CORRELATION AMONG CHRONOLOGICAL AGE, DENTAL AGE AND CERVICAL VERTEBRAE MATURITY IN ROMANIAN SUBJECTS

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CORRELATION AMONG CHRONOLOGICAL AGE, DENTAL AGE AND CERVICAL VERTEBRAE MATURITY IN ROMANIAN SUBJECTS (Abstract): Aim: The purpose of this study was to assess the correlation among the chronological age, the dental age and the skeletal maturity in adolescents and young adults. Materials and methods: The material consisted of panoramic and lateral cephalometric radiographs of 221 subjects, 146 girls (mean age 13.79 ±2.90) and 75 boys (mean age 13.46 ±2.82), inhabitants of Mures County (Central Romania). The chronological age was defined as the time from birth to the day the radiographs were taken. The dental age was evaluated according to Demirjian’s method for third molars mineralization stage. Skeletal maturity was evaluated on cephalometric radiographs using the cervical vertebrae maturation (CVM) method. Descriptive statistical and linear regression analysis was performed and a coefficient of correlation was calculated. Results: The mean values obtained for cervical stages for boys and girls were significant (p=0.0171). The third molar mineralization seems to be highly correlated with the gender’s chronological age for the whole group and for both genders as well (p<0.0001). The medium age of the cervical maturation showed to be younger in girls than in boys in CS1, CS3, CS5 and CS6 stages. In CS4 stages female subjects are in advance with almost 12 months, these subjects start (CS1) and end (CS6) the cervical maturation at a younger age. Conclusions: The results indicate that significant correlation exist between the chronological age and the dental age when crown development ends and between the chronological age and CVM (CS1 and CS6 stages for girls and CS2 and CS5 stages for boys). Keywords: DENTAL AGE, CERVICAL MATURITY, DEMIRJIAN INDEX, CHRONOLOGICAL AGE, MOLAR MINERALIZATION.

The assessment of the developmental stage of children, adolescents or young adults can be useful in many fields of medicine, even though it is difficult to do it because of the individual variation of overall developmental processes. Children with the same chronological age may show differences in the developmental stages of different biological systems (1). Assessing maturational status, whether the pubertal growth spurt of a patient has been reached or completed, can have a considerable influence on diagnosis, on treatment goals, on treatment planning, and on the eventual outcome of the orthodontic treatment (2). Considerable variations in the development among children of the same chronological age have led to the concept of bio-
logic or physiologic age. The physiologic age is the registry of progress towards maturity that can be estimated by somatic, sexual, skeletal and dental maturity (3).

The dental age has been defined in the literature as “the subject’s estimated age based on the level of tooth mineralization during the developmental process or on the eruption stage” (4). There were proposed many methods to assess this parameter: the stage of tooth eruption, the radiographic assessment of the length of the tooth crown and of the root (5). The mineralization of permanent teeth has been studied by a number of researchers (6). This type of examination can be easily done in everyday practice because the panoramic radiographs are usually a part of dental examination and there is no need of additional investigations. The dental age assessment based on tooth calcification visible on a radiograph was described by Demirjian et al. (7). Although this one is the most widely used method, it was formulated for the French Canadian population. The method evaluates the development of seven mandibular teeth from a panoramic radiograph and calculates dental age. Various researchers have tested the applicability of this method on different populations and certain correlations in patients with other racial background than the one this method was described for were found (8, 9). On the other hand, some authors reported significant differences between the dental age of French Canadian population and other populations (10, 11).

However, the study of the dental development remains a reliable method, because the development of a tooth is much less affected than other tissues by endocrine disorders or other developmental problems. Several studies concluded, that children with sexual, systemic or congenital disorders show small deviations in timing of dental development compared with healthy subjects (12, 13).

The degree of skeletal development is a reflection of the degree of physiological maturation of a subject (14). The bone age was shown to be as important as the chronological age in evaluating a patient’s physical development (15). The skeletal maturation can be assessed usually using radiological methods; the classical one is based on the analysis of the hand-wrist radiographs (16, 17).

