

SYSTEMATIC REVIEW

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A systematic review on how to diagnose deltoid ligament injuries—are we missing a uniform standard?

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Abstract

Background Up to now, there is no convincing evidence, that surgical treatment of deltoid ligament injuries, especially in the setting of ankle fractures, does result in improved outcome. One reason could be a missing diagnostic standard. The aim of the current systematic review was to analyze the applied diagnostic strategies for acute deltoid ligament injuries in outcome studies.

Methods MEDLINE, Scopus, Central, and EMBASE were searched through February 2022 for any original studies addressing diagnostics of acute deltoid injuries. The study was conducted per the PRISMA guidelines. The inclusion criteria were formed according to the PICOS criteria. The data assessed were study type, level of evidence, included fractures, time point and method of diagnosing deltoid ligament layers, differentiation between layers and syndesmotomic injuries.

Results 31 studies were included in the final analysis. Most studies ($n = 28$) based their decision to treat the deltoid ligament injury on radiologic findings only, with stressed radiographs ($n = 18$) being the most common. The radiographs were applied at one or more time points (preoperative, before ORIF, after ORIF, after ORIF and syndesmotomic repair). The most frequently assessed parameter was the Medial Clear Space (MCS, $n = 27$) with cut-off-values considered pathological ranging between $MCS > 1 \text{ mm}$ and $MCS > 6 \text{ mm}$.

Conclusion Comparing the 31 studies shows that a standardized method to diagnose deltoid ligament injuries is missing. Further research is needed to establish evidence-based guidelines on how to diagnose acute deltoid ligament injuries.

Trial registration Prospero ID: CRD42022307112.

Clinical trial number: not applicable.

Keywords Deltoid ligament injury, Deltoid ligament imaging, Deltoid ligament rupture, Deltoid ligament diagnostic, Medial ankle instability, Collateral ligaments, Systematic review, Ankle joint

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Introduction

The ankle joint is a complex joint, stabilized by its bony geometry as well as several ligamentous structures. One of the indispensable stabilizers is the deltoid ligament bundles. It centers the talus under the tibia, prevents lateral talar translation, and provides rotational stability [7,20,41,44].

The deltoid ligament bundle comprises a superficial (SDL) and deep (DDL) layer. The SDL comprises four, the DDL of two components, originating from the medial malleolus, spanning to the talus, calcaneus, spring ligament, and navicular bone [28,44]. Acute deltoid ligament injuries most often present in combination with ankle fractures [14,19,32]. To date there is no clear consensus that surgical treatment of an acute deltoid ligament injury results in superior patient rated outcome [14,22,29,52].

Interestingly, there appears to be a considerable knowledge gap on how to diagnose and rate the extent of an injury to the deltoid ligament complex. The applied diagnostic tools range from non-weightbearing radiographs to MRI, with again varying cut-off values [21,49,53,60]. Moreover, almost no study differentiates between the different layers or bundles of the deltoid ligament injured. Accordingly, efficacy of different treatment strategies is not comparable if injury patterns are not defined accurately.

The aim of the current study therefore was to assess the status quo of diagnostics applied in published outcome studies on deltoid ligament injuries.

Materials and method

The systematic review followed the Preferred Reporting Items for Systematic Reviews (PRISMA) guidelines [40] and was published a priory at Prospero (Prospero ID: CRD42022307112). The initial protocol was adapted due to an emerging number of other systematic reviews focusing on the patient rated outcome. Therefore, the authors decided to focus their systematic review on the applied diagnostics. The Prospero protocol was changed accordingly.

Search strategy

The research question was built according to the PICOS criteria (Table 1).

The search query was built upon the concepts “Ligament” AND “Deltoid” AND “Injury / Rupture / Imaging / Diagnosis”. The detailed search strategies are presented in Supplement 1. MEDLINE (PubMed), Scopus, Central and EMBASE were searched for original studies published from inception to February 2022. A grey literature search for conference proceedings in both Scopus and EMBASE was performed. Furthermore, the reference lists of other systematic reviews as well as those of papers included in this systematic review were hand-searched for additional eligible studies.

