Original Article
A comparison of surgical approaches for osteochondral lesions of the talus associated with ankle fractures

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Abstract: A randomized clinical trial was performed to compare the effectiveness of arthroscopic debridement plus drilling, microfracture or osteochondral autograft transplantation (OAT) in the treatment of osteochondral lesions of the talus (OLT) associated with ankle fractures. During March 2008 to March 2013, 153 patients with grade II-IV OLT associated with ankle fracture were randomized to receive arthroscopic debridement plus drilling (group A, n = 48), microfracture (group B, n = 53), or OAT (group C, n = 52). Ankle function was assessed using the American Orthopaedic Foot and Ankle Society score (AOFAS), the visual analogue scale (VAS), the Mazur ankle scoring system, the ankle joint range of motion (ROM), the Tegner Activity Scale (TAS) and magnetic resonance imaging (MRI) before and after surgery. The postoperative AOFAS, Mazur, ROM and TAS scores increased significantly compared with preoperative conditions in all three groups (all P < 0.05), while the VAS scores were significantly decreased in all groups (all P < 0.05). There were no differences between groups B and C with regard to postoperative AOFAS, Mazur, ROM, TAS and VAS scores (all P > 0.05), but these groups performed significantly better than group A (P < 0.05). Postoperative MRI examination also revealed better ankle recovery in groups B and C compared with group A. Arthroscopic debridement plus microfracture and OAT are better treatment options for OLT associated with ankle fractures and are clinically more effective than arthroscopic debridement plus drilling.

Keywords: Ankle fracture, osteochondral lesions of the talus, arthroscopic debridement, drilling, microfracture, osteochondral autograft transplantation

Introduction

Ankle fracture is regarded as one of the most frequent lower limb fractures and may substantially affect the daily activities of patients [1]. According to statistical data, the incidence of ankle fracture is approximately 184 per 100,000 people every year [2]. Surgery has been reported to be the most commonly used therapeutic method for ankle fracture and is often associated with improved outcomes, even in elderly patients [3, 4]. More than 50% of ankle sprains and fractures occur with osteochondral lesions of the talus (OLT), especially in ankle injuries associated with physical exercise and military training [5, 6]. Most OLT occurs in the lateral and medial talus and is diagnosed based on X-ray scans [7]. However, due to lack of understanding and limited diagnostic methods, OLT cases often go undetected if the ankle joint loses its normal anatomic relationships, and because the talus is in a hidden position, this fracture is difficult to detect using X-ray imaging [8].

Clinical therapies for OLT include conservative and surgical treatments. Surgical treatments include debridement, drilling, microfracture, abrasion, microcracks, cartilage transplantation and chondrocyte transplantation [9-14]. Thermann et al. reported that the success rate for non-surgical treatments is only 45% [15], and conservative treatment is generally referable for injuries with relatively small damage areas and stable lesions [16]. Currently, arthroscopic debridement is the most widely used clinical treatment and has played an important role in the treatment of OLT [17]. Developments based upon arthroscopic debridement, including arthroscopic debridement plus drilling, microfracture and osteochondral autograft transplantation (OAT), have demonstrated clinical effective-

ness. In this study, we randomly selected 153 patients diagnosed with grade II-IV OLT associated with ankle fracture to receive arthroscopic debridement plus drilling, microfracture or OAT to compare the effectiveness of the three treatments and discuss the relevant mechanisms of healing.

Subjects and methods

Participants

A total of 153 patients diagnosed with OLT (grade II-IV, as defined by the Berndt-Harty OLT staging system [18]) admitted between March 2008 and March 2013 were selected for this study. Inclusion criteria were an imaging diagnosis (ankle lateral X-ray or MRI) of ankle joint fracture with OLT; varying degrees of ankle pain that worsened after movement or loads and was accompanied by lameness, joint stiffness and dysfunction; and non-responsiveness to conservative treatment for three months. Exclusion criteria were severe cardiovascular and cerebrovascular diseases, haemorrhagic diseases or coagulation disorders, immature bone matrix, thrombosis, taking immunosuppressive drugs, cancer, pregnancy, history of mental illness, rheumatic joint inflammation, knock knees, whole body joint pain, and knee arthritis. Using the random number table method, patients were randomly divided into three treatment groups: group A included 48 patients who underwent routine arthroscopic debridement plus drilling; group B included 53 patients who underwent arthroscopic debridement and microfracture; group C included 52 patients who underwent arthroscopic debridement and OAT. This study was approved by the Internal Review Board of Linyi People's Hospital, and all patients gave their written informed consent.