A disadvantage of this method is that it requires additional radiographic images and exposure to radiation beside those used for an orthodontic diagnosis. A commonly used method nowadays is based on the radiological assessment of cervical vertebrae outlines, the so called cervical vertebrae method (CVM). The size and shape of C2, C3 an C4 vertebrae are analyzed and the skeletal age is divided in six stages (18). This method of assessment of skeletal maturity does not require extra radiation exposure for the patient, because the analysis can be performed on lateral cephalometric radiographs, which are often used in the orthodontic diagnosis.

The aim of this study was to find a correlation between the third molar mineralization stage and the cervical vertebral maturity in Romanian subjects and to evaluate if radiographic evaluation of the third molar’s development can be useful in the chronological age determination.

**MATERIAL AND METHODS**

After the research protocol was established, it was approved by the Ethical Committee of Scientific Research of the University of Medicine and Pharmacy from Tirgu Mures. A written consent was ob-
tained from each patient or their parents/legal representative in order to use patient’s radiographs for this study.

Thus, two hundred twenty-one subjects, 146 girls (mean age 13.79 ±2.90) and 75 boys (mean age 13.46 ±2.82) were selected from patients referred for an orthodontic treatment at the Orthodontic Department of Faculty of Dentistry, University of Medicine and Pharmacy from Tîrgu Mureș, Romania. For each subject the digital panoramic and the lateral cephalometric radiographs were analyzed. The digital radiographic images were performed with Pax Flex 3D, Vatech X-ray machine, the exposure time was 12.9 seconds, at 80kVp and 9.0mA. The dental imaging software used was EasyDent. By using digital radiographs, it allowed us to enlarge certain parts of the images and perform a clear tracing of the bones or of the intraosseous dental structures.

The inclusion criteria were: (1) children of Romanian origin, (2) no history of orthodontic treatment before this radiographic examination, (3) good general health (4) no growth affecting hormonal or systemic disease, (5) good quality of lateral cephalometric and panoramic radiographs, (6) no history of trauma or surgery in cephalic or cervical region.

The chronological age was calculated based on the date of birth and the amount of time that passed from birth to the day of the radiography. The obtained values were rounded down and noted in years and decimal points.

The dental age was described on panoramic X-rays, using the Demirjian’s method. The development of the four third molars was assessed on panoramic radiographs by means of the eight-grade scale according to Demirjian’s system (fig. 1). Every determination was performed once by every author and if the difference exceeded one developmental stage, a lower stage was chosen. The tooth calcification stages were rated from A to H and a numeric value was assessed for each stage from 0 to 8 (A=0 to H=8). For each molar a stage was determined and from the obtained values a medium value was calculated for every subject (19). When the third molars mineralization stages were statistically analyzed and correlations were defined, cases with agenesis and molars in the first stage (bud-stage) mineralization were not included in statistical analysis.

![Fig. 1. The classification of the degree of molar tooth mineralization according to Demirjian et al.](image)
Correlation among chronological age, dental age and cervical vertebrae maturity in Romanian subjects

Numeric values were added for each stage (CS1=1,…CS6=6) (18, 20). (fig. 2)

All data were introduced in Excel and a statistic analysis was performed using the Excel Data Analysis package. Than a main statistic interpretation was performed: the mean values were calculated for the chronological age and for the cervical vertebrae maturation separate per genders and for the whole study group. A descriptive statistical and linear regression analysis was performed and a coefficient of correlation was calculated. A Student-test was used to compare the mean values of the chronological age and the dental development stages within different skeletal maturation stages; p<.05 was considered significant. A Chi test was used to study the association between the cervical vertebrae maturation and the dental calcification for girls and boys separately and for the whole group. Pearson’s r correlation coefficient was calculated for the studied variables.

Fig. 2. The cervical vertebrae maturation stages

RESULTS
Comparing the mean values for all the studied variables between the two genders, chronological age and Demirjian index showed no statistical significance (p=0.41-0.43). The mean values obtained for cervical stages for boys and girls were significant (p=0.0171).

