of a growing child. Dental age is of particular interest to the orthodontist in planning the treatment of different types of malocclusions in relation to maxillofacial growth. It can also be a help in determining the age of skeletal material where other parts of the body are miss-

ing.

Numerous studies have been published on the correlations between the formation of teeth and other developmental occurrences. In an investigation carried out with the Stuart material, Gron (1962) noted that "tooth emergence appears to be more closely associated with the stage of root formation than with chronological or skeletal age of the child" (1962:584). In the light of her data, most teeth erupt clinically when root development is three-quarters complete. Data on the correlation between tooth formation and skeletal development have been published by Lamons and Gray (1958), Lauterstein (1961), and Liliequist and Lundberg (1971). Lamons and Gray (1958:690) report that skeletal age and dental development vary independently. Lauterstein (1961) maintains that an intimate correlation exists between root age and bone age (1961:164). Liliequist and Lundberg (1971) found also that there was a high correlation (r=0.88) between tooth development and the skeletal age of the hand-wrist (1971:109). Lauterstein (1961:164) found that there was "an intimate developmental relationship between root age and bone age" with a rank order correlation as high as 0.437.

Investigating the relationship between tooth formation and other maturational factors, Lewis and Garn (1960) found that the correlation varies at different developmental stages and ages. "Tooth formation proved no more variable and often less variable than the age developmental variability of menarche, hand age or the appearance of the ossification centers." (1960:72) They also report a correlation, but not a high one, between dental development and skeletal development (r=0.40) at sexual maturity (1960:76).

Krogman (1968a,b,c) examined the criteria and correlations of biological maturation that have been applied in recently published studies. Considering the factors of skeletal age, dental age, calcification age, ossification, hand age, menarche, and the maximum of the growth spurt, he concludes that tooth formation age and menarche are best suited to the determination of biological maturation because they vary least. He observes further that the application of the tooth formation findings in any given population to other populations can in many cases be of doubtful validity. Hunt and Gleiser (1955) also agree that, "with increasing age, boys and girls diverge much more rapidly in skeletal maturation than in the development of the permanent teeth." (1955:482)

Several authors have asserted that the calcification stage of the teeth is a far more reliable criterion in estimating the dental age than is the clinical eruption of the teeth, which is far more liable to be affected by many external factors. According to Fanning (1961) "tooth formation is preferable to tooth emergence for assessing dental age because it is not influenced as markedly by exogenous factors; and a rating is possible at all times from birth until the completion of the third molar at about twenty years of age." (1961:203) Gleiser and Hunt (1955) and Liliequist and Lundberg (1971) suggest that the calcification of a tooth may be a more meaningful indicator of somatic maturation than its clinical emergence. This view is supported by Nanda (1960) who found only a low correlation between the age at complete emergence of the permanent dentition, the age at the maximum rate of the circumpubertal growth spurt in height in both sexes, and the age at menarche in girls. Moorrees et al. (1963) reported that

tooth formation is superior to tooth emergence for assessing dental maturation. They also suggested that it is dangerous to assess total maturation of the individual from any one tissue system, particularly the teeth, because it has not been established that there is a direct and strong correlation between tooth development and other indicators of individual maturation (1963:1490).

INDICES OF DENTAL MATURATION

Until quite recently, clinical eruption has been the only criterion used for dental maturity. Norms derived from Logan and Kronfeld's data (1933) as modified by Schour and Massler (1940b), as well as from Hurme's (1949) and Clements et al. (1953) data have been used extensively. If clinical emergence is used as the criterion for dental age assessment, it can only be applied after the age of six years for the permanent dentition.

Bean (1914) was among the first to use clinical emergence to derive a dental age. The teeth were scored according to the sequence in which they erupted. Matiegka (1921) used a similar method for scoring each group of teeth according to their sequence of eruption. Cattell (1928), using his own data, attempted to use both of the previous methods and found that they didn't give satisfactory results because there was often too much variation in the sequence of eruption. He found that an easier and more satisfactory method was just to count the erupted teeth without worrying about the sequence (1928:28-30). Steggerda (1945) also experimented with three different methods for determining dental age from the mean age of eruption for

each tooth. He concluded as well, that the best method was just to count the teeth that were present. He found that "practically the same correlations were achieved as with the more elaborate methods." (1945:341)

Nolla (1960) was the first to use the developmental value obtained for each tooth to derive a dental age. The values for each tooth were added together and the sum for each arch was matched with a table for the tabulation of the dental age. Demirjian and Tanner (1973), used the approach of Tanner et al. (1962) to give each tooth a score depending on its stage of calcification. The scores on all the teeth were then added together to give a total maturity score which could be converted directly into a dental age, using an appropriate table of standards. Nevile (1973) utilized the mean age values for each tooth stage derived from his sample, to calculate a dental calcification age for each subject. The sum of all the mean ages corresponding to the tooth stages recorded for the subject were divided by the number of mean ages considered (1973:43).

GINGIVAL EMERGENCE

More than any other matter related to dental development, the clinical eruption of teeth has commanded the attention of research workers. Cumulative incidence curves representing the percentage of children at each age with a given tooth erupted have been drawn by various authors in cross-sectional surveys (Cattell, 1928; Hellman, 1943; Clements et al., 1953a; Hurme, 1948, 1949).

Many investigators have observed the existence of differences