Internal Fixation of Osteochondral Lesion of the Talus Involving a Large Bone Fragment

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Background: Internal fixation of an osteochondral lesion of the talus (OLT) can restore the congruency of the talus and maintain the subchondral bone and innate hyaline cartilage. However, OLT that is indicated for fixation is rarely encountered; hence, not many studies report on the results after the procedure.

Purpose: To evaluate the clinical and radiological outcomes after internal fixation of chronic OLT involving a large bone fragment of at least 10 mm in diameter and 3 mm in depth on computed tomography (CT).

Study Design: Case series; Level of evidence, 4.

Methods: We retrospectively reviewed the data of 26 patients with OLT treated with internal fixation between August 2014 and April 2018. Of the patients, 15 were male and 11 were female, with a mean age of 16 years (range, 11-29 years). The primary radiological outcome measurement was bone union assessed on the 6-month postoperative CT scan. Clinical outcomes were assessed at a mean of 27.7 months postoperatively.

Results: Twenty patients (77%) achieved bone union on postoperative CT scan. The mean 100-mm visual analog scale (VAS) improved from 30.5 ± 8.5 preoperatively to 13.4 ± 9.7 postoperatively ($P < .001$). The mean Foot Function Index (FFI) improved from 30.5 ± 6.7 preoperatively to 13.7 ± 9.8 postoperatively ($P < .001$). A malleolar osteotomy was not necessary to approach the lesion in 88% of patients. A bone fragment with an irregular margin and low density on the preoperative CT scan was significantly associated with nonunion (odds ratio: 7.67, 95% confidence interval: 2.67 to 22.02, $P = .008$). The difference in clinical outcomes between patients with skeletally immature ankles and those with skeletally mature ankles was not statistically significant. Patient age did not correlate with postoperative 100-mm VAS (Pearson correlation coefficient, $r = -0.07$, $P = 0.72$) or the postoperative FFI (Pearson correlation coefficient, $r = -0.05$, $P = .80$).

Conclusion: Internal fixation of an OLT involving a large bone fragment resulted in satisfactory clinical and radiologic outcomes. We found that patients with skeletally immature and mature ankles attained healing at comparable rates after the internal fixation of OLT.

Keywords: ankle; arthrotomy; fixation; malleolar osteotomy; osteochondral lesion of the talus

Arthroscopic bone marrow stimulation such as a microfracture is the most commonly utilized surgical treatment for a symptomatic osteochondral lesion of the talus (OLT).[8,9,19] However, it is recommended for small lesions of <107.4 mm^2 in area and/or 10.2 mm in diameter.[25,26] For large lesions, replacement surgery such as autologous osteochondral transplantation or osteochondral allografting is required.[1,16,19,23,27] Despite their excellent clinical results, these replacement procedures are not without risks or complications.[28] Autologous chondrocyte implantation can be considered. However, it is expensive and involves a 2-stage surgical procedure, with morbidity associated with harvesting a small portion of the normal articular cartilage.[19] This procedure often requires malleolar osteotomy.

In cases of OLT with a large bone fragment, fixation of the osteochondral fragment can be considered. This procedure has the advantages of restoration of the natural congruency of the talus and maintenance of the subchondral bone and innate hyaline cartilage. However, OLT with a bone fragment large enough for healing on the base of the lesion is rarely encountered; hence, not many studies have reported on the results after the procedure.[10,17,18,21,22] In a study that involved 1,068,215 people aged 2 to 19 years who were selected from the database of a large health care system, only 85 patients had ankle osteochondritis dissecans, while 206 patients had knee osteochondritis dissecans.[14,31,33] Among the 85 patients with ankle osteochondritis dissecans, 27 (32%) required surgery and only 4 (5%) underwent fixation. This low incidence of fixation could be attributed to the few cases indicated for

The American Journal of Sports Medicine
2021;49(4):1031–1039
DOI: 10.1177/0363546520988739

fixation or the reluctance of surgeons to perform internal fixation requiring malleolar osteotomy to approach the lesion, which can injure the growth plate in young patients with an open growth plate of the distal tibia.[11,33] Even for adults, malleolar osteotomy entails some complications.[4] However, unlike the exposure required for autologous osteochondral transplantation and allografting for the placement of large osteochondral plugs or an allograft block, for fragment fixation, the entire lesion does not have to be exposed and a malleolar osteotomy is not always required. We developed a method to approach the lesion without malleolar osteotomy. The purpose of this study was to evaluate the clinical and radiologic outcomes after internal fixation of OLT.

METHODS

Participants

We retrospectively reviewed the data of 26 patients with OLT treated with the current technique between August 2014 and December 2017 (Figure 1). This study was approved by Hallym University Institutional Review Board (IRB No. 2017-11-011) and the patients provided informed consent. Of the participants, 15 were male and 11 were female, with a mean age of 16 years (range, 11-29 years). Five patients had bilateral lesions, but contralateral side lesions were asymptomatic and no patients underwent bilateral fixation.

The indication for the procedure was a large OLT with a bone fragment of at least 10 mm in diameter and 3 mm in depth on computed tomography (CT) scan that failed to attain radiological union after 1 month of non-weight-bearing in a cast and 3 months of nonoperative treatment. Lesions with intact overlying cartilage of the osteochondral fragment on magnetic resonance imaging (MRI) and arthroscopic examination were indicated for the procedure.

The contraindications were cases with damaged or ulcerated cartilage on MRI scans and arthroscopic examination. Cases with the fragmentation of the bone fragment and cysts on CT scan and cases with osteoarthritis or infectious pathology were not considered for the procedure.

Preoperative Planning

Preoperatively, MRI and CT scans were obtained to assess the size, location, shape, and morphology of the lesion.

