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Factors influencing medial sesamoid arthritis in patients with hallux valgus deformity: Magnetic resonance imaging evaluation

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A B S T R A C T

Background: The importance of preoperative evaluation of the position and degree of arthritic changes of the medial sesamoid bone before hallux valgus correction is emerging. This is an observational study to evaluate the magnetic resonance imaging (MRI) findings of hallux valgus deformity, and assess the severity of and identify the factors that influence the arthritic changes in medial sesamoid-metatarsal (mSM) joints.
Methods: We reviewed weight-bearing anteroposterior radiographs, forefoot axial radiographs and MR images of 514 feet of 405 patients who underwent hallux valgus correction. On MRI, the degrees of the arthritic changes in the first metatarsophalangeal (MTP) and mSM joints were categorized into 5 classes. Binary logistic regression analysis was performed to identify the factors affecting the arthritic changes.
Results: The binary logistic regression analysis showed that advanced age, more lateralized position of medial sesamoid bone on forefoot axial radiograph, and higher MRI grade of arthritic change of the 1st MTP joint were significant factors contributing to medial sesamoid arthritis ($P < 0.001$, 0.001. 0.006, respectively).
Conclusions: Medial sesamoid arthritis can be assessed using MRI. The position of medial sesamoid bone on forefoot axial radiographs can strongly help predict the possibility of mSM joint arthritis.
Level of evidence: III, observational study.

1. Introduction

In orthopedic surgery, magnetic resonance imaging (MRI) is generally considered the most suitable tool to observe soft tissue structures including tendons, ligaments, menisci, and articular cartilages. Therefore, MRI is not usually performed before correcting hallux valgus deformity. Currently, there are only a few reports correlating hallux valgus deformity with MRI findings. Schweitzer et al. [1] reported, using 11 MRIs with hallux valgus and 9 with both hallux valgus and hallux rigidus, that the most common findings observed in hallux valgus were hypertrophic medial eminence (95%), sesamoid proliferation (90%), and adventitial bursitis (90%). They also found that osteophytes (77%), subchondral cysts, and bone marrow edema were commonly found with hallux rigidus. However, their study was limited by their small sample size.

A recent study by Katsui et al. [2] showed that lateral shift of the medial sesamoid bone was associated with progression of the hallux valgus deformity. They also reported that increasing lateral shift of the medial sesamoid bone was associated with worsening degenerative change within medial sesamoid-metatarsal (mSM) joint.

The importance of preoperative evaluation of the position of medial sesamoid bone and degree of arthritic changes in the mSM joint is emerging. Hence, the purpose of the present study was to evaluate the MRI findings of hallux valgus deformity, and particularly assess the severity of and identify the factors that influence the arthritic changes in the mSM joints.

To the best of our knowledge, there are no previous reports evaluating the MRI findings in hallux valgus deformity with a large sample size. We hypothesized that MRI would provide accurate and valuable information about the arthritic changes.

2. Materials and methods

2.1. Patient selection and demographics

A total of 535 feet of 428 consecutive patients who underwent radiographic and MRI evaluations before hallux valgus deformity

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correction between May 2012 and May 2017 were included in this study. Patients' charts were reviewed. Exclusion criteria were systemic inflammatory conditions such as rheumatoid arthritis or a history of trauma that could have affected the forefoot alignment. It is well known that a congenital absence of the medial sesamoid bone has been reported to be very rare [3,4]; however, we found 10 feet (1.91%) with an absent medial sesamoid bone. They were also excluded from this study.

Finally, 514 feet of 405 patients were enrolled (Fig. 1). The mean age was 53.0 ± 13.4 years; there were 47 men and 467 women. The numbers of right and left feet were 262 and 252, respectively.

The patients were divided into 3 subgroups based on the hallux valgus angle (HVA, angle between the 1st metatarsal and proximal phalanx) and the intermetatarsal angle (IMA, angle between the 1st and 2nd metatarsals), which reflected the severity of the deformity [5]. The mild group included patients with HVA between 20 and 30° and IMA less than 13°, while the moderate group included patients with HVA between 30 and 40° and IMA between 13 and 20°. The severe group included patients with HVA more than 40° and IMA more than 20°. A total of 118 (135 feet), 265 (339 feet), and 22 (40 feet) patients were enrolled in the mild, moderate, and severe groups, respectively.

