Foot and Ankle Surgery 25 (2019) 714–720

Contents lists available at ScienceDirect

Foot and Ankle Surgery

journal homepage: www.elsevier.com/locate/fas

Review

Adding deltoid ligament repair in ankle fracture treatment: Is it necessary? A systematic review

Sherif Dabash[a,*], Ahmed Elabd[b], Eric Potter[c], Isaac Fernandez[b], Chris Gerzina[c], Ahmed M. Thabet[b], William McGarvey[a], Amr Abdelgawad[b]

[a] Department of Orthopaedic Surgery, The University of Texas Health Science Center at Houston, 6431 Fannin Street, Houston, TX, 77030, United States
[b] Department of Orthopaedic Surgery & Rehabilitation, Texas Tech University Health Sciences Center – El Paso, 4801 Alberta Avenue, El Paso, TX, 79905 United States
[c] Department of Medical Education, Paul L. Foster School of Medicine, Texas Tech University Health Sciences Center – El Paso, Medical Education Building 2200, 5001 El Paso Drive, El Paso, TX, 79905, United States

ARTICLE INFO

Article history:
Received 30 May 2018
Received in revised form 18 August 2018
Accepted 2 November 2018

Keywords:
Ankle fracture
Deltoid ligament
Deltoid ligament reconstruction
Deltoid ligament repair
Medial collateral ligament ankle

ABSTRACT

Background: Deltoid ligament injuries are typically caused by supination-external rotation or pronation injury. Numerous ligament reconstruction techniques have been proposed; however, clear indications for operative repair have not yet been well established in the literature.
Methods: We reviewed primary research articles comparing ORIF treatment for ankle fracture with versus without deltoid ligament repair.
Results: Five studies were identified with a total of 281 patients. 137 patients underwent ORIF with deltoid repair, while 144 patients underwent ORIF without deltoid ligament repair. Clinical, radiographic, and functional outcomes, as well as complications were considered. The average follow-up was 31 months (range, 5–120).
Conclusions: Current literature does not provide clear indication for repair of the deltoid ligament at the time of ankle fracture repair. There may be some advantages of adding deltoid ligament repair for patients with high fibular fractures or in patients with concomitant syndesmotic fixation.
Level of clinical evidence: III.

Contents

* Corresponding author at: Department of Orthopaedic Surgery, The University of Texas Health Science Center at Houston, 6431 Fannin St, Houston, TX, 77030, United States.
E-mail addresses: sdabash@gmail.com, dabashs@hss.edu (S. Dabash).

https://doi.org/10.1016/j.fas.2018.11.001
1268-7731/

1. Introduction

The ankle is one of the most frequently injured joints in sporting activities [1]. There will be an expected three-fold rise in the incidence of ankle injuries are by 2030 [2]. In the ankle fracture classification described by Lauge-Hansen [3], the deltoid ligament (DL) injury, or medial malleolar fracture, occurs as the injury pattern continues around the ankle in a circular fashion. The three most characteristic mechanisms of injury of the DL occur from pronation-abduction, pronation-external rotation (PER), and supination-external rotation (SER) of the foot [3–5]. SER injury is the most common fracture type [6].

The deltoid ligament structures have always been in dispute for their names and morphology. The DL is a strong multi-banded complex made up of superficial and deep components that act as an important stabilizer of the ankle. The superficial deltoid layer includes the tibionavicular (TNL), tibiospring (TSL), and tibiocalcaneal ligaments (TCL), which cross the ankle and subtalar joints [7,8]. A recent anatomic study published about the composition of the deltoid ligament revealed that the Tibiocalcaneonavicular spring ligament (SL) is considered a component of the superficial deltoid [9,10]. The deep deltoid layer includes the anterior and posterior tibiotalar ligaments (aTTL and pTTL, respectively), which cross only the ankle joint (Figs. 1, 2) [7,8].

The superficial deltoid resists eversion of the hindfoot, while the deep deltoid is the primary restraint to external rotation of the talus [11]. During ankle motion, all parts of the DL function together to give static support to the ankle. Review of the literature shows that the major contributor to ankle stability against a valgus load is the deep DL, whereas the superficial DL is considered to be only a minor contributor [12–14].

