Clinical Comparison of the Osteochondral Autograft Transfer System and Subchondral Drilling in Osteochondral Defects of the First Metatarsal Head

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Clinical Comparison of the Osteochondral Autograft Transfer System and Subchondral Drilling in Osteochondral Defects of the First Metatarsal Head

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Background: Osteochondral defects of the first metatarsal head can deteriorate to osteoarthritis of the first metatarsophalangeal joint if left untreated. Treatment options for osteochondral defects of the first metatarsal head vary widely.

Purpose: To compare the clinical outcomes of the osteochondral autograft transfer system with those of subchondral drilling for the treatment of osteochondral defects of the first metatarsal head.

Study Design: Cohort study; Level of evidence, 3.

Methods: The authors retrospectively evaluated 24 cases of osteochondral defects of the first metatarsal head treated operatively; 14 patients underwent subchondral drilling (group A), while 10 were treated with the osteochondral autograft transfer system (group B). The association of variables of osteochondral defects with clinical outcomes was assessed in each group. Clinical outcomes were evaluated according to a visual analog scale (VAS) for pain, the American Orthopaedic Foot and Ankle Society (AOFAS) hallux metatarsophalangeal-interphalangeal scale, and the Roles and Maudsley score. The Tegner activity scale and an activity rating scale were used to determine the activity levels.

Results: The mean VAS score in both groups was significantly improved (from 6.9 $\pm$ 0.9 to 3.9 $\pm$ 1.3 in group A and from 7.4 $\pm$ 0.8 to 3.4 $\pm$ 1.2 in group B; $P < .05$). No difference was noted between the 2 groups at final follow-up ($P = .651$). The mean AOFAS score in both groups was significantly improved (from 62.9 $\pm$ 5.8 to 73.2 $\pm$ 8.2 in group A and from 65.0 $\pm$ 4.1 to 81.5 $\pm$ 5.8 in group B; $P < .05$). There was a significant difference in mean AOFAS score between the 2 groups at final follow-up ($P = .032$). Large defect size ($\geq$50 mm^2) and the existence of a subchondral cyst were significant predictors of unsatisfactory clinical outcomes in group A ($P = .047$ and $P = .019$, respectively). Multivariate analyses showed a defect size larger than 50 mm^2 was associated with significantly worse outcomes on the last follow-up VAS and AOFAS scores in group A ($P = .005$ for VAS and $P = .006$ for AOFAS). There was no association of defect size and subchondral cyst with clinical outcomes in group B ($P > .05$). No association was found between location of the defect area and clinical outcome in either group.

Conclusion: For osteochondral defects larger than 50 mm^2 or when a subchondral cyst exists, the osteochondral autograft transfer system could potentially be used as a treatment of choice for osteochondral defects of the first metatarsal head to restore functionality of the metatarsophalangeal joint.

Keywords: first metatarsal head; osteochondral defect; osteochondral autograft transfer system; subchondral drilling

Osteochondral injury of the first metatarsophalangeal joint is described in most of the literature as "osteochondritis dissecans" and as an early stage of hallux rigidus. Traumatic osteochondral lesions of the knee and ankle are relatively common and well described.[36] Most isolated lesions of osteochondral defects of the first metatarsal head are suggested to originate from trauma.[3,7,14,34] Traumatic injury to the first metatarsal head may lead to degeneration of the first metatarsophalangeal joint. Bonney and Macnab[4] found that a long metatarsal and proximal phalanx can cause traumatic degeneration of the first metatarsophalangeal joint.

The term "osteochondritis dissecans," recently coined osteochondral lesion or osteochondral defect, has been used to describe many types of localized trauma affecting articular surfaces.[2,3,7,25,35] The consequence to the articular surface after a traumatic injury can vary with respect

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to the severity of the injury. Less violent incidents may result in fibrillation or softening of the articular surface, while an incident of a greater intensity could lead to complete transchondral disruption and subchondral necrosis.[41]

First metatarsophalangeal joint mobility is important, as it allows a normal gait pattern and action of the windlass mechanism and assists in balance, impact reduction, and normal stance.[5] Therefore, osteochondral defects of the first metatarsal head should be treated properly so that the patient can perform daily activities as well as many sports activities. Osteochondral lesions have been treated with various methods including subchondral drilling, curettage, microabrasion, and microfracture.[2,25] In osteochondral lesions of the talus, marrow-inducing reparative procedures provide acceptable clinical results over midterm follow-up periods but often fail in the long term because of biomechanical insufficiency of the regenerative fibrocartilage and scar tissue that result from these methods.[1,22] Subsequently, osteochondral lesions may not respond to these marrow-inducing reparative procedures, and the articular surface may continue to deteriorate and lead to hallux rigidus. Therefore, the initial treatment of osteochondral defects of the first metatarsal head is very important to halting the progression thereof to hallux rigidus.

Alternative techniques such as osteochondral grafting, mosaicplasty, and frozen osteochondral allografts have been developed to transfer articular hyaline cartilage to replace the injured area.[15,16,18,19,29,35] However, studies on the osteochondral autograft transfer system for the treatment of osteochondral defects of the first metatarsal head have rarely been published. In the literature, only a few case studies have reported on the osteochondral autograft transfer system for the treatment of osteochondral defects of the first metatarsal head.[21,24,38,41] The aim of this study was (1) to investigate the clinical outcomes and postoperative activity levels of the osteochondral autograft transfer system in the treatment of osteochondral defects of the first metatarsal head, (2) to compare the outcomes thereof with those of subchondral drilling, and (3) to identify the prognostic factors associated with osteochondral defects of the first metatarsal head.

