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Procjena dentalne starosti djece u razvoju: usporedba između različitih europskih zemalja

Dental Age Estimation of Growing Children: Comparison Among Various European Countries

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Sažetak
Procjena dobi djece temeljno je pitanje u sudskoj medicini, pedijatrijskoj endokrinologiji i ortodontskom liječenju. Za to se koristi nekoliko metoda, uključujući i onu na osnovi razvoja kostiju i zuba. Budući da je nekoliko autora ustanovilo da se dentalne metode mogu razlikovati prema točnosti procjene, ovaj se rad temelji na poboljšanjima metode koju su razvili Cameriere i suradnici te ih proširuje na veći uzorak djece iz nekoliko europskih regija - 505 iz Italije, 304 s Kosova i 291 iz Slovenije. Također se ispitala učinkovitost metode u situacijama kada se različite populacije analiziraju zajedno. Koeficijenti korelacije procjenjivali su se između dobi i predvidivih varijabli. Statistička analiza obavljena je u statističkom programu S-PLUS 6 (S-PLUS 6.1 za Windowsov operativni sustav - Professional Edition, Release 1). Razina znatnosti postavljena je na 5%. Statistička analiza pokazala je da spol, zbroj normalno otvorenih apeksa i broj zuba s potpuno razvijenim korjenovima znatno utječu na procjenu starosti. Pripadnost različitim europskim regijama nije utjecala na parametre modela.

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Ključne riječi
određivanje starosti pomoću zuba; dentalna radiografija; sudska stomatologija; regresijska analiza

Uvod

Procjena starosti djece temeljno je pitanje u sudskoj medicini, pedijatrijskoj endokrinologiji i ortodontskom liječenju. Za to se koristi nekoliko metoda, uključujući i onu na osnovi razvoja kostiju i zuba.

Tijekom rasta primjena skeletalnih, dentalnih i antropoloških metoda omogućuje približnu procje-

Introduction

Age estimation in children is a fundamental question in forensic medicine, paediatric endocrinology and orthodontic treatment. Several methods deal with their age estimation, including methods based on bone and tooth development.

During the growth of a person, the application of skeletal, odontological and anthropological methods

nu dobi. Metode koje se najčešće rabe za procjenu skeletalne zrelosti koriste se područjem lijevog zgloba, kao npr. Tanner-Whitehouseova (1) i metoda FELS (2) te se na taj način može procjenjivati do dobi od 16 godina, do razdoblja u kojem je zrelost zgloba već 90%. Druge korisne metode temelje se na rendgenskim snimkama specifičnih struktura, kao što je hrskavica medijalne klavikularne epifize (3, 4).

No, te skeletalne metode imaju nekoliko nedostataka s obzirom na znatnu varijabilnost sazrijevanja kosti na koju utječu okolišni čimbenici. Alternativni pristup temelji se na dentalnom razvoju. On se čini prikladan za procjenjivanje dječje dobi, budući da stopu kalcifikacije više kontroliraju geni nego okoliš, a to znači da je i varijabilnost manja (5 do 7).

Kako bi se poboljšali načini procjene kronološke dobi djece, razvijene su i različite dentalnomedicinske metode koje procjenjuju faze erupcije uz prihvatljive granične pogreške. Zapravo sve one definiraju faze mineralizacije zuba opažene na rendgenskim snimkama te ih zatim kodiraju prema unaprijed određenim vrijednostima.

Najuobičajeniju metodu za procjenu dobi objavili su godine 1973. Demirjian, Goldstein i Tanner, a kasnije su je modificirali i drugi autori (8-10). Demirjianova metoda omogućuje izračun vrijednosti zrelosti kao funkcije dobi te njezin 95%-tni interval pouzdanosti, pa je prikladna za kliničare koji znaju stvarnu dob djece i žele znati je li bilo odstupanja te procijeniti da li je dentalna zrelost preuranjena ili zakašnjela. Budući da se procjene i njihovi predvidivi intervali računaju kao vrijednost zrelosti, ta metoda nije prikladna za procjenu dobi (11).

Kako bi poboljšali metodu, nekoliko je autora razvilo alternativne pristupe temeljene na mjerenju nekih važnih parametara zuba kao što su stupanj razgrananosti aspartatne kiseline u zubu (12-14) ili visina krune, širina apeksa i duljina pulpe na rendgenskim snimkama (15-17).

