Heian-period human skeletal remains from the Shomyoji shell midden in Yokohama City, Kanagawa Prefecture

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Abstract The excavation of the Shomyoji shell midden in 2017 recovered more than 26 human skeletal remains belonging to the Jomon, Kofun, and Heian periods. In this paper, we describe one Heian-period (AD 794–1185) individual (SK1), who was dated to 957–900 calBP by radiocarbon dating. SK1 is well preserved, presumably a male, and aged approximately 20–35 years. The morphology of the cranium and teeth are not similar to that seen in the Kanto Jomon and Kamakura populations; it is closer to that of Yayoi immigrants from northern Kyusyu. SK1 has a severe lesion around the hip joint, and the left innominate bone and femur are atrophied. From this lesion, we can presume that SK1 had suffered from a hip joint disease such as tuberculous arthritis of the hip.

Key words: human remains, Shomyoji shell midden, Heian period, palaeopathology, tuberculous arthritis of the hip

Introduction

The Shomyoji shell midden, whose name is derived from a temple established during the Kamakura period, is located in the city of Yokohama, Kanagawa Prefecture, in the Kanto region of Japan. This site has been excavated over 10 times in the past, and the shell mounds, belonging mainly to the late Jomon period (2300–1300 BC), are distributed over a wide area. A number of antiquities from the Jomon period, such as cord-mark pottery, stoneware, animal bones, human remains, and others, have been excavated from this site (Furuya and Saiki, 2019). An excavation conducted in 2017 yielded more than 26 human skeletal remains from various periods. The breakdown of these materials is as follows: 22 from the late Jomon, two from the final Jomon (1300–500 BC), one from the Kofun (third to seventh centuries AD), and one from the Heian (AD 794–1185) (Takahashi et al., 2019).

Among the excavated human remains, one Heian individual, catalogued as Dokoubo 1 (SK1), is worth studying, because current knowledge of Heian-period skeletons is very limited. One of the few that have been examined is from the Hasekouji-Shuhen site; this series exhibited dolichocrany but lacked alveolar prognathism (Matsumura et al., 2006), in contrast with the populations of the succeeding Kamakura period (AD 1185–1333), who possessed both dolichocrany and alveolar prognathism (Suzuki, 1956). Therefore, although SK1 is only one case, and thus may not be representative of the entire population, as one of the only well-preserved skeletons from the Heian period it is important to examine and describe its morphology. Moreover, SK1 exhibits a severe lesion around the hip joint; this kind of lesion has rarely been reported in archaeological skeletal remains from the Japanese archipelago and is therefore important to explore.

Thus, the objective of this study is to report the morphological and paleopathological characteristics of SK1. Through a comparison with populations from other periods, we also aim to clarify the relationship between SK1 and these other populations.

Materials and Methods

SK1 was buried in an extended posture. A few of the archaeological artifacts that were excavated with SK1, namely cord-mark pottery, an iron nail, and a ceramic shard, correspond to the period from the middle phase of the Jomon period to the medieval era. From there, we estimated the age of the specimen through radiocarbon dating.

To determine SK1’s sex, we applied the classic macroscopic features of the skull and right innominate bone mor-
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To estimate SK1’s age, we recorded the degree of cranial suture closure following the criteria provided by Sakaue (2015). Because of a severe lesion to the left innominate bone, we excluded both innominate bones from the age estimation. We estimated stature using lower limb bone length measurements, based on Fujii’s (1960) equation.

We collected linear measurements with digital sliding calipers (Mitutoyo), an osteometric board (GPM), and a tape measure, using Martin and Saller’s (1957) methods and definitions as described in Baba (1991). However, we measured upper facial height according to Howells (1973), and tibial mediolateral diameter followed the method recommended by Vallois (1938). We took facial flatness measurements according to the method outlined in Yamaguchi (1973). We attempted to measure all of the remaining teeth according to Fujita’s (1949) system of dental measurements.

We confirmed paleopathological features by macroscopic observation. To record occlusal surface wear of the dentition, we adopted Molnar’s (1971) system. We used the criteria from the World Health Organization (1977) to assess the dental caries. We used computed tomography (CT) to capture cross-sectional images of the femur. Both femurs were scanned in their anatomical position (Ruff, 2002). CT images captured 30%, 40%, 50%, 60%, 70%, and 80% of the maximum length from the proximal end using a SOMATOM Scope Power Ai Edition (Siemens Healthineers); each scan provided a 0.75-mm-thick slice. In these sections, we calculated total area (TA), cortical area (CA), medullary area (MA), and percentage of the cortical area (%CA) using ImageJ (http://rsbweb.nih.gov/ij/).