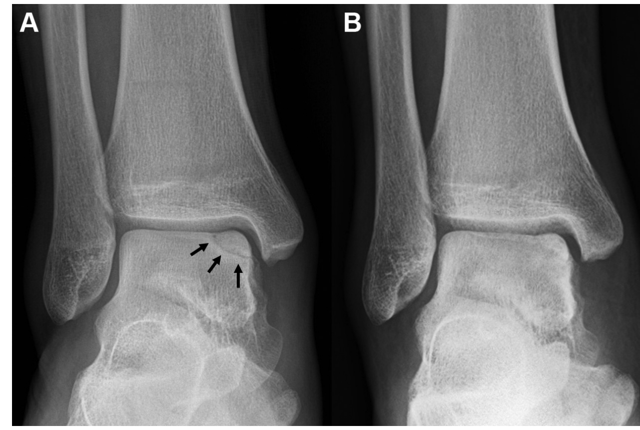

Figure 1. (A) A large osteochondral fragment on the medial talar dome was treated with internal fixation. (B) A follow-up radiography image showed a good union of the lesion. The arrows indicate the margin of the lesion.

The sagittal length of the lesion was measured as the largest diameter (mm) in the anteroposterior direction on sagittal CT images, and the coronal length was measured as the largest diameter (mm) in the mediolateral direction on the coronal CT images. The thickness was measured as the depth of the lesion on the coronal CT images. The area was calculated using the ellipse formula of coronal length $\times$ sagittal length $\times$ 0.79.[6] Fourteen lesions were located on the centromedial talar dome and 12 lesions on the posteromedial talar dome. The mean size of the fragment measured on the CT scan was 12.6 $\pm$ 1.7 mm in sagittal length, 8.1 $\pm$ 1.9 mm in coronal length, 4.4 $\pm$ 0.6 mm in depth, and 80.9 $\pm$ 22.6 mm^2 in area. MRI was used to assess the condition of the cartilage overlying the osteochondral fragment. Ankle lateral radiographs were obtained with the ankle in maximal dorsiflexion and plantarflexion to determine if the lesion could be accessed through arthrotomy (Figure 2). When >50% of the lesion could be uncovered from the tibial articular surface either in maximal dorsiflexion or plantarflexion, it was determined to be accessible through arthrotomy without malleolar osteotomy.

Operative Techniques

After spinal or general anesthesia, the patient was placed in a supine position. A standard ankle arthroscopic

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Submitted June 22, 2020; accepted October 26, 2020.

The authors declared that they have no conflicts of interest in the authorship and publication of this contribution. AOSSM checks author disclosures against the Open Payments Database (OPD). AOSSM has not conducted an independent investigation on the OPD and disclaims any liability or responsibility relating thereto.

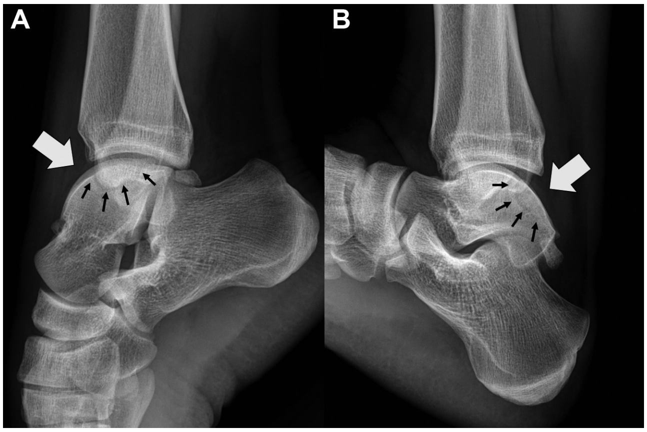

Figure 2. Ankle lateral radiographs were obtained with the ankle in (A) maximal plantarflexion and (B) dorsiflexion to determine if >50% of the lesion could be exposed out of the tibiotalar articulation from the anterior or posterior side. The black arrows indicate the margin of the lesion. The white arrows indicate that the lesion could be approached better from the posterior side.

examination was performed to assess the condition of the overlying cartilage of the lesion (Figure 3A). Lesions with damaged or ulcerated cartilage or large fissures over the osteochondral fragment were not indicated for fixation. When <50% of the lesion could be exposed even with maximal dorsiflexion or plantarflexion of the ankle joint, medial malleolar osteotomy was performed to approach the lesion. When >50% of the lesion could be exposed from the posterior side, the anterior part of the lesion was cut from the surrounding talus by using an arthroscopic knife and chisel to make a sharp osteochondral flap so that the fragment could later be taken out easily through posteromedial arthrotomy (Figure 3B).

Then, a longitudinal incision of 3 cm was made on the posterior border of the medial malleolus between the posterior tibial and flexor digitorum longus tendons (Figure 4A). The flexor digitorum longus tendon was retracted posteriorly to protect the neurovascular structures. Arthrotomy was performed longitudinally, and the posteromedial part of the talus was exposed. Maximal dorsiflexion of the ankle brought the lesion more posteriorly for better exposure. Flexion of the knee relaxed the gastrocnemius muscle to enable maximal dorsiflexion of the ankle. The posterior, medial, and lateral margins of the lesion were detached with a sharp blade. The anterior part of the lesion could not be exposed in most cases even with maximal dorsiflexion of the ankle with posteromedial arthrotomy. However, the osteochondral fragment could be detached from the talus and taken out from the ankle because of the previous detachment of the anterior part of the lesion through arthroscopy (Figure 4B). Sometimes, anteromedial arthrotomy was required to detach the anterior part of the fragment. In this case, maximal plantarflexion increased the exposure of the anterior part of the lesion. The base of the defect on the talus was examined, and fibrotic tissue and sclerotic bone were removed with a curette and bur (Figure

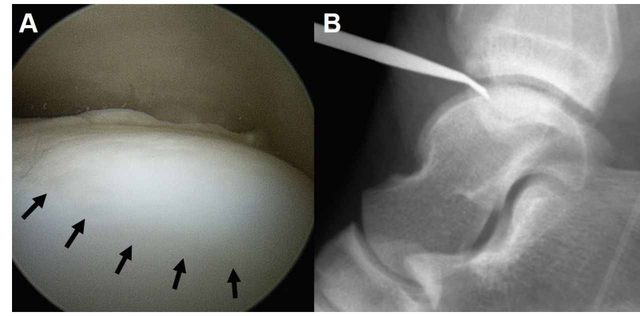

Figure 3. (A) Standard ankle arthroscopic examination was performed to assess the condition of the overlying cartilage. Cases with severely damaged or ulcerated cartilage were contraindicated for fixation. (B) The anterior part of the fragment was cut from the surrounding talus using an arthroscopic knife and chisel to make a sharp osteochondral flap so that the fragment could later be taken out easily through posteromedial arthrotomy. The arrows indicate the margin of the lesion.

