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Does dental caries affect dental development in children and adolescents?

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ABSTRACT

Objective: To investigate the effect of dental caries on dental development in Albanian children and adolescents.

Methods: In total, 118 children and adolescents from Albania, born in 1995-2004 and aged between 6 and 15 years old participated in this study. Dental Caries in deciduous dentition was assessed using Decayed-Filled-Teeth (dft) Index and dental caries in permanent dentition was assessed using Decayed-Missing-Filled-Teeth (DMFT) Index. Dental development of the permanent dentition was assessed using the Demirjian method. Linear and ordinal regression models were applied to analyze the effect of caries on dental age and on the development of each left mandibular tooth.

Results: Dental caries in deciduous dentition was estimated as a median dft of 2.0 (90% range, 0.0-9.1) and it was significantly associated with a lower dental age (β = -0.21; 95% CI: -0.29, -0.12) and with a delayed development of the canine, both premolars and the second molar. Untreated dental caries (dt) was associated with lower dental age (β = -0.19; 95% CI: -0.28, -0.10). Dental caries in permanent dentition was estimated as a median DMFT of 1.0 (90% range, 0.0-8.0) and was not significantly associated with dental age (β = 0.05; 95% CI: -0.04, 0.14). However, DMFT was associated with an advanced development of both premolars and the second molar.

Conclusion: The untreated caries in deciduous dentition will delay the development of permanent teeth.

3.2.1 INTRODUCTION

Dental development is a complex process that starts with the differentiation of dental lamina and ends with the final calcification of permanent teeth [1, 2]. Each part of the tooth must go through accurate stages of development to produce a healthy dentition [3].

Oral diseases arising during the process of dental development disturb the balance between a healthy dentition and a healthy oral cavity [1, 4]. Dental caries is a post-eruptive oral disease that affects the hard tissues of teeth in a destructive way due to bacterial activity [5]. Dental caries is recognized as the most common oral disease, but in the last decades it even has become the most common childhood disease worldwide [6, 7]. According to the Decayed, Missing and Filled Teeth (DMFT) Index the prevalence of dental caries in different regions of Europe varies from 1.0 (Scotland) to 5.8 (Kosovo) [8, 9]. Recent studies in Albanian population show a DMFT of 3.72 in 12 years old which peaks to 4.9 in 17 year old adolescents [10, 11]. Severe dental caries affects oral and general health of children and adolescents [4].

The increase in prevalence of dental caries is a result of dietary changes based on high-energy low cost food poor in nutrients and rich in sugar and fat [12]. On the other hand, the dietary changes have decreased the velocity of dental development in modern humans compared to our ancestors [13]. Sufficient supply of nutrients such as calcium, phosphorus and vitamins are essential for dental development and reduce the risk of dental caries [14, 15]. Furthermore, genes involved in enamel development are shown to have an important role in dental caries [16-18]. Although dietary and genetic factors link caries with dental development, the literature doesn't share insight on this relationship. Therefore, in this study we aimed to investigate the influence of dental caries on dental development in 118 Albanian children and adolescents.

3.2.2 MATERIAL AND METHODS

3.2.2.1 Study population

All the patients were referred for a dental visit to the general dental practice, Dent Ital Clinic located in Durrës, Albania. Patients were eligible to participate in the study due to selection criteria: (1) available Dental Panoramic Radiograph (DPR) taken between the age of 6-16 years, (2) were born after 1994, (3) had presented no severe acute or chronic diseases in their general anamnesis and (4) had experienced no craniofacial trauma or surgery. The selection information was obtained from the patient anamnesis present on the clinical files using the Child Health/ Dental History Form (ADA, 2006). The study sample consisted of 118 children and adolescents of Albanian ethnicity, born in 1995-2004 and aged between 7 and 15 years old. Signed parental approval was taken for the further oral examination, diagnostic tests and treatment. The utilization of DPRs is in accordance with the general treatment protocol, in respect to the legislation of Albanian Medical Ethics Committee. This study was conducted in accordance with the World Medical Association Declaration of Helsinki (2008) and it has been independently reviewed and approved by Albanian Ethics Committee of Dentistry.

