Skeletal Maturation in Different Vertical Facial Growth Pattern

Introduction

In orthodontics, determining biological age, in addition to knowing the chronological age of patients, is important for the diagnosis and development of a treatment plan (1). For development of a treatment plan it is very important to evaluate if the patient is near the peak of pubertal growth. It is believed that growth modification therapy of the maxilla is more effective when it starts before the peak of pubertal growth, while the approach that modifies mandibular growth should start after the peak (2).

To assess different stages of growth spurt we can use the following two methods: the hand-wrist radiographs and cervical vertebral maturation (CVM) method in the lateral cephalometric radiograph. Wong et al. have validated the CVM method and they made conclusion that since cephalometric radiograph is routinely made before entering any orthodontic treatment, to prevent unnecessary radiation for additional X-rays of hand, nowadays, this method is used as a gold standard for the diagnosis and development of a treatment plan (1). For development of a treatment plan it is very important to knowing the chronological age of patients, is important to determine whether there are differences in skeletal maturation among subjects with horizontal, vertical, and neutral growth patterns. Material and methods: The study was performed on 48 latero-lateral cephalograms of patients with horizontal, 48 with vertical and 50 with neutral growth patterns aged 12 to 18 years. Eight variables from the Zagreb 82 MOD, Bracchetti and Accord analysis, were selected for measuring angular and linear parameters on latero-lateral cephalograms. The assessment of skeletal maturation was done by using the CVMs method. Results: Statistical analysis showed significant differences in skeletal maturity (p < 0.001) between subjects with horizontal and vertical growth pattern and between the subjects with neutral and vertical growth pattern (p < 0.05), while no significant difference was found between patients with horizontal and neutral growth pattern. In the younger group (12 – 15 years) there was a statistically significant difference (p < 0.05) among subjects with horizontal and vertical growth patterns. In the older group (16 – 18 yrs) there was a statistically significant difference (p > 0.05) in skeletal maturity among subjects with vertical growth patterns compared with horizontal and neutral. In terms of stages of skeletal maturity, patients with a horizontal and neutral growth pattern in the younger group were on average in the fourth stage, and those with a vertical growth pattern in the third stage. In the older group, patients with a horizontal and neutral growth pattern were on average in the fifth stage of skeletal maturity and those with a vertical growth pattern in the fourth stage. Conclusion: According to the growth pattern, patients differ in the stage of skeletal maturity.

Uvod

Određivanje biološke dobi, uz poznavanje kronološke dobi pacijenata, važno je za postavljanje ispravne ortodontske dijagnoze i pripremu plana terapije (1). Za dobar plan terapije veoma je važno znati je li pacijent blizu vrhunca pubertetskog rasta. Poznato je da s terapijom modifikacije rasta (2).

Za određivanje različitih stadija pubertetskog rasta možemo se koristiti dvjema metodama – RTG snimkom kostiju šake i zgloba te stupanjem zrelosti cervikalne kralježnice (CVM). Wong i suradnici analizirali su CVM metodu i zaključili da, zbog rutinske primjene kefalograma prije početka ortodontske terapije, a radi sprječavanja nepotrebnog zračenja tijekom snimanja dodatne RTG snimke, danas je CVM metoda zlatni standard u određivanju stupnja pubertetskog rasta (3).
in determining pubertal growth (3). In terms of timing the right treatment and getting a better result, the knowledge of the skeletal maturation in association with craniofacial growth is also very important (4). The chronological and biological age of the patient, combined with knowledge of the type of craniofacial growth allows us to predict the right timing and outcome of orthodontic therapy; therefore, they are crucial in clinical as well as in scientific work. In the available literature there are studies which compared dental age with skeletal maturity (5,6), but the relationship between skeletal maturation and growth pattern has not yet been clarified; therefore, the aim of this cross-sectional retrospective study was to assess whether there are differences in skeletal maturation among patients with different vertical facial growth patterns.