4, C and D). Next, the base of the defect was drilled with a K-wire. The base of the fragment was examined, and the fibrous tissue was removed taking care not to break the fragment (Figure 4E). Cancellous bone was harvested from the lateral calcaneus and was impacted onto the base of the defect so that the fragment would not be depressed during fragment compression by the screw (Figure 4F). The osteochondral fragment was reduced on the defect (Figure 4G) and a 3.0-mm Bio-Compression Screw (Arthrex Inc) was fixed at the center of the lesion (Figure 4H). However, when the exposure was not sufficient to place the 3.0-mm bioabsorbable screw on the center of the fragment, one or two 1.5-mm metal screws were fixed on the posterior part through the posteromedial arthrotomy and 1 metal screw was fixed on the anterior part of the lesion through anteromedial arthrotomy with maximal plantarflexion. When the fragment was relatively thin (depth < 4.0 mm), 1.5-mm metal screws were used as a precaution because 3.0-mm bioabsorbable screws might break the fragment. Arthroscopy was performed to check for any step-off of the lesion and any bone debris left inside the ankle joint (Figure 4G). A below-knee cast was applied for 6 weeks postoperatively. After removal of the below-knee cast, a removable splint or cast boot was applied. Patients were kept non-weightbearing, but ankle motion exercises were encouraged. Weightbearing began 8 weeks postoperatively. The splint or cast boot was removed 8 to 10 weeks postoperatively. Metal screws were routinely removed at 6 months postoperatively when the bone union was confirmed on CT scan.

Clinical and Radiological Assessments

Clinical results were assessed using a 100-mm visual analog scale (VAS) and the Foot Function Index (FFI)[3,5] preoperatively and at 6 months, 1 year, and every subsequent year postoperatively. The FFI is a validated patient-assessed questionnaire containing 3 subscales as follows:

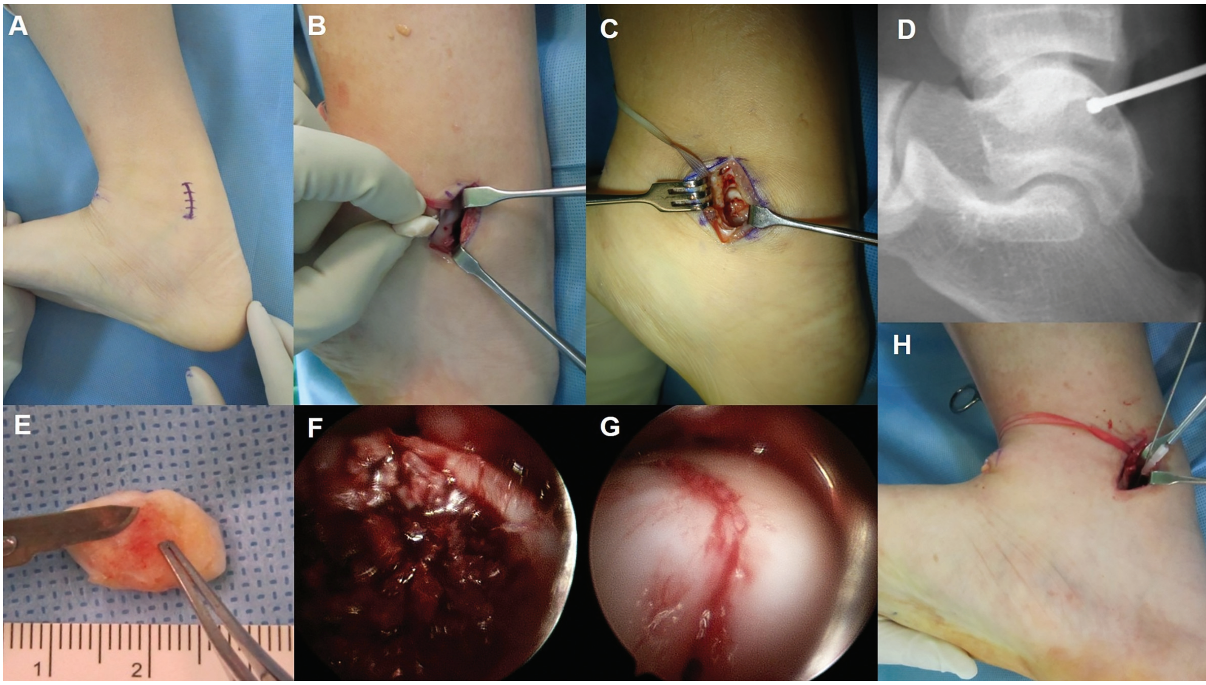

Figure 4. (A) A 3-cm longitudinal incision was made on the posterior border of the medial malleolus. (B) Maximal dorsiflexion of the ankle brought the lesion posteriorly for better exposure. The osteochondral fragment was taken out of the talus. (C) The base of the defect on the talus was examined. (D) A curette and bur were used to remove the fibrotic tissue and sclerotic bone on the base of the defect on the talus. (E) The fibrous tissue and necrotic bone on the base of the fragment were removed. (F) Cancellous bone was harvested from the lateral calcaneus and was impacted on the base of the defect so that the fragment would not be depressed by the screw during fragment compression. (G) The osteochondral fragment was reduced. (H) A bioabsorbable screw was fixed at the center of the lesion.

pain, disability, and activity limitations (total score of 100 points, with 100 being the worst).[3] The patients' medical records were reviewed to assess the clinical outcomes and postoperative complications. The bone fragment condition was assessed preoperatively on the CT scan either as a well-demarcated margin with an iso-density or an irregular margin with low-density to the underlying talus. The primary radiological outcome measurement was bone union assessed on the 6-month postoperative CT scan.[18,29] When >75% of continuity between the bone fragment and the talus was observed on the sagittal, coronal, and axial images that showed the largest bone fragment, bone union was considered to have been attained.[12]

Data normality was assessed using the Kolmogorov-Smirnov test. All data are expressed as mean ± standard deviation. The association between the condition of the bone fragment on the preoperative CT scan and radiological bone healing on the 6-month CT scan was examined using Fisher's exact test. The relationship between patients' age and the clinical outcomes was examined with Pearson correlation analysis. Wilcoxon signed-rank test was used to compare pre- and postoperative values using SPSS version 21.0 (IBM Corporation, Armonk, NY, USA). Differences with P values <.05 were considered statistically significant.

