Available online at www.sciencedirect.com

ScienceDirect

journal homepage: www.elsevier.com/locate/jasi

Original Article

Prevalence of sesamoid bones in the hands: 3D-reconstructed CT study

Hyun Il Lee [a], *Kyoung Hwan Koh* [b], *Hong Je Kang* [c], *Jae Sung Lee* [d], *Min Jong Park* [e,*]

[a] *Department of Orthopaedic Surgery, Gangneung Asan Hospital, University of Ulsan College of Medicine, Gangneung, Republic of Korea*
[b] *Department of Orthopaedic Surgery, Inje University Ilsan Paik Hospital, Goyang, Republic of Korea*
[c] *Department of Orthopaedic Surgery, Wonkwang University School of Medicine and Hospital, Iksan, Republic of Korea*
[d] *Department of Orthopaedic Surgery, Chung-Ang University, College of Medicine, Seoul, Republic of Korea*
[e] *Department of Orthopedic Surgery, Samsung Medical Center, SungKyunKwan University School of Medicine, Irwon-dong 50, Gangnam-Gu, Seoul 135-710, South Korea*

ARTICLE INFO

Article history:
Received 9 May 2014
Accepted 12 November 2014
Available online 2 December 2014

Key words:
Sesamoid bone
Hand
Prevalence
3-Dimensional computed tomography

ABSTRACT

Introduction: The prevalence of sesamoid bone in hand is known to be variable among populations of various geographic origins. Since counting with radiographs might be inaccurate due to superimposition of adjacent digits, we tried to overcome this obstacle using 3D-reconstructed CT in Korean patients. The purpose was to provide an accurate incidence of sesamoid bones using 3D-CT.

Methods: Sesamoid bones were examined in 427-CT images. 3D-CT images were analyzed by one observer and parts of hands (411-hands) were evaluated with radiograph to compare with CT results. Statistical analysis between the CT and radiograph results was performed.

Results: Sesamoids of metacarpo-phalangeal (MP) joint of the thumb were always present on both radial and ulnar sides, except for 9-cases (2.1%) where they were not present on radial side and 6-cases (1.5%) where they were not present on ulnar side. MP joint of the little finger was the second most prevalent location (62.8%). The sesamoid of the index finger MP joint and thumb interphalangeal joint was observed in 44% and 42.4%, respectively. There was a rare incidence in the MP joints of middle and ring finger (0.7%). The incidence of sesamoid bone was statistically different between the two counting methods for the MP joints of index and little finger and thumb interphalangeal joint ($P < 0.005$).

Discussion: We could observe five frequent sesamoid bones in the MP joints of the thumb, index, and little finger, and the interphalangeal joint of the thumb in Korean individuals. 3D-CT images revealed the accurate incidences of hand sesamoid bones.

* *Corresponding author*. Tel.: +82 2 3410 3509; fax: +82 2 3410 0061.
E-mail address: mjp3506@skku.edu (M.J. Park).

http://dx.doi.org/10.1016/j.jasi.2014.11.010

1. Introduction

The sesamoid bone, usually embedded in the tendon near the joint, has the role of maximizing the lever arm of the tendon and functions as a pulley.[1–3] In the hand, sesamoid bones are usually found in the metacarpo-phalangeal (MP) joint of the thumb, index, and little finger. Proper knowledge about the location of the sesamoid is important in the differential diagnosis of hand diseases. The sesamoid bone can be easily misdiagnosed as an avulsion fracture fragment, especially in comminuted articular fractures. Furthermore, sesamoid bones can themselves be fractured[4] or trapped inside the joint after a fracture-dislocation.[5] Inflammation, arthritic changes and painful clicking were reported as clinical features.[6–8] Trigger thumb was also observed in association with the sesamoid bone, mimicking stenosing tendinopathy.[9,10]

The prevalence and distribution of sesamoid bones in the hands is known to be variable among populations of various geographic origins.[11,12] It was reported that the incidence of thumb sesamoid bone is 100%, and that of the MP joints of index and little fingers is roughly 35% and 70%, respectively, in Caucasians.[13] In African people, the distribution was largely different to Caucasians.[14] Recently, the data from the Arabic population was also reported.[12] However, until now there has been no study demonstrating the prevalence of sesamoid bone in an East Asian population in English literature.

