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Growth indicators in orthodontic patients. Part 1: Comparison of cervical vertebral maturation and hand–wrist skeletal maturation

ABSTRACT

**Aim** The purpose of this study was to predict the skeletal maturation status based on the assessment of cervical vertebrae from lateral cephalometric radiographs and to compare these findings with the skeletal maturity of the same individuals judged from the hand-wrist radiographs.

**Methods** Lateral cephalometric and left hand-wrist radiographs of 393 Caucasian children from 8 to 18 years old were evaluated. On the hand-wrist radiographs the classification of Bjork [1972] and Grave and Brown [1976] was used to assess skeletal maturity (HWSS). Cervical vertebral maturation was also evaluated on lateral cephalometric radiographs using the improved CVM 5 method described by Baccetti, Franchi, and McNamara [2002]. These methods were correlated using the chi-squared test.

**Results** The chi-square test showed that skeletal maturation values obtained by the CVM 5 method were significantly correlated with the skeletal values obtained from the hand-wrist analysis for both genders (p<0.05). However, gender differentiation exists in CVM 5 method regarding the peak of growth spurt.

**Conclusion** The results of this study show that the CVM 5 method was compatible with a commonly used hand-wrist analysis method. The lateral cephalometric radiograph belonging to the standard set of records would be sufficient to evaluate skeletal maturity.

**Keywords:** Cervical Vertebral Maturation Stage (CVM 5), Hand-Wrist Skeletal Stage (HWSS).

Introduction

The use of hand–wrist radiographs to evaluate the maturational status is one of the oldest applications in the medical field. In 1898, three years after the discovery of X-rays, J. Poland, an English orthopedic surgeon, published the first atlas in which he described hand-wrist radiographs from 19 children from 1 to 17 years old. After him, Pryor in 1907, and Rotch in 1909, presented techniques for skeletal age evaluation by hand-wrist radiographs. Traditionally, hand-wrist radiography has been, and is still being used, for that purpose. The information from the hand-wrist radiograph has been used in two ways to evaluate the bone age of the child:

- Bone age can be obtained by comparing the radiograph in question with a series of standards radiographs representative of normal children at different chronologic ages, and assigning to the radiograph in question the age of the standard that matches it most closely (GP atlas) [Greulich and Pyle, 1959] or by assigning a weighted score to the developmental stage of each of the 20 bones in the hand and wrist, the bone age being the total score for the radiograph [TW2, TW3] [Tanner et al., 1975, 2001].

- The second method of assessment of the hand and wrist radiograph uses specific skeletal indicators to relate the skeletal status to the pubertal growth spurt. For analysis up to the age of 9 years, the stage of the carpal bones must be determined; thereafter, the development of metacarpal bones and phalanges should be evaluated [Bjork and Helm 1967; Brown et al., 1971; Chapman 1972; Bowden 1976; Grave and Brown 1976; Hagg and Taranger 1980, 1982; Fishman 1982].

The modifications in size and shape of the cervical vertebrae in growing subjects have gained interest over the last years as a biologic indicator of individual skeletal maturity. In 1972, Lamparski published an atlas that simulated the morphological changes in cervical vertebral bodies in puberty and used the changes to evaluate skeletal maturation. O’Reilly and Yanniello in 1988, based on Lamparski’s observations investigating the relationship of the stages of cervical vertebral maturation to growth changes in the mandible, created six stages of vertebral growth maturation (Cvs1-Cvs6). Hassel and Farman in 1995 provided an additional tool to determine growth evaluation in the adolescent patient based on cervical vertebral maturation. The cervical vertebrae maturation index (CVM1), which consists of six categories (initiation, acceleration, transition, deceleration, maturation and completion) was defined. In 2002, Baccetti, Franchi and McNamara updated the previous method devising the CVM 5 method, which is comprised of five maturational stages based on the second to fourth cervical vertebrae. The aim of this study is to compare the relationship between CVM 5 and HWSS.

Methods and materials

**Subject selection**

The lateral cephalometric and hand-wrist radiographs were examined from the archive of the Department of Orthodontics, Faculty of Dentistry, Marmara University, Istanbul, Turkey. More than 600 patient files were initially reviewed. A final sample of 393 subjects (223 females and 170 males) was selected in our study. To minimise the error, the same investigator who analysed the lateral cephalometric radiographs analysed the hand and wrist
radiographs as well. Subjects were selected according to the following criteria.

- Age between 8 and 18 years old.
- Hand-wrist and lateral cephalometric radiographs available with high clarity and good contrast.
- A time interval less than one month between the radiographs.
- No systemic diseases.
- No previous orthodontic treatment.