RESULTS

The results are summarized in Table 1. The mean follow-up duration was 27.7 months (range, 6-49 months). The mean 100-mm VAS improved from 30.5 ± 8.5 preoperatively to 13.4 ± 9.7 postoperatively ($P < .001$). The mean FFI improved from 30.5 ± 6.7 preoperatively to 13.7 ± 9.8 postoperatively ($P < .001$). The modified Brostrom procedure was performed for 3 patients. All the patients underwent a CT scan at 6 months postoperatively. Of the 26 patients, 20 (77%) achieved a radiological bone union (Figure 5). Three patients with OLT with an irregular margin and low density to the underlying talus on the preoperative CT scan failed to attain bone union. The condition of the bone fragment on the preoperative CT scan was significantly associated with nonunion (odds ratio, 7.67; 95% CI, 2.67-22.02; $P = .008$).

No significant difference in outcomes was found between the patients with skeletally immature ankles and those with skeletally mature ankles (Table 2). Patient age did not correlate with postoperative 100-mm VAS (Pearson correlation coefficient, $r = -0.07$, $P = .72$) or postoperative FFI (Pearson correlation coefficient, $r = -0.05$, $P = .80$). No significant difference in outcomes was observed between the use of absorbable and metal screws (Table 3).

TABLE 1
Details and Results for the 26 Patients[a]

Case	Sex	Age, y	Side	Growth plate[b]	Stage[c]	Location	Size of fragment (mm)[d]	Approach	Fixation type	No. of pins or screws	Bone graft	Bone union	Revision surgery	Follow-up (mo)	Final 100-mm VAS	Final FFI
1	M	13	R	Opened	III	PM	13.2 × 6.2 × 4.1	P	AP	2	No	No	Yes	12	45	34
2	F	20	R	Closed	III	CM	11.1 × 9.0 × 3.4	P	AP	2	No	No	Yes	6	28	30
3	M	18	B(R)	Closed	III	PM	16.5 × 10.1 × 5.2	P	AS	1	Yes	Yes	No	49	6	10
4	F	13	L	Opened	III	CM	14.1 × 6.7 × 4.2	P	AS	1	No	Yes	No	48	11	4
5	M	21	L	Closed	III	PM	10.3 × 8.3 × 3.4	P	MS	2	No	No	Yes	6	24	30
6	M	16	R	Closed	III	CM	10.9 × 10.3 × 4.4	MO	AS	1	Yes	Yes	Yes	24	13	14
7	M	14	B(R)	Opened	III	PM	12.6 × 5.3 × 4.3	P	AS	1	Yes	No	Yes	15	23	22
8	M	23	B(R)	Closed	III	CM	12.2 × 11.3 × 5.2	B	AS	1	Yes	Yes	No	48	9	13
9	F	11	L	Opened	III	CM	11.8 × 6.4 × 4.7	P	AS	1	Yes	Yes	No	36	0	2
10	M	20	L	Closed	II	CM	14.4 × 5.6 × 4.9	P	AS	1	Yes	No	Yes	6	18	18
11	M	17	L	Closed	III	CM	11.1 × 8.8 × 4.4	MO	AS	1	Yes	Yes	No	48	8	9
12	F	15	R	Closed	III	PM	14.1 × 7.2 × 4.3	P	MS	2	Yes	Yes	No	36	7	13
13	M	13	R	Opened	IV	PM	15.7 × 9.6 × 4.9	B	MS	3	Yes	Yes	No	36	14	10
14	M	16	R	Closed	III	CM	11.4 × 6.3 × 3.6	P	MS	2	Yes	No	No	12	28	38
15	F	15	L	Closed	III	PM	13.7 × 6.5 × 3.8	P	MS	2	Yes	Yes	No	35	12	15
16	M	18	L	Closed	IV	PM	14.3 × 7.3 × 5.2	P	AS	1	Yes	Yes	No	36	0	2
17	M	16	R	Closed	III	CM	11.3 × 11.2 × 5.3	B	MS	2	Yes	Yes	No	25	8	6
18	M	14	L	Opened	III	CM	14.1 × 10.2 × 4.8	P	AS	1	Yes	Yes	No	36	9	7
19	F	19	R	Closed	III	CM	10.1 × 9.4 × 4.2	MO	AS	2	Yes	Yes	No	24	6	7
20	M	18	R	Closed	III	PM	10.5 × 6.9 × 3.3	P	MS	2	Yes	Yes	No	24	10	17
21	F	15	R	Closed	III	CM	12.5 × 5.2 × 4.2	B	MS	2	Yes	Yes	No	24	14	13
22	F	29	L	Closed	III	CM	12.6 × 7.2 × 5.3	P	AS	1	Yes	Yes	No	25	8	5
23	F	12	L	Opened	III	CM	11.3 × 8.7 × 3.6	P	MS	2	Yes	Yes	No	36	12	9
24	F	16	B(L)	Closed	III	CM	14.3 × 8.8 × 5.1	P	AS	1	Yes	Yes	No	24	8	10
25	M	18	L	Closed	III	PM	10.4 × 7.6 × 4.2	P	MS	2	Yes	Yes	No	24	13	9
26	M	15	B(L)	Closed	III	PM	13.0 × 11.6 × 4.9	P	AS	1	Yes	Yes	No	24	14	12

[a]AP, absorbable pin; AS, absorbable screw; B, both from anterior and posterior; B(L), bilateral (operated on left); B(R), bilateral (operated on right); CM, centromedial; F, female; FFI, Foot Function Index; L, left; M, male; MO, malleolar osteotomy; MS, metal screw; P, posterior; PM, posteromedial; R, right; VAS, visual analog scale.
[b]Growth plate of distal tibia.
[c]Berndt and Harty Stage.[2]
[d]Size of a fragment is presented as sagittal length × coronal length × depth.