2.2. Ethical consideration

Informed consents were obtained in writing from all the patients before enrolling them in the study. This study was approved by our institutional ethical review committee and conformed to the tenets of the Declaration of Helsinki.

2.3. MRI evaluation

Patients were instructed to lie in the supine position. The ankles were positioned dorsiflexed 90° in the ankle coil with a knee extension to maintain a uniform position in all patients (Fig. 2A, B). Coronal slices were obtained on MRI; the position block was angled parallel to the metatarsal in the sagittal plane (Fig. 2C). Sagittal slices were obtained with the position block angled perpendicular to the parallel line to the sole in the axial plane (Fig. 2D).

2.4. Assessments

First, weight-bearing anteroposterior (AP) foot radiographs were assessed for the HVA, IMA, and distal metatarsal articular angle (DMAA). HVA was defined as the angle between the longitudinal axes of the first metatarsal and proximal phalanx. IMA was defined as the angle between the longitudinal axes of the first and second metatarsals. DMAA was defined as the angle between the perpendicular line to the distal metatarsal articular surface and the longitudinal axis of the first metatarsal.

In accordance with Coughlin and Shurnas' findings [6], the arthritic changes in the first metatarsophalangeal (MTP) joint were graded into 5 categories based on a combination of the range of motion, and radiographic and clinical examinations. To locate the medial sesamoid position, two different methods using two different radiographs were included. First, we used the method demonstrated by Hardy and Clapham [7] using weight-bearing anteroposterior foot radiographs. We also used another classification method by Katsui et al. [2] using forefoot axial images on

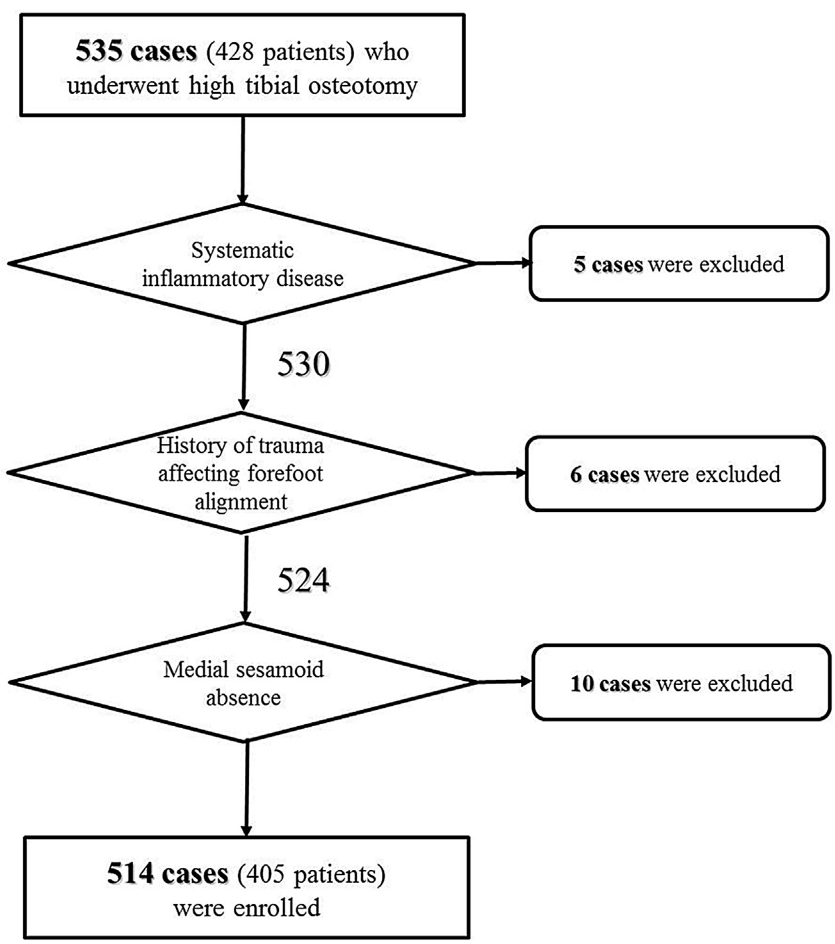

Fig. 1. The algorithm for patients selection.

