Casting Techniques for Gilt-bronze Pensive Bodhisattva Sculptures: Focusing on Korean National Treasures No. 78 and No. 83

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Introduction

Gilt-bronze Buddhist sculptures are created by first casting a desired image in bronze and then applying a thin coating of gold to the surfaces. Such gilt-bronze Buddhist sculptures have been steadily produced across Asia wherever Buddhism flourished since at least the first century CE, including in Central and Southeast Asia, India, China, Korea, and Japan. Research on the materials and production methods of Buddhist sculptures has offered new clues to help resolve questions that cannot be answered by stylistic and iconographic studies alone. In particular, scientific analysis has provided additional information on the materials and production methods of these Buddhist sculptures. Among ancient sculptural images, gilt-bronze Buddhist sculptures provide notable examples suitable for scientific research. Stylistic analysis performed with the naked eye in combination with information on materials and production methods gathered through scientific inspection allows a more accurate understanding and more objective interpretation of the temporal and spatial characteristics of Buddhist sculpture (Min Byoungchan 2015, 284–286).

In a broad sense, gilt-bronze Pensive Bodhisattva sculptures have been produced using the same methods as gilt-bronze sculptures of Buddhas. Unlike standing or seated Buddhist images, however, gilt-bronze Pensive Bodhisattva sculptures must have required more complex and elaborate techniques because of their unusual meditation pose (半跏思惟, *banga sayu*) with one leg resting horizontally across the other knee and the fingers resting against the cheek. This paper aims to examine the production techniques of two Pensive Bodhisattva images, respectively designated as National Treasure No. 78 and No. 83, that are considered finest examples of ancient Korean gilt-bronze Buddhist Sculpture. To this end, the paper first offers a general introduction of the production methods and materials common to ancient gilt-bronze Buddhist sculptures and then analyzes the casting techniques of these two National Treasures. The objectivity of the analysis and understanding of the fundamental features of the sculptures have been improved by examining them not only with the naked eye but also with contemporary non-destructive inspection such as X-ray Fluorescence (XRF) analysis, γ-ray radiography for identifying the structures in the interior, and 3D scanning.

Fig. 1. Gilt-bronze Seated Buddha. Gandhara, 1st–2nd century. H. 16.8 cm. The Metropolitan Museum of Art

Casting Techniques for Gilt-bronze Buddhist Sculptures

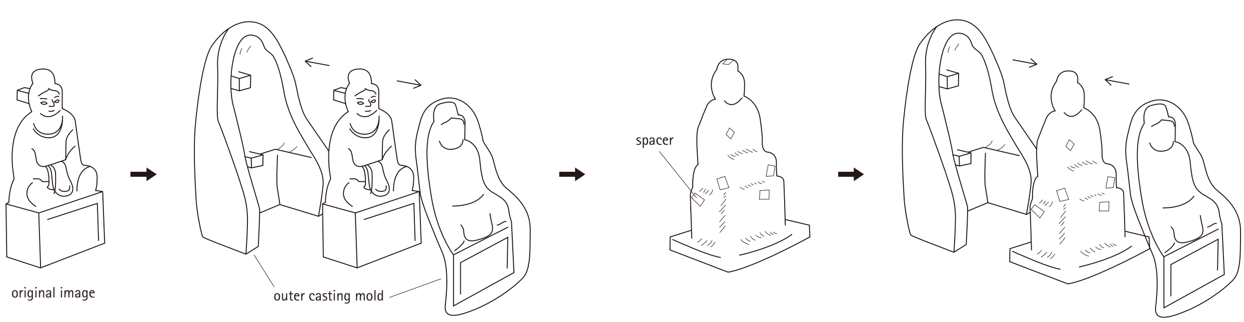
Gilt-bronze Buddhist sculptures created by gilding the surfaces of images cast in bronze are presumed to have been produced ever since Buddhist images were first created in India. The oldest existing gilt-bronze Buddhist sculpture is in the collection of the Metropolitan Museum of Art, New York (Fig. 1). Created in the first or second century CE, it is known to be excavated from a region in today's Afghanistan. As Buddhism spread eastward, gilt-bronze Buddhist sculptures were introduced to Central and Southeast Asia, China, Korea, and Japan. Soon, these areas began to produce their own gilt-bronze Buddhist sculptures. Depending on the region and time of production, the casting and gilding techniques and the components and proportions of the copper alloy differ. Thus, the gilt-bronze Buddhist sculpture is considered one of the most important topics in the study of ancient Buddhist sculpture.

Two primary techniques were used to cast bronze in ancient times: 1. Piece-mold casting (分割鑄造法), which originated in China and was used mostly in East Asia; and 2. Lost-wax casting (蜜蠟鑄造法 or 失蠟法), which originated on the Anatolian Plateau of Turkey or in the Middle East and spread throughout North Africa, Europe, and Asia.

Piece-mold Casting

When using the piece-mold casting technique, an original image is fashioned from clay. A release agent is applied to the image, and it is coated with an additional layer of clay. Once dried, the outer layer of clay is cut away. The surface of the original clay model is then evenly shaved away, and the cut outer sections are reassembled around it. The clay model becomes the inner core (內型土 or 中子), while the overlaid sections become the outer casting molds (外型土 or 鎔范). Spacers or chaplets (型持) are inserted between the core and the outer mold to maintain an even gap into which molten bronze is poured. Once the bronze cools, the clay molds can be removed, and the surface of the image can be plated with gold (Drawing 1).

Piece-mold casting is often used to create sculptures with simple structures since the outer molds have to be removed from the original model.[1] After a sculpture is cast, any metal that has seeped into the gaps between the outer mold sections creates protruding fins. In the case of gilt-bronze Buddhist sculptures, these burrs can be ground away or covered with gold. Those on iron sculptures are often left intact due to the nature of iron. Spacers used for maintaining the gap between the core and the outer molds, such as copper or iron plates with nails or small



Drawing 1. Piece-mold Casting (Based on Strahan 2010, 141, Fig. 8)

Fig. 2. Gilt-bronze Seated Buddha. China, 3rd–4th century. H. 32.0 cm. Harvard Art Museums

Fig. 3. Gilt-bronze Seated Buddha. Excavated from Ttukseom in Seoul. Three Kingdoms Period, 5th century. H. 4.9 cm. National Museum of Korea

clay core extensions deliberately left when shaving down the original model, often leave traces in a finished gilt-bronze or iron piece which are easily identifiable with the naked eye.

