A new quantitative multi-parameter method improves the accuracy of age estimation from oral findings

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Abstract

In forensic science, age estimation is an important step in identifying unidentified cadavers. As teeth are resistant to environmental degradation for long periods of time, they are often used to estimate age. Although there have been many reports of age estimation based on dental morphology, these methods tend to be subjective and cannot be used in the case of edentulous jaws. In the present study, we developed a new method of age estimation from dental parameters (number of upper teeth [UT], lower teeth [LT], and prostheses [NP]; tooth attrition [TA]; and occlusal area [OA]) and the mandibular angle (MA) measured at autopsy and proposed an equation for calculating the age. The results show that the mean error of this method is similar to that of previous methods, and even demonstrates improved accuracy in subjects aged >60 years. We also proposed an equation for age estimation from only the MA, and showed that we can perform age estimation even in edentulous cases using this equation. Because our method is superior in its simplicity, objectivity, and applicability when compared with previous methods, we believe our method will prove useful for age estimation in a wide variety of cases.

Key words: Age estimation, Dental parameters, Forensic science, Macroscopic examination, Oral findings

Introduction

In forensic cases in which only bones remain or when the cadavers are unidentified, severely burnt, or an advanced state of decomposition, age estimation is an important step for identification. Rapid and accurate age estimation is particularly important for identification of victims in mass autopsies, which may be performed in large-scale emergency and disaster situations. Bones or teeth can be examined for age estimation even in cases involving advanced decomposition because they resist detrimental environmental effects over relatively long periods of time. Thus, in many cases, bones or teeth are used for age estimation.

The most accurate method for age estimation from bones or teeth is amino acid racemization 〔1-15〕. However, this method requires a long time for estimation.

Other methods of age estimation for adults discussed in the literature include macroscopic and radiographic examination of the bones and teeth, which is based on features such as tooth attrition 〔16-25〕, periodontal recession 〔26-32〕, degree of closure of the cranial sutures 〔33-37〕 and pubic symphysis 〔26, 37-45〕. These methods, particularly macroscopic examination of the teeth, are employed for screening in mass autopsies, as they are relatively fast and simple to perform, require no special facilities, and are nondestructive. However, in these estimation methods, the interpretation of the findings tends to be subjective because it is affected by the evaluator's judgment. Thus, different estimates may be reached when different evaluators use these methods to assess the same cadaver.

In this study, we propose a new multi-parameter method of age estimation from dental parameters and mandibular angle (MA) measured at autopsy to make the process of identification by age estimation simpler and more objective than the methods described previously.

Materials and Methods

The study protocol was approved by the ethics committee of our institution.

Experimental Setup

The samples analyzed in this study consisted of the oral findings from 225 cadavers whose age and gender were known; the autopsies were performed in the Department of Legal Medicine at Nara Medical University between April 2011 and March 2013. Age data are expressed as the mean (SD). Dental parameters from 148 male and 77 female cadavers were evaluated in this study. The average ages of the male and female cadavers were 63.9 (18.1) years and 68.9 (21.9) years, respectively. Cadavers with oral findings in a mixed dentition stage were excluded from the present study.

Various dental parameters were measured to facilitate age estimation, and included the following: numbers of upper teeth (UT), lower teeth (LT), and prostheses (NP); tooth attrition (TA); and occlusal area (OA).

The OA, UT, LT, and NP parameters were obtained by counting. The TA measurement represents the degree of attrition of anterior teeth by phase score (Table 1). We separated the oral cavity into 5 regions (anterior, right premolar, left premolar, right molar, and left molar) to calculate the OA value (Figure 1). We also recorded the contact points of the upper and lower teeth, and the final OA value reflects the number of regions that have one or more contact points. An incision, which is a routine dissection procedure, was made from the angle of the mandible to the temporomandibular joint and the MA was calculated in degrees.

Statistical Analysis

We calculated Pearson's correlation coefficient between the dental parameters and the actual age of the cadaver, and the equation for age estimation was obtained by multiple regression analysis using dental parameters that showed correlations with age. Before performing these analyses, we tested the Variance Inflation Factor (VIF) for each parameter in order to investigate multicollinearity: Parameters with a VIF $\geq$ 10 were excluded from the regression analysis because of the risk of multicollinearity. Data splitting was performed for cross-validation of the model. The calculated age estimates were compared to the actual recorded age of the cadavers and the average of differences between the estimated and actual ages were referred to as the mean error. Additionally, we compared the mean error values for the total value and for each decade of age from this study with those of previous studies 〔28-30, 46〕.

