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Collaboration of Archaeologists, Historians and Bioarchaeologists During Removal of Clothing from Korean Mummy of Joseon Dynasty

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Abstract Recently, experts from various research fields made an interdisciplinary collaboration on well-preserved cultural or human remains discovered in fifteenth- to nineteenth-century Joseon tombs of Korea. The academic information acquired under the interdisciplinary collaboration was significant to researchers in Korea because it is entirely original and not to be commonly found in any library resource for historians. This report is the first of full, detailed descriptions about the research on Joseon tomb, by which the vivid glimpse of Joseon people's lives could be reconstructed, based on the clear archaeological, historical and biological evidences.

Keywords Korea · Joseon tombs · Clothing · Interdisciplinary study

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Introduction

In Korea, primary research on the people of the Joseon Dynasty (1392–1910) has been conducted, mostly based on extant historical documentation. This explains, at least in part, why archaeological findings of the same Joseon period have been given relatively scant attention until quite recently. For the past several decades, however, archaeologists have discovered Joseon tombs encapsulated by a lime-soil mixture barrier (LSMB tombs) that have surrendered cultural artifacts and human remains far better preserved than any of the other tombs discovered in Korea. The detailed archaeological findings obtained there were useful to obtaining a glimpse of Joseon people's lives.

One such example was our report on the 400-year-old Eung Tae's tomb (Lee et al. 2009a, b). An interdisciplinary working group composed of a variety of specialists collected well-preserved cultural artifacts such as clothing, letters, and memoranda from the tomb. The astounding preservation status aside, the academic value of Joseon tombs has begun to be reassessed because they provide invaluable clues useful for comprehending Joseon people and their society at a much deeper level (Lee et al. 2009a, b).

Among the various remains collected from Joseon tombs, the articles of highly preserved clothing have been very important to Korean textile historians. As early as 1964, Joseon clothing numbering, 200 or more pieces, were discovered from the tomb of Princess Cheong Yeon (1754–1821) (Koh 2006). From that time on, and especially once the construction boom in Korea picked up, additional plentiful examples have been collected from Joseon tombs. To the present time, clothing has been collected from 100 or more excavation sites, and the number of pieces collected since has exceeded 1,000, most of which are maintained in labs, museums, and institutions. Thanks to these resources and the clear evidence they represent, a history of Joseon clothing has been successfully reconstructed; even the differences in clothing styles for each timeline of the Joseon period can be ascertained in a detailed manner.

Joseon tombs, meanwhile, also have yielded another finding that has particular importance: well-preserved Korean mummies. Considering that no tradition of artificial mummification exists, and that the climate is completely unsuitable for natural mummification in Korea, the discoveries of Joseon mummies are truly exceptional. Even if the mechanism of mummification remains imperfectly understood, mummies have yielded rich information on the health and disease status of the Joseon people.

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Once scientific studies began in 2001, they have contributed significantly to the unraveling of the mystery of Korean mummies achieved thus far, becoming a well-established subject among Korean bioarchaeologists (Chang et al. 2006a, b, 2008; Kim et al. 2006a, b, 2008; Lee et al. 2007, 2009a, b; Lim et al. 2008, 2010; Oh et al. 2011; Seo et al. 2007, 2008; Shin et al. 2003a, b, 2009b, 2010, 2011).

One point that claims our attention, concerning studies on Joseon tombs, is the intense collaboration between archaeologists, textile historians, and bioarchaeologists. Initially, the researchers did not communicate with one another because the studies on Joseon tombs had been conducted independently in each specialty. After 2000, however, researchers began to feel the need to collaborate because the cultural and human remains were discovered together in the same Joseon tomb. Over the past several years, working groups of archaeologists, textile historians, and bioarchaeologists have been thus formed. Though they experienced many difficulties in the beginning, their collaborations have proven to be fruitful (Table 1). Such studies have started to answer many long-asked questions about Joseon tombs.

Joseon Tombs

The Joseon tombs reported in this study were constructed during the fifteenth to nineteenth centuries. According to previous archaeological reports, they are distributed over a significantly wide swath of the Korean peninsula (Fig. 1a). Well-preserved human remains and/or cultural artifacts have been found in those

Table 1 Joseon tombs examined by interdisciplinary collaboration of textile historians and bioarchaeologists in Korea

Tomb ID	Date of excavation	Removal of clothing in the lab	Affiliation
Yangju (child)	2001-11-15	X	A
Papyung Yoon	2002-09-06	O	B
Yongin	2005-09-14	X	C
Hadong 1	2006-04-08	X	C
Gongju 1–1	2007-02-13	O	C
SN 1–2	2007-10-25	O	C
Gangeung Choi	2007-11-09	O	C
SN PK	2007-11-16	O	C
Dangjin	2008-08-08	O	C
Seocheon	2008-08-22	O	C
Waegwan	2008-10-30	O	C
Hadong 2 (HD-2)	2009-06-01	O	C
Mungyeong	2010-04-18	X	C
Hongsung	2011-02-16	O	C
Sacheon	2011-10-14	O	C
Konkuk	?	X	C/D
Seoul	?	X	C

A, Dankook University; B, Korea University; C, Seoul National University; D, Konkuk University resembling, on account of the complete encapsulation of coffins in a LSMB, a well-made concrete block (Fig. 1b).

The Buddhist tradition, despite its having been deeply rooted in various Korean cultural traditions, began to be overturned at the end of fourteenth century. When the Confucianists toppled the Goryeo Dynasty (918-1392 CE), they undertook a reformation of Korean society, imposing strict restrictions on Buddhist practices in order to bring them in line with Confucianism, the new state ideology. Of the many Buddhist practices, the funeral ceremony became one of the highest-priority targets of the Confucianists' attacks.

The funeral rites of the Joseon Kingdom began to be stipulated by the codes of Confucianist rituals (*Garye* books) that were promulgated from the fifteenth century. Examples can be found in *Gukjo-ore-ui* (Joseon Dynasty 1474) or other guides to ritual published afterward (Table 2). Since the funeral rite provisions prescribed the structure of LSMB tombs in the fifteenth century, the prototype of the LSMB tomb emerged abruptly in the same period.

The abrupt emergence appears to have related to the cultural or ideological needs of the ruling class of Joseon society. The original structure of LSMB tombs had been recommended by Chu Hsi (1130-1200 CE), the famous reformer of Confucianism. He explained how LSMB tombs could be built as follows: "When the burial pit digging is completed, the mixture of lime, sand and soil must be spread on the bottom