The presence of sesamoid bone has been usually counted by cadaveric dissection[15] or plain radiograph.[11–14,16] Radiograph is a simple method to count a large number of subjects; however, there might be difficulty in accurate counting due to the superimposition of complex small bones such as adjacent metacarpal and phalangeal bones. Recently, a development of CT reconstruction that makes 3D-images possible has provided greater details of the complex bony structure in the orthopaedic arena. To solve the weakness in counting sesamoid bones with a plain radiograph, we used 3D-CT scanning for counting of sesamoid bones in Korean patients who visited hand clinics. This is the first attempt to utilize 3D-CT for sesamoid counting. Therefore, the purpose of the current study was to evaluate the prevalence of hand sesamoid bones with better accuracy using 3D-reconstructed CT in a Korean population.

2. Methods

From March 2005 to December 2009, the cases (East Asian population) from 4 regional hospitals in Korea were gathered. We retrospectively searched the database and found patients who had received 3D-reconstructed CT of the hand in an outpatient clinic or emergency department. We included only the adult patients, aged over 21 years at examination, as these patients have reached full skeletal maturation. This inclusion criterion resulted in a total of 474 hands. The exclusion criteria were as follows: 1) when the full area of the hand from the distal phalanx through to the proximal carpal bone was not covered (30 cases); 2) when there was an amputation of any part of the digits (1 case); 3) when a displaced or comminuted fracture extended to the articular surface (11 cases); and 4) when advanced osteoarthritis with multiple osteophytes or rheumatoid arthritis was seen (5 cases). Undisplaced fracture involving the joint was not excluded for the analysis. Shaft fracture was also not excluded. After the exclusions, a total of 427 hands remained that were appropriate for further analysis.

The CT image was obtained with LightSpeed VCT (GE Healthcare, Buckinghamshire, United Kingdom) or 16-multidetector Mx8000-IDT unit (Philips Medical Korea, Seoul, Korea). Most Images were obtained in a high-resolution mode using the 512 × 512 pixel matrix. The collimation was 16 × 0.625 or 16 × 1.25 mm, the tube parameters were 120 kVp and 200 mA. Multidetector CT was carried out and 3D reconstruction with multi-planar reformation (sagittal, coronal, and axial image) was performed with program provided by CT supplier (AW 4.0 [GE Healthcare] or Extended Brilliance Workstation [Philips]). The reasons for CT examination in individual patients were mostly due to acute trauma (241 patients for distal radius fracture and 121 patients for carpal bone, metacarpal, and phalanx fracture). The remaining portion were due to evaluation of a painful symptom of the hand (35 patients), osteoarthritis (12 patients, mostly carpometacarpal arthritis in the thumb), contusion (5 patients), a mass (3 patients), malunion (3 patients), deformity (2 patients), contracture (2 patients), or instability (2 patients). There were 281 male patients (66%) and 146 female patients (34%). Average age at the examination was 47.8 years old (range 21–89). The right hand was evaluated in 186 patients (44%) and the left in 241 patients (56%). There were 6 bilateral cases.

After gathering the CT images, image evaluation was performed by a single orthopaedic surgeon, who was hand fellowship-trained (Fig. 1). Axial, sagittal or coronal images were utilized as an adjunct to 3D-reconstruct image in order to enhance the accuracy of the counting. All the MP joints and interphalangeal joints of all five digits were inspected for the presence of sesamoid bone. The sesamoid bones of the radial and ulnar side were separately counted on the thumb MP joint. A fragment with a sharp margin presenting in an unusual location was considered as an avulsion fracture after review of the specific trauma history. Cases that were doubtful regarding the counting of the sesamoid bone on the 3D-CT (such as an old fracture fragment) were discussed among a panel of five hand surgeons, and a majority decision was considered final. Five cases were discussed among the panel due to ambiguity of the appearances.