When comparing cranial measurements, we employed Penrose’s shape distance (Penrose, 1954) and standardized means using eight cranial measurements (Martin’s no. 1, 8, 45, 46, 48, 51, 52, and 55). The basic axis of the standardized means was represented by the modern Kanto Japanese population (Suzuki, 1969). Other cranial metric data of comparative populations were from the following previous research: Jomon, Kofun, Kamakura, Edo, and Modern populations of the Kanto region (Suzuki, 1969); Yayoi immigrants from northern Kyusyu and Yamaguchi Prefecture (Nakahashi, 1993); and the Hasekoji-Shuhen site series (Matsumura et al., 2006). In comparison, we standardized upper facial height following Dodo (2000), and if it was measured by Martin’s method, we subtracted 2.5 mm from that measurement to match Howells’s method (1973).

In order to compare the complete dental measurements of SK1 with those of other population samples, we calculated the Q-mode correlation coefficients using nine buccolingual diameters, which are measurable for SK1, and the standard deviations obtained from the dental metric data of the modern Kanto Japanese sample (Matsumura, 1995). Thereafter, two-dimensional expressions of the multidimensional scaling method (Torgerson, 1958) based on correlation metrics were applied to visually interpret interpopulation relationships. We took other dental metric data of comparative population samples from the following studies: from Matsumura (1995), Jomon, Kamakura, Edo populations of the Kanto region, and the eastern Japan Kofun population; from Matsumura (1998), Yayoi immigrants from northern Kyusyu; and from Matsumura et al. (2006), the Hasekoji-Shuhen site series.

We determined the radiocarbon age of SK1 by accelerator mass spectrometry (AMS) at the Laboratory of Radiocarbon Dating in the University Museum at the University of Tokyo. We extracted collagen from a bone piece taken from the right rib. The methods used for collagen extraction and AMS pretreatment have been described in detail in Yoneda et al. (2002).

Results

The extracted collagen from SK1’s rib bone shows a conventional radiocarbon age of $1132 ± 22$ years BP (TKA-18927). The bone piece, weighing 0.25 g, produced a large amount of gelatin (10.5 mg), corresponding to a 4.7% yield. In addition to this high yield of gelatin, the carbon and nitrogen concentrations (46.7% C and 16.4% N) and atomic C/N ratio (3.3) show that biogenic collagen without diagenetic alterations is present in the bone sample, and the radiocarbon age is reliable (DeNiro, 1985; van Klinken, 1999). According to $\delta^{13}C$ valued at $–18.8\%$ in comparison with terrestrial and marine animals (–22.6% and –10.9%, respectively; Yoneda et al., 2016), the calibrated radiocarbon age was estimated with a mixed calibration curve of IntCal13 (68%) and Marine13 (32%) (Reimer et al., 2013) and assigned a
range of dates from 957 to 900 calBP (68.2%).

Figure 1 shows the skeletal remains and distribution of lesions on SK1. The rib fragments were not identified, except for the first rib, due to postmortem damage. All characteristics, including the developed supraorbital arch, mastoid process, external occipital crest, external occipital protuberance, thick supraorbital margins, and narrow and deep greater sciatic notch of the right innominate bone, indicate that SK1 is likely a male. The ectocranial coronal and lambdoidal sutures, which are used in age estimation, are partially fused. The coronal suture of the endocranium is almost closed except around the bregma, but the other endocranial sutures are not fused. The incisive maxillary suture is partly open on the inner left side, and the other maxillary sutures are open. The epiphyses of all limb bones had been fused. On the basis of these features, the age of SK1 is estimated at 20–35 years. The estimated stature based on right femoral length is 157.2 cm.

The skull of SK1 is well preserved (Figure 2); skull measurements are presented in Table 1. The cranial vault is mesocephalic (cranial index 76.9), not dolichocephalic as it is in the Kamakura population. The facial skeleton is high and wide (Virchow’s index 67.2). The orbital margins are carved, and the eye socket is quite rounded. The nasal root is flattened (simotic index 20.4). Alveolar prognathism was not confirmed by multiple facial angle measurements (profile angle 88, nasal profile angle 89, alveolar profile angle 84). The results of standardized means and Penrose’s shape distance using cranial series (Figure 3, Figure 4) indicate that SK1 is closely related to Yayoi immigrants and the Kanto Kofun populations, and separate from the Kanto Jomon, Kamakura, and modern populations.