MATERIALS AND METHODS

We retrospectively reviewed 22 consecutive patients (24 feet) with osteochondral defects of the first metatarsal head who underwent operations from May 2008 to June 2010. The first 14 feet (group A) were treated with subchondral drilling from May 2008 to March 2009, and the next 10 feet (group B) underwent treatment with the osteochondral autograft transfer system between April 2009 and June 2010. The average age of the patients was 38.9 years (range, 28-56 years), and the mean follow-up period was 25.1 months (range, 22-36 months). There were 8 men and 14 women. Among the patients, there were no professional athletes, but all patients tended to enjoy sports activities and experienced traumatic events to their great toes during sports activities before visiting our hospital. The types of sports activity in which the patients participated are listed in Figure 1. The most common sports were jogging, mountain climbing, and swimming. There were no significant differences in basic characteristics between the 2 groups regarding patient age, sex, follow-up period, and activity levels before injury (Table 1).

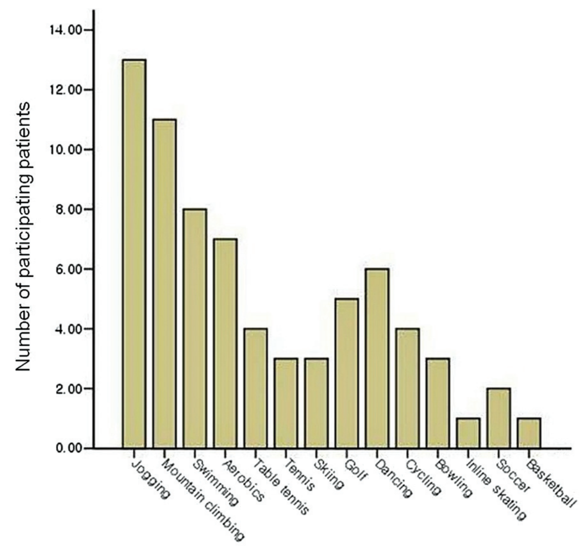

Figure 1. Sports activities in which the patients participated.

The operation was planned after identifying the osteochondral defect of the first metatarsal head through magnetic resonance imaging (MRI). All patients had localized osteochondral defects of the first metatarsal head on MRI, with symptoms of first metatarsophalangeal joint pain or functional limitations, despite a minimum of 3 months of

TABLE 1
Demographic Data[a]

	Group A (Subchondral Drilling)	Group B (OATS)	Total	P
No. of feet/No. of patients	14/13	10/9	24/22	
Age, y	39.1 ± 8.5	38.6 ± 9.4	38.9 ± 8.7	.93
Sex, male/female, n	6/7	2/7	8/14	.25
Follow-up period, mo	25.4 ± 1.7	24.7 ± 1.8	25.1 ± 1.7	.34
Preinjury Tegner scale	7.5 ± 1.0	7.3 ± 1.1	7.4 ± 1.0	.71
Preinjury ARS	12.9 ± 2.7	12.1 ± 1.9	12.5 ± 2.4	.51

[a]Values are expressed as mean ± standard deviation unless otherwise indicated. OATS, osteochondral autograft transfer system; ARS, activity rating scale.

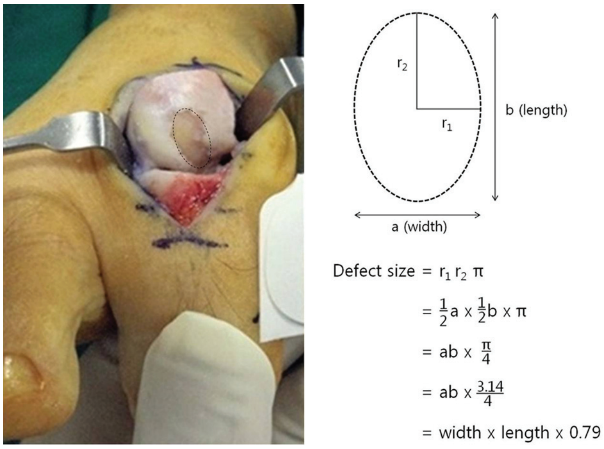

Figure 2. The size of the osteochondral defect was calculated by the ellipse formula.

nonoperative management. The study was further limited to primary cases with no previous surgical treatment, and patients with arthritic changes of their first metatarsophalangeal joint on plain radiographs were excluded. In all cases, the osteochondral defects of the first metatarsal head were localized to a focal area, and the cartilage of the articular surface of the proximal phalanx was intact. The preoperative range of motion of the first metatarsophalangeal joint was not restricted. All patients were evaluated clinically and radiographically before surgery and at last follow-up. For clinical evaluation, a visual analog scale (VAS) for pain and the American Orthopaedic Foot and Ankle Society (AOFAS) hallux metatarsophalangeal-interphalangeal scale were utilized. The Roles and Maudsley score was investigated for the evaluation of patient satisfaction with clinical results (Appendix 1, available online at http://ajs.sagepub.com/supplemental/). The Tegner activity scale[37] and an activity rating scale (ARS)[28] were utilized

