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Relationship between mandibular second molar calcification stages and cervical vertebrae maturity in Italian children and young adults

ABSTRACT

Aim *The aim of this study was to investigate the relationship between the stages of calcification of the mandibular second molar and the stages of skeletal maturity among Italian children and young adults.*
Materials and Methods *Cross-sectional descriptive study. The samples were derived from panoramic radiographs and lateral cephalograms of 500 Italian subjects aged from 10 to 20 years. Dental maturity index (DM) was assessed by calcification stages of the mandibular second molars according to the Demirjian method; skeletal maturity was evaluated with cervical vertebrae maturation index (CVM) according to Hassel and Farman. The Pearson r coefficient and Spearman rank correlation coefficient were estimated to determine the relationship between DM and CVM.*
Results *Skeletal maturation stages occurred earlier in females (about 6 months). A highly significant correlation between CVM and DM (0.78-0.86 cor according to Pearson test and 0.81-0.85 rho according to Spearman test) was found. DM stage E corresponds to phase CVM 1 and 2 (the phase prior to the growth spurt), DM stage F corresponds to the phase of pubertal growth spurt, stages CVM 2 and CVM 3; DM stage G is indicator of the growth spurt underway (CVM 3-4), but it can still be found during CVM 5 in females.*

Conclusion *The second mandibular molars can be considered reliable indicators for the evaluation of the growth phases. In case of females the end of the growth spurt it is not clearly associated with a dental maturity stage and needs to be stated with further parameters such as CVM.*

Keywords *Skeletal maturity; Cervical vertebrae; Mandibular second molar; Children; Young adults.*

Introduction

A reliable and precise assessment of skeletal maturity is very important in planning treatments for dental and maxillofacial anomalies. The clinician must be able to identify the period of growth spurt of the individual in order to plan the best therapy. Understanding whether a patient already underwent the puberty growth spurt or whether he/she must still experience it, is a basic parameter for a correct treatment choice. Sometimes the whole treatment depends on the growth factor [Björk and Helm, 1967; Björk, 1972; Moore et al., 1990]. An individual may experience skeletal growth in times and manners that can be very different to others. Almost every person shows the same skeletal growth patterns, but the start and the amount of growth vary considerably. With this in mind, it is more appropriate to talk about physiological growth, rather than chronological age. Physiological age is the rate of progress toward maturity and is measured by different parameters (somatic, gender-related, skeletal and dental maturity) [Sierra, 1987; Demirjian et al., 1985]. Somatic characteristics (height and weight increase) and gender-related features (menarche and voice break) have been shown to be unreliable and impractical when estimating the pubertal growth spurt [Fishman, 1979; Fishman, 1982].

Nowadays the assessment of skeletal maturity through observation of the developing bones is the most utilised method [Grave, 1994; Pasciuti et al., 2013]. Hand-wrist radiographs appear to be the most used exams, but they also involve exposure of a young patient to further radiation. The appropriateness of an increase in radiation exposure due to these x-ray exams has been and still is under discussion (British Orthodontic Society Guidelines) [Flores-Mir et al., 2004]. In recent years, the preferred method has been the analysis of the cervical vertebrae, obtainable through the lateral cephalogram. Such method is now widely spread, since it is a commonly used radiograph in orthodontic diagnostics [Mittal et al., 2009; Hassel and Farman, 1995; Baccetti et al., 2001].

Dental maturity index (DM) is also an indicator of the biological maturity of growing children [Coutinho et al., 1993; Perinetti et al, 2012]. The classification by Demirjian et al. [1973] has been in use for many years now, with a distinction of up to 8 different groups (A-H), based on the stage of calcification.

The calcification stage of individual teeth has already been associated with skeletal maturity in hand-wrist bone analysis and cervical vertebrae [Baccetti et al., 2007; Flores-Mir et al., 2005] showing a strong correlation considering second molars [Mittal et al., 2009; Valizadeh et al., 2012; Uysal et al., 2004; Kumar et al., 2012; Krailassiri et al., 2002]. However, there is evidence of significant alterations due to racial and environmental characteristics among different populations [Mack et al., 2013; Başaran et al., 2007; Mappes et al., 1992]. The ease of recognising dental developmental stages, together with the availability of intraoral or panoramic radiographs in most orthodontic or paediatric dental practices, are reason for attempting to assess physiologic maturity without resorting to hand-wrist radiographs.