Arthroscopic debridement

Patients were placed in the supine position and given lumbar spinal anaesthesia, with the rear ankle booster padded without a tourniquet. Intra-articular injection of epinephrine in 0.9% sodium chloride was used to fully fill the joint cavity and prevent bleeding. Using the medial and lateral approach, a blunt needle was inserted into a cone to connect with the 4 mm 30° arthroscopy (Smith & Nephew, USA). For patients with articular cartilage injury, we used a blue clamp and planer tools to remove cartilage debris, a plasma knife to trim the edges, and a small curette to scrape and polish cartilage defects of ischemic sclerosis of the subchondral bone.

Drilling operation

Following the debridement, we used a round burr to trim the fracture surface with the assistance of arthroscopy, and drilled holes with depths of 1.0-1.5 cm using 1.2 mm Kirschner wire (Arthrex, USA), with the number of holes depending on the size of the fracture defect, in order for the regenerated fibrocartilage to cover the defect area. If difficult to locate, the talar surface position was changed via flexion of the ankle after the first needle penetration, additional holes were drilled, and the site of surgery was eventually bandaged with sterile dressing.

Microfracture

Following the debridement, holes with depths of 3-4 mm were evenly drilled at intervals of 3-4 mm, perpendicular to the cartilage surface, using a micro-fracture device (Arthrex, USA) under arthroscopy, to allow wound errhysis. Upon completion, the tourniquet was relaxed to determine if the depths were adequate. Bleeding in these holes indicated suitable hole depth. Otherwise, it is necessary to deepen the bone holes. A thick cotton pad was used postoperatively to bandage the limb, without placement of intra-articular drainage.

Osteochondral autograft transplantation

Following the debridement, using a dedicated osteochondral autograft instrument system (Arthrex, USA) under arthroscopy, holes with diameters appropriate for the size of the fracture defect (4-9 mm) and 5.0 mm in depth were drilled perpendicularly to cartilage surface. A longitudinal incision of approximately 1 cm was performed on the outside of the ipsilateral patellofemoral joint to reveal the lateral femoral condyle edge, and a number of osteochondral cylinders with equal number, diameter and length as the drilled holes were carved from the upper non-weight-bearing surface of the condyle by using a cartilage remover perpendicularly to the cartilage surface. These osteochondral cylinders were planted directly into the holes in the affected area, and the graft surface area was fused using the articular surface as a reference arc. Finally, ankle fracture fixation and/or ligament repair were performed

Table 1. Comparison of patient characteristics

	Group A	Group B	Group C	F/x^2	P
The number of cases N	N = 48	N = 53	N = 52		
Age	33.64 ± 8.71	34.51 ± 6.45	33.18 ± 5.37	0.36	0.70
Sex					
Male	28	31	32	0.14	0.93
Female	20	22	20		
Berndt-Harty classification					
Phase II	8	7	6	0.69	0.95
Phase III	22	26	27		
Phase IV	18	20	19		

and the joint capsule was tightly sutured. Donor cartilage holes were closed with bone wax to stop the bleeding, and the knees were bandaged.

Postoperative treatments

The ankle joint was fixed for two weeks after surgery, and patients received physiotherapy involving knee and toe joint active functional training. Patients started ankle flexion and extension exercises and non-weight-bearing walking at 3-5 weeks after surgery and gradually transitioned to normal walking at 6 weeks. At three months after surgery, patients started weight-bearing exercise. At 6 months, the patients resumed physical activity and ankle function was assessed. Patients were regularly followed up for ankle function assessment and imaging examination every six months after surgery.

Evaluations

The 153 patients were followed up for 20-36 months, with an average follow-up time of 27.4 months. The American Orthopaedic Foot and Ankle Society score (AOFAS) was used for preoperative and postoperative ankle function assessments [19]; a score of 90-100 out of 100 was marked as excellent, 80-89 as good, 70-79 as acceptable, and < 70 as unsatisfactory. The visual analogue scale (VAS) [20]) was used for preoperative and postoperative ankle pain evaluations. The VAS measures pain by asking the patient to mark their perceived pain on a ruler, and the distance from the low end to the marked point is then used as quantitative measure of pain. The VAS has a maximum score of 10 points, with 0 as completely painless, 1-3 as mild pain, 4-6 as moderate pain,

and 7-10 as severe pain. The Mazur ankle scoring system provided comprehensive assessments of preoperative and postoperative ankle function [21], including pain and functional assessments; each were scored 0-50 points, with 0 as heavy pain or loss of function, and 50 as painless or normal function. A normal ankle is scored 100 points, with a score of 90-100 as excellent, 80-89 as good, 70-79 as acceptable, and < 70 as unsatisfactory. Range of motion (ROM) was assessed with an angle-measuring device by measuring ankle flexion angle, which was calculated as the sum of degrees of plantar flexion and dorsiflexion. A Tegner Activity Scale (TAS) [22] score above 4 indicates the elimination of all symptoms or the main symptoms and recovery of ankle function; a score of 3 or 4 indicates effectiveness of treatment, with the elimination of main symptoms and recovery or significant improvement of the ankle joint function; 2 or below indicates no significant improvement in symptoms or function. Some patients underwent MRI (Philips, Best, the Netherlands) examination of the talar cartilage after surgery and the results were compared with those obtained preoperatively.

