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Shifts in tooth maturation patterns in non-French Canadian boys

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Summary. *Aims*. This study was designed to evaluate the predictability of dental maturation patterns in non-French Canadian boys using the maturation curves developed by Demirjian & Goldstein [1].

Sample. Archival cephalometric radiographs taken during a longitudinal study (1930–1960) of Caucasian Americans were re-evaluated.

Methods. Maturation of the permanent teeth on the left side of the mandible was determined according to the methods described by Demirjian & Goldstein.

Results. Of the 79 boys studied, 12 (15·2%) started below Demirjian's median and continued as such during the maturation process. Seven (8·9%) started within the second standard deviation above Demirjian's median and continued as such during the maturation process. The remaining 60 boys (75·9%) started below the median of Demirjian's curves at an early age. They matured at a rate that placed them above the median value at the end of the study period. The shift took place before the age of 6 years in 46 (76·6%) cases and between the ages of 6 and 8 years in another nine (15%) cases. In five of the cases which started below Demirjian's median (8·3%) the shift only took place after the age of 9 years.

Conclusion. The shift from below median to above median value was considered an important factor in treatment planning. The data indicate that there is considerable risk for treatment planning prior to the age of 8 years. The risk is highest when the children are less than 6 years of age due to growth prediction uncertainties.

Review of the literature

Treatment planning can only be done satisfactorily if prediction of tooth maturation and eruption is accurate. Several different investigators have attempted correlation of tooth eruption, tooth maturation and chronological age [2].

The wide range of development observed for children at any given age means that chronological age often precludes precise assessment of dental maturation that can be used in predictive clinical diagnosis and subsequent treatment planning. While environmental factors play a role in tooth emergence following the premature loss or dental treatment of antecedent primary teeth [3,4], genetic factors must also be considered [5–7]. Moorrees & Kent [8] demonstrated a remarkable similarity in timing of crown formation and root formation stages in identical twins when compared with dizygotic twins in the study of 414 pairs of twins. This illustrated genetic influence. When dental maturity in children in different geographic areas of Finland was compared, dental age in a community with a fairly homogeneous population differed from that in a more heterogenous community [9]. While different methods of studying the radiographic appearance of teeth during development have been proposed and are in use, it is important that the method used shows precision, reliability and accuracy.

Few studies exist comparing different methods of assessment of dental maturity because very few researchers have access to large collections of serial radiographs. Hagg & Matsson [10] concluded that

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the precision of methods can vary with age; a problem that may have an impact in treatment planning.

A better understanding of the developmental process has resulted from radiographic studies and with better reproducibility than using methods relying on timing of eruption, because different researchers interpret eruption very differently. One group considers eruption to be the time of piercing of the gingiva (a very difficult moment to determine with precision), others consider it to be the time of occlusal alignment [11]. Some researchers have studied the question of 'fast' and 'slow' eruption patterns using emergence as the criteria, and have reported difficulty in obtaining accuracy with this method [12].

Evaluation of tooth maturation using the method of Demirjian & Goldstein [1] is thought to be of value. Hagg & Matsson [10] compared the reliability of three different methods for the assessment of dental maturity and concluded that the method described by Demirjian & Goldstein [1] affords a high degree of reliability and precision, particularly in younger children.

Previous studies in our laboratory [13] indicated that, in girls, there was a faster maturation than was indicated by Demirjian's composite curves in 11·1% of cases, while 19·4% progressed more slowly than did Demirjian's sample. Evaluation of our data demonstrated that most girls in this sample matured at a faster rate than the children evaluated by Demirjian & Goldstein [1].

Demirjian & Goldstein [1] established maturation percentiles and developed graphs for both sexes using chronological age as the abscissa and quadrant score as the ordinate. Separate graphs were plotted for boys and girls. The data obtained in our study were plotted similarly so as to obtain a separate growth pattern evaluation for each patient.

The purpose of this study was to evaluate the predictability of dental maturation patterns in non-French Canadian boys using the maturation curves developed by Demirjian & Goldstein [1] in a French Canadian population. Archival cephalometric radiographs of Caucasian American boys that were prepared during a longitudinal study (1930–1960) were the source of our data.