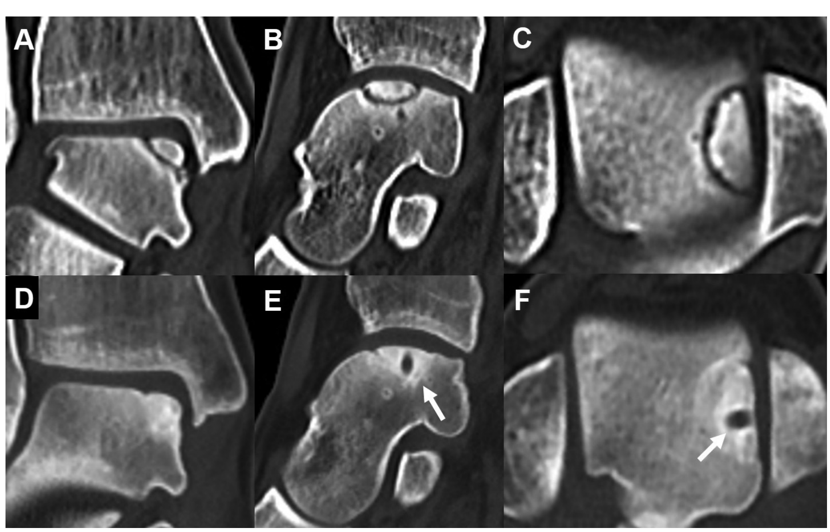

Figure 5. A large osteochondral fragment was present on the medial talar dome on the preoperative (A) coronal, (B) sagittal, and (C) axial CT scans. (D-F) Bone union was confirmed on the 6-month postoperative CT scans. The arrows indicate the insertion site of the bioabsorbable screw. CT, computed tomography.

Six patients had a nonunion (Figure 6). Five patients underwent another surgery with the removal of fragments and a bone autograft from the lateral calcaneus. For these 5 patients, the clinical outcomes assessed before the reoperation were considered as the final outcomes in the present study. The other patient with nonunion did not want another

TABLE 2
Comparison Between Patients With Skeletally Immature and Mature Ankles[a]

	Skeletally Immature (n = 7)	Skeletally Mature (n = 19)	*P* Value
Age, y	12.9 ± 1.1	18.2 ± 3.5	<.001
Sex, male/female	4/3	11/8	.97
Lesion size, mm^2	80.3 ± 26.4	81.1 ± 21.9	.80
Preoperative 100-mm VAS	24.3 ± 7.2	31.8 ± 8.3	.11
Preoperative FFI	27.2 ± 7.3	31.2 ± 6.6	.24
Follow-up, mo	31.3 ± 12.9	26.3 ± 13.3	.29
Bone union	5 (71)	15 (79)	.69
Postoperative 100-mm VAS	16.3 ± 14.4	12.3 ± 7.5	.49
Postoperative FFI	12.4 ± 11.6	14.1 ± 9.3	.35

[a]Data are given as n (%) or mean ± SD. Skeletal maturity was determined by whether the growth plate of the distal tibia was opened or closed. FFI, Foot Function Index; VAS, visual analog scale.

TABLE 3
Comparison of Outcomes Between the Use of Absorbable Screw and Metal Screw[a]

	Absorbable Screw (n = 14)	Metal Screw (n = 10)	*P* Value
Age, y	17.4 ± 4.6	15.9 ± 2.6	.38
Sex, male/female	8/6	6/4	.89
Lesion size, mm^2	86.9 ± 24.1	74.2 ± 21.1	.19
Preoperative 100-mm VAS	31.3 ± 8.5	29.6 ± 9.4	.67
Preoperative FFI	28.3 ± 5.7	31.9 ± 6.7	.18
Follow-up, mo	31.6 ± 13.5	25.8 ± 10.5	.27
Bone union	12 (86)	8 (80)	.71
Postoperative 100-mm VAS	9.5 ± 6.2	14.2 ± 6.7	.09
Postoperative FFI	9.5 ± 5.9	15.8 ± 10.3	.10

[a]Values are given as n (%) or mean ± SD. FFI, Foot Function Index; VAS, visual analog scale.

surgery. However, the patient was lost to follow-up and the clinical result assessed at 12 months postoperatively was considered as the final outcome. None of the patients showed neurological symptoms or other complications.

DISCUSSION

The most important finding of the present study was that the internal fixation of OLT involving a large bone fragment resulted in satisfactory clinical and radiological outcomes. A malleolar osteotomy was not necessary to approach the lesion in 88% of patients.

The natural course of the OLT with a large bone fragment is not well known.[30] It can either heal and remain asymptomatic or progress to fragmentation and degeneration and cause severe ankle pain. Decision making regarding the treatment is difficult especially for lesions involving a large bone fragment. The removal of the fragment for bone marrow stimulation such as microfracture can result in a large defect.[18] Replacement procedures such as autologous osteochondral transplantation or osteochondral allografting can be an option, but they are not without risks or complications.[28] These can be too invasive for young patients with skeletally immature ankles.[31] Internal fixation of the large osteochondral fragment to heal on the underlying talus can restore the natural congruency of the talar dome and preserve the subchondral bone and innate hyaline cartilage, which may be the best option theoretically. However, not many studies report on the results after the procedure.[10,17,18] In a study of 27 patients with OLT, 89% achieved good clinical results after fixation of the osteochondral fragment. However, the procedure required malleolar osteotomy.[17]

Two factors could lead to the reluctance of surgeons to perform internal fixation for a large OLT. One is the need for malleolar osteotomy to approach the lesion, and the other is the possibility of nonunion of the relatively small chronic bone fragment inside the joint.

