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Secular Trends in Age at Onset of Orthodontic Treatment in Adolescents

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ABSTRACT

Introduction: It was previously found that age of sexual maturity during the last two decades has declined. The purpose of this study was to investigate whether chronologic age, dental age and skeletal developmental stage at onset of orthodontic treatment have changed during the last few decades in the same manner. In addition, to find out whether correlations exist between these ages. Such changes might have implications on clinical orthodontic practice.

Methods: Panoramic and lateral cephalometric radiographs of 300 adolescents (139 males, 161 females) who began their orthodontic treatment during the years 1990-1992 or 2010-2012 (152 and 148 subjects, respectively) were examined. Chronologic, dental and skeletal ages were determined and compared between the two groups and correlations between these ages were calculated.

Results: Mean chronologic age was 12.26 ± 1.22 years during 1990-1992 and 12.63 ± 1.64 during 2010-2012 ($p=0.028$). Mean dental age was $12.27 \text{ years} \pm 1.88$ during 1990-1992 and 13.02 ± 2.20 during 2010-2012 ($p=0.002$). Mean skeletal developmental stage of subjects was 2.68 ± 1.60 during 1990-1992 and 2.99 ± 1.75 during 2010-2012 ($p>0.1$). Significant correlations were found between chronologic, dental and skeletal ages.

Conclusions: Although no significant change of skeletal developmental stage upon commencing orthodontic treatment has occurred over the last two decades, both chronologic and dental ages have increased, particularly for females. There is significant correlation between chronologic, dental and skeletal ages for the entire group, particularly for females.

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Introduction

Before commencing orthodontic treatment, the orthodontist has to consider some biological indicators in order to evaluate the patient's maturation. Such indicators are dental development or skeletal maturation. Dental age is one of the main tools that assist the orthodontist. Studies have reported numerous ways of assessing this parameter [1]. The atlas approach describes different chronological stages of dental development presented in tables. The chronological age can be estimated by comparing an individual's dental development with the tables [2]. A more sophisticated method that was developed later on summarized the developmental scores of an individual's teeth into one overall maturity score from which an estimation of chronological age is derived [3]. It has been proposed that tooth formation is a better method for determining dental maturation than tooth eruption [4]. By examining x-ray photographs (panoramic or periapical) of the patient, the physician evaluates root development of the permanent teeth, thus determining the patient's dental age [5].

Skeletal maturation is also considered as an important indicator while assessing the timing for beginning orthodontic treatment and while preparing a patient's treatment plan. Growth spurt,

growth duration and intensity of the mandible can be estimated by assessing the patient's skeletal growth. Identifying the point of acceleration is imperative during orthodontic treatment, especially in Class II patients [6].

In the past, evaluation of skeletal maturity was usually based on hand wrist x-rays, thus requiring additional exposure to radiation. Later on, assessment of lateral cephalograms, more specifically analyzing the cervical vertebral maturation, was found to be a reliable method for determining skeletal maturity [7]. These findings have been confirmed by several studies [8]. A new index that was developed in 2000 divided the development of neck vertebrae into six stages [9]. It was found that by inspecting the outline and morphology of the cervical vertebrae in lateral cephalometric evaluation, it is possible to determine the acceleration of body height, and thus of mandibular growth.

Back in the 1960's, Lewis et al. had already found an interrelationship between tooth formation and general growth and development [10]. They reported that tooth formation and especially tooth movement was highly correlated with sexual maturation, while its correlation with somatic growth was not as high. Another study in 2006 found positive correlation between dental age and skeletal maturation, and in addition suggested that these two can reflect general somatic growth [11]. In 2010,

Chen et al. introduced similar findings, concluding that there is a relation between dental and skeletal maturation⁷. Other studies have shown that there is a relation between teeth development and GnRH - gonadotropin axis, which is an integral part of sexual maturity [12].

There is a consistent search for the relationship between dental age, somatic and sexual maturity. Demirijian et al. found that the dental developmental mechanism is different and independent of somatic and sexual maturation [13]. Willems stated that tooth mineralization stages are much less affected by variation in nutritional and endocrine status than bone mineralization, and therefore provide a more accurate indication of chronological age [1].