Piece-mold casting began in China and was already in use from the Shang Dynasty (1600–1046 BCE). Most bronze vessels from the Shang Dynasty through the Han Dynasty (206 BCE–220 CE) were created using this technique (Cowell, Niece, and Rawson 2003, 80). When Buddhism was introduced to China around the fourth century CE, and the full-scale production of Buddhist images began, piece-mold casting was heavily employed to create early gilt-bronze Buddhist images. For example, gilt-bronze Buddhist sculptures in an archaic style, making the dhyana mudra (禪定印, meditation mudra) (Fig. 2), were mainly produced using this technique (Cowell, Niece, and Rawson 2003, 80). Following the subsequent introduction of lost-wax casting, piece-mold casting is presumed to have continued to be applied in the production of large Buddhist sculptures. In particular, massive iron Buddhist sculptures began to be made using this method, starting in the sixth century (Satō Akio 1981, 100). This method was used continuously for cast iron objects and colossal gilt-bronze Buddhist sculptures until the Qing Dynasty (1616–1912).

It is unknown precisely when piece-mold casting was

Fig. 4. Bottom of Fig. 3

introduced to the Korean Peninsula. However, two-part molds (合范), early versions of piece-mold casting, emerged there in the mid-Bronze Age (800–300 BCE), so it appears that piece-mold casting in its mature form was introduced in the late Bronze Age at the latest. With the advent of Buddhism, the technique was used from the beginning of the production of gilt-bronze Buddhist sculptures in Korea. As a case in point, a Gilt-bronze Seated Buddha produced around the fifth century was unearthed from Ttukseom in Seoul (Fig. 3). However, this sculpture was made using a two-part mold without a core inside rather than the full piece-mold casting technique with a core and multiple outer mold pieces. Differing from the archaic-style Chinese gilt-bronze Buddhist sculptures with hollow interiors, this example with an interior of solid bronze signals the emergence of characteristic gilt-bronze Buddhist sculptures on the Korean Peninsula (Fig. 4). The eventual introduction of lost-wax casting resulted in a reduction in the frequency of the use of piece-mold casting for small and mid-size gilt-bronze Buddhist sculptures, but it continued to be used for casting large Buddhist images. The Gyeongju National Museum's Gilt-bronze Standing Bhaisajyaguru Buddha (Fig. 5) from the Unified Silla (676–935) is a larger-than-life-size Buddhist sculpture formed using piece-mold casting. Numerous colossal iron Buddhist sculptures made across the peninsula after the eighth century also used this technique. Piece-mold casting continued to be applied to large Buddhist sculptures throughout Goryeo (918–1392) and Joseon (1392–1897). Moreover, it was introduced to Japan and was used in many massive Buddha sculptures, including the Great Buddha at Tōdaiji Temple (東大寺) in the eighth century during the Nara period (710–794), as well as the Kamakura Great Buddha at Kōtokuin Temple (高徳院) and other iron colossal Buddhas during the Kamakura period (1192–1333) (Min Byoungchan 2015, 284–285).

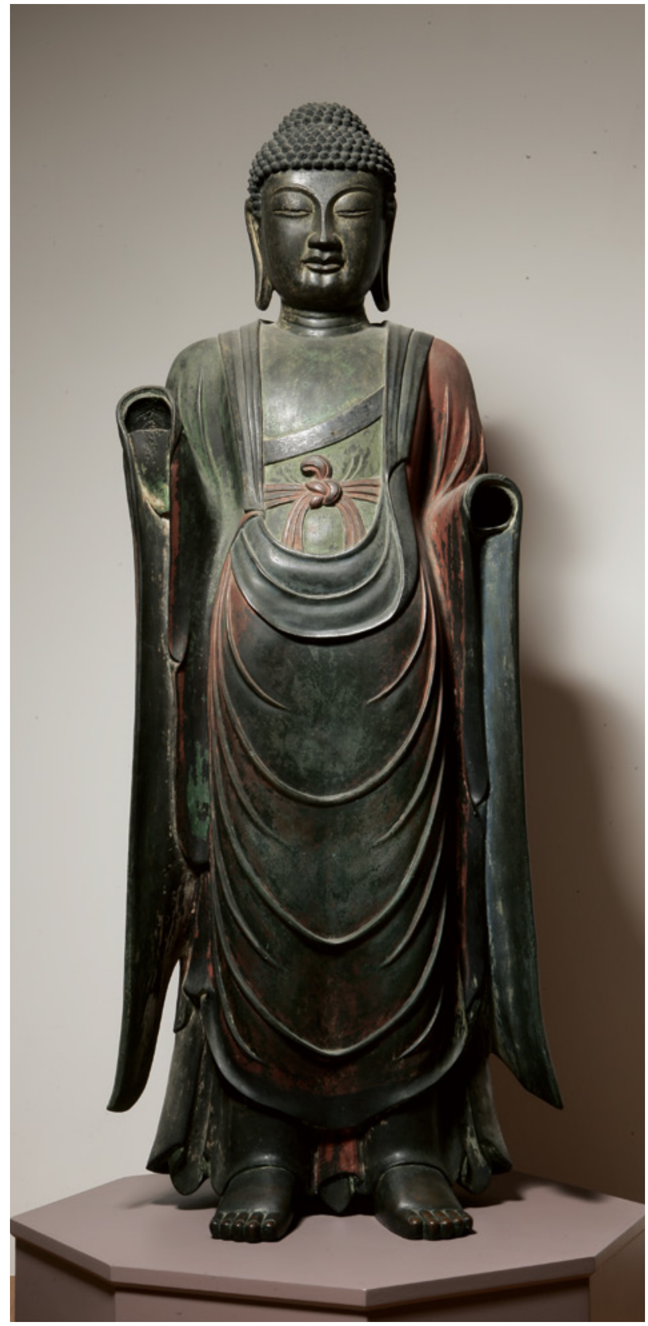


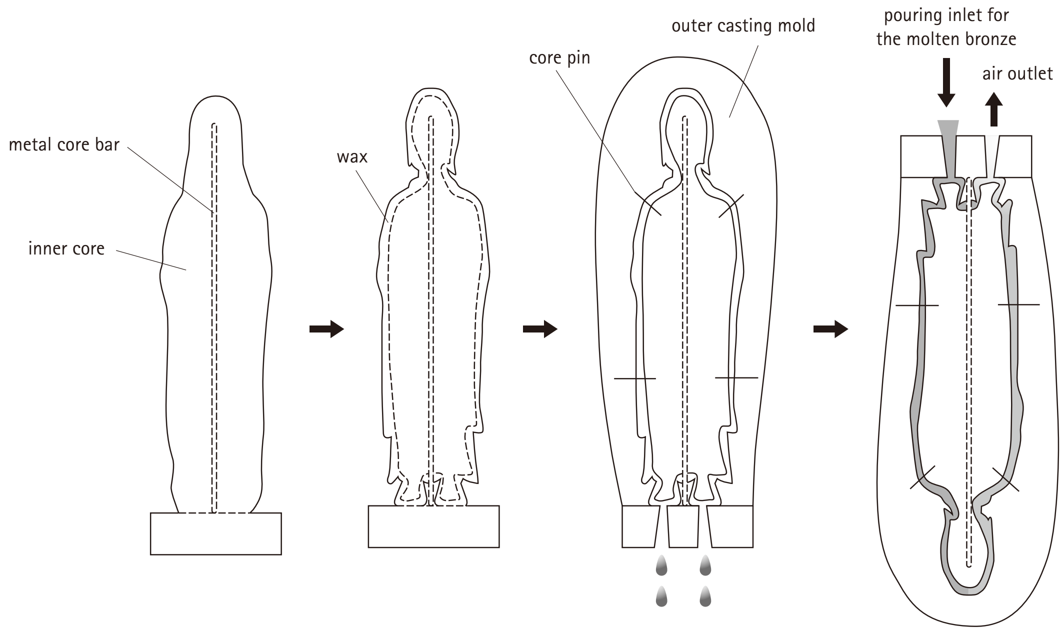
Fig. 5. Gilt-bronze Standing Bhaisajyaguru Buddha. Unified Silla, 8th century. H. 179.0 cm. Gyeongju National Museum. National Treasure No. 28