<table>
<thead>
<tr>
<th>Variable/group</th>
<th>Mean values</th>
<th>Probability of the test (p) between genders</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>male</td>
<td>female</td>
</tr>
<tr>
<td>Chronological age</td>
<td>13.46 ± 2.825</td>
<td>13.79 ± 2.903</td>
</tr>
<tr>
<td>Cervical stages</td>
<td>3.45 ± 1.445</td>
<td>3.95 ± 1.468</td>
</tr>
<tr>
<td>Demirjian's index</td>
<td>2.94 ± 1.348</td>
<td>3.08 ± 1.088</td>
</tr>
</tbody>
</table>

The mean values for the chronological and the dental ages for every cervical stage (CS1-CS6; tab. II) and tooth calcification stage (B-H; tab. III) were also calculated. As agenesis of third molar has an increasing tendency, we have included the modifications of Demirjian's method assigning scores of “0” in case of the absence of the third molar and “1” in case of the presence of a radiolucent bud (21). This is the reason why we excluded from our further statistical interpretation the subjects with agenesis of the third molar and those who had molars in a bud-stage.

A linear regression analysis and correlation was used to study the association between the chronological age and different cervical maturation stages (tab. IV) for girls and boys separately and for the whole group as well.
## TABLE II
The mean values of the chronological age for different cervical maturation stages

<table>
<thead>
<tr>
<th>Cervical stage/gender</th>
<th>n=75</th>
<th>n=146</th>
<th>Chronological age</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>males</td>
<td>females</td>
<td>males</td>
</tr>
<tr>
<td>CS1</td>
<td>7</td>
<td>9</td>
<td>12,00 ± 2,02</td>
</tr>
<tr>
<td>CS2</td>
<td>16</td>
<td>20</td>
<td>11,23 ± 1,80</td>
</tr>
<tr>
<td>CS3</td>
<td>12</td>
<td>19</td>
<td>13,46 ± 2,58</td>
</tr>
<tr>
<td>CS4</td>
<td>23</td>
<td>46</td>
<td>13,19 ± 2,00</td>
</tr>
<tr>
<td>CS5</td>
<td>10</td>
<td>25</td>
<td>15,37 ± 2,12</td>
</tr>
<tr>
<td>CS6</td>
<td>7</td>
<td>27</td>
<td>18,13 ± 2,26</td>
</tr>
</tbody>
</table>

## TABLE III
The mean values of the chronological age and its correlation with different tooth calcification stages (* statistically strong significance)

<table>
<thead>
<tr>
<th>Variable/tooth calcification stage</th>
<th>Mean value of chronological age</th>
<th>Probability of the test (p)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>females</td>
<td>males</td>
</tr>
<tr>
<td>B</td>
<td>11,18 ± 1,89</td>
<td>11,76 ± 1,82</td>
</tr>
<tr>
<td>C</td>
<td>13,59 ± 1,36</td>
<td>11,95 ± 1,69</td>
</tr>
<tr>
<td>D</td>
<td>14,15 ± 1,52</td>
<td>13,82 ± 2,18</td>
</tr>
<tr>
<td>E</td>
<td>15,11 ± 2,49</td>
<td>14,65 ± 1,92</td>
</tr>
<tr>
<td>F</td>
<td>18,59 ± 1,91</td>
<td>17,13 ± 1,37</td>
</tr>
<tr>
<td>G</td>
<td>23.4</td>
<td>19,10 ± 2,54</td>
</tr>
<tr>
<td>H</td>
<td>20,85 ± 1,34</td>
<td>21,76 ± 1,82</td>
</tr>
</tbody>
</table>

**Fig. 3 a.** Chronological age in females related to Demirjian’s index
Correlation among chronological age, dental age and cervical vertebrae maturity in Romanian subjects

**Fig. 3b.** Chronological age in males related to Demirjian’s index

**Fig. 3c.** Chronological age for the whole studied group related to Demirjian’s index

**TABLE IV**
The correlation coefficients between the chronological age and different cervical maturation stages (* statistically strong significance)

<table>
<thead>
<tr>
<th>Cervical maturation stages</th>
<th>Correlation coefficient (r)</th>
<th>Probability of the test (p)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>males</td>
<td>females</td>
</tr>
<tr>
<td>CS1</td>
<td>0.22449196</td>
<td>0.844149912</td>
</tr>
<tr>
<td>CS2</td>
<td>0.683256604</td>
<td>0.277205275</td>
</tr>
<tr>
<td>CS3</td>
<td>0.161717393</td>
<td>0.406287936</td>
</tr>
<tr>
<td>CS4</td>
<td>0.517959851</td>
<td>0.583360207</td>
</tr>
<tr>
<td>CS5</td>
<td>0.622213149</td>
<td>0.570683236</td>
</tr>
<tr>
<td>CS6</td>
<td>0.637864788</td>
<td>0.809276152</td>
</tr>
</tbody>
</table>
TABLE V

