The contribution of anterior deltoid ligament to ankle stability in isolated lateral malleolar fractures

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ABSTRACT

The treatment of isolated lateral malleolar fractures with deltoid ligament rupture remains controversial. We prospectively analysed 35 patients with isolated lateral malleolar fractures during 2006–2013. Radiography and magnetic resonance imaging (MRI) were performed to assess the degree of reduction, ligament damage, and stability. Internal fixation was performed for all unstable valgus fractures with unacceptable fracture parameters. Fractures with residual valgus instability after fixation underwent anterior deltoid repair. The mean anterior deltoid ligament grade based on MRI was significantly different between the high-grade unstable group and the stable and low-grade unstable groups (p = 0.037 and 0.004, respectively). Postoperative medial clear space measurements were not significantly different between groups. MRI was shown to be a useful tool in the preoperative identification of isolated lateral malleolar fractures prone to valgus instability. In the case of high-grade unstable fractures of the lateral malleolus, repair of the anterior deltoid ligament is adequate for restoring medial stability.

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Introduction

The deltoid ligament complex is considered the primary stabiliser of the ankle joint against a valgus force. It is primarily divided into superficial and deep components. The superficial deltoid ligament is composed of the tibiospring, tibionavicular, tibiocalcaneal, and superficial posterior tibiotalar ligaments; the anterior and posterior tibiotalar ligaments comprise the deep deltoid ligament [1]. In a cadaveric study by Campbell et al., the tibionavicular, tibiospring, and deep posterior tibiotalar ligaments were found to be present in all specimens. The other ligaments, however, had a variable appearance. They, therefore, considered only the three former ligaments as the main components of the deltoid ligament complex (Fig. 1) [2]. Previous studies have shown that the major contributor to ankle stability against a valgus load is the deep deltoid ligament. The superficial deltoid ligament is considered to have only minimal contribution to stability [3,5,8]. According to Michelsen, in his cadaveric study, transaction of only the superficial deltoid ligament did not cause significant widening of the medial clear space (MCS) with application of a laterally directed force [3]. Walling and Sanders proposed that pure ligamentous injuries of the deltoid ligament complex in isolated lateral malleolar fracture cases do not require repair after adequate lateral fixation [4]. However, in our experience, some patients who underwent fixation of isolated lateral malleolar fractures had valgus instability. In these patients, preoperative magnetic resonance imaging (MRI) revealed deltoid ligament complex damage of varying degrees, which leads us to the hypothesis that deltoid ligament damage predisposes patients with isolated lateral malleolar fractures to instability even after fixation. The purpose of this study was to assess the contribution of the anterior deltoid ligament to ankle stability against a valgus force in patients with isolated lateral malleolar fractures.

Materials and methods

Institutional review board approval was obtained for reviewing data of patients with isolated lateral malleolar fractures in our institution. From 2006 to 2013, 35 of these cases were seen.
Patients with open fractures and obvious syndesmotic instability were excluded from our study. All patients were treated according to our study’s standard treatment protocol (Fig. 2). Preoperative imaging included standard anterior to posterior (AP), mortise, and lateral ankle radiography and ankle MRI. Anterior and posterior deltoid ligament damage on preoperative MRI was classified as follows: Grade 0, no damage; Grade I, periligamentous edema present; Grade II, a partial tear presenting as laxity, irregular contour, or partial discontinuity with hyperintensity of the ligament; and Grade III, a complete ligament tear (Fig. 3) [5].

In this study, the tibionavicular and tibiospring ligaments represented the anterior deltoid ligament, and the deep posterior tibiotalar ligament represented the posterior deltoid ligament (Fig. 1) [2]. Fractures were classified using the Lauge-Hansen classification, and the degree of ligament damage seen on MRI was recorded. The radiographic and MRI findings were recorded after consensus between two musculoskeletal radiologists (with 15 years and 5 years of experience in musculoskeletal imaging respectively) who were blinded to the surgical findings. Valgus stress test under general anaesthesia with intraoperative imaging was performed for all patients. Fractures with displacement <2 mm, no shortening, no rotation, talar tilt of 1–2°, and MCS <5 mm on the valgus stress test were classified as the stable group (Group S) [4]. Lateral malleolar fixation was performed in the patients with instability, whereas those who had no instability underwent closed reduction and application of a short leg cast. After fixation of the lateral malleolar fracture, the valgus stress test was repeated and checked fluoroscopically. Patients with residual valgus instability were classified as the high-grade unstable group (Group H), and then superficial anterior deltoid ligament repair was performed using the 3.0 mm suture anchor device (Suture-Tek®, Arthrex, Inc., FL, USA) in this group. Although the ruptured
Fig. 3. MRI grading of deltoid ligament injury. (A) Grade I injury (TN, TS) of the anterior deltoid ligament (16-year-old man with SER IV injury). (B) Grade II injury (TC, TS) of the anterior deltoid ligament (61-year-old woman with SER IV injury). (C) Grade III injury (TC, TS) of the anterior deltoid ligament (43-year-old man with SER IV injury). (D) Grade I injury (PTT) of the posterior deltoid ligament (18-year-old man with SER IV injury). (E) Grade II injury (PTT) of the posterior deltoid ligament (16-year-old boy with SER IV injury). (F) Grade III injury (PTT) of the posterior deltoid ligament (43-year-old man with SER IV injury) [5]. SER: supination external rotation. TN: tibionavicular ligament. TS: tibiospring ligament. TC: tibiocalcaneal ligament. PTT: posterior tibiotalar ligament.
Statistical analysis

