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Mini-Screws-Only Fixation Method for Small Fragments of Medial Malleolus Fractures

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Background: Open reduction and internal fixation is the standard treatment for a displaced medial malleolus fracture (MMFx), achieving ankle stability and bony union to prevent post-traumatic arthritis. Previous fixation techniques including tension band wiring and unicortical screw fixation are not optimal for fixation of small fragments in MMFx due to their small size and poor manipulability. Here, we describe a novel surgical method using mini-screws only for fixation of small fragments in MMFx.

Methods: We conducted a retrospective consecutive study of patients who underwent surgery using mini-screws for small fragment MMFx between April 2013 and March 2018. We reviewed the patients' clinical characteristics and assessed the fracture features radiographically. Clinical outcomes were assessed by measuring the range of motion of both ankle joints and investigating symptomatic implants. We reviewed the radiographic outcomes of the medial malleolus and the functional outcomes using the Foot and Ankle Outcome Score (FAOS) at the last follow-up.

Results: Nine patients were included in the study. The minimal follow-up period was 27 months. There was no incidental bone breakage during the procedure. All MMFx healed without reduction loss, nonunion, or implant failure at the last follow-up. Two patients had mild osteoarthritic changes of the ankle joint. The mean FAOS score of the patients was 80.99 (range, 65.44–98.42). No patients required removal of the hardware.

Conclusions: Fixation of comminuted fractures of the medial malleolus using mini-screws for young adult patients is a straightforward and simple technique. Safe fixation of the anterior and posterior colliculi reduces the risk of implant irritation symptoms that necessitate implant removal.

Keywords: *Ankle fracture, Medial malleolus, Comminution, Mini-screw, Interfragmentary fixation*

The medial malleolus consists of the anterior and posterior colliculi and intercollicular groove.[1] An anterior colliculus fracture has a fracture line extending obliquely or transversely between the anterior edge and the intercollicular groove. A supracollicular fracture has a fracture line above the intercollicular groove with an intact deltoid ligament attached to the fracture fragment. Skie et al.[2] reported on the clinical results of operative treatment of anterior colliculus fractures: in this seemingly innocuous injury, it can be difficult to achieve stable fixation of the fragment intraoperatively, leading to painful nonunion. The fixation techniques for medial malleolus fracture (MMFx) include tension band wiring and fixation with unicortical screws.[2-5] However, these methods can be technically challenging due to the risk of further fragmentation of the small osseous fragments with use of larger implants. Small fragments are not amenable to stabilization using the standard 4.0-mm partial threaded cannulated screws.[6] This situation is frequently encountered with smaller fractures of the anterior colliculus, which commonly represent su-

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perficial deltoid ligament avulsion injury.[7]

We hypothesized that small fracture fragments of the medial malleolus could be treated using commercially available mini-screws. The mini-screws-only fixation method may provide appropriate fragment compression while minimizing implant surface area in contact with the fracture fragments.

METHODS

We conducted a retrospective consecutive study of patients who underwent surgery for MMFx. This study was approved by Kangwon National University Hospital Institutional Review Board (IRB No. 10-038-07), and all patients provided informed consent. All patients' radiographic images were obtained preoperatively. Fractures were classified radiographically according to the AO/OTA classification and all were multi-fragmentary fractures. We defined a small single fragment as < 20 mm in width and < 15 mm in height in preoperative X-rays (Fig. 1). The definition of small fragment was applied to the largest fragment of MMFx and there were other smaller fragments. Between April 2013 and March 2018, 9 patients were included in the study. The exclusion criteria were MMFx accompanied by distal tibial metaphyseal fractures, for which we could not achieve a stable ankle using mini-screws-only fixation, thus requiring plate and screw fixation, and patients who already exhibited degenerative arthritic features of the ankle joint (osteophytes or subchondral sclerosis) in preoperative radiography. The patients' clinical characteristics are summarized in Table 1.

