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Promotion of European Medicine and Japanese Craftsmanship Seen in Okuda Wooden Human Skeleton Made During Edo Era, Japan

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Abstract In the late Edo era, a human skeleton intended for medical education was carved from cypress wood by a craftsman, Ikeuchi under the supervision of a medical doctor, Banri Okuda in Osaka City. The model for the carving was based on a criminal's skeleton. The skeleton was beautifully made to be articulated and assembled by various methods, which reveals excellent craftsmanship. By and large, the wooden skeleton shows morphological characteristics usually seen in early middle-aged females of the Edo era. The wooden skeleton might have been used for the promotion of European medicine, which was emergent in the Edo era Japan, rather than for practical medical education.

Key words: Wooden skeleton, Craftsmanship, Medical history, Edo era, Japan

History of Okuda Wooden Skeleton

In the Edo era, books of European medicine were introduced by Dutch merchants and knowledge of European medicine was gradually developing in Japan (Ogawa, 1955). The government prohibited anatomical studies using real human bodies or skeletons, because of religious reasons.

In the late Edo era, about ten wooden skeletons were made for medical study and teaching (Kabahara, 1971; Kure & Fijikawa, 1983). In all probability in 1820, in Osaka, a wooden skeleton was carved by a craftsman, Ikeuchi (first name unknown), under the supervision of a medical doctor, Banri Okuda (Fig. 1). Consequently, the wooden skeleton is called the "Okuda wooden skeleton". In 1822, the wooden skeleton was donated to the Medical Institution of the Owari feudal load on the recommendations of Okuda's old friend, Shunzo Yoshida, and the official medical doctor of the Owari feudal lord, Shizan Asai.

Among five wooden skeletons preserved until today, the Okuda wooden skeleton was most precisely made and was kept in superb condition. It is now stored in the National Science Museum, Tokyo, under care of the second author.

Assemblage of the Wooden Skeleton

If necessary, the Okuda wooden skeleton can be mounted in a sitting position on a pedestal and pillar (Fig. 1). Usually, bones were packed separately in five small inner boxes made from paulownia wood, a quite common way to keep precious materials in Japan (Fig. 2). The small boxes were stored, with the pedestal, pillar, and iron plates, in a big outer wooden box made from cypress wood.

The five small boxes contained, 1) the skull, 2) thorax and claviculae, 3) pelvis, 4) long limb bones, and 5) hand and foot bones, scapulae, and cervical and lumber vertebrae. The pedestal consists of two wooden plates which can be assembled using wooden tenons (Fig. 1). The pillar can also be joined to the pedestal by wooden tenons