All data were analyzed using the SPSS statistical software package (Version 19.0). Values of $P < 0.05$ from 2-tailed analysis were considered statistically significant.

Results

Figure 2 summarizes the correlation between cadaver age and dental parameters. The positive correlations between both age and MA, and age and TA demonstrate that both mandibular angle and tooth attrition increase with age. The negative correlations between age and each of OA, UT, LT, and NP show that these parameters decrease with age.

On the basis of our analysis of these results, we devised an equation for age estimation (Table 2). All dental parameters had a VIF < 10 and therefore were included in the equation.

The mean error when the MA is included in the equation is 7.1 (5.2) years, and when the MA is excluded, the mean error is 7.7 (5.8) years; however, this difference is not statistically significant. Table 3 shows the equation for age estimation by using only the MA. The total mean error is 9.7 (5.2) years.

The total mean error was similar to those reported in previous studies 〔28-30, 46〕 of age estimation from teeth (Table 4). However, the mean error for each age category differs from previous studies; in subjects aged < 40 years, the mean error of this study is larger, and in subjects aged > 60 years, the mean error is smaller than previously reported (Figure 3).

Discussion

In previous reports, the methods of age estimation involved the subjective interpretation of findings from macroscopic and radiographic examinations, which meant that results depended on the evaluator's judgment and were susceptible to human error. For example, age estimation based on TA 〔16-25〕 is affected by evaluator judgment and considered subjective because this method requires a comparison of the degree of TA with a schema of TA scores. Other methods, such as the assessment of apical translucency 〔46-50〕, and periodontal recession 〔26-32〕 often yield results that are not reproducible between examiners. Estimation methods from radiographic findings such as the degree of root formation 〔51-56〕 require X-ray systems and experience in the interpretation of radiographs. Moreover, human error can also occur with these methods, not only because of subjective interpretation of the findings, but also from varying radiograph quality.

For reliable and reproducible age estimation, evaluation criteria that are less reliant on examiner interpretation are necessary. To reduce the degree of subjectivity in this study, we used 5 dental parameters: TA, OA, UT, LT, and NP. Because 4 parameters (all except TA) are calculated by counting, the result is obtained immediately and the risk of human error is minimized. Furthermore, to reduce the subjectivity of TA assessment, we devised a simplified scoring system using only the anterior teeth. Thus, this method can perform age estimation even in cases when the TA score of the molar teeth cannot be calculated, such as in cases of burns and trismus.

It is generally considered that TA increases with age and that NP, UT, LT, and OA decrease with age because of tooth loss. This assumption was demonstrated in the present study. Therefore, we consider these dental parameters useful for age estimation.

The total mean error in age estimation using our method is similar to that reported in previous methods 〔28-30, 46〕. This demonstrates that our method, which can be performed more simply and includes more objective dental parameters, is as accurate as previous methods that are subjective and require longer amounts of time for estimation. Furthermore, the accuracy of this method for age estimation in subjects aged > 60 years was greater than with previous methods.

Age-estimation methods based on macroscopic findings use inter-individual variations in oral findings and changes that occur with aging. Previous methods have investigated tooth attrition 〔16-25〕, apical translucency 〔46-50〕, and periodontal recession 〔26-32〕, and these changes are unlikely to occur in young people. On the other hand, in our study, we focused on the number of teeth and dental treatments, and these changes are unlikely to occur in elderly people. Therefore, the difference in oral parameters used in this study and in previous studies may have resulted in the greater accuracy of our age-estimation method in elderly subjects.

Some of the methods used for age estimation in previous studies show a significant increase in mean error in subjects aged > 60 years and can only be used for younger subjects. Thus, our equation is useful for age estimation in older subjects because there have been no accurate equations reported in previous methods for this age group.

A previous study documented a correlation between age and MA measured radiographically

[57] . However, to date, no studies have proposed an equation for age estimation based on MA. In this study, we measured the MA during autopsy and demonstrated that the MA correlates positively with age. We also presented an equation for age estimation based solely on MA, and investigated the accuracy of this method; the mean error of age estimation using this method is 9.7 (5.2) years. Although the mean error of this equation is larger than when 5 dental parameters are used for age estimation, our results demonstrate that this method could be a valuable tool in the identification of cases involving an edentulous jaw or only a mandibular bone.

Although the accuracy of age estimation in our equation was higher when MA was included with the other dental parameters compared to when MA was not included, the difference was not significant. This suggests that we can perform estimations with the same accuracy in autopsy cases where the MA can be calculated as well as in inquest cases where the MA cannot be calculated.