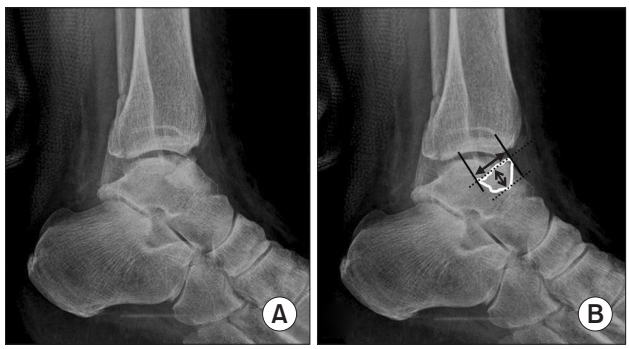

Fig. 1. (A, B) Measurement of medial malleolar fragments. The closed arrow indicates the medial malleolar width (1.2 cm) and the open arrow shows the medial malleolar height (0.7 cm).

The fractures were fixed with mini-screws only, using a unicortical method from the malleolar tip to the distal tibial metaphysis. The screw properties were reviewed as diameter, number, length, and purchase ratio. The definition of purchase ratio is the ratio between the lengths of a screw purchasing in the malleolar and a tibial fragment. All patients were evaluated clinically and radiographically at the final follow-up. The fracture morphology and screw property are summarized in Table 2.

We assessed the active range of ankle motion and the presence of any symptomatic implants. The range of motion was measured at both ankle joints using a goniometer for dorsiflexion and plantar flexion, and the percentage of the angle of the operated ankle compared to the healthy one was calculated. Implant-related symptoms were defined as medial ankle pain, palpable hardware, any restriction in wearing shoes, and the need for hardware removal based on the evaluation of implant discomfort.

Table 1. Clinical Characteristics of the Patients

Patient no.	Injury age (yr)/ sex	Delay from injury to surgery (day)	Injury mechanism	AO/OTA classification	Body mass index (kg/m^2)	Underlying disease
1	20/Male	18	Sports	NA	22.8	None
2	26/Male	11	Direct contusion	44B3.2	33.0	None
3	52/Male	57	Slip down	NA	22.1	DM
4	49/Male	27	Fall down	44C1.2	24.2	None
5	23/Male	16	Traffic accident	NA	23.2	None
6	38/Male	4	Slip down	44C1.3	23.1	None
7	14/Female	1	Slip down	44A3.3	21.2	None
8	65/Female	9	Slip down	44B3.2	22.2	Osteoporosis
9	21/Male	11	Sports	44B3.2	21.4	Atopic dermatitis

OTA: Orthopaedic Trauma Association, NA: not applicable, DM: diabetes mellitus.

Table 2. Fracture Morphology and Screw Property

Patient no.	No. of fractured fragments	Width/height (mm)*	Diameter of screws (mm)	Screw length (mm)†	Purchase ratio, mean (range)‡
1	1	7/5	2.3	11 (1), 14 (1), 20 (1)	0.39 (0.23–0.67)
2	2	15/12	2.7	20 (3), 22 (1)	0.45 (0.45–0.46)
3	1	18/12	2.7	32 (1), 34 (1)	0.23 (0.22–0.23)
4	2	18/14	2.7	38 (2), 50 (1)	0.26 (0.22–0.29)
5	6	19/14	2.7	38 (1), 40 (4)	0.27 (0.17–0.34)
6	1	18/13	2.3	24 (1)	0.31 (0.24–0.39)
			2.7	38 (2)	
7	1	19/10	2.3	24 (2)	0.22 (0.16–0.27)
			2.7	38 (1)	
8	1	18/11	2.7	40 (2)	0.31 (0.30–0.33)
9	3	19/11	2.7	14 (1), 16 (1), 30 (4)	0.25 (0.18–0.44)

*Width and height of the largest fractured fragment. †The data in parentheses are numbers. ‡Ratio between the lengths of screws purchasing in the medial malleolar and tibial fragment.