**Material and methods**

The sample included 146 pretreatment lateral cephalographs (82 females and 64 males) of patients aged 12–18 selected from the Department of Orthodontics, University Hospital Centre Zagreb. Lateral cephalographs were routinely made before orthodontic treatment. More than a thousand patient files were reviewed. The study was approved by the Ethics Committee of the School of Dental Medicine, University of Zagreb since the cephalographs were made according to diagnostic procedures. The patient's parents signed a voluntary written informed consent. All subjects with determined craniofacial anomalies, skeletal deviations in the sagittal dimension, respiratory problems, and positive history of unfavorable habits were excluded from the study because of the possible effect on the development of the alveolar bone and dimensions of the midface.

**Rtg cephalometric analysis**

To assess the growth pattern, a cephalometric analysis was performed using the Dolphin 10.5 software. All variables that were used for this purpose are shown in Table 1. The norms of all values were derived from a previous study on subjects of all values were derived from a previous study on subjects of normal occlusion from the Croatian ethnicity (7).

**Assessment of cervical vertebral maturation index**

Cervical vertebral maturation was determined on lateral cephalometric radiographs using cervical vertebrae maturation stages (CVMS) (8–11), a method modified by Baccetti et al. (12). The morphology of the bodies of the second (C2), third (C3), and fourth (C4) cervical vertebrae were analyzed by using the Dolphin 10.5 software. All variables that were used for this purpose are shown in Table 1. The norms of all values were derived from a previous study on subjects of normal occlusion from the Croatian ethnicity (7).

**Table 1**

| No. | Measured values | Mjerene vrijednosti | Name of the measure | Mean value | Srednja vrijednost | Type of measurement |
|-----|-----------------|---------------------|---------------------|------------|--------------------|---------------------|
| 1   | Y axis • Kur Y osi | N - S - Go | 66.5±3.5 | Angular • Angularna |
| 2   | Basal plane angle • Medučeljusni kut | sp - pm: go - m | 25±5 | Angular • Angularna |
| 3   | Articular angle • Zglobni kut | S - Ar - Go | 39.5±5 | Angular • Angularna |
| 4   | Gonial angle • Mandibulariski kut | M - Go - Ar | 127.5±5 | Angular • Angularna |
| 5   | Upper gonial angle • Gornji odsečak mandibularnog kuta | N - Go - Ar | 54.5±4 | Angular • Angularna |
| 6   | Mandibular plane angle • Kut nagiba baze mandibule | N-S: Go-M | 32.44±7 | Angular • Angularna |
| 7   | Anterior and posterior face height ratio • Prednji i stražnji omjer duljine lica | S-Go; N-Me | 61±2 % | Angular • Angularna |

Osim poznavanja stupnja pubertetskoga rasta, važno je znati i odnos stupnja pubertetskoga rasta s kraniofakcijalnim rastom (4). Kronološka i biološka dob pacijenata, uz poznavanje vrste kraniofakcijalnog rasta, utječe na pravodobni početak i predviđanje rezultata ortodontske terapije i zato su vrlo važne kako u znanstvenom tako i u kliničkom radu. U literaturi se mogu pronaći studije u kojima se uspoređuju dentalna dob pacijenata i njihova skeletna zrelost (5, 6), ali odnos obrascia kraniofakcijalnog rasta i skeletne zrelosti još nije potpuno razjašnjen. U skladu s tim, svrha ovoga retrospektivnog istraživanja bila je odrediti postoje li razlike u stupnju skeletne zrelosti kod pacijenata s različitim obrascima rasta kraniofakcijalnog sustava.

**Materiali i metode**

U istraživanje je bilo uključeno 146 lateralnih rendgenskih kefalograma pacijenata (82 od žena i 64 od muškaraca) u dobi od 12 do 18 godina izabranih u Zavodu za ortodoncijsku kliničku bolnici Zagreb. Lateralni kefalogrami su snimani bio je jedinstven cilj istraživanja, a ukupno je pregledano više od 1000 pacijenata. Istraživanje je odobrilo Etničko povjerenstvo Stomatološkog fakulteta Sveučilišta Zagreb. Roditelji pacijenata potpisali su informiran pristanak za sudjelovanje u istraživanju. Svi pacijenti s kraniofakcijalnim anomalijama, skeletnim devijacijama u sagitalnoj dimenziji, respiratornim problemima te neodgovarajućim navikama nisu bili uključeni u istraživanje zbog mogućeg utjecaja na razvoj alveolarne kosti i lica.