**Lateral cephalometric radiographs**

Lateral cephalometric X-ray radiographs were taken for each subject at the Marmara University, Faculty of Dentistry, Oral Diagnosis and Radiology Department. To standardize the spinal position all radiographs were obtained with the patient positioned so that the X-ray beam was perpendicular to the head. A mirror was positioned in front of the X-ray machine (Vera, view POC5, MORITA MFGCOR, Kyoto Japan) and the patients were instructed to look into it and not to rotate the head. All films were 18 x 24 cm (Kodak X-omat K100), and they were developed using Okamato Medical X-ray film automatic processor.

**Visual analysis**

The morphology of the second, third and fourth cervical vertebrae was evaluated placing the film on a conventional negatoscope (X-RAY Co.-Amityville, N.Y., USA). In order to determine skeletal maturation of each subject by evaluating the lateral cephalometric radiographs, the improved version of the cervical vertebral maturation stage method (CVMS) developed by Baccetti, Franchi and McNamara was used [2002]. This method consists of five maturational stages (CVMS I through CVMS V) covering the entire growing period for both males and females (Fig. 1).

**Hand-wrist analysis**

The nine ossification events of the well-known method developed by Bjork [1967], Grave and Brown [1976] were used to determine the stage of hand-wrist skeletal maturation in each individual, and each hand-wrist radiograph was assigned to one of the nine stages described. We used the above method because it includes the evaluation of both carpal and metacarpal bones, thus covering the entire growing period (Fig. 2).

**Statistical methods**

The relationship among the nine maturational stages of hand-wrist radiographs and the five maturational stages of cervical vertebrae was to be assessed using chi-square-test. But because some tables have very small expected frequencies a preliminary statistics had to be applied to decide about the different manner of categorization between males and females.

**Preliminary statistics**

The nine stages of hand-wrist maturation indicators could be condensed into three categories for both genders, in agreement with Grave, Brown and Bjork [Rakosi et al., 1993]. The stages 1-3 correspond to the pre-peak period, 4-5 to the peak of growth spurt, and 6-9 belong to the post-peak period. The CVMS method consists of five maturation stages (CVMS I through CVMS V), while the peak of growth spurt occurs between CVMS II and CVMS III. According to them, the CVMS I clearly belongs in the pre-peak period whereas the CVMS IV and CVMS V occur in the post-peak period.

Observing our tabulate statistics we could confirm their opinion (Table 1). However, in females the tabulate data showed that CVMS II seems to belong more to the peak than to the pre-peak period, as Grave and Townsend [2003] supported (Table 2). Both Fisher’s exact (Table 3) and chi-squared tests (Table 4) confirmed our observation.

When CVMS I and II are compared to HWSS 1, 2 and 3 (pre-peak) by the Fisher’s exact test, the association between these two classifications was not statistically significant (p-value = 0.1070, p>0.05). We used the Fisher’s exact test because the chi-square test is not reliable for tables with frequencies below 5. One the other hand, when comparing CVMS II and III with hand-wrist skeletal stages 4 and 5 (peak growth spurt) by chi-squared test (since the expected frequencies were large enough)
the two staging methods were significantly associated (p<0.001). Modification of HWSS and CVMS under this new staging approach is shown in Table 5.

**Table 3** - Fisher’s exact test.

**Table 4** - Chi-square test: CVMS II and III and HWSS 4 and 5. Expected counts are printed below observed counts.

**Table 5** - Modification of HWSS and CVMS method.

The hypothesis that the two measurements are the same. From the results we can infer that the two measurements for CVMS and HWSS are not statistically significantly different (p=0.1608 for CVMS and p=1.000 for HWSS).

**Results**

**Evaluation of the error of method**

The Wilcoxon signed rank method tests the null hypothesis that the two measurements are the same. From the results we can infer that the two measurements for CVMS and HWSS are not statistically significantly different (p=0.1608 for CVMS and p=1.000 for HWSS).

**Descriptive statistics**

The distribution of hand-wrist skeletal stages and the cervical vertebral maturation stages in 393 individuals is reported in Table 6. With the hand-wrist classification method, the majority of our subjects belonged to the first (15.5%) and fifth stage (15%). According to the CVMS method most of the subjects belonged to the second stage (CVMS II, 26.2%). Table 7 and 8 show the distributions in both sexes. The largest occurrence in females were HWSS 9 and CVMS V, whereas in males, it was HWSS 1 and CVMS I.

**Cervical vertebral maturation vs. hand-wrist skeletal stages**

Our results (Table 9 and 10) show that the HWSS/CVMS classifications, as well as the 3-stage classifications (pre-peak/peak/post-peak) are associated in both females (p<0.05) and males (p<0.05). Below is presented a detailed comparison of each CVMS with the corresponding HWSS.