Lost-wax Casting

In lost-wax casting, an inner core is coated in wax, and the details of the desired model are sculpted. It is then covered with additional clay to create an outer mold. Iron core pins (釘) are inserted through the wax to immobilize the core and the outer mold, preventing them from adhering. The wax is melted away using heat, and molten bronze is poured into the channels left by the wax. The outer mold is broken away after the liquid bronze cools. The bronze image is taken out and can then be plated with gold (Drawing 2).

Lost-wax casting is conventionally considered more appropriate than piece-mold casting for complex and elaborate bronze sculptures since wax is conducive to being modeled into the desired shape. It is suitable for expressing realistic and natural textures and for producing voluminous three-dimensional sculptural images. Moreover, instead of requiring relatively large copper plates or clay core extensions as spacers, thin iron nails can be used to link the inner core and outer mold, thus leaving minimal marks for removal after casting. In the case of colossal sculptures, however, it could be problematic to obtain the great quantities of wax required from nature. In addition, it is not apparent to the naked eye whether the wax is completely removed from the mold or not, and the removal itself is also quite demanding work. If molten bronze is introduced to a mold where some wax still remains, the process can result in failure.

It has yet to be determined exactly when and where the lost-wax casting technique was invented. However, a large number of copper alloy objects produced around 3500 BCE using the technique have been excavated from Ghassulian sites in Nahal Mishmar on the Sinai Peninsula located in between the Mediterranean Sea and the Dead Sea (Moorey 1988, 171–173).



Drawing 2. Lost-wax Casting

These objects are the oldest known examples using the lost-wax casting method. Accordingly, lost-wax casting is presumed to have originated either in the Middle East or on the Anatolian plateau of Turkey, where bronze goods are believed to have been first produced (around 3500 BCE at the latest). The technique was introduced to Egypt around 1500 BCE and later spread across the Greek and Roman spheres via the Mediterranean Sea, making it the prevalent bronze casting method of ancient Europe.

While the piece-mold casting technique was developed in China and disseminated only throughout East Asia, lost-wax casting originated in Southwest Asia and spread across the old continents of Asia, Europe, and North Africa. Lost-wax casting reached Afghanistan, Gandara, and the downstream portions of the Indus River Valley no later than the fourth century BCE during Alexander the Great's expedition into Asia. With the advent of Buddhism around the fourth century, gilt-bronze Buddhist sculptures using the lost-wax casting technique began to be produced in China. There, traditional piece-mold casting is believed to have been regularly used for large-scale Buddhist sculptures or those with simple forms, and lost-wax casting was reserved for small- and medium-sized and complex Buddhist sculptures. Lost-wax casting had been imported to Korea by the sixth century. During the Three Kingdoms period, most small- and medium-sized gilt-bronze Buddhist sculptures were created using this method. These include Gilt-bronze Standing Buddha with Inscription of "Yeongachilnyeon" (延嘉七年, the seventh Yeonga year) produced in 539 and two Gilt-bronze Standing Avalokitesvara Bodhisattva images excavated from Seonsan in Gyeongsangbuk-do Province (Fig. 6). Along the transmission route of Buddhism, the lost-wax casting was introduced not only to Japan but also to the Southeast Asian Buddhist countries, including Vietnam, Cambodia, and Thailand, where the gilt-bronze Buddhist sculpture productions existed. (Min Byoungchan 2015, 285).

Lost-wax casting is commonly considered useful for producing complicated and elaborate objects, while piece-mold casting is best for simple or large objects. However, there is no evidence pointing to the use of lost-wax casting among the exquisite bronze objects dating to the fourth and fifth century BCE recently excavated in China, including the *zunpan* (尊盤, ritual wine vessel) from the Tomb of Marquis Yi of Zeng (曾侯乙墓) and the *jin* (禁, ritual altar table) from Xiasi, Xichuan. (Su Rongyu 2003, 31–33). Therefore, it is hard to conclude a sculpture's casting method—whether it used lost-wax or piece-mold—simply from its size or the complexity of its form.

Composition of Bronze and Gilding Methods

In a narrow sense, bronze is fundamentally an alloy of copper and tin. However, component analysis of ancient Buddhist sculptures in bronze has revealed that copper-tin-lead alloys were far more frequent than simple copper-tin alloys.[2] Many bronze Buddhist sculptures from ancient China also consisted of copper, tin, and lead, and in some cases of only copper and lead. Tin is one of the more suitable metallic elements for casting since it is economical. Moreover, tin can be easily alloyed since its melting point is lower than that of lead. Even after being melted down, tin has greater fluidity than lead alloys. Nevertheless, it is relatively rare and its production is confined to a limited number of areas (Park Junwoo 2012). The inclusion of lead in bronze is presumed to be a result of its use as a substitute for tin in regions where the latter is difficult to obtain.

Fig. 6. Gilt-bronze Standing Bodhisattva. Excavated from Seonsan in Gyeong-sangbuk-do Province. Three Kingdoms Period, 7th century. H. 33.0 cm. National Museum of Korea. National Treasure No. 183

A majority of ancient Korean bronze objects show an alloy composed of copper, tin, and lead similar to that found in ancient Chinese versions. Tin was not produced at all in Korea, and even copper mines were scarce (Ministry of Commerce Industry and Energy and Korea Resources Corporation 2007, 14). Thus, most of the materials required to produce bronze appear to have been imported from China. Japan also had no local sources of tin, but rich copper deposits were available there. Accordingly, large-scale Buddhist sculptures were cast in Japan from early on using indigenously produced copper (Murakami Takashi 2007, 3). Unlike their Chinese or Korean counterparts, gilt-bronze Buddhist sculptures in ancient Japan were made of bronze that was almost entirely copper, with nearly no tin and lead, or a version composed of copper and around 3% tin or copper with a minute quantity of either arsenic or lead (Hirao Yoshimitsu 1996, 411).