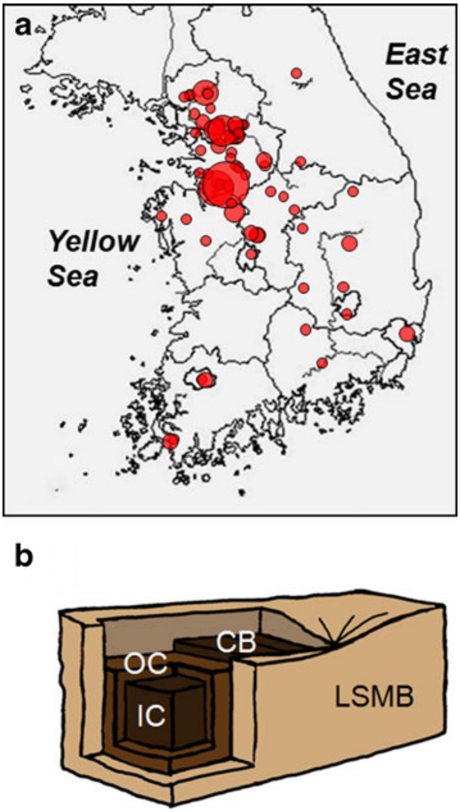

Fig. 1 **a** Distribution of LSMB tombs discovered in archaeological fields of Korea. The *circle* size represents the number of tombs found within the same region. **b** Structure of Joseon tomb fortified by lime-soil mixture barrier (LSMB). In general, two coffins were identified in the same tomb: inner (IC) and outer coffins (OC). Upon the outer coffin lid, cross bars (CB) were placed. The coffins were fully encapsulated by LSMB, isolating it from the outside environment

Table 2 Joseon Garye books

Korean name	Translated in English	Author(s)	Published year
Gukjo-ore-ui	National Five Rites	Suk Ju Shin et al.	1474
Jujagarye	Family Rites of Chu Hsi	Chu Hsi	1169
Garyejimnam	Collected Views on the Family Rites	Jang-saeng Kim	1685
Garyejimnamdoseol	Illustrated Account of the Collected Views on the Family Rites	Jang-saeng Kim	1685
Garyewollyu	Source Stream of the Family Rites	Yu Gye	1714

These books for ritual codes published during Joseon Dynasty included precise descriptions on the neo-Confuciansits' rituals, which should be invented by neo-Confucianist intellectuals of Joseon Dynasty

of the pit…. The mixture must also be poured to make the lateral wall of the LSMB…. It becomes hardened like a stone after time has passed. Bugs and grave robbers cannot infiltrate into the tomb" (Chu 1999). Chu Hsi thought that the Confucianists should be buried after death in the tomb that was to be composed of a wooden coffin fortified by and encapsulating the LSMB. The LSMB tomb was uniformly respected as the ideal burial system by the ruling class until the fall of the Joseon Dynasty.

Chu Hsi's recommendation on the LSMB tomb, in fact, came to be accepted by all ritual books published during the Joseon period. One of the most impressive examples was condolence items for the funeral ceremony collected from Joseon tombs. Since the shapes of the items discovered from Joseon tombs were almost identical to those depicted in *Garye* books of the Joseon Dynasty, we could understand how sincere descriptions for funeral ceremonies in *Garye* books were respected by Joseon nobles (Fig. 2).

Clothing Discovered in Joseon Tombs

The studies on *Garye* books have also been important to textile historians in Korea because even the dressing of a corpse preparatory to the Joseon funeral ceremony was believed to be performed in a fixed, deliberate way, following the restrictions in *Garye* books (Lee and Park 2002). According to them, dead Joseon people, differing from Egyptians wrapped in bandages, were described to have been wrapped using various clothes belonging to the deceased or his or her acquaintances.

In general, at the funeral ceremony, many pieces of clothing and textiles (numbering about 70) should have been interred into the coffin, the arrangement of which was strictly stipulated by the provisions in *Garye* books. Clothes contained in LSMB tombs could be classified into shrouds (*Suyi* in Korean) and those used to fill vacant spaces within the coffin (*Soryumeui, Daeryumeui,* and *Bogong* in Korean). The dead individual wore skirts, trousers, jackets or coats as *Suyi* clothing, and a number of clothes was stacked around the shrouded dead body (i.e., *Soryumeui* and *Daeryumeui*) or filled in the empty spaces of the coffin (*Bogong*) (Fig. 3).

Based on the knowledge accumulated so far, it appears that after many pieces of *Soryumeui* clothing were stacked upon the shrouded dead individual, they were

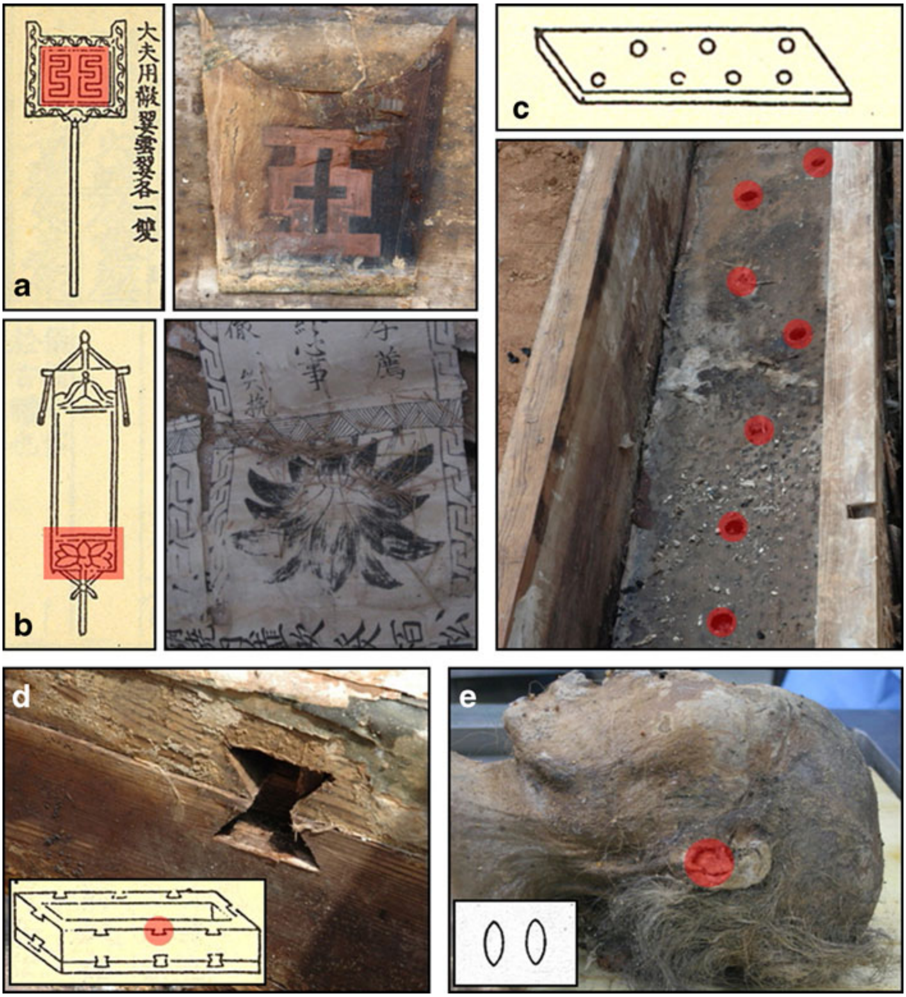

Fig. 2 The cultural remains depicted in Garyejimnamdoseol and the correspondent cultural artifacts discovered during investigation into Joseon tombs. **a** *Asap*, a symbol used during funeral procession. **b** *Manjang*, a flag used during funeral procession. **c** The basal plate of the coffin. Note the holes representing the Great Dipper. **d** The wood wedge securing the coffin and **e** ear plug were also depicted in Garyejimnamdoseol

wrapped altogether with a broad textile called *Soryumgeum*. The other *Daeryumeui* clothing was stacked again on the *Soryumgeum* wrapping package. The bundle was wrapped finally by a *Daeryumgeum* textile. After the dead-body bundle was set inside the coffin, many pieces of *Bogong* clothing were used for filling the empty space still remaining between the dead body bundle and the coffin (see Fig. 3).

