FORENSIC ODONTOLOGICAL EXAMINATION OF A 1500 YEAR-OLD HUMAN REMAIN IN ANCIENT KOREA (GAYA).

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ABSTRACT

Forensic odontological examination was performed on one of the 1500-year old human remains of ancient Korea (Gaya) excavated from a burial site at Songhyeon-dong, Changnyeong, South Korea in April, 2008. The main purpose of the examination was to age estimate the remains and record any dental characteristics to aid full-body reconstruction and life history data collection. Oral and radiographic examinations and metric data collection were conducted. During the oral examination, the following observations were made: dental caries, semi-circular abrasion on the maxillary right lateral incisor and enamel hypoplasia on the left and right canines and first premolars in the mandible. The metric data was similar to that of average metric data of modern Koreans. Age estimation was initially conducted using the degree of dental attrition with methods of Takei and Yun, and was estimated to be approximately 40 years. However, it was observed in the radiographic examination, that the maxillary right second molar, together with the mandibular left and right second and third molars had incompletely developed root apices. The age estimation was then performed using the developmental status of the lower second and third molars. The age was estimated to be approximately 16 years using Lee's method which was consistent with the estimation using forensic anthropology. This case study highlights that the degree of attrition should not be used as a sole indicator for age estimation.

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Keywords: Dental age estimation, attrition, enamel hypoplasia, Korea, ancient remains.

Running Title: Forensic odontological examination of a 1500-year old Korean human remain.

INTRODUCTION

Human skeletons of four individuals: two males and two females, were recovered from a burial site at Songhyeon-dong, Changnyeong, South Korea in April, 2008. Archaeological evidence and analysis of the remains suggested that the burial site is of the early 6th century A.D. At that time, the region in which the burial site is located was under the rule of Gaya, an ancient kingdom of Korea. The remains seem to be the subject of one of the burial customs of Gaya; burying servants along with their master (owner of the tomb) in order to serve them in their afterlife. Under the supervision of Gaya National Research Institute of Cultural Heritage (GNRICH), comprehensive research was conducted by a multidisciplinary team in the fields of archaeology, paleopathology, anthropology, forensic odontology, human anatomy, genetics, chemistry, physics and fine arts. This research was conducted from July 2008 for a year in order to gather the life history of the remains. Full-body reconstruction was a part of the research and one of the female remains was selected since the skeletal elements were relatively well preserved. Essential information for the reconstruction such as age, sex, stature was estimated by the team. Age estimation was conducted using forensic odontology since teeth can produce more accurate estimations than other age indicators of the body.[1] A thorough forensic odontological examination was conducted to record dental characteristics which could reveal important aspects of her life history.

MATERIALS AND METHODS

Macroscopic examination (using naked eye and a magnifying glass) as well as radiographic examination was performed on the maxillary and mandibular dentition. The examinations were performed by a well-trained forensic odontologist. Age estimation methods, using the degree of attrition by Takei[2] and Yun[3] which were developed on modern samples of Japanese and Koreans respectively, were utilized during the macroscopic examination. Developmental and pathological characteristics observable were also recorded.

Crown height, bucco-lingual diameter, mesio-distal diameter, and root length of teeth were measured with a vernier caliper (Mitutoyo Co., Tokyo, Japan). It was impossible to collect data on teeth that suffered postmortem loss of crown and/or root. Visual root examination was not observed in teeth that could not be extracted with passive finger pressure in order to avoid destruction of the archaeological remains.

Radiological examination was conducted on all the existing teeth using CT scans and periapical radiographs. It was impossible to take a panoramic radiograph because of technical difficulties due to a loss and/or destruction of skull bones that support the maxilla. Some incompletely developed second and third molars were observed in the radiographs. Age estimation was conducted using Lee's method[4] which uses the second and third molar developmental status of Koreans. In this case, the right side was chosen because it showed clearer images for evaluation - Lee et al[4] found that there was no statistically significant difference between the left and right side in the developmental status of second and third molars. Also any pathologic lesions of bones and teeth observed in the radiographs were recorded and analysed.

RESULTS
Macroscopic Examination
The maxillary left lateral incisor, second premolar and second molar could not be examined due to postmortem loss. Advanced dental caries was observed in the maxillary left first premolar (Fig. 1). Moderate and insipient dental caries were observed in some mandibular molars (Fig. 2). Partial enamel loss due to fracture was observed in the maxillary right second premolar.

