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The Anatomical and Histological Pattern of Cremated Bone from Bronze Age Grave of Pyeongtaek in South Korea

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Abstract: *Although cremated bones can provide valuable information on the ancient people's life, very few anthropological analyses were conducted on the burnt bones from archaeological sites in South Korea. As for the ancient (Pyeongtaek) bones (8th to 6th BCE), we conducted anatomical and histological analyses to estimate the cremation pattern of the Bronze Age in Korea. In this report, we can show that the Bronze Age bones were cremated before burial and different morphological changes occurred in the bones during the cremation, due to varying ranges of the heat that were not acting evenly across the bones. We speculate that cremation technology had not yet reached a high level during the Bronze Age of Korea, which must be further proven by archaeological works in the future.*

Keywords: *Cremation, Scanning electron microscopy, Histology, Bronze Age, Korea*

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Introduction

Anatomical and histological science enrich the scientific interpretation of cremated bones collected from the archaeological sites. A scientific study of heat-induced histological changes can reveal many aspects about cremation history. For example, gross anatomical research and electron microscopy can exhibit heat-induced changes in the bones (Hoden, Phakey & Clement 1995; Ubelaker 2009; Lim et al. 2015).

In Korea, post-mortem cremation was a long-time funeral practice (Lim et al. 2015). Throughout Three Kingdoms (BC 1st century to 676 CE), Unified Silla (676 to 935 CE) and Goryeo periods (918 to 1392 CE), Koreans conducted cremation as important funeral practice that was respected by Buddhists. In our previous histological study on Unified Silla bones, we reported the cremation pattern of histological analysis (Lim et al. 2015).

In Korean history, archaeologists often found the traces of cremation inside the graves of Bronze Age in Korea (15th to 5th century BCE). Considering Bronze Age cremation was implemented before Buddhism was introduced in Korea (4th century CE), it could have been different in many ways from those cremated after Buddhism was introduced into Korea. Unlike Buddhist cremation, however, there was no literary records concerning the Bronze Age cremation in Korea at all, so little was known about it so far.

Recently, we had an opportunity to anthropologically examine cremated bones from the Pyeongtaek archaeological site dating to the Bronze Age. Our current report on the Bronze Age bones could be meaningful to anatomists who have interested in the quest of funeral traditions in East Asia from the anthropological perspective.

Case Report

We used human burnt bones found at the Bronze Age grave in South Korea. The bones were discovered at a stone coffin tomb of Hwayang District, Pyeongtaek City, South Korea. The archaeological investigation was conducted in 2021 by Dowon Institute of Cultural Heritage (Pyeongtaek, South Korea).

In archaeology, the grave was likely constructed in the 8th to 6th BCE. The tomb was located between 25 to 26 meters above sea level. To make a burial pit, the rock bed was dug down, and then the grave walls were completed by assembling stones. The size of the grave was 49 cm × 28 cm × 32 cm. Only small parts of human skeletal remains were buried inside the Pyeongtaek stone coffin. The human bones appear to have been cremated at another place and then moved to a stone coffin for a permanent secondary burial. A stone knife was also found on the floor inside the grave (Fig. 1A-C).

The Pyeongtaek bones were fragile due to possible combustion, being piled up inside the stone coffin tomb. The majority of bones were fragmented, shrunken, and distorted. They showed fractures and cracks on the surface of bones (Fig. 1D). The skeletons are mostly long bone fragments, and the skull fragments and teeth were not included. We studied bone fragments' color and size, following Subirà et al.'s method (Subirà, Ruiz & Guardiola-Bufi 2011). The bone color was white or grey.

We tried to estimate the minimum number of individuals (MNI). Determining MNI was not easy, but it would be reasonable to estimate it as at least one individual buried because duplication of bones was not identified in this case. The sex and age at death of the cremated bones were estimated by standard morphological criteria of Buikstra & Ubelaker (1994) but could not be estimated due to fragmentary bones. The study of body position and orientation was also limited due to secondary depositional contexts.

To estimate more accurate cremation-temperature ranges, scanning electron microscope (SEM) was also applied to this case. We conducted SEM analysis following the protocols of Hayat (1970) and Bozzola & Russell (1992). In brief, the samples were pre-fixed in 2% paraformaldehyde / 2.5% glutaraldehyde in neutral phosphate buffer (0.1 M), and then were post-fixed for 2 hours in 1% (w/v) osmic acid. They were then treated in a graded ethanol series and isoamyl acetate, and then Pt-Pd-coated by an anion coater (E-1030, Hitachi, Japan). The samples were observed with S-4700 SEM (Hitachi, Japan) (Lim et al. 2015).

In our SEM results, Harversian canals and osteocyte lacunae could be observed in the bones (Fig. 2A-C). In SEM results, we could not see any morphological evidence of collagen fibers in burnt bones. In small parts of Pyeongtaek case, bone fragments show a weak pattern of osteon lamellae (Fig. 2D) whereas wider parts of the bones exhibit completely disappearing pattern of osteon lamellae (Fig. 2E, F). SEM images reveal that the Pyeongtaek bones are consisted of newly formed, crystalized materials. Crystallization is widely observed in all the bone fragments. Many bone crystals show round or hexagonal patterns of similar size (Fig. 3A-F). We also observe some crystals with irregular or rhombohedral morphologies too (Fig. 4A-F).