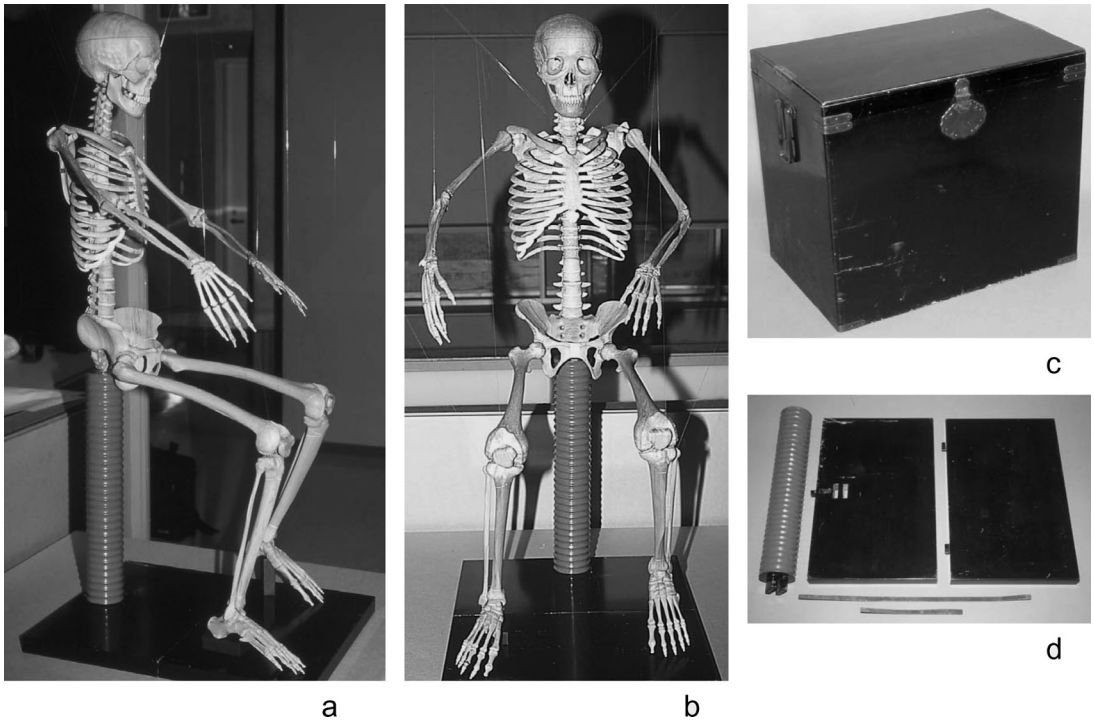

Fig. 1. Okuda wooden skeleton. a, b, the wooden skeleton mounted on the assembled pedestal and pillar. c, the outer box to contain the wooden skeleton. d, the pedestal, pillar and iron plates.

with locking mechanisms. The outer box and pedestal were painted in black with Japanese lacquer (Urushi), and the pillar was red. The small inner boxes were not painted.

The wooden bones were made from cypress wood. The surface texture of the bones is beautiful and smooth, suggesting that the bones were carved by a skilled craftsman using sharp cutting knives and were polished carefully. No paint was applied to the surface.

The bones can be assembled and/or combined in different ways, as follows;

1. A large iron plate is inserted in the narrow space from the hole of the pillar, through the lumber vertebral canal, to the thoracic vertebral canal, and a smaller iron plate is inserted in the narrow space from the thoracic vertebral canal, through the cervical vertebral canal to the holes of the two wooden pieces tentatively fixed in the foramen magnum and the center of the endocranial cavity, respectively, by which the vertebral column and the skull are mounted on the pedestal and pillar (Fig. 1).
2. Detachable metal (brass) pivots are used in the shoulder, hip and knee joints (Fig. 4). When one piece of pivot is inserted to the other piece and is twisted counter-clockwise, the pivot will be locked. A metal plate and a pin are used to fix the scapula to ribs (Fig. 6).
3. Wooden square tenons are used to fix the sternoclavicular joint and bamboo sticks are used to fix other joints (Figs. 4–6).
4. Several pieces of wood are glued together to form the thorax, vertebral column, and pelvis, respectively (Fig. 5). Most parts of the right and left halves of the thorax (the sternum, twelve ribs, and posterior parts of the twelve vertebral bodies) are carved from one piece of wood, respectively and glued together to the thoracic vertebral column which is made up from twelve vertebral bodies and twelve arcs with spines. Sawdust

Fig. 2. Okuda wooden skeleton. a to e, boxes to contain the skull, thorax, pelvis, limb and other bones, respectively. Originally the claviculae were contained with the thorax.

mixed with glue was embedded on the upper terminal plate of the first vertebra and the lower terminal plate of the twelfth vertebra (Fig. 5). The pelvis was made from one piece of wood, but the pieces of woods for the sacrum and the coxae had been once separated, carved and glued together. The cartilage of the pubic symphysis was made from another piece of wood and painted white.

5. In the right hand and left foot, the carpal and second to fifth metacarpal bones and the tarsal bones were made from one piece of wood, respectively, for unknown reason (Fig. 3).

Outline of the Morphology of the Skeleton

In the Okuda wooden skeleton, all the bones of the body were replicated, except the hyoid bones, laryngeal cartilage, coccyges, and small sesamoid bones. In this section, the bones of the Okuda wooden skeleton are analyzed, and in turn some features of the model individual's skeleton, on which the Okuda wooden skeleton was based, will be estimated. Morphological features indicate that this individual was an early middle-aged female. Detailed morphology of the wooden skeleton will be explained elsewhere.

