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Effectiveness and limitations of human identification from cremains: A report of two cases

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ABSTRACT

The present study of two case reports of the victims of the Great East Japan Earthquake demonstrates the effectiveness and limitations of using dental cone-beam computed tomography (CBCT) imaging of cremains as a means of identification. In case 1, identification was assisted by further expanding the age range of the cremains evaluated on macroscopy by obtaining CBCT images of the cremated maxilla. The findings of case 2 presented the possibility that the deceased and the candidate were the same person by superimposing the CBCT images of the cremated patella on the X-ray of the candidate. However, since cremated bones are deformed to varying degrees, it is clear that the images obtained before, rather than after, cremation are more effective in comparing post-mortem and ante-mortem images. Thus, it is necessary to collect extensive and diverse data on the deceased before cremation.

1. Introduction

Cremation is the main method of the final disposition of a dead human body used in Japan. Even when remains have not been identified, cremation is performed after obtaining post-mortem (PM) records. The cremains are then placed in a funerary urn and given to a local government agency in the vicinity of the location where the bodies were found. Remains of numerous casualties of the tsunami caused by the Great East Japan Earthquake on 11 March 2011 were cremated without sufficient PM records for identification; a lack of sufficient dental records was especially apparent. Even 9 years after the disaster, there were 48 cases of unidentified remains in Iwate Prefecture [1]. Procedurally, the remains of all these cases have been cremated.

In the past years, efforts by the local police have resulted in the establishment of the identity of some of these unidentified remains. In multiple cases, cremains have been successfully given to their families following detailed investigations; identification was assisted by dental cone-beam computed tomography (CBCT). Herein, we present two cases demonstrating the effectiveness and limitations of using CBCT imaging of cremains for identification.

2. Case report

2.1. Case 1

This was the case of a burnt male body found immediately after the disaster. As skin contractures resulting from burns rendered it impossible to open the deceased's mouth, the PM dental data recorded at the morgue were limited to the anterior mandibular teeth, with no further information useful to identify the body. Even with a justifiable reason, such as the identification of an unknown deceased person, an intentional skin incision without a court's permission is considered the destruction of a corpse and is punishable by law in Japan [2]. Thus, the body was sent for cremation after acquiring a DNA sample, without taking dental records, and the identification of the remains was stagnated for a long period.

After 8 years, DNA database searches found a potential candidate, a 39-year-old man when he went missing. However, his medical records, including dental records, were lost in the tsunami that followed the earthquake. One sibling emerged as a blood relative from DNA profiling results with DNA-VIEW (produced by Brenner CH, Human Rights

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Centre, UC Berkeley, CA, USA) [3] using samples obtained from the remains. However, during DNA typing using AmpFLSTR™ Yfiler™ PCR Amplification Kit (Thermo Fisher Scientific, Inc., MA, USA), one locus did not match that of the remains. There were no other close relatives; therefore, the identity of the remains could not be verified. Thus, additional evidence was required for definitive identification.

At this point, the condition of the bones in the cremains was evaluated. Within the remnants of the maxilla, one piece of hard tissue considered to be a root remain was found, and the alveolar part of the maxilla was noted to be flat throughout (Fig. 1A, B, C). It was estimated to be an elderly person; that was not matched with the candidate. The candidate's family stated that their missing relative had lost his front teeth by age 39. However, from macroscopy, the cremains could not be conclusively determined to be consistent with a 39-year-old person. Therefore, further investigation of the maxilla was conducted to determine.

CBCT imaging was performed on the bones from the cremains using KaVo OP 3D Vision and OnDemand3D Dental software (KaVo Dental Systems Co., Ltd. Tokyo, Japan). The images were compared to those of the maxilla samples, which were existing CBCT data of living persons from X: a 41-year-old male without teeth as a sample close to the candidate's age and Y: a 75-year-old male without teeth as an elderly comparison sample'. These comparisons were performed after approval by the Ethics Committee of Iwate Medical University, School of Dentistry (approval No. 01302).