3.2.2.2 The assessment of dental caries

Dental caries was evaluated by an independent examiner (B.D) based on Dental Panoramic Radiographs (DPRs) taken with IMAX PLUS CEPH machine (CCD resolution, 10.4/5.2 pixels/mm). When the examiner had uncertainties to evaluate caries in specific teeth, necessary information about extracted and filled teeth was retrieved from the patient clinical files to clarify the doubts. As 68% of the participants had a mixed dentition, the Decayed and Filled Teeth Index for the deciduous dentition (dft) and the Decayed, Missing and Filled Index for the permanent dentition (DMFT) were used to estimate dental caries. "d/D" component is used to describe decayed teeth which include carious teeth, filled teeth with recurrent decay and elements of which only the root is present. "M" component is used to describe missing teeth due to dental caries. We did not consider the "m" component for the missing teeth in deciduous dentition, due to the difficulty in distinguishing a missing tooth due to exfoliation with a missing tooth due to caries. "f/F" component is used to describe filled teeth due to caries. Teeth are considered filled when one or more permanent restorations are present and there is no recurrent caries or any area of the tooth with primary caries. For dft and DMFT, each affected tooth is counted as one for the three index components. The obtained values for the three index components are summed up to calculate dft and DMFT for every participant. Third molars are not considered in the DMFT Index.

3.2.2.3 The assessment of dental development in permanent dentition

Dental development was defined using the Demirjian's method, the most worldwide used method due to the simplicity in application [19]. The same examiner who evaluated dental caries, experienced in using Demirjian's method [20], determined the eight stages of development (1 to 8) for each of the seven permanent teeth located in the lower left quadrant (excluding the third molar). In case any permanent tooth in the left mandible was congenitally missing, the stage of development was assessed from the corresponding tooth in the right mandible. The obtained stages of development were weighted using three different dental age standards (Dutch, French- Canadian and Saudi) and subsequently for each standard separately summed to calculate the gender specific maturity scores. Finally, standard tables were used to convert the dental maturity score into dental age. The dental age standard that presented the best approach of dental age with chronological age was chosen as a proxy for dental development and applied in further statistical analysis.

3.2.2.4 Statistical analysis

We calculated the Intra-Class Correlation (ICC) to test the agreement between two independent examiners who assessed dental caries and stages of development (1 to 8) for each of the seven left mandibular teeth in a random subsample of 25 DPRs from the study population.

The association between dental caries in deciduous dentition (dft) and dental development (dental age) was analyzed using two linear regression models. In Model 1 we analyzed the crude association between dft and dental age in children and adolescents. In Model 2, we additionally adjusted for sex, age, hypodontia and DMFT. The same analysis and models were applied to test separately the effect of decayed teeth (dt) and filled teeth (ft) on dental age.

The association between dental caries in permanent dentition (DMFT) and dental development (dental age) was analyzed using two linear regression models. In Model 1 we analyzed the crude association between DMFT and dental age in children and adolescents. In Model 2, we additionally adjusted for sex, age, hypodontia and dft. The same analysis and models were applied to test separately the effect of decayed (DT), missing (MT) and filled teeth (FT) on dental age.

The association between dental caries in deciduous dentition (dft) and development of each left mandibular permanent tooth was analyzed using an ordinal regression model, adjusted for sex, age, hypodontia and DMFT. For this analysis the severity of dental caries in deciduous dentition (dft) was categorized in tertiles as 1-no dental caries (dft = 0), 2-mild dental caries (1≤dft≤3), 3-moderate to severe dental caries (dft ≥ 4) (21). The first group of children with no dental caries (dft = 0) was used as the reference group. The same analysis was performed to study the association between dental caries in permanent dentition (DMFT) and development of each left mandibular permanent tooth. In this case, the ordinal regression model was adjusted for sex, age, hypodontia and dft. The same approach applied to categorize the dft was also used to categorize the DMFT. The result was considered statistically significant for a p-value ≤0.05. All statistical analyses in this study were performed using statistical software Statistical Package for Social Sciences version 21.0 (SPSS Inc. Chicago, IL, USA).