The methods for plating the surfaces of Buddhist sculptures with gold include mercury amalgamation, hand application of thin gold leaf to an adhesive layer of lacquer varnish, and application of a golden lacquer in which gold powder has been mixed with glue. Distinguishing between methods can be extremely difficult with the naked eye alone, but composition analysis of the plating layers can be more revealing. Ancient Buddhist sculptures were gilded chiefly using a mercury amalgamation technique, but some were gilded with gold leaf. In mercury amalgamation, a mixture of one part gold dust to five parts mercury is first applied to the surfaces of a sculpture. The mercury is evaporated by heating the surface to over 400 degrees Celsius, but the gold dust remains attached (Kobayashi Yukio 1989, 208). Since mercury amalgamation is more durable than applications of gold leaf or paint, gilding performed using this method typically remains in good condition for longer periods of time. Depending on the region or period, a discernable difference in the golden color can be found based on the proportion of gold dust to mercury, the thickness of the gilding, and the purity of the gold used, all of which reflect temporal and regional characteristics of the gilding (Min Byongchan 2015, 286).

Characteristics and Production Methods of Gilt-bronze Pensive Bodhisattva (National Treasure No. 78)

Listed as the state-designated cultural property, this Gilt-bronze Pensive Bodhisattva (Fig. 7) is commonly referred to simply as "National Treasure No. 78" after its designation number. It has elsewhere been referred to as Pensive Bodhisattva with a "Pagoda-shaped Crown" (塔形寶冠) or with a "Triple Mountain-shaped Crown with Sun and Moon Decoration" (日月飾三山冠) due to its uniquely ornamented crown. This sculpture is highly prized along with another similar-sized Gilt-bronze Pensive Bodhisattva designated as National Treasure No. 83 (Fig. 13). They are considered two of the most exquisite and representative Buddhist sculptures from the Three Kingdoms period. Other notable medium- and large-sized Pensive Bodhisattva sculptures produced around the same time include Wooden Pensive Bodhisattva, likely made in Silla (57 BCE–935 CE) in the seventh century and currently housed at Kōryūji Temple (広隆寺) in Kyoto, and an Asuka period Wooden Pensive Bodhisattva from the seventh century at Chūgūji Temple (中宮寺) in Nara, Japan.

In 1912, the Japanese Government-General of Korea paid the Japanese businessman and antique collector Fuchikami Teisuke (淵上貞助) 4,000 won—estimated nearly as Three billion won in today's currency, based on the then-and-now price of rice—for National Treasure No. 78 (Hwang Suyeong 1998, 81–83). In 1916, one year after the Government-General of Korea established its museum, the first Governor-General Terauchi Masatake (寺内正毅, 1852–1916) donated to the museum roughly 100 national treasure-level objects held by the colonial government, including Goryeo celadon works and National Treasure No. 78. The precise excavation site of the sculpture is unknown. However, the Korean Buddhist art history pioneer Dr. Hwang Suyeong assumed based on the testimony of Japanese people who were aware of the circulation of Korean antiques during the period that it might have been enshrined at a temple in the northern portion of Gyeongsangbuk-do Province, either in Yeongju or Andong (Hwang Suyeong 1998, 83). Yeongju and Andong were the regions where Buddhism was first introduced in Silla; also found in these areas are the Stone Pensive Bodhisattva sculpture (excavated from Bukji-ri in Yeongju, which is the largest existing pensive bodhisattva), and multiple small gilt-bronze pensive bodhisattva images (Min Byoungchan 2015, 266).

Fig. 7. Gilt-bronze Pensive Bodhisattva. Three Kingdoms Period, late 6th century. H. 82.0 cm. National Museum of Korea. National Treasure No. 78

National Treasure No. 78 reflects the Buddhist sculptural style of the Eastern Wei Dynasty (534–550) of China in its ornate crown, gentle faint smile, slender body, drapery folds sharply pointing upwards on both arms, and single-petaled lotus footrest. In particular, the elaborate crown is adorned with simplified designs of natural elements, animals, and plants, including the sun, crescent moon, birds' wings, and foliage. These designs originated in Assyria in Anatolia or the Persian Empire on the Iranian Plateau and were transmitted to China, Korea, and Japan via Central Asia through the active cultural exchanges taking place at the time. They were used to decorate the coronals of rulers, symbolizing supreme authority or a sacred role as an intermediary between the divine and humanity. Adopted into Buddhist art, these designs were used to adorn bodhisattvas' crowns to indicate the deity's dignity and nobility.

Examination with both the naked eye and using scientific methods such as XRF analysis and γ-ray radiography of the surface and interior of this sculpture unveiled some unusual features connected to the production techniques applied.