Additionally, prior documentation and reports on ageing-related changes in the maxilla were referenced [4–8]. Hence, the CBCT images were evaluated to determine the age range of the cremains in terms of the following radiographic age-related findings in the maxilla:

1. Bone density loss (bone resorption), accompanied by an increase in adipose and connective tissues [5].
2. Thinning and decrease in the cancellous bone mass [5,8].
3. Minor thinning of the cortical bone on the entire alveolar process and the bony palate of the maxilla starting at the age of 30 years and increasing in severity at the age of 60 years and older [4,5,7].
4. Shrinking and relative inward movement of the alveolar process towards the maxillary sinus floor in edentulous maxillae, as the edentulous alveolar process becomes smaller inwardly due to its absorption over the years [6].
5. Age-related changes, such as the slight expansion of the maxillary sinus, the extension of the sinus towards the root apex side, and the thinning of the maxillary sinus wall. The cortical bone at the maxillary sinus floor tends to be thicker in edentulous maxillae than in dentulous maxillae. In addition, a thin cancellous bone appears at the maxillary sinus floor [5,6].

Results of the radiographic findings in the CBCT images of the cremains compared to the sample images of X and Y were as follows. The evaluation of the items mentioned in points 1 and 2 was impossible because the cancellous bone and the soft (adipose and connective) tissues of the remains were degenerated by heating. From the sagittal and frontal images, thinning of the alveolar process cortical bone in the molar region was observed, but the thickness of the cortical bony palate was maintained (point 3) (Fig. 2A, B). The alveolar process height of the alveolar bone of the front teeth and the molars were sufficiently maintained, even with consideration for physiological bone resorption due to tooth extraction. The right alveolar depression, confirmed by the horizontal and panoramic images, could be the alveolar fossa (arrows of Fig. 2C and 3) following tooth loss or extraction just before death based on the remaining lamina dura; therefore, it was estimated that the alveolar process was not significantly reduced (point 3) (Figs. 2C and 3).

The fluoroscopic imaging of the occlusal surface showed that the alveolar processes of the cremated bone and the comparison sample X were located outward from the maxillary sinus floor, and the alveolar processes were not absorbed much; hence, it was considered that it had not been long since the loss of teeth. The alveolar process of the comparison sample Y was located inside the maxillary sinus floor; the finding showed that the alveolar process had been absorbed from the lateral side (point 4) (Fig. 4). The contour of the maxillary sinus floor of the comparison sample Y was undefined due to the appearance of the cortical bone thickness and the cancellous bone, whereas the contour of the maxillary sinus floor of the cremated bone and the comparison sample X was relatively defined. Sufficient distance could be confirmed between the maxillary sinus floor and the alveolar cortical bone of the cremated maxilla (point 5) (Fig. 5).

These cremains' findings did not clearly indicate that they belonged to an older person; rather, they suggested a possible age range of 30–60 years, and the candidate's age, 39 years old, could be considered the estimated age [4–8]. Thus, we concluded that the cremains were possible to be originated from a 39-year-old candidate.

2.2. Case 2

This was the case of a burnt female body found immediately after the disaster. The body was sent for cremation without the collection of DNA samples because the heart blood was unable to be extracted, and the nails could not be collected due to burning. Therefore, the cremains were stored in the government office.

The multiple candidates emerged from the missing persons of the disaster, depending on their sex and estimated age. Eight years after the earthquake, a possible relative of the deceased claimed that the hairstyle of a burnt body in one of the photographs disclosed at a regularly held conference for the families of the deceased resembled that of a missing family member. Therefore, it became more likely that the woman would eventually be the candidate. STR type and mitochondrial DNA type tests