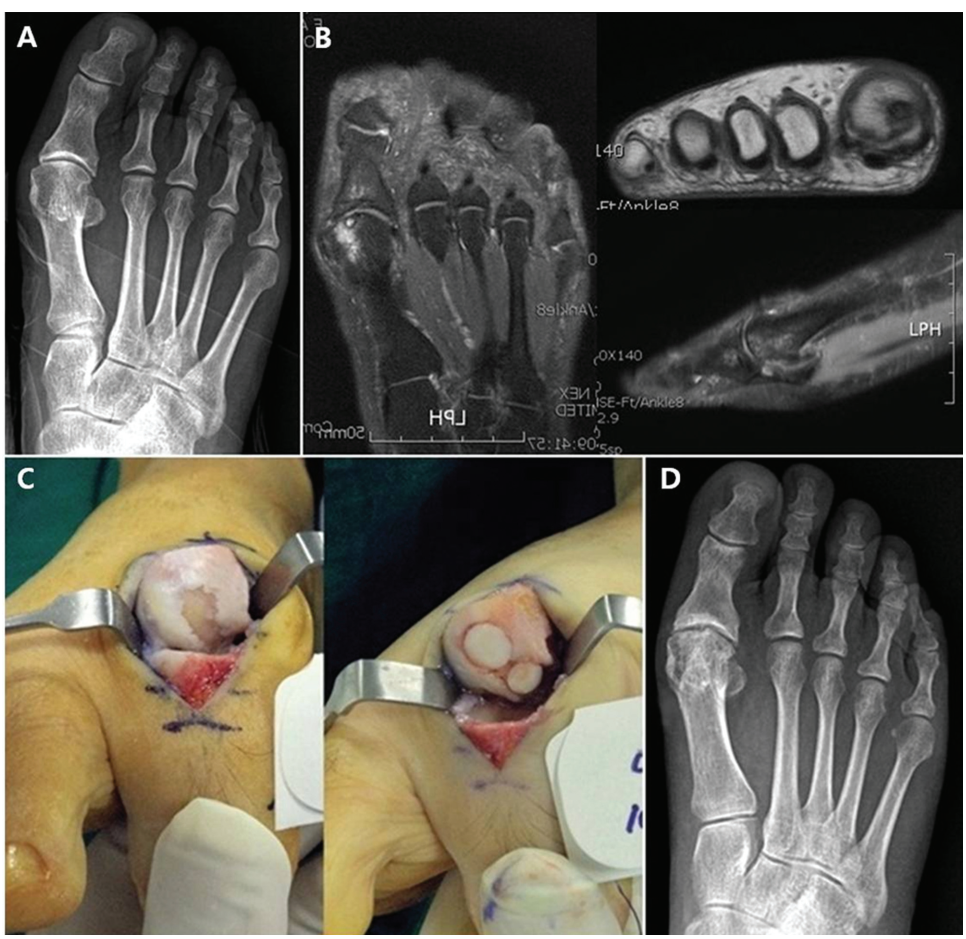

Figure 3. (A) Preoperative anteroposterior radiograph of the right foot. (B) Magnetic resonance imaging scans. T2-weighted coronal and sagittal images showing the osteochondral defect, subchondral cyst, and subchondral bone edema of the first metatarsal head. T1-weighted axial image showing the defect of the first metatarsal head. (C) Intraoperative photographs. Two osteochondral plugs were impacted in the defect site, and subchondral drilling was performed at the uncovered site between the impacted 2 plugs. (D) Anteroposterior radiograph of the right foot at 9 months after the operation. Degenerative arthritic change was observed in the first metatarsophalangeal joint.

to determine sporting and activity levels. Although the Tegner activity scale and the ARS were originally designed for the knee, they are intended for facilitating outcomes research in sports medicine. The period to return to sports activity after surgery was also investigated. At preoperative and last follow-up examinations, we obtained anteroposterior and lateral weightbearing radiographs to assess the first metatarsophalangeal joint for degenerative arthritis. We performed MRI to measure the size and location of lesions and to evaluate any associated lesions (eg, subchondral cyst) before the operation. To avoid potential bias, an independent observer who was a musculoskeletal trained radiologist, not involved in the care of the patients and blinded to the intention of this study, evaluated the MRI films. The width and length of the defect area were measured with coronal, sagittal, and axial MRI scans, and the largest dimension was selected. We reconfirmed the defect size with a ruler intraoperatively, and the defect size was calculated by the ellipse formula (Figure 2). We compared the size measurements (width, length, and size) based on MRI with those determined intraoperatively, and a good correlation was found by linear regression analysis ($r = .83$, $P < .001$).

Surgical Technique

The patient was placed in the supine position under spinal anesthesia. A thigh tourniquet was used for hemostasis. A 6-cm linear dorsal incision was made overlying the right first metatarsophalangeal joint, parallel to the extensor hallucis longus. A linear capsulotomy was performed to expose the first metatarsophalangeal joint. After identifying the lesion, we trimmed the peripheral rim of the lesion and measured its size.

For the osteochondral autograft transfer, the osteochondral autograft transfer system (OATS) instrumentation set (Arthrex Inc, Naples, Florida) was used for the recipient site preparation as well as the osteochondral plug harvest and transplantation. The diameters of the plug and recipient socket were determined by measuring the size of the cartilage defect with a sizer/tamp. Under direct visualization through a mini-arthrotomy just lateral to the patellar tendon, an osteochondral plug was cored out from the lateral edge of the lateral trochlea using a donor tube harvester. The donor graft was obtained slightly larger than the osteochondral lesion to ensure that the lesion was completely resected. The donor plug was delivered to the recipient site and impacted flush with the surrounding articular cartilage of the first metatarsal head. In 1 case, 2 donor plugs were transplanted because of the large size of the osteochondral defect. Subchondral drilling was performed at the uncovered site between the impacted 2 plugs.