We reviewed the radiographic outcomes of the medial malleolus as to whether there was a reduction loss of the fracture, healing problem, or arthritic change in the ankle joint. Functional outcomes of the patients were evaluated using the Foot and Ankle Outcome Score (FAOS).[8]

Surgical Technique

The patient was positioned supine on the operating room table under appropriate anaesthesia. A bump support was placed underneath the injured side hip, and a tourniquet was applied high on the operative thigh. An anteromedial L-shaped incision was performed. The structures to avoid are the lesser saphenous vein and nerve in the anterior aspect and the posterior tibial tendon in the distal and inferior aspects of the incision. If the skin was not suitable for surgery due to swelling, bulla, or laceration, the operation was delayed. A subcutaneous dissection was carried down sharply to the bone, and the periosteum was inspected and elevated for anatomical reduction. We approached carefully not to damage the deltoid ligament attached to the distal fragment. The fragments were moved to inspect the talar dome for chondral injury. The displaced fragments were reduced in the anatomical position, and compressive reduction was maintained using small, pointed reduction clamps. After confirming the reduction status and estimating an adequate drill trajectory using a C-arm, mini-screws (Stryker Leibinger, Freiburg, Germany) with a diameter of 2.3 mm or 2.7 mm were meticulously inserted after retrograde drilling with the unicortical fixation method (Fig. 2). The small diameter of the screws facilitates easy insertion into the narrow space of the medial malleolus area. When the fragment is too small, 2.3-mm-diameter screws can be added. The mini-screw heads were inserted to contact the tip of the medial malleolus so as not to irritate the deltoid ligament and the overlying skin. The countersinking procedure was omitted. The inserted screws were examined to determine whether they penetrated the tibiotalar joint using fluoroscopy. Thereafter, periosteal and skin sutures were completed after a suction drainage was inserted. Other fracture components, if any, were treated using standard methods.

Postoperatively, the ankle was immobilized and elevated in a plaster splint for 3 days to allow wound healing. Patients started active ankle protective range of motion exercises thereafter. Weight-bearing walking was allowed when the patients' symptoms permitted. Patients were followed postoperatively in the outpatient clinic to assess the outcome of the surgery.

RESULTS

Stable fixation was achieved with only mini-screws in all cases of small fragment MMFx. There was neither incidental breakage of the fracture fragments during drilling and insertion of screws into the bone nor screw loosening. All fractures healed without the occurrence of any displace-