Cranium

The wooden skull is small and gracile (Fig. 3, Table 1). The attachment areas for muscles are generally narrow and smooth. However, the superior nuchal line is marked and goes superiorly, as is seen in males. Moreover, the mastoid process is large for a female. The cranial vault was cut

Table 1. Comparision of metric data of Okuda wooden skeleton.

Item with Martin's No.	Okuda skeleton Present study	Edo female mean (δ) Suzuki; Endo *et al*.	Edo male mean (δ) Suzuki; Endo *et al*.
CRANIUM			
Maximum length (1)	176	175 (7.3)	182 (6.6)
Maximum breadth (8)	144	137 (4.9)	140 (4.8)
Basion-bregma height (17)	137	133 (3.9)	138 (4.9)
Facial length (40)	91	97 (5.3)	99 (4.7)
Bizygomatic breadth (45)	131	126 (5.2)	135 (4.9)
Middle facial breadth (46)	81	95 (3.9)	100 (4.9)
Facial height (47)	113	**115 (5.7)	118 (7.5)
Upper facial height (48)	61	68 (3.6)	69 (6.5)
Orbital breadth (51)	33	42 (1.8)	43 (1.9)
Orbital height (52)	31	35 (1.8)	34 (1.8)
Nasal breadth (54)	23	25 (1.4)	26 (2.0)
Nasal height (55)	47	50 (2.5)	53 (2.9)
Bigonial breadth (66)	88	95 (6.4)	103 (5.9)
Height of ramus (70)	49	58 (5.5)	68 (6.4)
Breadth of ramus (71)	28	31 (3.7)	35 (2.7)
CLAVICULA			
Maximum length (1)	156	128 (12.1)	139 (8.7)
Circumference at middle (6)	45	31 (0.9)	38 (4.6)
SCAPULA			
Morphological length (1)	145	136 (11.1)	155 (6.9)
Morphological breadth (2)	90	94 (5.0)	101 (4.6)
HUMERUS			
Maximum length (1)	265	270 (11.6)	297 (11.7)
Upper breadth (3)	46	43 (1.8)	49 (2.4)
Minimum circumference (7)	51	54 (3.1)	64 (3.8)
RADIUS			
Maximum length (1)	198	200 (8.4)	224 (10.9)
Circumference at middle (5(5))	34	38 (2.1)	44 (2.8)
ULNA			
Maximum length (1)	216	223 (10.5)	242 (12.5)
Minimum circumference (3)	32	32 (2.2)	36 (2.6)
PELVIS			
Height of pelvis (1)	183	188 (8.3)	206 (9.8)
Maximum breadth (2)	240	248 (4.7)	262 (11.4)
Iliac breadth (12)	138	145 (7.0)	147 (2.6)
Sagittal diam. of inlet (23)	111	118 (13.2)	105 (12.7)
Transverse diam. of inlet (24)	115	121 (7.5)	119 (6.8)
FEMUR			
Maximum diameter (1)	396	378 (20.5)	414 (18.6)
Circumference at middle (8)	77	77 (6.4)	87 (5.7)
Circumference of head (20)	120	129 (5.6)	147 (6.1)
Bicondylar breadth (21)	77	70 (3.9)	80 (3.3)
PATELLA			
Maximum breadth (2)	46	*40 (2.8)	*45 (2.9)
TIBIA			
Maximum length (1)	312	302 (10.9)	327 (17.1)
Bicondylar breadth (3)	66	68 (3.8)	75 (3.3)
Breadth of lower epihpysis (6)	37	44 (2.5)	50 (3.1)
Maximum diam. at middle (8)	33	25 (2.2)	30 (1.9)
Transverse diam. at middle (9)	20	19 (1.4)	22 (1.7)
Circumference at middle (10)	80	70 (4.5)	80 (4.4)
FIBULA			
Maximum length (1)	304	296 (15.8)	327 (14.5)
Circumference at middle (4)	30	37 (2.4)	43 (4.2)

Suzuki (1967); Endo, Hojo, Kimura (1967); * Kato & Harada (1960); ** Morita (1950)

Fig. 3. Okuda wooden skeleton. a, b, the wooden cranium (right) and Edo female cranium (left). All the Edo female bones for comparison belong to one individual excavated from Minamimoto-machi Sugenji site in Tokyo. The traditional bamboo scale is 30 cm long. c, a bipartite zygoma. d, the internal cranial base and internal calotte.