3.2.3 RESULTS

3.2.3.1 Sample characteristics and inter-examiner agreement

The general characteristics of the participants are presented in Table 3.2.1. All individuals were born between 1995 and 2004, and all their DPRs were taken between 2008 and 2016. Dental age calculated from the Dutch standard (median 10.7, 90% range 7.4-16.0), French-Canadian standard (median 11.8, 90% range 7.9-16.0) and Saudi standard (median 11.1, 90% range 7.0-13.2) were significantly higher ($p < 0.05$) from the chronological age (median 10.0, 90% range 7.0-14.0) when the DPR was taken. The French-Canadian standard presented the best approach of dental age with chronological age in our study population ($R^2 = 0.75$), hence dental age calculated from this standard was used as a proxy of dental development in our statistical analysis. The frequency of hypodontia in the study sample was 5.9% and no individual had more than two missing teeth. The second lower premolars were the most common missing teeth (57.0%). Inter-examiner agreement for the assessment of dental caries and stages of development for each left mandibular tooth was moderate to perfect (ICC = 0.67 to 1.00).

3.2.3.2 Dental caries in the deciduous dentition

Dental caries in the deciduous dentition was estimated as a median dft of 2.0 (90% range, 0.0-9.1). The dft was not significantly different between boys and girls (p 0.95). Overall, 59.0% of the children had at least one decayed, missing or filled deciduous tooth. Among the patients that experienced dental caries in the deciduous dentition (dft): 94.3% had at least

Table 3.2.1. General characteristics of the study population

Descriptive characteristics	**Overall** (N = 118)	**Boys** (N = 54)	**Girls** (N = 64)	**p-value**
Age	10.00 (7.0, 14.0)	10.00 (8.0, 14.3)	10.00 (7.0, 14)	0.56
Maturity score	94.50 (71.7, 100.0)	93.25 (71.7, 100.0)	92.28 (68.9, 100.0)	0.07
Dental development measurements				
Dental age from Dutch standard	10.70 (7.4, 16.0)	10.75 (7.4, 16.0)	10.70 (6.8, 16.0)	0.44
Dental age from French-Canadian standard	11.75 (7.9, 16.0)	11.65 (8.1, 16.0)	11.90 (7.7, 16.0)	0.67
Dental age from Saudi standard	11.09 (7.0, 13.2)	11.08 (7.1, 13.2	11.13 (6.5, 12.7)	0.96
Stage of development for the first incisor	8 (7.0, 8.0)	8 (7.0, 8.0)	8 (7.0, 8.0)	0.50
Stage of development for the second incisor	8 (6.0, 8.0)	8 (6.0, 8.0)	8 (6.0, 8.0)	0.82
Stage of development for the canine	7 (5.0, 8.0)	6 (5.0, 8.0)	7 (5.0, 8.0)	0.57
Stage of development for the first premolar	6 (5.0, 8.0)	6 (5.0, 8.0)	6 (4.3, 8.0)	0.87
Stage of development for the second premolar	6 (4.0, 8.0)	6 (4.0, 8.0)	6 (4.0, 8.0)	0.88
Stage of development for the first molar	8 (7.0, 8.0)	8 (7.0, 8.0)	8 (7.0, 8.0)	0.96
Stage of development for the second molar	6 (4.0, 8.0)	6 (4.0, 8.0)	6 (4.0, 8.0)	0.99
Dental Caries Indexes and their components				
dft	2.00 (0.0, 9.1)	2.00 (0.0, 8.0)	1.50 (0.0, 11.8)	0.95
dt	1.00 (0.0, 8.0)	1.50 (0.0, 7.3)	1.00(0.0, 8.8)	0.85
ft	0.00 (0.0, 2.1)	0.00 (0.0, 2.8)	0.00 (0.0, 3.5)	0.11
DMFT	1.00 (0.0, 8.0)	1.00 (0.0, 8.3)	1.00 (0.0, 7.8)	0.73
DT	0.00 (0.0, 5.0)	0.00 (0.0, 7.5)	0.00 (0.0, 4.0)	0.49
MT	0.00 (0.0, 1.0)	0.00 (0.0, 1.3)	0.00 (0.0, 1.0)	0.72
FT	0.00 (0.0, 4.0)	0.00 (0.0, 4.0)	0.00 (0.0, 3.8)	0.72
Hypodontia (N; %)	7 (5.9%)	4 (7.4%)	3 (4.7%)	0.41

