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Katarzyna Różyło, *Katarzyna Gruszka, Ingrid Różyło-Kalinowska

Comparison of radiological dental age estimation by means of the method by Cameriere and the modified European formula

Department of Dental and Maxillofacial Radiodiagnostics, Medical University of Lublin
Head of Department: Professor Katarzyna Różyło, MD, PhD

Keywords

dental age, Cameriere's method, Cameriere's European formula, chronological age

Summary

Introduction. Dental age apart from skeletal age is an important factor in the estimation of biological age of patients. Its evaluation is crucial in making decisions concerning diagnostic algorithms and treatment options in such fields of medicine as paedodontics, conservative dentistry, orthodontics, paediatrics or endocrinology as well as for forensic purposes. There are various methods of radiological dental age estimation and their validity is related to the studied population.
Aim. The aim of the paper is to estimate dental age by means of two radiological methods based on panoramic radiographs, i.e. the original method by Cameriere and the modified European formula.
Material and methods. The material consisted of 2148 digital radiographs taken in patients of both genders, aged from 5 to 15 years, with visible germs of all permanent teeth, apart from third molars. Two methods by Cameriere were applied – the original one and the European formula. Statistical analysis was performed.
Results. Dental age obtained by means of the two Cameriere's methods was significantly different from chronological age (Wilcoxon's test, $p < 0.001$). However, in the case of the original method the mean dental age was lower than the chronological one, while the European formula led to the overestimation of dental age.
Conclusions. The European formula is more suitable for the evaluation of the Polish population than the original method by Cameriere.

Introduction

Chronological or calendar age is the time between birth and the time of examination expressed as the number of years, months and days elapsed. Developmental age, on the other hand, is defined as the biological maturity of an individual and the level of systemic growth.

The indicators of developmental age include:
- morphological (biological) age,
- age of secondary sex characteristics,
- skeletal age,
- dental age (1, 2).

Alongside skeletal age, dental age is another factor used to determine a patient's biological age, which was first described in the 19th century (3). Its evaluation is crucial in making decisions concerning diagnostic algorithms and treatment options in such fields of medicine as paedodontics, conservative dentistry, orthodontics, paediatrics or endocrinology (4, 5), as well as for forensic purposes (6). A dentist in a forensic medicine team uses dental age estimation as one of the methods used to identify human corpse or remains of unknown identity (6-8).

Dental age is determined based on the analysis of teeth present in the oral cavity, deciduous teeth resorption and the stage of permanent teeth development (9-12). A clinical method accounting for the order and number of erupted teeth compared with standard tables allows for the estimation of dental age (13, 14). The assessment of the level of dental mineralisation based on radiographic images is a more precise method. Methods of radiological assessment are based on the analysis of the process of dental mineralisation from the point when a bony crypt appears (a brighter area in the bone) to the closure of the apical opening (15).

There are qualitative methods (e.g. Demirjian's, Nolla's, Gustafson and Koch's) as well as quantitative methods. The only currently used quantitative method is Cameriere's method whereby dental age estimation is based on the measurement of tooth length and the apex width of seven permanent teeth in the left mandible. In 2006 Cameriere developed a formula for the estimation of dental age based on these measurements; subsequently, in 2007, he presented a modification of the formula for the European population.

Aim

The aim of the study was to compare dental age determined based on Cameriere's method using the original formula and the European formula.

Material and methods

The research material was radiological documentation collected in the database of the Department of Dental and Maxillofacial Radiodiagnostics of the Medical University of Lublin in 2005-2016.

The analysis included 2148 panoramic radiographs of patients aged from 5 to 15 years. The number of girls was 1109 and the number of boys was 1039. All germs of permanent teeth were visible on the images, except for third molars in the mandible.

All measurements, patient's details such as name, surname, gender, date of birth and the date of the panoramic radiograph were recorded in a Microsoft Excel spreadsheet.

The first stage of the study involved determining the patients' chronological age. It was obtained by subtracting the date of birth from the date of the panoramic radiograph.

Cameriere's method involves the measurement of open apex width of teeth with uncompleted development and of the height of these teeth. Panoramic radiographic images of permanent left mandibular teeth with the exception of the third molar were analysed.

The following measurements were taken on each radiographic film:

Ai, i = 1…7 – distance between the internal walls of an open dental apex; for double-root teeth measurements of both apices were summed up,

Li, i = 1…7 – the length of a tooth with uncompleted apical development,

xi = Ai/Li, i = 1…7 – the ratio of both values calculated in order to eliminate the impact of panoramic radiograph magnification.

Subsequently, x values for each tooth were summed up to obtain an s value:

$$s = x1 + x2 + x3 + x4 + x5 + x6 + x7,$$

where:

N0 – the number of teeth with completed development of the tooth apex,

g – 0 for girls and 1 for boys.