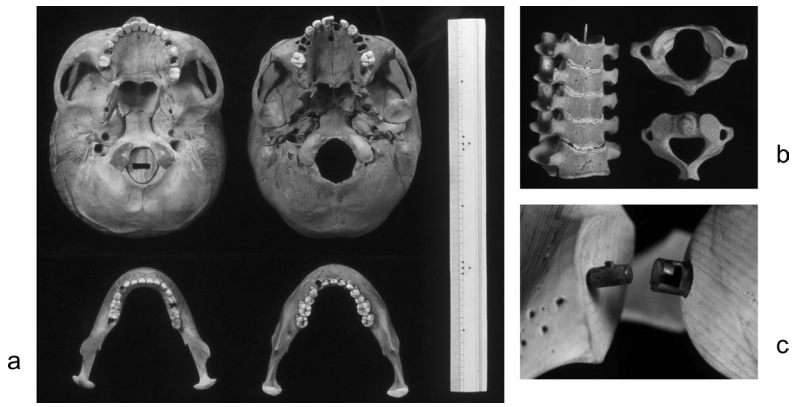

Fig. 4. Okuda wooden skeleton. a, the wooden skull and mandible (left) and Edo female skull and mandible (right). b, the cervical vertebrae. c, a metal pivot on the shoulder joint. The scale is 30 cm long.

horizontally at the widest portion and the endocranial cavity can be opened (Fig. 3). Most of the foramina for nerves and vessels which penetrate the cranial base were carved adequately, but some were not carved or carved insufficiently. (Figs. 3, 4).

The face is cuneiform in its anterior view (Fig. 3, Table 1). The supraorbital region is smooth and superciliary arcs are slightly swollen. The nasal bridge is not projected, as is usual for Edo females. Both right and left zygomatic bones are divided into two (upper and lower) parts, which is called a bipartite zygoma or *Os Japonicum* (Fig. 3). Compared to usual Edo skulls, the palate

is located much more posteriorly with no signs of alveolar prognathism (Fig. 3).

The teeth are small and malocclusion is not present. The teeth were carved separately from the jaw bones and inserted in the alveolar sockets.

As a whole, the skull was beautifully reconstructed and it was without doubt useful for medical education in that time. Significantly, the skull was carved from one piece of wood and no corrections were made, which indicates the high skill and sense of the craftsmanship.

Postcranial bones

The thorax is very wide and the ribs are not inclined as is normal but almost horizontal, which implies that the model skeleton was decayed and the ribs had already separated from the vertebral column (Fig. 5). The costal cartilage and xiphoid are painted white. The 11th and 12th ribs are not floating as is normal, but are inadequately connected to the upper ribs by costal cartilage.

The claviculae are too large for a female and are similar to those of a male (Fig. 6, Table 1). Probably the claviculae of the model skeleton were lost or were deformed and the craftsman referred to claviculae from a male.

The arms and hands are slender, as is usual for Edo females (Fig. 3). The humeri, ulnae and radii were carved a little vaguely. In the carpal bones, the pisiform was not articulated with the triquatrum, as is normal, but was incorrectly inserted between the scaphoid and trapezoid (Fig. 3).

The pelvis is small but indicates typical female characteristics (Table 1, Fig. 5). The right and left femora exhibit a strange shape. Compared to those of the average Edo female, the head and superior segment are a little smaller but the distal end is much larger and almost equal to those of males (Fig. 7, Table 1). The shape of the distal end is also disporportionate. Moreover, the patellae are too large for a female. Probably, the distal ends of the femora and the patellae of the model skeleton have been lost or badly deformed.