From the age estimation conducted using methods utilizing the degree of attrition; age was estimated to be about 39.05±5.00 years using Takei's method,[2] and about 42.38±4.97 years using Yun's method[3] (Table 1).

Semi-circular abrasion was observed on the incisal edge of the maxillary right lateral incisor (Fig. 3) and enamel hypoplasia was found on the labial side of the left and right mandibular canines and the first premolars (Fig. 4). Asymmetry was not observed between the left and right side and the metric data were similar with the average of modern Korean dentitions published by Oh et al.[5] (Table 2).

Radiological Examination
Any morphological variation or pathologic findings were not observed in the radiographs (Fig. 5). The maxillary right second molar and the left and right mandibular second and third molars were found to be incompletely developed, and the third molars were impacted (Figs. 6 and 7).

Age estimation was conducted using Lee's method[4] utilising the developmental state of the second and third molars of the mandible. Lee's method[4] has a gender-specific regression equation and the sex of the individual was confirmed by DNA analysis to be female. Therefore the regression formula for females was used in estimating the age of the remains. The age was estimated to be 16.39±1.41 years using a second molar, 16.94±1.68 using a third molar, and 16.44±1.27 using a combination of second and third molars.

DISCUSSION
Age estimation was emphasized during this forensic odontological examination for the reconstruction of the selected female human remains. During examination using methods based on the degree of attrition, dentine exposure was found in several teeth of the remains and the age was estimated to be approximately 40 years using the two methods, of Takei[2] and Yun.[3] However, it was found that her dental development was incomplete upon radiographic examination suggesting a much younger age. A possible reason for such contradiction is because the methods used here were developed on samples of the modern population of Korea and Japan and it is highly probable that there are many differences in many aspects which can affect the degree of attrition between modern and archaeological populations.

Age estimation using dental development is relatively more accurate and reliable because there is a low variability among individuals.[1] However, it can only be applied to individuals with incomplete dental development, which means age estimation of sub-adults is relatively more accurate compared to that of adults. The remain's age estimation was conducted again using dental developmental status, since her dental development was incomplete, and the age was estimated to be approximately just over 16 years, which was consistent with the estimation using anthropological age indicators. Most of the long bones were recovered except the right

femur and left tibia, and it was observed that epiphyseal plate closure was not yet complete. Based on this information, the age was estimated to be about 15 to 17 years.

Age estimation methods using the degree of attrition are greatly affected by different factors of a population such as ancestry, socio-economic status, diet as well as temporal variation. These factors should be carefully considered before extrapolating the results on a different population. For instance, Brothwell's method[6] was developed on an English population, thus applying it to Koreans should be avoided, but if deemed necessary it should be used with caution. For the remains examined in this research, a standard developed with an archaeological Korean population would have offered the best estimation. Research into the development of appropriate standards cannot be stressed enough. Despite the disadvantage that there are just too many factors to be taken into consideration, methods using the degree of attrition are still frequently utilized since they are non-invasive, easy to use, and have a relatively high inter-observer reliability. Nevertheless, it should be kept in mind that the degree of attrition should not be used as a sole indicator for age estimation. In this research, the inaccuracy of the age estimation using the degree of attrition would not have been realised if the radiographs were not examined for dental development status. In addition, quality assurance of dental age estimation of the International Organisation for Forensic Odonto-Stomatology (IOFOS) recommends using at least two independent statistical methods.[7]

Uniquely shaped abrasion was observed in the maxillary right lateral incisor. This abrasion was categorized as B/2 according to Romero,[8] who published a standard of classification regarding artificial dental modification. Such modification could be due to a number of different reasons such as sorcery, aesthetics, or other social reasons. It could be caused by repetitive actions using a particular part of the dentition. Fox[9] claimed that a uniform pattern of striation found in maxillary incisors of Paleolithic men was caused from their repetitive actions of using teeth for securely holding foodstuff in order to cut them using lithic tools. The remain's wear in this project may be a result of repetitive action during sewing, based on the knowledge that many Korean women often cut a thread with their teeth while sewing (instead of using scissors).

Loss of enamel due to enamel hypoplasia was observed on the labial side of left and right mandibular canines and first premolars. There are various causes of enamel hypoplasia, generally caused by systemic insults which can affect the formation of enamel. Factors causing such systemic insults include: infection, metabolic disorder and malnutrition which share similar clinical findings and therefore it is often impossible to confirm exactly which of these cause enamel hypoplasia.[10] Nevertheless, it was clear that she had suffered several systemic insults and detailed analysis should be conducted with pathological characteristics observed from the bones in order to find out the specific disease.