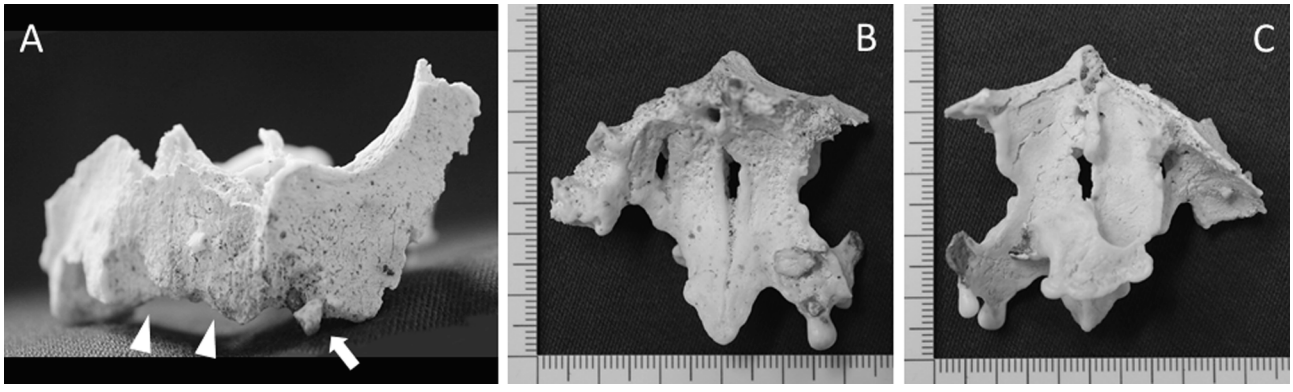

Fig. 1. The maxilla of the remain in case 1 after cremation; frontal (A), occlusal surface (B), and maxillary sinus floor surface planes (C). One piece of hard tissue considered to be a root remain was found (arrow), and the alveolar part was flat throughout (arrowheads).

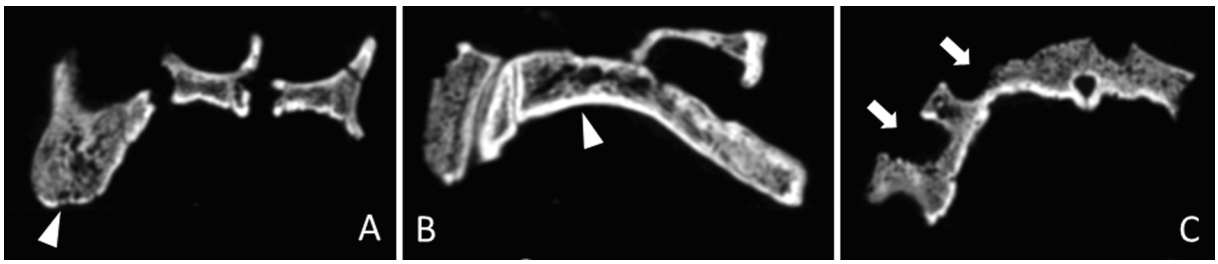

Fig. 2. Cone-beam computed tomography images of the maxilla of the remains in case 1; frontal (A), sagittal (B), and horizontal planes (C). Thinning of the alveolar process cortical bone in the molar region was observed (arrowhead in A), but the thickness of the cortical bony palate was maintained (arrowhead in B). The right alveolar depression can be determined to be the alveolar fossa (arrows in C).

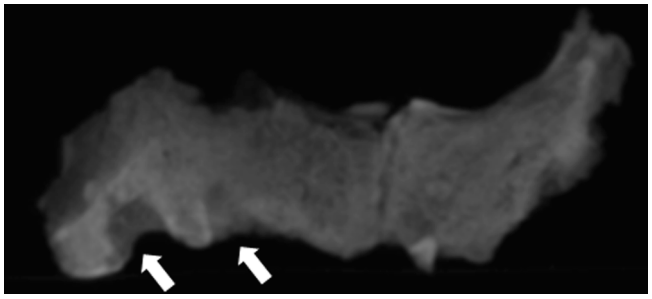

Fig. 3. The panoramic image by cone-beam computed tomography of the remains in case 1. The right alveolar depression can be determined to be the alveolar fossa (arrows). It was suggested that it did not pass for a long time after tooth loss since the margins of the alveolar processes obviously remained.

were tried from the cremated bone. However, the types could not be detected. Because the facial structures could be distinguished, although the body was burnt, the facial morphologic criteria of the photographs of the burnt body and the snapshots of the candidate which were provided by the family were compared; the left and right inner canthi, the ratio of the distance between the left and right inner canthi, the left and right alar base, the shape of the mandible edge, and the attachment of the left auricular lobule to the skin surface of both were similar. However, there was no definitive finding to identify the victim.