Methods

The data for the study were collected from duplicates of serial cephalometric radiographs of male patients from the study files of the Department of Orthodontics of the College of Dentistry, University of Illinois. Use of this material was approved by the Institutional Review Board for Human Studies. These radiographs were obtained by Dr John G. Crawford from the collection at the Child Research Council, University of Colorado School of Medicine, Denver, Colorado [14]. The original longitudinal study was started in 1930 and many of the patients were followed for more than 20 years. The Caucasian Americans were examined soon after birth and annually thereafter. Cephalometric radiographs were taken at each examination. In almost all cases the dentition was complete for the duration of the study. In a few cases, some teeth were extracted when orthodontic treatment was initiated. When dental agenesis occurred the cases were excluded. A few small amalgam restorations were present in some of the patients, but most had little dental pathology. All interpretations and evaluations of tooth maturation were performed by the same investigator to assure consistency. Only cases where multiple radiographs were available were studied. Cases where radiographs were taken before the third birthday of the child as first records were the cases of choice. Because the medical histories of the children were not available there was no possibility of excluding patients with systemic diseases. To compensate for the lack of health histories, eight to 10 radiographs were evaluated in most cases. Patients with fewer than five radiographs in the series were excluded.

The method used for scoring dental age was that described by Demirjian & Goldstein [1]. The stages of development of each tooth were defined according to the maturity of the crown and root. A total of eight stages (A–H) for each tooth based on the degree of calcification and root formation were defined. Stage A in both uniradicular and multiradicular teeth is defined as the start of calcification at the most occlusal part of the crypt in the form of a small inverted cone. Stage H is defined as the stage in which the apical end of the root is complete and the periodontal membrane has a uniform width around the root and its apex. The intermediate stages establish a continuum.

After each tooth was evaluated and given a letter score, the letters were translated into numerical scores derived from Demirjian's standard tables. For uniformity, all the teeth of the lower left quadrant with the exception of the third molars

were used in this study. The numerical score for the quadrant was the sum of the scores of the teeth evaluated. This number is converted into a dental age score using the appropriate table.

Results

Of the 79 boys studied, seven (8·9%) started the maturation process above the median value of Demirjian's curves and continued as such during the maturation process. Another 12 boys (15·2%) started the maturation process below Demirjian's median value and continued as such during the maturation process. The remaining 60 boys (75·9%) started below the median of Demirjian's maturation curves at an early age but then matured at a faster rate than the French Canadian sample, which placed them above the median value at the end of the study period. When these 60 cases were evaluated it was noted that the shift in maturation status took place before the age of 6 years in 46 (76·6%) cases, and before the age of 9 years in another nine (15%) cases. In five boys (8·3%) the shift took place after the age of 9 years (Table 1, Figs 1 & 2). The shift from below the median value to above the median value was thought an important aspect to be considered in treatment planning of young patients. Figures 3 and 4 show calculated dental maturation scores plotted against chronological age for two patients. These curves are plotted on Demirjian's grid and show Demirjian's percentile curves.

Discussion

There is agreement among authors that children of the same chronological age can present great variation in maturation. Grøn [2] compared dental eruption and chronological age and concluded that tooth emergence was more closely related to dental root development than to skeletal or chronological age. She felt that timing for serial extractions should be based on root development because this would be the best indicator of maturity.

Currently there is emphasis on avoidance of unnecessary dental therapy and the need to max-

Table 1. Age at which mean development was achieved in our sample of Caucasian American boys.*

Age (years)	*n*
2·7–4	8 (13·3%)
4·1–5	16 (26·7%)
5·1–6	22 (36·7%)
6·1–7	6 (10·0%)
7·1–8	3 (5·0%)
8·1–9	1 (1·7%)
>9·1	4 (1·7%)

*Twelve boys remained below the mean throughout maturation and seven boys were above the mean throughout maturation.

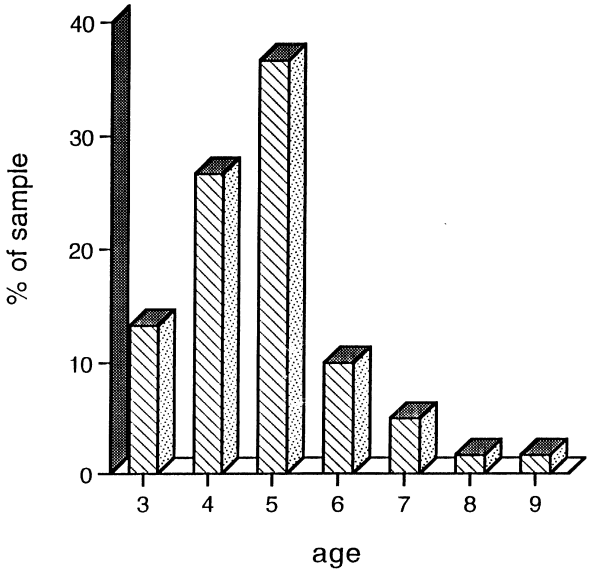

Fig. 1. Percentage of sample achieving mean development each year according to Demirjian & Goldstein's tables.