Abbreviations: Values are medians and 90% range; dft (Decayed-Filled-Teeth Index for the deciduous dentition); dt (decayed deciduous teeth); ft (filled deciduous teeth); DMFT (Decayed-Missing-Filled-Teeth Index for the permanent dentition); DT (decayed permanent teeth); MT (missing permanent teeth); FT (filled permanent teeth); p-values were obtained using the Independent samples Kruskal-Wallis Non-Parametric test and Chi-Square test

one decayed deciduous tooth (dt) and 24.3% had at least one filled deciduous tooth. Among the patients that had at least one decayed deciduous tooth (dt), 37.9% had at least also one decayed permanent tooth. The most common decayed deciduous teeth were the lower and upper first molars (32.0%) followed by the lower and upper second molars (29.0%). The most common filled deciduous teeth were the second molars (10.0%).

3.2.3.3 Dental caries in permanent dentition

Dental caries in the permanent dentition was estimated as a median DMFT of 1.0 (90% range, 0.0-8.0). The DMFT was not significantly different between boys and girls (p = 0.73). Overall, 56.0% of the participants had at least one decayed, missing or filled permanent tooth. Among the patients that experienced dental caries in the permanent dentition (DMFT): 71.2% had at least one decayed permanent tooth (DT), 15.2% had at least one missing permanent tooth (MT) and 53.0% had at least one filled permanent tooth (FT). Among the patients that had at least one decayed permanent tooth (DT), 53.2% had also at least also one decayed deciduous tooth (dt). The most common decayed permanent teeth were the lower first molars (31.0%)

followed by upper first molars (19.0%) and upper incisors (8.0%). The lower first molars were also the most common filled (18.0%) and extracted (6.0%) permanent teeth.

3.2.3.4 The association between dental caries in deciduous dentition (dft) and dental age

The results of the linear regression analysis are presented in Table 3.2.2. Model 1 revealed a statistically significant negative effect of dft, dt and ft on dental age. After considering the potential confounders (sex, age, DMFT and hypodontia) in Model 2, the effect of dft and dt on dental age attenuated, meanwhile the effect of ft on dental age disappeared. Hence, dental caries (dft) was significantly associated with lower dental age (β = -0.21; 95% CI: -0.29, -0.12). The untreated dental caries (dt) was associated with lower dental age (β = -0.19; 95% CI: -0.28, -0.10). The treated dental caries (ft) was not associated with dental age (β = -0.08; 95% CI: -0.25, 0.08).