Many medial ligamentous injuries can be overlooked due to clinical focus on the lateral side of the ankle [15]. Several diagnostic modalities have been studied, but there is no consensus in the literature as to which is the most effective. Medial clear space (MCS) widening on gravity stress radiographs has been used as a predictive tool for DL rupture [12], while others advocate visualization with arthroscopy and MRI.

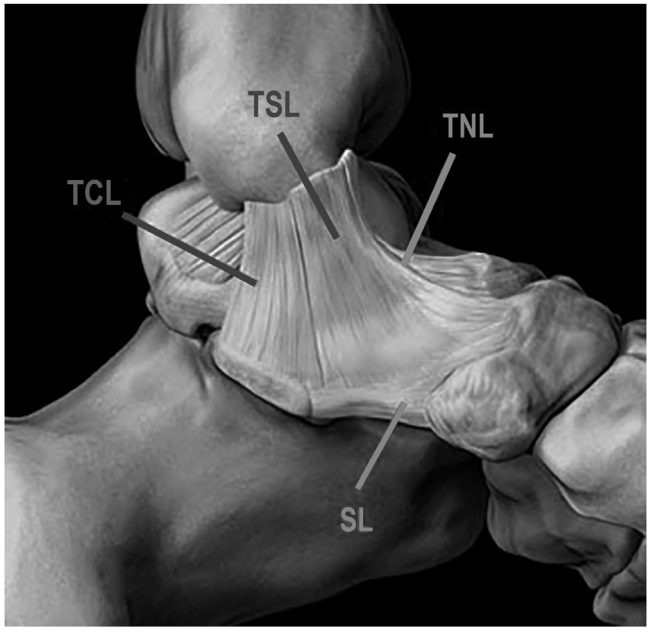

Fig. 1. Illustration of the ligaments comprising the superficial deltoid ligament SL = Tibiocalcaneonavicular spring ligament. TNL = tibionavicular ligament. TCL = tibiocalcaneal ligament. TSL = tibiospring ligament.

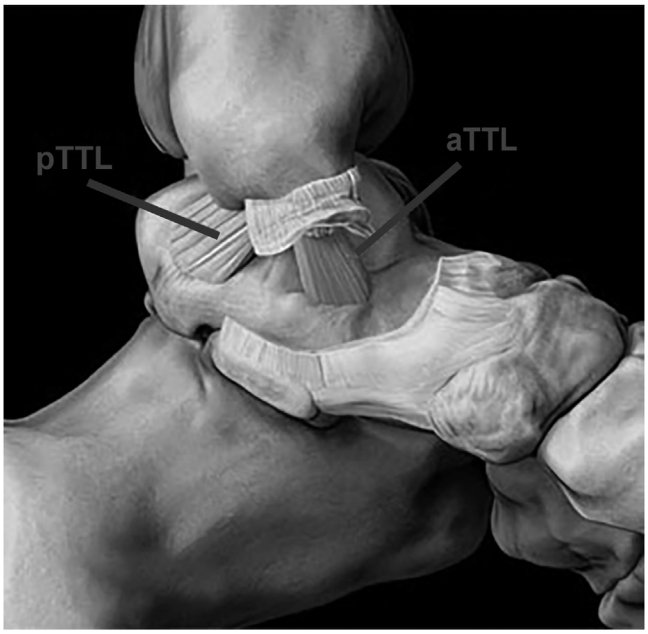

Fig. 2. Illustration of the ligaments comprising the deep deltoid ligament pTTL = posterior tibiotalar ligament. aTTL = anterior tibiotalar ligament.

Controversy surrounds the treatment of DL rupture as well. Authors and practitioners disagree on the severity of injury needed to justify operative intervention, or whether it is indicated at all. Some studies have shown repair of the ruptured ligament to be beneficial with satisfactory results [16–20]. Other studies report that repair of the DL is not necessary for ankle healing [21–25].