For the past several decades, the general knowledge about Joseon clothing, especially about dressing a corpse for the funeral ceremony, has been expanded by the efforts of textile historians in Korea. However, even though we expect that the clothing contained in most Joseon tombs should have been arranged in similar fashion, there is still some debate among Korean researchers. Improving the

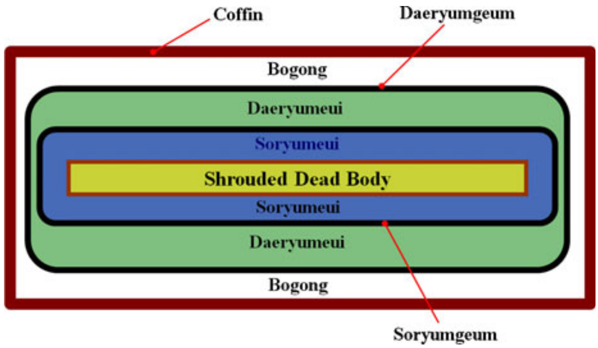

Fig. 3 The clothing arranged within the coffin. Shrouded dead body and *Soryeumeui* clothing were wrapped by *Soryumgeum*. The *Soryumgeum* bundle and *Daeryumeui* clothing were wrapped by *Daeryumgeum* once again. *Bogong* clothing was used to be packed in the empty space in the coffin

information by studying more medieval tombs is desirable for the full account of textile history of the Joseon Dynasty.

Archaeological Information

Actually, a detailed account of clothing removal from mummies has been very rare in any country until now. Except for virtual unwrapping of mummies by CT image processing techniques (Cesarani et al. 2003; Winder et al. 2006), we know of only one rare example: the unwrapping of a 1,600-year-old Peruvian female mummy. In this study, the authors showed a high elite female laid to rest in full regalia; the information thereby obtained has proven invaluable to the textile experts' study of the history of Peruvian clothing (Williams 2006).

Impressed by this feat, we also planned to report one of our Joseon mummy cases. Since the full process of clothing removal from Joseon mummies has not yet been introduced, we report here the details of one of our best studies on the Joseon tombs. In this case, the information, entirely original and not to be commonly found in any library resource for historians, can be acquired under the interdisciplinary collaboration of archaeologists, historians, and bioarchaeologists.

On June 1, 2009, by the Andong National University Museum, a LSMB tomb of the Joseon Dynasty (nicknamed HD-2 by bioarchaeologists) was unearthed in Hadong City of Korea (Fig. 4).

Coffins were identified when the LSMB was broken (see Fig. 4a–d). After archaeologists discovered a dead individual in the coffin, wrapped by well-preserved clothing, it was transferred to bioarchaeologists' lab (see Fig. 4e and f).

The personal profile of the dead female was obtained by historians, based on the information described in the tombstone or clan lineage book (*Jokbo* in Korean) (Fig. 5). Briefly, she was the second wife of Heehyun, the fourteenth descendant of the clan founder. She had three sons. Even though her birth and death dates were not available in the clan lineage book, we conclude that she must have lived in the late sixteenth to early seventeenth century because her husband was alive in 1610-50; and Duin, her third son, was born in 1627 (see Fig. 5). For a more in-depth study of this

Fig. 4 Archaeological Information of HD-2 tomb. **a** At the archaeological site, lime soil mixture barrier (LSMB) around the coffin started to be broken. **b** to **d** Inner (IC) or outer (OC) coffins were identified. **e** and **f** When the inner coffin lid was opened, the dead body was wrapped with a number of clothes. Asterisks in (**f**) indicate hemp ropes tied around the Daeryumgeum (OtC)

case, archaeologists called for an interdisciplinary collaboration between various research fields.

Removal of Clothing

In the current study, textile specialists removed the clothing from the HD-2 case. Suitable precautions were observed during the procedure of clothing removal to minimize biological contamination. During the removal of clothing, every researcher wore sterilized gowns, head caps, gloves and masks. The examination tools employed in clothing removal or biological sampling were sterilized before use (or some of them were disposable). Every procedure employed in shroud removal was recorded or photographed by textile experts.

Various kinds of space-filling *Bogong* clothing were first discovered by textile historians. After removing them, *Daeryumgeum,* the comforter used to wrap the body bundle, was exposed underneath (Fig. 6a). When hemp ropes around the body bundle

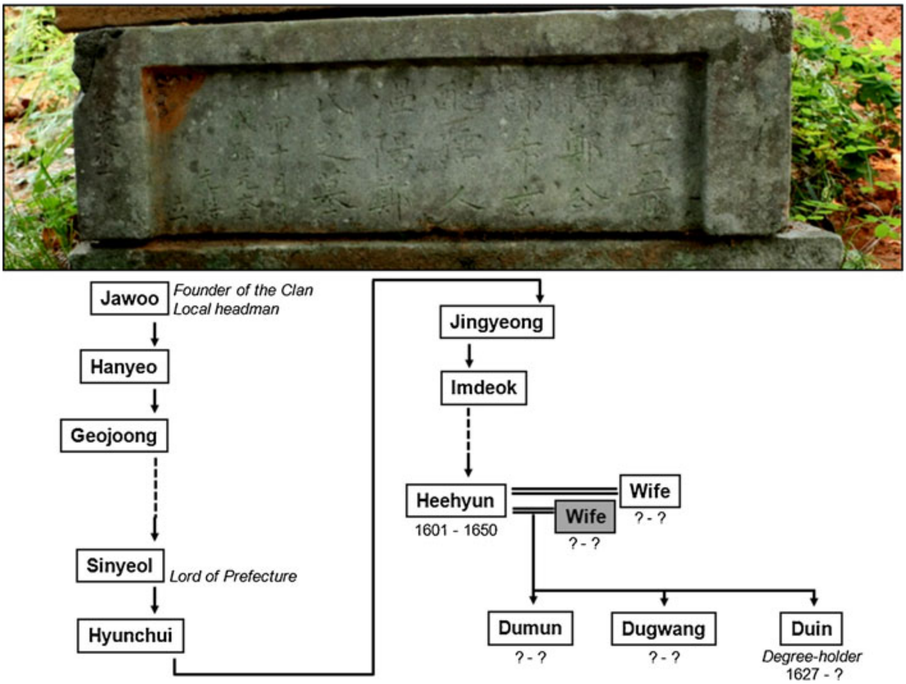

Fig. 5 A family tree of the dead female. The information was obtained from historic records such as tombstone (the upper picture) or family record of the Clan (the lower family tree). Mummified female was a second wife (*shaded box* in family tree) of Heehyun, the fourteenth descendant of the founder of the clan. There were three sons between her and her husband. Even though her dates of birth and death were not clearly known to us, she seems to have been living in early seventeenth century because her husband was living in 1601 to 1650; and her third son, Duin, was born in 1627

were untied; and the *Daeryumgeum* was unfolded (Fig. 6b), *Soryumgeum* textile could be identified just beneath it (Fig. 6c and d). After we removed the *Soryumgeum* textile (Fig. 7a), many pieces of *Soryumeui* clothing (four *Jogori*; one *Jangot*; one *Baji*; one *Gaedanggo*) were stacked upon the shrouded dead body (Fig. 7b and c). A *Jogori* was found covering the face (Fig. 7d), which covering, when removed, exposed the man's headdress and face veil (Fig. 7e). The *Soryumeui* covering the trunk also were found. On the *Soryumeui* clothing, we found a *Gaedanggo* trousers, possibly made for a child (Fig. 7e).