Cameriere je (18) predstavio metodu za procjenu kronološke dobi djece na temelju odnosa dobi i mjerenja otvorenih apeksa zuba. Taj je način dao pouzdane procjene kod 455 talijanske djece bijele rase. Budući da je nekoliko autora ustanovilo da se dentalnomedicinske metode razlikuju u točnosti kada je riječ o različitim populacijama, u ovom smo istraživanju pokušali primijeniti metodu Camerierea i njegovih suradnika (18) na većem uzorku djece iz nekoliko europskih regija, kako bi se ispitala njezina učinkovitost kada se zajedno ispituju različite populacije.

allow an approximate assessment of age. The methods most frequently used for skeletal maturity are those concerning the left hand-wrist area e.g., Tanner-Whitehouse (1) and FELS (2) methods, which can produce estimates up to the age of 16 years, at which time wrist maturation is complete in 90% of subjects. Other useful methods are based on radiographs of specific structures such as the medial clavicular epiphysis cartilage (3, 4).

However, these skeletal methods present some drawbacks in view of the considerable variability in bone maturation, which is influenced by environmental factors. An alternative approach based on dental development has been shown to be suitable for children's age determination because the calcification rate is more controlled by genes than by environmental factors and this means lower variability (5-7).

To improve the methods for estimation of chronological age in children, various odontological methods have also been developed, assessing eruption phases within acceptable error limits. Basically, these methods define the stages of mineralization of teeth observed in radiographs and code them according to predetermined scores.

The most common method for age estimation was published in 1973 by Demirjian, Goldstein and Tanner, and subsequently modified by other authors (8-10). The Demirjian method does offer the possibility of calculating a maturity score as a function of age and its 95% confidence interval, and is therefore designed for clinicians, who know the real ages of children and want to know if they deviate from the norm, to ascertain if their dental maturity is advanced or delayed. Since the estimates and their predictive intervals are calculated for the maturity score, this method is inappropriate for chronological age estimation (11).

To improve the method, several authors have developed alternative approaches based on the measurement of some significant tooth parameters, such as the degree of racemization of aspartic acid in tooth enamel (12-14) or crown height, apex width root and pulp length of teeth observed in radiographs (15-17).

In (18), Cameriere presented a method for assessing chronological age in children based on the relationship between age and measurement of open apices in teeth. This method gave reliable estimates of the ages of 455 Italian Caucasian children. Since several authors have shown that odontological methods can differ in accuracy when different pop-

Materijal i metode

Analizirane su ortopantomogramske snimke ukupno 1100 djece, od toga broja bilo je 505 talijanske djece, 304 kosovske te 291 slovensko dijete (509 dječaka, 591 djevojčica) u dobi od 5 do 15 godina (Tablica 1.). Rendgenske snimke digitalizirane su skeniranjem te su snimljene kao kompjutorski dokumenti koji su obrađeni u programu Adobe Photoshop 7.

Procjenjivalo se sedam trajnih donjih zuba. Izračunat je broj zuba s potpuno razvijenim korijenom te broj potpuno zatvorenih apikalnih krajeva korjenova (N_0).

Zubi s nedovršenim razvojem, tj. s otvorenim apeksima, također su pregledani. Za jednokorijene zube mjerena je udaljenost A_i (i = 1,…,5) između unutarnjih strana otvorenog apeksa. Za dvokorijene zube mjerena je udaljenost A_i, (i = 6,7) i zbroj udaljenosti između unutarnjih strana obaju otvorenih apeksa. Kako bi se u obzir uzele moguće razlike u povećanju i angulaciji rendgenskih snimki, mjerenja su normalizirana dijeljenjem s dužinom zuba (L_i, i = 1,…,7).

Na kraju, dentalna se zrelost procjenjivala normaliziranim mjerenjem sedam trajnih donjih lijevih zuba (xi = A_i/L_i, i = 1,…,7), zbrojem normaliziranih otvorenih apeksa (s) i brojem (N_0) zuba sa završenim razvojem korijena.

ulations are considered, in this study we apply the method developed by Cameriere et al. (18) to a larger sample of children belonging to several European regions to investigate the efficiency of the method when various populations are pooled together.