Orthodontic treatment is usually performed during puberty, when the adolescent undergoes different physiological and anatomical changes, such as an increase in levels of growth hormone (GH), insulin-like growth factor 1 (IGF-1), and sex hormones (testosterone and estrogen). Combination of these factors contributes to pubertal spurt, which in turn was found to be related to skeletal maturation rather than to chronologic age, and to differ between boys and girls [14,15].

There is a relation between age at menarche, which reflects the pubertal physiologic age and skeletal maturation. Findings indicate that female orthodontic patients had passed pubertal growth spurt by a year when they experienced their menarche [16].

As previously published, the age of sexual maturity has been declining during the last decades, mainly from 1990, and tends to change between different ethnic groups [17]. In Taiwan, the mean menarche age of female orthodontic patients has declined, with an estimated downward shift of 0.47 year per decade [16]. In Israel, no change in age at menarche was seen among women born between 1875-1970, but there was a clear downwards trend from 13.4 to 12.8 in women born at 1970 and 1990, respectively [18].

As previously shown, there is evidence of correlations between skeletal maturation, somatic growth, dental age and sexual maturity. Therefore, there might be an influence of aforementioned declining sexual maturity age over the last two decades on the age at onset of orthodontic treatments. The purpose of this study is to investigate whether the chronologic age, dental age and skeletal developmental stage at onset of orthodontic treatment decreased during the last few decades, and to find out whether correlations exist between these different ages.

Materials and Methods

The sample used in this retrospective cross-sectional study included 300 young orthodontic patients (139 males, 161 females) whose files were randomly selected from the orthodontic department of XXX at XXX Medical Center, XXX. All subjects began their orthodontic treatment either during the years 1990-1992 or 2010-2012 (152 and 148 subjects, respectively). Three different physiologic ages were evaluated separately for each subject, as follows, relying on his/her panoramic and lateral cephalometric X-rays, which were taken immediately before commencing the orthodontic treatment.

Chronologic age was calculated by subtracting the patient's date of birth from the date stated on the patient's panoramic and cephalometric diagnostic radiographs. Dental age of the patients was determined by their panoramic x-ray, specifically by the degree of their dentition roots development, using the accepted values of Gorlin and Profit [4,19].

Skeletal developmental stage was assessed by the lateral cephalometric radiographs. Skeletal maturation was determined by cervical vertebral maturation index, which was divided into six consecutive developmental stages (Cvs 1 through Cvs 6), as was described by Lamparski and modified by Franchi et al. [9,20].

The research protocol was reviewed and approved by the local Ethical Committee of XXX. Signed informed consent was not obtained, as was determined by the committee. As for the reliability and reproducibility of dental and skeletal developmental stage assessments, a pilot study that was conducted by two operators (S.E, B.S.N) prior to data collection assessed 30 randomly chosen radiographs for calibration and training. The reliability of assessment for both operators at the pilot study showed high correlation values. Cronbach's alpha for comparing dental age as stated by both operators was 0.992 with an interclass correlation coefficient (ICC) of 0.985 (95% CI 0.981-0.988). Cronbach's alpha for comparing skeletal developmental stage as stated by both operators was 0.998 with ICC of 0.996 (95% CI 0.995-0.997), and Kappa value for comparison of skeletal developmental stage was 0.969 for both operators.

As for the complete sample, each radiograph was separately assessed by two different operators (S.E, B.S.N), without knowing the patient's sex, chronologic age, or date of file. The results were compared, and when differences in evaluation for one of the parameters exceeded one developmental stage or one year, the radiograph was discussed by the operators and reevaluated. A mean value was calculated for every measurement by both operators, and served as basis for statistics. Cronbach's alpha for comparing dental age as stated by both operators was 0.995 with interclass correlation coefficient (ICC) of 0.995 (95% CI 0.993-0.996). Paired samples correlation between skeletal developmental stage as stated by both operators using T-test was 0.996.

Statistical computations were performed by means of computer software (SPSS for Windows, release 21, SPSS, Inc). Mean chronological and dental age was calculated and unpaired T-test was used to compare these ages between the two periods. Mann-Whitney Test was used to compare mean skeletal developmental stages between the two periods. Pearson correlation coefficient was used to measure the association between dental and chronologic ages. Spearman's rho was used to measure the association between skeletal developmental stage and dental or chronologic age.