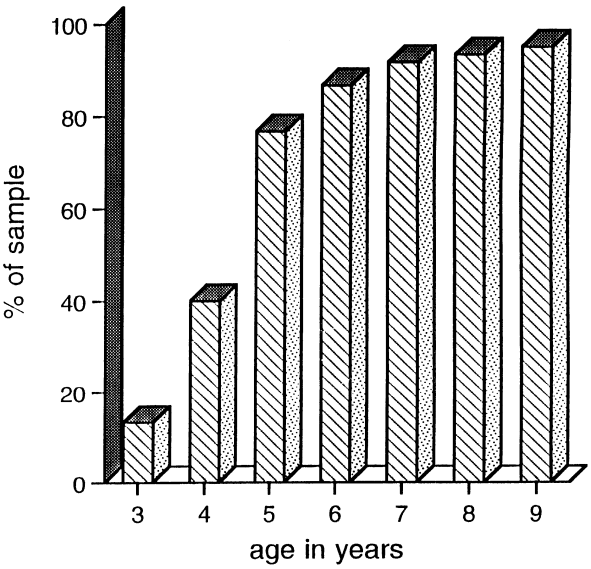

Fig. 2. Cumulative percentage of sample achieving mean development according to Demirjian & Goldstein's tables.

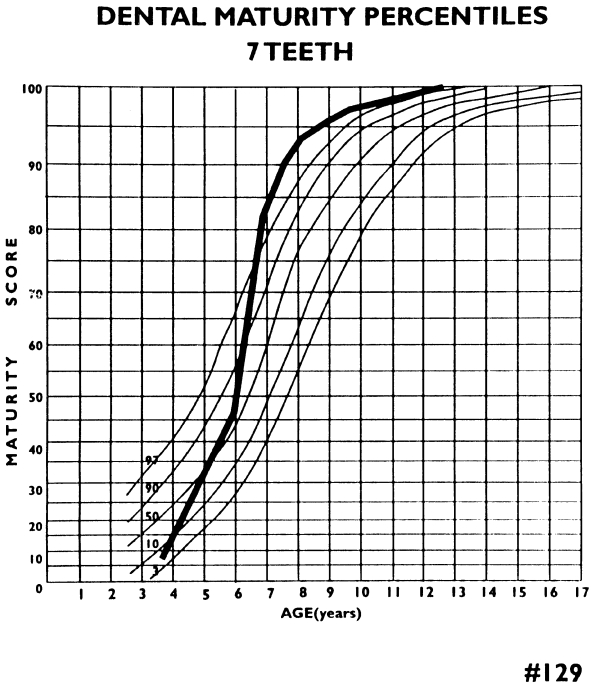

Fig. 3. Patient #129 shows dental maturation scores below the 10th percentile under the age of 4 years. The maturation curve crossed the 50th percentile line at the age of 5 years and the 90th percentile curve between the ages of 6 and 7 years.