Statistical analyses

Statistical analyses were performed using SPSS 20.0 statistical software (SPSS, Chicago, IL). Quantitative data were presented as the mean ± standard deviation ($\bar{x}$ ± s), differences between any two groups were compared using the t-test, and differences among multiple groups were compared using analysis of variance. Count data were presented as percentages or rates, and differences between groups were compared using the chi-square test. P < 0.05 was considered statistically significant.

Table 2. Comparison of preoperative and postoperative ankle function scores among the three groups of patients

Groups	The number of cases	AOFAS score		VAS score		Mazur score	
		Preoperative	Postoperative	Preoperative	Postoperative	Preoperative	Postoperative
Group A	48	53.7 ± 8.6 (42-75)	64.9 ± 9.8* (52-85)	7.5 ± 1.1 (5-9)	5.2 ± 0.8* (3-6)	52.1 ± 8.7 (37-77)	80.1 ± 9.8* (70-89)
Group B	53	52.4 ± 7.3 (41-75)	76.7 ± 8.4* (52-93)	7.6 ± 0.9 (5-9)	2.7 ± 0.3* (1-5)	51.8 ± 9.6 (35-76)	92.3 ± 7.4* (82-98)
Group C	52	54.5 ± 6.5 (42-77)	79.6 ± 6.5* (54-93)	7.5 ± 1.3 (5-8)	2.4 ± 0.4* (1-4)	53.4 ± 7.4 (37-78)	95.2 ± 8.8* (86-98)

Note: Compared with the preoperative score, *$P < 0.01$; AOFAS: The American Orthopaedic Foot and Ankle Society score; VAS: Visual analogue scale.

Table 3. Comparison of preoperative and postoperative ankle movement assessments among the three groups of patients

Groups	The number of cases	ROM score		Tegner score	
		Preoperative	Postoperative	Preoperative	Postoperative
Group A	48	44.1° ± 5.8° (35°-60°)	54.7° ± 9.7°* (45°-70°)	1.8 ± 0.3 (1-3)	3.6 ± 1.1* (2-4)
Group B	53	43.3° ± 5.8° (34°-60°)	67.8° ± 12.4°* (52°-84°)	1.8 ± 0.1 (1-3)	4.6 ± 1.3* (4-5)
Group C	52	42.7° ± 5.8° (35°-58°)	68.9° ± 11.2°* (51°-87°)	1.9 ± 0.7 (1-3)	4.7 ± 2.1* (4-5)

Note: Compared with the preoperative score, *$P < 0.05$; ROM: Range of motion.

Results

Participants' characteristics

Group A included 48 patients (28 male and 20 female), with an age range of 16 to 50 years and an average age of 33.64 ± 8.71 years; group B included 53 patients (31 male and 22 female), with an age range of 18 to 49 years and an average age of 34.51 ± 6.45 years; group C included 52 patients (32 male and 20 female), with an age range of 17 to 48 years and an average age of 33.18 ± 5.37 years. The three groups were comparable with respect to baseline characteristics (all $P > 0.05$), as shown in **Table 1**.

Comparison of preoperative and postoperative surgery ankle function scores among the three groups

Ankle function as assessed by AOFAS, VAS, and Mazur scales showed significant improvements in postoperative AOFAS and Mazur scores for all patients after surgery (all $P < 0.05$), but there were significant decreases in the VAS scores compared with preoperative conditions ($P < 0.05$) (**Table 2**).

Comparison of preoperative and postoperative ankle movement among the three groups

As shown in **Table 3**, the average preoperative ROM scores for the three groups were 44.1° ± 5.8°, 43.3° ± 5.8° and 42.7° ± 5.8°, respec-

tively, and the average postoperative ROM scores increased to 54.7° ± 9.7°, 67.8° ± 12.4° and 68.9° ± 11.2°, which were all significantly different between preoperative and postoperative values (all $P < 0.05$). The average preoperative Tegner scores were 1.8 ± 0.3, 1.8 ± 0.1 and 1.9 ± 0.7, respectively, and the average postoperative scores increased to 3.6 ± 1.1, 4.6 ± 1.3 and 4.7 ± 2.1, which were also significantly different between preoperative and postoperative levels (all $P < 0.05$).

Comparison of the treatment effects on ankle functions among the three groups

As shown in **Table 4**, there were no significant differences in the changes in AOFAS score, VAS score, Mazur score, ROM measurements and Tegner rating before and after treatment between the patients of groups B and C (all $P > 0.05$). However, improvements in ankle function scores were statistically greater among groups B and C compared with group A (all $P < 0.05$).