Dental measurements are presented in Table 2. The Molnar’s attrition score of each tooth is >4, except the upper right M2 and M3 and left upper P1 and P2; the overall attrition of SK1’s dentition is severely progressed. Tooth decay was observed in three teeth: the upper right first molar has a caries lesion limited to the enamel; the left side of the lower third molars have cavitated lesions showing dentin; and the

| Martin’s no. | Variable                      | SK1          |
|-------------|-------------------------------|--------------|
| 1           | Maximum cranial length        | 186          |
| 8           | Maximum cranial breadth       | 143          |
| 9           | Maximum frontal breadth       | 101          |
| 43          | Upper facial breadth          | 109.6        |
| 45          | Bimaxillary breadth           | 140.9        |
| 46          | Bilamellar breadth            | 105.1        |
| 48          | Upper facial height           | 70.6         |
| 51          | Orbital breadth               | R 44.3/L 42.6|
| 52          | Orbital height                | R 35.9/L 35.5|
| 55          | Nasal height                  | 53.4         |
| 66          | Bigonial breadth              | 107.3        |
| 69          | Symphyseal height             | 34.2         |
| 70          | Ramus height                  | R 59.6/L 61.4|
| 71          | Ramus breadth                 | R 37.5/L 36.9|
| 72          | Profile angle                 | 88           |
| 73          | Nasal profile angle           | 89           |
| 74          | Alveolar profile angle        | 84           |
| 8:1         | Cranial index                 | 76.9         |
| 48:45       | Upper facial index            | 50.1         |
| 48:46       | Upper facial index (Virchow)  | 67.2         |
|             | Frontal chord                 | 102.6        |
|             | Frontal subtense              | 14.3         |
|             | Frontal index                 | 13.9         |
|             | Simotic chord                 | 11.1         |
|             | Simotic subtense              | 2.3          |
|             | Simotic index                 | 20.4         |
|             | Zygomatic chord               | 103.5        |
|             | Zygomatic index               | 17.9         |
|             | Zygomatic index               | 17.3         |

Figure 2. Frontal and lateral views of SK1’s skull.
upper right canine is decayed. Periapical bone defects were observed in the upper right canine, upper right first premolar, lower left premolars, and lower left molars. As a result of the Q-mode correlation coefficients (Figure 5), SK1 was categorized into a group that is distant from any other population; however, it is closer to the Yayoi immigrants and eastern Japan Kofun population than to the Jomon, Edo and Kama-kura populations. The Hasekoji-Shuhen site samples are also unavailable because of tooth fracture or impaction.

In previous studies, the early historic Hasekouji-Shuhen site population had indicated a degree of influence from immigrant populations in their skeletal morphology (Matsumura et al., 2006). SK1, belonging to the Heian period, indicated similar results in cranial morphometry and is similar to Yayoi immigrants but dissimilar to the Jomon population.

### Table 2. Dental crown measurements (mm) of SK1

| Mesiodistal diameters | Right | Left |
|----------------------|-------|------|
| UI1                  | 8.09  | 7.71 |
| UI2                  | 5.70  | 5.90 |
| UC                   | ×     | 6.85 |
| UP1                  | ×     | 6.35 |
| UP2                  | 6.56  | 6.12 |
| UM1                  | 9.64  | 9.71 |
| UM2                  | 8.82  | —    |
| UM3                  | 8.23  | —    |
| LI1                  | ×     | ×    |
| LI2                  | ×     | 10.17|
| LC                   | ×     | 6.23 |
| LP1                  | 6.25  | ×    |
| LP2                  | 6.91  | —    |
| LM1                  | ×     | —    |
| LM2                  | —     | —    |
| LM3                  | —     | 10.72|

| Buccolingual diameters | Right | Left |
|------------------------|-------|------|
| UI1                    | 7.38  | 7.43 |
| UI2                    | 6.27  | 6.41 |
| UC                     | ×     | 8.46 |
| UP1                    | ×     | 10.17|
| UP2                    | 9.12  | 9.00 |
| UM1                    | 11.65 | 11.83|
| UM2                    | 11.30 | —    |
| UM3                    | 10.31 | —    |
| LI1                    | 5.55  | 5.70 |
| LI2                    | 5.77  | 5.90 |
| LC                     | 7.97  | 7.97 |
| LP1                    | 8.20  | 8.53 |
| LP2                    | 8.90  | —    |
| LM1                    | ×     | —    |
| LM2                    | —     | —    |
| LM3                    | —     | 10.75|

*, Approximate value based on measurements taken from near the landmarks; —, not detected; ×, tooth is present but measurements are unavailable because of tooth fracture or impaction.

the right side than on the left. The other measurements of the upper limbs did not indicate differences between the sides. The left glenohumeral joint exhibits osteoarthritis (Figure 6a, f), and the deltoid eminence is more developed on the left side than on the right.