Before the disaster, the candidate had visited a nearby hospital for treatment of knee pain. The radiographs of the left knee joint had been acquired and stored at the hospital (Fig. 6). Therefore, we looked for the left patella among the cremated bones to compare it to the radiographs of the candidate's knee. This was the only scientific appraisal method that was compared the shape of the patella, and it was decided to conclude the identification from the results.

The left patella was taken for imaging using CBCT (3D Accuitomo, J. Morita Corp., Kyoto, Japan) and converted into a three-dimensional

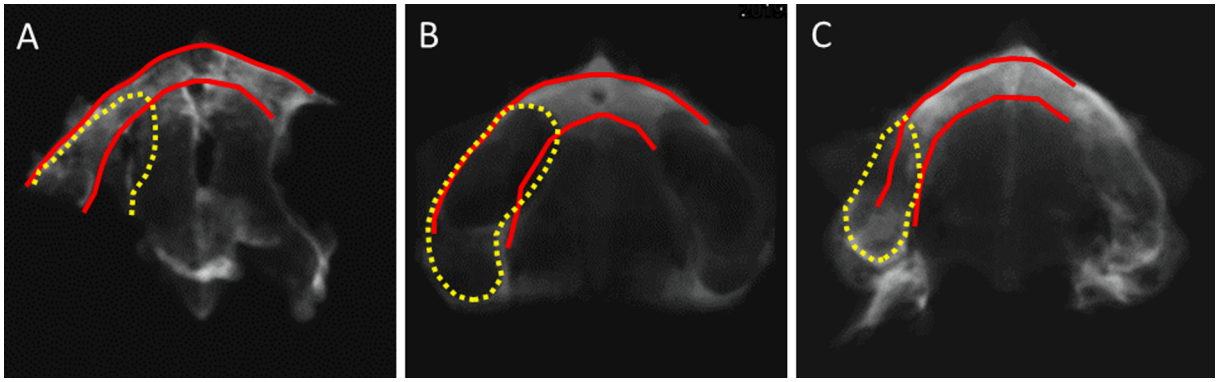

Fig. 4. Fluoroscopic images showing the findings of the occlusal surface for the remains in case 1 (A), X: a 41-year-old man without teeth (B), and Y: a 75-year-old man without teeth (C). Alveolar processes are indicated by red lines, and the maxillary sinus floor is indicated by yellow dot lines. The alveolar processes of case 1 and X are located outward to the maxillary sinus floor. The alveolar process of the comparison sample Y is located inside the maxillary sinus floor. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

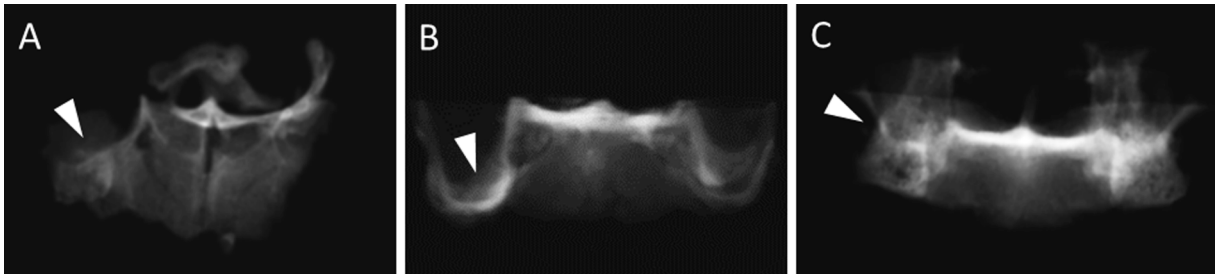

Fig. 5. The fluoroscopic images showing the findings on the frontal view for the remains in case 1 (A), X: a 41-year-old man without teeth (B), and Y: a 75-year-old man without teeth (C). The maxillary sinus floor of Y is undefined, whereas those of the remains in case 1 and X are relatively defined (arrowheads).

