Correspondence between Dental and Skeletal Maturity Parameters
Among Patients with Different Sagittal Relationships at the end of Puberty Period

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Abstract

Objective of the research was to evaluate level of correspondence between skeletal and dental maturity parameters and their relation to chronological age among orthodontic patients with different sagittal relationship at the end of puberty period. A sample of 61 patients' datasets (clinical records, OPG, cephalogram) aged 15-17 years old was divided into 3 subgroups considering specifics of sagittal relationship (I, II and III Class). For each subgroup evaluation of dental age and staging of teeth development were provided with the use of Demirjian's method. Evaluation of skeletal maturity was provided with the use of cervical vertebral maturation (CVM) method by the analysis of present cephalograms.85.24% persons were registered with H stage of second molars development, 80.32% persons with H stage of canines development, and 95.08% persons with H stage of second premolars development with no statistical differences of developmental stages distribution of above mentioned teeth between I, II and III Class (p >0.05). Correlation values between canine developmental stages and CS5 and CS6 were equal to the range of 0.52-0.64 and 0.60-0.69 respectively; between second premolar developmental stages and CS5 and CS6 – 0.61-0.67 and 0.60-0.69 respectively; between second molar developmental stages and CS5 and CS6 – 0.51-0.53 and 0.50-0.58 respectively. Obtained results allow to resume that deviations of dental age among persons with different sagittal relationship prior to orthodontic treatment characterized with the analogical tendencies of distribution, thus providing us with primary evidences for theoretical hypothesis that dental maturation patterns used for dental age estimation are not influenced by the fact of different sagittal relationship itself. However, obtained results are not competent to conclude that essential causes of sagittal relationship changes have no effect on dental maturation processes.

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Introduction

Use of forensic dental methods has increasingly broadened over past decades not only for specific forensic investigation or identification purposes, but also for variety of clinical implications.[1,2,3,4] During orthodontic treatment planning of children and adolescents clinicians should take into account present patient's phase of skeletal maturity, which will influence timing of the planned iatrogenic interventions.[3,5] Several approaches have been developed to assist dentist during the evaluation of skeletal maturity phase of orthodontic patients, including methods with radiographic examination of hand-wrist area, cervical vertebras and dental apexes.[6,7,8,9,10] Correspondence between the results obtained with the use of these methods remains discussible, nevertheless different levels of correlation have been established between dental maturation parameters and developmental patterns of phalanxes and cervical vertebras.[3,5,8,9]

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Such disagreement between the results of skeletal maturity evaluation using different approaches could be argued by the different accuracy of the methods, possible physiological time gap between development of different skeletal structures, individual patterns of skeletal development and presence of pathologies.[5]

Previously obtained results helped to conclude that intensive skeletal growth could influence parameters of dental development used in dental age estimation methods.[10] Nevertheless, some studies showing that practical utility of dental maturity criteria for the reliable evaluation of skeletal maturity phase is limited, thus narrowing possibilities of using such indicators for argumentation of specific orthodontic treatment timing.[5] But it should be noted that effective use of any dental age estimation techniques is limited to some specific conditions under which parameters that applied for age calculation (volume of pulp chamber, height of anatomical crown, root apex tissue integrity, length of root) are not altered by some kind of pathology or iatrogenic interventions. Latter could influence not only the reliability of the outcome results, but also provoke complicacy with the consistent protocol realization of different dental age estimation methods. Nevertheless, previously different researches have published evidences due to which reliable dental age estimation procedure could be successfully implemented even during pathological attrition condition or even after provided orthodontic treatment.[11,12]

Also, chronological age parameter itself playing role in the process of establishing associations between dental and skeletal maturation phases, since in the period of pubertal spurt these criteria could greatly variate within their correspondence levels.[13,14] This tendency argument the need to find complementary pattern between dental and skeletal maturity phases during period of growth stabilization (at the end of puberty period) first, and only after that start to investigate those interrelations during growth spurt stage.

Considering above-mentioned facts, the present research **aims** to evaluate level of correspondence between skeletal and dental maturity parameters and their relation to chronological age among orthodontic patients with different sagittal relationship at the end of puberty period.