The tibial shafts are flattened on both sides and wide anteroposteriorly (Fig. 7, Table 1). The anterior margin of the tibia forms a sharp crest caudally, suggesting the presence of a well-developed tibialis anterior muscle in the model skeleton. In the fibula, muscle markings are clear and

Fig. 5. Okuda wooden skeleton. a, the wooden thorax. b, close up of the inferior of the thorax. c, d, the wooden pelvis (right) and Edo female pelvis (left). The scale is 30 cm long.

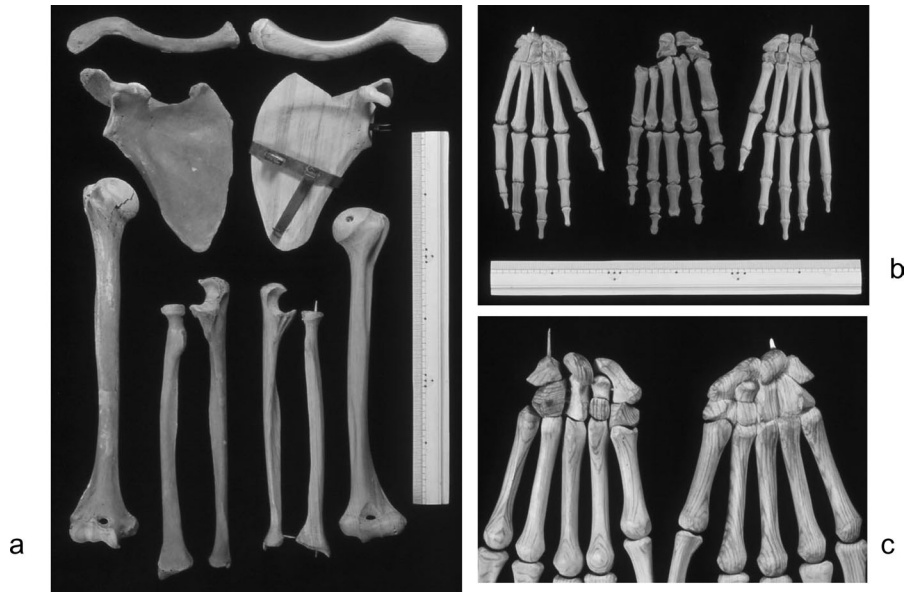

Fig. 6. Okuda wooden skeleton. a, the wooden left upper limb bones (right half) and Edo female right upper limb bones (left half). The scale is 30 cm long. b, the wooden right and left hand bones and Edo female right hand bones (middle, some bones are missing). c, close up of wooden hand bones (palmer view). Note that the right carpal and second to fifth metacarpal bones (right) were made from one piece of wood.

form sharp grooves on the shaft.

The feet are somewhat long in relation to the legs (Fig. 7). The big toe is only a little thicker than the other toes, which differs from typical individuals where the big toe is roughly twice the thickness of the other toes.

Estimation of the Individual Features

The stature of the wooden skeleton was estimated from the lengths of the left tibia and humerus as 146 cm, using the formula of Fujii (1960). This stature is slightly larger than the average stature of the Edo females (Hiramoto, 1972).

The wooden skeleton shows the same morphological characteristics as those of Edo people in almost all aspects, except in the flatness of the tibia and the posterior location of the palate. However, it is still reasonable to infer that the wooden skeleton was reconstructed from an individual of Edo era, Japan.

The individual of the model skeleton was estimated as an early middle-aged female. Her mandible was very narrow and the palate was much retreated, so that her face looked elegant, which was quite rare in the Edo era.

Her upper limbs are slender but her lower legs are stout, suggesting that she did not engage in hard physical labor but she often walked long distances. In the Edo era, people wore Kimono. Because kimono restricted the walk to small strides, people used their legs and feet more than their hips and thighs, which resulted in thick muscle development in the lower legs.

During maceration of the criminal's skeleton, the skeleton lost most of the ligaments and cartilages, which resulted in Okuda misunderstanding some of the arrangements of the human skeleton.