The aim of this study is the analysis of the relationship of various calcification stages of the second molars with the skeletal maturity stages, by means of an analysis of the cervical vertebrae maturation index (CVM) in a group of Italian children and young adults.

Materials and methods

This study was designed as a cross-sectional descriptive study.

The samples were derived from dental panoramics and lateral cephalograms of 500 subjets scheduled at the Unit of Orthodontics and Paediatric Dentistry of the University of Milan, Italy.

The selection criteria were: only Italian subjects; no genetic deformities; no agenesis, no transposition, no infraocclusion; no previous orthodontic treatment; no history of facial trauma; no previous extraction of permanent teeth; interval between the lateral cephalogram and the panoramic radiograph not exceed 1 month.

We obtained a sample of 403 Italian subjects (196 female and 207 male) aged from 10 to 20 years. A total of 806 radiographic images were evaluated.

Assessment of dental calcification stage

Tooth calcification was rated according to the method described by Demirjian et al. [1973] in which one of the 8 stages (from A to H) is assigned.

Assessment of skeletal maturation

CVM was determined according to Hassel and Farman [1995] considering 6 stages from 1 to 6. This method depended on the anatomical changes of three vertebrae (C2, C3 and C4) considering their inferior border (presence of a concavity at C2, C3, C4) and the differences in shape of their body (trapezoid, rectangular horizontal, square, rectangular vertical).

Statistics

The examinations were undertaken by 2 different orthodontists, without any knowledge about the chronological ages of the subjects. In order to test the reproducibility of the assessments, 15 panoramic and lateral cephalograms were re-evaluated by the same two investigators 4 weeks after the first evaluation. Intra-observer and inter-observer differences were statistically tested (Kappa statistic for concordance). Descriptive statistics were done by determining means and standard deviations of the chronological ages for the six stages of CVM. Frequency and percentage distribution of the stages of calcification were evaluated separately for males and females. The Pearson r coefficient and Spearman rank correlation coefficient were estimated to determine the relationship between DM and CVM.

Results

The reproducibility of all the assessments was very good. As inter-observer agreement, the weighted kappa statistics were 0.86 for DM assessments and 0.85 for CVM. The kappa statistics for intra-observer agreement were 0.97 for DM assessments and 0.94 for CVM. The main skeletal maturation (CVM 2-5) appeared to occur remarkably earlier in females (about 8-9 months). In particular, considering stage 3 the mean chronologic age was 13.12 years for female and 13.97 for male individuals; in stage 4 it was 14.02 and 14.92

CVM Stage	gender	n. of subjects	mean	SD
Stage 1	Male	19	10.38	0.40
	Female	19	10.43	0.37
Stage 2	Male	37	11.78	1.13
	Female	28	11.07	0.57
Stage 3	Male	48	13.97	0.67
	Female	33	13.12	1.10
Stage 4	Male	44	14.92	0.73
	Female	47	14.02	1.02
Stage 5	Male	38	16.27	1.04
	Female	43	15.51	0.89
Stage 6	Male	21	18.30	1.07
	Female	26	17.92	1.19
Total		403	207	196

TABLE 1 Distribution of chronological ages and gender for all subjects grouped by CVM stages.

CVM Stage	DM Stage					
	D	E	F	G	H	TOTAL
Stage 1	3	13	2	1	\	19
%	16%	68%	11%	5%		
Stage 2	6	15	11	5	\	37
%	16%	41%	30%	14%		
Stage 3	2	1	11	31	3	48
%	4%	2%	23%	65%		
Stage 4	\	\	3	36	5	44
%			7%	82%	11%	
Stage 5	\	\	\	15	23	38
%				39%	61%	
Stage 6	\	\	\	3	18	21
%				14%	86%	207

TABLE 2 Association between CVM stages and DM stages for males.

CVM Stage	DM Stage					
	D	E	F	G	H	TOTAL
Stage 1	\	17	2	\	\	19
%		89%	11%			
Stage 2	\	18	8	2	\	28
%		64%	29%	7%		
Stage 3	\	1	9	23	\	33
%		3%	27%	70%		
Stage 4	\	\	7	40	\	47
%			15%	85%		
Stage 5	\	\	\	27	16	43
%				63%	37%	
Stage 6	\	\	\	3	23	26
%				12%	88%	196

TABLE 3 Association between CVM stages and DM stages for females.

for females and males respectively (Table 1). Again, the higher the DM stage, the higher the CVM stage. Stage E included the highest percentage distribution (68%) at stage 1 of the CVM. In stage 2 of CVM classification there were a higher level for class E (41%) and a growing percentage for class F (30%); G were predominant for CVM stage 3 (65 %) and even more for stage 4 (82%). Stage H displayed a high percent distribution with stage 5 (61%) and 86% distribution with CVM stage 6 (Tables 2, 3).