Materials and methods

The study included analysis of 811 randomly chosen panoramic x-ray results(digital OPGs, Planmeca)obtained before orthodontic treatmentfrom the database of Orthodontic Department at University Dental Clinic (Faculty of Dentistry, Uzhhorod National University).All OPGs were gathered from the previously obtained results of diagnostics with no additional x-ray examination provided specifically for this research. Inclusion criteria for further analysis of primary formed patients' datasets of OPGs consisted of next parameters: 1) absence of congenital disorders or deformities of the teeth-jaw system; 2) absence of hypodontia, primary edentulism or facts of trauma; 3) age of the patient in the range of 15-17 years (which corresponds to average end of puberty period among males and females); 4) presence of data about registration of patient sagittal relationship by professional orthodontist; 5) presence of patient's cephalogram obtained before orthodontic treatment in the database of patients' diagnostic results with difference between OPG and cephalogram reception no more than 1 month. These parameters were analyzed by the investigation of patients' medical records and technical properties of OPGs and cephalograms among datasets that were initially randomly selected for research.

Due to the inclusion criteria the study sample of patients' digital datasets was reduced to 61 pieces that were further analyzed with the use of specific methods. Parents of children whose medical records, OPGs and cephalograms were used for the research were informed with conditions and rules of the research methodology and signed agreement form to use previously mentioned data as study material. All digital datasets of patients' information were anonymized and encoded to assure integrity of the study.

All 61 patients' datasets were divided into 3 subgroups considering specifics of sagittal relationship (I, II and III Class). For each subgroup evaluation of dental age and staging of teeth development were provided with the use of Demirjian's method, protocol of which was realized due to the original proceedings proposed by Demirjian and Goldstein.[15,16] Considering Transcarpathian origin of all study subjects, additional age estimation was provided with the

use of adapted correction formulas.[2]Evaluation of skeletal maturity was provided with the use of cervical vertebral maturation (CVM) method by the analysis of present cephalograms.[17,18,19]

The study protocol was approved by the Ethics Committee of Uzhhorod National University (Ukraine).

Statistical analysis was conducted with the use of Statistica software (statsoft.com). Mean values of dental and chronological age were calculated for each class of sagittal relationship separately considering differences between these parameters among males and females. Post hoc analysis was provided to evaluate pattern of deviation distribution during dental age estimation among subjects with different sagittal relationship.Percentage distribution of the dental developmental stages and cervical vertebra maturity stages was calculated in each study subgroup and among all study samples. Criterion of correlation (Pearson coefficient) and p-value estimation for Pearson's r were used for evaluation the level of association between dental and chronological age parameters. Relationship between CVM stages and dental development stages were estimated using Spearman rank correlation coefficient.Tabulation of obtained results was provided in Microsoft Excel software (Microsoft Office 2019, Microsoft)[20].

Results

Among all study sample, 23 persons (37.70%) were registered with I Class sagittal relationship, 19 persons (31.15%) with II Class relationship, and 19 persons (31.15%) with III Class relationship. Obtained dental age values evaluated with the use of Demirjian's method were overestimated among all study subjects independently on registered sagittal relationship: among persons with I Class on 0.49±0.35 years; among persons with II Class on 0.37±0.69 years; among persons with III Class on 0.64±0.47 years.Retrospective (post hoc) analysis of dental age overestimated values compare to chronological age has shown that obtained results were not statistically different between persons with I (95% CI, 0.32 to 0.62 years) and II (95% CI, 0.27 to 0.54 years) Classes of sagittal relationship ($p > 0.05$); analogically no statistical difference was registered between overestimated dental age values comparing subgroups of I and III Classes (95% CI, 0.39 to 0.72 years) ($p > 0.05$). Average overestimation level among all study subjects considering gender criteria reached 0.44 years (95% CI, 0.27 to 0.52 years) in males and 0.50 years (95% CI, 0.34 to 0.72 years) in females.