Beneath the *Soryumeui* clothing, we found that various types of the *Suyi* shrouds were worn by the dead female. The preservation status of the shrouds was quite good. A *Myeokmok* (face veil) was draped upon the dead female's face (Fig. 8a). A number of coats and skirts had been used as shrouds (Fig. 8b). The textiles used for the shoes, socks, and other garments and accoutrements were identified in the course of removing the clothes (Fig. 8c). The wig worn by the female could also be identified during the investigation (Fig. 8d).

Two *Jangot* (coat), two *Jogori* (jacket) and three *Jeoksam* (undershirt) were used as *Suyi* clothing. The dead person also wore five *Chima* (skirts), two *Gaedanggo* (open drawers), and three *Hapdanggo* (drawers). Superior preservation status of this case was clearly seen in some artifacts. *Jihye* (paper shoes) and *Boson* (socks) were

Fig. 6 **a** After removing *Bogong* clothing, *Daeryumgeum* (39), the comforter used to wrap the body bundle, was exposed. **b** After hemp ropes (35) were untied from the body bundle, the *Daeryumgeum* (39) was unfolded. **c** Another comforter *Soryumgeum* (28) could be also identified. 30, hemp ropes tied around the *Soryumgeum*. **d** is magnified image of (**c**)

preserved quite well (Fig. 9a–d). After the many *Suyi* pieces of jackets and undershirts were collected, the body, finally, lay exposed (Fig. 10). Information on the clothing and other cultural artifacts collected in unwrapping the current HD-2 case is summarized in Table 3.

According to textile historians' expectations, based upon the previous studies, the dead Joseon female was shrouded by various types of clothing, generally following a stereotypical way described in *Garye* books. However, we also found a unique feature that did not conform to the Confucianists' instructions. Briefly, the clothing in this study were arranged in the following order, from the surface to the deep layers: (1) Clothing filled in the empty space around the dead body bundle (*Bogong*); (2) *Daeryumgeum* textile; (3) *Soryumgeum* textile; (4) *Soryumeui* clothing; and (5) Shrouds (*Suyi*) worn by a dead person (see Table 3). After all, though the proscription on the arrangement of clothing in *Garye* books was sincerely respected by Joseon

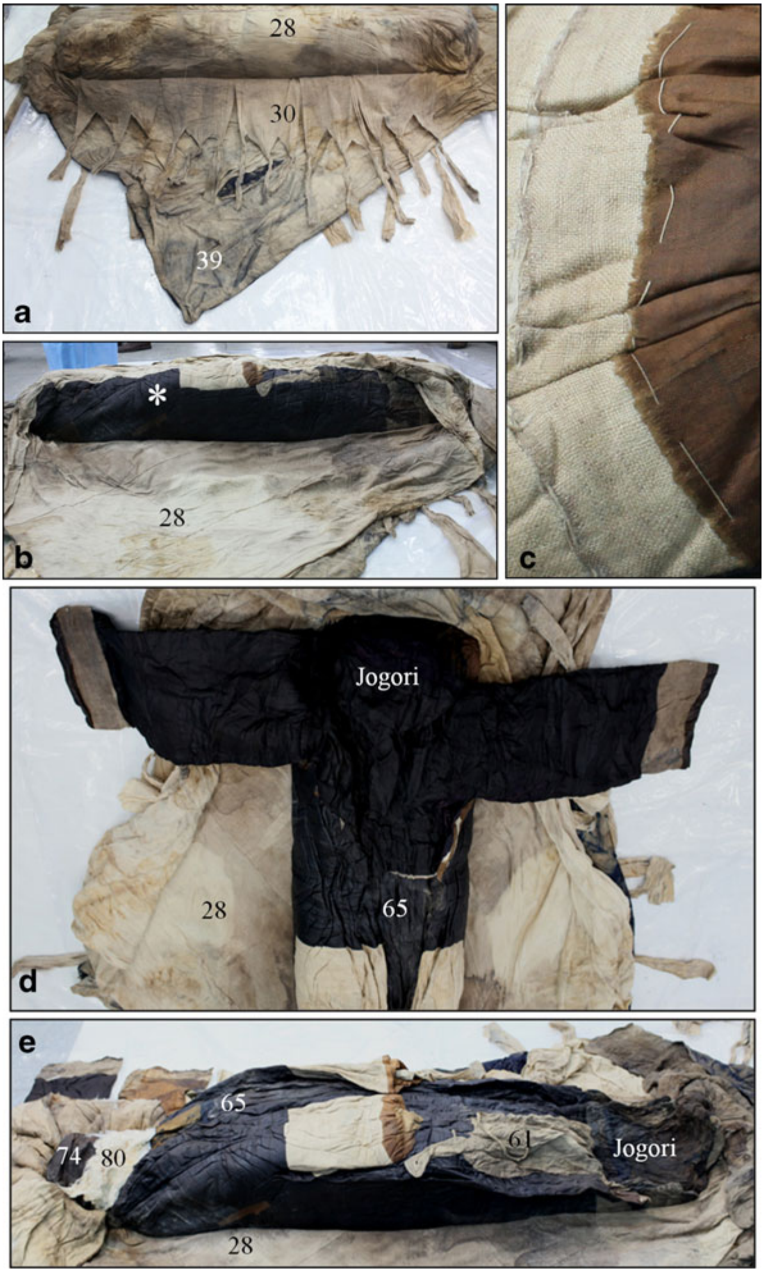

Fig. 7 **a** The arrangement of *Daeryumgeum* (39), hemp ropes (30) and *Soryumgeum* (28). **b** After removal of *Soryumgeum*, many pieces of *Soryumeui* clothing (*asterisks*) were stacked upon the shrouded dead body. **c** Magnified image of a *Soryumeui* clothing, showing well-preserved condition of the textile. **d** A *Jogori* was found covering the face. 65, the *Jangot* of *Soryumeui*. **e** After removal of *Jogori* covering the face, face veil (*Myeokmok*) was exposed. 80, cotton. Another *Jogori* could be seen in front of foot. A *Gaedanggo* trousers (61), possibly made for a child, could be found. 74, face veil