Study selection and data extraction

The search results of each database were exported to Endnote™ (Vs. 20.1, Fa. Clarivate). Based on the standard Endnote™ algorithm, duplicates were removed. The final dataset was imported into Covidence™ (Melbourne, Australia) which again removed duplicates. The further study selection process was conducted by two independent reviewers (JS, ANMN) within Covidence™. Conflicts were resolved by a third reviewer (SFB).

A data extraction sheet was built in Excel (JS, ANMN) and was filled by two independent reviewers (JS, ANMN). The data assessed were study type (e.g., case series, retrospective cohort, randomized clinical trial), the level of evidence, and methods of diagnosis, (included fractures, syndesmotic injuries, differentiation of layers). The two data sheets were finally merged, and the disagreement was resolved by discussion (JS, ANMN, SFB).

Risk of bias assessment

The studies’ level of evidence was assessed according to the criteria published by Wright et al. [56]. The risk of bias was assessed by The Methodological Index for

Table 1 PICOS criteria defining the inclusion and exclusion criteria

Population	Skeletal mature patients with an acute injury to the deltoid ligament complex, either isolated or in combination with an ankle fracture and/or syndesmotic injury
Intervention	Conscious decision to either treat or not treat an acute injury to the deltoid ligament. Studies must report on their approach how to diagnose deltoid ligament injury
Comparison	not applicable
Outcomes	Any objective outcome parameters such as radiographic measurements, clinical data or patient rated outcome scores
Study	Eligible were any English written cadaver/biomechanical or clinical studies, regardless of the study design, with at least 10 patients included

Non-randomized Studies (MINORS), which has also been validated for randomized controlled trials [47].

Data analysis

A descriptive analysis was performed for the different diagnostics applied, as well as for the individual cut-off values used. These were listed separately per the time they were assessed, i.e. preoperative, before open reduction and internal fixation (ORIF), after ORIF, and after ORIF and syndesmotic stabilization.

Results

The study selection process is depicted per the PRISMA recommendations in Fig. 1. Out of 3726 studies, 31 studies were eligible. Biomechanical studies were excluded due to a missing diagnostic approach in these studies. All 31 studies included fracture cases. No study on isolated, acute deltoid ligament injuries meeting the herein defined criteria could be identified. Twenty-six studies conducted some sort of deltoid ligament repair [2–4,8,9,12,16,18,21,26,27,31,33–35,37,42,46,48–50,53,55,57,58,60]. The treatment approaches included suture anchor(s), [4,8,12,18,21,26,27,31,33,35,37,38,42,45,46,48,50,53,55,57,58,60] and/or direct suture [3,6,8,12,16,27,49,55,57,58,60]. One study used a anterior tibialis tendon graft for repair [23]. Five studies consciously only addressed the bony injuries and did not treat the deltoid

ligament injury [5,24,30,51,59]. Reasons for not addressing the unstable deltoid ligament were a purely diagnostic approach [5]. Three studies assessed the patient rated outcome following untreated deltoid ligament injury, [25,30,59] and Teijwani et al. compared the outcome of functional bimalleolar injuries to actual bimalleolar fractures [51].

Per the MINORS criteria, the non-randomized, non-comparative studies reached 8/16 points ($n=10$), comparative studies 13/24 points ($n=16$), and RCTs 15/24 points ($n=5$) on average, a detailed overview is depicted in Supplement 2. A detailed overview of all 31 studies included is provided in Supplement 3.

An overview of the individual diagnostic tools per the time points they were applied is outlined in Fig. 2. Each grey square resembles a study in which the diagnostic tool was applied as part of their assessment routine to set the indication to address the deltoid ligament injury. If a single study applied several diagnostic tools, it is resembled by several grey squares. The number of squares therefore does not resemble the number of studies, but the number of diagnostic tools applied. Most studies (90%; $n=28$) based their indication to operate on the deltoid ligament on radiologic diagnostics [3–5,8,9,12,16,18,21,25,27,30,31,33–35,37,42,46,48–51,53,55,57,58,60], the remaining 10% ($n=3$) on a combination of radiologic- and clinical examination