In conclusion, the advantages of our method are as follows: the mean error is significantly less in elderly subjects, age estimation can be performed less invasively, and we can perform age estimation even in edentulous cases if the MA can be calculated. On the other hand, the disadvantages of this method are as follows: this method is not applicable to edentulous cases when only the maxilla bone is present, and the mean error is large in cases of younger subjects with extensive tooth loss. However, we think this method is useful for age estimation based on macroscopic findings because this method is superior in its simplicity, objectivity, and applicability when compared with previous methods of age estimation based on macroscopic and X-ray findings.

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口腔内所見を用いた新たな年齢推定法

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要旨

身元不明遺体の個人同定において，年齢推定は重要な指標の一つである．歯牙は損傷の激しい遺体においても長時間残存しているため，年齢推定に用いられることが多い．歯牙の肉眼的所見からの年齢推定法は多く報告されているが，判定方法が主観的なものであり，無歯顎の症例には使用できないものであった．今回われわれは，上顎および下顎の歯牙数，補綴物の数，歯牙の咬耗度，咬合接触域，および下顎角の角度を使用した，新たな年齢推定の方法を考案した．今回の結果，われわれの方法は，過去に報告された歯牙の肉眼的所見からの年齢推定法とほぼ同程度の誤差で推定を行うことができ，60 歳以上の高齢者では，過去の方法よりも正確な推定を行うことができることが分かった．またわれわれは，無歯顎症例でも年齢推定を行うことができるよう，下顎角の角度のみからの推定式も考案した．過去の方法に比べわれわれの方法は，口腔内所見を簡便に測定でき，測定者による誤差が少ない客観的な方法であり，より多くの症例に使用できることから，年齢推定において有用な方法であると思われる．

Table legends

Table 1: Tooth Attrition (TA) score

Table 2: Age estimation equations

Equation 1: Include MA

Equation 2: Exclude MA

MA: Mandibular Angle

TA: Tooth Attrition

OA: Occlusal Area

UT: Number of Upper Teeth

LT: Number of Lower Teeth

NP: Number of Prosthesis

R: Correlation Coefficient

R^2: Correlation of determination

Table 3: Age estimation equation from MA

MA: Mandibular Angle

R: Correlation Coefficient

R^2: Correlation of determination

Table 4: Comparison of the mean error of present study with that of previous methods

(the mean error values of previous reports (Ref. 29, 30, 46) were calculated by applying the data obtained from Ubelaker's study (Ref. 28) to each of the methods in these studies.)

Figure legends

Figure 1: The region of Occlusal Area (OA)

1. Anterior
2. Right premolar
3. Left premolar
4. Right molar
5. Left molar

Figure 2: Correlation between dental parameters and age

Figure 3: Compare the mean error of estimation methods in each decade

(the mean error values of previous reports (Ref. 29, 30, 46) were calculated by applying the data obtained from Ubelaker's study (Ref. 28) to each of the methods in these studies.)

Table 1

Phase	
0	**No attrition**
1	**Attrition within enamel**
2	**Pinpoint dentine exposure**
3	**Distinct line of dentine exposure**
4 (a)	**Remarkable change of tooth height (case of residual root)**
4 (b)	**The case of all anterior teeth were covered by prosthesis**
5	**The case of no anterior teeth**
6	**Edentulous jaw**

Table 2

Equation 1	**Age= 1.06MA+3.39TA-1.94OA-0.3UT-0.3LT+0.87NP-79.5**
R	0.79
R^2	0.63
Adjusted R^2	0.62

Equation 2	**Age= 3.47TA-1.68OA-0.58UT-0.64LT+1.1NP+56.5**
R	0.79
R^2	0.63
Adjusted R^2	0.62

Table 3

Equation	Age= 2.28MA-222.7
R	0.63
R^2	0.4
Adjusted R^2	0.4

Table 4

Method	n	Mean error	S.D.	Reference
Present Study	225	7.13	5.19	
Ubelaker et al.	100	6.29	5.97	28
Prince et al.	100	7.63	6.56	29
Lamendin et al.	100	8.28	7.4	30
Bang et al.	100	8.77	6.65	46