Internal fixation of OLT usually requires malleolar osteotomy.[10,17,21,22] However, for young patients with an open growth plate, malleolar osteotomy may injure the growth plate. Even for adults, malleolar osteotomy entails some complications. In a study of 50 biplane medial malleolar osteotomies, 30.0% of cases had a malunion with a mean incongruency of 2 mm.[4] However, for fixation of OLT, unlike the exposure required for autologous osteochondral transplantation and allografting, the entire lesion does not have to be exposed and malleolar osteotomy is not always required. In a cadaveric study, 33% of the talus in the anteroposterior length and 30% of its mediolateral length could be reached by posteromedial arthrotomy without malleolar osteotomy.[34] Through anteromedial arthrotomy, 50% of the talus in the anteroposterior length

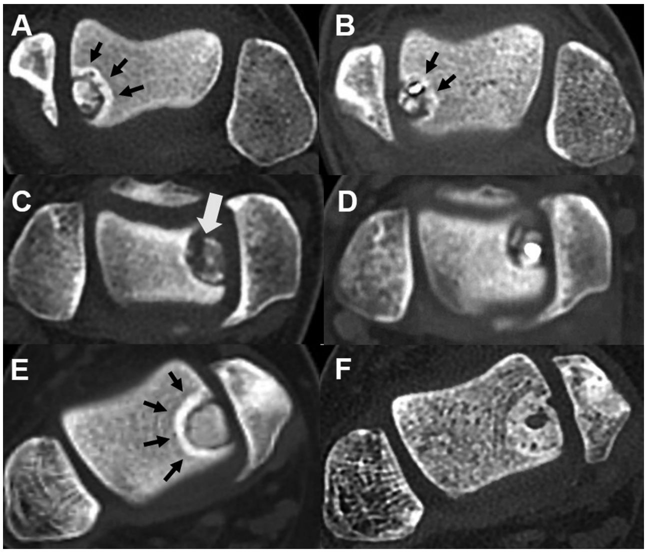

Figure 6. (A) Preoperative axial CT scan showing thick sclerotic bone surrounding the osteochondral fragment. (B) Insufficient removal of the sclerotic bone on the base of the defect resulted in nonunion. (C) A large fragment with an irregular margin and low density was observed on the preoperative CT scan. (D) Nonunion was observed on the 6-month postoperative CT scan after the fixation of the fragment. (E) A large osteochondral fragment with a well-demarcated margin and iso-density with the talus was surrounded by thick sclerotic bone. (F) A 6-month postoperative CT scan showed good healing after thorough preparation of the base and internal fixation with a bioabsorbable screw. The black arrows indicate the sclerotic bone. The white arrow indicates a large bone fragment with an irregular margin and low density. CT, computed tomography.

and 36% of its mediolateral length could be reached. When the ankle is placed in maximal dorsiflexion or plantarflexion, more areas can be reached without malleolar osteotomy. In the present study, we preoperatively checked if >50% of the lesion could be exposed out of the tibiotalar articulation from the posterior or anterior direction by using ankle lateral radiography with the ankle in maximal dorsiflexion and plantarflexion. This enabled sufficient exposure of the lesion for fixation without malleolar osteotomy in 88% of the patients. None of the patients with an open growth plate required malleolar osteotomy.

In our series, 6 patients failed to attain a bone union. In 2 patients, we did not totally detach and remove the fragment, but only lifted the osteochondral flap from the posterior to remove the fibrous tissue and necrotic bone and fixed the fragment with absorbable pins without a bone graft. On the postoperative CT scan, the sclerotic rim was still observed surrounding the unhealed fragment (Figure 6, A and B). The nonunion might have occurred due to insufficient preparation of the base of the talar defect or a lack of bone graft or firm fixation of the fragment. When nonunion occurred, we took out the fragment and removed the sclerotic bone thoroughly and impacted a bone graft into the defect created by the removal of the sclerotic bone and used screws for firm fixation after fragment reduction (Figure 6, E and F). Sclerosis on the base of the lesion can impede the revascularization of the fragment, and we believe that thorough preparation of the base of the talar defect is important for fragment healing.

Another 3 cases of nonunion occurred in the patients with poor bone condition of the fragment with an irregular margin and low density on the preoperative CT scan (Figure 6, C and D). Although fixation is recommended for OLT with a fragment size of at least 10 mm in diameter and 3 mm in thickness,[17,18,26] we believe the bone fragment condition should also be considered to obtain good healing. Nakasa et al[21] studied 18 ankles treated with fixation of the OLT with different fragment conditions. MRI at 1 year showed good bone incorporation in all ankles of different preoperative bone fragment conditions including normal, segmentation, and absorption.[21] However, they noted that they could not confirm bone-to-bone healing, especially in the absorption group, because CT scans could not be obtained.[10] In the present study, when we evaluated the fragment with a follow-up CT scan after fixation, all 3 cases with poor preoperative bone fragment condition resulted in nonunion, even when the size of the fragment was large (Figure 6, C and D). The condition of the bone fragment with an irregular margin and low density on the preoperative CT scan was significantly associated with nonunion (odds ratio = 7.67, 95% CI = 2.67-22.02, p = .008). After experiencing nonunion in the cases with a poor bone condition on the preoperative CT scan, we stopped applying fixation for these cases. However, more cases should be added to confirm this finding. Successful bone union has been reported after fixation of a waffle-shaped, small-thickness acute traumatic osteochondral fragment of the talus.[24,29] This may also indicate that the condition of the fragment is important in bone healing in addition to its size because the healing potential of acute traumatic cases is expected to be better than that of chronic cases. Further studies in a larger population are required on this matter.

In 1 case of nonunion, we obtained preoperative radiographs and MRI scans; nevertheless, we did not perform a preoperative CT scan to evaluate the osteochondral fragment. We later found cases with fracture lines on the bone fragment that were not found on the simple radiographs and MRI scans but were found on the CT scans (Figure 7). The fracture lines were difficult to locate even on arthroscopic examination or after the fragment was taken out of the talus and examined. We suspect that there could have been some fragmentation of the lesion in this nonunion case that was not found preoperatively or intraoperatively and may have led to more fragmentation after screw insertion. This led us to routinely check preoperative CT scans to assess for fracture lines of the lesion.

After experiencing 6 nonunion cases, we modified the procedure to a firmer fixation with screws and a bone graft and excluded cases with fragmentation and poor bone condition of the fragment with an irregular margin and low density to the underlying talus on preoperative CT scan. After these modifications, we achieved 100% union for the remaining 11 consecutive patients.