Materials and Methods

Orthopantomographs taken from a total of 1100 children, 505 Italian, 304 Kosovan and 291 Slovenian children (509 male, 591 female) aged between 5 and 15 years were analysed (Table 1). X-rays were digitized by scanner and images were recorded on computer files, which were processed by a computer-aided drafting program (Adobe Photoshop 7).

The seven permanent mandibular teeth were assessed. The number of teeth with complete root development and completely closed apical ends of roots (N_0) were calculated.

Teeth with incomplete root development, and therefore with open apices, were also examined. For teeth with one root, distance A_i, i = 1,..,5 between the inner side of the open apex was measured. For teeth with two roots, A_i, i = 6,7 the sum of the distances between the inner sides of the two open apices was evaluated. In order to take into account the effect of possible differences in magnification and angulation among X-rays, measurements were normalized by dividing by tooth length (Li, i = 1,..,7).

Lastly, dental maturity was evaluated using the normalized measurements of the seven permanent left mandibular teeth (xi = Ai / Li, i = 1,…,7), the sum of the normalized open apices (s) and the number (N_0) of teeth with completed root development.

Tablica 1. Distribucija dobi i spola talijanskoga, kosovskog i slovenskog uzorka.
Table 1. Age and gender distribution of the Italian, Kosovan and Slovenian sample.

Dob • Age	Italija • Italy		Kosovo • Kossovo		Slovenija • Slovenia		Ukupno • Total
	m	f	m	f	m	f	
5 - 7	15	25	11	9	3	10	73
7 - 8	30	38	19	16	11	18	132
8 - 9	40	53	30	30	12	20	185
9 - 10	42	41	28	27	18	29	185
10 - 11	24	38	18	22	24	29	155
11 - 12	26	21	22	11	21	25	126
12 - 13	21	17	12	16	16	26	108
13 - 14	33	26	13	8	7	13	100
14 - 15	7	8	3	9	3	6	36
Ukupno • Total	238	267	156	148	115	176	1100

Statistička analiza

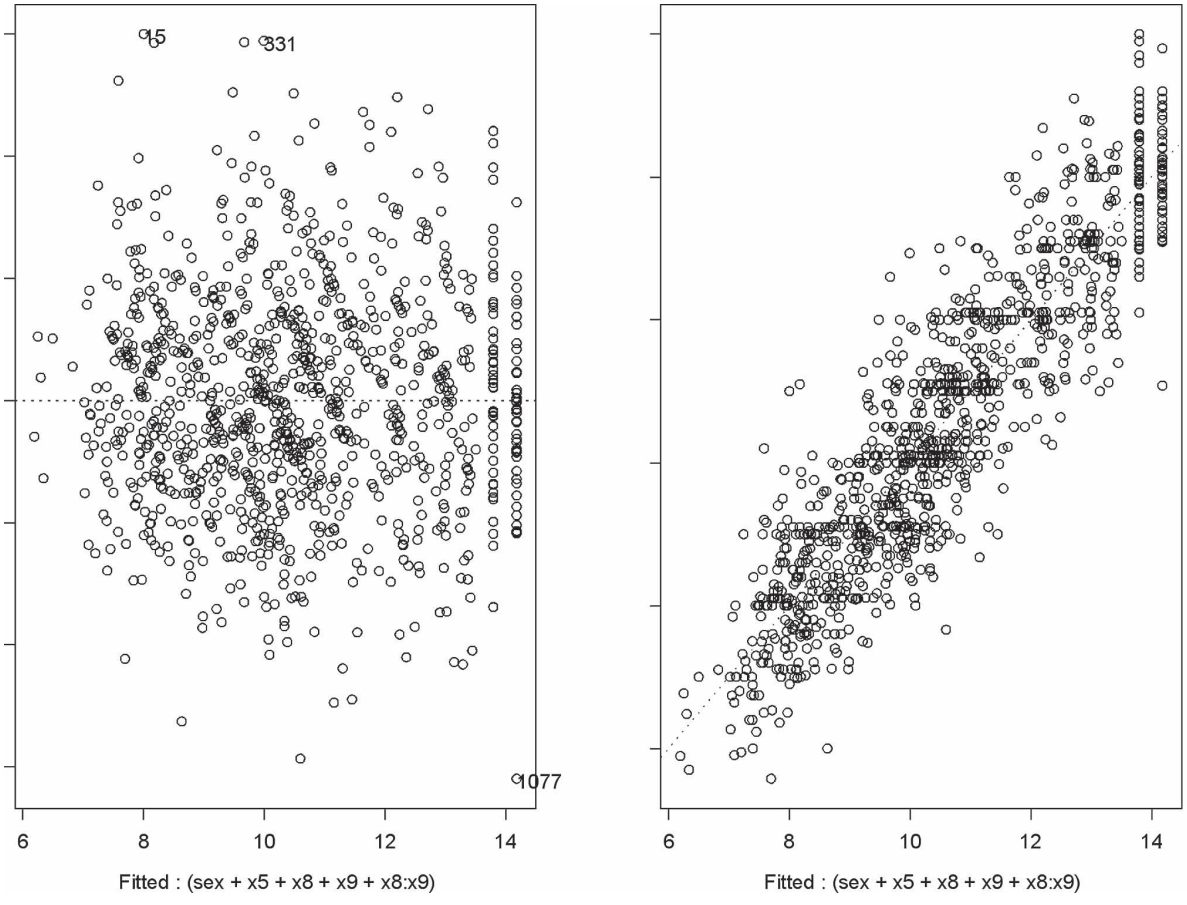
Sve morfološke varijable (xi; i = 1,…,7; s, N_0) te spol ispitanika uneseni su u dokument Excel te su korištene kao predvidive varijable za procjenu dobi u statističkoj analizi.