The purpose of this article is to review the literature of DL repair and establish a clear indication for operative intervention.

2. Materials and methods

This systematic review was conducted according to the guidelines described in the Preferred Reporting Items for Systematic Reviews and Meta-Analyses for Protocols 2015 (PRISMA-P 2015) [26]. The primary aim of this study was to compare operative repair of the DL versus non-repair in the current literature in patients who sustain unstable ankle fractures.

2.1. Study design and search methods

An electronic literature search was conducted on PubMed and ScienceDirect databases using the search terms “Deltoid ligament”, “Deltoid ligament repair”, “Deltoid ligament reconstruction”, and “medial collateral ligament ankle”. The references of relevant articles were also reviewed for additional publications. Articles were not restricted based on language or publication date.

2.2. Inclusion criteria

Studies were included if they contained comparative clinical evaluation of nonoperative treatment versus surgical repair of DL in adults who sustained a closed ankle fracture with suspected DL injury. Studies were excluded if they were case reports, case series, conference abstracts, or publications that only discussed repair or nonoperative treatment of DL.

2.3. Data extraction and quality assessment

We documented the type of study (e.g. randomized clinical trial, retrospective cohort), level of evidence, methods, outcome measures and rates of complications at the latest point of follow-up. Data was extracted by one researcher (E.P.) and reviewed by the primary author (S.D.). When the average was taken across all included studies, a weighted mean was used.

3. Results

3.1. Study selection process

The process of study selection is presented in Fig. 3. A total of 6295 potentially relevant articles were identified, 473 from PubMed and 5822 from Science Direct. Of these, 6263 were left after removing duplicates. After screening the titles and abstracts, 6178 records were excluded. 85 reports were retrieved in full text. Sixty-three records strictly focused on repair of the syndesmosis without any attention given to the DL and were excluded. Eight records were case series and excluded due to lack of a control group. Six records did not include supination-external rotation fractures in their inclusion criteria and were excluded. Two records compared trans-syndesmotic fixation to DL repair and were excluded. One record was a biomechanical study and was excluded.

Four retrospective cohort studies and one randomized controlled trial (RCT) were eligible for the systematic review [27–31].

3.2. Study characteristics

The five studies were published between 1995 and 2017. A total of 281 patients were reviewed, of which 137 ankles received reconstruction of the DL, and 144 ankles did not receive reconstruction of the DL. Studies varied between the use of fiber wire sutures or suture anchors. The investigators looked at clinical, functional, and radiographic outcomes, as well as complications. The average follow-up time was 31 months (range, 5–120). The five studies are summarized in Table 1.

Stromsoe et al. randomized 50 patients of Weber B and C ankle fractures with radiographic evidence of DL disruption (MCS widening) to receive either direct primary ligament repair or to leave the medial ligaments to heal *in situ* after ORIF of the fibula. This study examined whether repair of a ruptured DL influenced early mobilization or outcomes. Restoration of the tibiotalar mortise was confirmed intraoperatively. The patients were followed for a mean of 17 months (range, 5–35). Radiographs of both groups indicated normal fracture healing. The anatomic position of the fibula and the talus in the ankle mortise was maintained. The duration in surgery in the DL repair group was longer. No other differences were found. The authors concluded that operative repair of the deltoid was unnecessary as long as the mortise anatomy was re-established. This was the only RTC that could be found related to our review [31].

Woo et al. examined 78 consecutive cases of SER, PER ankle fractures with DL injury. All patients were treated with ORIF of the lateral malleolus fracture. Forty-one patients had DL repair, and the remaining 37 patients were treated conservatively regarding the deltoid injury. The average follow-up was 17 months (range, 12–24). Patients were assessed using the Foot Function Index, AOFAS hindfoot score, and visual analog scale (VAS). DL repair patients were noted to have a smaller MCS on final follow-up ($p < 0.001$) than conservative management. Clinical outcomes were not significantly different between the two groups. Comparing the patients who had concomitant syndesmotic fixation in both groups, the repair group showed smaller MCS and improved outcomes scores when compared with the non-repair cohort. The authors concluded that medial instability may exist even after fixation of ankle fracture and syndesmosis [30].