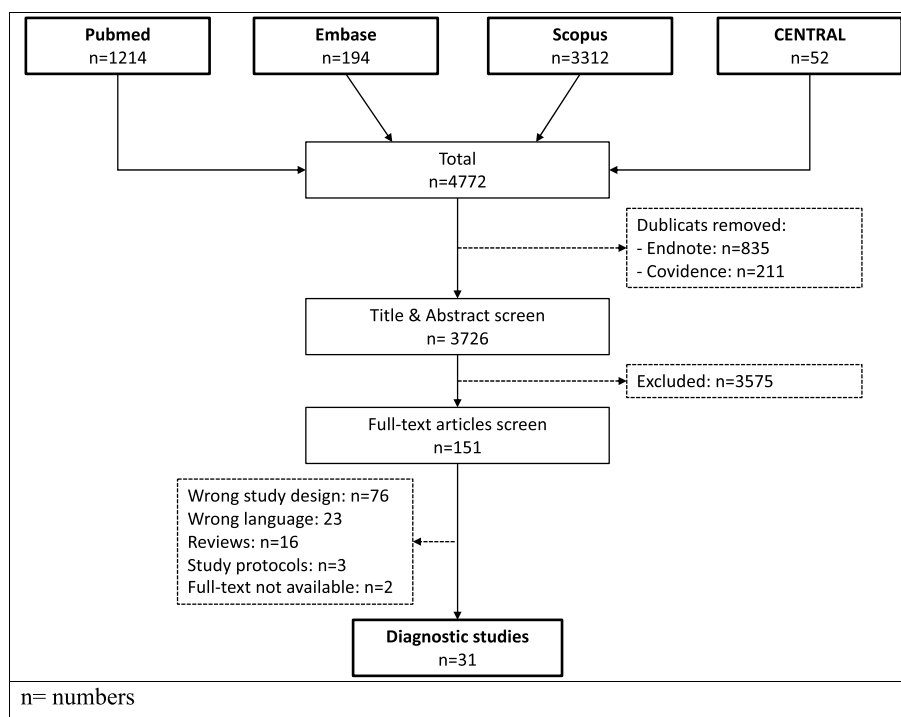
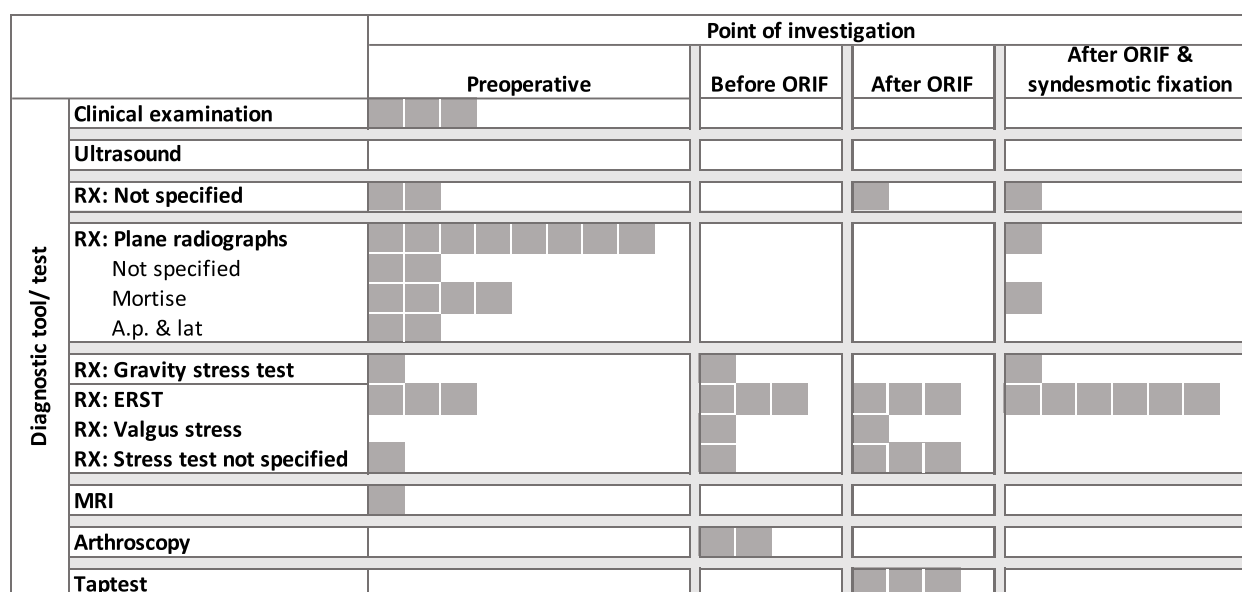