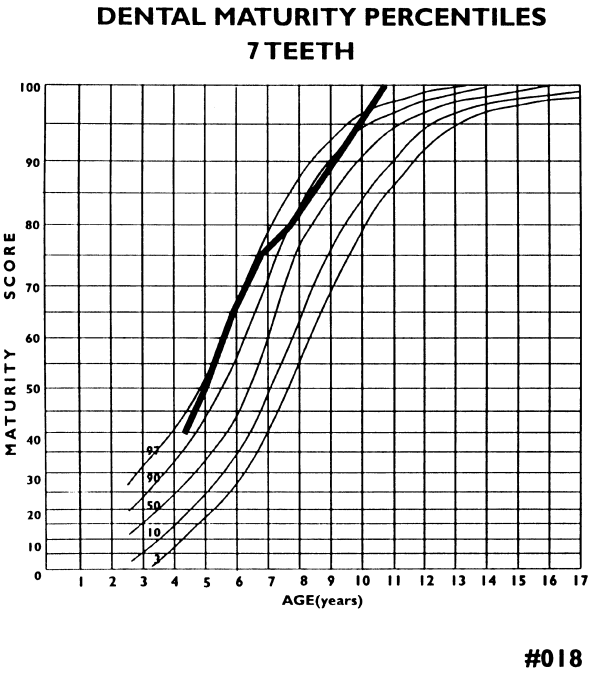

Fig. 4. Patient #18 presented at the age of 4 years at the 90th percentile and was in the 97th percentile when aged 5 and 6 years. The patient stayed at that percentile until shortly before the age of 7 years, when the maturation rate curve dropped slightly but continued on the upper part of Demirjian's system curves.

imize the effectiveness of therapy given. This is partly to be careful of resource allocation. To achieve this, it is important to focus the time of treatment to take advantage of developmental and growth changes, both during and after the period of therapy. Distinguishing between favourable and unfavourable developmental conditions is required in order to establish guidelines for treatment planning in the mixed dentition, to project future developmental trends and to recognize the most favourable time for clinical intervention. In some instances failure to recognize individual developmental pattern variations or trends may result in unnecessary treatment for the patient. However, oversimplification and lack of recognition of unfavourable patterns may also affect the outcome. To this end it is necessary to know the reliability of a predictor of patient growth and development and how this predictor should be applied in individual cases, particularly since, in most cases, only limited longitudinal data for each patient is available. By using radiographic methods it is possible to standardize the evaluation process and obtain a better understanding of the growth changes occurring in patients. Several chronological dental eruption tables have been prepared and these have demonstrated that eruption varies greatly from individual to individual, between genders and also among different population groups [9,15–17].

Availability of longitudinal records is a major aid in monitoring the development of the individual. Only longitudinal studies can provide sufficient data for understanding of the maturation process in patients.

The reason for this study was to attempt to predict maturation patterns in order to distinguish slow and fast maturers. Evaluation of the data demonstrated that most boys in our sample did not follow the maturation rate of the French Canadian boys evaluated by Demirjian & Goldstein [1]. Our sample matured at a faster rate. Whether these findings are due to a combination of all teeth in the arch or whether rules determining maturation act independently for each tooth in the arch, creating specific parameters and maturation rates, remains to be ascertained.

In view of the present recommendations for radiation exposure, annual radiography of patients solely for gathering research data is not justified. Therefore, we used previously collected data. Some of the sample predates Demirjian's sample while

some overlaps part of it. If the differences between our sample and Demirjian's sample were due only to the time at which they were collected, the predicted shift from Demirjian's results would have been in the opposite direction to that found.

Further studies on intra-individual variations should also demonstrate correlations in dental development that could be useful in treatment planning.

Findings in a cross-sectional study demonstrating that Finnish children were more advanced in dental maturation than French Canadian children have been published [9]. Because the data reported the development stages at age 9·5 years, it is not possible to determine if a shift in maturation rate had ever been present in this sample. Hagg & Matsson [10] noted in their study of different methods of assessment of dental maturation that Demirjian's method is more accurate at younger ages than when older Swedish children are evaluated. Possibly there is a shift in this population toward a faster maturation (similar to the one found in the present sample), which could interfere with the standards proposed by Demirjian. Our data indicate that there is considerable risk in predicting growth for treatment planning prior to the age of 8 years. The risk is highest in children below the age of 6 years.

Resumé. *But*. Evaluer la prédictibilité des schémas de maturation dentaire chez des garçons canadiens non-français à l'aide des courbes de maturation mises au point par Demirjian et Goldstein (1).
Echantillon. Des radiographies céphalométriques d'archives prises pendant une étude longitudinale (1930–1960) d'américains caucasiens ont été étudiées à nouveau.
Méthodes. La maturation de dents permanentes du côté gauche de la mandibule a été notée selon les méthodes décrites par Demirjian et Goldstein.
Résultats. Parmi les 79 garçons étudiés, 12 (15·2%) commençaient en deçà de la médiane de la courbe de Demirjian et continuaient de même pendant tout le processus de maturation. Sept (8·9%) commençaient à deux déviations-standart au delà de la médiane de Demirjian et continuaient de même pendant le processus de maturation. Les 60 autres (75·9%) commençaient en deçà de la médiane de la courbe de Demirjian dans leur petite enfance. Ils maturaient à un rythme qui les situait au delà de la valeur médiane à la fin de la période d'étude. Le changement se situait avant l'âge de six ans dans 46 cas (76·6%) et entre l'âge de six et huit dans neuf autres cas (15%). Dans cinq de ces cas, qui commençaient en deçà de la médiane de Demirjian, le changement prenait place après l'âge de neuf ans.
Conclusion. Le changement de en deçà à au delà de la valeur médiane a été considéré comme un élément important dans le plan de traitement. Il y a un risque important à établir un plan de traitement avant l'âge de huit ans. Le risque est le plus important quand les enfants ont moins de six ans en raison des incertitudes dans la prédiction de croissance.