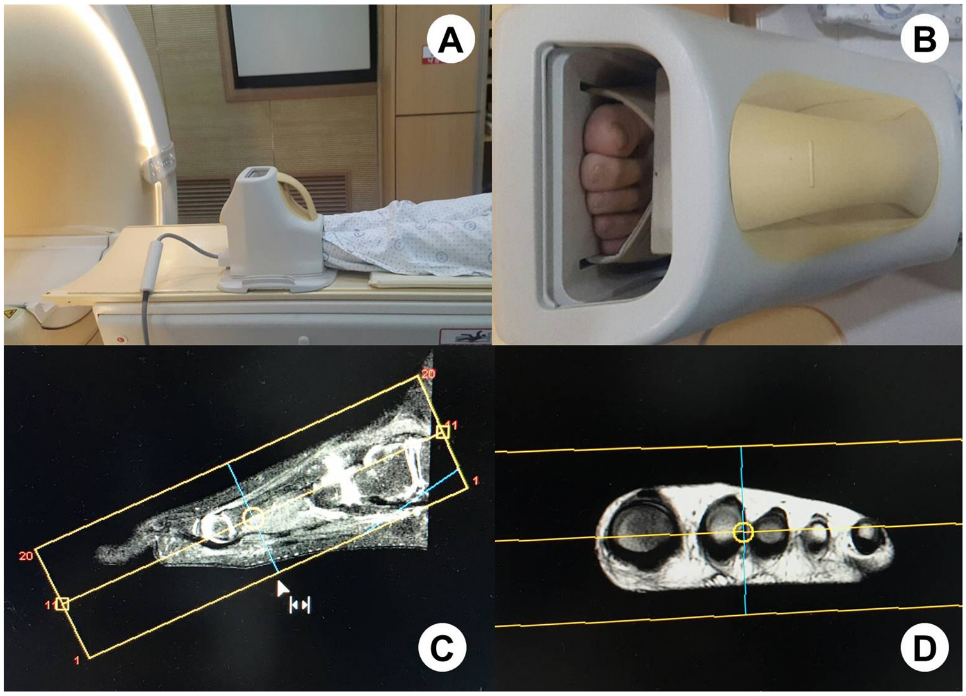

Fig. 2. The ankle was positioned dorsiflexed 90° in the ankle coil with a knee extension to maintain a uniform position in all patients (A, B). The MRI technician took coronal slices using the angled position block parallel to the metatarsal bone in the sagittal plane (C). Sagittal slices were obtained with the position block angled perpendicular to the parallel line to the sole in the axial plane (D).

computerized tomography (CT) Katsui et al. divided the degenerative changes in the mSM joint into 2 categories: cases with an intact inter-sesamoid ridge and no bony erosion or cystic lesions were identified as osteoarthritis, OA, (−), and cases with evidence of erosive or cystic changes in the mSM joint or disappearance of the inter-sesamoid ridge were identified as OA (+).

In our study, we used forefoot axial radiographs [8] instead of CT to position the MTP joint at its lowest point. This procedure required a specially designed standing apparatus in which the patients' feet were adjusted to raise the hindfoot by 20° and the forefoot by 10° as described by Choi et al. [9] (Fig. 3). The medial sesamoid position was classified into 3 grades. Grade 1 showed the medial sesamoid to be entirely medial to the intersesamoid ridge; grade 2 had the medial sesamoid subluxated laterally but located below the intersesamoid ridge; and grade 3 had the medial sesamoid located entirely lateral to the intersesamoid ridge (Fig. 4).

Fig. 3. An apparatus in which the patients' feet were adjusted to raise the hindfoot by 20° and the forefoot by 10° was used for axial radiography of the forefoot. This apparatus simulated the position of the medial sesamoid bone during ambulation.

The degrees of arthritic changes of the first MTP or mSM joints on MRI were graded into 5 categories based on the criteria (Fig. 5) as described in the systematic review by Menashe et al. [10].