Results

Chronologic age

Mean chronologic age of subjects was 12.26 years \pm 1.22 (95% CI 12.06 - 12.45) during the years 1990-1992 and 12.63 \pm 1.64 (95 % CI 12.36 - 12.89) during 2010-2012 (table 1).

Table 1: Chronologic age, dental age and skeletal developmental stage averages

	gender	1990-1992				2010-2012			
		count	range	average	SD	count	range	average	SD
chronologic age	males	68	10.2-15.9	12.29	1.18	71	9.6-16.8	12.42	1.55
	females	84	9.4-16.3	12.23	1.26	77	9.6-16.8	12.82	1.7
	total	152	9.4-16.3	12.26	1.22	148	9.6-16.8	12.63	1.64
panoramic	males	68	8.5-16.0	11.88	1.74	71	8.5-17.0	12.26	2.01
	females	84	8.0-17.0	12.58	1.94	77	8.8-17.0	13.72	2.14
	total	152	8.0-17.0	12.27	1.88	148	8.5-17.0	13.02	2.2
cephalometrics	males	68	1.0-6.0	2.03	1.27	71	1.0-5.0	2.25	1.39
	females	84	1.0-6.0	3.21	1.65	78	1.0-6.0	3.67	1.78
	total	152	1.0-6.0	2.68	1.6	148	1.0-6.0	2.99	1.75

(a) - T Test

(b) - Mann-Whitney Test

Difference between the groups was statistically significant ($p=0.028$). When comparing the chronologic age by gender, we found that the mean chronologic age in the female group was significantly higher during the years 2010-2012 than during 1990-1992 by 0.59 years ($p=0.014$). No significant difference was found between the males during the years 2010-2012 and 1990-1992.

Dental Age

Mean dental age of subjects was 12.27 ± 1.88 (95% CI 11.97 - 12.57) in the years 1990-1992, and 13.02 ± 2.20 (95% CI 12.63 - 13.38) during 2010-2012 (table 1). Difference between the groups was statistically significant ($p=0.002$). The age of the female group was significantly higher during the years 2010-2012 than during 1990-1992 by 1.14 years ($p=0.001$). No significant difference was found between the males during the years 2010-2012 and 1990-1992.

Skeletal Developmental Stage

Mean skeletal developmental stage of subjects was 2.68 ± 1.60 (95% CI 2.43 - 2.94) in the years 1990-1992, and 2.99 ± 1.75 (95% CI 2.71 - 3.27) during 2010-2012 (table 1). The difference between the groups was not statistically significant, neither as a whole group, nor as gender-separated groups.

Correlations

Correlation between chronologic and dental age was 0.695 according to Pearson's correlation coefficient (table 2).

Table 2: Cross-correlations between chronologic age, dental age and skeletal developmental

Stages		chronologic age	dental age	skeletal developmental stage
chronologic age	males	1	0.692 ^{**} (a)	0.397 ^{**} (b)
	females	1	0.714 ^{**} (a)	0.602 ^{**} (b)
	total	1	0.695 ^{**} (a)	0.502 ^{**} (b)
dental age	males	0.692 ^{**} (a)	1	0.366 ^{**} (b)
	females	0.714 ^{**} (a)	1	0.525 ^{**} (b)
	total	0.695 ^{**} (a)	1	0.525 ^{**} (b)
skeletal developmental stage	males	0.397 ^{**} (b)	0.366 ^{**} (b)	1
	females	0.602 ^{**} (b)	0.525 ^{**} (b)	1
	total	0.502 ^{**} (b)	0.525 ^{**} (b)	1

** Correlation is significant at the 0.01 level (2-tailed)

(a) Pearson correlation

(b) Spearman's rho

Correlation between chronologic and skeletal developmental stage was 0.502, and correlation between dental and skeletal developmental stages was 0.525, both according to Spearman's rho. All different correlations were significant at level 0.01. All three correlations were stronger for females than for males.

Discussion

The results of this study demonstrate that both chronologic and dental ages at onset of orthodontic treatment have increased over the last two decades, particularly in girls. As opposed to those ages, skeletal developmental stage has not significantly changed. Surprisingly, the downwards trend of sexual maturity age in XXX at the same period has not affected the age of beginning orthodontic treatment, despite the aforementioned correlations between sexual maturity, dental age and skeletal maturation [18].