Zusammenfassung. *Ziele*. Diese Studien möchten das Vorausbestimmen der dentalen Maturation bei kanadischen Knaben nicht französischer herkunft, zu finden, zu diesen Zweck wurden die Maturationskurven von Demirjian und Goldstein angewendet.
Material. Fernröntgenbilder aus dem Archiv einer longitudinalen Studie (1930–1960) von weissen Amerikaner wurden wieder beurteilt.
Methode. Die Maturation von bleibenden Zähne der rechten Seite der Mandibula wurde bestimmt mittels der Kurven der oben genannter Autoren.
Resultate. Von den 79 Knaben 12 (15·2%) begannen unter der Demirjian Mediane und blieben so während des Maturationsprogress. 7 (8·9%) begannen innerhalb der zweiten Standart Abweichungen, oberhalb der Demirjiam Mediane und blieben dort während des Maturationsprozesses. Die restlichen 60 (75·9%) begannen unter der Mediane der Demirijanischen Kurven in einen frühen Alter. Sie maturierten in einen Mass dass sie, am Ende der Studienperiode, oberhalb der Mediane plazierte. Der Uebergang, fand statt in 46 Fälle (76%), vor dem 6. Lebensalter, und zwischen 6 und 8 Jahren in weiteren 9 Fälle (15%). Bei 5 Fälle (8·3%) welche auch unter der Mediane begannen, fand der Uebergang erst nach den 9. Lebensjahr statt. Der Uebergang von unter der Mediane zu oberhalb der Mediane wurde als wichtiger Aspekt, bei der Therapieplanung gewertet. Demzufolge ist es riskant diese Planung vor den 8. Lebensjahr zu beginnen. Dieses Risiko ist am höchsten wenn die Kinder weniger als 6 Jahre alt sind, wegen der Unsicherheiten der Wachstumsprognose.

Resume. *Objetivos*. Este estudio se diseñó para evaluar la capacidad de predicción de los patrones de maduración dental en niños canadienses no franceses usando las curvas de maduración desarrolladas por Demirjian y Goldstein.

Muestra. Se volvieron a evaluar radiografias cefalométricas de archivo tomadas durante un estudio longitudinal (1930–1960) sobre americanos caucásicos.
Métodos. La maduración de los dientes permanentes en el lado izquierdo de la mandibula se determinó según los métodos descritos por Demirjian y Goldstein.
Resultados. De los 79 niños estudiados, 12 (15·2%) empezaron por debajo de la media de Demirjian y continuaron así durante el proceso de maduración. Siete (8·9%) empezaron en la segunda desviación estándar por encima de la media de Demirjian y continuaron así durante el proceso de maduración. Los restantes 60 (75·9%) empezaron por debajo de la media de las curvas de Demirjian a una edad temprana. Maduraron a un ritmo que les colocó por encima del valor medio al final del periodo de estudio. El cambio tuvo lugar antes de la edad de seis años en 46 (76·6%) casos y entre las edades de seis y ocho años en otros nueve casos (15%). En cinco de estos casos que empezaron por debajo de la media de Demirjian (8·3%) el cambio sólo tuvo lugar después de la edad de nueve años.
Conclusión. El cambio desde un valor por debajo de la media hasta ostro por encima de la media se consideró como un aspecto importante en el plan de tratamiento. Este dato indica una caracteristica importante del plan de tratamiento; hay un riesgo considerable cuando el plan de tratamiento es anterior a la edad de ocho años. El riesgo es más alto cuando los niños son menores de seis años debido a la incerteza en la predicción del crecimiento.

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