Maynou et al. reviewed 35 patients with lateral malleolus fracture and DL injury. 18 patients were treated with ORIF and DL repair, while 17 patients were treated with only ORIF. The patients were followed for an average of 56 months (range, 7–120). Subjective and objective analysis showed no significant difference between the two groups ($p = 0.56$ and $p = 0.12$, respectively). The study found no differences in the postoperative complication rate. The authors concluded that DL repair is unnecessary if ORIF of the fibula achieves an anatomical reconstitution of the ankle mortise [29].

Plazas et al. reviewed 44 patients with SER, PER ankle fractures and DL injury. All patients were treated with lateral malleolus ORIF. Thirty-three patients had DL repair, while the remaining 11

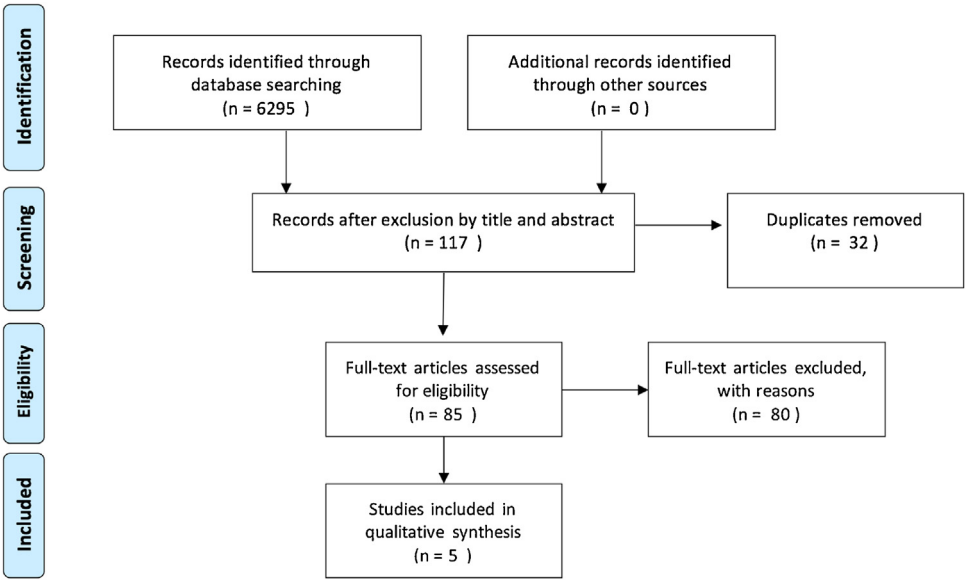

Fig. 3. Flow diagram depicting study selection algorithm (created using PRISMA 2009 Flow diagram, version 2.1.3).

Table 1
Summary of included studies.