National Treasure No. 78 shows detailed sculptural

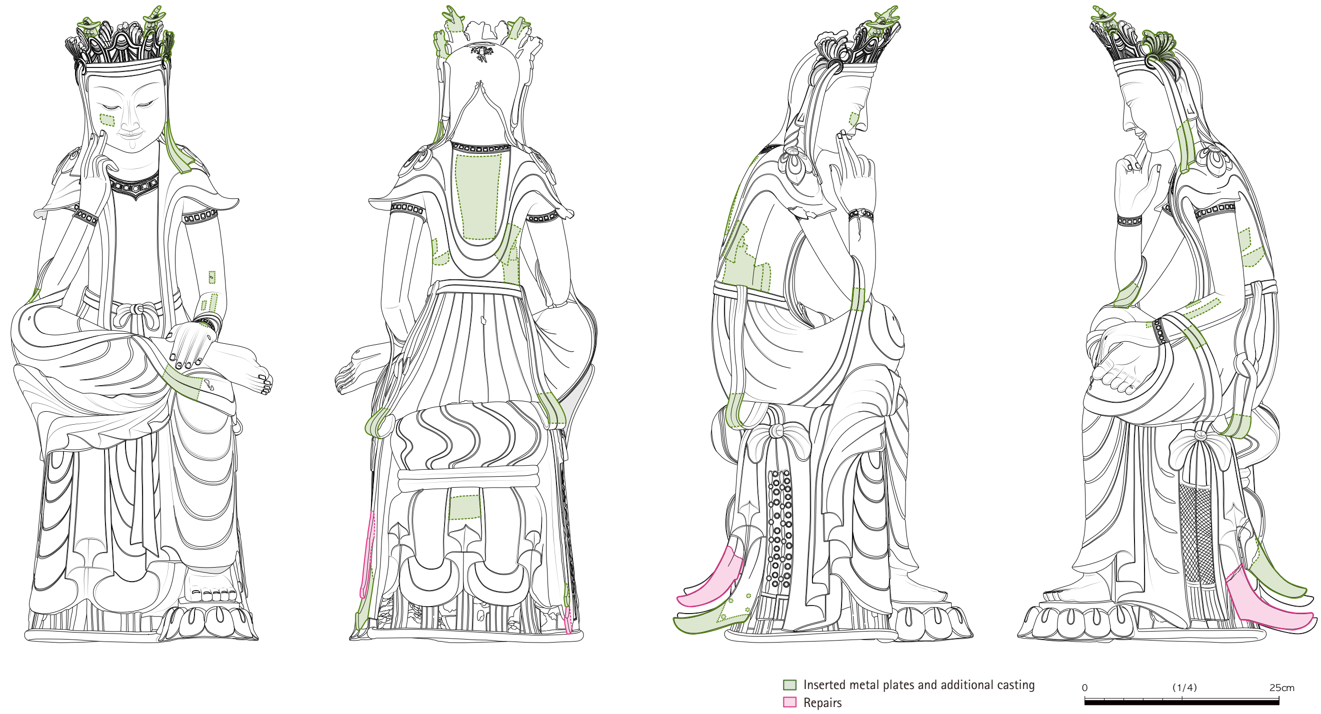
Fig. 8. Detail of Fig. 7

Fig. 10. Interior of Lotus-shaped Footrest of Fig. 7

Fig. 9. Interior and Core Pins of Fig. 7

expressions in its complex crown, drapery folds facing upwards as if supporting the knee of the right leg, and the skirts of the robe separated from the body of the figure, all of which would be difficult to cast except through the lost-wax casting (Fig. 8). Inside this sculpture are core pins commonly associated with the use of lost-wax casting (Fig. 9). However, this sculpture differs slightly from others made using lost-wax casting in that the patterns on its interior reflect those on the exterior, the curves of the interior and exterior match, and it maintains an overall thin and uniform thickness of about four millimeters in the bronze. Moreover, unlike the thin body, the round edges of the bottommost parts of the lotus-shaped footrest and cylindrical chair are notably thick, measuring over 10 millimeters, and appear unusual, like modeling clay that has been pressed with a spatula (Fig. 10).

γ-ray radiography has also revealed several peculiarities in this sculpture. As a case in point, there are indications of a subsequently affixed semielliptical copper plate of about 20 centimeters in width and 10 centimeters in length between the necklace and the U-shaped drapery on the back (Drawing 3). This copper plate was attached to cover a gap created during casting. However, the quality of the work is so high that the marks are not easily apparent to the eye. Inside the chest portion of the sculpture, a vertical and a horizontal metal core bar intersect in the form of a cross. The vertical core bar reaches up to where the neck is, and there is an additional vertical core



Drawing 3. Inserted Metal Plates, Additional Casting, and Repairs of Fig. 7

bar within the head (Fig. 11). That is to say, two separate metal core bars were used in the body and head. Besides, despite the smooth surface of the sculpture's collarbone area (Fig. 12), γ-ray radiography revealed thick, horizontal protruding lines on the inside of the base of the neck, which is thought to be burrs created during casting. The two vertical metal core bars indicate that the inner cores for the head and body were sculpted separately and then joined. This caused microcracks between the attached parts of the head and body, and molten bronze flowing into the cracks formed burrs.

According to XRF analysis, the main body of the sculpture is an alloy of copper and tin (approximately 5% tin). However, the copper plate attached on the back and additional repairs on both sides of the sculpture are made of an alloy of copper and lead (approximately 3% lead) with no tin. Moreover, the detached skirts of the robe and some parts of the decorations on the crown were revealed to be alloys of copper and lead (Drawing 4). This suggests multiple—at least two or more—casting processes were carried out. The re-casting with copper-lead alloys and repairs resulted from some casting defects induced by an irregular flow of molten metal during the first casting process and some parts of the skirt where molten metal could not easily reach since they are separated from the main body.[3]

Based on scientific analysis and observation of the interior of National Treasure No. 78, it is highly likely that the sculpture was produced using lost-wax casting. However, it also presents features of piece-mold casting, such as the thin and even walls of the bronze. The modeling method is also unusual compared to the typical process. The inner cores for the head, body, and lotus footrest with the left foot on were separately shaped and wax-coated. These parted wax models were then joined together to form a single, complete wax model for the sculpture. The exact reason for this is unknown. Nevertheless, since already hard-to-handle material wax becomes far more difficult to manage as it gets larger, we suspect that National Treasure No. 78 was produced in separate pieces.

This sculpture appears to have been created by shaping an inner core similar in size and form to the desired finished image, applying a thin, even wax layer, and then carving into the surface of wax as desired. The use of a thin wax layer brought out the consistent thickness of the sculpture and the matching internal and external forms, both often found in sculptures using the piece-mold casting. The thin wax layer also led to the flat, nearly volume-less expression of drapery folds and belt decorations. The wax-coated head and left foot with the lotus footrest were sculpted and attached to the main body,