For subchondral drilling, a 0.9-mm-diameter Kirschner wire was used for multiple drillings of the subchondral bone of the defect site. For cases of cystic lesion, gelatinous materials in the cystic cavity were removed by a curette. The bleeding base was confirmed by releasing the tourniquet.

After the operation, we recommended tolerable heel weightbearing to patients without great toe weightbearing for a period of 4 weeks. Patients began both active and passive range of motion exercises to the first metatarsophalangeal joint at 4 weeks after the operation. Sports or high-impact activities were limited for at least 3 months.

Statistical Analysis

The Wilcoxon signed-rank test was conducted for the evaluation of changes in preoperative and last follow-up values, and the Mann-Whitney U test was performed for the comparison of results between groups A and B. Either the χ^2 test or Fisher exact test was used to compare categorical data. To compare the sports activities in which the patients participated before and after surgery, the McNemar test was performed. Multivariate logistic regression analyses were used to assess the variables of osteochondral defects (such as defect size, location, and existence of subchondral cyst) independently associated with satisfaction with clinical results for each group. To analyze the association of the size and location of the osteochondral defect with clinical results, we divided the patients according to defect size into large defect size ($\geq$50 mm^2) and small defect size ($<$50 mm^2) groups. For locating the osteochondral defect, we divided the first metatarsal head into 3 parts horizontally and demarcated central and peripheral areas (one third of dorsal and plantar areas). We defined satisfactory clinical results as a VAS score of less than 4 points, AOFAS score of more than 80, and a good or excellent Roles and Maudsley score at the last follow-up. Odds ratios (ORs) were calculated with 95% confidence intervals (CIs). The principal dependent variable was VAS and AOFAS scores at the last follow-up. We used stepwise multivariate linear regression to assess the associations between osteochondral defect size and clinical outcome (last follow-up VAS and AOFAS scores) in each group. Statistical analysis was performed using SPSS software version 12.0.1 (SPSS Inc, Chicago, Illinois), with significance defined as $P < .05$.

RESULTS

In 9 feet, only 1 osteochondral plug was used (8-mm-diameter plug in 7 feet and 10-mm-diameter plug in 2 feet) for conducting the osteochondral autograft transfer system procedure. In 1 case, the defect area was too large and long to cover the defect area with 1 osteochondral plug; the width and length of the defect area were 6 and 12 mm, respectively, and 2 osteochondral plugs (6-mm-diameter and 8-mm-diameter plugs) were used to carry out the osteochondral autograft transfer system procedure. In that case, the uncovered area was formed between the plugs, and multiple subchondral drilling was performed additionally in that area (Figure 3).

Clinical Outcomes at Follow-up

The mean VAS score in both groups was significantly improved from 6.9 $\pm$ 0.9 to 3.9 $\pm$ 1.3 in group A and from 7.4 $\pm$ 0.8 to 3.4 $\pm$ 1.2 in group B ($P < .05$). No difference was noted between the 2 groups at final follow-up (P =

TABLE 2
Clinical and Functional Results[a]

	Group A (Subchondral Drilling)		Group B (OATS)	
	Preoperatively	Last Follow-up	Preoperatively	Last Follow-up
VAS	6.9 ± 0.9	3.9 ± 1.3	7.4 ± 0.8	3.4 ± 1.2
AOFAS score[b]	62.9 ± 5.8	73.2 ± 8.2	65.0 ± 4.1	81.5 ± 5.8
RM score, n (%)[b]				
Excellent	0 (0)	1 (7)	0 (0)	4 (40)
Good	0 (0)	4 (29)	0 (0)	5 (50)
Fair	6 (43)	6 (43)	4 (40)	1 (10)
Poor	8 (57)	3 (21)	6 (60)	0 (0)
Tegner scale[b]	3.4 ± 0.9	4.6 ± 0.7	3.7 ± 0.9	5.8 ± 1.1
ARS[b]	8.9 ± 1.9	8.7 ± 1.7	8.6 ± 2.0	10.9 ± 1.9

[a]Values are expressed as mean ± standard deviation unless otherwise indicated. OATS, osteochondral autograft transfer system; VAS, visual analog scale; AOFAS, American Orthopaedic Foot and Ankle Society; RM, Roles and Maudsley; ARS, activity rating scale.
[b]Statistically significant differences are observed between the groups ($P < .05$).

TABLE 3
List of Reported Sports Activities[a]

	Group A (Subchondral Drilling)			Group B (OATS)		
Type of Sports Activity	Preoperative	Postoperative	*P*	Preoperative	Postoperative	*P*
Jogging	5 (36)	7 (50)	.500	3 (30)	9 (90)	.031[b]
Swimming	4 (29)	9 (64)	.063	4 (40)	9 (90)	.063
Mountain climbing	1 (7)	4 (29)	.250	2 (20)	8 (80)	.031[b]
Badminton	0 (0)	1 (7)	—	1 (10)	6 (60)	.063
Aerobics	1 (7)	3 (21)	.500	1 (10)	4 (40)	.250
Table tennis	2 (14)	5 (36)	.250	2 (20)	5 (50)	.375
Tennis	0 (0)	1 (7)	—	0 (0)	2 (20)	—
Skiing	2 (14)	5 (36)	.250	2 (20)	6 (60)	.125
Golf	4 (29)	9 (64)	.063	3 (30)	7 (70)	.219
Dancing	0 (0)	0 (0)	—	0 (0)	2 (20)	—
Cycling	2 (14)	5 (36)	.375	3 (30)	6 (60)	.375
Bowling	0 (0)	0 (0)	—	0 (0)	3 (30)	—
Inline skating	0 (0)	0 (0)	—	0 (0)	1 (10)	—
Soccer	0 (0)	1 (7)	—	0 (0)	3 (30)	—
Basketball	0 (0)	0 (0)	—	0 (0)	2 (20)	—

[a]Values are expressed as n (%). OATS, osteochondral autograft transfer system.
[b]Significantly different (McNemar test, $P < .05$).