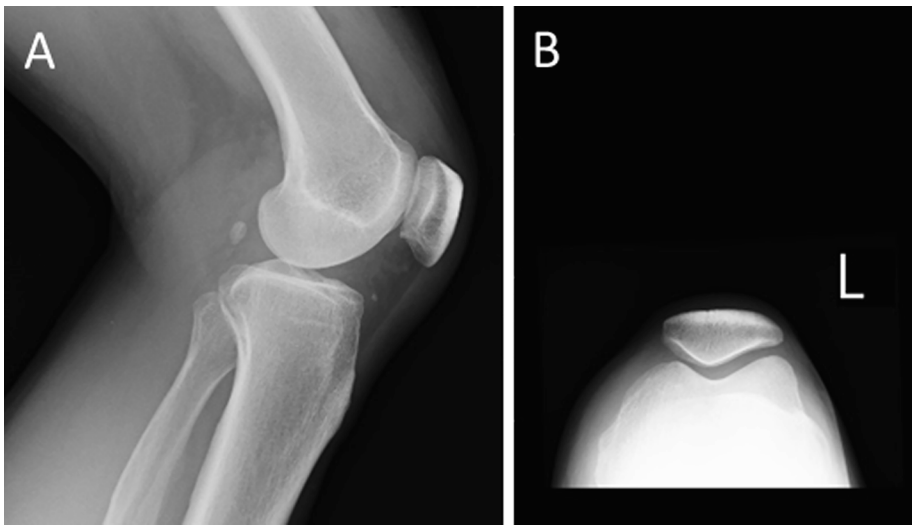

Fig. 6. The radiographs of the left knee joint of the candidate in case 2 showing the lateral (A) and top surface planes (B).

model using OnDemand 3D Dental software (KaVo Dental Systems Co., Ltd. Tokyo, Japan). Although the patella showed cracks and damages due to heating (Fig. 7), we tried to superimpose the CBCT images of the patella on the radiographs of the candidate's left knee joint. In the superimposition of these images, the dimension of the CBCT image was adjusted using the base and apex of the patella, as well as the fibular and medial margin as reference points. The shape of the medial surface of the patella was matched, despite a slight morphological difference in the

Fig. 7. The patella of the remains in case 2 after cremation showing the anterior (A) and posterior planes (B). Cone-beam computed tomography images showing the anterior (C) and posterior findings (D).

anterior view of the patella. Furthermore, the comparison of the upper surface of the base of the patella showed that the shape and position of the base of both images were highly similar (Fig. 8).

Sex determination by morphometry of the patella was performed with measurements using the software, HBM-Rugle (Medic Engineering, Inc. Kyoto, Japan). The measured values in this study were compared to those of the Japanese samples in the study by Michiue et al. The maximum height, maximum thickness, and mass volume of the patella were 30.8 mm, 13.2 mm, and 5.4 cm^3, respectively; therefore, the specimen was estimated to belong to a female [9].

Thus, these findings did not provide for excluding as the candidate of the deceased, it also did not provide indisputable evidence for the identification.

3. Discussion

In case 1, the cremains' identification was assisted by further establishing the macroscopically estimated age range of the cremated maxilla by using CBCT. From these results, it can be said that obtaining CBCT images of the maxillofacial skeleton of dead bodies may provide new findings that could help streamline the candidates for unidentified cremains. Fundamentally, the identification of the remains was almost completed using the results of the DNA typing conducted before CBCT imaging. So far, multiple mistakes have occurred during the identification of the victims of this disaster. Furthermore, there are still many missing persons. Thus, extreme caution is required in this disaster victim identification process.