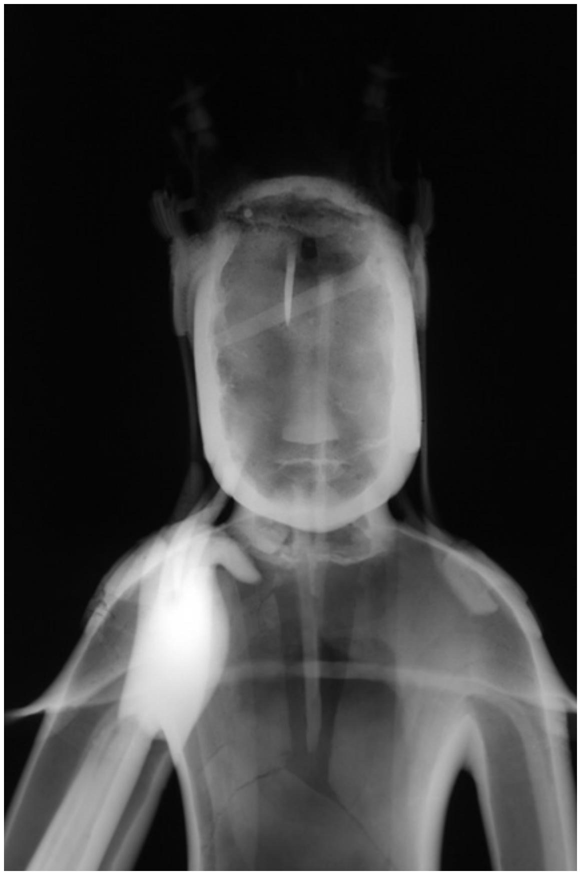
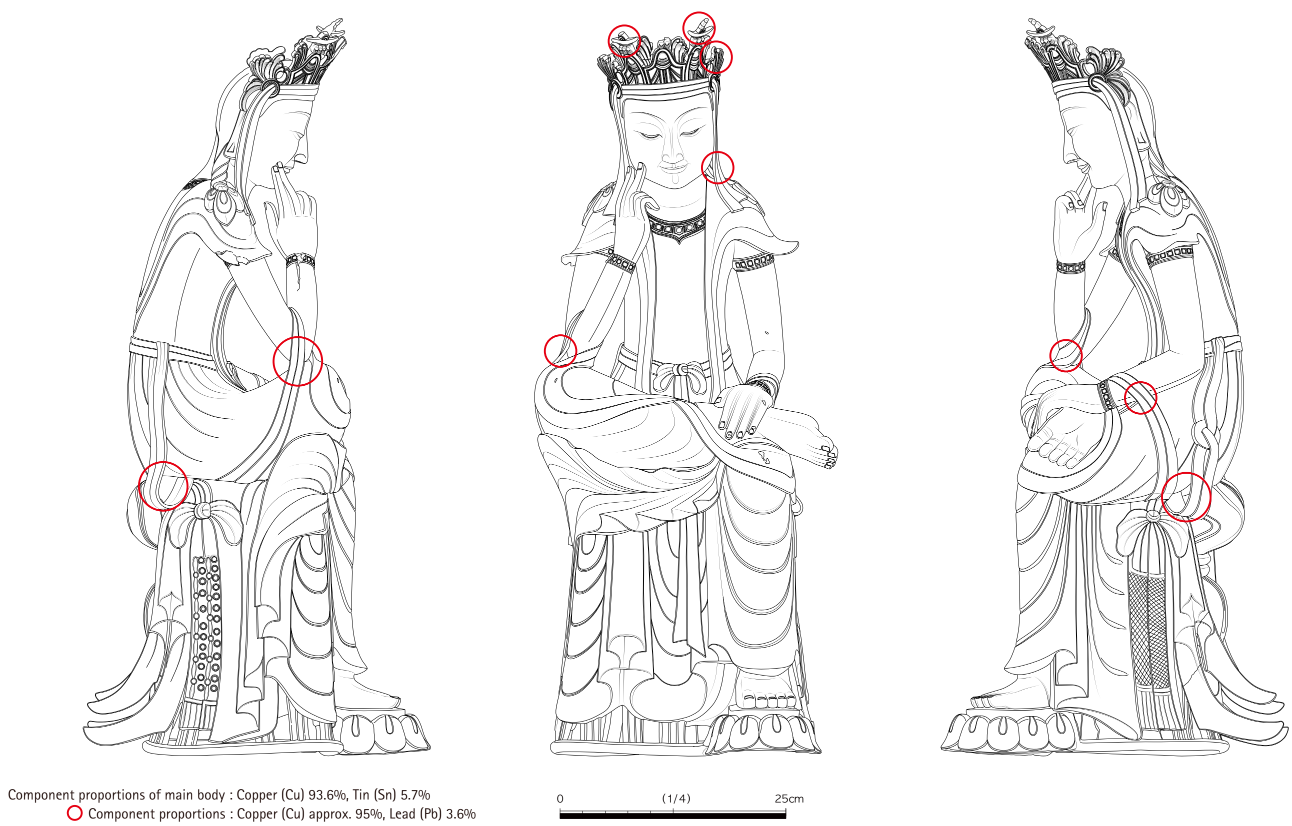
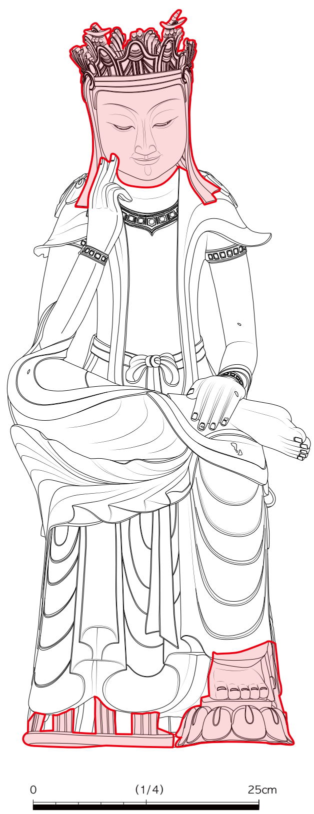


Fig. 11. γ-ray Radiography Image of Fig. 7

Fig. 12. Upper Torso of Fig. 7



Drawing 4. Metal Components of Fig. 7



Drawing 5. Three Sections Sculpted Using Additional Wax of Fig. 7

and round sculpted wax edges at the bottommost pedestal were also added (Drawing 5). After this basic shape for the sculpture was formed, the wax image was completed by carving detailed designs and drapery that is detached from the main body. It was then meticulously coated with additional clay to form the outer mold and dried. The wax was melted and completely removed through the application of heat. Next, molten bronze was poured into the channels left by the wax. However, the molten bronze failed to penetrate to the center of the back, waist, the upper portion of the rear of the cylindrical chair, the top of the head, and the drapery that is detached from the body, hair, and the endpieces of the crown, resulting in casting defects. These parts were filled in using a molten alloy of high-purity copper and lead, rather than the copper-tin alloy used during the initial casting process. The molten alloy was poured directly into some of the defective parts, while separately cast segments were attached to others. It is hard to know with perfect certainty why alloys composed of different metal elements were utilized for these repairs. However, such alloys were likely used since alloys with a high percentage of copper allow easier repairs. Furthermore, it is possible that the lead detected was used for soldering rather than alloying. Even though the relatively thin-walled design of the sculpture compared to its size did not allow the molten bronze to flow smoothly, the defective parts were perfectly repaired using advanced soldering techniques and the properties inherent in the metal. Accordingly, a well-made sculpture was created with the repairs indistinguishable to the naked eye.

Characteristics and Production Methods of Gilt-bronze Pensive Bodhisattva (National Treasure No. 83)

National Treasure No. 83, a Gilt-bronze Pensive Bodhisattva (Fig. 13), has been referred to as Pensive Bodhisattva with a “Three-peaked Crown” (三山冠) since the sculpture wears a distinctive crown featuring a row of three rounded peaks. It has also been called “Deoksugung Pensive Bodhisattva” since it was once in the collection of the former Deoksugung Palace Museum (integrated into present-day National Museum of Korea in 1969). Both National Treasure No. 83 and the previously-discussed National Treasure No. 78 of similar size are among the finest examples of Korean Buddhist sculpture. Its resemblance to Wooden Pensive Bodhisattva at Kōryūji Temple in Kyoto has led to a comparative discussion of these two sculptures in terms of Buddhist art history (Min Byoungchan 2015, 271).

The Yi Royal Household Museum (later Deoksugung Palace Museum) purchased this sculpture for 2,600 won (nearly two billion in today's won, based on the rice price) in 1912 from Kajiyama Yoshihide (梶山義英), a Japanese antique dealer who was active in Seoul. However, its precise excavation site is unknown. Sekino Takashi (關野貞), a professor at the University of Tokyo who conducted research on cultural assets in Korea, mentioned that the sculpture was found at a temple site near the Oreung Royal Tombs in Gyeongju, but he failed to provide concrete evidence. Based on the testimony of the former director of the Gyeongju National Museum, Osaka Kintarō (大坂金太郎), head monks at temples around Gyeongju, and neighborhood residents, Dr. Hwang Suyeong suggested that the sculpture might have been unearthed from a temple site in the vicinity of Seonbangsa Temple Site (禪房寺址) on the west side of Namsan Mountain in Gyeongju (Hwang Suyeong 1998, 37–41).