We compared the results of the CT counting with the plain radiograph in patients who had both types of images available (411 cases). In order to do this analysis, the same orthopaedic surgeon analyzed the antero-posterior and oblique radiograph by conventional methods 1 month after the CT analysis (Fig. 1). The concordance rate between the two methods was calculated.

Statistical analysis was performed using SPSS version 19.0. The comparison of frequency regarding to gender or side was conducted with Fisher's exact test. The concordance rate between simple radiograph and 3D-reconstructed CT was evaluated by McNemar's test. A p-value of ≤ 0.05 was considered significant.

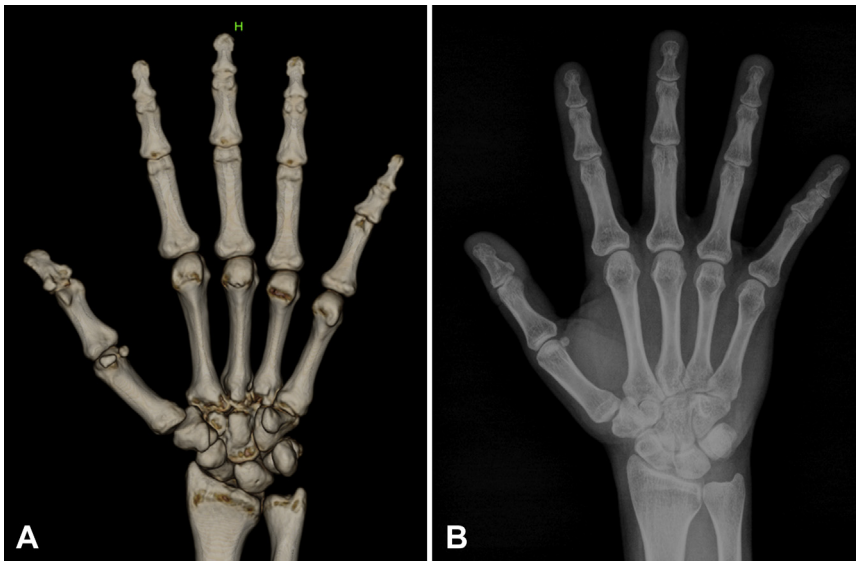

Fig. 1 – Evaluation of images. (A) Typical 3D-reconstructed CT image (B) Antero-posterior X-ray of the hand.

3. Results

The average number of sesamoids in one hand was 3.5 (range, 0–7, Fig. 2). Location of sesamoid and its respective prevalence are described in Table 1. Two sesamoid bones in the thumb MP joint were the most frequent findings, at 97.9 and 98.6%, respectively for the radial and ulnar side. A sesamoid bone in the MP joint of little finger was the second most frequent finding. Sesamoid bones in the MP joints of middle and ring finger were rare, at 0.7%, respectively (Fig. 3). These sesamoids were usually much smaller than the others. The sesamoid bones of the interphalangeal (IP) joint were mostly observed in the thumb (42.4%). In one patient, the proximal IP joint sesamoid bones were observed in the middle and ring fingers, respectively.

We evaluated the pattern of sesamoid distribution in the individual hand. The most frequent pattern in the individual hand was a case which has total of two sesamoids in the thumb MP joint (as shown in Fig. 1A), and this pattern existed in 20.4% of the study population. This means that 20.4% of our study population had just two sesamoids bone in their hand and those sesamoids are located in thumb MP joints (Table 2). The second most common pattern was a case which has total of 4 sesamoid bones (2 in the thumb MP joint, 1 in the MP joint of index finger, and 1 in the MP joint of little finger), which was found in 19.4% of the total population.