The correlation coefficients between the chronological age and different tooth mineralization stages (B-H) in different cervical maturation stages (CS1-CS6). (*statistically strong significance)

<table>
<thead>
<tr>
<th>Cervical maturation stages /gender</th>
<th>Correlation coefficient (r)</th>
<th>Probability of the test (p)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>males</td>
<td>females</td>
</tr>
<tr>
<td>CS1</td>
<td>0.2245</td>
<td>0.8441</td>
</tr>
<tr>
<td>CS2</td>
<td>0.6833</td>
<td>0.2772</td>
</tr>
<tr>
<td>CS3</td>
<td>0.1617</td>
<td>0.4063</td>
</tr>
<tr>
<td>CS4</td>
<td>0.518</td>
<td>0.5834</td>
</tr>
<tr>
<td>CS5</td>
<td>0.6222</td>
<td>0.5707</td>
</tr>
<tr>
<td>CS6</td>
<td>0.6379</td>
<td>0.8093</td>
</tr>
</tbody>
</table>

TABLE VI

The correlation coefficients between the chronological age and different tooth mineralization stages (B-H) for genders (*statistically strong significance)

<table>
<thead>
<tr>
<th>Subjects</th>
<th>Correlation coefficient (r)</th>
<th>Probability of the test (p)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Whole group (n=221)</td>
<td>0.7065</td>
<td>&lt;0.0001*</td>
</tr>
<tr>
<td>Male subjects (n=75)</td>
<td>0.7178</td>
<td>&lt;0.0001*</td>
</tr>
<tr>
<td>Female subjects (n=146)</td>
<td>0.7078</td>
<td>&lt;0.0001*</td>
</tr>
</tbody>
</table>

DISCUSSION

When the age determination is required, correlation amongst the chronological age, the skeletal maturity and the tooth development related dental age can be helpful. The evaluation of the chronological age becomes simple if we are aware of patient personal data. The intraosseous tooth development is mostly genetically coordinated and seems to be independent of patient’s general conditions and nutrition (22). After the young permanent dentition is complete, in adolescent period, the only unerupted permanent tooth remains the third molar. Even though the age estimation using dental methods have shortcomings and the third molars can have individual pattern of calcification rhythm, formation or intraosseous position, it remains the only tooth which can help in the dental age evaluation in post-pubertal age and for young adults (23).

The determination of skeletal maturation is extremely important in many fields of medicine. In pediatric dentistry and orthodontics, it will help in right the timing of treatment and it will make possible an individualized treatment planning. In forensic sciences it may help in emerging or young adult’s corps or skeletons age identification. Beside the hand-wrist method, CVM is a valid indicator of skeletal growth during the pubertal period (24).

Although there is a strong relationship between the skeletal and the somatic maturation, this correlation seemed to be inconclusive between dental age and skeletal maturity (25). Studies revealed different concordance between dental age and skeletal maturity, which can be explained by differences in the evaluation methods, age and racial background of the studied subjects (26, 27, 28).

The selected subjects in our study were referred for orthodontic treatment; the
mean age of subjects of different gender was almost the same and the mean age of the studied group was 13.68 ± 2.875, an age when the permanent dentition is about to be completed (tab. I). When the correlation between the mean age and the skeletal maturity was assessed, the medium age of the cervical maturation showed to be younger in girls than in boys in CS1, CS3, CS5 and CS6 stages, in CS4 stages female subjects are in advance with almost 12 month. The female subjects start (CS1) and end (CS6) the cervical maturation at a younger age (tab. II)

Spearman’s rank correlation coefficient (tab. IV) revealed a good relationship between the chronological age and the cervical stages in males \( r=0.68, p=0.00 \) for CS2 and in females \( r=0.80, p=0.00 \) for CS6. The lowest correlation was observed in CS1 for males \( r=0.22 p=0.63 \) and in CS2 for females \( r=0.27 p=0.23 \).

