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Wood identification of Japanese Shinto deity statues in Matsunoo-taisha Shrine in Kyoto by synchrotron X-ray microtomography and conventional microscopy methods

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Abstract

Research on the wood species of Japanese Buddhist statues has an over 60 years' history and recently many Buddhist "Ichiboku" statues carved out of a single bole made from the Nara to Heian periods were scientifically revealed to be made of *Torreya nucifera*. Shinto deity statues in Japan, however, have not yet been investigated scientifically. Because many Shinto deity statues are enshrined behind closed doors, there are fewer opportunities to investigate them. To examine the differences and similarities in wood selection between Buddhist and Shinto deity statues, wood identification was conducted on the 11 Shinto deity statues of Matsunoo-taisha Shrine, Kyoto, Japan, using synchrotron X-ray microtomography and conventional microscopy methods. The results indicated two female deity statues with the ink inscriptions indicating the production year of 1143 were of *Torreya nucifera*, one female deity statue of *Zelkova serrata*, and the other eight statues, i.e., two female deity statues, four male deity statues and two priestly attire deity statues of *Prunus* s.l. spp.

Keywords: Synchrotron X-ray microtomography, Japanese Shinto deity statues, Wood species identification

Introduction

Wood identification of archeological materials and wooden heritages has provided useful information on the origin and historical background of the cultural heritage and sometimes provided a new perspective as well [1]. Wood identification has recently played an important role in the interpretation of wood selection for Buddhist statues from the late eighth century [2–4].

Japanese art historians have been discussing wood selection for Japanese Buddhist statues for many years. In the ancient period in Japan, the type of wood used for statues might have changed drastically from *Cinnamomum camphora* in the seventh century to coniferous wood in the eighth century. In 1964, Jiro Kohara who pioneered research on the scientific wood identification of wooden statues published the results of the wood identification of 682 Buddhist statues [5]. By several researchers, scientific wood identification of ancient wooden statues has been systematically conducted [2–4]. A hypothesis was proposed that the selection of *Torreya nucifera* for the eighth century statues is induced by Haku (cupressaceous wood in China) as an alternative to Santalum used in India for statues and that this selection might have been brought to Japan with the arrival of Tang monk Ganjin in Japan [2].

Buddhist statues have been investigated from various aspects. Compared to Buddhist statues, however, the study of Japanese Shinto deity statues has been comparatively behind [6]. Because Shinto deity statues tend to be enshrined behind closed doors as gods, this provided difficulties in investigating them. Thus a systematic investigation of deity statues has lagged behind and most deities have been studied only structurally, historically, and art historically.

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Buddhist and Shinto deity statues are not contradictory objects, but Shinto deity statues should be contained within Buddhist statues [7]. Under the influence of Buddhism, traditional Japanese Shinto deities came to be expressed through statues [7]. The statue of deity in Japan is regarded to be made for the first time from Nara to early Heian periods with a flow of the syncretization of Shinto with Buddhism [8] and spread across the country. The influence of Buddhist statues can be seen in various aspects of early deity statues. Buddhist and Shinto deity statues, however, differ considerably in terms of style, because Buddhist statues are basically made to be worshipped by people and because their features are made unisexual. By contrast, Shinto deity statues are made as male or female deities and are enshrined behind closed doors. Identifying the wood species of Shinto statues will clarify their relationship with Buddhism.

This study focused on the wood selection of Shinto deity statues in Matsunoo-taisha [Matsu•no•o - taisha] Shrine, Kyoto, Japan worshiping a landlord deity and having a relatively weak contact with Buddhism [9]. Matsunoo-taisha Shrine includes several auxiliary/subsidiary shrines such as Shino-ōkami-no-yashiro-jinja Shrine, Koromode-jinja Shrine, San-no-miya-jinja Shrine, Munakata-jinja Shrine, Ichitani-jinja Shrine and Tsukuyomi-jinja Shrine [9]. Shinto deity statues have been handed down in this main shrine and these auxiliary/subsidiary shrines. Statues placed at auxiliary/subsidiary shrines have been on display in a new exhibition hall of the main shrine since 2010 [9]. When the new exhibition hall was opened, we conducted a wood sample collection together with Shiro Itoh, the director of the Wakayama Prefectural Museum. In this research, we applied the conventional preparation method and synchrotron X-ray microtomography (SRX-ray μCT) method [10, 11] for the wood identification of the wooden statues. SRX-ray μCT methods hold great potential, because of its nondestructive character. And samples could be reused for chemical and DNA analyses.