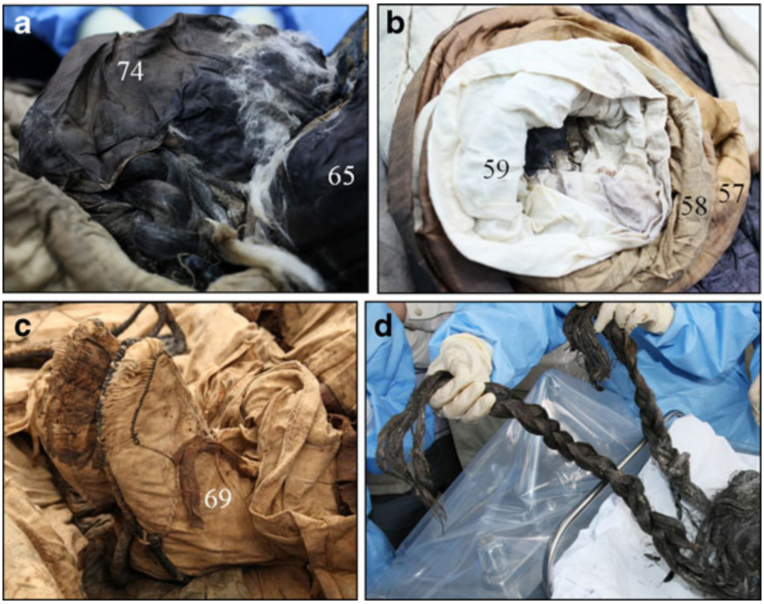

Fig. 8 Various *Suyi* shrouds worn by the dead female. **a** *Myeokmok* (face veil, 74) was draped upon the face. 65 is the *Jangot* of *Soryumeui*. **b** Many *Jeoksam* (57, 58, 59) coats were used as shrouds. **c** *Boson* (69), the socks, could be observed. **d** The wig worn by the female

people, our study showed minor modification: the absence of *Daeryumeui* clothing between *Daeryumgeum* and *Soryumgeum* textiles.

Even if the information about Joseon funeral rites has been successfully elucidated by a series of textile historians' researches, the exact findings in each case is still open to conjecture, as seen in this case. In this regard, the future collaborative study of the clothing from Joseon tombs will be extremely important for researchers in Korea because from them they can acquire much detailed information about how Joseon morticians shrouded the dead.

The Mummy Discovered in Joseon Tomb

Accidentally, like the cultural artifacts, the LSMB tombs have generally surrendered human remains, such as mummies, that were preserved much better than those taken from any other types of tombs discovered in Korea. Reports on Korean mummies discovered from LSMB tombs first surfaced as early as 1968. Though this and the subsequent finds aroused considerable media interest in Korea, no scientific studies were initially done, except for simple preliminary anthropological reports. Later in the 2000s, a scientific plan for Korean mummy studies started to be devised by different groups of scientists after they realized the need of interdisciplinary collaboration for revealing the mysteries of mummification in Korea (Table 4).

Actually, though desiccation (Spindler et al. 1996) or freezing (Hart-Hansen et al. 1991; Hess et al. 1998; Reinhard 1996; Zimmermann 1996) was proposed as preventative factors against the natural decomposition of human bodies, we cannot

Fig. 9 **a** *Chima* (51), *Jangot* (53), *Jogori* (55), and *Jeoksam (57, 58, 59)* were used as *Suyi* clothing. **b** Textile historians discovered that *Chima* (skirt, 51) was worn by the female loosely, that might be due to her pregnancy. **c** Superior preservation condition could be seen in *Jihye* (paper shoes, 78) and *Boson* (69, socks). **d** *Jangot* (53, 54) and *Jogori* (55, 56) used as shrouds

confirm why the human remains were preserved so perfectly in Joseon tombs. We can only suggest possible factors that may in part (or even acting together) have been responsible for it. One such factor might be the tomb design of LSMB tombs. Because well-preserved human bodies have been discovered only when LSMB constructed around the coffin was not destroyed even at the time of discovery, the

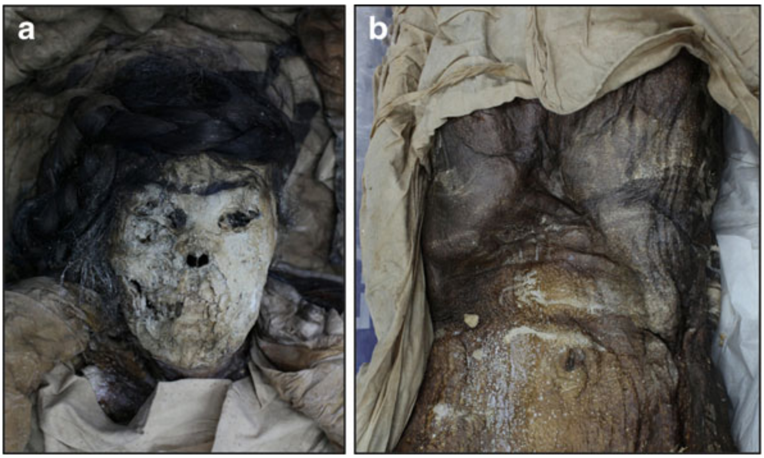

Fig. 10 After *Suyi* clothing was removed, the mummified body could be finally exposed. **a** Face. **b** Thorax and Abdomen

Table 3 Cultural remains from HD-2 tombs

Classification		Name	Material
Bogong	8	Hansam	Cotton
	7	Chima	Linen
	13	Gil	N.D.
	14	Gil	N.D.
	15	Sleeves	N.D.
	16	Sleeves	N.D.
	17	Seop	N.D.
	18	Mu	N.D.
	19	Mu	N.D.
	30	Mu	N.D.
	21	Mu	N.D.
	22	Boson	Cotton/Cotton
	23	Boson	Cotton/Cotton
	9	Durumagi	Cotton/Cotton
	10	Jeoksam	Linen
	11	Jogori	Hemp/Hemp
	12	Jogori (Child)	Cotton/Hemp
Ropes	35	Ropes	Hemp
Daeryumgeum	39	Daeryumgeum	Cotton/Cotton
Daeryumui	None	None	None
Ropes	30	Ropes	Hemp
Soryumgeum	28	Soryumgeum	Cotton
Soryumui	67	Jogori	Silk/Cotton
	66	Jogori	Silk/Cotton
	80	Cotton	Cotton
	65	Jangot	Cotton/Cotton
	64	Jogori (female)	Cotton/Cotton
	61	Gaedanggo (child)	Cotton
	63	Sapokbaji	Cotton
	62	Jogori (male)	Cotton
Shrouds	52	Belt	Silk
	53	Jangot	Silk/Cotton
	54	Jangot	Silk/Cotton
	55	Jogori	Silk/Cotton
	56	Jogori	Silk
	57	Jeoksam	Cotton
	58	Jeoksam	Silk
	59	Jeoksam	Cotton
	51	Chima	Cotton/Cotton
	50	Chima	Silk/Cotton
	49	Chima	Cotton

Table 3 (continued)

Classification	Name	Material
48	Chima	Cotton
47	Chima	Cotton
42	Gaedanggo	Cotton/Cotton
43	Gaedanggo	Cotton/Cotton
44	Hapdanggo	Cotton
45	Hapdanggo	Cotton
46	Hapdanggo	Cotton
74	Myeokmok	Silk
78	Jihye	Straw/Paper
69	Boson	Cotton

maintenance of a barrier might effect and guarantee the complete sealing of the inner space of the tomb from the outside environment.