Fig. 1 Study selection flow chart according to the PRISMA guidelines



findings [2,26,59]. The clinical findings used were swelling, pain and tenderness in two studies, [31,59] hematoma/bruising, and a positive dimple sign in one study [26]. Another eight studies reported on clinical findings but did not incorporate them into their diagnostic algorithm [3–5,9,37,55,57,58]. Twenty-seven studies based their radiologic diagnostics solely on radiographs: 15 studies facilitated stressed radiographs [2,5,18,27,31,33–35,42,46,48,50,51,53,55], seven studies unstressed radiographs [3,12,25,37,49,59,60], one study stressed and unstressed radiographs [58], and four studies did not specify which type of radiographs were used [8,16,30,57]. The remaining four studies used stressed radiographs and MRI [21] ($n=1$), stressed radiographs and arthroscopy [26] ($n=1$), arthroscopy [4] ($n=1$) or sonography [9] ($n=1$). The most applied stressed radiography was the external rotation stress test [2,26,31,34,42,46,48,50,51,53,55,58] ($n=12$). Other facilitated tests, either solely or additionally, were the gravity stress test, [5,31,55] valgus stress test [33,50], and the tap test [5,57]. Four studies did not further specify which stress test was used [18,21,27,35].

81% of studies set the indication at one time point (preoperative [2,8,9,12,21,25,31,37,49,51,59,60] ($n=12$), intraoperative before ORIF [4,17,18,50] ($n=4$), after ORIF [16,27,33] ($n=3$), after ORIF and syndesmotic repair [3,30,34,42,46,55] ($n=6$)), the remaining six studies reevaluated the indication at different time points [5,26,35,48,57,58]. Overall, 18 out of the 31 studies included, differentiated between a syndesmotic and

deltoid ligament injury [3,4,8,12,18,26,27,33,35,37,42,46,48,50,51,55,57,60].

Next, the individual radiographic tools were analyzed per the chosen cut-off parameter (Fig. 3). Similar to Fig. 2, each grey square resembles one diagnostic. Therefore, a single study can be resembled by multiple squares. The most commonly assessed parameter was the MCS ($n=27$), either solely [2,3,5,8,12,16,18,21,25,31,35,37,42,46,48–51,53,55,59,60] ($n=22$), or in combination with other parameters [26,33,34,57,58] ($n=5$). The remaining studies either used arthroscopy,4 ultrasonography [8], or did not further specify the parameter used [27,30].

The cut-off criteria for the MCS varied between MCS>1mm [58] and MCS>6 mm, [2,5,8,12,18,21,25,31,34,37,42,46,48,52,53,55,57,58,60] and/ or was compared to the superior joint space [5,49,50,53,55] / lateral clear space [49]. Four studies used the talar tilt, [26,33,34,57] out of which only one study stated an actual cut-off value (more than two degrees) [33]. Seven studies did not specify a cut-off value [3,9,16,26,35,51,59].

Overall, two studies (9%) differentiated between the DDL and SDL preoperatively, either by MRI [33] or sonography [9], 20 studies (65%) did not differentiate between the SDL and DDL for diagnostic purposes [3,5,12,16,18,21,25,30,31,34,37,42,46,48,49,51,53,57–59] and eight studies (26%) differentiated SDL and DDL intraoperatively by direct visualization