Study	Comparative groups		Results	FU/mo.	Main conclusion
Stromsoe et al. Norway 1995 LOE: II	- 50 patients - Weber B and C fractures - Radiologic evidence of deltoid ligament injury. - Matched groups.		- No differences were found except for a longer duration of surgery in the repair group.	17 (5–35)	Ruptured deltoid ligament can be left unexplored without any effect either on early mobilization or on the long-term result.
	[25] ORIF with deltoid exploration and suturing. 20: had syndesmotic fixation	[25] ORIF without deltoid exploration. 19: had syndesmotic fixation			
Woo et al. Korea 2017 LOE: III	- 78 patients - SER, PER ankle fractures with deltoid ligament injury - matched groups.		Whole group results: - No radiologic difference except Final F/U MCS was smaller in the repair group. - No functional difference. If only Syndesmotic fixation patients are compared: Repair group showed smaller final MCS, and all clinical outcomes were better. - no complications in Both groups	17 (12–24)	Deltoid ligament rupture with syndesmosis instability in ankle fractures may benefit from a direct open repair of deltoid ligament
	[41] If stress radiograph after fixation shows MCS widening: - ORIF with deltoid repair with suture anchors and fiber wire sutures 17: had syndesmotic fixation	[37] If stress radiograph after fixation doesn't show shows MCS widening: - ORIF without deltoid repair 27: had syndesmotic fixation			
Maynou et al. France 1997 LOE: III	- 35 patients - Lateral malleolus fracture with Deltoid ligament injury.		-No significant difference.	56	Repair of the deltoid ligament is unnecessary if the internal fixation of the fibula achieves anatomical mortise.
	[18] ORIF with deltoid repair	[17] ORIF without deltoid			
Plazas et al. Spain 2011 LOE: III	- 44 Patients - SER, PER ankle fractures. - Evidence of deltoid ligament injury		- Satisfactory result was obtained in both groups	12 (6–20)	Deltoid ligament can be repaired with good functional results.
	[33] ORIF with deltoid repair	[11] ORIF without deltoid			
Zhao et al. China 2017 LOE: III	- 74 patients. - Weber B, C with deltoid ligament injury (MCS > 6 mm)		- No significant difference in Weber B fractures. - Weber C showed a positive correlation with malreduction. However, if the DL was repaired, the malreduction rate decreased significantly (P = 0.04)	53.7 (14–97)	- In Weber B, DL repair may be not necessary after anatomic reduction of the bony structures. - In Weber C, DL repair is helpful to decrease the rate of malreduction.
	[20] ORIF with deltoid repair with suture anchors	[54] ORIF without repair.			

patients were treated conservatively. AOFAS ankle score was used for clinical and functional assessment. The mean follow-up was 12 months (range, 6–20). Satisfactory outcomes were obtained in both groups. The authors concluded that DL repair can be added to the procedure with good functional results; however, they did not report more favorable results in either group [28].

Zhao et al. reviewed 74 patients with Weber B and C ankle fractures and DL injury (MCS > 6-mm). Twenty patients were treated with ORIF of lateral malleolus and deltoid repair using suture anchors and bone sutures. The remaining 54 patients were treated with ORIF only. The mean follow-up was 53.7 months (range, 14–97). Outcomes measured were preoperative, postoperative, and final follow-up MCS, using the AOFAS and VAS score system. The results indicated that there was not a difference between the 2 groups; however, if only patients with Weber C fractures were considered, the repair group showed better reduction when compared to the non-repair group ($p = 0.03$). The authors concluded that surgical repair of the DL is helpful in decreasing the postoperative MCS and malreduction rate, especially for the Weber C ankle fractures [27].

3.3. Functional outcomes

AOFAS ankle scores were reported by Woo et al., Plazas et al., and Zhao et al. Woo et al. reported that their scores were 92.8 ± 3.9 for the repair group and 91.6 ± 4.7 in the non-repair group ($p = 0.805$). Plazas et al. reported scores of 95.2 (range, 55–100) for the repair group and 94.2 (range, 70–100) for the non-repair group (no p-value reported). Zhao et al. reported that their scores were 88.0 ± 5.8 for the repair group and 85.9 ± 8.7 in the non-repair group ($p = 0.32$). There were no significant differences between the two groups for any of these studies. Woo et al. did find a statistically significant difference between patients who underwent syndesmotic fixation between the repair and non-repair groups. The AOFAS scores reported were an average of 93.1 ± 3.9 in repair group and 89.8 ± 3.7 for the non-repair group ($p = 0.02$) [30]. Maynou et al. used a modified Cedell classification to evaluate the outcomes in their study. The difference between their groups was not significant [29].

3.4. Radiographic outcomes

In all studies, the radiographic outcomes were satisfactory with no differences regarding the reduction of talus in the ankle mortise or MCS width between the repair and non-repair groups. Woo et al. obtained a smaller MCS at the final follow-up in the repair group ($p < 0.001$) [30]. Zhao et al. found that Weber C injuries had a positive correlation with malreduction in the non-repair group [27].