Materials and methods

In this study, Shinto deity statues of Matsunoo-taisha Shrine, in Kyoto city, Kyoto Prefecture, Japan were investigated. The Shrine has several auxiliary/subsidiary shrines described in Introduction. 21 Shinto deity statues have been handed down. Scientific identification was conducted on 11 statues which were enshrined in several auxiliary/subsidiary shrines (Fig. 1). They were assumed to be made in the twelfth century from an artistic historical perspective (Table 1) [9]. Female deity statues 3 and 4 enshrined at different auxiliary/subsidiary shrines had similar ink inscriptions at the bottom that strongly suggested that their production were in 1143.

Small samples were collected from cracks and hollows in consultation with an art specialist Shiro Itoh without harming the surface of the statues.

Among the 11 samples, 1 sample was not deteriorated and also had enough size for preparation. In addition, it was identified as a soft wood even by the naked eyes. So, we applied preparation method for this sample. The sample was soaked in water for softening. Thin sections were taken using either single- or double-edged razor blades in the cross, radial and tangential directions (approximately 20 μm thick). The sections were heated on a hot plate with glycerin: ethanol (=1:1) to remove air bubbles and mounted with gum–chloral (a mixture of gum arabic and chloral hydrate). The slides were studied under an optical microscope (Olympus BX51) and photos were taken with a digital camera (Olympus DP70).

Other ten samples were studied with SRX-ray μCT at SPring-8 in Hyogo Prefecture, Japan. As reported in the research of the past [10, 11], we have made it possible to identify wood species using SRX-ray μCT. SPring-8 is a large synchrotron radiation facility that uses narrow, powerful electron beams of electromagnetic radiation to reconstitute a three-dimensional image of the wood's anatomical micro-structure. A tiny sample was fixed on a specially designed stage of the SRX-ray μCT equipment. Transmitted images obtained thorough the beamline 20XU were recorded by a Hamamatsu High-Resolution camera (0.472 μm/pixel). The reconstituted images were further analyzed with the "VGStudio" and "ImageJ" software. The anatomical features necessary for identification are often observed based on microscopy. So, thickness of wood sections should be around 10–20 μm. Each original reconstituted slice made by the SRX-ray μCT was under 0.5 μm thick, so it was necessary to increase the depth information so as not to lose anatomical information. For this purpose, 24 slices were integrated and approximately 12-μm-thick pseudo-micrographs were prepared. This allowed wood anatomical features from the literature to be compared to the data obtained by SRX-ray μCT. Anatomical characteristics were referenced from previous publications [12, 13]. For identification, we referenced Wood Diversity HSDB network (http://database.rish.kyoto-u.ac.jp/cgi-bin/bmi/en/namazu.cgi) in Japan.

Results

Our results showed that *Prunus* s.l. spp. (d–k in Table 1), *Torreya nucifera* (b and c in Table 1) and *Zelkova serrata* (a in Table 1) were used for the studied Shinto statues. Refer to Table 1 and Appendix here.

Female deity 1

No growth ring boundaries were observed. An abrupt transition from distinctly wide vessels over 100–200 μm

Fig. 1 Photographs of Shinto deity statues in Matsunoo-taisha Shrine (**a**–**k**)

in diameter to the latewood vessel clusters of the same growth ring suggests ring porosity (Fig. 2a). Perforation is simple (Fig. 2e). Narrow vessel elements composing vessel clusters have fine helical thickenings throughout the body. Ground tissue fibers are narrow diameter and thick walled with narrow lumina, pit structure is not observed. Rays are 6–7 cells in width, mostly 300–400 μm high, and heterocellular comprising mostly of procumbent cells in the body with 1 (− 2) square marginal cells that often include large prismatic crystals (Fig. 2c). From the above-described features, it is likely to be made by domestic wood and this was identified as *Zelkova serrata* (Fig. 2).