In the innominate bones (Figure 7), the left side is thinner and smaller than the right. Thickness at a point 3 cm below the iliac tubercle on the iliac pillar is 11.0 mm on the right and 5.2 mm on the left. Additionally, maximum pelvic height and iliac height are higher on the right side. The attachment site of the gluteal muscle is not identifiable on the left side. The shape of the greater sciatic notch is different on both sides, and the right side indicates a male-like shape, while the left side indicates a female-like shape (Figure 7a). The left side acetabulum was partly broken postmortem, and only a part of the anterior margin, upper margin, posterior margin, and articular surface around these margins is recognizable (Figure 7a, b). The posterior part of the acetabulum is deformed and presents a flat shape. No osteophytes were observed around the remaining acetabular margin, and porotic lesions were recognized on the articular surface around the superior posterior margin of the acetabulum (Figure 7d).

Figure 8 shows a photograph of both femurs of SK1. The left femur exhibits a complete antemortem loss of the femoral head and the lesser trochanter, and porotic lesions are observed on the proximal end of the femur (Figure 8b, c). The region of the lesser trochanter is strongly depressed, and the surface of this part is smooth (Figure 8b, c, d). This depressed part of the proximal femur engages well with the flattened part behind the acetabulum of the left innominate bone (Figure 7c). The diaphysis of the left femur is markedly atrophied (Figure 8a). The midshaft circumference of the left femur is 18% smaller than that of the right femur. Figure 9 shows CT images of the femoral diaphyseal cross-section, and the cross-sectional areas of both femurs are indicated in Table 4. These data indicate that the TA and CA on the left side are clearly smaller than those on the right side, while the MA does not exhibit such differences; therefore, the %CA is smaller on the left side. The soleal line is more developed on the right side than on the left (Figure 5g). The relatively longer distal part of the upper and lower limbs, known to be characteristic of the Jomon population (Tahara and Kaifu, 2015), was not recognized in SK1.

### Discussion

In previous studies, the early historic Hasekouji-Shuhen site population had indicated a degree of influence from immigrant populations in their skeletal morphology (Matsumura et al., 2006). SK1, belonging to the Heian period, indicated similar results in cranial morphometry and is similar to Yayoi immigrants but dissimilar to the Jomon population. Similarly, dental measurements indicated that SK1 is closer to the Yayoi immigrants than to the other populations. This result agrees with the cranial measurements of SK1, other than the difference from the Hasekouji-Shuhen series. These results suggest that SK1 was influenced by the Yayoi or subsequent immigrant populations. Furthermore, this scenario is supported by a recent study on the mtDNA of Shomyoji population, showing that SK1’s haplogroup is vastly differ-
ent from those of the Jomon skeletons (Takahashi et al., 2019).

During the Kamakura period, which occurred after the Heian period, the population was characterized by a dolichocranic cranium and alveolar prognathism (Suzuki, 1956). Although SK1 was excavated from a site close to the many famous Kamakura period sites, such as Zaimokuza and Yuigahama-minami, and is dated to a similar time period, SK1 does not show the characteristic cranial shape of the Kamakura people. The Hasekouji-Shuhen series is 100–200
Figure 5. Two-dimensional expression of the multidimensional scaling method applied to distances of transformed Q-mode correlation coefficients based on nine crown diameters in seven populations. Hasekouji-Shuhen: skeletal remains from the Hasekouji-Shuhen site in Kamakura City dated from the Nara to the early Heian period. Data of each population are from Matsumura (1995, 1998) and Matsumura et al. (2006).

Figure 6. Skeletal lesions excluding that of the hip joint. (a) Marginal lipping around the right-side glenoid fossa. (b) Osteoarthritis on the right-side inferior articular facet of the seventh cervical vertebra. (c) Mild compression fracture on the first lumbar vertebra. (d) Osteophyte development of the third lumbar vertebral body. (e) Osteoarthritis on the left-side superior articular facet of the sacrum. (f) Osteoarthritis around the left side of the humeral head. (g) Differences in the development of both sides of the soleal line. In each figure, arrows indicate lesion or side difference. Scale bar: 10 mm.
years older than SK1 and does not indicate alveolar prognathism, while a slight tendency toward dolichocranic crania was recognized (Matsumura et al., 2006). Alveolar prognathism was recognized as a similar tendency between SK1 and the Hasekojï-Shuhœn people, which may be a characteristic that clearly appeared after the Kamakura period. One limitation in the analysis is that SK1 is the only Heian individual from the Shomyjoji shell midden.

As previously stated, decayed tooth and alveolar bone defects, which are likely due to severe caries, were observed in SK1. According to these observations, SK1 does not appear to have maintained good oral hygiene.