Table 3.2.2. The association between the Decayed Filled Index (dft) and dental age

	Model 1			Model 2		
	β	95% CI	p-value	β	95% CI	p-value
dft	-0.56	(-0.67, -0.48)	<0.01**	-0.21	(-0.29, -0.12)	<0.01**
dt	-0.58	(-0.69, -0.47)	<0.01**	-0.19	(-0.28, -0.10)	<0.01**
ft	-0.46	(-0.78, -0.14)	0.01*	-0.08	(-0.25, 0.08)	0.31

Abbreviations: β –regression coefficients, CI – confidence interval
Model 1: the crude association between dft and dental age;
Model 2: was additionally adjusted for sex, age, DMFT and hypodontia; Significant values: * p<0.05, ** p<0.01

3.2.3.5 The association between dental caries in permanent dentition (DMFT) and dental age

The results of the linear regression analysis are presented in Table 3.2.3. Model 1 revealed a statistically significant positive effect of DMFT, DT, MT and FT on dental age. After considering the potential confounders (sex, age, dft and hypodontia) in Model 2, the effect of DMFT, DT and MT on dental age disappeared. Meanwhile the effect of FT on dental age remained still significant but attenuated (β = 0.20; 95% CI: 0.03, 0.38).

Table 3.2.3. The association between the Decayed Missed Filled Index (DMFT Index) and dental age

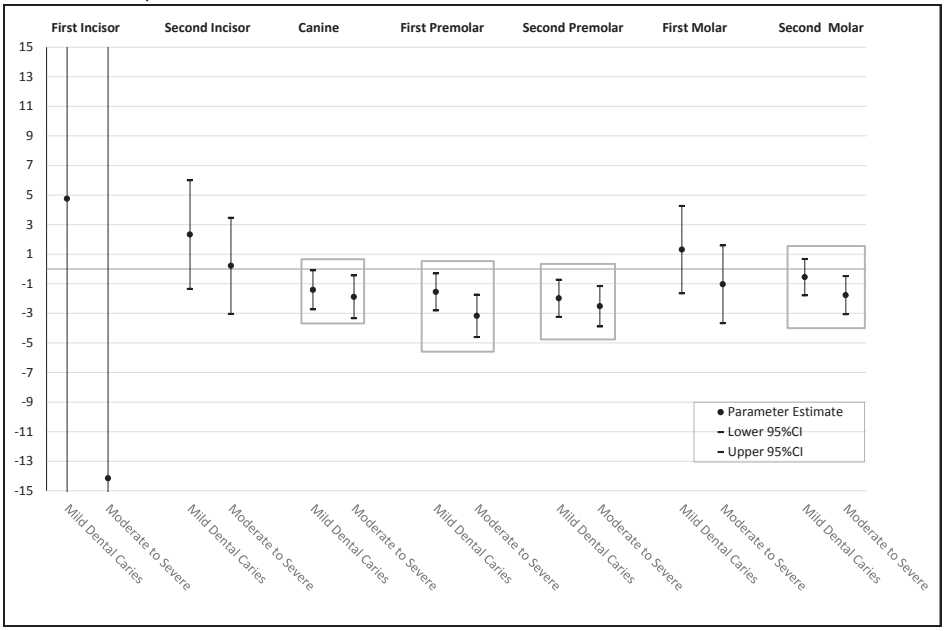
	Model 1			Model 2		
	β	95% CI	p-value	β	95% CI	p-value
DMFT	0.45	(0.30, 0.60)	<0.01**	0.05	(-0.04, 0.14)	0.24
DT	0.35	(0.16, 0.55)	<0.01**	-0.02	(-0.12, 0.08)	0.70
MT	1.35	(0.57, 2.13)	<0.01**	0.35	(-0.02, 0.71)	0.06
FT	0.73	(0.37, 1.10)	<0.01**	0.20	(0.03, 0.38)	0.03*

Abbreviations: β –regression coefficients, CI – confidence interval
Model 1: the crude association between DMFT and dental age;
Model 2: was additionally adjusted for sex, age, dft and hypodontia; Significant values: * p<0.05, ** p<0.01

3.2.3.6 The association between dental caries in deciduous dentition (dft) and development of each left mandibular permanent tooth