**Rendgenska kefalometrijska analiza**

Za određivanje obrascia rasta lica korištena je kefalometrijska analiza u programu Dolphin 10.5.

Sve korištene varijable nalaze se u tablici 1. Srednje vrijednosti dobivene su iz dosadašnjih istraživanja provedenih na pacijentima s normalnom okluzijom iz hrvatske populacije (7).

**Određivanje stupnja zrelosti cervicalnih kralježaka**

Stupanj zrelosti cervicalnih kralježaka određen je kroz korištenje CVM metodom (8 – 11) prema Baccetti i suradnicima (12). Analizirana je morfologija tipa drugoga (C2), trećega (C3) i četvrtega (C4) cervicalnog kralježaka. Ova analiza i mjerenja obavio je jedan istraživač. Ra-
alyzed. All analysis and measurement were performed by one researcher. To assess the reproducibility, 30 randomly selected lateral cephalographs were reevaluated eight weeks later by the same investigator. The results were evaluated by the Spearman-Brown formula.

Statistical analysis

Statistical calculations were made by using Statistical Package for Social Sciences software for Windows software system (version PASW 18), (SPSS Inc., Chicago, SAD). The level of significance was set at p-values of <0.05. To test the normality of distribution, the Kolmogorov-Smirnov and Shapiro-Wilk tests were used. Each variable was presented by the mean, standard deviation and maximum and minimum values. For the numerical variables (degree of bone maturity, age), the following parametric tests were used: T-test, ANOVA and associated post hoc Scheffe test.

Results

Patients’ characteristics

The study involved 146 patients aged 12 - 18 years (average age 14.9 years). According to gender, there were 64 male patients (43.83%) and 82 female patients (56.17%). The distribution of patients by gender did not differ according to age (T-test, p = 0.315).

According to growth pattern, the subjects were allocated into three groups. In Group 1, there were 48 subjects with horizontal growth pattern, in Group 2, there were 48 subjects with vertical growth pattern and in Group 3, there were 50 subjects with neutral growth pattern.

Skeletal maturation and growth patterns

The mean values for skeletal maturity for subjects with different growth patterns are shown in Table 2. The obtained difference was statistically significant (ANOVA: F = 9.417; d.f. = 2; p < 0.001), and the Scheffe test confirms that there was a significant difference between patients with horizontal and vertical growth patterns in the younger group.
and between neutral and vertical growth patterns in the older group of patients (p \(<\) 0.05), while there was no significant difference in the degree of skeletal maturation between horizontal and neutral growth pattern (p \(\geq\) 0.05) (Table 3).

**Relationship between skeletal maturation and growth pattern in different age groups**

Patients were divided into two age groups. 57.5% of them were in the first group (12 to 15 years) and 42.5% in the second group (16 to 18 years).

According to growth patterns and degree of skeletal maturity development, the distribution of the first group is shown in Figure 1 and of the second group in Figure 2.

In the age group 12-15 years, the obtain results revealed a statistically significant difference in stage of skeletal development between the subjects with horizontal and vertical growth patterns, (ANOVA; F = 4.802; P = 0.011) (Table 4).

