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Review article

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Injury to the distal tibiofibular syndesmosis, ways to improve treatment results (literature review)

D.A. Nikiforov[1]✉, M.A. Panin[2,3], V.G. Protsko[2,4], R.D. Borgut[2,5], R.N. Aliev[2,6]

[1] Clinic CJSC MCK, Moscow, Russian Federation
[2] Peoples' Friendship University of Russia, Moscow, Russian Federation
[3] City Clinical Hospital No. 17, Moscow, Russian Federation
[4] City Clinical Hospital No. 7, Moscow, Russian Federation
[5] Clinical K + 31, Moscow, Russian Federation
[6] City Clinical Hospital No. 31, Moscow, Russian Federation

Corresponding author: Dmitry A. Nikiforov, nikiforovmd@gmail.com

Abstract

Introduction Treatment of patients with distal tibiofibular syndesmosis (DTFS) ruptures remains controversial. Ankle fractures accompanied by syndesmosis rupture are associated with worse outcomes. There is no diagnosis and treatment algorithm for such injuries to date. **The objective** was to summarize the data on diagnosis and treatment of syndesmotic injury alone and in combination with ankle fractures through world literature review. **Material and methods** A systematic literature search was undertaken using elibrary, PubMed, ResearchGate databases with articles dated 1990 and later. The search depth was 30 years. With preliminary information collected low-relevant articles were excluded. Meta-analysis studies, randomized controlled trials, systematic reviews, cadaveric biomechanical studies were reviewed. **Results** Screws and suture buttons can be used to fix DTFS, and Volkmann, Shaput and Wagstaff fractures being transosseous injuries to DTFS can be repaired with osteosynthesis. Imaging evaluation of reduction can be produced with radiography, MSCT, MRI and arthroscopy. Partial injuries to the DTFS, if timely detected, can be treated conservatively with transition to surgical stabilization if signs of instability persist. **Discussion** Conventional radiography has very low diagnostic value for DTFS injury. Bilateral MSCT is recommended for assessment of a syndesmotic injury and MRI of the ankle joint is practical for partial isolated injuries. Concomitant injuries of the fibular notch of the tibia are recommended to address first prior to transsyndesmotic fixation. Open reduction of displaced DTFS is accompanied by a lower risk of fibular malposition and malreduction. Suture buttons are practical for transsyndesmotic fixation. Removal of positional screws does not affect the functional result of treatment. More stable osteosynthesis would be needed for DTFS injury in neuropathy.

Keywords: tibio-fibular syndesmosis, distal tibio-ibular syndesmosis rupture, trimalleolar fracture, positional screw, suture button, posterior malleolus fracture, Folkmann triangle

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INTRODUCTION

About 1 % of adult population suffers from ankle arthritis. Posttraumatic arthritis accounts for 78 % of ankle arthritis with the majority of cases developing after trimalleolar fractures [1, 2].

Posttraumatic arthritis likely results from irreversible cartilage damage sustained at the time of injury and chronic cartilage overloading resulting from articular incongruity and instability [3–6]. Restoration of normal anatomy is necessary for articular congruity, and fixation of syndesmosis is necessary for stability. Axial loading in the neutral position does not fully reflect the extent of changes in the peak loading on the articular cartilage in instability. A cadaver study showed that an axial load of 300 N in the presence of a 3 mm clear space of 50 % of the area on the articular surface of the ankle joint increased peak loads by 50 %, and a 20 N force applied in the anteroposterior direction (imitation of walking) led to 800 % increase in peak loads [7].