Kronološka dob izračunata iz datuma rođenja navedenoga na rendgenskoj snimci, također je zabilježena u Excelu. Koeficijenti korelacije procjenjivali su se između dobi i predvidivih varijabli. Kako bi se dobila procijenjena dob kao funkcija morfoloških varijabli i spola, razvijen je model multiple linearne regresije s interakcijama prvog stupnja odabirom onih varijabli koje znatno pridonose procjeni dobi i to metodom postupnog odabira. Zatim je primijenjena analiza kovarijance (ANCOVA) kako bi se ispitale moguće interakcije između važnih morfoloških varijabli i nacionalnosti. Statistička analiza provedena je statističkim programom S-PLUS 6 (S-PLUS 6, za Windowsov operativni sustav, Professional Edition, Release 1). Razina znatnosti postavljena je na 5%.

Statistical analyses

All morphological variables, xi, i = 1,..7; s, N_0, and subjects' gender were entered in an EXCEL file, for use as predictive variables for age estimation in the subsequent statistical analysis.

Chronological age, calculated by subtracting date of birth from date of radiograph, was also recorded in an EXCEL file. Correlation coefficients were evaluated between age and predictive variables. In order to obtain an estimated age as a function of the morphological variables and subject's gender, a multiple linear regression model with first-order interactions was developed, by selecting those variables which contributed significantly to age estimation using the stepwise selection method. Analysis of covariance (ANCOVA) was then applied to study possible interactions between significant morphological variables and nationality. Statistical analysis was performed with the S-PLUS 6 statistical program (S-PLUS 6.1 for Windows, Professional Edition, Release 1). The significance threshold was set at 5%.



Slika 1. Prikaz rezidualnih i usklađenih vrijednosti (lijevo) te prikaz opaženih i predviđenih vrijednosti (desno) uz pomoć regresijskog modela (1).

Figure 1. Plot of the residuals against the fitted values (left panel) and plot of the observed against predicted values (right panel) by using regression model (1).

Rezultati

Svi koeficijenti korelacije između dobi i morfoloških varijabli bili su negativni. Dob ispitanika oblikovana je kao funkcija morfoloških varijabli (prediktora), a da bi se model optimizirao, primijenjen je postupni regresijski postupak. Rezultati ANCOVA-e pokazuju da su spol i varijable x5 (drugi premolar), s, N_0 i prvostupanjska interakcija između s i N_0 znatno pridonijeli usklađenosti, tako da su samo te varijable uključene u regresijski model i dale su sljedeću formulu linearne regresije:
dob = 9,063 + 0,386 g + 1,268 x5 + 0,676 N_0 – 0,913 s – 0,175 s × N_0 (1), u kojoj je "g" varijabla s vrijednostima 1 za muški i 0 za ženski spol. Valja istaknuti da pripadnost različitim europskim regijama nije znatno utjecala na procjenu dobi.