Subsequently, all variables were used in the formula developed by Cameriere for the European population:

$$Age = 8.387 + 0.282\ g - 1.692 \times 5 + 0.835\ N0 - 0.116\ s - 0.139\ N0$$

and for the general population:

$$Age = 8.971 + 0.375\ g - 1.631 \times 5 + 0.674\ N0 - 1.034\ s - 0.76\ s\ N0.$$

Statistical analysis was performed on the data using the Wilcoxon's test and the absolute error test.

Results

Dental age estimated using two versions of the Cameriere's method was significantly different from chronological age (Wilcoxon's test, $p < 0.001$) (tab. 1). However, in the case of the Cameriere's method for the general population the age obtained was lower on average than the chronological one; for the European formula, on the other hand, chronological age was overestimated (tab. 2).

It can also be noted that the absolute error value for the Cameriere'a method was slightly higher than for the European formula (tab. 2, 3). The Wilcoxon's

Tab. 1. Wilcoxon's test results: significance of differences between dental age and chronological age in the whole study group

Wilcoxon's test	p
Cameriere's method	0.001
Cameriere's method European formula	0.001

Tab. 2. Mean age of study subjects by calculation method (all children)

Methoxd	Age in the sample		Calculated age	
	mean	standard deviation	mean	standard deviation
Cameriere's	10.55 (N = 2148)	2.07	9.89 (N = 2148)	2.70
Cameriere's (European formula)	10.55 (N = 2148)	2.07	11.16 (N = 2148)	2.11

Tab. 3. Absolute error statistics by calculation method (all children)

Method	Absolute error				
	mean	standard deviation	minimum	maximum	median
Cameriere's	-0.66 (N = 2148)	1.56	-7.45	6.47	-0.75
Cameriere's (European formula)	0.61 (N = 2148)	1.28	-5.90	7.78	0.57

Tab. 4. Significance of differences between error distributions for two methods of dental age assessment

Wilcoxon's test	p
Cameriere's method	0.001
Cameriere's method (European formula)	0.001

test also demonstrated statistically significant differences between error distributions for the two methods ($p < 0.001$) (tab. 4).

As in the case of the whole study group, the girls' dental age obtained with the different Cameriere's methods was significantly different from chronological age (Wilcoxon's test, $p < 0.001$) and one of the methods yielded lower results on average (tab. 5).

Here, error distributions also differed (Wilcoxon's test, $p < 0.001$). However, it can be noted that the mean error of the original Camerierex's method was smaller than that of its European variant (tab. 6).

The differences between dental age obtained using different Cameriere's methods and chronological age were statistically significant for boys as well (Wilcoxon's test, $p < 0.001$). As previously, the European formula produced higher results (tab. 7).

The differences between error distributions for these two methods were confirmed by the Wilcoxon's test with a significance level of $p < 0.001$. However, Cameriere's European formula proved to be more precise for this group (tab. 8).

Figure 1 presents the differences in error size for different groups reported above.

Tab. 5. Mean age of study subjects by calculation method (girls)

Method	Age in the sample		Calculated age	
	mean	standard deviation	mean	standard deviation
Cameriere's	10.61 (N = 1109)	2.14	10.14 (N = 1109)	2.73
Cameriere's (European formula)	10.61 (N = 1109)	2.14	11.36 (N = 1109)	2.14

Tab. 6. Absolute error statistics by calculation method (girls)

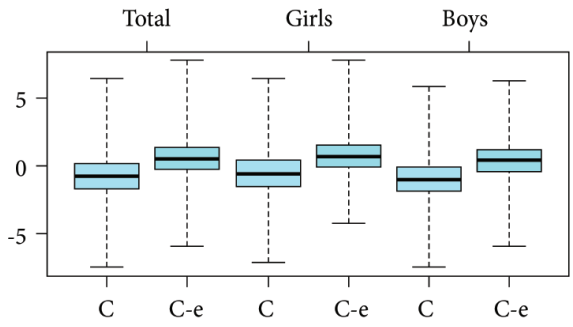
Method	Absolute error				
	mean	standard deviation	minimum	maximum	median
Cameriere's	-0.47 (N = 1109)	1.52	-7.05	6.47	-0.54
Cameriere's (European formula)	0.75 (N = 1109)	1.28	-4.20	7.78	0.70

Tab. 7. Mean age of study subjects by calculation method (boys)

Method	Age in the sample		Calculated age	
	mean	standard deviation	mean	standard deviation
Cameriere's	10.48 (N = 1039)	1.98	9.62 (N = 1039)	2.66
Cameriere's (European formula)	10.48 (N = 1039)	1.98	10.95 (N = 1039)	2.05

Tab. 8. Absolute error statistics by calculation method (boys)