Discussion

Uberalker (2009) revealed that curvilinear or transverse fractures in gross morphology of bone fragments can be typical signs of cremation. Researchers also showed that white bony fragments increase in number with longer heat-exposure during cremation (van Vark 1970; Fairgrieve 2008; Ubelaker 2009). In gross morphology of the current Pyeongtaek case, we observe transverse or curvilinear cracks on white bone fragments. By a report of Subirà, Ruiz & Guardiola-Bufi (2011), discoloration in Pyeongtaek bones might indicate that the cremation temperature of the case could have reached at least as high as 650–700 °C.

Since burnt bones' ultramicroscopic pattern is known to relate with temperature ranges of cremation (Hoden, Phakey & Clement 1995), we also conducted SEM study. We note that organic component of bones (e.g., collagens) could not stand temperatures over a certain temperature (400 °C) (Hoden, Phakey & Clement 1995; Koon, Nicholson & Collins 2003). Herrmann (Herrmann 1977) also proposed that cremation reaches 700–900 °C for the complete combustion of organic materials in the bones. Considering no organic component was observed in our SEM results, by the propositions of previous articles, the cremation temperature of Pyeongtaek case may have reached at least 400-900 °C.

In the estimation of cremation pattern, Haversian canals and osteocyte lacunae could be also helpful. Hoden, Phakey & Clement (1995) proposed that osteocyte lacunae and Harversian canals are maintained at 1400 °C, but when applied to over 1600 °C, the structures disappear by melting and recrystallisation of bone minerals on cooling. In our SEM results of Pyeongtaek bones, Harversian canals and osteocyte lacunae are still observed, which indicates that cremation temperature in Pyeongtaek case did not exceed the temperature of meting and recrystallization Holden et al. suggested.

More detailed clue could be conjectured by the crystallization pattern on SEM images. Holck (1986) proposed that small spherical crystals could be found in burnt bones at low temperature (600 °C), but hexagonal-type crystals become predominant at higher temperatures (800 to 1400 °C). In the cremated bones, Hoden, Phakey & Clement (1995) also supposed that rhombohedral or irregular crystals can emerge in the temperature range of 1000 to 1400 °C. Since we observe all above mentioned crystals (round, hexagonal, irregular, and rhomboidal), as for the Pyeongtaek case, temperature applied to the bones might have been different depending on the area.

Figure 1: The cremated bones found at Bronze Age grave. (A) The Bronze Age grave found at Pyeongtaek City, South Korea. (B) Cremated bone fragments (yellow arrows) and (C) stone knife (white arrow) identified at the bottom of grave. (D) Collected bone fragments. The color was white or grey. They showed fractures and cracks.

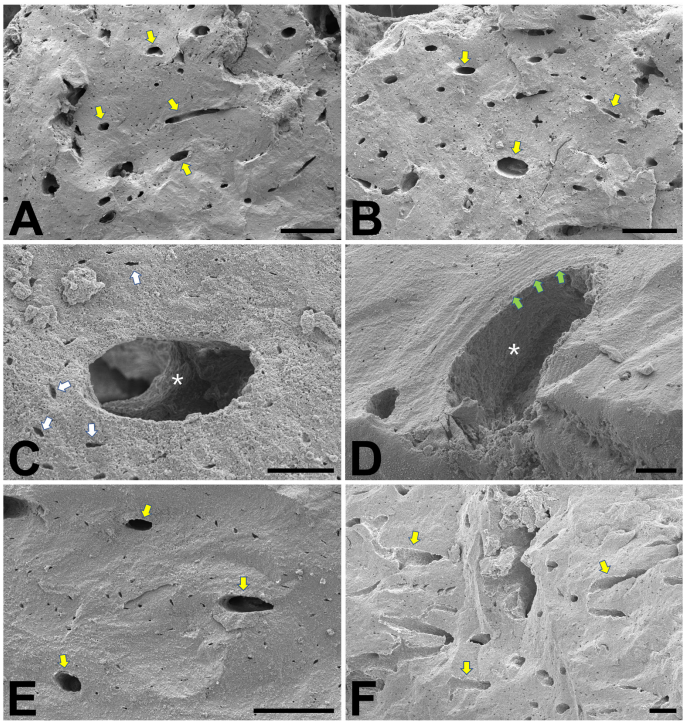

Figure 2: Scanning electron microscope images of cremated bone of Pyeongtaek. (A) and (B) Harversian canals are indicated by yellow arrows. (C) Harversian canal (asterisk) and osteocyte lacunae (white arrows). (D) Very weak pattern of osteon lamellae (indicated by green arrows) remained in some part of bones. (E) and (F) Osteon lamellae were not observed in most parts of cremated bones. Harversian canals indicated by yellow arrows. Scale bars: (A) and (B) 200 µm; (C) and (D) 50 µm; (E) and (F) 100 µm.