U jednadžbi (1) se samo mijenja spol, tako da se seksualni dimorfizam ne mijenja s dobi, ali jednadžba pokazuje napredak u dentalnoj zrelosti djevojčica svih dobi. Taj model ima najnižu vrijednost AIC-a (Akaike Information Criteriona) među modelima multiple regresije, a kada su se koristili svi prediktori minimalno je poboljšana usklađenost modela. Model (1) je razjasnio 83,3% varijance ($R^2 = 0,833$). Naša metoda, temeljena na normaliziranim otvorenim apeksima sedam donjih lijevih trajnih zuba, rabi dvostupanjsku polinomsku funkciju (1) koja je pokazala medijan apsolutne vrijednosti rezidualne pogreške manji od 0,03 godine (medijan = -0,0254 godine; interkvartilni raspon = 1,16 godina), a rezidualna standardna pogreška procjene bila je 0,89 godina.

Rasprava

Potreba za procjenom dobi živih osoba sve je važnija u forenzičnoj stomatologiji, budući da u Europu stiže sve više imigranata (ilegalnih ili drugačijih), a oni u njezine države dolaze bez prihvatljivih identifikacijskih isprava i, općenito, sve više osoba dolazi bez ikakvih podataka o rođenju ili su oni manjkavi. (18).

Istraživanje morfoloških parametara zuba na dentalnim rendgenskim snimkama pouzdanije je od ostalih metoda procjene dobi, a ujedno je i najčešće korištena metoda za određivanje dobi na živima. Nekoliko je istraživanja pokazalo da morfološka mjerenja mogu biti pouzdana i na panoramskim rendgenskim snimkama, pod uvjetom da se obave neke korekcije te da se u obzir uzme individualna

Results

All correlation coefficients between age and morphological variables were significant and negative. Subject's age was modeled as a function of the morphological variables (predictors) and, to optimize the model, a stepwise regression procedure was applied. The ANCOVA results show that gender and the variables x5 (second premolar), s, N_0 and the first-order interaction between s and N_0 contributed significantly to the fit, so that only these variables were included in the regression model, yielding the following linear regression formula:
Age = 9.063 + 0.386 g + 1.268 x5 + 0.676 N_0 – 0.913 s -0.175 s · N_0 (1)
where "g" is a variable with values of 1 for males and 0 for females. It is notable that belonging to various European regions did not have significant influence on age estimation.

In the equation (1), only the intercept varies with gender, and therefore sexual dimorphism does not change with age, but the equation does indicate an advance in dental maturity for girls at all ages. This model had the lowest Akaike Information Criterion (AIC) value among multiple regression models, and there was a modest improvement in the model fit when all predictors were used. Model (1) explained 83.3% of variance ($R^2 = 0.833$). Our method, based on the normalized open apices of the seven permanent left mandibular teeth, employed a second-degree polynomial function, (1) which showed a median of the absolute value of residual error of less a 0.03 years (median = -0.0254 years; interquartile range = 1.16 years), and the residual standard error of estimate was 0.89 years.

Discussion

The need to estimate the age of living individuals is becoming increasingly important in forensic odontology, since there are increasing numbers of immigrants (illegal or otherwise) who arrive in a country without acceptable identification papers and, more generally, individuals with missing or uncertain birth data. (18).

The study of the morphological parameters of teeth on dental X-rays of adult humans is more reliable than most of the other methods for age estimation, and also it is the most commonly used method to determine the age in living humans. Several studies show that morphological measurements can be reliably made by panoramic radiography, provided that some corrections are made to take into account

varijabilnost veličine zuba te razlike u povećanju rendgenskih snimki i angulacija između rendgenskih zraka i filma.

Analiza kovarijance pokazala je da spol znatno utječe na procjenu dobi te su ti parametri uključeni kao faktor u jednadžbu modela, dok pripadnost različitim europskim regijama nije znatnije utjecala na procjenu dobi.