For cases in which remains are compared to data from multiple candidates to determine compatibility, dental data is an effective identification method and can be useful in order to exclude or not potential candidates. Even if no traces of dental treatment are found, X-ray imaging from PM data can be used to compare tooth root and pulp morphology and cancellous bone structures in the X-ray imaging of the candidates' ante-mortem (AM) data. However, the degradation in post-cremation bones makes it challenging to match them with AM data. Regarding age-related histological changes [8,10], the evaluation becomes impossible after heating due to degradation of the cancellous bone. In the present case, external findings of the maxilla on naked-eye morphological observations, which remained after the cremation, were insufficient to narrow the age range. Thus, CBCT images were acquired and compared to known findings related to general age-related changes in the maxilla. These comparisons established an approximate age range, which, combined with the information from the surviving family members, helped determine whether there were inconsistencies between the cremains and the potential candidate.

The patella, used for identification in Case 2, is known to differ between men and women, and researchers from several countries have previously reported on sex-based identification using the patella [9,11–16]. It is reportedly challenging to demonstrate individual differences of patellae [16]. As the patella is originally chestnut-shaped, one could tell that the patella of Case 2 was damaged in cremation and did not retain its original shape. When only cremated bones are the source of identification, they should be cautiously used as a means of identification. More research and case reports are necessary to consider using the shape of cremains for forensic identifications at present.

In Case 2, the candidate's son had survived the disaster. If samples for DNA typing had been collected before cremation, the long-term wait for victim identification could have been avoided. This was unfortunate as the victim was cremated without adequate PM data due to the chaos that occurred immediately after the large-scale disaster. Japanese law did not allow any damage to the bodies, even if it was the act for identification when the Great East Japan earthquake occurred. Most responders had a fear of violating the law for over a month after the disaster. A month after the disaster, the acts were considered justifiable, and at present, legislation has established that minor invasions aimed at taking DNA samples for identification can be carried out by the police, who are the first responder of disasters.

If DNA typing was not possible in case 1, the candidates could not have been found and might be treated as unidentified corpses till now. Therefore, it must be said that the results of the CBCT images in this report became helpful for personal identification by chance. Case 2 is an extremely inadequate case in which there were no DNA, fingerprints, or dental findings as PM record materials, and only facial photographs were taken. However, the elimination method from the multiple candidates by a steady investigation by the Japanese police eventually narrowed down the candidates to one person, and to confirm their distinctiveness, patella had to be used. In the two cases shown in this report, the identification was challenging because they were cremated without enough PM record collection.

DNA paternity test using the sample that can be extracted only means the dead body and the candidate are 'not inconsistent as the same person'. An image-based shape comparison, a tool that can be used to 'determine the identification', utilized the variety of morphological differences among humans. Collation between the same simple X-ray images is also effective [17–19], but by acquiring the image of the dead body from CBCT, it is easy to superimpose the 3D image and the simple