.651). The mean AOFAS score in both groups was significantly improved from 62.9 ± 5.8 to 73.2 ± 8.2 in group A and from 65.0 ± 4.1 to 81.5 ± 5.8 in group B ($P < .05$). There was a significant difference in mean AOFAS score between the 2 groups at final follow-up ($P = .032$). According to the Roles and Maudsley score, 5 of 14 cases (35%) showed good to excellent results in group A, and 9 of 10 cases (90%) showed good to excellent results in group B. The Roles and Maudsley score showed significantly greater improvement in group B after the operation ($P = .040$) (Table 2).

Sports Activities

Patients returned to sports activities on average at 16.4 ± 2.1 weeks in group A and at 15.9 ± 1.7 weeks in group B after surgery ($P = .666$). The activity levels according to the Tegner activity scale and the ARS from preoperative to final follow-up are summarized in Table 2. Activity levels according to the Tegner activity scale improved significantly in both groups ($P < .05$). There was a significant difference in Tegner activity scale score between the 2 groups at final follow-up ($P = .016$). Scores of the ARS increased significantly from 8.6 ± 2.0 to 10.9 ± 1.9 in group B ($P = .007$) but were unchanged from 8.9 ± 1.9 to 8.7 ± 1.7 in group A ($P = .809$). There was a significant difference in scores of the ARS between the 2 groups at final follow-up ($P = .009$).

The most frequently reported sports activities preoperatively were jogging (36%), swimming (29%), and golf (29%) in group A and swimming (40%), jogging (30%), golf (30%), and cycling (30%) in group B. The most frequently reported

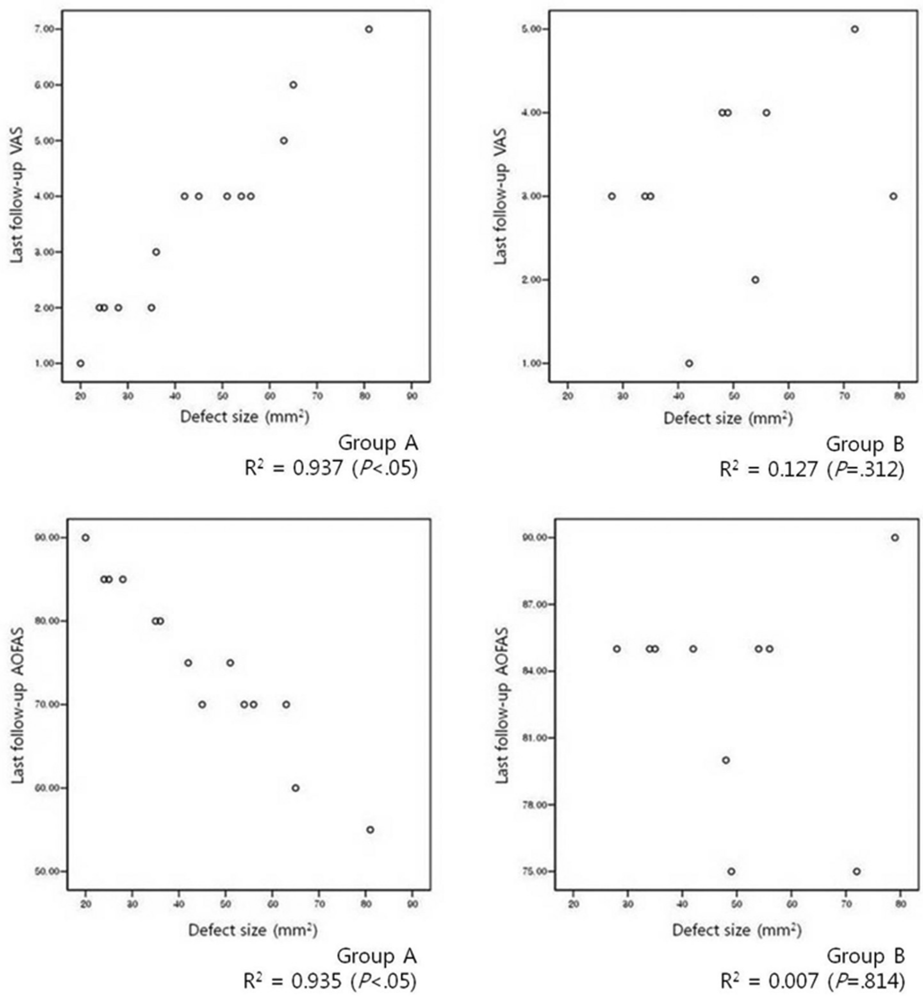

Figure 4. Correlation between defect size and last follow-up visual analog scale and American Orthopaedic Foot and Ankle Society scores in groups A and B.

sports activities after surgery were swimming (64%), golf (64%), and jogging (50%) in group A and jogging (90%), swimming (90%), and mountain climbing (80%) in group B. Statistical analysis between preoperative and postoperative situations showed a significant difference for only jogging and mountain climbing (P = .031) in group B (Table 3).