Comparison of MADLG with MPDLG and that of MIMCS with MUMCS across groups was done using the Mann–Whitney U test (Tables 1–3), and comparison of MIMCS and MUMCS among groups was done using the Wilcoxon signed rank test. p values <0.05 were considered significant. Statistical analysis was performed using SPSS v20.0 (SPSS Inc., Chicago, Illinois, USA).

Results

Thirty-five patients were included in the study. Of these, 19 were women, with a mean age of 41.6 (16–67) years. Fifteen patients were allocated to Group S and 10 to Group H. All fractures were Lauge-Hansen supination-external rotation type, Weber B. The MADLG for the S, L, and H groups was 1.8, 1.8, and 2.6, while the MPDLG was 1.3, 1.8, and 2.2, respectively (Tables 1–3). The Mann–Whitney U test revealed a significantly different MADLG in the H group compared to the S and L groups (p = 0.037 and 0.004, respectively) (Tables 2 and 3). The MPDLG in the H group was also significantly different from that in the S group (p = 0.011) (Table 2).

The MIMCS measurement for the S, L, and H groups was 4.57, 4.34, and 4.91, whereas the MUMCS measurement was 4.01, 4.41, and 4.56, respectively. There was no significant difference between the MIMCS and MUMCS across groups (Tables 1–3).

Table 1: Comparison of MADLG, MPDLG, MIMCS, and MUMCS between Group S and Group L.

<table>
<thead>
<tr>
<th>Group (N)</th>
<th>MADLG</th>
<th>MPDLG</th>
<th>MIMCS</th>
<th>MUMCS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group S (10)</td>
<td>1.8</td>
<td>1.3</td>
<td>4.57</td>
<td>4.01</td>
</tr>
<tr>
<td>Group L (15)</td>
<td>1.8</td>
<td>1.8</td>
<td>4.34</td>
<td>4.41</td>
</tr>
<tr>
<td>p value</td>
<td>0.888</td>
<td>0.052</td>
<td>0.373</td>
<td>0.234</td>
</tr>
</tbody>
</table>

MADLG: (preoperative) mean anterior deltoid ligament grade. MPDLG: (preoperative) mean posterior deltoid ligament grade. MIMCS: (postoperative) mean injured medial clear space. MUMCS: (postoperative) mean uninjured medial clear space.

Table 2: Comparison of MADLG, MPDLG, MIMCS, and MUMCS between Group S and Group H.

<table>
<thead>
<tr>
<th>Group (N)</th>
<th>MADLG</th>
<th>MPDLG</th>
<th>MIMCS</th>
<th>MUMCS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group S (15)</td>
<td>1.8</td>
<td>1.3</td>
<td>4.57</td>
<td>4.01</td>
</tr>
<tr>
<td>Group H (10)</td>
<td>2.6</td>
<td>2.2</td>
<td>4.91</td>
<td>4.56</td>
</tr>
<tr>
<td>p value</td>
<td>0.037</td>
<td>0.011</td>
<td>0.426</td>
<td>0.596</td>
</tr>
</tbody>
</table>

MADLG: (preoperative) mean anterior deltoid ligament grade. MPDLG: (preoperative) mean posterior deltoid ligament grade. MIMCS: (postoperative) mean injured medial clear space. MUMCS: (postoperative) mean uninjured medial clear space.

Discussion

The deltoid ligament complex limits external rotation of the talus, particularly in plantarflexion, and restricts lateral shifting and anterior displacement of the talus. Biomechanical studies involving physiologically loaded ankle models demonstrate that an uninjured medial complex of the ankle centres the talus beneath the tibial plafond, regardless of a displaced lateral malleolar fracture [11,13,14]. Several studies have reported that the anterior deltoid ligament, originating from the anterior colliculus, contributes minimally to medial stability of the ankle [3,7–9]. Anatomical studies have shown that the posterior tibiotalar ligament is the primary and consistent intraarticular component of the deep deltoid [11,12].