Female deity statues 3 and 4

Even growth ring boundaries are not included, the transition from the earlywood to the latewood is gradual (Fig. 3a). Rays are 3–9 cells in height and exclusively uniseriate (Fig. 3b and e). Helical thickenings in pairs are clearly present in longitudinal tracheids (Fig. 3b, c, e and f). Crossfield pitting is cupressoid and 1–4 pits per crossfield (Fig. 3c). Although the sample

Table 1 Details of deity statues and identification results

Statue number	Statue in Fig. 1	Height (cm) cited from Ref. [6]	Wood species	Place of enshrinement (auxiliary/subsidiary shrines of the Matsunoo-taisha Shrine), cited from Ref. [6]
Female deity 1	a	42.8	*Zelkova serrata*	Ichitani-jinja Shrine or Munakata-jinja Shrine
Female deity 3	b	33.6	*Torreya nucifera*	Ichitani-jinja Shrine or Munakata-jinja Shrine
Female deity 4	c	29.8	*Torreya nucifera*	San-nomiya-jinja Shrine
Female deity 5	d	29.4	*Prunus* s.l. sp.[a]	Konpira-jinja Shrine
Female deity 6	e	35.1	*Prunus* s.l. sp.[a]	Unknown
Male deity 8	f	42.8	*Prunus* s.l. sp.[a]	Koromode-jinja Shrine
Male deity 9	g	38.4	*Prunus* s.l. sp.[a]	Unknown
Male deity 10	h	39.0	*Prunus* s.l. sp.[a]	Shino-ōkami-no-yashiro-jinja Shrine
Male deity 11	i	31.6	*Prunus* s.l. sp.[a]	Shino-ōkami-no-yashiro-jinja Shrine
Priestly attire deity 15	j	40.5	*Prunus* s.l. sp.[a]	Unknown
Priestly attire deity 16	k	35.3	*Prunus* s.l. sp.[a]	Unknown

Especially, female deity statues 3 and 4 have similar ink inscriptions at the bottom though they were enshrined at different auxiliary/subsidiary shrines. From ink inscriptions, they are supposed to be made in 1143

[a] Species is not defined

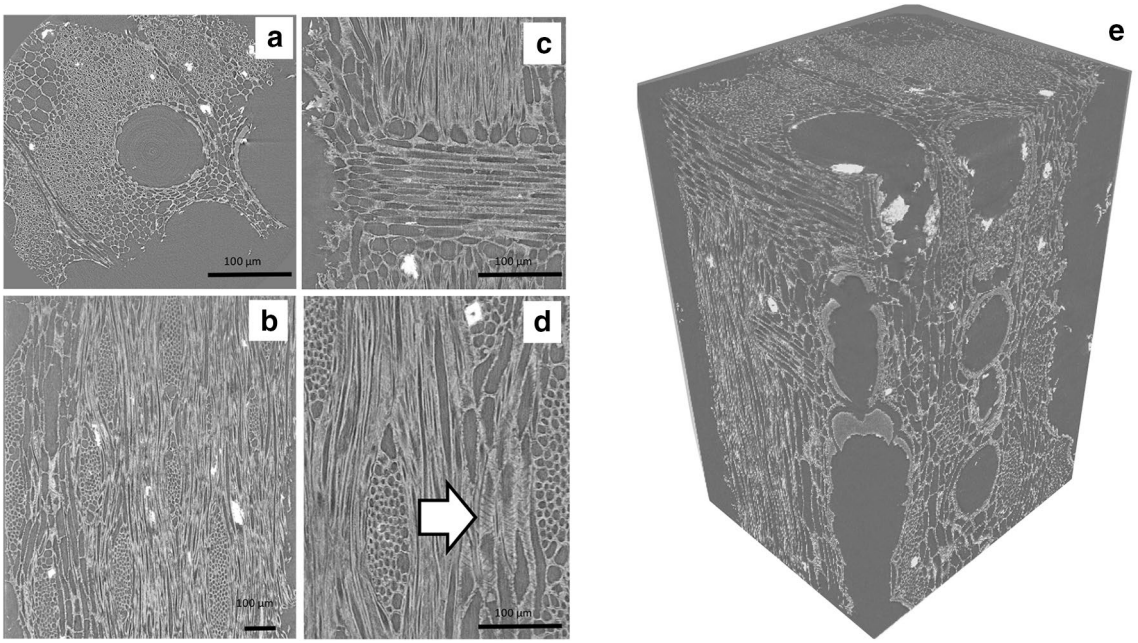

Fig. 2 Pseudo-sections constructed from the SRX-ray µCT dataset from SPring-8 for female deity 1 (a in Table 1). **a** cross-section, **b** tangential section, **c** radial section, **d** magnified image of tangential section and **e** 3D image

from female deity 4 is too deteriorated to see the cross-field pitting type and number (Fig. 3f), helical thickenings in pairs indicated identity. From above-described features, they are likely to be made by domestic wood which was identified as *T. nucifera*.