Method	Absolute error				
	mean	standard deviation	minimum	maximum	median
Cameriere's	-0.86 (N = 1039)	1.57	-7.45	5.85	-0.97
Cameriere's (European formula)	0.47 (N = 1039)	1.28	-5.90	6.30	0.41



C – Cameriere's method
C-e – Cameriere's method for European children

Fig. 1. Error size by method

Discussion

Calendar age does not always reflect biological maturity of a patient; therefore, a reliable way of assessing developmental age is necessary. Dental age is considered to be the most useful method for the estimation of chronological age (16). Appropriate estimation of developmental age is crucial for orthodontists since it allows for the planning of orthodontic treatment, which is strictly associated with developmental milestones (17). Gustafson and Koch (18) demonstrated that gender affects the formation of tooth germs. Earlier development of tooth germs is observed in girls. All researchers to date have based their research on the retrospective analysis of panoramic radiographs in a population of a selected ethnic origin. We are currently living in the times of progressive globalisation and migration; as a result, the determination of ethnic origin will be increasingly difficult, which may result in a reduced precision of dental age assessment methods.

Cameriere et al. (19) developed a formula for the estimation of dental age based on left mandibular permanent teeth measurements. The original formula allowing for the calculation of dental age was developed based on the analysis of panoramic radiographs in a group of 455 of Italian children (213 boys and 242 girls), aged from 5 to 15 years. This formula had to be modified to fit other populations, which has led to the creation of other formulae. The European formula was developed based on the analysis of 2652 panoramic radiographs of individuals aged 4 to 16 years (1382 boys and 1270 girls). All patients were Caucasian (they came from Croatia, Spain, Kosovo, Germany, Slovenia, Great Britain and Italy (20). Other researchers have also modified Cameriere's formula. Rai et al. (21) analysed 480 panoramic radiographs of children aged from 3 to 15 years who came from northern, central and southern parts of India. Panoramic radiographs of patients with malocclusion and those undergoing orthodontic treatment were removed from the analysis in order to exclude the possible influence of the defects and therapy on dental age assessment using Cameriere's method for the Indian population. Their modification of Cameriere's formula included a new C variable which accounted for regional variation within the country. The g value (impact of gender) and a variable concerning the second premolar were excluded from the formula.

Cugati et al. (22) analysed 421 panoramic radiographs of Malaysian children aged from 5 to 16 years and concluded that not all variables in the European formula (20) and changes to the Indian formula (21) have a significant impact on dental age assessment in the Malaysian population using Cameriere's method.

Gulsahi et al. (23) analysed 573 panoramic radiographs of a population of Turkish children aged from 8 to 15 years using Cameriere's method. They compared chronological age with dental age and concluded that dental age was accelerated both in boys (by 0.44 years) and in girls (by 0.21 years).

De Luca et al. (24) analysed 502 panoramic radiographs of children aged from 5 to 15 years. Their research demonstrated that there is a slight acceleration of dental age compared to calendar age of 0.1 years in girls, while there is a 100% consistency between them in boys. According to the authors of the study cited above the best method for dental age assessment in the Mexican population is Cameriere's method.

Javadinejad et al. (25) analysed 537 panoramic radiographs of Iranian children aged from 3.9 to 14.5 years using Demirjian's, Willems', Cameriere's and Smith's methods. Chronological age was 8.93 ± 2.04 years. Dental age acceleration in comparison to calendar age was observed in Demirjian's (0.87 ± 1.0 years), Willems' (0.36 ± 0.87 years), Smith's (0.06 ± 0.63 years) and Cameriere's (0.19 ± 0.86 years) methods.

Smith's method was characterised by the highest accuracy compared to other methods. In their study Cameriere et al. (26) compared Cameriere's and

Demirjian's methods in Peruvian children aged from 9.5 to 16.5 years. They concluded that Cameriere's method was a more useful method for dental age assessment in this population.

Kumaresan et al. (27) analysed 426 panoramic radiographs of Malaysian children aged from 5 to 16 years using Cameriere's, Nolla's, Demirjian's, Haavikko's and Willems' methods and concluded that dental age was overestimated when the following methods were used: Nolla's by 0.97 years, Willems' by 0.54 years and Demirjian's by 0.54 years. It was underestimated using the following methods: Cameriere's by 0.4 years and Haavikko's by 1.3 years. The most precise method for dental age estimation in Malaysian children is Cameriere's method, while methods by Haavikko and Demirjian are the least precise ones. The order of usefulness of dental age estimation methods is the following: Cameriere's, Willems', Nolla's, Haavikko's and Demirjian's method.

Conclusions

Based on the present authors' own research it was concluded that Cameriere's European formula is more precise for the assessment of dental age in the Polish population than the original Cameriere's formula.