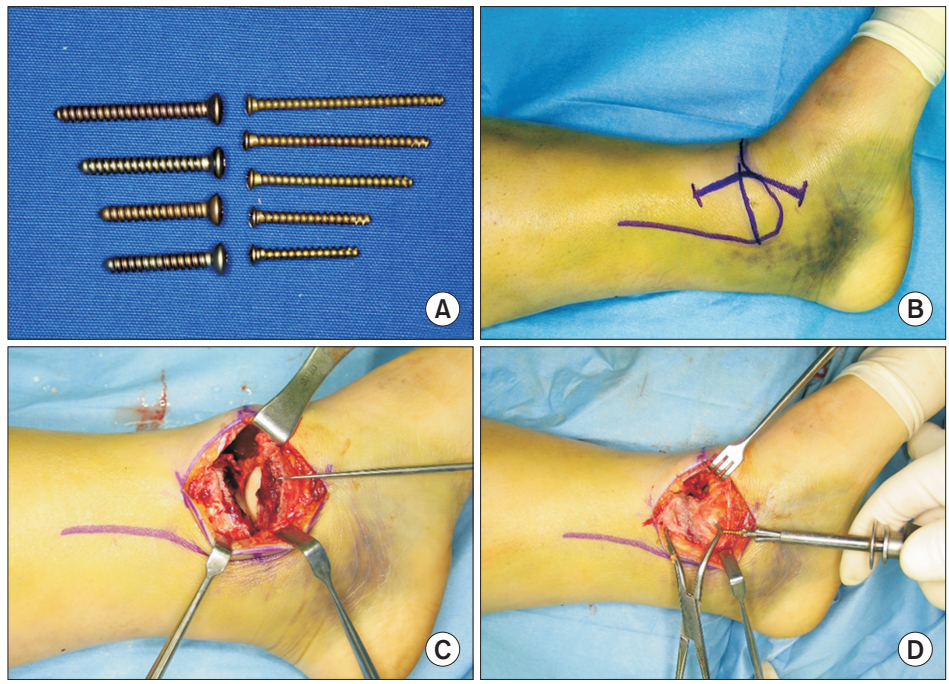

Fig. 2. (A) Comparison of the screw profiles. The right column shows the profile of 2.7-mm mini-screws, and the left column shows the profile of 3.5-mm cortical screws. Note the low profile of the 2.7-mm screw head. (B) A skin incision designed for a medial malleolus fracture. The markings outline the anteromedial margin of the distal tibia. (C) With the dissection carried down sharply to the bone, the periosteum was elevated by 1 mm proximally and distally. The fracture should be open to allow for visual inspection of the talar dome for chondral injury. The medial gutter should be irrigated for any loose hematomas or debris that may impede reduction. (D) With temporary compression reduction through the aid of a reduction clamp, a 2.7-mm mini-screw was inserted from the distal tip of the medial malleolus. It was necessary to drill a small hole in the distal medial tibia to anchor one arm of the clamp.

Table 3. Surgical Outcomes of the Cases

Patient no.	Bony union (wk)	Follow-up (mo)	Complication	DA stage*
1	8	40	None	0
2	11	38	None	0
3	10	17	None	1
4	8	25	None	0
5	15	22	Soft tissue	0
6	10	20	None	0
7	6	28	None	0
8	7	30	None	1
9	6	26	Implant irritation	0

DA: degenerative arthritis.
*DA stage is defined by Takakura classification of ankle arthritis.

ment, nonunion, or implant failure at the final follow-up.

The 2.3-mm mini-screws were used in 3 cases. The mean number of 2.3-mm mini-screws inserted was 2 (range, 1–3), the mean length of 2.3-mm mini-screws was 19.5 mm (range, 11–24 mm), and the mean purchase ratio was 0.30 (range, 0.16–0.67). The 2.7-mm mini-screws were used in 8 cases. The mean number of 2.7-mm mini-screws inserted was 3 (range, 1–6), the mean length of 2.7-mm mini-screws was 33.25 mm (range, 14–50 mm), and the mean purchase ratio was 0.30 (range, 0.17–0.46). Both 2.3-mm and 2.7-mm

Table 4. Foot and Ankle Outcome Score

Patient no.	Symptom	Pain	ADL	Sport & Rec	QOL	Average
1	89.3	91.7	95.6	85	87.5	89.82
2	100	97.2	98.5	90	100	97.14
3	100	100	97.1	95	100	98.42
4	71.43	66.67	69.11	45	75	65.44
5	71.43	91.67	94.12	80	81.25	83.69
6	75	66.67	67.65	55	75	67.86
7	89.29	91.67	94.12	90	93.75	91.77
8	71.43	61.11	67.65	60	75	67.04
9	71.43	66.67	70.59	55	75	67.74

ADL: activities of daily living, Sport & Rec: sport and recreation function, QOL: foot and ankle-related quality of life.

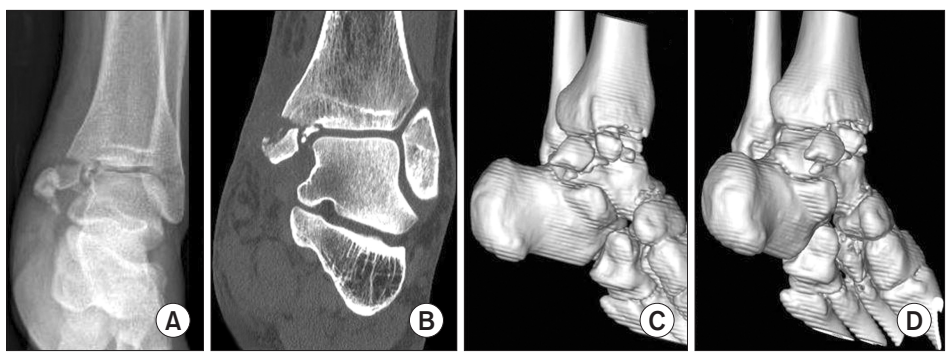

Fig. 3. (A) Radiographic image of an ankle of a 23-year-old woman showing an isolated medial malleolar fracture with a comminuted anterior collicular fragment. (B) Coronal computed tomography (CT) image. (C, D) Three-dimensional reconstruction CT image of the medial malleolus. Multiple displaced fragments of the medial malleolus were too small to be fixed with a 4.0-mm cannulated screw or tension band wiring.

mini-screws were used together in 2 cases.