2.5. Statistical analysis

A descriptive analysis was performed for all the variables including the mean and standard deviation or frequency. Data normality was tested using a Kolmogorov–Smirnov test. One-way analysis of variance (ANOVA) was used to compare continuous variables (Age, HVA, IMA and DMAA) among the three subgroups. Post-hoc analysis was performed by using Bonferroni correction. Kruskal–Walis test was used to compare ordinal variables among the three subgroups. Post-hoc analysis was performed using a Mann–Whitney test.

To validate MRI grading system of arthritic changes of the first MTP or mSM joints, one orthopedic surgeon and one radiologist graded 30 randomly selected feet twice, with a 2-month interval between the assessments. Random selection was done by the blinded practitioner who was not involved in this study. The inter-observer reliability and the intra-observer reproducibility were measured using intra-class correlation coefficients (ICCs). The mean values for the inter-observer reliability and intra-observer reproducibility of the MRI grade of arthritic changes in the first MTP joint were 0.76 and 0.84, respectively, while those in the mSM joint were 0.77 and 0.82, respectively.

Definite arthritis of the mSM joint was defined as MRI grade of 3 or higher. Binary logistic regression analysis was used to determine the factors affecting arthritis of the mSM joints.

Statistical analyses were performed using SPSS software, version 19 (IBM Corp., Armonk, NY, USA). Statistical significance was determined at a P-value less than 0.05 for all analyses.

3. Results

The overall parameters of radiographs and MR images are presented in Table 1. Data of the three subgroups divided by the severity of the deformity are demonstrated in Table 2. The mean

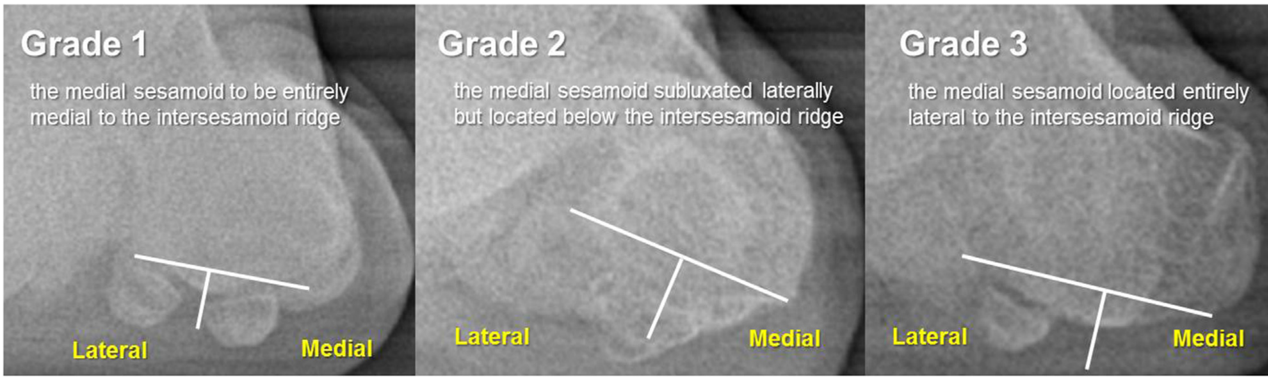

Fig. 4. The position of the medial sesamoid bone was graded according to the relationship between the medial sesamoid and intersesamoid ridge on forefoot axial radiographs.

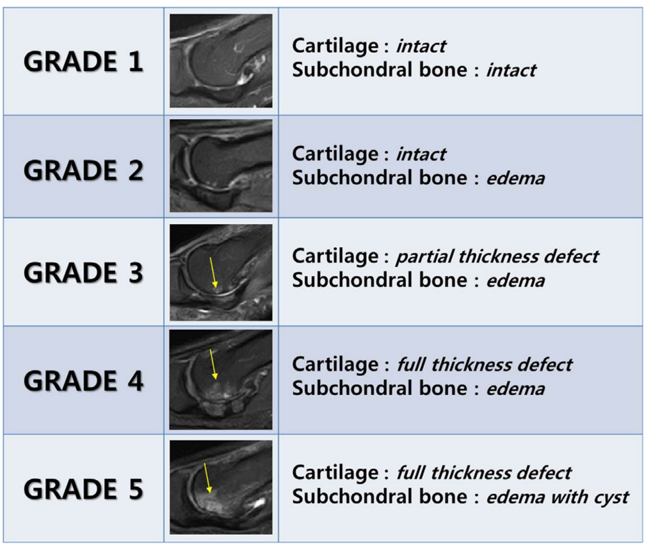

Fig. 5. Our method to classify the degree of arthritic changes of the medial sesamoid-metatarsal joint based on the statuses of the articular cartilage and subchondral bone.