We should also consider the possible involvement of lime (calcium oxide, CaO) in Korean mummification. This substance is known to have an affinity for water, combining with it in an exothermic reaction and producing the compound known as calcium hydroxide. In doing so, heat is generated, which has been speculated to be a crucial factor in mummification elsewhere (Aufderheide 2003). The heat produced by LSMB around the coffin might have been also responsible for the mummification of Joseon people. Of course, however, each of these

Table 4 All Korean mummies investigated by scientists

Mummy ID	Date of excavation	Investigated by
Yangju (child)	2001-11-15	I
Papyung Yoon	2002-09-06	II
Bong/black	2003	II
Hakbong	2004-05-20	II
Jangseong	2006-03	II
Hadong 1	2006-04-08	III
SN 1–2	2007-10-25	III
Gangeung Choi	2007-11-09	III
SN PK	2007-11-16	III
Dangjin	2008-08-08	III
Naju	2009-04	II
Hadong 2 (HD-2)	2009-06-01	III
Mungyeong	2010-04-18	III
Osan	2010-05	II
Hongsung	2011-02-16	III
Konkuk	?	III
Seoul	?	III

I, Dankook University; II, Korea University; III, Seoul National University hypotheses should be verified by well-designed archaeological experiments before generalization.

During the removal of clothing in our study, textile historians and bioarchaeologists also discovered the mummified, dead individual. Based on Fujii's equation (1960), the stature of the female mummy was estimated to be 149.75 cm. We determined that she was about 20–30 years old by estimating the age at death based on dental attrition. In the study of dental pathology, the dead female showed dental caries on both maxillary second molars (Fig. 11a). While examining the mummified organs in the internal cavity (Fig. 11b–d), we also collected biological samples for molecular analysis.

We discovered that the dead female seems to have been pregnant because fetal bones were discovered during an investigation into the female's trousers (Fig. 12a and b). The fetal bones include skull fragments, ribs, humerus, radius, ulna, hip bone fragment, femur, tibia and fibula but no hand or foot bones were discovered there (Fig. 12c). When we examined the dead woman's body, we also found that the abdominal skin was a little extended, which also reflected the pregnant state of the dead female. The age at death of the fetus was estimated to be about 32 weeks by the measurement of the right femur (75 mm), based on Shohat and Romano-Zelekha (2001) method. The mummified mother was not likely to be dead during parturition; rather, should have died from other etiologies than a difficult delivery.

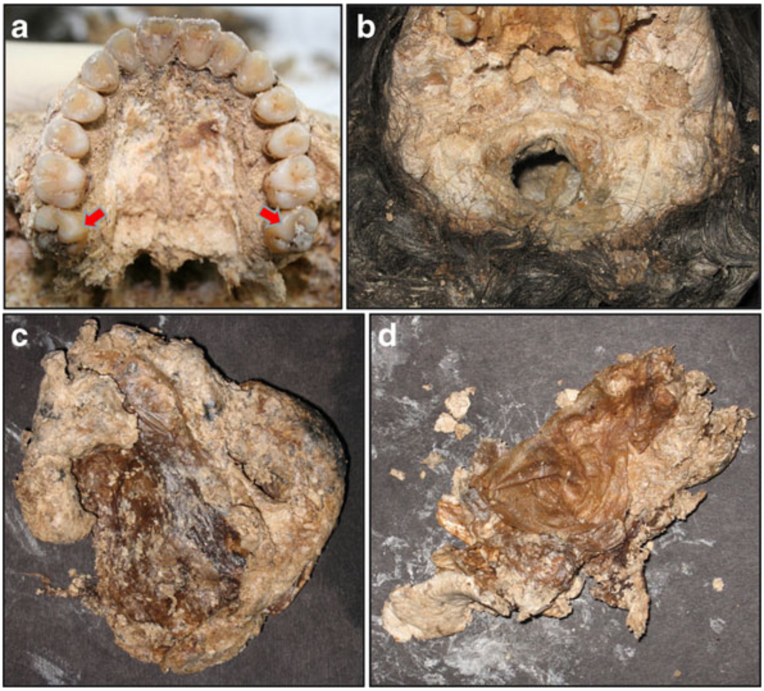

Fig. 11 **a** Maxillary teeth. Dental attrition shows that she was 20–30 years old. Dental caries were found in 2nd molar of both side (indicated by *arrows*). The preservation status of internal organs was quite good. **b** Brain in the skull. **c** Heart. **d** Intestine

Fig. 12 (**a**) Investigation into the female's trousers (**b**) Fetal bones from the trousers. (**c**) The fetal bones include skull fragments, ribs, humerus (H), radius (R), ulna (U), hip bone fragment (Hp), femur (F), tibia (T) and fibula (F)

Ancient DNA Analysis

Recently, aDNA study is a newly emerging field that is attracting keen attention in the community of archaeological science (Marota and Rollo 2002). In general, aDNA analysis has recently been used to investigate the genetic affiliations of the ancient subjects from archaeological sites, for clarifying their origin or the ancestor–descendant relationships between them and the present-day counterparts (Iwamura et al. 2004; Ricaut et al. 2006a).

In many respects, however, aDNA study is known to be different from modern DNA analysis. Damaged by post-mortem hydrolic and oxidative reactions, aDNA molecules are easily degraded into very short fragments, being detected usually in very low concentrations (Ho and Gilbert 2010; Pääbo 1989). Over the decades, the authenticity of aDNA work has been seriously challenged because a few aDNA reports have turned out to be the outcomes of modern-DNA contamination, possibly caused by PCR amplification of contaminant DNA (Marota and Rollo 2002).

To help researchers avoid the pitfall of modern DNA contamination, various recommendations for authentic aDNA studies, such as *Authenticity Criteria to Determine Ancient DNA Sequences* etc., have been developed as guides to aDNA researchers (Hofreiter et al. 2001). Briefly, specialized facilities and strict laboratory protocols were recommended for authentic aDNA analysis (Ho and Gilbert 2010). In our case, to meet the environmental criteria for keeping modern DNA contamination to a minimum, every research participant always wore sterilized gowns, head caps, gloves, and masks. Nobody was permitted to have contact with the cultural or human remains without permission. Every tool in this study was sterilized before use. The samples obtained were stored in sterilized containers. We also tried to follow the criteria as closely as possible.

For our aDNA analysis, we took the samples (0.2–0.3 g) of the HD-2 brain still preserved within the skull. The extraction of DNA from mummified brain followed the method of Kim et al. (2011). Following the extraction method of Kim et al. (2011), the surface of brain sample was abraded and exposed to UV for 20 min. The sample was incubated in 1 ml of TE buffer (pH 8.0; including 50 mM of EDTA; 1 mg/ml of proteinase K; 1 % SDS; 0.1M DTT) at 56 °C for 24 h. Total DNA from lysates was extracted with an equal volume of phenol/chloroform/isoamyl alcohol (25:24:1). Purification of extracted DNA was done with QIAmp PCR purification kit (QIAGEN, Germany); and using it, PCR amplification was done (Appendix I). Cloning and sequencing of amplified PCR products was done for determining consensus mtDNA haplotype of HD-2 case (Appendix II). The experiments were repeated by two independent labs A and B.

We could obtain the consensus sequence of mtDNA from nine clones obtained in Labs A and B. Most clone sequences were identical except for only two clones (PS1 B1-1 and PS2 A1-1) showing single nucleotide substitutions. Consensus sequence could be determined by alignment of individual clone sequences (Fig. 13). Consensus mitotype of the dead female was 16223T, 16300G, 16316G, 16362C, 73G, 153G, 309.1C, 315.1C.