Female deity statues 5 and 6, male deity statues 8–11 and priestly attire deity statues 15 and 16

Figure 4 shows pseudo-micrographs of male deity 8. Diffuse porous (Fig. 4a) with simple perforation plate is seen in Fig. 4e. Without a growth ring boundary,

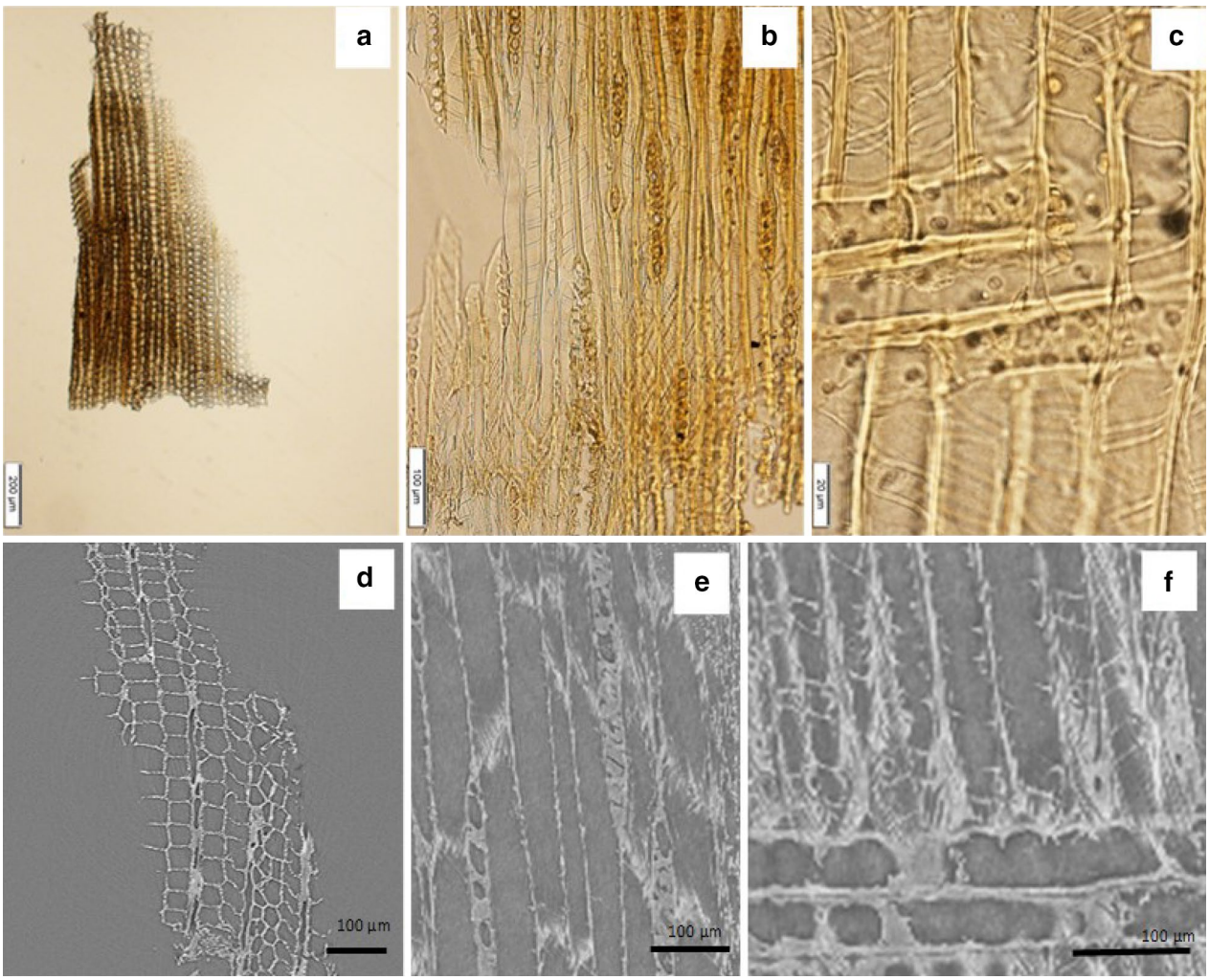

Fig. 3 Micrographs of female deity 3 (b in Table 1) and pseudo-sections constructed from the SRX-ray µCT dataset from SPring-8 for Female 4 (**c** in Table 1). **a**, **d** cross-section, **b**, **e** tangential section and **c**, **f** radial section