age in the severe group was significantly higher ($P < 0.0001$) than that in the mild and moderate groups; the mean ages of the latter two groups were not significantly different ($P = 0.324$). Both positions of the medial sesamoid by Hardy and Clapham [7] on AP foot radiographs and by Katsui et al. [2] on forefoot axial radiographs were highest in the severe group followed by the moderate and mild group ($P < 0.0001$). In terms of arthritic changes in the first MTP joint, Coughlin and Shurnas' grades were not significantly different among three groups ($P = 0.548$). Also, there was no significant difference on MRI grade of arthritic change of the 1st MTP joint among the three groups ($P = 0.062$). Similarly, the MRI grades of arthritis in the mSM joints were not different among three groups ($P = 0.301$).

The result of the binary logistic regression analysis is shown in Table 3. An advanced age, more lateralized position of medial sesamoid bone on forefoot axial radiograph and higher MRI grade of arthritic change of the 1st MTP joint were significant factors contributing to medial sesamoid-metatarsal joint arthritis ($P < 0.001$, 0.001. 0.006, respectively).

Radiographic and MRI parameters according to the MRI grade of arthritic change of medial sesamoid-metatarsal joint are summarized in Table 4.

4. Discussion

Our data suggested that no correlation was found between the severity of hallux valgus, as measured using HVA and IMA, and the degree of the arthritic changes of the mSM joint. Like the findings by Katsui et al. [2], the result of our study showed that MRI grade of arthritic change of mSM joint was not significantly different among three subgroups divided by HVA and IMA, although the medial sesamoid bone was significantly lateralized in severely deformed group. Likewise, the result of the binary logistic regression analysis showed the MRI degree of the arthritic changes in the mSM joint was not significantly correlated with HVA ($P = 0.612$) or IMA ($P = 0.837$).

Interestingly, mSM joint arthritis was not significantly related to the position of the medial sesamoid bone on anteroposterior radiograph ($P = 0.859$); rather it was so correlated on forefoot axial

Table 1
Overall patients' parameters.

Parameter	Value
Age	53.0 ± 13.4 (range, 48–76)
Sex (male/female)	47/467
Direction (right/left)	262/252
HVA (°)	33.6 ± 9.0
IMA (°)	15.2 ± 3.2
DMAA (°)	11.8 ± 9.4
Coughlin and Shurnas' grade of hallux rigidus [6] (0/1/2/3/4/)	1.3 ± 0.6 (0/363/131/20/0)
Medial sesamoid position by Hardy and Clapham [7] on anteroposterior foot radiographs (1/2/3/4/5/6/7)	6.0 ± 1.2 (2/7/12/32/93/125/243)
Medial sesamoid position by Katsui et al. [2] on forefoot axial radiographs (1/2/3)	2.7 ± 0.5 (20/96/398)
MRI grade of arthritic change of the 1st MTP joint (1/2/3/4/5)	1.7 ± 1.3 (389/13/24/61/27)
MRI grade of arthritic change of the mSM joint (1/2/3/4/5)	2.2 ± 1.4 (260/67/15/146/26)

HVA, hallux valgus angle; IMA, the first to second intermetatarsal angle; DMAA, distal metatarsal articular angle; MRI, magnetic resonance image; MTP, metatarsophalangeal; mSM, medial sesamoid-metatarsal.

Table 2
Parameters of 3 subgroups divided by the deformity severity.