Use of correction formula helped to reduce overestimationdifferences between chronological and dental age to the next: among persons with I Class to 0.27±0.19 years; among persons with II Class to 0.31±0.25 years; among persons with III Class to 0.38±0.31 years. Retrospective (post hoc) analysis of dental age overestimated values obtained with the use of correction formulas compare to chronological age has shown analogical pattern with no statistical differences between all three classes: I Class (95% CI, 0.21 to 0.39 years), II Class (95% CI, 0.28 to 0.41 years), III Class (95% CI, 0.32 to 0.65 years) ($p > 0.05$). Average overestimation level with the use of correction formula among all study subjects reached 0.30 years (95% CI, 0.21 to 0.49 years) in males and 0.39 years (95% CI, 0.29 to 0.65 years) in females.

Person's correlation between chronological age and dental age estimated with the use of original protocol proposed by Demirjian reached r=0.79 (p < 0.05), during the use of adapted correction formulas r=0.84 (p < 0.05).

Among all study subjects 85.24% persons were registered with H stage of second molars development, 80.32% persons with H stage of canine development, and 95.08% persons with H stage of second premolars development with no statistical differences of developmental stages distribution of above mentioned teeth between I, II and III Class (p > 0.05). Considering cervical vertebras development among all study subjects, 68.85% persons were registered with stage CS5 and 24.59% persons with stage CS6. Among all study subjects 15-17 years old correlation values between canine developmental stages and CS5 and CS6 were equal to the range of 0.52-0.64 and 0.60-0.69 respectively; between second premolar developmental stages and CS5 and CS6 – 0.61-0.67 and 0.60-0.69 respectively; between second molar developmental stages and CS5 and CS6 – 0.51-0.53 and 0.50-0.58 respectively.

No statistically reliable association was registered between some specific class of sagittal relationship and relevant changes of

intercorrelation within skeletal and dental maturity parameters (p > 0.05).

Discussion

Considering orthodontic patients' specifics several previously published studies have found that different orthodontic pathologies or deformities itself could influence dental developmental pattern, thus changing reliability of results during skeletal maturity evaluation by the dental status.[6,10,21]

During retrospective study provided by Celikoglu et al. it was found that orthodontic patients with different skeletal malocclusions demonstrates approximately twice greater discrepancy between chronological and dental age compare to patients with Class I relationship.[21]Statistically significant difference between passport age and dental age was registered only among females with Class III relationship. Interestingly that in the research provided by Lauc et al., authors have found that ANB Class III male patients characterized by significantly marked difference between chronological and dental age parameters compare to ANB Class II and Class I patients.[10] Moreover, Class III orthodontic patients had shown the same pattern of results formation compare to patients of other classes, based on what authors resumed that Class III male patients marked with typical but faster dental development, which is not associated with females.[10] Probably such difference in results obtained by Celikoglu et al.[21] and Lauc et al.[10] considering gender parameter could be explained by the use of different age estimation techniques: in the first study Demirjian's method have been used, while in second study Willems's and Cameriere's methods were implemented. In our study we have not found any statistically significant overestimation differences between chronological and dental age among patients with I, II and III Class of sagittal relationship, even though III Class patients have shown the greatest absolute discrepancy between dental and chronological age parameters. So, obtained results are similar to those described by Celikoglu et al.,[21] but absence of statistical difference in our research could be argumented by relatively small study sample size compare to the sample size in the Celikoglu's study (63 patients vs 525 patients). Considering limitation of our study due to small study sample, we could just provide hypothesis that dental maturation patterns used for dental age estimation are not influenced by the fact of different sagittal relationship itself, but forapprovement of such hypothesis there is a need for further research withanalysis of greater study sample.

Previous research has found that even though dental and skeletal maturity were highly correlated, but diagnostic possibilities of using dental maturation staging for precise verification of skeletal maturation phase is restricted.[5] Dental maturation parameters were statistically argumented for confirmation of pre-pubertal growth stage, while no statistically approved criteria were notified for registration of pubertal growth spurt.[22]On the other hand,it was also found that diversity between skeletal and chronological ages were still referred to age parameter itself.[13,14]In our study we have provide research on the interrelation between skeletal and dental maturity among patients at the end of puberty period, considering variations of these association during growth spurt. Even in conditions of all study subjects being aged from 15 to 17 years, we found out strong correlation between dental and chronological age parameters using classical Demirjian's approach and modified correction formula approach.