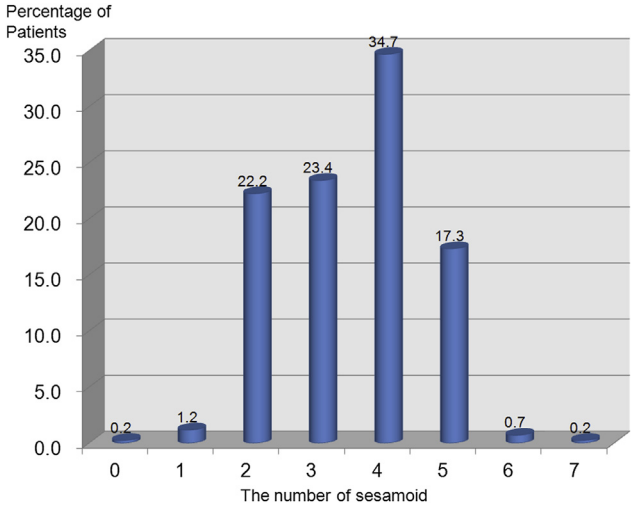

Fig. 2 – Total prevalence of the sesamoid bone in one hand.

We analyzed the prevalence of sesamoid in relation to gender and side (Table 3). Subgroup analysis regarding to gender showed that there was the same rate in both genders. Although the female had higher frequency of sesamoid bone in thumb IP joint than male, this could not achieve statistically significant difference ($P = 0.250$). Subgroup analysis regarding to side (right or left) showed that the frequencies in MP joint of thumb and all finger are same in both sides. However, the frequency of sesamoid in thumb IP joints was significantly higher in right hand compared with left hand.

In 411 cases, we compared the counting results by 3D-reconstructed CT with that by plain radiograph. Although the concordance rate for the thumb MP joint was excellent, we found that the prevalence of sesamoid bone in the MP joints of index and little finger and thumb IP joint was underestimated significantly in simple radiographs compared with 3D-

Table 1 – Prevalence of sesamoid bone in each location.

Location	Count	Percent
Thumb MP radial side	418	97.9
Thumb MP ulnar side	421	98.6
MP of index finger	188	44.0
MP of middle finger	3	0.7
MP of ring finger	3	0.7
MP of little finger	268	62.8
IP of thumb	181	42.4

Fig. 3 – Rare presentation of the sesamoid bone in the 3rd MP joint.

reconstructed CT (Table 4). Especially, the difference was greater for the MP joint of little finger and the thumb IP joint.

4. Discussion

Our aim was to determine the prevalence of sesamoid bones in the hands of Korean patients with 3D-reconstructed CT. This was the first study using 3D-reconstructed CT for the more accurate counting of the sesamoid bones. A review of total 427 CT images was performed in order to assess the location and incidence of sesamoid bones. While plain radiograph has been used to identify the sesamoid bone, we thought that there was substantial room for improvement by using 3D-CT. Each coronal, sagittal, and axial CT image alone might have limitations in accurate counting because there is a possibility that the sesamoid is not included in any cutting slice due to its small size. With 3D-reconstructed images as a definitive method, we could count the sesamoid with little ambiguity.

The sesamoid bone is usually underestimated in the clinical situation due to its small size and less notable appearance in plain radiographs. However, many pathologic symptoms can be related to this small bone. Arthritis has often been described as present between a sesamoid and phalangeal bone.[10,17] Recently chronic sesamoiditis was acceptably treated with steroid injections on a long-term basis. When conservative treatment failed, sesamoidectomy was able to relieve the symptoms. Triggering associated with the sesamoid in a thumb IP joint was also successfully treated with excision.[9] Three cases with painful clicking of the thumb IP joints caused by a sesamoid bone were also treated with sesamoidectomy.[6] Good relief of pain and full recovery of strength were reported. In case of sesamoid fractures, more frequent occurrence was reported in thumb ulnar side and this trauma was closely related with sports injury.[18–20] Routine anteroposterior and lateral radiographs might be unremarkable, and oblique radiograph were often necessary either in thumb[18] or other fingers.[21] Fracture was usually managed with conservative treatment; however, in some cases sesamoid excision was eventually required due to unresolved pain.[21,22] A high index of suspicion warrants sesamoid-related pathology as a differential diagnosis for hand diseases. Therefore, proper knowledge about the incidence of sesamoid in specific locations is essential. Appropriate diagnostic evaluations such as plain radiograph and CT analysis should be performed so as not to miss sesamoid-related pathology in suspicious cases.