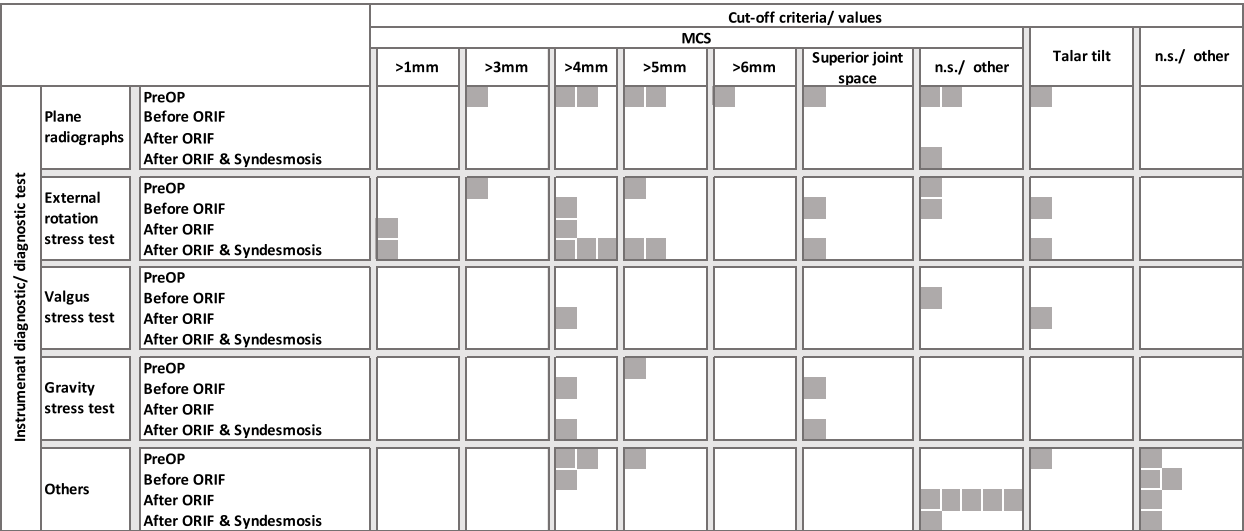


Fig. 3 Cut-off parameter according to the applied diagnostics and time points

[2,4,8,27,35,50,55,60]. The authors of one study [26] were contacted via email and stated, that they diagnosed an SDL injury pre-surgically clinically and a DDL injury intraoperatively via arthroscopy.

Discussion

Based on a systematic literature review, the authored identified 31 studies reporting on diagnostic strategies to identify deltoid ligament injuries. These studies revealed a significant inconsistency, with respect to the tests applied, the chosen cut-off criteria and the time points of assessment. Consequently, we are still missing a uniform standard to diagnose deltoid ligament instability.

To date, the available literature is inconclusive on whether a deltoid ligament repair in ankle fracture cases result in a superior outcome, or not. Some comparative studies have advocated not repairing the associated deltoid injury if the fibula and syndesmosis were adequately reduced and the anatomical position of the talus was restored [3,36,49,50]. Other investigators have recommended to explore and repair the deltoid [31,55,57,60]. One reason for these inconclusive findings could be varying diagnostic strategies. The current study aimed to investigate this heterogeneity in diagnostic strategies in studies reporting on the outcome of deltoid ligament injuries.

The diagnostic strategies applied in the studies analyzed revealed an astonishing heterogeneity. Overall, no standard diagnostic approach or cut-off values could be identified.

Compared to conventional radiographs, direct visualization via arthroscopy is considered the most reliable diagnostic approach, especially for the DDL [1,10,11].

Still, arthroscopy is an invasive procedure, which could be hard to argue, as final data on the efficiency of deltoid ligament repair, at least in fracture cases, are still missing [29]. MRI often is believed the non-invasive gold standard to assess ligamentous injuries. Crim et al. conducted a comparative study and reported a sensitivity/specificity for SDL injuries of 83%/94% and for the DDL 69%/98% for MRI compared to intraoperative findings [13]. Other studies were able to show, that the sensitivity/specificity of MRI is further impaired in fracture cases [15,39,54]. Finally, although MRI is good at indicating an injury to a ligament, it has limitations in distinguishing between an injury and a complete rupture [32]. Beside to those imaging limitations, MRI is expensive and not widely available compared to radiography or ultrasound. Therefore, there is a need for a reliable, easily available diagnostic tool to identify deltoid ligament injuries, best separate for SDL and DDL injuries.