The results of the ordinal regression analysis are presented in Figure 3.2.1. The development of the canine, the first premolar and the second premolar were statistically significant delayed in the group of mild dental caries (1≤dft≤3) compared to the reference group (dft = 0). This delay of development consisted of 1.41 (95% CI; -2.73, -0.09) lower stages for the canine, 1.55 (95% CI; -2.80, -0.30) lower stages for the first premolar and 1.98 (95% CI; -3.23, -0.72) lower stages for the second premolar. Development of the canine, the first premolar, the second premolar and the second molar was statistically significantly delayed in the group of moderate to severe dental caries (dft ≥ 4) compared to the reference group (dft = 0). This delay of development consisted of 1.89 (95% CI; -3.33, -0.44) lower stages for the canine, 3.17 (95% CI; -4.60, -1.73) lower stages for the first premolar, 2.52 (95% CI; -3.89, -1.15) lower stages for the second premolar and 1.77 (95% CI; -3.06, -0.48) lower stages for the second molar. The ordinal regression analysis performed for central incisor presented uninterpretable parameter estimates because this tooth was in the final stage of development, hence all the values fell in one category.

Figure 3.2.1. The association between dental caries in deciduous dentition (dft) and development of each left mandibular permanent tooth

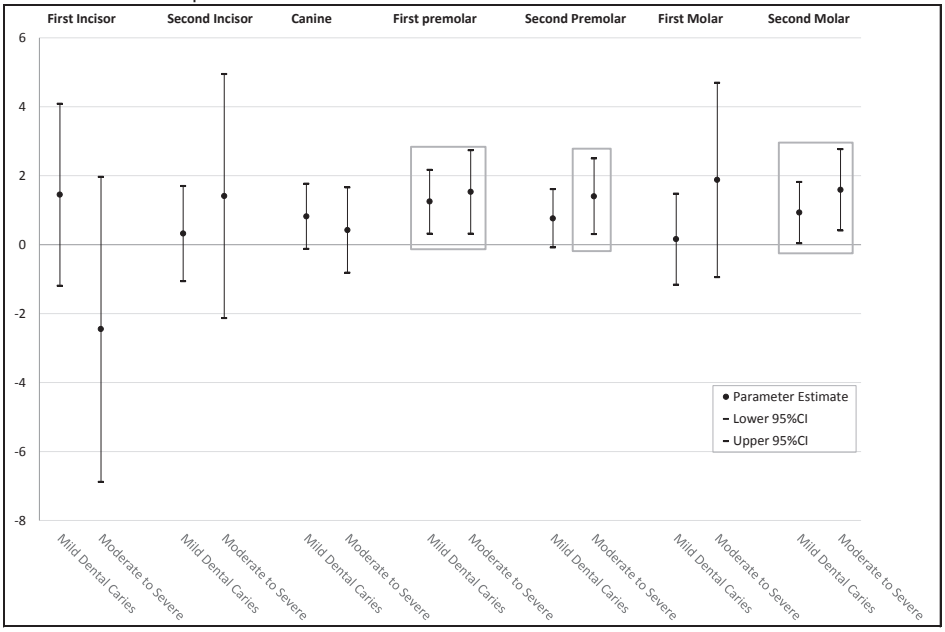


Abbreviations: Mild Dental Caries→1≤ dft ≤3; Moderate to Severe Dental Caries→dft ≤4; Reference Group→dft = 0; All parameter estimates and corresponding 95% CI were obtained from ordinal regression model adjusted for sex, age, DMFT and hypodontia; Significant values are presented in grey squares

3.2.3.7 The association between dental caries in permanent dentition (DMFT) and development of each left mandibular permanent tooth

The results of the ordinal regression analysis are presented in Figure 3.2.2. Development of first premolar and second molar was statistically significantly advanced in the group of mild dental caries (1≤DMFT≤3) compared to the reference group (DMFT = 0). This advance in development consisted of 1.25 (95% CI; 0.32, 2.17) higher stages for first premolar and 0.93 (95% CI; 0.04, 0.82) higher stages for second molar. Development of the first premolar, the second premolar and the second molar was significantly advanced in the group of moderate to severe dental caries (DMFT ≥ 4) compared to the reference group (DMFT = 0). This advance in development consisted of 1.53 (95% CI; 0.32, 2.74) higher stages for the first premolar, 1.40 (95% CI; 0.31, 2.50) higher stages for the second premolar and 1.59 (95% CI; 0.41, 2.77) higher stages for the second molar.