Svi normalizirani otvoreni apeksi pokazali su znatnu korelaciju s dobi. Posebice je zbroj otvorenih apeksa (s) i broj (N_0) zuba s dovršenim razvojem korijena pridonosio usklađenosti modela.

Taj je rezultat omogućio uporabu jedne jednadžbe za procjenu dobi sve djece u uzorku, bez obzira na etničko podrijetlo. Eksplanatorne varijable bile su iste kao i u modelu korištenom u prije objavljenom radu (19).

Ti rezultati ističu opravdanost upotrebe x5, s i N_0 kao razvojnih markera, posebice kada se dobivena preciznost i točnost uspoređuju s izračunima skeletalne dobi dobivenima drugim tehnikama, npr. rendgenskim snimkama specifičnih struktura, kao što je medijalna epifizna hrskavica klavikule.

Budući da dentalni razvoj u forenzičnom kontekstu ne teče linearno, neki su autori rabili kurvilinearne funkcije kako bi uskladili kronološku i dentalnu dob. Kod Demirjianovih vrijednosti zrelosti (20) primjenjuju se trostupanjske polinomske funkcije.

Naša metoda temeljena na normaliziranim otvorenim apeksima sedam trajnih donjih lijevih zuba rabi dvostupanjsku polinomsku funkciju (1) koja daje medijan apsolutne vrijednosti rezidualne pogreške manji od 0,04 godine (medijan = -0,035 godina; interkvartilni raspon 1,18 godina), a rezidualnu standardnu pogrešku od 0,93 godine. Zato se ona može usporediti s drugim metodama procjene dobi kod djece te je istodobno učinkovita i precizna.

Zaključak

Ovaj rad potvrđuje vrijednost dentalnomedicinskih metoda za procjenu biološke starosti u forenzičnom kontekstu.

Buduća istraživanja trebala bi ispitati mogućnosti modela u opisivanju rasta ljudi različitog zemljopisnog i etničkog podrijetla koji će se ponajprije provoditi na djeci različitih europskih naroda, a zatim i s drugih kontinenata.

individual variability in tooth size and differences in magnification of radiographs and angulation between X-ray beam and film.

Analysis of covariance showed that gender had a significant influence on age estimation, and this parameter was therefore included as a factor in the model equation, whereas belonging to various European regions did not have a significant influence on age estimation.

All normalized open apices showed a significant correlation with age. The sum of normalized open apices (s) and number (N_0) of teeth with complete root development contributed significantly to the model fit to the data.

This result allowed the use of a single equation to estimate the age of all the children in the sample, independently of their ethnic origin. The explanatory variables were also the same as the model considered in the earlier research (19).

These results indicate the appropriateness of using x5, s and N_0 as developmental markers, especially when comparing the obtained precision and accuracy with other skeletal age calculation techniques, for example on radiographs of specific structures such as the medial clavicular epiphyseal cartilage.

Since dental development does not follow a linear progression, in the forensic context, some authors have employed curvilinear functions to relate chronological and dental ages. In particular, when dental maturity is evaluated using Demirjian's maturity score, third degree polynomial functions are used (20).

Our method, based on the normalized open apices of the seven permanent left mandibular teeth, employed the second degree polynomial function (1), which gave a median of the absolute value of residual error of a then 0.04 years (median = -0.035 years; interquartile range = 1.18 years), and the residual standard error was 0.93 years. It is therefore comparable to other methods for age estimation in children, and is reasonably efficient and accurate.

Conclusion

The present research confirms the validity of dental methods together with other methods for accessing biological age in the forensic context.

Future researches should aim at studying the ability of the model to describe the growth of people with different geographic and ethnic origins, using firstly samples of children from various European nations and then children from other continents.