	Mild (n = 135, 20° ≤ HVA < 30°, IMA < 13°)	Moderate (n = 339, 30° ≤ HVA < 40° 13° ≤ IMA < 20 °)	Severe (n = 40, 40° ≤ HVA 20° ≤ IMA)	*P*-value
Age	51.1 ± 13.4	53.2 ± 13.8	58.2 ± 6.7	<0.0001
HVA (°)	27.3 ± 6.6	35.0 ± 8.6	42.3 ± 6.8	<0.0001
IMA (°)	11.5 ± 1.3	15.9 ± 1.9	21.5 ± 1.6	<0.0001
DMAA (°)	9.6 ± 7.6	12.9 ± 9.8	10.1 ± 8.0	0.437
Coughlin and Shurnas' grade of hallux rigidus [6] (0/1/2/3/4)	1.4 ± 0.7 (0/92/31/12/0)	1.3 ± 0.5 (0/248/83/8/0)	1.4 ± 0.5 (0/23/17/0/0)	0.548
Medial sesamoid position by Hardy and Clapham [7] on anteroposterior foot radiographs (1/2/3/4/5/6/7)	5.1 ± 1.3 (0/7/7/21/53/24/23)	6.3 ± 1.0 (2/0/5/11/40/99/182)	7.0 ± 0.2 (0/0/0/0/0/2/38)	<0.0001
Medial sesamoid position by Katsui et al. [2] on forefoot axial radiograph (1/2/3)	1.6 ± 0.6 (13/52/70)	2.8 ± 0.5 (7/44/288)	3.0 ± 0.0 (0/0/40)	<0.0001
MRI grade of arthritic change of the 1st MTP joint (1/2/3/4/5)	1.8 ± 1.4 (100/3/3/21/9)	1.6 ± 1.2 (265/10/15/33/16)	2.0 ± 1.4 (25/0/6/7/2)	0.062
MRI grade of arthritic change of the mSM joint (1/2/3/4/5)	2.4 ± 1.5 (63/20/0/46/6)	2.2 ± 1.4 (175/47/14/86/17)	2.4 ± 1.6 (22/0/1/14/3)	0.301

HVA, hallux valgus angle; MRI, magnetic resonance image; IMA, the first to second intermetatarsal angle; DMAA, distal metatarsal articular angle; MTP, metatarsophalangeal; mSM, medial sesamoid-metatarsal; AOFAS, American orthopaedic foot and ankle society.

Table 3
The results of binary logistic regression analysis for factors contributing medial sesamoid-metatarsal joint arthritis.

	Exp (B)	95% CI for Exp (B)	*P*-value
Age	1.050	1.027–1.074	<0.001
HVA (°)	1.008	0.977–1.040	0.612
IMA (°)	0.991	0.913–1.076	0.837
DMAA (°)	1.001	0.973–1.019	0.721
Coughlin and Shurnas' grade of hallux rigidus [6]	1.745	0.230–13.242	0.590
Medial sesamoid position by Hardy and Clapham [7] on foot anteroposterior radiographs	1.154	0.597–2.174	0.859
Medial sesamoid position by Katsui et al. [2] on forefoot axial radiographs	2.610	1.888–11.234	0.001
MRI grade of arthritic change of the 1st MTP joint	3.853	1.463–10.146	0.006

HVA, hallux valgus angle; IMA, the first to second intermetatarsal angle; DMAA, distal metatarsal articular angle; MRI, magnetic resonance image; MTP, metatarsophalangeal; CI, confidence interval

Table 4
Radiographic and MRI parameters according to the MRI grade of arthritic change of medial sesamoid-metatarsal joint.