SK1 has a severe lesion around the left hip joint and atrophy of the left femur and innominate bone. The lesion on the left femoral head suggests the existence of femoral head necrosis or an erosive lesion. Moreover, the deformed part of the proximal femur and the flattened part behind the acetabulum are well fitted, which suggests the possibility that a false joint formed between these regions after dislocation. In addition, the severe atrophy of the left femur and innominate bone, the less developed attachment site of the gluteal muscle group of the left innominate bone, and the asymmetric shape of the greater sciatic notch all suggest that SK1 had a disease from a relatively young age. The lesions found in the other regions (Figure 6) are not as specific as the left hip lesion; therefore, it is likely that these lesions are related to overuse, similar to the compensatory movement accompanying the main hip lesion.

Tuberculosis of the hip corresponds with SK1’s lesion. The disease occurs mainly in childhood, and onset after 25 years is rare (Aufderheide and Rodriguez-Martin, 1998, p. 139). Death from this disease normally occurs around the mid-20s to 30 years old (Ortner, 2003, pp. 235–237). The lesions found in the other regions (Figure 6) are not as specific as the left hip lesion; therefore, it is likely that these lesions are related to overuse, similar to the compensatory movement accompanying the main hip lesion.

*Table 3. Cranial Measurements (mm) of SK1*

| Clavicle       | Right | Left |
|----------------|-------|------|
| 1 Maximum length | 142   | —    |
| 4 Transverse midshaft diameter | 10.9  | 11.5 |
| 5 Sagittal midshaft diameter | 13.1  | 12   |
| 6 Midshaft circumference | 40    | 40   |

*Humerus*

| 1 Maximum length | 301   | 291  |
| 3 Minimum circumference | 63    | 61   |
| 5 Maximum midshaft diameter | 23.1  | 23.7 |
| 6 Minimum midshaft diameter | 17.4  | 17.2 |
| 5:6 Midshaft index | 75.3  | 72.6 |
| 7a Midshaft circumference | 68    | 70   |
| 9 Transverse head diameter | 45.9  | 42.8 |
| 10 Sagittal head diameter | 45.8  | 45.4 |

*Femur*

| 1 Maximum length | 424   | —    |
| 2 Physiological length | 420  | —    |
| 6 Sagittal midshaft diameter | 28.7  | 26   |
| 7 Transverse midshaft diameter | 27.1  | 20.5 |
| 8 Midshaft circumference | 90    | 74   |

*Pelvis*

| 1 Maximum pelvic height | 208   | (195) |
| 10 Iliac height | 98.7  | 90.4  |
| 15(1) Greater sciatic notch depth | 28.1  | 31.6  |
the bone destruction caused by this disease is much more limited. An exception to this is when the disease appears in an infant, wherein complete destruction of the femoral head can occur, frequently accompanied by osteomyelitis of the femoral shaft (Ortner, 2003, p. 237). Furthermore, tuberculosis is much more common than septic arthritis (Ortner, 2003, p. 237). Because of the similarity of the lesions characterizing both diseases, it is difficult to complete a differen-

Figure 7. Skeletal lesions in the innominate bones. (a) Both innominate bones. (b) An enlarged inferior view of the left innominate bone. Arrows indicate the margin of the acetabulum. (c) Lateral view of the left hip joint. Femur and os coxa fitted with each lesioned part of the flattened area behind the acetabulum and proximal femur. (d) An enlarged inferior view of the left acetabulum. Arrows indicate porotic lesions on the anterior and posterior surfaces.

Figure 8. Skeletal lesion in the femur of SK1. (a) Both femurs (the square indicates the lesioned part indicated in b–d). (b) Anterior view of the left proximal femur. (c) Posterior view of the left proximal femur. (d) Medial view of the left proximal femur.
tial diagnosis; however, in the case of SK1, tuberculosis of the hip is a more likely diagnosis than septic arthritis of the hip.

As with other diseases, such as a fracture of the femoral neck, idiopathic necrosis of the femoral head can occur along with femoral head necrosis and dislocation of the hip joint. However, they do not commonly result in complete destruction of the femoral head. In late cases of idiopathic necrosis, the femoral head exhibits a deformed, flattened shape with varus formation (Aufderheide and Rodriguez-Martin, 1998, p. 89). Thus, no factor positively supports the presence of these necrotizing diseases in SK1.

SK1 exhibits asymmetrical development of the attachment of the deltoid and soleus, and osteoarthritis of the left glenohumeral joint. These tendencies indicate the possibility that SK1 heavily used his left arm and right leg to compensate for the difficulties with his left leg.

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