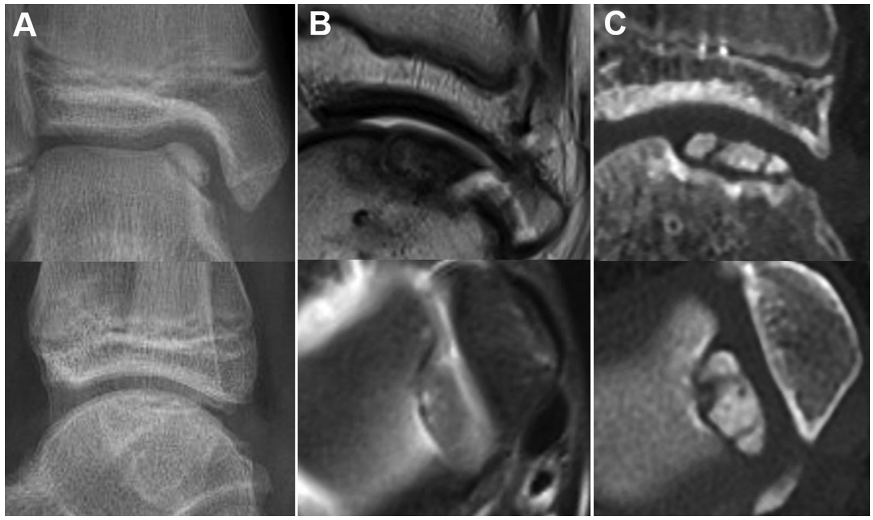

Figure 7. A large fragment was found on the medial talar dome. However, fragmentation was not suspected on the (A) plain radiographs and (B) magnetic resonance imaging. However, on the (C) computed tomography scans, fragmentation was evident.

We found that patients with skeletally immature or mature ankles heal at comparable rates after internal fixation of OLT, which is similar to patients with osteochondritis dissecans of the knee.[32] Patient age at the time of surgery did not correlate with the postoperative 100-mm VAS (Pearson correlation coefficient, $r = -0.07$, $P = .72$), or the postoperative FFI (Pearson correlation coefficient, $r = -0.05$, $P = .80$).

The current technique has limitations. A minimally invasive technique such as arthroscopic fixation has been reported with good clinical outcomes.[13,15,18,20] Compared with open procedures, the arthroscopic technique can reduce postoperative swelling and pain and result in fewer complications and faster recovery time. However, arthroscopic fixation can be technically demanding. In the present study, of the 23 patients (88%) who did not require malleolar osteotomy, all showed greater exposure of the lesion posteriorly by maximal dorsiflexion of the ankle as compared with anterior exposure by maximal plantarflexion (Figure 2). We believe that the arthroscopic technique is best indicated for anterior lesions that can be easily approached from the anterior side. Another routinely performed surgery involves the use of metal screws in relatively thin fragments. Unlike the absorbable headless screw, we could not fully bury the screw head inside the small bone fragment, although it was buried inside the cartilage. We were concerned about the possibility that this may later damage the apposed tibial articular cartilage when the talar cartilage is worn out and the screw head is exposed. Good clinical and radiological outcomes have been reported after using bone pegs or bioabsorbable pins for fixation that do not require removal.[7,10,17,21,22] This can be a good option, but these pegs or pins without threads can retract into the joint if the fragment does not heal onto the talus. Firm fixation with fragment compression is better with screws.[1] Small screws of 1.0 mm in size (Synthes) with a head diameter of 1.6 mm are available.

The study is limited by its retrospective, noncomparative design and the small number of participants with a short follow-up period. However, cases of large-sized OLT indicated for fixation are rare. The small number of participants in this study was inevitable owing to the low incidence of this condition. The patients with a follow-up period <24 months were those with nonunion who underwent revision surgery for fragment excision and bone grafting. We considered it more appropriate to include the outcomes assessed just before the revision surgery as the latest outcomes of the internal fixation of OLT in these patients. One patient with nonunion did not undergo revision surgery but was lost to follow-up after 12 months postoperatively. We included the outcomes assessed at 12 months as the latest outcome in this patient. As the size of the lesion was measured only for the bone fragment on the CT scan, a direct comparison with those reported in the previous literature on OLT measured on MRI may not be appropriate.

Although we cannot recommend this procedure as a preferred method for OLT involving a large bone fragment, the outcomes in this case series of 26 patients were encouraging. A future study with a larger population and longer follow-up period with a comparative group may further confirm these findings.

CONCLUSION

Internal fixation of OLT involving a large bone fragment resulted in satisfactory clinical and radiological outcomes that were comparable between the patients with skeletally immature ankles and those with mature ankles. A malleolar osteotomy was not necessary if >50% of the lesion could be exposed out of the tibiotalar articulation either from the anterior or posterior side with maximal plantarflexion or dorsiflexion of the ankle. A preoperative CT scan is necessary to assess the condition of the bone fragment before internal fixation.