National Treasure No. 83 wears a three-sided crown consisting of three pieced-together semicircles. Its unadorned

Fig. 13. Gilt-bronze Pensive Bodhisattva. Silla, early 7th century. H. 93.5 cm. National Museum of Korea. National Treasure No. 83

Fig. 14. Head of Gilt-bronze Pensive Bodhisattva. Excavated from Hwangryongsa Temple Site. Silla, early 7th century. H. 8.2 cm, W. 4.9 cm. National Museum of Korea

Fig. 15. Interior of Fig. 13

surface creates a simple yet intense impression. The shape of the crown is a relatively unique style rarely seen in other countries, including India and China. However, similar examples can be found in Pensive Bodhisattva sculptures from the Silla Kingdom, including Rock-carved Pensive Bodhisattva at Sinseonam Hermitage on Danseoksan Mountain in Gyeongju, Head of Gilt-bronze Pensive Bodhisattva excavated from the Hwangryongsa Temple site (Fig. 14); and Gilt-bronze Pensive Bodhisattva found in Seonggeon-dong, Gyeongju (Min Byoungchan 2015, 271).

Like National Treasure No. 78, this sculpture has been studied both with the naked eye and also with scientific methods, including γ-ray radiography. Its bronze alloy components were examined through XRF analysis. These analyses have revealed several important characteristics related to the production methods involved.

As seen in National Treasure No. 78, the topography of the interior of this sculpture mostly matches to its exterior (Fig. 15). Core pins maintaining a gap between the inner core and outer mold are also found in several places. Some of the clay used for the inner core remains inside the sculpture, including small fragments of thin vegetative stems and sandy clay mixed with coarse sand (Fig. 16). This is a considerable departure from the case of National Treasure No. 78, which used very fine clay (Fig. 17).

Like National Treasure No. 78, National Treasure No. 83 was created using a conventional lost-wax casting in which the

Fig. 16. Detail of the Clay Used for the Inner Core of Fig. 13

Fig. 17. Detail of the Clay Used for the Inner Core of Fig. 7

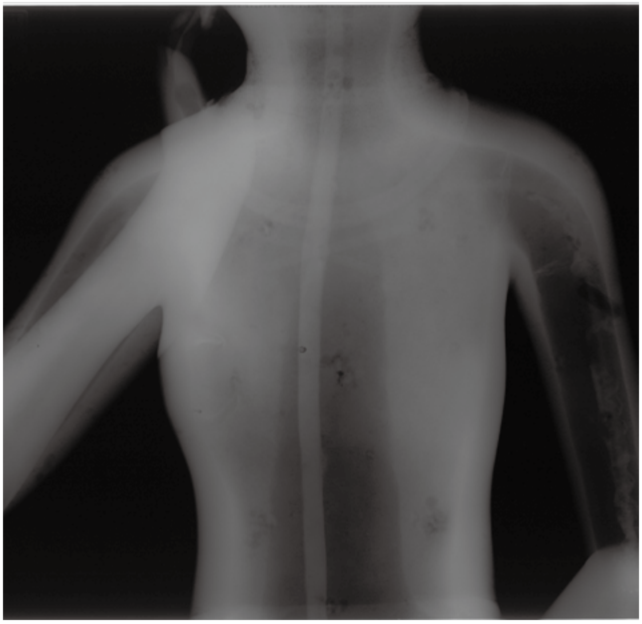
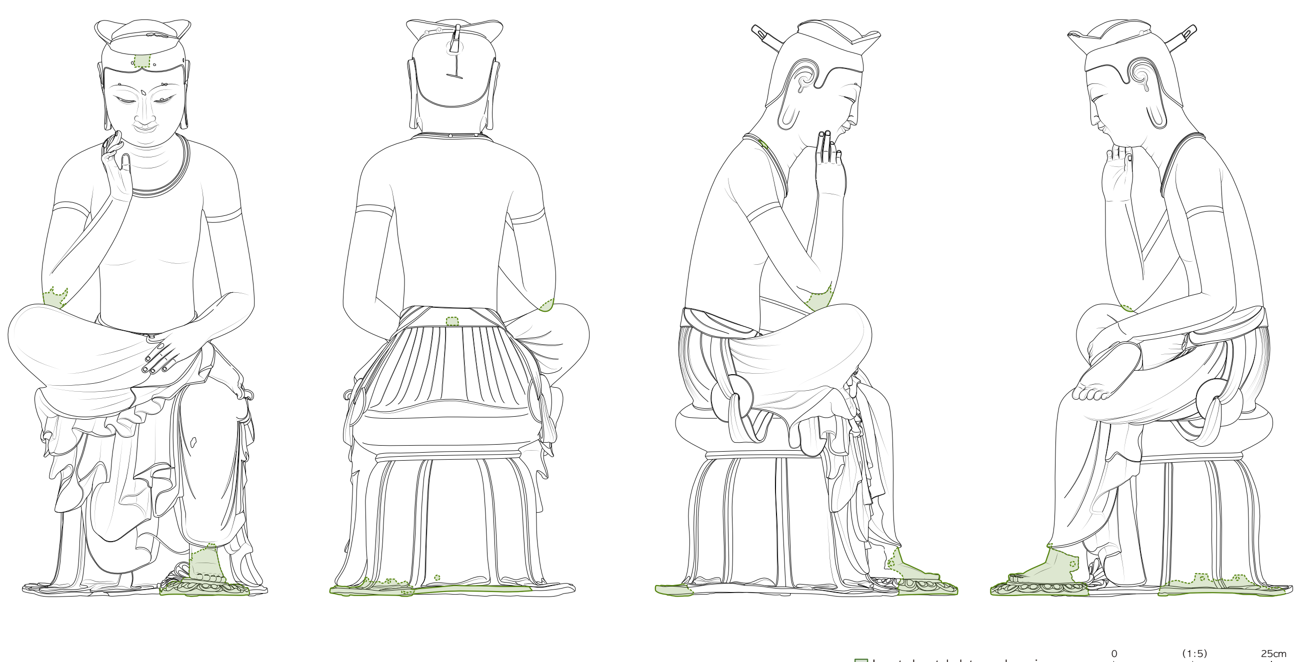


Fig. 18. γ-ray Radiography Image of Fig. 13

inner core was molded into a shape similar to that of the desired image, the inner core was covered with wax, the wax was further sculpted, the wax was removed with heat, and molten bronze was poured into the space left behind. However, it differs from No. 78 in that the head and body made up a single inner core. Except in the lower areas of the rear of the pedestal, the left foot, and the lotus-shaped footrest, no severe casting defects are present. The thickness of National Treasure No. 83 is greater than that of No. 78, which resulted a smooth flow of the molten bronze. Besides, the use of an inner core mixed with sand and thin plant stems cut into three-centimeter lengths facilitates the release of air from the inner space, which would otherwise interrupt the flow of molten bronze. In terms of casting method only, National Treasure No. 83 demonstrates more advanced technique compared to No. 78.