3.5. Complications

Superficial infection was reported in the repair group (3/137) and in the non-repair group (3/144). Medial instability was reported in the repair group (2/137) and in the non-repair group (2/144). Medial suture intolerance (1/137), algodystrophy (1/137), and degenerative arthritis (1/137) were reported in the repair groups. Reoperation due to syndesmotic screw malposition was reported in the repair group (1/137) and was reported in the non-repair group (2/144). Zhao et al. reported malreduction (11/54) and failure and reoperation due to symptomatic malreduction (4/54) [27]. These complications were limited to the non-repair group. No complications were reported in the repair group. Combined complication rates between the studies show a statistically significant lower complication rate in the repair group vs the non-repair group (p value = 0.0225) (Table 2).

4. Discussion

The DL complex plays an important role in ankle joint stability. It is the primary restraint of lateral shifting and anterior displacement of the talus [32]. Biomechanical studies have demonstrated that the normal DL centers the talus in the ankle mortise, regardless of a displaced lateral malleolar fracture [12,33–35]. Management of acute DL injuries associated with ankle fracture fixation is controversial, with no consensus regarding the indications of operative repair or the treatment plan.

In 1972, Weber stated that operative treatment of the ankle should always start with exploration of the medial part of the ankle and repair of the DL. Anatomical reconstruction of the lateral part of the ankle may be impossible if there is DL interposition [36]. Others, including Heim and De Souza et al., thought that the exploration of the medial ankle was unnecessary when a perfect anatomical reconstruction of the ankle mortise is obtained [21,37].

Many case series have applied DL repair in the setting of ankle fractures with deltoid injuries [16–18]. They reported satisfactory results with no complications. Hsu et al. treated 14 NFL players with lateral malleolus and DL injury concomitant with

Table 2
Summary of complications.

Study	Repair group N = 137	Non-repair group N = 144	Observations
Stromsoe et al.	[1] Reoperation [2] Superficial infection	[2] Reoperation [2] superficial infection	- All reoperation cases were for poorly positioned screw - All superficial wounds healed with antibiotics
Woo et al.	No complications recorded		
Maynou et al.	[2] Medial instability [1] Degenerative osteoarthritis	[2] Medial instability	More ossification of deltoid ligament in repair group
Plazas et al.	[1] Algodystrophy. [1] Medial suture intolerance. [1] Superficial infection.	[1] Superficial infection	
Zhao et al.	None	[11] Malreduction [4] Failure with reoperation	
Complication rate (combined studies)	6.6%	15.3%	$p = 0.0225$

syndesmotic injury. Patients were treated with ORIF of lateral malleolus, repair of the superficial DL with suture anchors, and suture button fixation of the syndesmotic injury. The authors obtained satisfactory results with no complications at the one year follow-up interval [16].

There were several case series in the literature that chose to deal with DL injury non-operatively [21–25]. The authors of these studies obtained good results with low complication rates. With complications mostly unrelated to instability, they concluded that there is no need for repair of the DL. Zeeger et al. recommended that exploration of the DL is only indicated if there is doubt about the congruity of the medial joint space on the mortise-view radiograph [23]. This point can be contrasted, however, in a study performed by Johnson and Hill, where eight of twenty-six patients without DL repair demonstrated laxity of the DL with abduction or external rotation. The authors concluded that leaving a ruptured DL unrepaired does not produce acceptable results [19].

Regarding maintenance of reduction and ankle stability, three studies showed satisfactory results in both groups; however, Woo et al. found smaller MCS at final follow-up in the repair group. Regarding clinical and functional outcomes, results were comparable and satisfactory; however, Woo et al. reported better clinical and functional outcomes for those who had syndesmotic fixation and DL repair compared to those with syndesmotic fixation without DL repair [30]. Zhao et al. found a statistically significant correlation between non-repair of DL and malreduction/failure ($p = 0.03$) in Weber C ankle fractures [27].

Considering the overall complications, there was a statistically significant increase in the complication rate in the non-repair group when compared with the repair group. ($p = 0.0225$). However, this correlation appeared because the Zhao et al. study had a significant difference between the complication rates of the two groups. In their study, they initially found that operative repair of DL can significantly decrease the postoperative MCS ($p < 0.05$) and can also decrease the malreduction rate ($p < 0.05$). The authors suggested that this was because of the higher malreduction rate in the non-repair group. They concluded that Weber C injuries had a positive correlation with malreduction, but no correlation was found between malreduction and treatment methods (Table 2) [27].