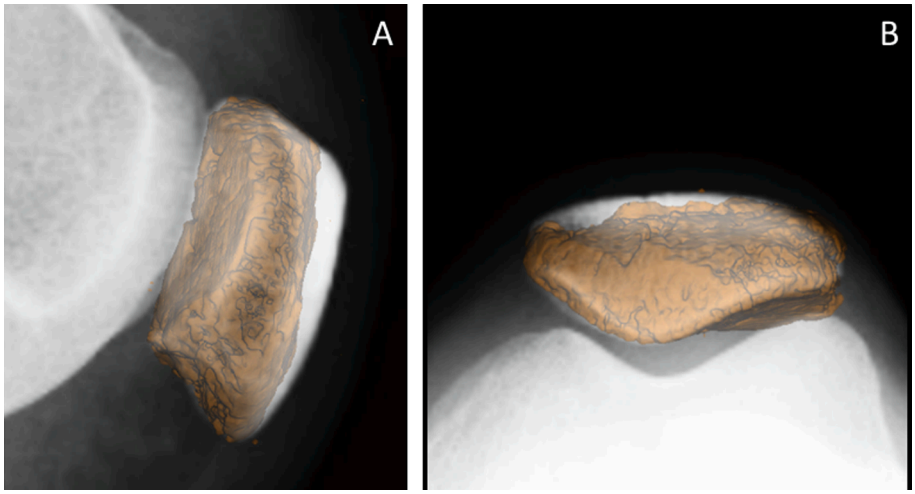

Fig. 8. Superimposition of the Cone-beam computed tomography images of the patella from the cremains on the radiographs of the candidate's left knee joint showing the lateral (A) and top surface findings (B). The dimension of the CBCT image was adjusted using the base and apex of the patella and the fibular and medial margin as reference points. The shape of the medial surface of the patella almost matched, despite a slight deviation in the front of the bone.

X-ray image that is the candidate's AM record. In addition, since the perspective generated by the shooting distance can be easily corrected by software, a more accurate superposition than a simple X-ray image can be performed. If the comparison material between the dead body and the candidate is saved as a three-dimensional image, it is possible to compare the complicated shape of the skull base and the shape of a custom-made denture that varies with each person [20].

Various materials of high quality for identification should be collected during the disaster victim identification. In Japan, cremation of the deceased shortly after death is believed to help the spirit rest peacefully; thus, even unidentified bodies are cremated quickly. Moreover, in this turmoil of the disaster, the relatives made a judgment that the body is their family by looking at the faces of the dead body who were lined up in the mortuaries, and the police believed the families' decision and handed over the victim to the bereaved family.

It is necessary to have daily and continuous education and acquire disaster victim identification technology for the actual responders; moreover, the realization of the nation regarding the importance of a large number of personnel and great amount of time for accurate disaster victim identification is also necessary. The Nankai Trough earthquake, which is said to occur in western Japan with a high probability, is expected to kill 320,000 people. Therefore, attempts have been made to collect DNA from some expected disaster-stricken residents. There is also the discussion of creating a database of dental clinical information, which will be used as AM records, but the law has not been established, and it is not straightforward from the perspective of personal information protection.

If sufficient PM records are taken before cremation, they can be used to compare the AM records of potential candidates for the identification of the remains. It is clear that images obtained before rather than after cremation are more effective in determining the differences and similitudes between PM and AM images.

4. Consideration

Owing to insufficient sampling from the bodies of the deceased persons of the Great East Japan Earthquake of March 2011 at the time of discovery, their identification process is still ongoing. At that time, we were unable to collect sufficient PM data, such as fingerprints, DNA, or even dental records, which usually form the basis of personal identification. Therefore, we need to ensure that those involved in disaster victim identification in Japan collect such samples thoroughly.

Additionally, because of the difficulties in identifying deceased persons from cremains, preserving all types of images in PM records before cremation is extremely important when large-scale disasters result in numerous casualties. These data can be used for reliable comparison with the AM data of potential candidates.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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References