widely spaced helical thickenings (arrowhead in Fig. 4b) are observed on inner vessel walls. Intervessel pitting is alternate (Fig. 4b) and prismatic crystals occurred in idioplast and chambered axial parenchyma cells (Fig. 4c and d). Rays are 1–5 cells in width and heterogeneous comprising mostly of procumbent cells in the body with 1 (−4) square marginal cells. Axial parenchyma is vasicentric and ray parenchyma is not prominent. From above-described features, they are likely to be made by domestic wood which was identified as *Prunus* s.l. spp.

Prunus s.l. consists of several genera. From the above characteristics we observed, it is difficult to narrow the genus clearly. So we described them as *Prunus* s.l. spp.

Discussion

Among the 11 Shinto deity statues in Matsunoo-taisha Shrine, 8 of them were made of *Prunus* s.l. spp., 2 of *Torreya nucifera*, and 1 of *Zelkova serrata,* even though past literature [9] suggested that most of the statues were made of *Cinnamomum camphora* or *Zelkova serrata* by naked eyes observations. Only female deity statues 3 and 4 (made in 1143) were made of *T. nucifera*, and this is accords with our report about the wood species used for deity statues [8], when most of Shinto deity statues were thought to be made of softwood. Thus, statues in Matsunoo-taisha Shrine made of *T. nucifera* provide important information for the wood selection criteria used for deity statues in the twelfth century in Kyoto.