Following the methods of Ricaut et al. (2004, 2005, 2006a, b) and Haak et al. (2005), the absence of modern DNA contamination could be confirmed by mtDNA haplotype comparison of hypervariable regions 1 (HV1: 16026-16365) and 2 (HV2: 73-340) from HD-2 and participating researchers' samples. Since we did not find any identical sequence between them (Table 5), DNA obtained from HD-2 sample should

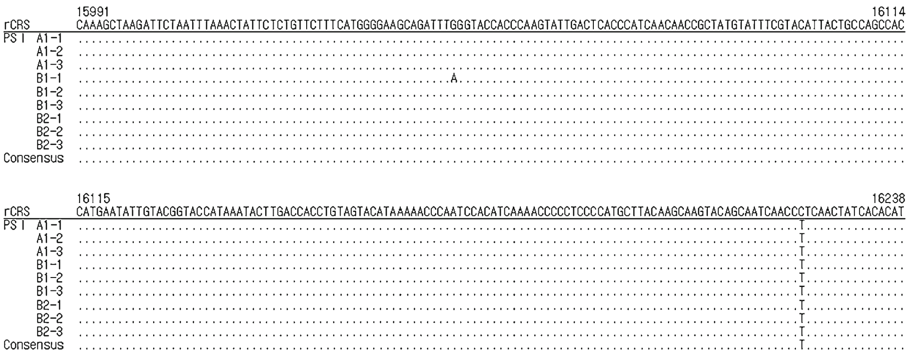

Fig. 13 PCR amplicons of PS I (15971–16258, 288 bp), PS II (16144–16410, 267 bp), PS III (15–240, 244 bp) and PS IV (155–484, 330 bp) mtDNA were cloned and sequenced. We could get the consensus sequence of mtDNA from 9 clones obtained in Labs A and B. PCR in lab B was repeated twice. Most clone sequences of Labs A and B were identical to each other, except for only two clones (PS1 B1-1 and PS2 A1-1) showing single nucleotide substitutions. Consensus sequence could be determined by alignment of individual clone sequences. rCRS, revised Cambridge Reference Sequence (accession number NC_012920)

Table 5 Hypervariable regions

Subject	Hypervariable region		Haplogroup
	HVI (16026-16365)	HVII (73-340)	
HD2	16223T 16300G 16316G 16362C	73G 153G 309.1C 315.1C	D4g
[a]RS1	16172C 16174T 16223T 16362C	73G 263G 309.1C 315.1C	D4g
[a]RS2	16183C 16189C 16220C 16254G 16298C 16362C	73G 248d 263G 310.1C	F3b
[a]RS3	16129A 16182C 16183C 16189C 16232A 16249C 16304C 16311C 16344T	73G 152C 248d 263G 310.1C	D6c

[a] RS1-3, researchers

have been the endogenous DNA of the dead person, but not the outcome of modern DNA contamination. The recovery and analysis of authentic aDNA sequences from Joseon people could be successfully achieved in this study, by genotyping every individual who had contact with a sample and excluding all possible sources of contamination during the experiment.

When haplogroups were assigned by sequence data of the control region using mtDNAmanager (http://mtmanager.yonsei.ac.kr), the haplotype of HD-2 belongs to the East Asian haplogroup D4g. The haplogroup is known to be the major one among northeast Asian populations, that was likely to have been expanded from the center of East Asia (Gao et al. 2007).

The Future of Interdisciplinary Collaboration

Recently, the information on cultural and human remains commonly obtained from LSMB tombs has become invaluable to Korean researchers. Initially, researchers in individual fields had independently studied Joseon tombs. Thus, the experts from the various specialties did not actively exchange their information. Though the data continued to be accumulated in a specific research field, a comprehensive view to acquire a vivid glimpse of the Joseon people's lives remained elusive.

However, archaeologists, historians, and bioarchaeologists in Korea began to collaborate with each other, owing to the basic fact that cultural artifacts and human remains commonly were found mixed together in Joseon tombs. First of all, as bodies in Joseon tombs are wrapped heavily in clothing, even at the time of discovery, bioarchaeologists require the assistance of textile historians in order to be able to collect their biological samples without causing damage to invaluable cultural artifacts. In addition, historical information can also be transferred back to bioarchaeologists, aiding them in their particular investigations of human remains. In this study, bioarchaeologists were informed of the historically obtained data concerning the dead individual's sex (female) and socioeconomic status (from a rich noble family). Such data transferred from historians beforehand were very benefitial to bioarchaeologists, in that they were used as contextual information in the scientific examinations on the same mummified female.

We should also note that bioarchaeologists' authentic aDNA analysis could not have been achieved without the textile historians' help. Though there are many experimental criteria recommended for authentic aDNA analysis, most of the provisions still centered on lab work (e.g., abrasion of bone surface for removal of contaminants, etc). However, as for archaeologically obtained samples, many scientists worried about the authenticity of results because most of them have been collected from places where potential contaminants are easily transferred (Hermann and Hummel 1994; Melchior et al. 2008; Roberts and Ingham 2008). To overcome this problem, sampling under well-appointed, contamination-free laboratory conditions becomes much more important for authentic aDNA analysis.

From the perspective of authentic aDNA analysis, sampling from Joseon mummies, in fact, has a number of merits. Above all, since the coffin is completely sealed in the Joseon tomb, the dead body is almost isolated from the outside environment (i.e., the surrounding soil) until the discovery of the tomb (Kim et al. 2008; Lee et al. 2007, 2009b; Lim et al. 2008; Seo et al. 2008; Shin et al. 2009a, b). Such isolation can be further fulfilled by the fact that the dead individual was heavily clad in clothes for the funeral. In fact, modern DNA contamination can be minimized if entombed bodies, which remain enshrouded in clothing and textiles at the time of their discovery, are subject to clothing removal by researchers who are knowledgeable and skilled in the art of sterilized sampling under well-controlled conditions. The benefits of interdisciplinary collaboration have not been limited to bioarchaeologists. Conversely, the biological information acquired by bioarchaeologists often proved relevant and beneficial to the work of textile historians. As an example of such collaboration, in this study we can see how anthropological studies on the mummified female could benefit the textile historians' interpretation of findings obtained during clothing removal.

Although the female was described in the clan lineage book as having had three sons, the records did not mention anything about her additional pregnancy. However, with the discovery of fetal bones, we can confirm that she was expecting her fourth child. The extent of fetal development (32 weeks) showed that she had died of an unknown pathology. Significantly, the fact that the woman was pregnant at the time of her death could not have been known by reference to any of the extant historical documents, but could be obtained only by anthropological examination. The anthropological findings could shed light, for textile historians, on why *Chima* (skirts) were worn so loosely (see Fig. 9b).

All in all, it can be stated with confidence that interdisciplinary collaboration has become much more important to the study of well-preserved cultural artifacts or human remains found within Joseon tombs. Academic information acquired in each research field could have been transferred freely between them, being used as contextual information in scientific examinations on the same subject. Even though there are before us many unresolved mysteries and technical difficulties, we can be optimistic about the prospects of this study because the data obtained from the Joseon tombs, on which textile historians and bioarchaeologists depend for their better understanding of Joseon society and people, is otherwise unobtainable.