γ-ray radiograph has shown that inside the sculpture is a thick, square metal core bar that descends from the head to the pedestal. Two other metal core bars in the chest cross in the shape of an "X" and extend to both arms (Fig. 18). The converging points of the vertical and the two horizontal core bars were not knotted or tied with strings. Instead, the thin horizontal bars penetrate the thick bar through drilled holes, intersecting there like a cross. The thin bars extending into both arms are securely fastened to the thick bar, which prevented defects that could have otherwise occurred due to shifting in the inner core within the slim arms during the casting process. The thin bars inside the arms are coiled with a twine-like wire. This coiled wire, which is not found in National Treasure No. 78, is presumed to have been used to more securely attach the coarse-grained sandy clay to the metal bars.

According to the XRF analysis of the metal components, the main body of National Treasure No. 83 consists of bronze with 4–5% tin. This is nearly identical to the composition of the main body of National Treasure No. 78. Three repaired parts—



Drawing 6. Inserted Metal Plates and Repairs of Fig. 13 (National Museum of Korea 2017, 66–67)

two on the bottom of the cylindrical chair and one on the frontal left foot resting on the lotus footrest—also underwent the XRF analysis. It was revealed that only one of them was repaired using bronze with identical components as the main body, but the left foot-footrest and the repair on the bottom-left chair were repaired using nearly pure copper with almost no tin (Drawing 6). The section where the repair materials match those of the main body is thought to have been repaired around the time when the sculpture was cast. The repairs on the other parts are presumed to have been performed during the Unified Silla period or later. The difference in the forms of the surface indicates that the repairs on the pedestal were not carried out simultaneously. In a similar vein, the use of pure copper, which began to be fully utilized for Buddhist sculptures during the Unified Silla period, suggests that these repairs were also performed at different times. It is likely that the three sections were all repaired when the sculpture was first cast, but two of the sections later failed and had to be repaired once again.

Conclusion

This comprehensive examination of National Treasures No. 78 and No. 83 through careful observation with the naked eye, γ-ray radiography, and XRF analysis of the metal components has improved the understanding of these sculptures and allowed inferences to be made about their production methods.

Fundamentally, these two sculptures were both produced using lost-wax casting with core pins. However, they show differences in the modeling of the inner core and the application and the sculpting of the wax.

A vertical metal core bar was inserted into the head and another into the body of National Treasure No. 78. Inside the clavicle area where the neck and chest meet are burrs created by the permeation of molten bronze. Moreover, repairs of its casting defects can be observed in several places, including the decorations of the crown, drapery, back, both sides, and cylindrical chair. Unlike the bronze of the main body containing tin, nearly pure copper was used for these repairs. The walls of the sculpture are very thin, measuring about four millimeters, and extremely fine clay was used for the inner core.

In the case of National Treasure No. 78, the inner cores for the head and body were separately sculpted, then a thin, even layer of wax was applied over the cores, creating rough wax model parts. The discretely-formed head and body were joined, and the left foot and footrest, which were sculpted only in wax without an inner core, were attached. Additional layers of wax were added to the protruding designs, such as the hair and belt decorations, and were further sculpted. After elaborately carving additional details, the whole wax sculpture was completed. An outer mold was established by covering the wax sculpture with clay. After the wax was removed with heat, molten bronze was poured into the mold to cast the sculpture. Its complex crown decorations, thin walls, and the fine clay used for the inner core allowing only poor air ventilation all hampered the flow of the molten bronze, leading to a number of casting defects. Accordingly, defective areas were repaired by recasting or by attaching new parts. Lastly, the surface of the sculpture was plated with gold. The thin layers of wax affected the volume of the completed work and created an intense feeling of flatness.

Compared to No. 78, National Treasure No. 83 presents a relatively simple internal structure of core bars. It has a single vertical core bar and two metal bars in the chest area extending into both arms and penetrating the vertical core bar to intersect in the form of a cross. This simple metal bar structure was firmly fastened to the inner core to hold it steady. Its inner core consists of a sandy clay mixed with pieces of thin plant stems, and its bronze is relatively thick at roughly 10 millimeters. This sculpture is considered to be almost perfectly cast and shows a high level of completeness with almost no repairs required beyond two spots on the bottom and the left foot.

In the case of No. 83, metal bars were erected, a single inner clay core was shaped, and a thick layer of wax was applied. By lightly carving the wax layer or adding additional wax, a complete wax model was achieved. Next, the wax image was covered with another layer of clay to form the outer mold. After the wax was removed with heat, molten bronze was poured in to cast the sculpture. Almost no casting defects occurred. After the bottom and left foot were repaired, the sculpture was finished with gilding. The use of the thick wax layer allowed an abundant sense of volume and added a three-dimensional effect and further reality to the drapery folds.

Although National Treasure No. 78 and No. 83 both employ the same production method, that is, lost-wax casting, they show differences components of the inner core, the thickness of the finished sculpture, and the usage of wax. In National Treasure No. 78, the fine clay core caused poor ventilation of the air trapped inside the mold channels when the molten bronze was poured. In turn, together with the thin-walled design of sculpture, this poor ventilation hampered the fluidity of the molten bronze, leading to numerous casting defects. On the other hand, National Treasure No. 83 achieved even thickness with a smooth flow of molten bronze and used a coarse-grained sandy clay for its inner core that facilitated the release of air. Both sculptures show a similar composition for the bronze with a roughly 5% addition of tin. However, they differ greatly in the level of casting completeness due to the fluidity of the molten metal, the method of using core bars to fasten the inner core, and the placement of core pins. Such differences indicate that National Treasure No. 83 utilized much more advanced casting techniques than did National Treasure No. 78.

Translated by Kwon Ye Gee and Park Shinhee

This article is an abridged and revised English version of "Casting Techniques of Gilt-bronze Pensive Bodhisattva Statues: Korean National Treasures No. 78 and No. 83" (금동반가사유상의 제작 방법 연구: 국보 78, 국보 83호 반가사유상을 중심으로), previously published in 2016 in *National Museum of Korea Art Journal* (미술자료) 89.

1 Piece-mold casting can, however, be used to cast sculptures with intricate structures if the piece is divided into several parts that can be cast separately and then welded together, or if the outer molds are split into several pieces.

2 The National Museum of Korea and Osaka University in Japan carried out the project "Korea-Japan Joint Study of East Asian Gilt-bronze Buddhist Sculptures from the 5th to the 9th Centuries" from 2009 to 2012. They conducted a component analysis of gilt-bronze Buddhist sculptures scattered around the world, including in East Asia, using a portable XRF. According to the results of this analysis, gilt-bronze Buddhist sculptures from most countries outside of Japan turned out to be composed of copper, tin, and lead. See Min Byoungchan and Kwon Kangmi 2017, 470–474.

3 Since some of the areas of the sculpture under examination contain a small amount of lead (about 1.5%), there is a strong possibility that the molten metal used for repairs was pure copper and that the lead is simply contamination or was used for soldering.

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