5. Conclusion

Current literature does not provide enough evidence to clearly determine an indication for operative intervention in regard to the DL in the setting of ankle fractures. There may be some advantages of adding deltoid ligament repair for patients with high fibular fractures (Weber C) or in patients with concomitant syndesmotic injury and fixation. More RTCs are needed to establish clear indications for DL repair, however, DL repair should be in consideration by the operating surgeon.

Conflicts of interest

The authors have no conflict of interest to report.

Financial disclosure

None reported.

Acknowledgements

We wish to thank Denni Zhao for contributing the medical illustrations for this paper.

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

References

[1] Brosky T., Nyland J, Nitz A, Caborn DN. The ankle ligaments: consideration of syndesmotic injury and implications for rehabilitation. J Orthop Sports Phys Ther 1995;21:197.
[2] Kannus P, Palvanen M, Niemi S, Parkkari J, Jarvinen M. Increasing number and incidence of low-trauma ankle fractures in elderly people: Finnish statistics during 1970–2000 and projections for the future. Bone 2002;31:430.
[3] Lauge-Hansen N. Fractures of the ankle. II. Combined experimental-surgical and experimental-roentgenologic investigations. Arch Surg 1950;60:957.
[4] Yde J. The Lauge Hansen classification of malleolar fractures. Acta Orthop Scand 1980;51:181.
[5] Sclafani SJ. Ligamentous injury of the lower tibiofibular syndesmosis: radiographic evidence. Radiology 1985;156:21.
[6] Gougoulias N, Khanna A, Sakellariou A, Maffulli N. Supination-external rotation ankle fractures: stability a key issue. Clin Orthop Relat Res 2010;468:243.
[7] Milner CE, Soames RW. The medial collateral ligaments of the human ankle joint: anatomical variations. Foot Ankle Int 1998;19:289.
[8] Hintermann B, Valderrabano V, Boss A, Trouillier HH, Dick W. Medial ankle instability. Am J Sports Med 2004;32:183.
[9] Grunfeld R, Oh I, Flemister S, Ketz J. Reconstruction of the deltoid-spring ligament: tibiocalcaneonavicular ligament complex. Tech Foot Ankle Surg 2016;15:39.
[10] Cromeens BP, Kirchhoff CA, Patterson RM, Motley T, Stewart D, Fisher C, et al. An attachment-based description of the medial collateral and spring ligament complexes. Foot Ankle Int 2015;36:710.
[11] Campbell KJ, Michalski MP, Wilson KJ, Goldsmith MT, Wijdicks CA, LaPrade RF, et al. The ligament anatomy of the deltoid complex of the ankle: a qualitative and quantitative anatomical study. J Bone Joint Surg Am 2014;96:e62.
[12] Michelsen JD, Ahn UM, Helgemo SL. Motion of the ankle in a simulated supination-external rotation fracture model. J Bone Joint Surg Am 1996;78:1024.
[13] Pankovich AM. Acute indirect ankle injuries in the adult. 1981. J Orthop Trauma 2002;16:58.
[14] Jeong MS, Choi YS, Kim YJ, Kim JS, Young KW, Jung YY. Deltoid ligament in acute ankle injury: MR imaging analysis. Skeletal Radiol 2014;43:655.
[15] Gardner MJ, Demetrakopoulos D, Briggs SM, Helfet DL, Lorich DG. Malreduction of the tibiofibular syndesmosis in ankle fractures. Foot Ankle Int 2006;27:788.
[16] Hsu AR, Lareau CR, Anderson RB. Repair of acute superficial deltoid complex avulsion during ankle fracture fixation in National Football League players. Foot Ankle Int 2015;36:1272.
[17] Yan S, Sa S, Long-xiang S, Cong-feng L, Chang-qing Z, Bing-fang Z, et al. Anchors for the treatment of ankle fracture combined with deltoid ligament injury. Chin J Tissue Eng Res 2013;39:.