CONCLUSION

Much can be learned from studying ancient remains. In this case, age estimation initially conducted using the degree of attrition was found to be inaccurate following radiographic examination of the dentition. The age of the human remains utilising Lee's method[3] on the developmental state of the second and third molars of the mandible was estimated to be approximately 16 years old from the forensic odontological examination. This case study highlights that the degree of attrition should not be used as a sole indicator for age estimation. It was suggested that the remains had suffered from a number of systemic insults causing enamel hypoplasia. Metric data analysis showed that there is no significant difference in the morphology of teeth between a 1500-year old human remain and modern population.

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FIGURES

Fig.1. *Advanced dental caries observed on maxillary left first premolar.*

Fig.2. *Moderate dental caries observed on mandibular left second molar.*

Fig.3. *Semi-circular abrasion found on incisal edge of maxillary right lateral incisor.*

Fig.6. *Periapical radiograph of mandibular right third molar.*

Fig.4. *Enamel hypoplasia observed on labial surfaces of mandibular right canine and first premolar.*
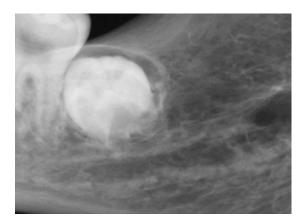

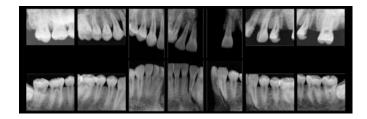**Fig.7.** *Periapical radiograph of mandibular left third molar.*

Fig.5. *Periapical radiographs of maxillary and mandibular dentition excluding third molars.*

TABLES

Table 1. *Attrition degree of the examined ancient human remain*

Maxillary teeth FDI notation	*17*	*16*	*15*	*14*	*13*	*12*	*11*	*21*	*22*	*23*	*24*	*25*	*26*	*27*
Takei[a]	B	C	B	B	C	B	C	C	—	C	B	—	C	—
Yun[b]	2/3	1Sc	2S	2S	Sc	Lc	Lc	Lc	—	Sc	1S	—	1Sc	—
Mandiblular teeth FDI notation	*47*	*46*	*45*	*44*	*43*	*42*	*41*	*31*	*32*	*33*	*34*	*35*	*36*	*37*
Takei[a]	B	C	A	A	C	B	B	B	B	C	B	B	C	B
Yun[b]	2B	5Pc	1S	1S	Sc	Lc	Lc	Lc	Lc	Sc	1B	2/3	3Pc	2/3

[a]Method presented by Takei[2] for scoring a degree of attrition
[b]Method presented by Yun[3] for scoring a degree of attrition

Table 2. *Metric data of the examined ancient human remain*

Maxillary teeth	*17*	*16*	*15*	*14*	*13*	*12*	*11*	*21*	*22*	*23*	*24*	*25*	*26*	*27*
CH[a] (mm)	7.89	7.26	7.77	8.40	10.18	10.40	11.40	11.04	—	10.91	8.72	—	7.84	—
MDD[b] (mm)	10.45	10.43	6.74	7.36	7.89	7.90	8.19	8.27	—	8.01	—	—	10.69	—
BLD[c] (mm)	11.75	11.52	9.27	9.65	8.78	6.58	11.27	—	—	8.98	9.80	—	11.76	—
RL[d] (mm)	—	—	—	—	—	11.80	10.79	11.36	—	13.58	—	—	—	—
Mandibular teeth	*47*	*46*	*45*	*44*	*43*	*42*	*41*	*31*	*32*	*33*	*34*	*35*	*36*	*37*
CH[a] (mm)	6.36	6.29	7.62	8.73	11.35	10.10	8.96	8.99	10.00	11.24	8.57	7.03	6.46	7.77
MDD[b] (mm)	11.18	11.01	6.82	6.75	6.83	6.24	5.09	5.20	6.38	7.19	7.15	6.64	10.83	11.39
BLD[c] (mm)	10.32	10.74	8.21	8.01	8.17	6.52	5.66	5.82	6.46	8.32	8.14	8.13	10.62	10.42
RL[d] (mm)	—	—	—	—	—	—	—	—	—	—	—	—	—	11.08

[a]Crown height
[b]Mesio-distal diameter
[c]Bucco-lingual diameter
[d]Root length