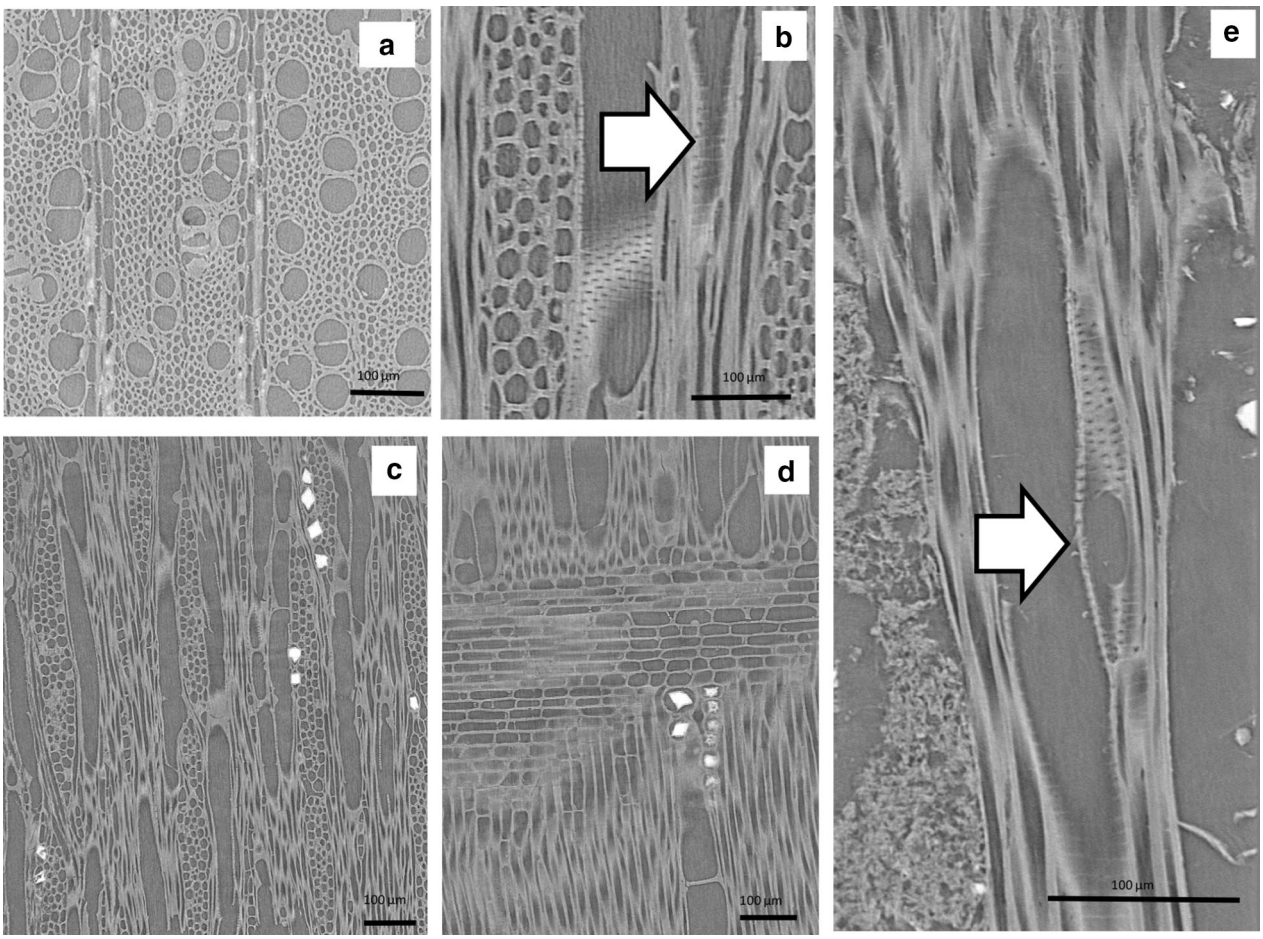

Fig. 4 Pseudo-sections constructed from the SRX-ray µCT dataset from SPring-8 for male deity 8 (f in Table 1). **a** cross-section, **b**, **c**, **e** tangential section, d: radial section. **b** and **e** are magnified images of tangential sections. The sample is typical diffuse porous wood (**a**) with a simple perforation plate (**e**). In the radial and tangential sections, widely spaced spiral thickenings (arrowhead in **b**) are observed. In the tangential section, an alternate arrangement of intervessel pitting is clearly observed (**b**) and prismatic crystals exist in chambered AP cells (**d**)

There have been several investigations of Shinto deity statues from the view point of art history. Naomi Oka [14] examined the wooden statues of Matsunoo-taisha Shrine and a Buddhist temple (both in Kyoto Prefecture, Japan) and he presumed that sculptors of Buddhist statues were also engaged in making deity statues in Heian Period. Nagasaka drew the inference [7] that a pupil of Ganjin spread a syncretization of Shinto with Buddhism.

Matsunoo-taisha Shrine, which had a strong relationship with the lord of the Hata clan, has a unique historical background even in Japan. The Hata clan were supposed to be immigrants from Korean Peninsula and settled down in Kyoto area [9]. They worshiped landowner gods and ancestral gods and supposed to have relatively a weak contact with Buddhism [9]. In Matsunoo-taisha Shrine, three famous deity statues are assumed to be made in the ninth century with softwood [15]. They are relatively larger than other deity statues we studied in this shrine and are estimated to be made from a single bole, because the position of their wood cores and tree ring arrangements are similar [15] each other.

In our study, *Prunus* s.l. spp., *Zelkova serrata* and *Torreya nucifera* were used for 11 deity statues of the twelfth century. To clarify the reasons of this wood selection, identifying the materials of three deity statues from the ninth century seem to be very important.

We hope that this research will contribute to discussing the historical origins of statues and to elucidating the historical background of wood selection for deity statues in Japan. Our study provided a fresh insight into the field of deity study and will help interpreting why and how Buddhism affected Shinto in Japan.

Conclusion

Our results showed a possibility of revealing differences in the wood selection between Shinto and Buddhist statues in ancient Japan and also in other Asian countries. This is an initial step that opens the way for further investigation on Shinto deity statues. For further investigation, identification and dating of many statues would be necessary.

Abbreviation

SRX-ray μCT: Synchrotron X-ray microtomography.

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Authors' contributions

ST and JS have participated sufficiently in wood identification and are responsible for the entire contents. Both authors read and approved the final manuscript.

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Availability of data and materials

All data analyzed during this study are included in this published article.

Competing interests

The authors declare that they have no competing interests.

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