Many authors proved that the cervical vertebrae maturation (CVM) has a high level of correlation with individual skeletal maturation (29, 30) and the greatest increase in mandibular length occurred during the pubertal growth spurt and that this could be assessed during the interval between CS3 and CS4 (31, 32). Based on our findings, the pubertal spurt appears with almost one year earlier in female subjects and the whole skeletal maturation is more accelerated in girls.

Correlations between the chronological age and the cervical vertebrae maturation in different studies revealed that this depends on the subject’s racial background. Most of the studies found correlation coefficient: a low correlation was found in Chinese (33) and Brazilian (34) subjects, high correlation was found by other several studies (35, 36, 37, 38).

Analyzing the correlation between the chronological age and the different stages of the cervical maturation in both genders, we concluded, that the cervical vertebrae maturity increased as the chronological age increased. The cervical maturation starts earlier in girls and the pubertal growth spurt (CS3 stage) takes place earlier in girls, too: the difference between the medium ages is around 6 months. Another interesting information is that the cervical maturation ends (CS6 stage) with almost two years earlier in female subject, which means that the onset of puberty is related to gender. Statistically strong significance was found in the CS1, CS4 and CS5 stages in female and CS2, CS4 stages in male subjects. The same results were found by several other studies (39, 40, 41).

Analyzing the mean ages for the different CVM stages and the third molar mineralization stages we observed that crown formation of the third molars (D stage) became completed around the pubertal growth spurt (CS3 stage) in males, meanwhile in female subjects this was observed in a later stage (CS4 stage) of cervical maturation. In the last stage of the cervical maturation (CS6 stage) where the skeletal maturation comes to end, two-third of the third molar root length (F stage) is developed in both genders.

Analyzing the significance of statistical data correlation between the chronological age and the third molars mineralization in different skeletal maturation stages, we found that the female subjects present stronger correlations in the second part of cervical maturation (CS4-CS6 stages), meanwhile for male subjects’ significant correlations were observed in CS2 and CS4 stages. The third molar mineralization seems to be highly correlated with the gen-
order’s chronological age for the whole group and for both genders as well (p<0.0001).

Studying the mean values for Demirjian’s index (tab. III), there were slightly differences between the two genders at the commencement of the third molar mineralization (B stage) or at the age of complete crown formation (D stage), but the root development (G stage) ended earlier in male subjects. A significant statistical probability was found in D stage (p<0.0001) of mineralization for both genders and in F stage (p=0.0004) for the female subjects. The assessment of dental mineralization in order to evaluate the dental age seems to be a more accurate method than the study of sequence and of the phenomenon of eruption (42).

Studying the relationship between the third molar development and the chronological age, several studies found statistically significant correlations in the third-molar development between males and females especially in stages D and G (43) or in stages E-G (44). Regarding the age of tooth development, as most of the studies concluded, the female subjects present a delayed development of both the upper and lower third molars compared to the boys (45, 46, 47).

CONCLUSIONS
The number of the studied cases and the fact that they all come from one county can be considered limitations of our study. In order to evaluate the correlation among the chronological age, the dental development and the skeletal age for Romanian subjects, a higher number of subjects from other parts of the country should be selected.

Based on our findings, we conclude the following:

- The root development ended earlier in female subjects, D and F stages of tooth calcification showed significant correlation with the chronological age.
- A strong significant correlation between the chronological age and the tooth mineralization stages was found in D stage of Demirjian’s classification (crown formation is complete), for both genders
- The crown formation of the third molars is completed at the age of pubertal growth spurt (CS3) in males and in a later stage of cervical maturation (CS4 stage) in females
- At the age of complete skeletal maturation (CS6 stage) two-third of the third molars roots are developed
- The commencement (CS1) and the end (CS6) of the cervical vertebrae maturation happens earlier in female patients, the last stage of the cervical maturations ends (CS6 stage) with almost two years earlier in female subject.
- A significant correlation between the chronological age and CVM was found in CS1 and CS6 stages for girls and CS2 and CS5 stages for boys.

REFERENCES
Correlation among chronological age, dental age and cervical vertebrae maturity in Romanian subjects