Several publications have contributed to the improved understanding of the prevalence of sesamoid bone in various ethnic groups.[5,11–16,23–25] Through these reports, the incidence of sesamoid bones in specific locations showed substantial differences among individual from various populations. Recently, Yammine undertook systematic review on the prevalence of sesamoid bones and we could obtain the overall prevalence and ancestry-specific prevalence of three different ethnic groups from this systematic review (Table 5).[26] We also calculated the prevalence for East Asian population (mainly Korean and Japanese) by summing up from several articles and our result. The results showed that the incidence in the thumb MP joint was not different among people of 4 ethnic backgrounds. The rarity of sesamoid in the MP joints of middle and ring finger was also the same among 4 groups. The incidence in the MP of index finger was remarkably lower in Africans (23.2%) compared with other groups (38.1–44.0%). The sesamoid bones in the MP joint of little finger and thumb IP joint were the most variable in incidence. Africans had the lowest incidence of sesamoid in the MP joint of little finger and the highest incidence (near 100%) in the thumb IP joint. Caucasians and the East Asian

Table 2 – Frequent patterns of sesamoid bones in the individual hand.

Thumb MP radial side	Thumb MP ulnar side	MP-II	MP-V	Thumb IP	Count	Percent
+	+				87	20.4
+	+	+	+		83	19.4
+	+	+	+	+	73	17.1
+	+		+	+	52	12.2
The other patterns					107	25.1

Table 3 – Sesamoid frequency by gender and side.

	n (%)	MP-I radial (%)[a]	MP-I ulnar (%)	MP-II	MP-III	MPIV	MP-V	IP-I
Male	270 (66%)	97.8	98.9	43.0	0.7	0.7	62.2	41.9
Female	141 (34%)	97.9	97.9	44.7	0.7	0.7	64.5	48.2
P value[b]		1.000	0.417	0.754	1.000	1.000	0.668	0.250
Right	230 (56%)	98.3	98.3	44.0	0.9	0.4	64.8	48.7
Left	181 (44%)	97.2	98.9	43.1	0.6	1.1	60.8	38.1
P value		0.515	0.669	0.920	1.000	0.585	0.412	0.036

[a] Frequency was noted with percentage.
[b] Fisher's exact test.

Table 4 – Comparison between X-ray and CT with McNemar's test.

Location	X-ray (percent)	CT (percent)	*p* Value
Thumb MP radial side	97.8	97.8	1.0
Thumb MP ulnar side	98.5	98.5	1.0
MP of index finger	39.7	43.6	**0.005**
MP of middle finger	0.5	0.7	1.0
MP of ring finger	1.0	0.7	1.0
MP of little finger	51.3	63.0	**0.000**
Thumb IP	30.9	44.0	**0.000**

$p < 0.05$ is highlighted with bold.

group have similar prevalence in these two joints. The Middle Eastern group had the lowest incidence (24.9%) in thumb IP joint. Although this data showed that the incidence in Africans is quite different from other ethnic groups, it should be considered that the part of African data had been evaluated using only antero-posterior radiographs.[14] The results might therefore be inaccurate, especially for the counting of the sesamoid in MP joints of the index and little fingers.

For a long time, the mechanical and genetic hypotheses were considered to be important for the generation and distribution of sesamoid bone within hand.[14,26,27] Bizzaro stated that both factors are equally essential for the full picture.[15] Mechanical factor such as overuse of hand or fingers had been suggested because pressure during manual work was higher at thumb joints, MP-II, and MP-V, where the highest sesamoid frequencies could be found.[15,28] Although our subgroup analysis showed that right hand had higher frequency of sesamoid in thumb IP joint compared with left hand, this tendency was not repeated in systematic review; no significant difference was noted in thumb and fingers according to side.[26] The result of frequency according to gender is inconsistent since there was no gender preference in the current study and systematic review showed that there was slightly high frequency of sesamoid bone in female finger MP joint compared with men. Since the men or right hand (dominant hand in the most people) has to possess more sesamoid to confirm the mechanical hypothesis to be true, the current evidence gives week support to the mechanical hypothesis. As shown in our results and systematic review, there was clear difference in sesamoid frequency among various ancestries. Each ancestry including East Asian group has distinct profile for sesamoid distribution. Therefore we can conclude that genetic background has profound role in the frequency distribution of sesamoid bone. A few authors also suggested that genetic background is associated with sesamoid frequency in hand[11–13] and foot.[29]