Association Between Variables of Osteochondral Defect and Clinical Outcome

The mean defect size was 44.6 ± 17.9 mm^2 in group A and 49.7 ± 16.4 mm^2 in group B (P = .428). In multivariate analyses, for the last follow-up VAS score, the defect size accounted for 93.7% of the variability in group A and 12.7% in group B. For the last follow-up AOFAS score, the defect size accounted for 93.5% of the variability in group A and 0.7% in group B (Figure 4). As illustrated in the scatter plot, patients with a defect size larger than 50 mm^2 had significantly worse outcomes according to last follow-up VAS and AOFAS scores than patients with a defect size smaller than 50 mm^2 in group A (P = .005 for VAS and P = .006 for AOFAS). When considering the results of last follow-up VAS and AOFAS scores, defect size was an independent predictor of clinical outcomes of subchondral drilling ($P < .05$). However, defect size did not independently predict the clinical outcomes of the osteochondral autograft transfer system ($P > .05$).

When considering a VAS score of less than 4 points, an AOFAS score of more than 80, and a good or excellent Roles and Maudsley score at last follow-up as a satisfactory clinical outcome, large defect size (≥50 mm^2) and the existence of a subchondral cyst were significant predictors of unsatisfactory clinical outcomes, with an OR of 0.067 (95% CI, 0.005-0.970) and 0.028 (95% CI, 0.001-0.555), respectively, compared with small defect size (<50 mm^2) and the nonexistence of a subchondral cyst in group A (P = .047 and P = .019, respectively). These correlations were not observed in group B. No association was found between location of the defect area and clinical outcome in both groups (Appendix 2, available online).

Association Between Variables of Osteochondral Defect and Arthritic Change of the First Metatarsophalangeal Joint

Degenerative arthritis of the first metatarsophalangeal joint was assessed according to anteroposterior and lateral weightbearing radiographs at the last follow-up. In group A, degenerative arthritis of the first metatarsophalangeal joint was observed in 6 cases at the last follow-up. In group B, degenerative arthritis of the first metatarsophalangeal joint was observed in 1 case at 9 months after the operation (Figure 3). Large defect size ($\geq$50 mm^2) and the existence of a subchondral cyst were significantly associated with the development of degenerative arthritis of the first metatarsophalangeal joint in group A (P = .011 and P = .037, respectively), but no association was found between location of the defect area and degenerative arthritis of the first metatarsophalangeal joint in group A (P = .133). No associations were found between the defect size, the existence of a subchondral cyst, and location of the defect area and the development of degenerative arthritis of the first metatarsophalangeal joint in group B ($P > .05$).

Other Prognostic Factors

We used logistic regression models to assess the independent effects of patient age, sex, body mass index (BMI), and duration of symptoms on clinical outcomes in each group (Appendix 3, available online). Median values were used as a standard for dividing the groups according to patient age (<37 or $\geq$37 years), BMI (<26.0 or $\geq$26.0), and duration of symptoms (<20 or $\geq$20 weeks). No prognostic factors including the patient's age, sex, BMI, and duration of symptoms showed a significant influence on clinical outcomes ($P > .05$). According to the Cox regression analysis, there were no significant correlations between all prognostic factors and defect size or the existence of a subchondral cyst ($P > .05$) (Appendix 4, available online).

DISCUSSION

Isolated osteochondral defects of the first metatarsal head are suggested to result from trauma.[3,7,14,34] However, the diagnosis of an isolated osteochondral defect of the first metatarsal head is very difficult because the initial symptoms may be vague or ambiguous, particularly when the lesion is caused by a trivial injury. Also, the patient may or may not recall the traumatic incident, and it is possible that the initial incident may have occurred many months before diagnosis.[41] Magnetic resonance imaging evaluation with clinical suspicion may be helpful to establish the diagnosis, as radiographic findings frequently fail to demonstrate the full extent of articular damage.[11] An osteochondral defect could deteriorate into a sizable necrotic fragment and progress to hallux rigidus if left untreated. Nonoperative therapy typically includes some degree of protection with immobilization, frequently followed by a physical therapy regimen. Vancil and Mozena[40] described a treatment algorithm for osteochondritis dissecans of the first metatarsophalangeal joint based on the type of lesion present. They recommended an attempt at nonoperative therapy before any type of surgical intervention in stage 1, 2, or 3 lesions but noted that stage 4 lesions would most likely not respond to any type of nonoperative measure. Surgical excision of the fragment was recommended for stage 4 lesions. Furthermore, they concluded that the probability of further arthrosis in these lesions was almost certain, with the need for additional surgical intervention likely.[40] In our study, all the patients were treated nonoperatively with medication and cast immobilization for some weeks until the symptom was improved. If the symptom remained despite a minimum of 3 months of nonoperative management, MRI evaluation was performed.

Healing of an osteochondral defect depends on several factors, including the depth and orientation of the lesion, orientation of the fracture line, age of the patient, time from injury, the radiographic stage at the time of presentation, and degree of fibrous tissue replacement of bone.[8] Many studies have reported on the prognostic factors in osteochondral lesions of the talus, and a strong correlation between lesion size and clinical outcome was reported by many authors.[9,17,19] However, only a few studies have reported on the prognostic factors of osteochondral defects of the first metatarsal head. Kravitz[24] reported that the size and location of the defect are the major factors influencing the choice of which surgical procedure to perform. Draper and Fallat[12] reported that damaged articular cartilage has a very limited potential of healing and that articular defects larger than 2 to 4 mm in diameter rarely heal.