Assessment of long-term results of ankle fracture repair showed the importance of the displaced distal tibiofibular syndesmosis (DTFS) adequately eliminated with stable fixation to be ensured [8]. The frequency of errors in eliminating displaced DTFS ranges from 16 to 52 % of cases according to postoperative MSCT [8–10]. The complication rate can be determined by the type of ankle fracture (B or C according to AO classification), the presence of a posterior malleolus fracture, fracture-dislocation, the surgical technique used (lateral approach and closed correction, posterolateral approach and open repair), the type of fixators used (one or two tricortical and four-cortical screws or one or two buttons) [11, 12]. Ways offered to improve the results of treatment of displaced DTFS include adequate diagnosis, the use of

MSCT in suspicion of DTFS rupture and the restoration of the normal anatomy of the fibular notch in all cases if possible, and the use of button fixators to reduce the risk of malreduction and breakage of metal fixators, and, consequently, loss of reduction. Clear criteria for malreduction and comparison groups are extremely important for an adequate assessment of treatment results. The same radiographs or MSCT findings can be interpreted by radiologists in different ways depending on evaluation criteria they use as normal. Bilateral MSCT is becoming the standard for postoperative assessment of adequate reduction and stability of the DTFS fixation.

The **objective** was to summarize the data on diagnosis and treatment of syndesmotic injury alone and in combination with ankle fractures through world literature review.

MATERIAL AND METHODS

A systematic literature search was undertaken using elibrary, PubMed, ResearchGate databases. The search depth was 30 years. With preliminary information collected low-relevant articles were excluded. Randomized controlled trial, systematic reviews, cadaveric biomechanical studies, experimental studies, case reports, cohort studies were reviewed. The keywords used for the search included distal syndesmosis rupture, posterior malleolus, trimalleolar fracture, syndesmosis screw, syndesmosis fixation, syndesmosis malreduction, posttraumatic arthritis of the ankle, syndesmosis sprain, anatomy of distal tibiofibular syndesmosis, suture button, + randomized trial, + cohort trial, + diagnosis, + management. We analyzed 168 articles. From them, studies dated before 1990, "case reports" involving less than 10 patients, cohort studies with a follow-up period of less than 1 year, studies involving an exclusively conservative approach to treatment were excluded.

We finally presented an analysis of 2 randomized studies that compared suture button and positional screw, 14 cohort studies that compared different types of screw fixation of DTFS ruptures, the functional results, the need for osteosynthesis of the broken posterior malleolus and removal of positional screws. We also analyzed 4 retrospective studies that evaluated the correlation between functional outcome and residual instability and malposition, 9 studies reporting radiological diagnosis, MSCT diagnosis, MRI diagnosis, arthroscopic diagnosis of DTFS injuries, and 3 biomechanical studies of DTFS, 4 experimental studies evaluating the effect of instability and a step on the articular surface on healing and remodeling of cartilage tissue and the risk of arthrosis in an animal model, and one epidemiological study describing risks of post-traumatic ankle arthritis.

RESULTS

Anatomy

The tibia and fibula are securely connected to each other by the distal tibiofibular syndesmosis. The DTFS is made up of four ligaments including the anterior and posterior inferior tibiofibular ligaments, the interosseous ligament and the interosseous membrane in the more proximal part. The syndesmosis complex provides a high degree of stability and allows the fibula to move in the tibial notch in the anterior-to-posterior direction and rotate outward with the total amplitude of movement not exceeding 2 mm. With the small amplitude, the possibility of such a movement is extremely important, since the talus has a semi-cylindrical shape, with wider anterior portion as compared to the posterior aspect and the fibula should release the 2 mm to allow ankle dorsiflexion. Syndesmosis ligament injuries can include ruptures of all or several of the above ligaments and fractures including the attachment points: a fracture of the posterior malleolus or Volkman fracture, Chaput fracture and Vagstaffe fracture (Fig. 1).