Figure 3.2.2. The association between dental caries in permanent dentition (DMFT) and development of each left mandibular permanent tooth



Abbreviations: Mild Dental Caries→1≤DMFT≤3; Moderate to Severe Dental Caries→DMFT≤4; Reference Group→DMFT = 0; All parameter estimates and corresponding 95% CI were obtained from ordinal regression model adjusted for sex, age, dft and hypodontia; Significant values are presented in grey squares

3.2.4 DISCUSSION

The main finding of this study suggests that dental caries in the deciduous dentition delays development of the permanent teeth with approximately 3-7 months. Furthermore, dental caries in the deciduous dentition was associated with delayed development of the canine,

the first premolar, the second premolar and the second molar. In addition, a higher dft resulted in lower developmental stages for these teeth, increasing the importance of early detection and treatment need of carious lesions in the deciduous teeth. The disturbed dental development will have an impact on mastication, word articulation and esthetics [22, 23] that will be converted into complaints about eating, speaking, smiling and appearance in the future. As most of the central incisors, the lateral incisors and the first molars had already reached the final stage of development any significant finding couldn't be reported for the association between caries in deciduous dentition and development of both incisors and first molar. Hence, to understand better this association, we suggest investigations performed at an earlier age interval.

The treatment of carious lesions in permanent dentition by dental filling (FT) was the only DMFT index component significantly associated with an advanced dental age. The patients of our study had mostly massive dental fillings that quite often included the canal roots of permanent teeth. Taking in consideration the treatment intervention in these teeth to stimulate apexogenesis or apexification, an apex closure before the predicted time is expected [24, 25]. Consequently, the filled permanent teeth presented the final stage '8' of development in the DPR image. Dental caries in the permanent dentition was associated with an advanced development of the first premolar, the second premolar and the second molar. The reaction of the dentin and pulp to dental caries explains this finding [26]. The occurrence of caries leads to a demineralization of the enamel, which in turn stimulates odontoblasts to produce dentin. This hypermineralization process will precipitate the apex closure and the final stage of dental development. The lack of similar investigations limited us to show comparisons between the findings. However considering the known biological pathways, the persistence of a bacterial activity is followed by demineralization of hydroxyapatite prisms [27]. By the other side, the velocity of matrix secretion in hard tissues of teeth defines the developmental stages distinguished in a X-ray image. In the mixed dentition, a higher bacterial activity will increase the demineralization of deciduous teeth [2]. In response, the velocity of mineralization in permanent dentition might be decreased.