Only two out of the 31 included studies did use arthroscopy [4,26] and only one study used MRI [21] to diagnose a deltoid ligament rupture. None of the studies included based their indication to address the medial side on the clinical examination alone. This is not surprising, as previous studies were able to show its limited value [17]. The most used apparative diagnostic modality were radiographs, either unstressed [3,12,24,37,49,59,60] (*n*=7) or stressed [2,5,18,27,31,33–35,42,46,48,50,51,53,55,58] (*n*=16). The ERST was the most applied stressed radiograph [2,26,31,34,42,46,48,50,51,53,55,58] (*n*=12).

For both, unstressed and stressed radiographs, the most assessed parameter was the MCS. Still, cut-off values for the MCS ranged between MCS>1 mm and MCS>6 mm, with a MCS widening of 4 mm being the

most used value. However, DeAngelis et al. were able to show a false-positive deltoid rupture rate of 54% when using 4 mm MCS as a cut-off value, when compared to arthroscopy [17]. The most applied stress radiography was the ERST under fluoroscopy [2,26,31,34,42,46,48,50,51,53,55,58] ($n=12$). Interestingly, the 4 mm cut-off value was applied for different time points throughout the surgery, i.e. before ORIF, after ORIF, and after ORIF and stabilization of the syndesmosis. One would assume, that with an increase in mortise stability during the surgical treatment, the MCS cut-off value should change. Cheung et al. argued to assess deltoid ligament stability after ORIF of the bony injuries and syndesmotic stabilization, as the MCS assessed during the ERST is also influenced by an syndesmotic instability [10].

A promising, but still considerably underrated diagnostic alternative is ultrasound. Similar to radiography and MRI, it is non-invasive, but it can be performed dynamically. A dynamic examination technique, as stress radiographs, allows to visualize a possible dynamic instability, which often cannot be delineated in static examination techniques, such as unstressed radiographs or MRI. Rosa et al. have reported a sensitivity/specificity for ultrasonographic examination in fracture cases as high as 100%/90% [43]. Still, only one out of thirty examined studies study identified in the current systematic review did use sonography [9].

The huge diagnostic gap for deltoid ligament injuries becomes even more evident when one does consider, that it would be desirable to differentiate between SDL, DDL or combined injuries. Per the current systematic review, only less than a third of the studies (nine studies) differentiated between the SDL and DDL in their diagnostics, [2,4,8,26,27,35,50,55,60] with again great heterogeneity.

De Krom et al. [15] conducted a systematic review and meta-analysis including studies that specifically reported on the sensitivity/specificity and positive/negative predictive value of any diagnostic tool to diagnose deltoid ligament rupture. They concluded that “Ultrasonography and gravity stress radiography seem the most accurate diagnostic tools”. But when looking at the individual reference test of the included studies (Manual ERST: $n=5$, Gravity stress test: $n=2$; MRI: $n=2$; Radiography/Arthrography/intraoperative visualization: $n=1$ each) it becomes evident, that these were not only heterogenic, but all miss a valid reference test, i.e. arthroscopy. Therefore, the authors believe that the data available neither allow to conduct a meta-analysis nor do they allow to draw a conclusion on the “most accurate diagnostic tool”.

Considering the data currently available in the literature, we are missing a non-invasive standard to diagnose SLD and/or DDL injuries. The currently applied

diagnostics in outcome studies are heterogeneous to the extent, that these studies are close to incomparable.

The major limitation of the current study is the above outlined heterogeneity of the studies available. Further limitations are the restriction to English language, and the exclusion of studies with less than 10 patients. Still, the authors followed the strict criteria for systematic reviews.

Conclusion

The diagnosis of deltoid ligament injuries and instability is still missing a consensus. Literature is lacking exact definitions for deltoid instability, diagnostic measures, cut-off values and even the timing of the measurements for this injury. Evidently, high-level randomized trials in addition to adequately performed biomechanical studies are in abundant demand.

Supplementary Information

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Supplementary Material 1.

Supplementary Material 2.

Supplementary Material 3.

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Author's contributions

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Availability of data and materials

All data analysed during this study is provided within the manuscript and supplementary information files.

Declarations

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Consent of publication

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Competing interests

The authors declare no competing interests.

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