In the age group 16-18 years, statistically significant differences were found between patients with horizontal and vertical growth patterns and those with vertical and neutral growth patterns, (ANOVA; F=4.802; P=0.011) (Table 5).

| Neutral • Neutralni | Horizontal • Horizontalni | Vertical • Vertikalni |
|---------------------|---------------------------|-----------------------|
|                     |                           |                       |

Scheffe post-hoc test • Scheffeov post-hoc test; p<0.05

| Neutral • Neutralni | Horizontal • Horizontalni | Vertical • Vertikalni |
|---------------------|---------------------------|-----------------------|
|                     |                           |                       |

Scheffe post-hoc test • Scheffeov post-hoc test; p<0.05

Odnos skeletne zrelosti i obrasca rasta unutar različitih skupina

Pacijenti su podijeljeni u dvije skupine. Njih 57,5 % nalazi se u prvoj skupini (12 – 15 godina), a 42,5 % svrstano je u drugu dobnu skupinu (16 – 18 godina).

Na slici 1. je distribuciju pacijenata prve skupine prema odgovarajućem obrascu rasta i stupnju skeletne zrelosti, a distribucija pacijenata druge skupine nalazi se na slici 2.

Unutar dobne skupine od 12 do 15 godina rezultati pokazuju statistički značajnu razliku u stupnju skeletne zrelosti između pacijenata s horizontalnim i vertikalnim obrascem rasta (ANOVA; F = 4,802; P = 0,011) (tablica 4.).

Unutar starije dobne skupine (16 – 18 godina) statistički značajna razlika pronađena je između pacijenata s horizontalnim i vertikalnim obrascem rasta te s vertikalnim i neutralnim (ANOVA; F = 4,802; P = 0,011) (tablica 5.).
Discussion

The face changes during childhood, adolescence and adulthood. The craniofacial growth is continuous, however, the growth of individual parts of the head does not occur continuously over time (13-16).

The knowledge of the growth pattern and the degree of skeletal maturity in patients is mandatory for the right orthodontic treatment, both timing and type.

The most frequent method to assess skeletal growth is to analyze the cervical vertebrae on routinely made cephalographs, known as the CVMS method (17-20). Szemraj et al. (21) have confirmed that this diagnostic approach has a high degree of correlation with the hand wrist method and it is considered reliable in clinical, as well as in scientific work. Accordingly, in this research, the CVMS method was used to determine skeletal growth.

The obtained results showed a statistically significant difference in skeletal maturation time between patients with vertical and horizontal growth patterns, thus confirming the null hypothesis. Subjects with horizontal and neutral growth patterns aged 12-15 years were on average in the fourth stage of skeletal maturity, while those with a vertical growth pattern were in the third stage of skeletal maturation. Patients in the age group 16-18 years with vertical growth pattern had mean skeletal age in the fourth stage and those with horizontal and neutral growth pattern in the fifth stage.

Gottimukkala et al. (22) have undertaken a comparison of the skeletal age between long and short face children in the South Indian Population and concluded that subjects with vertical growth patterns should be expected to reach higher levels of skeletal maturity than horizontal growers. A possible explanation for the opposite values, from the ones in this study, was a difference in methodology since they have used both hand-wrist radiographs and lateral cephalographs.

Perinetti et al. performed a study on the Italian population. Their results have shown that there is a very small correlation between different craniofacial growth and skeletal maturation, apart from patients with vertical craniofacial growth pattern in CVM stage 3. Those results are statistically significant, but clinically, they can be found only in extreme cases (4). In their research, they have used different cephalometric measurements than ones used in this study. Moreover, there is evidence that besides the growth pattern, some other factors could also influence the level of skeletal maturity, such as genetics, nutrition, socioeconomic status and ethnicity (23). Hence, those are the factors that can explain the differences in results between this and their study.

Due to a lack of similar research the obtained results are very difficult to compare. Furthermore, research should be supplemented by a larger number of growth indicators.