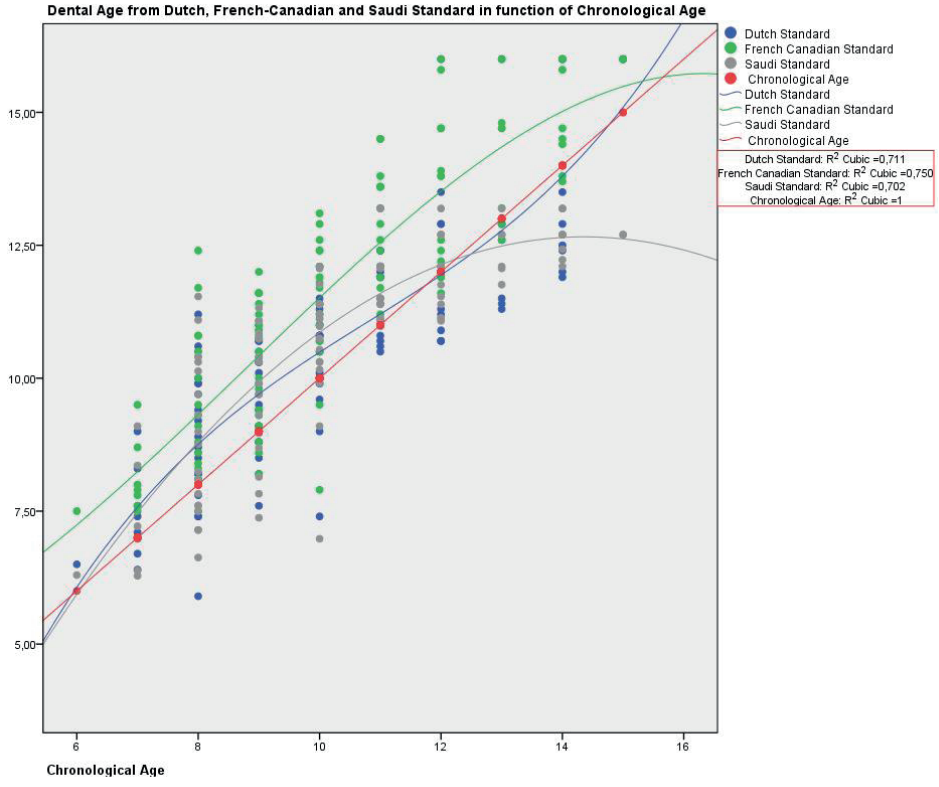
The DMFT index is the most common method used to assess the prevalence of dental caries [28]. The Index is reported to underestimate dental caries when scored from clinical examination without X-ray imaging [29]. In dental practice, the DPR is recognized as the main tool to ascertain dental age and as a diagnostic detector of dental caries, as well [19, 30]. In theory, a DPR has sufficient accuracy to diagnose carious lesions, similarly with the bitewing radiograph for the posterior teeth [31]. However this approach is less precise to detect the proximal dental caries [32]. In lack of a golden standard to accurately evaluate caries and in need of a method that would facilitate the assessment of both caries and dental development [33], DPRs were primary used in the current study. To clarify uncertainties for the carious lesions aroused when using only X-ray images, necessary information was retrieved from the clinical files of patients as a second step.

Dental age was calculated from three standards, the French-Canadian standard, the Dutch standard and the Saudi standard [19, 34, 35]. The French-Canadian standard overestimates dental age in different populations [36], a trend that was present in our study population as well.

Because of the lack of a population-based dental age standard that could approximately represent the Albanian population, we applied two more dental age standards, one European (Dutch standard) and one from the Middle East (Saudi standard), Albania being geographically in the middle. We concluded that the French-Canadian standard corresponded better to the chronological age of our participants (R^2 = 0.75; Figure 3.2.3), however an improvement of this standard in Albanian population is needed to obtain the best approach of dental development.

Severe dental caries in the deciduous dentition is followed by a high risk of dental caries in the permanent teeth, due to the higher bacterial activity and vulnerability of permanent teeth during the 2-4 first years after eruption [37]. Furthermore severe dental caries in deciduous and permanent dentition affects children's quality of life causing pain, weight gain and low psycho-social well-being [4]. The restorative treatment plan that follows the clinical examination should take into consideration not only the risk of caries but also the development of the dentition [38]. We showed, that dental caries in the deciduous dentition, especially the untreated dental caries (dt), is followed by a delayed development of the permanent dentition.

Figure 3.2.3. The schematic presentation of the dental age standard that corresponded the best to the chronological age of the participants



The Y-axis represents dental age

Additionally, there was an obvious negligence between treated dental caries in deciduous dentition (ft = 24.3%) and treated dental caries in permanent dentition (FT = 53.0%). New strategies that will increase the awareness of treating dental caries in deciduous dentition are needed to prevent the delay of dental development in the future.

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