[18] Yu G-r, Zhang M-z, Aiyer A, Tang X, Xie M, Zeng L-r, et al. Repair of the acute deltoid ligament complex rupture associated with ankle fractures: a multicenter clinical study. J FootAnkle Surg 2015;54:198.
[19] Johnson D, Hill J. Fracture-dislocation of the ankle with rupture of the deltoid ligament. Injury 1988;19:59.
[20] Little MM, Berkes MB, Schottel PC, Garner MR, Lazaro LE, Birnbaum JF, et al. Anatomic fixation of supination external rotation type IV equivalent ankle fractures. J Orthop Trauma 2015;29:250.
[21] De Souza L, Gustilo RB, Meyer TJ. Results of operative treatment of displaced external rotation-abduction fractures of the ankle. JBJS 1985;67:1066.
[22] Harper MC. Deltoid ligament: an anatomical evaluation of function. Foot Ankle 1987;8:19.
[23] Zeegers AV, van der Werken C. Rupture of the deltoid ligament in ankle fractures: should it be repaired? Injury 1989;20:39.
[24] Tourne Y, Charbel A, Picard F, Montbarbon E, Saragaglia D. Surgical treatment of bi-and trimalleolar ankle fractures: should the medial collateral ligament be sutured or not? J Foot Ankle Surg 1999;38:24.
[25] Baird RA, Jackson ST. Fractures of the distal part of the fibula with associated disruption of the deltoid ligament. Treatment without repair of the deltoid ligament. J Bone Joint Surg Am 1987;69:1346.
[26] Moher D, Shamseer L, Clarke M, Ghersi D, Liberati A, Petticrew M, et al. Preferred reporting items for systematic review and meta-analysis protocols (PRISMA-P) 2015 statement. Syst Rev 2015;4:1.
[27] Zhao HM, Lu J, Zhang F, Wen XD, Li Y, Hao DJ, et al. Surgical treatment of ankle fracture with or without deltoid ligament repair: a comparative study. BMC Musculoskelet Disord 2017;18:543.
[28] Plazas LI, Marco FL, Munuera AS, Gilabert JS, Gálvez AG, de la Asunción MF, et al. Resultados de la reparación quirúrgica Del ligamento deltoideo en las fracturas equivalentes bimaleolares. Revista del Pie y Tobillo 2011;25:12.
[29] Maynou C, Lesage P, Mestdagh H, Butruille Y. Indication for surgical treatment of deltoid ligament rupture in ankle fractures. J Bone Joint Surg Br 1999;81:357.
[30] Woo SH, Bae SY, Chung HJ. Short-term results of a ruptured deltoid ligament repair during an acute ankle fracture fixation. Foot Ankle Int 2018;39:35.
[31] Stromsoe K, Hoqevold HE, Skjeldal S, Alho A. The repair of a ruptured deltoid ligament is not necessary in ankle fractures. Bone Joint J 1995;77:920.
[32] Watanabe K, Kitaoka HB, Berglund LJ, Zhao KD, Kaufman KR, An KN. The role of ankle ligaments and articular geometry in stabilizing the ankle. Clin Biomech (Bristol, Avon) 2012;27:189.

[33] Kusnezov NA, Eisenstein ED, Diab N, Thabet AM, Abdelgawad A. Medial malleolar fractures and associated deltoid ligament disruptions: current management controversies. Orthopedics 2017;40:e216.
[34] Schuberth JM, Collman DR, Rush SM, Ford LA. Deltoid ligament integrity in lateral malleolar fractures: a comparative analysis of arthroscopic and radiographic assessments. J Foot Ankle Surg 2004;43:20.
[35] Harris J, Fallat L. Effects of isolated Weber B fibular fractures on the tibiotalar contact area. J Foot Ankle Surg 2004;43:3.
[36] Weber BG. Die verletzungen des oberen sprunggelenkes. Huber; 1966.
[37] Heim U. Injuries of the median-ligament apparatus of the ankle joint and its treatment. Hefte Unfallheilkd 1978;125.