From Table 3 it is clear that lower CVM stages were more frequently associated with lower DM stages. Conversely, the higher the CVM stage, the higher the DM stage for female individuals.

Moreover, there is an important difference considering CVM stage 5: in males stage 5 is related with the H stage when in females the second molar seems to be still in the G stage. This means that when the female has already passed her pubertal growth spurt (CVI stage 5), the second molar still requires more time to go through the stage H of development.

Table 4 (*P<0.005) shows the correlation indexes between CVM and DM, chronological age and DM, chronological age and CVM. We confirm the higher correlation (Pearson and Spearman test) considering CVM and the age of the individual for male and female with 0.92 and 0.91 values.

A high correlation was found also for the association between chronological age and DM (0.82-0.86 cor and 0.84-0.86 rho).

Also the correlation between CVM and DM (0.78-0.86 cor and 0.81-0.85rho) was found a little lower but still with significant statistical values.

CVM and DM			
PEARSON (cor)		SPEARMAN (rho)	
M	F	M	F
0.78	0.86	0.81	0.85
Chronological age and DM			
PEARSON (cor)		SPEARMAN (rho)	
M	F	M	F
0.82	0.86	0.84	0.86
Chronological age and CVM			
PEARSON (cor)		SPEARMAN (rho)	
M	F	M	F
0.92	0.91	0.92	0.91

TABLE 4 Pearson and Spearman correlation coefficients between CVM, DM and chronological ages in males and females.

Discussion

Identification of the pubertal growth spurt during orthodontic treatment is essential for the set-up of a correct treatment plan and optimal correction of dental-skeletal problems [Björk and Helm, 1967; Björk, 1972; More et al., 1990].

Various methods for the identification of the most adequate moment for an intervention have been devised so far, taking advantage particularly of the growth spurt of the patient. We have taken into consideration the one suggested by Hassel and Farman [1995], based on the analysis of the cervical vertebrae. On the other side, a correct evaluation of the vertebrae can only be obtained following a lateral cephalogram of the skull, which is therefore to be considered as an additional radiograph and an exposure to x-rays which could sometimes be avoided. In this regard we wish to mention here the ALARA principle ("as low as reasonably achievable"), and the growing interest in trying to reduce the risk of radioactive exposure.

The possibility to determine the stage of skeletal maturity based upon the teeth development could therefore be considered an easily applicable method, implying a reduced radioactive exposure and very helpful in common medical practice [Coutinho et al., 1993; Perinetti et al., 2012; Baccetti et al., 2007; Flores-Mir et al., 2005; Valizadeh et al., 2012; Uysal et al., 2004; Kumar et al., 2012; Krailassiri et al., 2002; Mack et al., 2013; Başaran et al., 2007].

We used the classification of dental maturity of the Demirjian method. This method evaluates shape and development phase of the roots without taking into consideration any numeric measurement parameters which could be possibly altered by projections by the x-rays [Demirjian et al., 1973; Demirjian et al., 1985].

Various studies have already proven the correlation between skeletal development and DM, showing different correlation depending on the teeth considered [Coutinho et al., 1993; Perinetti et al., 2012; Baccetti et al., 2007; Flores-Mir et al., 2005; Valizadeh et al., 2012; Uysal et al., 2004; Kumar et al., 2012; Krailassiri et al., 2002; Mack et al., 2013; Başaran et al., 2007].

To this effect, it has been highlighted a strong correlation when taking into account the maturity of the second mandibular molar. This factor has been assessed on groups of individuals with precisely defined ethnic and racial as well as social characteristics. This has not been considered yet in a population such as the one we analysed. This is an important element, because racial differences can influence the skeletal growth and/or the dental maturity in a significant way.