Interestingly, it was recently found that irrespective of gender, most subjects undergoing orthodontic treatment in Germany were 12-13 years old [21]. At this age, 60% of the girls and only 38% of the boys had already attained advanced stages of pubertal development. This discrepancy could have therapeutic implications, and might suggest that different factors are involved in orthodontic treatment seeking by adolescents other than pubertal development. Indeed, a recent study conducted in Brazil revealed that poor self-perceived aesthetics, more severe malocclusion and better socioeconomic position significantly influenced the decision to seek orthodontic treatment [22]. Moreover, parents' perception of their child's need for treatment was found in Brazil as a factor associated to the desire for treatment [23]. Hence, the onset of orthodontic treatment is a result of several factors, including socioeconomic, behavioral or physiological, and not only objective physiological factors such as skeletal developmental stage, sexual maturity or dental age. Decreased sexual maturity age, therefore, is not necessarily reflected by similar decrease in onset of orthodontic treatment, as was shown in our results. This might suggest a possible explanation to the results obtained in this study.

Nonetheless, the increase that was found in skeletal developmental stage was not statistically significant. Since the skeletal developmental stage was positively correlated to the chronologic and dental ages which have increased, we believe that the lack of statistical significance of the increasing skeletal age might be

due to difficulty in achieving reproducible results while trying to determine the CVM stage as was previously stated by Gabriel et al [24].

Moreover, the difficulty in determining the correct skeletal developmental stage could further provide some explanation for the lower correlation found between skeletal developmental stage and dental or chronologic age, contrary to the good correlation between dental and chronologic age, as was found in this study as well as in previous works. Our findings show high correlation between chronologic and dental age ($r=0.714$ in females, $r=0.692$ in males), and are consistent with Rosylo-Kalinowska et al who reported a similar correlation of 0.77 in females and 0.79 in males [25]. Furthermore, our results confirm the findings of Uysal et al who found positive and higher correlation between chronologic age and skeletal maturation ($r=0.68$ in males, 0.82 in females), as indicated in our study ($r=0.397$ in males, $r=0.602$ in females) [26]. In addition, we found that the correlation between dental and skeletal maturation was 0.366 in males and 0.602 in females. These findings were similar to those of Chen et al, who observed a correlation of a 0.464 - 0.496 for males and 0.391 - 0.582 for females [7]. Noteworthy is the fact that all correlations are lower in males than in females, as was mentioned in previous works, probably due to the fact that CVM method is more reliable in females [20,26,27].

Some methodological limitations of the present study should be considered in interpreting the data. The investigated period in this research was considerably short and lasted two decades. Thus, our results might have potentially missed secular trends, which usually take longer. Nevertheless, we assumed that decreasing sexual maturity age that took place in many countries including XXX over the same short period of time should already have influenced the skeletal, dental and chronological ages at onset of orthodontic treatment as well [18].

Data on socioeconomic status of the subject were not available in this study. Nevertheless, previous studies have shown contradictory results regarding the relationship between socioeconomic status and age of sexual maturation. Some researches demonstrated that improvement in socioeconomic conditions and overall health contribute to the trend toward earlier sexual maturation through a variety of suggested mechanisms [28,29]. However, others found the opposite, with reduction in age at menarche, thus raising questions about the causality of these factors [30]. Yet, socioeconomic status might have affected the results by influencing the decision to seek for orthodontic treatment, as discussed earlier, thus potentially changing the age at beginning of orthodontic treatment.

Further research is recommended in order to find out whether there is a trend of decreasing age at beginning of orthodontic treatment. Such research should be expanded and conducted on larger and diverse population and during a longer period of time. In addition, socioeconomic status of the subjects should be obtained. Possibly, non-physiological parameters such as behavioral changes or social norms take longer to be expressed. Since they influence the age at onset of orthodontic treatment, we expect to observe a decrease of this age in the future. These potential changes might have implications on clinical orthodontic practice. Although treatment timing has to be decided individually according to the dental and skeletal status of the respective patient, clinicians and public health institutes should be aware of developing trends.

Conclusions

1. Chronologic and dental age at beginning of orthodontic treatment have increased over the last two decades for the entire group, particularly for females.
2. The increase of skeletal developmental stage at beginning of orthodontic treatment over the last two decades was statistically insignificant.
3. There are significant correlations between chronologic, dental and skeletal developmental stages for the entire group, especially for females.

Conflict of Interest

None to declare.

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