In our study, the defect size was a significant predictor of clinical outcome in the subchondral drilling group (P = .047), but no association was found in the osteochondral autograft transfer system group (P = .748) (Appendix 2, available online). The shape of the metatarsal head is spherical, and the peripheral aspect of cartilage in the metatarsal head is more fragile than that of the central area. Moreover, surgical treatment, including subchondral drilling and the osteochondral autograft transfer system, of a peripheral area defect is more difficult when restoring the articular surface. Lee et al[26] reported that peripheral osteochondral lesions of the talus were not as well repaired as central lesions after subchondral drilling. With the osteochondral autograft transfer system, the peripheral surface of cartilage in the metatarsal head is inclined, and trimming the margin of the osteochondral plug is very important to restoring the joint configuration. In the present study, to investigate the correlation between location of the osteochondral defect and clinical outcomes, we divided the first metatarsal head into 3 parts horizontally and demarcated central and peripheral areas (one third of dorsal and plantar areas). However, no associations were found between location of the defect and clinical outcome in both groups (Appendix 2, available online). We considered that these results may be changed after longer term follow-up, as the durability of the regenerated fibrous cartilage after subchondral drilling is known to deteriorate as time passes.[13,26] Also, with the osteochondral autograft transfer system, the integration of donor and recipient

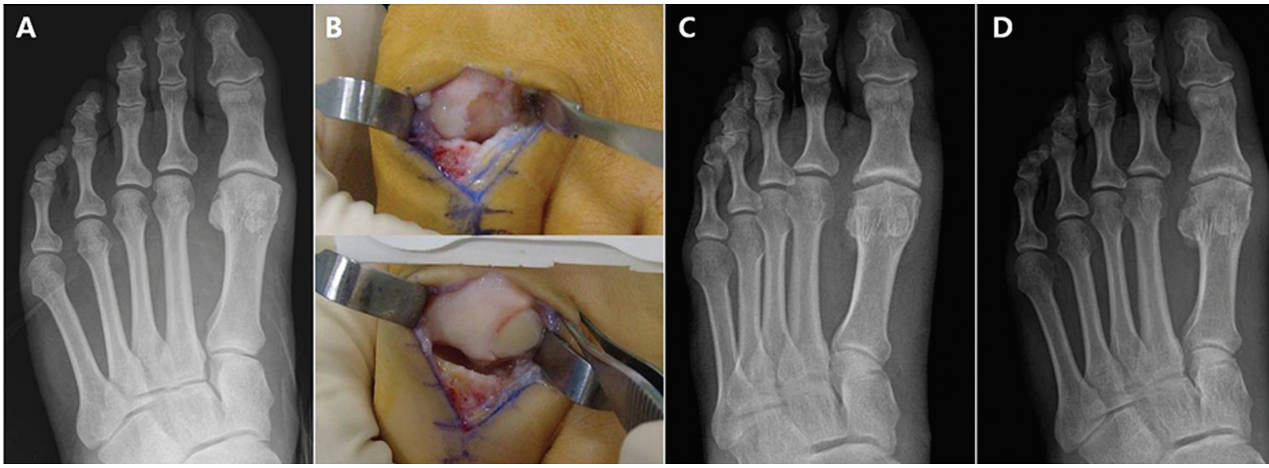

Figure 5. (A) Preoperative anteroposterior radiograph of the left foot. (B) Intraoperative photographs. The 10-mm-diameter plug was grafted to the defect area. (C) Postoperative anteroposterior radiograph of the left foot. Uneven radiographic appearance of the subchondral bone was observed. (D) Anteroposterior radiograph of the left foot at 18 months after the operation. No interval change was found compared with the postoperative radiograph.

hyaline cartilage can be difficult because of different mechanical properties and varying thickness of donor hyaline cartilage with respect to that of the recipient.[6,19,27] Therefore, long-term evaluations are required to investigate the association between location of the defect and clinical outcomes.

In multivariate analyses, we found that the defect size accounted for 93.7% of the variability in the last follow-up VAS score and 93.5% of the variability in the last follow-up AOFAS score in group A. As illustrated in the scatter plot, the cutoff point of defect size seemed to be 50 mm^2 (Figure 4). The patients with a defect size larger than 50 mm^2 had significantly worse outcomes according to last follow-up VAS and AOFAS scores than patients with a defect size smaller than 50 mm^2 in the subchondral drilling group (P = .005 for VAS and P = .006 for AOFAS), but in the osteochondral autograft transfer system group, the defect size did not influence the last follow-up VAS and AOFAS scores. Accordingly, we recommend the osteochondral autograft transfer system rather than subchondral drilling for the treatment of osteochondral defects of the first metatarsal head larger than 50 mm^2.

Kravitz[24] reported that the primary indication for treatment with the osteochondral autograft transfer system was the presence of a large subchondral cyst in the metatarsal head. Marrow-inducing reparative procedures such as chondral abrasion arthroplasty could worsen the cystic condition of the metatarsal head. It has been postulated that synovial cysts can be caused by synovial fluid intrusion through a defect in the articular cartilage.[24] Second-look arthroscopy after talar osteochondral drilling has also shown irregular chondral surfaces.[16,23] Therefore, replacement of the articular cartilage and subchondral bone in this case would provide normal hyaline cartilage and strengthen the subchondral bone.[20] This is in agreement with the findings of our study. In the subchondral drilling group, the existence of a subchondral cyst significantly worsened the clinical outcomes (P = .019). However, the clinical outcomes of the osteochondral autograft transfer system group were not influenced by the presence of a subchondral cyst (Appendix 2, available online). We also found that the existence of a subchondral cyst was significantly associated with the development of degenerative arthritis of the first metatarsophalangeal joint in the subchondral drilling group (P = .037). Therefore, to evaluate the defect size and the presence of subchondral cysts, we suggest that preoperative MRI be used, not only for diagnostic methods but also for prognostic purposes.