In the study of Perinetti et al.[22] authors have found that positive likehood ratio greater than 10 during comparison of dental maturity stages and cervical vertebra maturation stages were registered only in pre-pubertal growth phase using second molar and first premolars as an indicator, while in the Rózyło-Kalinowska et al.[23] study the highest correlation was found between CVM and second premolar and canines among both genders. In both these studies Demirjian's method was used for evaluation of dental maturity phase. Sachan K. also found significant correlation between cervical vertebrae maturation phase and canine calcification phase using Nolla's method for grading the latter parameter.[24,25] Goyal S. and colleagues had shown that canine stage F-E by the Demirjian system among both genders could be representative for 2 stage of skeletal maturity evaluated by cervical vertebrae maturation index, thus corresponding to the start of accelerating growth phase.[26] Litsas and coauthors noted the most prominent correlation between second molar development stage and CVM stages, while

the lowest correlation was found using canines as an indicator.[3] It is also important to mention that strongest correlation between passport and dental age was registered during Stage IV of skeletal maturity estimated by CVM.[3] In our study we have found that among 15-17 years old study subjects correlation values between canine development stages and CS5 and CS6 were equal to the range of 0.52-0.64 and 0,60-0,69 respectively; between second premolar development stage and CS5 and CS6 – 0.61-0.67 and 0.60-0.69 respectively; between second molar development stage and CS5 and CS6 – 0.51-0.53 and 0.50-0.58 respectively. Some discrepancy with previously published results could be argumented by the influence of relatively small study sample and specific age range of study subjects, but overall tendencies of interrelations between dental development stages and CVM stages were according to evidences obtained from other studies.

There are also results showing presence of association between dental development and skeletal maturity phase using other scoring approaches. Khan and Ijaz have found correlation between canine calcification stages and skeletal maturity indicators using for such purpose Demirjian and Fishman classifications respectively.[27] Authors specified that canine stage F by Demirjian system corresponds to the MP3 stage of Fishman system and represents the start of accelerating period of growth, while stage G correspond to the S and MP3CAP stages and represented rapid growth velocity.[27] Use of Fishman skeletal system as a referent helped to find out significant correlation between skeletal maturity indicators and mandibular canines developmental stages evaluated by Demirjian's method among males aged 9-14 years.[28] Surendran et al. had stated that use of Demirjian's method helped to identify only prepubertal and postpubertal growth phases that corresponded to the modified middle phalanx of third finger (MP3) stage.[29] Results of our study have shown efficiency of Demirjian's method for accurate age estimation among study subjects at the end of puberty period, even though modified technique with the use of correction formula was characterized with lower level of age deviations.

In the review of Morris J.M and Park J.H. authors characterized dentition parameters as "rough indicator" and "adjunct" method for evaluation of patient skeletal growth phase.[5]

Authors also highlighted the causes of variability of dental criteria during evaluation of skeletal maturation stage. Such causes have included problems of categorization for dental stages among different classification systems (while adding more stages in such classification for greater accuracy, practical use of such systems become more difficult), use of different radiographic examination techniques, results of which could not be appropriately compared, individual growth patterns that deviates from average norms.[5] Nevertheless, based on the obtained results we can resume that dental classification staging proposed by Demirjian could be used as primary diagnostic procedure in complex of skeletal maturity evaluation with other anatomical references for upgrading time-efficiency of different dental treatment approaches.

Conclusions

Considering limited conditions of provided study and its pilot design over the population of Transcarapthian region, obtained results allow to resume that deviations of dental age estimation among persons with different sagittal relationship prior to orthodontic treatment characterized with the analogical tendencies of distribution, thus providing us with primary evidences for theoretical hypothesis that dental maturation patterns used for dental age estimation are not influenced by the fact of different sagittal relationship itself. However, obtained results are not competent to conclude that essential causes of sagittal relationship changes have no effect on dental maturation processes, which in turn could limit the possibilities for age estimation by dental status and argument the need to conduct future research in this field. Use of other anthropological benchmarks, such as cervical vertebra maturation criteria, along with developmental dental references, could optimize the process of person's maturity evaluation during complex forensic examination and orthodontic treatment planning.

Declaration of Interest

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