The large size and deformation of the clavicular and distal femora suggest typical methods of torture or punishment in the Edo era. These methods include, putting a heavy yoke on the shoulders (claviculae were broken) and resting large flat stones on the knees (femora were broken) when criminals were sitting upright.

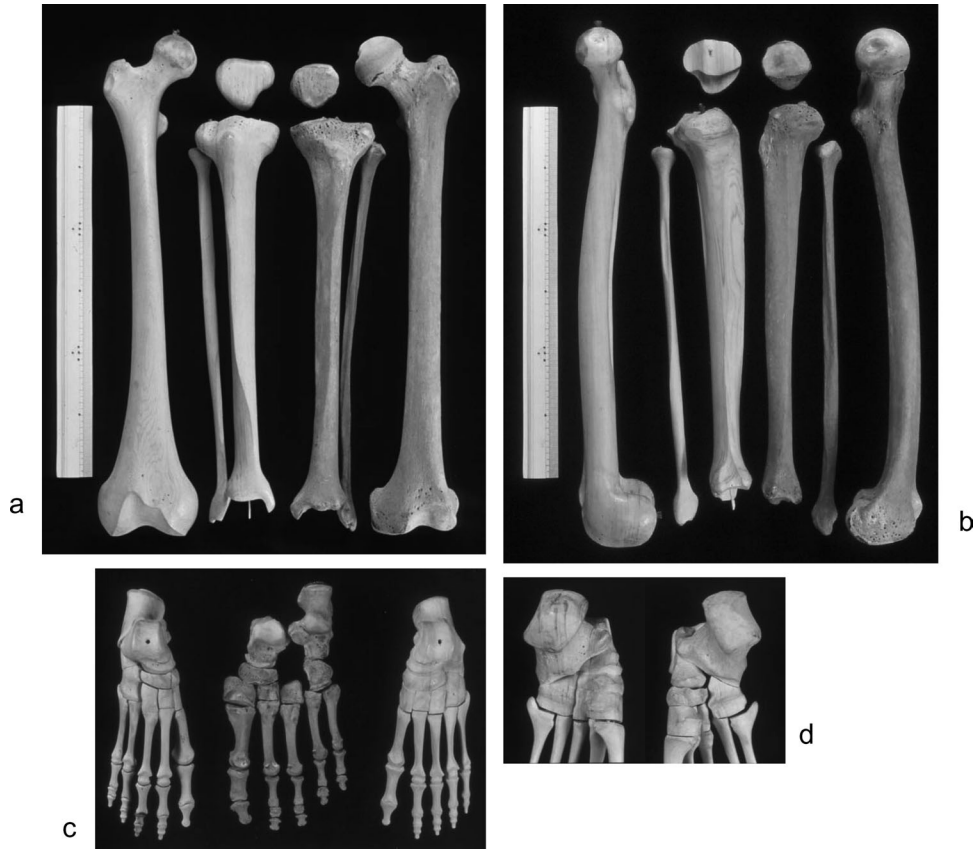

Fig. 7. Okuda wooden skeleton. a, b, the wooden right lower limb bones (left half) and Edo female left lower limb bones (right half). The scale is 30 cm long. c, the wooden right and left foot bones and Edo female left foot bones (middle). d, close up of the foot bones (planter view). Note that left tarsal bones (left) were made from one piece of wood.

Significance in the Medical History of Japan

It was a great innovation to construct wooden human skeletons for medical education, in the social milieu of the Edo era. These skeletons reflect both the scientific willingness and the craftsmanship at that time.

Among wooden skeletons made in the Edo era, the Okuda wooden skeleton is unique. While in other wooden skeletons the skulls were made from several pieces of wood and all the bones were painted, in the Okuda skeleton the skull was carved from one piece of wood. Furthermore, the surfaces of all the bones were not painted, but were polished as if each bone was a wooden sculpture.

However, it is inferred that the Okuda wooden skeleton was not used for actual medical education, because the wooden bones are extraordinary well-preserved and clean, without any dirt. Considering the facts that the wooden skeleton was donated to Owari Medical Institution and that it was shown to the general public in some special exhibitions, the wooden skeleton was used rather as one of the political purposes for the promotion of European medicine.

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