An interesting finding was observed on the postoperative radiographs of the osteochondral autograft transfer system group. An uneven radiographic appearance of the subchondral bone was found in 3 cases treated with osteochondral autograft transfer (Figure 5). This subchondral bone mismatch was caused by thicker articular cartilage present in the distal femur when harvesting the donor graft from the distal femur. Kravitz[24] evaluated this subchondral bone mismatch with follow-up MRI and reported that there were no obvious joint incongruities in the sagittal view upon MRI, despite radiographic findings. However, the clinical outcomes of these patients in our study were satisfactory.

In this study, degeneration of the first metatarsophalangeal joint was found in 1 case from the osteochondral autograft transfer system group. In that case, the osteochondral defect was too large and long to cover the defect area with 1 osteochondral plug, and 2 osteochondral plugs were used. An uncovered area was formed between the plugs because of the round shape of the plugs (Figure 3). We assumed that the regeneration of fibrocartilage was insufficient, despite performing an additional subchondral drilling procedure in the uncovered area, and following processes, such as scar tissue infiltration and synovial reaction, caused degeneration of the first metatarsophalangeal joint. Further evaluation with a larger number of cases is needed to determine the cause of degenerative change.

A functional great toe is important considering its role during gait. In healthy patients, the forces during the push-off phase under the first metatarsal head and hallux, taken together, account for about 53% of the body weight.[10] Accordingly, loss of first metatarsophalangeal joint motion may not be acceptable for active patients who aim to resume recreational and sports activities. Therefore, it is very important to restore the functionality of the metatarsophalangeal joint. Activity levels have the potential to provide a valuable dimension to outcomes measurement. There are many studies that investigate the sports activity level after surgery of hip, knee, and ankle joints. However, there are little data in the orthopaedic literature that investigate that of the first metatarsophalangeal joint. In this study, we investigated the activity level using the Tegner activity scale[37] and the ARS,[28] which are most frequently used. Paul et al[32] reported that the Tegner activity scale dropped significantly from 5.9 ± 2.2 preoperatively to 5.0 ± 2.0 (P = .001) and that the ARS decreased significantly from 8.9 ± 5.7 to 6.8 ± 5.4 (P = .003) after osteochondral transplantation of the talus. In our study, the Tegner activity scale improved significantly in both groups ($P < .05$), and the ARS increased significantly from 8.6 ± 2.0 to 10.9 ± 1.9 in group B (P = .007) but decreased from 8.9 ± 1.9 to 8.7 ± 1.7 in group A (P = .809). There were significant differences in both scales between the 2 groups at final follow-up (P = .016 and P = .009, respectively) (Table 2). In this study, we also investigated the type of sports activities in which patients participated before and after surgery in both groups (Table 3). Daniilidis et al[10] recommend low-impact sports activities such as walking, hiking, swimming, dancing, golf, and cycling after first metatarsophalangeal joint replacement. In our study, most patients returned to not only low-impact sports activities but also high-impact sports activities such as jogging, mountain climbing, soccer, and basketball after surgery. Also, statistical analysis between preoperative and postoperative situations showed a significant difference for jogging and mountain climbing (P = .031) in group B (Table 3). Mithoefer et al[30] reported that time to return to sports participation ranged between 7 and 18 months depending on the cartilage repair technique of the knee joint. Average time to return to sport was 8 ± 1 months after microfracture and 7 ± 2 months after osteochondral autograft transfer. In our study, patients returned to full activities at an average of 16.4 ± 2.1 weeks in group A and at 15.9 ± 1.7 weeks in group B after surgery (P = .666). The periods to return to sports activity were short after osteochondral autograft transfer in both studies, but there were no significant differences ($P > .05$).

There were no complications in our study, including nerve injury, infection, and delayed wound healing. Potential donor site morbidity at the knee after harvesting an osteochondral graft for the talus is discussed in the current literature.[31,33,39] However, in the current study, there was no donor site morbidity in group B. We suggest that the surgeon should bear in mind that the metatarsal head is small in comparison with the talus or distal femur when contemplating performing the osteochondral autograft transfer system procedure. Possible sequelae such as pathological fracture or articular collapse can occur during the operation, and if a subchondral cyst exists or the metatarsal bone is feeble, more caution is needed.

The major limitations of our study are the small number of cases and the relatively short duration of the follow-up period. For more accurate evaluation and comparison of the results of the osteochondral autograft transfer system to those of subchondral drilling for the treatment of osteochondral defects of the first metatarsal head, a prospective study and a larger series of cases with a longer follow-up period are required. Follow-up MRI would have been helpful for evaluating grafted cartilage in the osteochondral autograft transfer system group and regeneration of cartilage in the subchondral drilling group. We concluded that the preoperative measurement of initial defect size using MRI provides valuable prognostic information on the clinical outcome of osteochondral defects of the first metatarsal head.

The encouraging outcomes of this study suggest that the osteochondral autograft transfer system for the first metatarsal head could potentially be utilized to restore the functionality of a metatarsophalangeal joint. If the osteochondral defect is larger than 50 mm^2 or a subchondral cyst exists, the osteochondral autograft transfer system should be considered as the treatment of choice rather than subchondral drilling for the treatment of osteochondral defects of the first metatarsal head.

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