Abstract
Age estimation in children is a fundamental question in forensic medicine, paediatric endocrinology and orthodontic treatment. Several methods deal with their age estimation, including methods based on bone and on tooth development.
Since several authors have shown that odontological methods can differ in accuracy when different populations are considered, this paper focuses on improvement of the method developed by Cameriere et al., extending it to a larger sample of children belonging to several European regions - 505 Italian, 304 Kossovan and 291 Slovenian children, and investigates the efficiency of the method when various populations are pooled together. Correlation coefficients were evaluated between age and predictive variables. Statistical analysis was performed with the S-PLUS 6 statistical program (S-PLUS 6.1 for Windows, Professional Edition, Release 1). The significance threshold was set at 5%. Statistical analysis indicated that gender, sum of normalized open apices and number of teeth with complete root development have a significant influence on age estimation. Belonging to various European regions did not have a significant influence on model parameters.

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Key words
age determination by teeth; radiography, dental; forensic dentistry; regression analysis

References

1. Tanner JM, Healy MJR, Goldstein H, Cameron N. Assesment of skeletal maturity and prediction of adults height (TW3 Method). London: W.B. Saunders; 2001.
2. Roche AF, Cameron Chumlea W, Thissen D. Assessing the skeletal maturity of the hand- wrist: Fels method. Springfield: Charles C. Thomas Publisher; 1988.
3. Schmeling A, Schulz R, Reisinger W, Muhler M, Wernecke KD, Geserick G. Studies on the time frame for ossification of the medial clavicular epiphyseal cartilage in conventional radiography. Int J Legal Med. 2004;118(1):5-8.
4. Schulz R, Mühler M, Mutze S, Schmidt S, Reisinger W, Schmeling A. Studies on the time frame of ossification of the medial epiphysis of the clavicle as revealed by CT scans. Int J Legal Med. 2005;119(3):142-5.
5. Nolla C. The development of permanent teeth. J Dent Child. 1960;27:254.
6. Moorrees CF, Fanning EA, Hunt EE Jr. Age variation of formation stages for ten permanent teeth. J Dent Res. 1963;42:1490-502
7. Gleiser I, Hunt EE. The permanent mandibular first molar; its calcification, eruption, and decay. Am J Phys Anthropol. 1955;13(2):253-83.
8. Demirjian A, Goldstein H, Tanner JM. A new system of dental age assessment. Hum Biol. 1973;45(2):211-27.
9. Chaillet N, Nyström M, Kataja M, Demirjian A. Dental maturity curves in Finnish children: Demirjian's method revisited and polynomial functions for age estimation. J Forensic Sci. 2004;49(6):1324-31.
10. Koshy S, Tandon S. Dental age assessment: the applicability of Demirjian's method in South Indian children. Forensic Sci Int.1998;94(1-2):73-85.
11. Teivens A, Mornstad H. A modification of the Demirijan method for age estimation in children. J Forensic Odontostomatol. 2001;19(2):26-30.
12. Ritz-Timme S, Laumeier I, Collins M. Age estimation based on aspartic acid racemization in elastin from the yellow ligaments. Int J Legal Med. 2003;117(2):96-101.
13. Ohtani S, Ito R, Yamamoto T. Differences in the D/L aspartic acid ratios in dentin among different types of teeth from the same individual and estimated age. Int J Legal Med. 2003;117(3):149-52.
14. Ohtani S, Ito R, Arany S, Yamamoto T. Racemization in enamel among different types of teeth from the same individual. Int J Legal Med. 2005;119(2):66-9.
15. Mörnstad H, Staaf V, Welander U. Age estimation with aid of tooth development: a new method based on objective measurements. Scand J Dental Res. 1994;102(3):137-43.
16. Cameriere R, Ferrante L, Cingolani M. Variations in pulp/tooth area ratio as an indicator of age: a preliminary study. J Forensic Sci. 2004; 49(2):317-9.
17. Paewinsky E, Pfeiffer H, Brinkmann B. Quantification of secondary dentine formation from orthopantomograms-a contribution to forensic age estimation methods in adults. Int J Legal Med. 2005;119(1):27-30.
18. Solheim T. Vonen A. Dental age estimation, quality assurance and age estimation of asylum seekers in Norway. Forensic Sci Int. 2006;159 Suppl 1:S56-60.
19. Cameriere R, Ferrante L, Cingolani M. Age estimation in children by measurement of open apices in teeth. Int J Legal Med. 2006;120(1):49-52.
20. Chaillet N, Demirjian A. Dental maturity in South France: A comparison between Demirjian's method and polynomial functions. J Forensic Sci. 2004;49(5):1059-66.