Conclusions

A difference in the degree of skeletal maturity among subjects with different vertical facial growth patterns was found (p <0.001). Patients with horizontal and neutral growth patterns didn’t show significant differences in skeletal maturity. Subjects with a vertical growth pattern were in a high-

Rasprava

Lice se mijenja tijekom djetinjstva, adolescencije i zrele dobi. Kraniofacialni rast je kontinuiran, no rast pojedinih dijelova glave to ne prati u cijelosti (13 – 16 ). Poznavanje obrasca rasta i stupnja skeletne zrelosti prijeklo je potrebno za pravodobno početak i odabir ortodontske terapije. Najčešće korištena metoda za određivanje stupnja skeletne zrelosti jest CVM metoda koja se provodi na rutinski snimljenim kefalogramima (17 – 20). Szemraj i suradnici (21) potvrdili su da navedena metoda ima visok stupanj korelacije s metodom šake i zgloba te je jednako pouzdana u kliničkom i znanstvenom radu. Zbog navedenoga je u ovom istraživanju za određivanje stupnja skeletne zrelosti korištena ta metoda.

Dobiveni rezultati pokazuju statistički značajnu razliku u stupnju skeletne zrelosti između pacijenata s vertikalnim i horizontalnim obrazcem rasta pa je prihvaćena nulta hipoteza. Pacijenti s horizontalnim i neutralnim obrazcem rasta u dobi od 12 do 15 godina prosječno su se nalazili u četvrtom stupnju skeletne zrelosti, a oni s vertikalnim pripadali su trećem stupnju. Pacijenti u doboj skupini od 16 do 18 godina, s vertikalnim obrazcem rasta, prosječno su pripadali četvrtom stupnju skeletne zrelosti, a oni s horizontalnim i neutralnim obrazcem najčešće su bili u petom. Gottimukkala i suradnici (22) uspoređivali su među južnom indijskom populacijom stupanj skeletne zrelosti kod djece s dugim i kratkim licem. Prema njihovim rezultatima, kod pacijenata s vertikalnim obrazcem rasta očekuje se ranije skeletno sazrijevanje u usporedbi s onima s horizontalnim. Moguće objašnjenje za različite rezultate, od onih dobivenih u ovom istraživanju, jest razlika u odabranoj metodologiji zato što je u njihovu istraživanju korišten CVM i analiza šake.

Perinetti i suradnici radili su istraživanja na talijanskoj populaciji. Njihovi rezultati pokazuju da je korelacija između različitog stupnja skeletne zrelosti te različitog obrazca rasta veoma mala, osim među pacijentima s vertikalnim obrazcem rasta i stupnjem skeletne zrelosti CVM 3. Navedeni rezultati klinički su značajni, ali mogu se primijeniti samo u ekstremlnim slučajevima (4). U svojem su se radu koristili drukčijim kefalometrijskim mjerama od onih u ovoj studiji. Nadalje, u literaturi se ističe da, osim obrazca rasta, i drugi čimbenici mogu utjecati na stupanj skeletne zrelosti – genetika, prehrana, socijalno-ekonomski status i etnička pripadnost (23).

Zbog različitih metoda procjene stupnja skeletne maturacije teško je usporediti dobivene rezultate, a ubuduće je potrebno proširiti istraživanje te uzeti u obzir više različitih čimbenika rasta.

Zaključak

Pronađena je razlika u stupnju skeletne zrelosti među pacijentima s različitim obrazcem rasta (p < 0,001). Pacijenti s horizontalnim i neutralnim obrazcem nisu pokazali statistički značajnu razliku u stupnju skeletne zrelosti. Pacijenti s vertikalnim obrazcem rasta, u usporedbi s onima s horizontalnim obrazcem rasta, u dobi od 16-18 godina, s vertikalnim obrazcem rasta, prosječno su pripadali četvrtom stupnju skeletne zrelosti, a oni s horizontalnim i neutralnim obrazcem najčešće su bili u petom. Gottimukkala i suradnici (22) uspoređivali su među južnom indijskom populacijom stupanj skeletne zrelosti kod djece s dugim i kratkim licem. Prema njihovim rezultatima, kod pacijenata s vertikalnim obrazcem rasta očekuje se ranije skeletno sazrijevanje u usporedbi s onima s horizontalnim. Moguće objašnjenje za različite rezultate, od onih dobivenih u ovom istraživanju, jest razlika u odabranoj metodologiji zato što je u njihovu istraživanju korišten CVM i analiza šake.

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Conflict of interest

The authors report no conflict of interest.

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