Conflict of interest

None

Correspondence

*Katarzyna Gruszka
Zakład Rentgenodiagnostyki Stomatologicznej i Szczękowo-Twarzowej
Uniwersytet Medyczny w Lublinie
ul. Karmelicka 7, 20-081 Lublin
tel.: +48 (81) 528-79-72
katarzyna.gruszka@o2.pl

References

1. Knychalska-Karwan Z: Zbiór wskaźników stomatologicznych, klasyfikacji i testów. Czelej, Lublin 2010.
2. Olczak-Kowalczyk D, Szczepańska J, Kaczmarek U: Współczesna stomatologia wieku rozwojowego. Med Tour Press, Otwock 2017.
3. Hubert E: Rozwój dzieci z rozszczepem podniebienia pierwotnego i wtórnego. Czas Stomatol 1986; 39(8): 519-524.
4. Demirjian A, Goldstein H, Tanner M: A new system for dental age assessment. Hum Biol 1973; 45(2): 211-227.
5. Schuster G, Lermer W, Witt E: Using the internet for teaching orthodontic X-ray analysis. J Orofac Orthop 2002; 63: 163-169.
6. Otocki P: Określenie wieku osobniczego na podstawie zębów. Przegl Antropol 1988; 54: 65-82.
7. Karłowska I: Zarys współczesnej ortodoncji. PZWL, Warszawa 2013.
8. Szpringer-Nodzak M: Stomatologia wieku rozwojowego. PZWL, Warszawa 1999.
9. Różyło TK, Różyło-Kalinowska I: Radiologia stomatologiczna. PZWL, Warszawa 2007.
10. Kiworkowa-Rączkowska E, Różyło-Kalinowska I, Ścibak-Boroch A: Radiological evaluation of dental age. Ann UMCS Sect D 2006; 61: 342-345.
11. Kiworkowa-Rączkowska E, Różyło-Kalinowska I: Przydatność klinicznej i radiologicznej oceny wieku zębowego. As Stomatol 2006; 4: 15-16.
12. Śmiech-Słomkowska G, Jarnecka B: Rozwój fizyczny a wiek zębowy dzieci w wieku 7-10 lat. Czas Stomatol 1990; 43(7): 434-438.
13. Butti AC: Haavikko's method to assess dental age in Italian children. Eur J Orthod April 2009; 31(2): 250-255.
14. Kahn de Gruner S: Determining skeletal age using cervical vertebrae from lateral headfilm. World J Orthod 2005; 6 (suppl.).
15. Pisulska-Otremba A, Polaczek T, Flegier H: Ocena rozwoju zębów na podstawie radiogramów. Czas Stomatol 1979; 32: 571-576.
16. Maber M, Liversidge H, Hector M: Accuracy of age estimation of radiographic methods using developing teeth. Forensic Sci Int 2006; 15(159, suppl. 1): 68-73.
17. Sobieska E, Fester A, Nieborak M, Zadurska M: Metody oceny wieku zębowego u pacjentów w wieku rozwojowym. Forum Ortod 2015; 11: 36-48.
18. Gustafson G, Koch G: Age estimation up to 16 years of age based on dental development. Odontol Rev 1974; 25: 297-306.
19. Cameriere R, Ferrante L, Cingolani M: Age estimation in children by measurement of open apices in teeth. Int J Legal Med 2006; 120: 49-52.
20. Cameriere R, De Angelis D, Ferrante L et al.: Age estimation in children by measurement of open apices in teeth: a European formula. Int J Legal Med 2007; 121: 449-453.
21. Rai V, Saha S, Yadav G et al.: Dental and skeletal maturity – a biological indicator of chronologic age. J Clin Diag Res 2014; 8(9): 60-64.

22. Cugati N, Kumaresan R, Srinivasan B, Karthikeyan P: Dental age estimation of growing children by measurement of open apices: A Malaysian formula. J Forensic Dent Sci 2015; 7(3): 227-231.
23. Gulsahi A, Tirali R, Cehreli S et al.: The reliability of Cameriere's method in Turkish Children: A preliminary report. Forensic Sci Int 2015; 249: 319.e1-319.e5.
24. De Luca S, De Giorgio S, Butti AC et al.: Age estimation in children by measurement of open apices in tooth roots: Study of a Mexican sample. Forensic Sci Int 2012; 221: 155.e1-155.e7.
25. Javadinejad S, Sekhavati H, Ghafari R: A comparison of the accuracy of four age estimation methods based on panoramic radiography of developing teeth. J Orthod Dento D 2015; 9(2): 72-78.
26. Cameriere R, Flores-Mir C, Mauricio F, Ferrante L: Effects of nutrition on timing of mineralization in teeth in a Peruvian sample by the Cameriere and Demirjian methods. A Hum Biol 2007; 34: 547-556.
27. Kumaresan R, Cugati N, Chandrasekaran B, Kartheikeyan P: Reliability and validity of five radiographic dental-age estimation methods in a population of Malaysian children. J In Clin Dent 2016; 7: 102-109.

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