The clinical outcomes are summarized in Table 3. The minimal follow-up period was 27 months (maximum, 40). According to Takakura's classification,[9] there was no radiographic evidence of arthritic changes in the ankle joints from the last follow-up except in 2 older patients. The FAOS scores of the patients showed a satisfactory outcome (mean; 80.99, range; 65.44–98.42) (Table 4). The average range of motion for ankle dorsiflexion and plantar flexion did not show a significant difference.

No patients complained of implant irritation except one male patient who had vague mild pain around the medial malleolus without objective surgical complications. However, he was satisfied with the surgical outcome and did not request removal of the hardware.

Case Illustration

Patient 5 was a 23-year-old man who sustained a left ankle fracture in a motorcycle accident. Because of direct injury to the medial side of the ankle, the soft tissue was too poor for immediate surgery. Images showed a severely comminuted MMFx of the tibia (Fig. 3). The images showed no malalignment of the talus, but its protection by the medial malleolus of the tibia was gone, which means a medial subluxation of the talus could have occurred. Surgical restoration was planned for anatomical reduction of the medial malleolus of the tibia. Due to the poor soft tissue condition, the operation was delayed for 16 days. Despite confirmation of skin necrosis, a surgical approach to the fracture was planned. A skin incision was performed by avoiding the necrotic area (Fig. 4). The L-shaped incision allowed access to the fracture site. The surgical procedure for the fracture was performed as described above. We first fixed the fracture in the deep area of the joint cartilage. Then, the large fracture fragments were fixed using mini-screws. Stability of the talus was confirmed through

Fig. 4. Photograph showing necrotic changes of the skin on the medial side of the ankle at 2 weeks after injury. Surgery for the medial malleolus fracture was performed after recovery of soft-tissue damage.

Fig. 5. Immediate postoperative X-rays. Five 2.7-mm mini-screws were inserted from the distal tip of the medial malleolus. Each screw was inserted with a parallel trajectory. The two posterior collicular screws were carefully inserted to prevent posterior tibial tendon attrition and tendon rupture. It was possible to cover the area over the screws with healthy skin and negative pressure wound therapy was used to prevent necrosis. There remained a medial malleolar fracture gap.

intraoperative fluoroscopy. It was possible to cover the area over the screws with healthy skin. The area not covered with skin was covered with a negative pressure wound treatment. Immobilization was performed using a posterior short leg splint (Fig. 5). Union of the medial malleolus was achieved at 7 months postoperatively (Fig. 6).

The exfoliated skin area was covered with a split-thickness skin graft 16 days after the first surgery. There were no infections or other problems despite soft-tissue damage. The patient began to walk with crutches with partial weight bearing 3 months after surgery. The X-ray taken 7 months after surgery showed union of the fracture with no arthritic changes. The FAOS score of the patient 22 months after surgery was excellent and the patient had recovered to preinjury levels of activity.

Fig. 6. Radiographs showing consolidation without callus formation at 7 months postoperatively. The fracture gap that was detected in the immediate postoperative X-ray is no longer seen. The ankle joint recovered congruency without back-out of screws or loosening.

DISCUSSION

The medial malleolus of the ankle is a small projection of the distal tibia. When an MMFx is placed in the anatomical position by operative reduction, cancellous bone can develop from the distal fracture fragment. Comminuted fractures of this area give rise to very small fracture fragments and implantation of small orthopedic hardware is required. Different fracture patterns have led to different reduction methods. In our study, the displaced fragments were reduced in the anatomical position by reduction clamps for compression reduction. After confirmation of the reduction status, mini-screws (2.3 mm or 2.7 mm) were inserted using a retrograde insertion from the distal to the proximal part of the tibia. All MMFx healed without any displacement and achieved satisfactory clinical outcomes. This is the first report of this fixation method for severely comminuted small fragment MMFx.