REFERENCES

1. Barrett I, King AH, Riester S, et al. Internal fixation of unstable osteochondritis dissecans in the skeletally mature knee with metal screws. *Cartilage*. 2016;7(2):157-162.
2. Berndt AL, Harty M. Transchondral fractures (osteochondritis dissecans) of the talus. *J Bone Joint Surg Am*. 2004;86(6):1336.
3. Budiman-Mak E, Conrad KJ, Roach KE. The foot function index: a measure of foot pain and disability. *J Clin Epidemiol*. 1991;44(6): 561-570.
4. Bull PE, Berlet GC, Canini C, Hyer CF. Rate of malunion following bi-plane chevron medial malleolar osteotomy. *Foot Ankle Int*. 2016; 37(6):620-626.
5. Carlsson AM. Assessment of chronic pain. I. Aspects of the reliability and validity of the visual analogue scale. *Pain*. 1983;16(1):87-101.
6. Choi WJ, Park KK, Kim BS, Lee JW. Osteochondral lesion of the talus: is there a critical defect size for poor outcome? *Am J Sports Med*. 2009;37(10):1974-1980.
7. Chun KC, Kim KM, Jeong KJ, Lee YC, Kim JW, Chun CH. Arthroscopic bioabsorbable screw fixation of unstable osteochondritis dissecans in adolescents: clinical results, magnetic resonance imaging, and second-look arthroscopic findings. *Clin Orthop Surg*. 2016; 8(1):57-64.
8. Dekker TJ, Dekker PK, Tainter DM, Easley ME, Adams SB. Treatment of osteochondral lesions of the talus: a critical analysis review. *JBJS Rev*. 2017;5(3):01874474-201703000-00001.
9. Ferkel RD, Zanotti RM, Komenda GA, et al. Arthroscopic treatment of chronic osteochondral lesions of the talus: long-term results. *Am J Sports Med*. 2008;36(9):1750-1762.
10. Haraguchi N, Shiratsuchi T, Ota K, Ozeki T, Gibu M, Niki H. Fixation of the osteochondral talar fragment yields good results regardless of lesion size or chronicity. *Knee Surg Sports Traumatol Arthrosc*. 2020; 28(1):291-297.
11. Higuera J, Laguna R, Peral M, Aranda E, Soleto J. Osteochondritis dissecans of the talus during childhood and adolescence. *J Pediatr Orthop*. 1998;18(3):328-332.
12. Jones CP, Coughlin MJ, Shurnas PS. Prospective CT scan evaluation of hindfoot nonunions treated with revision surgery and low-intensity ultrasound stimulation. *Foot Ankle Int*. 2006;27(4):229-235.
13. Kerkhoffs GM, Reilingh ML, Gerards RM, de Leeuw PA. Lift, drill, fill and fix (LDFF): a new arthroscopic treatment for talar osteochondral defects. *Knee Surg Sports Traumatol Arthrosc*. 2016;24(4):1265-1271.
14. Kessler JI, Weiss JM, Nikizad H, et al. Osteochondritis dissecans of the ankle in children and adolescents: demographics and epidemiology. *Am J Sports Med*. 2014;42(9):2165-2171.
15. Kim HN, Kim GL, Park JY, Woo KJ, Park YW. Fixation of a posteromedial osteochondral lesion of the talus using a three-portal posterior arthroscopic technique. *J Foot Ankle Surg*. 2013;52(3):402-405.
16. Kim T, Haskell A. Patient-reported outcomes after structural autograft for large or cystic talar dome osteochondral lesions. *Foot Ankle Int*. 2020;41(5):549-555.
17. Kumai T, Takakura Y, Kitada C, Tanaka Y, Hayashi K. Fixation of osteochondral lesions of the talus using cortical bone pegs. *J Bone Joint Surg Br*. 2002;84(3):369-374.
18. Lambers KTA, Dahmen J, Reilingh ML, van Bergen CJA, Stufkens SAS, Kerkhoffs GMMJ. Arthroscopic lift, drill, fill and fix (LDFF) is an effective treatment option for primary talar osteochondral defects. *Knee Surg Sports Traumatol Arthrosc*. 2020;28(1):141-147.
19. Murawski CD, Kennedy JG. Operative treatment of osteochondral lesions of the talus. *J Bone Joint Surg Am*. 2013;95(11):1045-1054.
20. Nakagawa S, Hara K, Minami G, Arai Y, Kubo T. Arthroscopic fixation technique for osteochondral lesions of the talus. *Foot Ankle Int*. 2010;31(11):1025-1027.
21. Nakasa T, Ikuta Y, Ota Y, Kanemitsu M, Adachi N. Clinical results of bioabsorbable pin fixation relative to the bone condition for osteochondral lesion of the talus. *Foot Ankle Int*. 2019;40(12):1388-1396.
22. Nakasa T, Ikuta Y, Tsuyuguchi Y, Ota Y, Kanemitsu M, Adachi N. MRI tracking of the effect of bioabsorbable pins on bone marrow edema after fixation of the osteochondral fragment in the talus. *Foot Ankle Int*. 2019;40(3):323-329.
23. Nguyen A, Ramasamy A, Walsh M, McMenemy L, Calder JDF. Autologous osteochondral transplantation for large osteochondral lesions of the talus is a viable option in an athletic population. *Am J Sports Med*. 2019;47(14):3429-3435.
24. Park CH, Choi CH. A novel method using bone peg fixation for acute osteochondral fracture of the talus: a surgical technique. *Arch Orthop Trauma Surg*. 2019;139(2):197-202.
25. Ramponi L, Yasui Y, Murawski CD, et al. Lesion size is a predictor of clinical outcomes after bone marrow stimulation for osteochondral lesions of the talus: a systematic review. *Am J Sports Med*. 2017;45(7):1698-1705.
26. Reilingh ML, Murawski CD, DiGiovanni CW, et al. Fixation techniques: proceedings of the International Consensus Meeting on Cartilage Repair of the Ankle. *Foot Ankle Int*. 2018;39(1_suppl):23S-27S.
27. Shimozono Y, Hurley ET, Nguyen JT, Deyer TW, Kennedy JG. Allograft compared with autograft in osteochondral transplantation for the treatment of osteochondral lesions of the talus. *J Bone Joint Surg Am*. 2018;100(21):1838-1844.
28. Shimozono Y, Seow D, Yasui Y, Fields K, Kennedy JG. Knee-to-talus donor-site morbidity following autologous osteochondral transplantation: a meta-analysis with best-case and worst-case analysis. *Clin Orthop Relat Res*. 2019;477(8):1915-1931.
29. Stroud CC, Marks RM. Imaging of osteochondral lesions of the talus. *Foot Ankle Clin*. 2000;5(1):119-133.
30. van Dijk CN, Reilingh ML, Zengerink M, van Bergen CJ. Osteochondral defects in the ankle: why painful?. *Knee Surg Sports Traumatol Arthrosc*. 2010;18(5):570-580.
31. Vannini F, Cavallo M, Baldassarri M, et al. Treatment of juvenile osteochondritis dissecans of the talus: current concepts review. *Joints*. 2015;2(4):188-191.
32. Weiss JM, Nikizad H, Shea KG, et al. The incidence of surgery in osteochondritis dissecans in children and adolescents. *Orthop J Sports Med*. 2016;4(3):2325967116635515.
33. Wu IT, Custers RJH, Desai VS, et al. Internal fixation of unstable osteochondritis dissecans: do open growth plates improve healing rate? *Am J Sports Med*. 2018;46(10):2394-2401.
34. Young KW, Deland JT, Lee KT, Lee YK. Medial approaches to osteochondral lesion of the talus without medial malleolar osteotomy. *Knee Surg Sports Traumatol Arthrosc*. 2010;18(5):634-637.