- **CVMS I**: in the majority of our subjects (87.3%) the CVMS I corresponded to the first two hand-wrist skeletal stages, and only in seven children the CVMS I coincided with the third stage of hand-wrist maturation, which represents the end of the pre-peak period.
- **CVMS II**: among the females, 63% exhibited concordance between the CVMS II and the peak period of hand-wrist radiograph (stage 4, 5), whereas 36.9% of the CVMS II belonged to the pre-peak period of the
stage 5 occur simultaneously, whereas in 20% CVMS III appears at the beginning of the post-peak period (stage 6; DP3u). In 68% of males, the CVMS III occurred along with stage 5, whereas in 8% CVMS III belonged to the beginning of the post-peak period. According to our findings, CVMS III corresponds mainly to the peak growth spurt, with females having a tendency to begin their post-peak period when CVMS III occurs.

- CVMS IV: in our female population, CVMS IV corresponds to the beginning of the post-peak period in 14.2% (stage 6), to stage 7 and stage 8 in 48.9% and, finally, to the end of growth in 36.7% (stage 9). For males, CVMS IV corresponds to the beginning of post-peak period in 22.5%, and to main post-peak and end of growth in equal amounts of 38.7%. Therefore, we can support that CVMS IV mainly belongs to both the post-peak and end of growth periods.

- CVMS V: 69 patients in our investigation exhibited CVMS V; 84% of them belonged to the end of the growth period (stage 9; Ru), and the rest of them belonged to the post-peak period (stages 7 and 8).

Discussion

The cervical vertebral maturation method has gained attention in recent years. The method is based on the morphological characteristics of the cervical vertebrae at different developmental stages, which are correlated with different growth rates in facial structures. It describes the entire circumpubertal period by covering all significant phases in craniofacial growth during adolescence and young adulthood, and it is valid for both sexes [Baccetti et al., 2002; Gandini et al. 2006; Soegiharto BM et al., 2008; Caldas Mde et al., 2010]. It is suitable for orthodontic diagnosis and for classifying groups of patients according to skeletal maturation.

The issue of timing in dentofacial orthopedics is a fundamental aspect for adequate treatment planning, and for the reasonable anticipation of both short-term and long-term therapeutic outcomes. It is well established that the maxillary protraction therapy protocol is able to induce significantly more favorable skeletal changes when it is initiated before the pubertal peak in skeletal growth [Hagg and Pancherz, 1988; Graber, 1998; Proffit and Field, 2000; Graber et al., 2005]. Most of the papers in the literature indicate that CVM stage II represents the proper timing for initiation of the orthopedic phase of treatment, as the peak of growth spurt will occur shortly after this stage [Franchi et al., 2000; Baccetti and Franchi, 2001; Baccetti et al., 2002; Faltin et al., 2004; Soegiharto et al., 2008].

The reliability of cervical vertebral maturation as an indicator of growth estimation has been tested also in the past in different population groups [Kucukkeles et al., 1999, Baccetti et al., 2002; Rajaropal and Kansal 2002; San Roman et al., 2002; Hessa Abdulla Alkhal et al., 2008; Ricky et al., 2009]. Most of these investigations showed a significant relationship between the two assessments, concluding that cervical vertebral maturation is a reliable, reproducible and valid method for growth estimation in orthodontic patients. We are in agreement with the

hand-wrist analysis. The opposite was true for males. 37% of CVMS II belonged to the peak period of the hand-wrist analysis, whereas 62.5% corresponded to the pre-peak period. It seems that CVMS II occurs between the end of pre-peak period and the accelerative phase of the peak growth spurt in boys (stage 3 and 4), whereas between the accelerative phase and the peak growth spurt in girls (stage 4 and 5).

- CVMS III: among the females, 64.4% of CVMS III and
studies mentioned above regarding the pre-peak and post-peak period. However, according to our results, particular attention should be paid to gender differentiation during the peak period. According to our results CVMS II occurs between the end of pre-peak and the accelerative phase of the peak of growth spurt in boys, and between the accelerative phase and the peak of growth spurt in girls. We are in agreement with Grave and Townsend [2003], who supported that CVMS II for girls seems to belong more to the peak than the pre-peak stage. In their Australian sample they found that while CVMS II in males clearly belongs to the end of the pre-peak growth period, in females CVMS II appears to be more variable. Therefore, in females even when the curvature in the lower border of C3 is starting to form (at the beginning of CVMS II), it seems necessary to determine the skeletal age in a quantitative rather than in a qualitative format (Part II).

The CVMS method is useful to detect the peak period, and it is easy to record and reproduce. More importantly, it requires no additional x-ray exposure to the routine lateral cephalograms.

Conclusion

In males, CVMS I and II belong to pre-peak period, CVMS III to the peak period, and CVMS IV and V to the post-peak period. In females, CVMS I belongs to the pre-peak period, CVMS II and III to the peak period, and CVMS IV and V to the post-peak period. The comparison of the three categories (pre-peak, peak, post-peak) of HWSS and CVMS revealed statistically significant associations between the two methods for both sexes.

References

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