In comparison with the results counted with a plain radiograph, there was a significant difference in the incidence of sesamoid bones at the MP joints of index and little fingers and the IP joint of thumb. When we assumed 3D-CT images as the gold standard, the detection rate was increased with 3D-CT compared with radiograph (increase of detection rate: 3.9%, 11.7% and 13.1%, respectively). The small size of the sesamoid bone in the little finger MP joint and thumb IP joint might pose more difficulty in identifying its presence in plain radiographs. This fact indicates that counting using a simple radiograph could underestimate the real prevalence in the MP joints of index and little fingers and thumb IP joint. Although a true lateral radiograph image could be helpful in the case of thumb IP joints for accurate counting, 3D-CT would be a better option for the sesamoid bone in the MP joints of index and little fingers.

Table 5 – Incidence (%) of sesamoid bones in various ethnic groups, as reported in the literature.

Ethnicity	MP					IP
	Thumb[c]	Index finger	Middle finger	Ring finger	Little finger	Thumb
Systematic review[a]						
Overall	99.9	38.1	1.5	0.6	55.4	57.6
African	99.7	23.2	0.3	0.3	26.4	95.1
European	99.8	45	1.5	1.3	71.3	57.4
Middle Eastern	99.8	39.4	1.5	0.8	46.6	24.9
East Asian[b]	98.6	44.0	0.7	0.7	62.8	52.8

[a] Results of other ancestry were brought from recent systematic review.[26]
[b] Results summed up from the following reference[16,24] and the data from the current article (Korean and Japanese).
[c] Prevalence of at least one sesamoid in thumb MP joint.

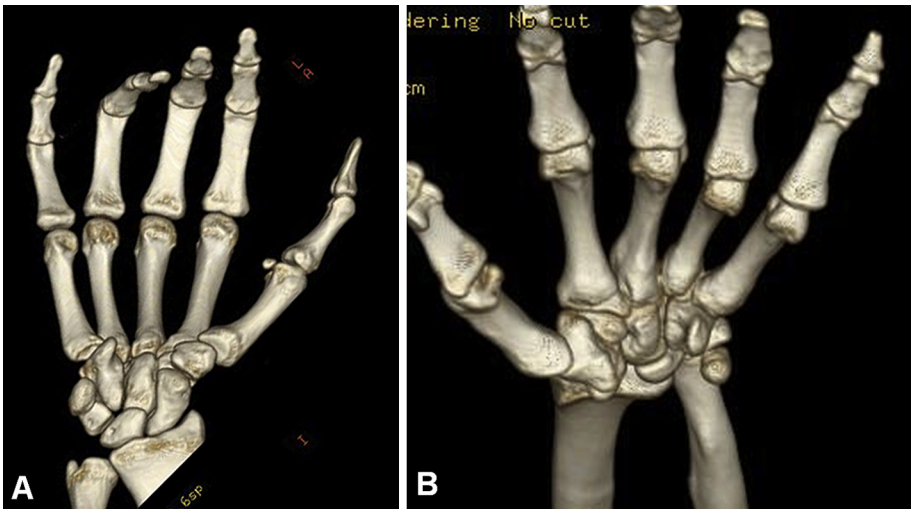

Fig. 4 – Exceptional cases with absence of one (A) or two thumb sesamoid bones (B) in the MP joint.