Comparison of ankle MRI results before and after treatment

A subset of patients in each group received MRI scans of talar cartilage after treatment, and their results were compared with preoperative scans. As shown in **Figures 1-3**, all three treatments showed effective repair of the talar cartilage. Further comparison of postoperative MRI showed similar recovery in patients of

Table 4. Comparison of changes in ankle function scores among the three groups

Groups	Number of cases	Change value of AOFAS score before and after operation	Change value of VAS score before and after operation	Change value of Mazur score before and after operation	Change value of ROM score before and after operation	Change value of Tegner score before and after operation
Group A	48	11.2 ± 0.7	2.3 ± 0.4	28.0 ± 1.7	10.6 ± 2.6	1.8 ± 0.2
Group B	53	24.3 ± 1.6*	4.9 ± 0.7*	40.5 ± 4.1*	24.5 ± 5.4*	2.8 ± 0.7*
Group C	52	25.1 ± 1.3*	5.1 ± 1.2*	41.8 ± 3.2*	26.2 ± 7.3*	2.8 ± 0.3*

NOTE: *refers to $P < 0.05$ when compared with group A. AOFAS: The American Orthopaedic Foot and Ankle Society score; VAS: Visual analogue scale. ROM: Range of motion.

Figure 1. MRI results before and after surgery for a group A patient. A. The cartilage damage area before surgery; B. 27-month follow-up showed significant improvement in the scope and extent of lesions but also showed that the cartilage surface is not smooth.

Figure 2. MRI results before and after surgery for a group B patient. A. The cartilage damage area before surgery; B. 27-month follow-up scan showing the neck of the talus and calcaneus bone tunnel and that the surface of the articular cartilage is smooth.

group B and group C, which were characterized by smoother cartilage surfaces in lesion areas compared with group A.

Discussion

In this study of OLT, we performed the first clinical trial comparing the effectiveness of arthroscopic debridement plus drilling, microfracture or OAT for OLT. We found that all three treatments led to improved ankle function as assessed by Mazur and AOFAS scores but resulted in decreased VAS scores. In addition, we observed significant improvements in ankle movement and function as assessed by ROM and TAS scores after treatment. These findings suggest that the three different surgeries are effective clinical treatments for OLT. Their effectiveness is most likely due to the shared arthroscopic debridement procedure, which requires a relatively small incision wound and causes minimal damage to the internal structure of the joint, allowing the patients to recover faster and making these surgeries more acceptable [23, 24].

Preliminary data on the changes in ankle functions and activity level compared among the three treatment groups showed no significant differences between group B and group C, both of which performed significantly better than group A. In addition, postoperative MRI results exhibited a similar pattern to that of ankle function assessments, with better cartilage recovery observed in groups B and C compared with group A. Our results were consistent with Lee et al.'s report of MRI changes in patients

Figure 3. MRI results before and after surgery for a group C patient. A. The cartilage damage area before surgery; B. 27-month follow-up showing that the graft was well integrated with surrounding tissue and that the articular cartilage surface was smooth.

treated with OAT [25]. The microfracture procedure performed on the cartilage lesion area is believed to stimulate subchondral bone regeneration, condensing bone marrow cells and blood to form smooth and sturdy tissue and facilitate production of fibrocartilage to provide coverage for defect areas, eventually improving joint function and reducing pain [26]. The advantage of OAT is that it can provide cartilage that is complete hyaline, which plays a critical role in articular surface remodelling and optimal ankle joint cartilage recovery. Moreover, OAT can also provide chondrocytes and extracellular matrix, which can simultaneously rebuild subchondral bone. The subchondral bone fibrocartilage helps to bind the osteochondral cylinders into the cartilage holes, which play an important role in normal cartilage biological function [27, 28]. The drilling operation can open up the dense subchondral bone layer and promote bone marrow stromal stem cells' movement into the fracture defect and their differentiation into chondrocytes in the joint environment, ultimately forming fibrous cartilage. However, due to the biomechanical defectiveness of the regenerated fibrocartilage and its inability to resist wear, the cartilage tissue generated after the drilling operation is more prone to degeneration under mechanical stress, causing traumatic arthritis, aseptic necrosis of subchondral bone, and subsequent osteochondritis disse-

cans of the talus, all of which may affect ankle function [29].

This study suggests that arthroscopic debridement plus drilling, microfracture and OAT are all effective treatments for OLT, but the latter two procedures may perform better than the former with regard to ankle function. However, our study has certain limitations, including a relatively small sample size, short follow-up time, and the lack of retrospective analysis. A large-scale clinical study would be desirable to guide the clinical application of these treatments. In addition, OLT has a high rate of misdiagnosis; therefore, early detection and treatment can prevent ankle arthritis and chronic pain.

Disclosure of conflict of interest

None.

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