	Grade 1 (n = 260)	Grade 2 (n = 67)	Grade 3 (n = 15)	Grade 4 (n = 146)	Grade 5 (n = 26)
HVA (°)	33.2 ± 9.2	33.1 ± 6.9	39.2 ± 5.1	34.2 ± 9.5	36.8 ± 8.
IMA (°)	15.2 ± 3.0	14.7 ± 2.8	16.9 ± 2.1	14.9 ± 3.3	16.0 ± 4.3
DMAA (°)	11.4 ± 10.1	11.2 ± 7.5	20.3 ± 13.3	11.4 ± 8.2	14.5 ± 8.5
Coughlin and Shurnas' grade of hallux rigidus [6] (0/1/2/3/4)	1.2 ± 0.5 (0/211/39/10/0)	1.4 ± 0.6 (0/42/22/3/0)	1.5 ± 0.5 (0/0/8/7/0)	1.5 ± 0.6 (0/87/52/7/0)	1.4 ± 0.5 (0/15/11/0/0)
Medial sesamoid position by Hardy and Clapham [7] on foot anteroposterior radiographs (1/2/3/4/5/6/7)	6.1 ± 1.2 (0/7/9/8/43/64/129)	5.5 ± 1.4 (2/0/2/9/18/19/17)	6.7 ± 0.6 (0/0/0/0/1/2/12)	6.1 ± 1.1 (0/0/1/13/30/29/73)	6.3 ± 0.9 (0/0/0/2/1/11/12)
Medial sesamoid position by Katsui et al. [2] on forefoot axial radiographs (1/2/3)	2.5 ± 0.6 (16/51/193)	2.7 ± 0.6 (4/27/36)	2.9 ± 0.4 (0/2/13)	2.9 ± 0.3 (0/14/132)	2.9 ± 0.3 (0/2/24)
MRI grade of arthritic change of the 1st MTP joint (1/2/3/4/5)	1.4 ± 1.0 (222/6/8/16/8)	1.7 ± 1.3 (50/4/0/10/3)	1.9 ± 1.4 (10/0/1/4/0)	2.1 ± 1.5 (91/3/12/26/14)	2.1 ± 1.5 (16/0/3/5/2)

HVA, hallux valgus angle; IMA, the first to second intermetatarsal angle; DMAA, distal metatarsal articular angle; MRI, magnetic resonance image; MTP, metatarsophalangeal; n, number.

radiograph ($P = 0.001$). Therefore, simulating the position of the medial sesamoid bone during ambulation in forefoot axial radiographs can strongly help predict the possibility of mSM joint arthritis.

Arthritis of the first MTP and mSM joints and hallux valgus can be due to degenerative processes; therefore, surgeon should be aware of the possibility of arthritis of theses joints while correcting hallux valgus deformity. In our study, we used a MRI grading system for assessing the arthritic changes in the mSM and first MTP joints based on the statuses of the articular cartilage and subchondral bone [10]. To more effectively predict mSM arthritis, the degree of arthritis of the 1st MTP joint should be evaluated using MRI since the Coughlin and Shurnas' grade of hallux rigidus was not significantly correlated with mSM arthritis.

Regarding patient's age, age was a significant contributing factor on mSM joint arthritis by binary regression logistic analysis ($P < 0.001$). Also, severely deformed group showed the highest mean age than mildly and moderately deformed group ($P < 0.0001$).

The reason we focused on the status of the medial sesamoid bone was that many studies have reported the relationship between the position of the medial sesamoid bone, degenerative changes, and functional outcomes [2,11–14]. Chen et al. [11] showed that correcting the medial sesamoid position would improve the functional outcome and satisfaction after hallux valgus corrective surgery. They recommended correcting the medial sesamoid bone position to Hardy and Clapham grade 4 or less to improve functional outcome and satisfaction after hallux valgus surgery. Postoperative medial sesamoid bone position was a predictor of functional outcome and patient satisfaction. Okuda et al. [14] also emphasized the important role of the medial sesamoid bone in hallux valgus deformity. Failure to obtain intraoperative reduction of the metatarsal head over the medial sesamoid bone is a proven risk factor for recurrence because the position of the sesamoid is a surrogate marker for the forces acting along the tendons.

The main limitation of the current study was that we did not determine a correlation between the degree of arthritis of the mSM joint and pes planus or cavus deformity. There have been reports that the inclination of the first metatarsal can change depending on the height of the medial longitudinal arch [15]. Further studies on this topic are required. Another limitation was that we did not compare our MRI findings to the actual intraoperative cartilage statuses of the first MTP and mSM joints. Nevertheless, this study is meaningful because it is the first study with a large sample to assess the severity of and identify the factors that influence the arthritic changes in mSM joints for the patients with hallux valgus deformity using MRI.