Conclusion

In Korea, well-preserved mummies and associated cultural artifacts have been commonly found in Joseon tombs constructed during the fifteenth to the nineteenth centuries. Because the mummies were, with few exceptions, heavily shrouded, and cultural artifacts and human remains typically were found mixed together in the same tomb, experts from various research fields should have collaborated with each other for the study of Joseon tombs. Academic data obtained by researchers could have moved freely between them, as contextual information for each field's examinations on the same subject. This is the first full description of the interdisciplinary collaboration for a Joseon tomb, by which a particular glimpse of Joseon people's lives can be shown clearly based on the scientific evidence.

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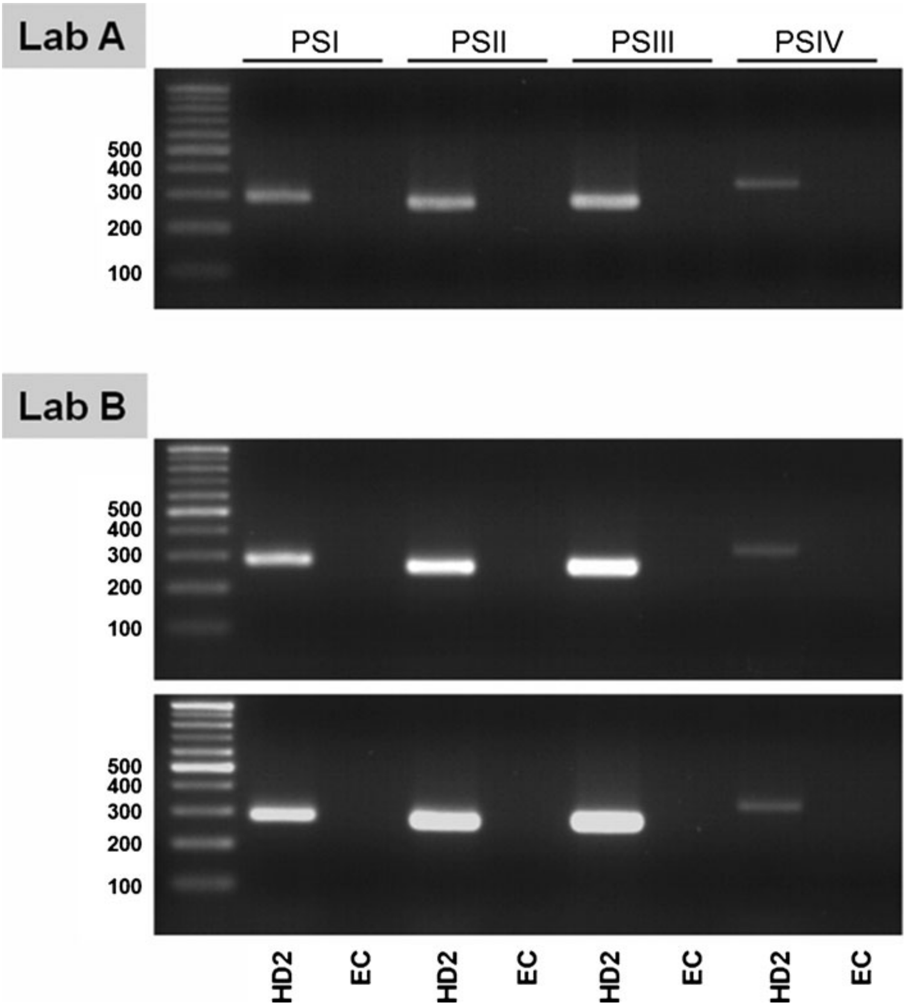
Appendix I. PCR Amplification in This Study

After quantification was done by NanoDrop™ ND-1000 Spectrophotometer (Thermo Fisher Scientific, MA, USA), the mixture for PCR amplification of DNA was prepared. 40 ng of DNA was mixed with premix containing 1 mg/ml of BSA (New England Biolabs, MA), 10 pmol of each primer (Integrated DNA Technology, USA), 0.25 mM of dNTP mixture (Invitrogen, USA), 1X PCR buffer, 2 mM of $MgSO_4$ and 1 unit of Platinum™ *Taq* Polymerase High fidelity (Invitrogen, USA). PCR conditions used in this study were as follows: pre-denaturation at 94 °C for 10 min; 38 cycles of denaturation at 94 °C for 20 s; annealing at 56 °C for 10 s; extension at 72 °C for 30 s; final extension at 72 °C for 10 min. PCR amplification was performed using a PTC-200 DNA Engine (Bio-Rad Laboratories, Hercules, CA). Primer sets used for this study were as follows. 288-bp PS I: F15971 (5'-TTA ACT CCA CCA TTA GCA CC-3') and R16258 (5'-TGG CTT TGG AGT TGC AGT TG-3'); 267-bp PS II: F16144 (5'-TGA CCA CCT GTA GTA CAT AA-3') and R16410 (5'-GAG GAT GGT GGT CAA GGG AC-3'); 244-bp PS III: F15 (5'-CAC CCT ATT AAC CAC TCA CG-3') and R258 (5'-GTT ATG ATG TCT GTG TGG AA-3'); 330-bp PS IV: F155 (5'-TAT TTA TCG CAC CTA CGT TC-3') and R484 (5'-TGA GAT TAG TAG TAT GGG AG-3') (Holland and Huffine 2011).

Appendix II. Cloning of Amplified DNA Fragment in This Study

When PCR products of 20 μl could be separated as specific bands (288 bp for PS I; 267 bp for PS II; 244 bp for PS III; 330 bp for PS IV) by a 2 % agarose gel electrophoresis, they were purified with QIAqucik Gel Extraction Kit (Qiagen, Germany).



Electrophoresis showed specific bands for PCR products of HD-2 case both in Lab A and B results (288 bp for PS I; 267 bp for PS II; 244 bp for PS III; 330 bp for PS IV). PCR in Lab B was repeated two times. EC, extraction (negative) control.

Ligation of amplified fragment into plasmid vector was done with pGEM-T Easy Vector System (Promega, USA). Briefly, quantity of extracted DNA was measured again by NanoDrop^{TM} ND-1000 spectrophotometer (Thermo Fisher Scientific, Waltham, MA, USA). 10 ul of ligation mixture (5 μl of 2X Rapid Ligation buffer, 1 μl of pGEM-T Easy Vector, 1 μl of T4 DNA ligase and 3 μl of gel extracted DNA) was incubated overnight at 4 °C; and after then, the vector was transformed into competent cells (ECOS-101, Yeastern Biotech, Taipei, Taiwan). They were then plated on LB agar plate (50 μg/ml of ampicillin, 0.5 mM IPTG, and 40 ug/μl X-

GAL); and were incubated at 37 °C for 12 h. Selected white colonies were incubated in 5 ml of LB Broth, with shaking for 12 h (at 37 °C, 220 rpm). After Plasmid in cultured bacteria was isolated with QIAprep spin miniprep kit (Qiagen, Germany), sequencing was done on each strand using ABI Prism BigDye Terminator Cycle Sequencing Ready Reaction Kit (Applied Biosystems, USA) according to manufacturer instruction. The sequence reaction products were analyzed by ABI Prism 3100 automatic sequencer (Applied Biosystems, USA).

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