[1] Iwate Pref. police official site. http://www2.pref.iwate.jp/~hp0802/oshirase/kouhou/saigaijyouhou/20110311.html (accessed 2020-09-15).
[2] Internet compendium of Laws, criminal law, https://xn–eckucmux0ukcy120betvc.com/m40hou45/ (accessed 2021-05-13).
[3] C.H. Brenner, Forensic Mathematics. http://dna-view.com/ (accessed 2020-12-04).
[4] Y. Kamijyo, Atlas Oral Anatomy 1 Osteology (Cranium) second edition, 201–206, Anatomu Co., Ltd, Tokyo, 1982.
[5] A. Uragou, Age-related changes in various oral tissues, 28–59, Quintessence Publishing Co., Ltd, Tokyo, 1991.
[6] Y. Ide, H. Agematsu, A morphological change of mandible and maxilla after loss of teeth, Jpn. J. Oral Biol. 39 (2) (1997) 79–90.
[7] J.R. Clifford, G. Julie, P.B. John, The Aging Skeleton, 329–371, Academic Press, Massachusetts, 1999.
[8] Y. Kamigaki, I. Sato, T. Yosue, Histological and radiographic study of human edentulous and dentulous maxilla, Anat. Sci. Int. 92 (4) (2017) 470–482, https://doi.org/10.1007/s12565-016-0344-z.
[9] T. Michiue, A.M. Hishmat, S. Oritani, K. Miyamoto, M.F. Amin, T. Ishikawa, H. Maeda, Virtual computed tomography morphometry of the patella for estimation of sex using postmortem Japanese adult data in forensic identification, Forensic Sci. Int. 285 (206) (2018) e1–206.e6, https://doi.org/10.1016/j.forsciint.2017.11.029.
[10] G. Grévin, P. Bailet, G. Quatrehomme, A. Ollier, Anatomical reconstruction of fragments of burned human bones: a necessary means for forensic identification, Forensic Sci. Int. 96 (2-3) (1998) 129–134, https://doi.org/10.1016/S0379-0738(98)00115-7.
[11] M.R. Dayal, M.A. Bidmos, Discriminant sex in South African blacks using patella dimensions, J. Forensic Sci. 50 (2005) 1294–1297, https://doi.org/10.1520/JFS2004306.
[12] M. Mahfouz, A. Badawi, B. Merkl, E.E.A. Fatah, E. Pritchard, K. Kesler, M. Moore, R. Jantz, L. Jantz, Patella sex determination by 3D statistical shape models and nonlinear classifiers, Forensic Sci. Int. 173 (2-3) (2007) 161–170, https://doi.org/10.1016/j.forsciint.2007.02.024.
[13] M. Akhlaghi, A. Sheikhazadi, A. Naghsh, G. Dorvashi, Identification of sex in Iranian population using patella dimensions, J. Forensic Leg. Med. 17 (2010) 150-155. https://doi.org/ 10.1016/j.jflm.2009.11.005.
[14] S.A. Abdelaleen, O.A. Hassan, I.K. Abdelazeen, M. Abdelazeen, A. Kader, Role of patellar imaging using 3D computed tomography in determination of sex and stature in upper Egypt population, Int. J. Forensic Sci. Res. 4 (2016) 289–296. https://doi.org/10.19070/2332-287X-1600067.
[15] T.R. Peckmann, S. Meek, N. Dilkie, A. Rozendaal, Determination of sex from the patella in a contemporary Spanish population, J. Forensic Leg. Med. 44 (2016) 84-91. hts://doi.org/10.1016/j.jflm.2016.09.007.
[16] H. Yasar Teke, Ö. Ünlütürk, E. Günaydin, S. Duran, S. Özsoy, Determining gender by taking measurements from magnetic resonance images of the patella, J. Forensic Leg. Med. 58 (2018) 87–92, https://doi.org/10.1016/j.jflm.2018.05.002.
[17] C.J. Alexander, G.A. Foote, Radiology in forensic identification: The Mt Erebus disaster, Australas Radiol. 42 (4) (1998) 321–326, https://doi.org/10.1111/j.1440-1673.1998.tb00531.x.
[18] P.R. Matthew, W.G.J. William, N.S. Carl, Radiographic comparison of a fractured clavicle exhibiting a pseudo-arthrosis, J. Forensic Sci. 57 (2012) 1094–1097, https://doi.org/10.1111/j.1556-4029.2012.02069.x.
[19] R.F. Silva, A. Franco, F.F. Picoli, F.G. Nunes, C. Estrela, Dental identification through endodontic radiographic records: a case report, Acta Stomatol. Croat. 48 (2014) 147–150.
[20] A. Kumagai, T. Kobayashi, Y. Oyamada, M. Izumisawa, N. Takahashi, H. Biwasaka, T. Aoki, K. Dewa, Two victims of Great East Japan earthquake for which digital image analysis helped in identification, Res. Pract. Forens. Med. 62 (2019) 61–67.