5. Conclusions

The degree of MRI-discernable arthritic changes of the mSM joint was contributed by advanced age, more lateralized position of the medial sesamoid bone on forefoot axial radiograph, and higher MRI grade of arthritic change of the 1st MTP joint. Neither HVA nor IMA were significantly correlated to mSM joint arthritis.

Conflict of interest

The authors declare that they have no conflict of interest.

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References

[1] Schweitzer M.E., Maheshwari S, Shabshin N. Hallux valgus and hallux rigidus: MRI findings. Clin Imaging 1999;23:397–402.
[2] Katsui R, Samoto N, Taniguchi A, Akahane M, Isomoto S, Sugimoto K, et al. Relationship between displacement and degenerative changes of the sesamoids in hallux valgus. Foot Ankle Int 2016;37:1303–9, doi:http://dx.doi.org/10.1177/1071100716661827.
[3] Le Minor JM. Congenital absence of the lateral metatarso-phalangeal sesamoid bone of the human hallux: a case report. Surg Radiol Anat 1999;21:225–7, doi:http://dx.doi.org/10.1007/BF01630908.
[4] Kanatli U, Ozturk AM, Ercan NG, Ozalay M, Daglar B, Yetkin H. Absence of the medial sesamoid bone associated with metatarsophalangeal pain. Clin Anat 2006;19:634–9, doi:http://dx.doi.org/10.1002/ca.20282.
[5] Coughlin MJ, Mann RA, Saltzmann CL. Hallux valgus. Mann's surgery of foot and ankle. 9th ed. Philadelphia, PA: Mosby; 2014. p. 155–321.
[6] Coughlin MJ, Shurnas PJ. Soft tissue arthroplasty for hallux rigidus. Foot Ankle Int 2003;24:661–72, doi:http://dx.doi.org/10.1177/107110070302400902.
[7] Hardy RH, Clapham JC. Observations on hallux valgus; based on a controlled series. Bone Joint Surg Br 1951;33-B:376–91.
[8] Suzuki J, Tanaka Y, Takaoka T, Kadono K, Takakura Y. Axial radiographic evaluation in hallux valgus: evaluation of the transverse arch in the forefoot. J Orthop Sci 2004;9:446–51, doi:http://dx.doi.org/10.1007/s00776-004-0800-9.
[9] Choi JY, Suh YM, Yeom JW, Suh JS. Comparison of postoperative height changes of the second metatarsal among 3 osteotomy methods for hallux valgus deformity correction. Foot Ankle Int 2017;38(1):20–6.
[10] Menashe L, Hirko K, Losina E, Kloppenburg M, Zhang W, Li L, et al. The diagnostic performance of MRI in osteoarthritis: a systematic review and meta-analysis. Osteoarthritis Cartilage 2012;20:13–21, doi:http://dx.doi.org/10.1016/j.joca.2011.10.003.
[11] Chen JY, Rikhraj K, Gatot C, Lee JYY, Rikhraj IS. Tibial sesamoid position influence on functional outcome and satisfaction after hallux valgus surgery. Foot Ankle Int 2016;37:1178–82, doi:http://dx.doi.org/10.1177/1071100716658456.
[12] Huang E, Charlton T, Ajayi S, Thordarson D. Effect of various hallux valgus reconstruction on sesamoid location: a radiographic study. Foot Ankle Int 2013;34:99–103, doi:http://dx.doi.org/10.1177/1071100712464356.
[13] Wilson JD, Baines J, Siddique MS, Fleck R. The effect of sesamoid position on outcome following scarf osteotomy for hallux abducto valgus. Foot Ankle Surg 2008;15(2):65–8.
[14] Okuda R, Kinoshita M, Yasuda T, Jotoku T, Kitano N, Shima H. Postoperative incomplete reduction of the sesamoids as a risk factor for recurrence of hallux valgus. J Bone Joint Surg Am 2009;91:1637–45.
[15] Glasoe WM, Nuckley DJ, Ludewig PM. Hallux valgus and the first metatarsal arch segment: a theoretical biomechanical perspective. Phys Ther 2010;90:110–20, doi:http://dx.doi.org/10.2522/ptj.20080298.