There are a variety of fracture patterns in the medial malleolus; therefore, various internal fixation techniques exist. These include 4.0-mm cortical screw fixation, 4.0-mm cancellous lag screw fixation, tension band wiring,[5] suture anchor fixation,[10] and fixation using screws with anti-glide plates in different configurations. A previous study showed that a couple of 4.0-mm partial threaded cannulated screws were enough to fix a simple MMFx.[11] The technique of 4.0-mm screw insertion is straightfor-

ward, requiring less dissection of soft tissue; however, breakage of the small bone fragment or implant loosening in the case of poor bone quality is possible. Although tension band fixation for a fracture is an effective method and applicable for a small bone fragment with poor bone quality, it may require additional surgical dissection and a longer operative time and can complicate implant removal.[5] Clinical application of the screws for MMFx creates problems, which can alter the management of the fracture: the bone fragment might easily break if the fracture is osteoporotic and comminuted. In two previous studies, the mechanical properties of fine-threaded K-wires or mini-screws in a synthetic foam block and in an animal cancellous bone model were analysed; both reported that the fixation materials had comparable mechanical strength to conventional implants.[12,13] Relative to thread diameter, fine-threaded screws are superior to conventional cancellous and cortical screws in cancellous bone.[14-16] There are several advantages of this fixation method. The mini-screws alleviate implant irritation with low-profile screw heads, which minimizes the need for implant removal as demonstrated by the present study. They also reduce incidental bone breakage during the screw insertion process. The small diameter of the drill bit may reduce the possibility of breakage of fracture fragments in contrast to the larger heads of conventional 4.0-mm cancellous screws, which increase the risk of bone fragments being split into pieces. The full-threaded screws could prevent back-out of the screw.

Using the mini-screw technique could provide stability for fixation of fragile bone fragments. Our operative findings indicate that the mini-screw technique did not cause incidental breakage of the fragments, screw back-out, or screw loosening. It is technically very difficult to hold two 3.5-mm or 4.0-mm drill bits on a 2-cm fracture fragment. When screws are inserted, it should be driven from the distal end of a fracture. When a smaller fracture of the anterior colliculus occurs, which commonly represents superficial deltoid ligament avulsion injury, it is impossible to fix it by making a hole in the desired position with a large drill bit and inserting a screw. Two or more screws should be embedded to prevent rotation of the fracture fragment. But the standard screw head is so large that the free space will actually not be sufficient to prevent overlapping of the screw heads.

Implantation of orthopedic hardware around the medial malleolus is often associated with irritation because of its subcutaneous location or the associated tendonitis that comes with the tendon stretched over the implant. Persistent pain in the region of the implanted hardware after radiographic evidence of fracture union commonly leads to hardware removal. The mini-screw technique alleviates implant irritation with low-profile screw heads, which minimizes the risk of hardware-related symptoms and the need for implant removal.

Our study has several limitations. First, it was a non-comparative study and subject to the limitations of such a design; however, the data were obtained from a consecutively updated prospective database on all patients who were operated on. Our study was limited to patients with the mini-screws-only fixation technique and it lacked a comparative group to prove the superiority of this method. As severely comminuted MMFx is expected to have a very bad prognosis, we selected a reduction method hoping for good clinical results. The mini-screw technique appeared to achieve stability and reduction using only one or two screws for small fracture fragments. Therefore, the significance of this study can be found in the fact that it applied a reduction method for difficult to treat MMFx and demonstrated good clinical outcomes. Second, the sample size was small, which was related to the low incidence of comminuted MMFx. Therefore, further study should involve a greater number of cases and compare treatment outcomes between standard fixation methods and this novel mini-screw technique to provide additional validity. Third, our study was limited to younger adults with good bone quality, and thus further study in older patients with poor bone quality is necessary.

Fixation of comminuted fractures of the medial malleolus using mini-screws can be a simple and straightforward method for young adult patients, providing sufficient stability to the fracture site with low local morbidity.

CONFLICT OF INTEREST

No potential conflict of interest relevant to this article was reported.

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