The thumb sesamoid bone has been known as universally existing.[3,12–14,23,25] However, some authors reported a few exceptional cases where people do not carry one or two sesamoid bones in the MP joint of thumb.[11,15] We also found a few exceptional cases (Fig. 4). Evidence of fusion or bony ankylosis between the sesamoid and metacarpal head, which can be present in osteomyelitis or prolonged septic conditions, was absent in all of the cases. It seems that the sesamoids in the thumb MP joint, either single or both, might be absent in particular individuals, with very low incidence.

Recently, Seki et al reported the prevalence of the sesamoid bone in the IP joint of the fingers in the Japanese population.[16] They showed that the prevalence for the index, middle, ring, and little finger was 0% (0 of 172), 0.4% (1 of 244), 0.5% (1 of 183), and 1% (2 of 179), respectively. They used a lateral X-ray for each finger, separately. In our current study, we found only 1 sesamoid bone (0.2%) in the middle and ring finger PIP joints, respectively, in a single patient. A small fragment of an intra-articular fracture is hard to distinguish from a sesamoid when it is evaluated with only a simple radiograph. In our experience, 3D-reconstructed CT was sufficiently sensitive as we could distinguish the sesamoid from a small avulsion fracture fragment or detached osteophyte. Therefore, questionable images on an radiograph warrant further evaluation with a 3D-CT.

There are several limitations of this study. First, since we used CT images of the patients who visited the hospitals for a clinical reason, the study population could not represent the normal regional population. However, several previous studies have also used radiograph from patients following hand trauma.[11,12,14,16] This is because obtaining a radiograph in a normal population is unethical and impractical in most countries currently. When a trauma history was present, we could not discriminate conclusively whether the observed fragment was a fracture fragment or a sesamoid bone. This was especially true in the thumb IP joint since the volar side is frequently injured by an avulsion fracture. Therefore, we checked for any thumb trauma history in the medical chart when the thumb IP joint sesamoid bone was observed, to rule out the possibility of a fracture fragment. Second, interobserver and intraobserver reliability was not analyzed. Because the primary purpose of the current study was to report the incidence of sesamoid bones in the hands accurately, and not to compare the accuracy of the counting method, we did not make a great effort to perform serial checks by several readers. There was a report that interobserver and intraobserver reliability was good even with plain radiographs.[11]

There are several strengths of the current study. First, this is the first study to use CT to count the sesamoid bone. Second, we counted a large number of CT scans, gathering the cases from multiple centers. Our number of cases (427 hands) is comparable with the case numbers (225–442 hands) of a previous simple radiograph study.[11,12,14] Third, we counted the thumb MP joint sesamoid bone on either side (radial or ulnar side), separately. The radial side sesamoid bone of the thumb might not be seen well in conventional hand AP and oblique radiograph. With 3D-reconstructed CT we could accurately count each sesamoid separately.

We observed five frequent sesamoid bones in Koreans who visited the hand clinics: two in the MP of the thumb, one in the index and the little finger, respectively, and one in the IP of the thumb. The prevalence was partially different from other ethnic groups. With 3D-reconstructed CT, we could attain an accurate counting of the sesamoid bone, creating precise baseline data for an East Asian population.

Conflicts of interest

All authors have none to declare.