Currently, medial instability in ankle fractures is determined by measuring the MCS on plain radiographs. Previously, Schuberth et al. assessed the accuracy of plain radiographs in determining deltoid ligament damage using MCS measurements. They found that for a MCS of 4 mm, the false positive rate was 53.6%. False positive rates were 26.9% and 7.7% for MCS >5 mm and >6 mm, respectively. They suggested that deltoid ligament integrity could not be reliably predicted by the MCS on injury radiographs of displaced lateral malleolar fractures [11]. Jeong et al. reported that MRI was the most precise tool for identifying deltoid ligament injury. The posterior tibiotalar ligament was an important stabiliser of the medial plantar arch, and its dysfunction was often associated with a tibiospring ligament disorder, which contributes to medial ankle instability. Superficial deltoid ligament injury was more frequently observed than deep deltoid ligament injury in their study [5]. Using MRI and our grading system [5], we found significant differences only in the anterior deltoid ligament grades of high-grade unstable fractures compared to stable and low-grade unstable fractures. Based on this, the anterior deltoid ligament appears to contribute more to ankle stability than previously thought. This can also be predictive of the need for anterior deltoid repair in addition to lateral stabilisation for isolated lateral malleolus fractures, thereby demonstrating the value of early MRI in formulating the treatment plan for such injuries. Previous studies have suggested that surgical management may be needed in patients with a complex ankle fracture and medial soft tissue interposition or instability of the mortise due to complete rupture of the majority in the deltoid ligament [5,15–17].

Currently, repair of the deltoid ligament is recommended if medial instability is present. Tibiotalar contact stress is altered if the talus is laterally displaced. As total contact stress decreases, the total stress per area increases, theoretically increasing the damage in specific areas of the ankle joint during physiological loading. Generation of high stress concentrations may lead to osteoarthritids. Clinical investigations have shown radiographic signs of
osteoarthritis in ankles with lateral talar shift >2 mm [14]. Clement et al. found that a higher MCS (>5 mm) on stress radiographs correlates with a lower American Orthopedic Foot and Ankle Society score in isolated lateral malleolar fractures; larger MCS values (>5 mm) seem amenable to operative treatment, but the deltoid ligament injury status was not evaluated [10]. Based on our protocol, we measured the MCS on radiographs obtained for all patients at 3 months post-treatment. We found no significant difference in the mean MCS measures between groups (Tables 2 and 3). There was also no difference within the low-grade and high-grade unstable groups compared to their uninjured extremities, using the Wilcoxon signed rank test. This suggests that surgical repair of the superficial anterior deltoid ligament might be adequate to restore stability in the valgus stress condition. In addition, use of MRI and our grading system might appear to be a suitable strategy for identifying patients who will have residual valgus instability. For patients with grade 0 or I anterior deltoid ligament damage on MRI, we recommend short leg casting if the lateral malleolus is within acceptable parameters. In those with grade II anterior deltoid ligament damage, the valgus stress test should be performed post-fixation. Anterior deltoid repair might be needed, if there is any residual instability. For grade III damage, deltoid repair might be necessary along with internal fixation of the lateral malleolus. And this line of management may be considered or recommended in adults with isolated lateral malleolar fracture. However, in the stable group, intragroup assessment of MIMCS was significantly different compared to the MUMCS at 3 months after the injury. This could mean that the initial trauma was enough to stretch the deltoid ligament but not rupture it and made MRI interpretation difficult. Casting may have been sufficient for adequate uniting of the fibular fracture, but the deltoid ligament may still be lax. And MRI could correlate with stress test. Although stress test and MRI demonstrate the same, MRI is pain free and does not require general anaesthesia. Therefore we evaluated MRI along with the stress view.

The limitations of this study include a small sample size, which can have an effect on the power to identify statistical significance. Our follow-up duration was only 3 months, which is too short a time to know the functional prognosis, and only radiographic parameters were assessed as outcomes. The functional status, which can be different from the radiographic changes, was not assessed. To exactly determine the contribution of the anterior deltoid ligament repair to stability, a comparison between patients who have undergone repair and those with high-grade unstable fractures but have not undergone repair is needed. In addition, consensus review by two readers who had a disparity in experience levels might be another limitation.

Conclusions

Management of isolated lateral malleolar fractures remains a subject of controversy. Our experience has shown that valgus instability may exist even after fixation of these fractures. Repair of the anterior deltoid ligament appears to be adequate in limiting postoperative lateral talar excursion, thereby indicating that the anterior deltoid may have a larger contribution to medial stability than previously thought. Further prospective studies with larger samples and longer follow-up duration are required to streamline the treatment protocol for isolated lateral malleolar fractures. To our knowledge, this comprehensive study is the first to evaluate not only the correlation between the preoperative MRI grade and treatment modality but also anterior deltoid ligament integrity as a factor in high-grade, unstable, isolated lateral malleolar fractures.

Conflict of interest

None of the author of this paper has a financial or personal relationship with other people or organisation that could inappropriately influence or bias the content of the paper.

References