Figure 1

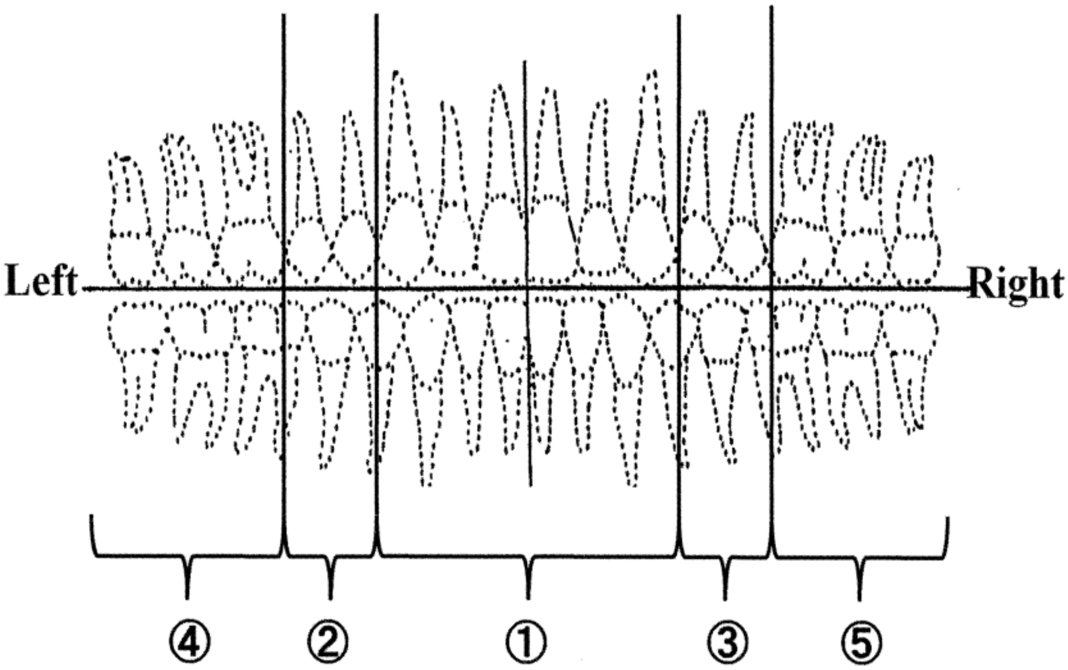
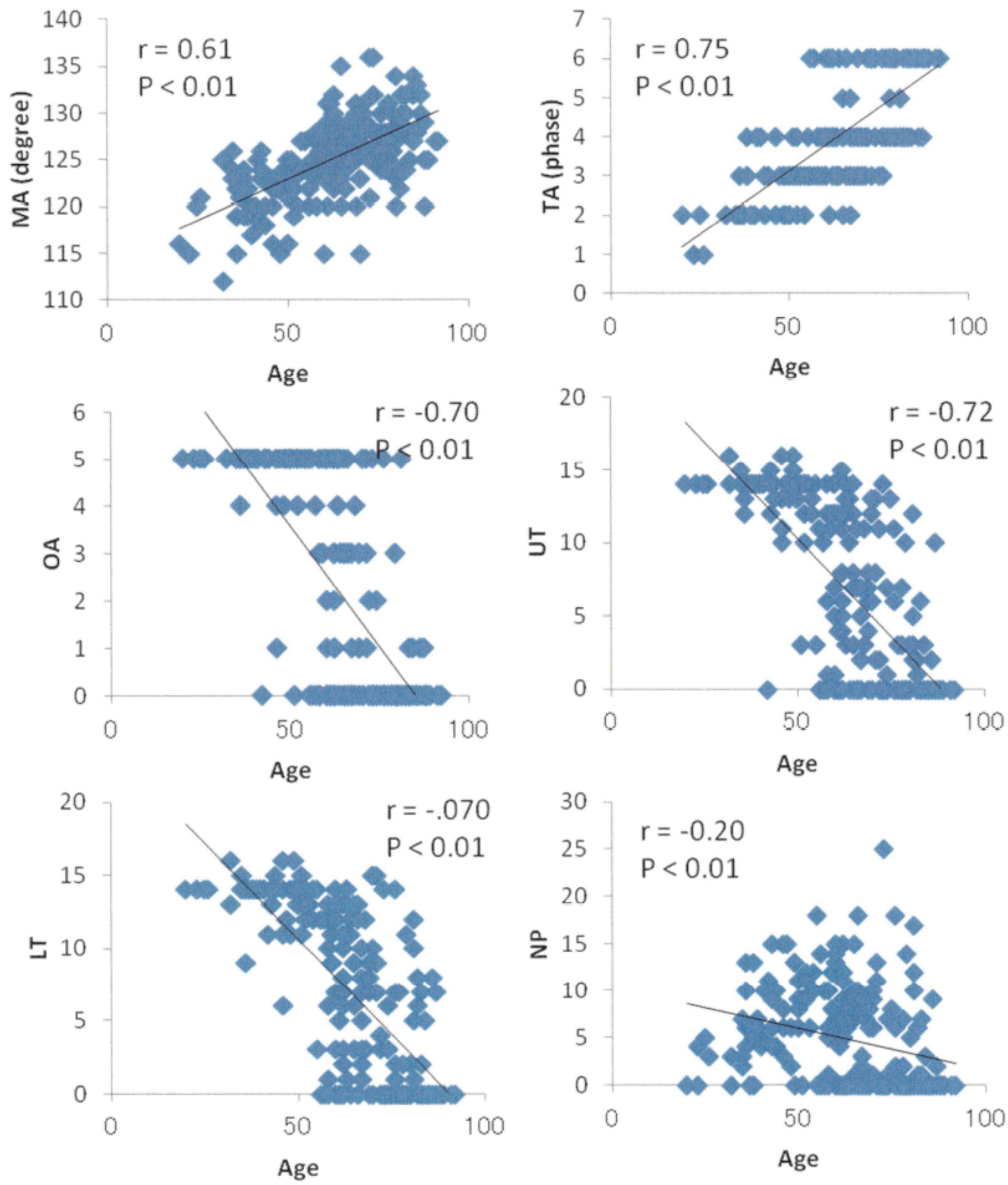
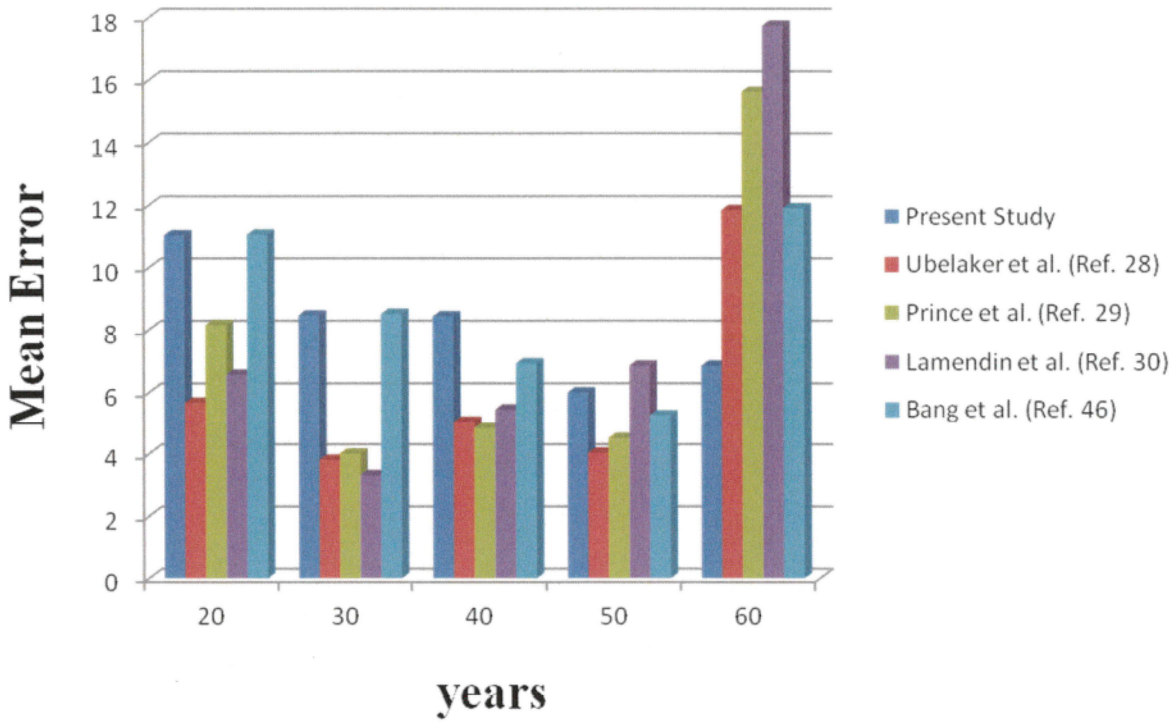


Figure 2



r = 0.61
P < 0.01
MA (degree)
Age
r = 0.75
P < 0.01
TA (phase)
Age
r = -0.70
P < 0.01
OA
Age
r = -0.72
P < 0.01
UT
Age
r = -.070
P < 0.01
LT
Age
r = -0.20
P < 0.01
NP
Age

Figure 3


18
16
14
12
10
8
6
4
2
0
Mean Error
20
30
40
50
60
years
Present Study
Ubelaker et al. (Ref. 28)
Prince et al. (Ref. 29)
Lamendin et al. (Ref. 30)
Bang et al. (Ref. 46)