We decided to analyse the second mandibular molar because in our opinion the other teeth are subject to various possible restrictions. In particular, canines are for instance teeth that will often appear to have a completely formed root at the chronological age of about 13: the skeletal growth of both males and females often takes place around those years and also after such time span, until the age of 15-16 years [Coutinho et al., 1993; Baccetti et al., 2008; Engström et al., 1983; Ró żyło-Kalinowska et al., 2011]. The second molars are on the other side also teeth that tend to complete their development around the age of 16-17, the age range that includes also the pubertal growth spurt. The choice of the lower arch is due to an easier overview of the structural anatomy of the second molar roots: in the upper arch the development of the roots appears more difficult to identify, due to their overlapping with other anatomical structures such as the maxillary sinuses, the palate, etc. We have chosen to assess the root calcification instead, since the eruption phase can be highly influenced by various environmental factors, which do not alter the root mineralisation in a significant way. The analysis of the roots growth is therefore to be considered as a more reliable method, being also less susceptible to variations.

As already reported in other studies, it has been confirmed that the skeletal development in females tends to take place considerably earlier than in males [Coutinho et al., 1993; Perinetti et al., 2012; Baccetti et al., 2007; Flores-Mir et al., 2005; Valizadeh et al., 2012; Uysal et al., 2004; Kumar et al., 2012; Krailassiri et al., 2002; Mack et al., 2013; Başaran et al., 2007].

A very important aspect that emerges from this study is the fact that males tend to have a more advanced dental maturity development compared to the one found in females, considering the same CVM. This factor appears to be very relevant when considering in particular the vertebral development 5: in males this phase takes place on average more than seven months later than in females; moreover, in this phase the dental maturation of the second molar is mostly associated with phase H in males compared to females, where the second molar is still under formation and can therefore be identified as phase G (Table 2, 3). This difference is fundamental. In all subjects the growth spurt (CVM 3-4) is associated to phase G of dental maturation; in females, where the spurt occurs earlier compared to males, in the following phase CVM 5 there are still the second molars in phase G. Subsequently, if for males phase CVM 5 (end of the growth spurt) is correlated also with the complete dental maturation of the second molar (phase H), in females such association is not as reliable, resulting in a less precise identification of the growth spurt on the basis of dental maturation.

In order to stress the importance of this factor and also the relevance of ethnic and social diversities, one needs only to consider these data in comparison with the elements reported in other examined groups:

a) among the Indian population phase CVM 5 is significantly associated to DM H [Krailassiri et al., 2002];
b) among the Turkish population phase CVM 5 is associated equally to DM G and H [Kumar et al., 2012];
c) among the Polish population phase CVM 5 in females shows a ratio similar to the one described also in our study, but it defines a balance between DM G and H in male individuals [Różyło-Kalinowska et al., 2011];
d) among the Chinese population male individuals show a predominance of DM G in phase CVM 5 [Chen et al., 2010].

This is what emerges as important in our study, which included a representative group of the Italian population. From a statistical point of view, our study found a good correlation between DM of the second molar and CVM index (Table 4), both through the Pearson (0.78-0.86) and Spearman tests (0.81-0.85). To this effect we can confirm the possibility to obtain reliable information concerning the stage of skeletal growth of a given individual by mean of assessment of root maturity of the second lower molar. This study also shows how phase H is mainly associated with CVM 5 and 6 (only 5 individuals have a dental index H in CVM 4). This can therefore be considered a useful and highly reliable parameter which can help assess whether an individual is past the growth spurt, thus assuming there will be a limited or completed growth.

Conclusion

Staging of skeletal development through the CVM index shows and confirms a considerably more precocious growth (about 6-7 months) in females.

Statistically it appears to be a significant correlation (cor 0.78 for males and 0.86 for females, rho 0.81 for males and 0.85 for females) considering DM and CVM stages. DM stage E corresponds in all subjects to phase CVM 1 and 2 (the phase prior to the growth spurt), DM stage F corresponds to the phase right around the beginning of the pubertal growth spurt, stages CVM 2 and CVM 3, DM stage G is highly significant as indicator of the growth spurt underway (CVM 3-4), but it is important to point out that it can still be found during CVM 5 in females, while DM stage H relates to the end of the pubertal growth spurt both in males and females.

The second mandibular molars can therefore be seen as reliable indicators for the evaluation of the growth phases, bearing in mind that, in the case of females, when trying to identify the end of the growth spurt it is necessary to assess the dental maturity in association with further parameters such as CVM.

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