REFERENCES

1. Oxnard CE. Tensile forces in skeletal structures. *J Morphol.* 1971;134:425–435.

2. Holladay SD, Smith BJ, Smallwood JE, Hudson LC. Absence of an osseous patella and other observations in macropodidae stifle. *Anat Rec*. 1990;226:112–114.
3. Goldberg I, Nathan H. Anatomy and pathology of the sesamoid bones. The hand compared to the foot. *Int Orthop*. 1987;11:141–147.
4. Shaw M, Lyburn ID, Torreggiani WC, Watura R. Comminuted fracture of the ulnar sesamoid of the metacarpophalangeal joint of the thumb: an uncommon injury. *J Emerg Med*. 2003;24:437–439.
5. Wood VE. The sesamoid bones of the hand and their pathology. *J Hand Surg Br*. 1984;9:261–264.
6. Ecker JO, Edwick SJ, Ebert JR. Painful clicking of the thumb interphalangeal joint caused by a sesamoid bone: a report of three cases. *J Hand Surg Am*. 2012;37:423–426.
7. Stadalnik RC, Dublin AB. Sesamoid periostitis in the thumb in Reiter's syndrome. Case report. *J Bone Joint Surg Am*. 1975;57:279.
8. Resnick D, Niwayama G, Feingold ML. The sesamoid bones of the hands and feet: participators in arthritis. *Radiology*. 1977;123:57–62.
9. Brown M, Manktelow RT. A new cause of trigger thumb. *J Hand Surg Am*. 1992;17:688–690.
10. Kim JY, Sung JH, Seo JG. Sesamoid arthritis mimicking trigger thumb. *Orthopedics*. 2011;34:228.
11. Amar E, Rozenblat Y, Chechik O. Sesamoid and accessory bones of the hand–an epidemiologic survey in a Mediterranean population. *Clin Anat*. 2011;24:183–187.
12. Dharap AS, Al-Hashimi H, Kassab S, Abu-Hijleh MF. Incidence and ossification of sesamoid bones in the hands and feet: a radiographic study in an Arab population. *Clin Anat*. 2007;20:416–423.
13. Joseph J. The sesamoid bones of the hand and the time of fusion of the epiphyses of the thumb. *J Anat*. 1951;85: 230–241.
14. Msamati BC, Igbigbi PS. Radiographic appearance of sesamoid bones in the hands and feet of Malawian subjects. *Clin Anat*. 2001;14:248–253.
15. Bizarro AH. On sesamoid and supernumerary bones of the limbs. *J Anat*. 1921;55(Pt 4):256–268.
16. Seki Y, Hoshino Y, Kuroda H. Prevalence of sesamoid bones in the interphalangeal joint of the thumb and fingers: a radiographic study. *Clin Anat*. 2012;26:823–826.
17. Chin AY, Sebastin SJ, Wong M, Teoh LC. Long-term results using a treatment algorithm for chronic sesamoiditis of the thumb metacarpophalangeal joint. *J Hand Surg Am*. 2013;38:316–321.
18. Altun M, Erdil H, Aras H, Gumusburun E. Fracture of the ulnar sesamoid of the thumb in a handball player. *Clin J Sport Med*. 2000;10:300–301.
19. Bruser P. Pathology of the sesamoid bones of the hand. *Handchir Mikrochir Plast Chir*. 1994;26:302–306.
20. Dong PR, Seeger LL, Shapiro MS, Levere SM. Fractures of the sesamoid bones of the thumb. *Am J Sports Med*. 1995;23:336–339.
21. Capo JA, Kuremsky MA, Gaston RG. Fractures of the lesser sesamoids: case series. *J Hand Surg Am*. 2013;38:1941–1944.
22. Hansen CA, Peterson TH. Fracture of the thumb sesamoid bones. *J Hand Surg Am*. 1987;12:269–270.
23. Fawcett E. The sesamoid bones of the hand: a skiagraphic confirmation of the work done by Pfitzner. *J Anat Physiol*. 1896;31(Pt 1):157–161.
24. Kim JS, Baek GH, Chung MS, Lee S, Kim JB. The location and distribution of hand sesamoid bones in Korean. *J Korean Soc Surg Hand*. 2004;9:21–25.
25. Hubay CA. Sesamoid bones of the hands and feet. *Am J Roentgenol Radium Ther*. 1949;61:493–505.
26. Yammine K. The prevalence of the sesamoid bones of the hand: a systematic review and meta-analysis. *Clin Anat*. 2014;27:1291–1303.
27. Sarin VK, Carter DR. Mechanobiology and joint conformity regulate endochondral ossification of sesamoids. *J Orthop Res*. 2000;18:706–712.
28. Lewis OJ. Joint remodelling and the evolution of the human hand. *J Anat*. 1977;123(Pt 1):157–201.
29. Yammine K. The sesamoids of the feet in humans: a systematic review and meta-analysis. *Anat Sci Int*. 2014 May 7 [Epub ahead of print, PMID: 24801385].