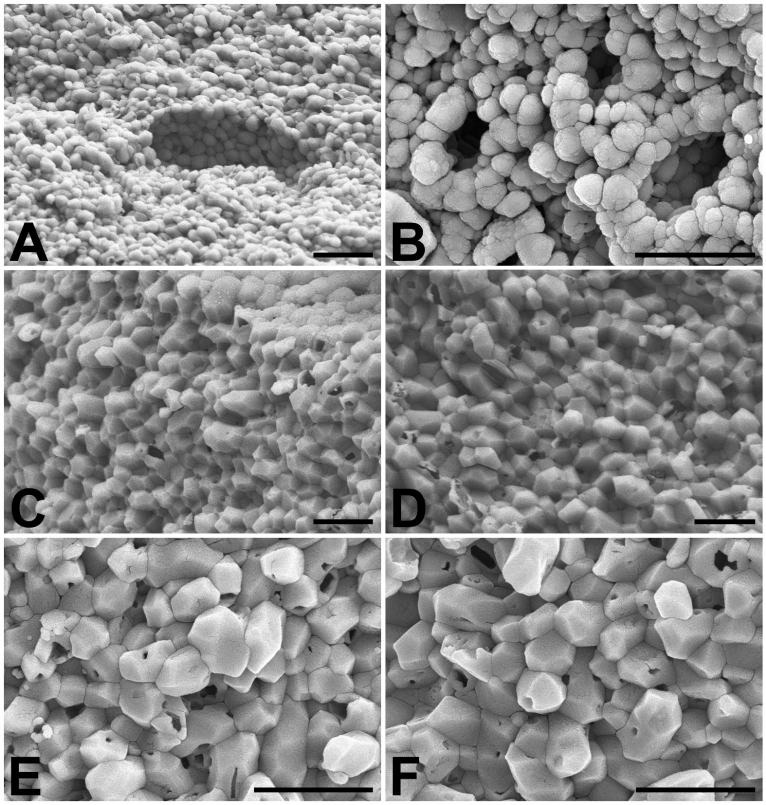

Figure 3: Scanning electron microscope images of cremated bone fragments. Many bone crystals showed round (spherical) or hexagonal patterns of similar size. Small spherical crystals in (A) and (B). Hexagonal-type crystals can be seen in (C) to (F). Scale bars: 2 µm.

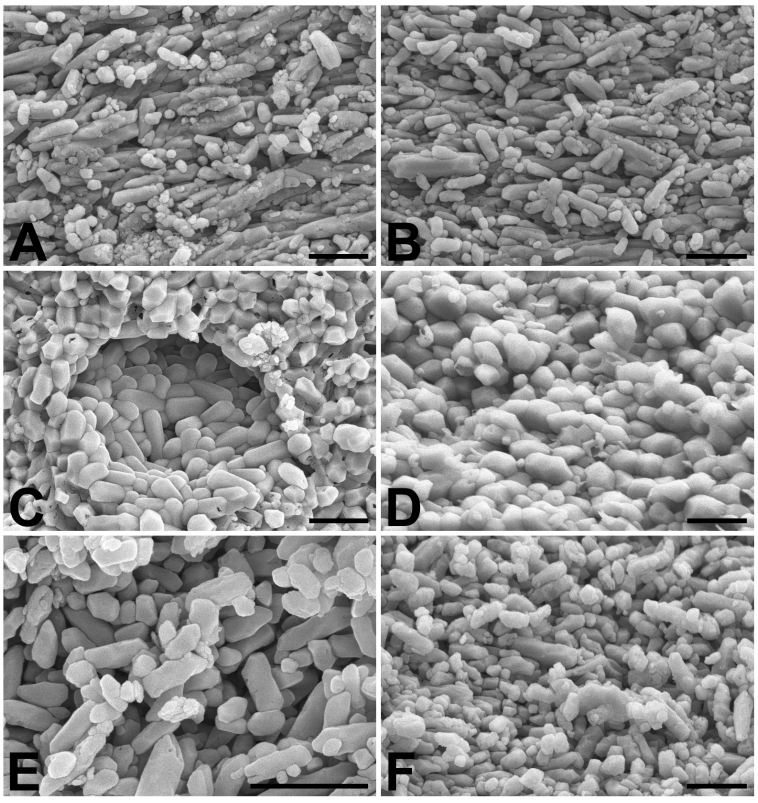

Figure 4: Irregular or rhombohedral crystals were observed in these SEM images of cremated bone fragments. Scale bars: 2 µm.

Concerning the morphological study of cremated bones, we cannot deny that the accurate temperature should be further adjusted by subsequent researches adopting novel techniques in the future. Nevertheless, at least we are certain that the Pyeongtaek bones were evidently cremated before burial and by our SEM findings, different histological changes occurred in the bones during the cremation, due to varying ranges of the heat that were not acting evenly across the bones. In short, we cannot rule out that the cremation technology of the Bronze Age had not yet reached a high level as seen in the later stage of Korean history, which must be archaeologically confirmed in the future.

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Competing Interests

The authors have no competing interests to declare.

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