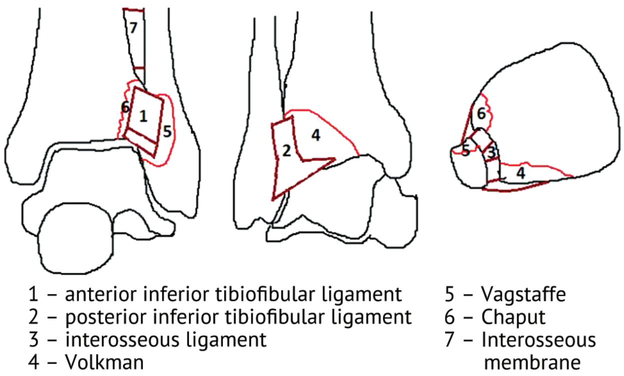

Fig. 1 Bony and ligamentous structures forming the distal tibiofibular syndesmosis

Biomechanics

Normal DTFS provides a high degree of stability of the ankle joint and a significant range of flexion and extension. The talus is cone-shaped in the axial plane with fibula displacing posteriorly, proximally and rotating laterally creating space for the wider portion at dorsiflexion. Fibular mobility at the DTFS level was evaluated by A. Beumer et al. The authors proposed to consider the obtained data as a variant of the physiological norm for movements in DTFS. During the external rotation stress test with a 75 Nm force, it caused 2–5° external rotation, 0–2.5 mm medial translation and 1.0–3.1 mm posterior displacement of the fibula. (Fig. 2) [13].

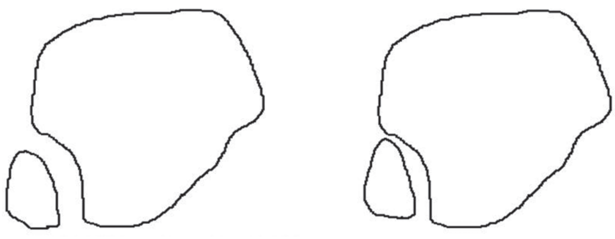

Fig. 2 The amplitude of movements of the fibula at the level of DTFS

A variety of factors leading to an incorrect position of the DTFS can include shortening of the fibula with inadequate reduction, fibular rotation, anterior and posterior translation, excessive compression. The structure of the fibular notch can be impaired with displaced posterior or anterior portion (a Volkman triangle or a Chaput fragment). Technically correct placement of the sharp pointed repositional forceps is very important in closed reduction of displaceed DTFS identifying the level of syndesmosis at the lateral fibula and the mid of the anteroposterior tibia on the lateral view. The repositional forceps placed in a different projection can lead to the fibula translated anteriorly or posteriorly, respectively [14]. The restoration of the normal anatomy of the fibula facilitates adequate translation and rotation, but the risk persists and remains high with the closed reduction of the displaced DTFS.

Diagnosis

In 2017, the European Association of Sports Traumatology, Knee Surgery and Arthroscopy (ESSKA-AFAS) recommended using pain at palpation projected in the anterior inferior tibial-fibular ligament (AITFL), posterior inferior tibial-fibular ligament (PITFL), fibula translation test and Cotton test as clinical diagnostic criteria for DTFS injury [15]. Many authors report difficulties in diagnosis of syndesmotic injury and posterior malleolar fractures with standard AP and lateral views due to anatomical variety of the fibular notch of the tibia with the depth ranging from 8 to 0 mm, a flat or semicircular cross-section (Fig. 3) [16, 17].

Types of fibular notch of tibia and the appearance with MSCT and Mortise view

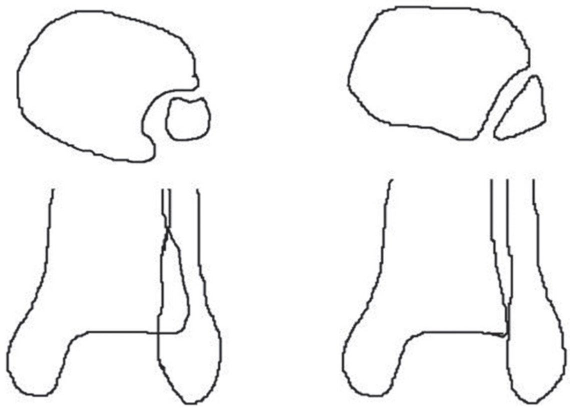

Fig. 3 Anatomical variants of the DTFS structure and the radiological features (diagram)

The specific feature causes difficulties in the radiological assessment of reduction of displaced DTFS [18–21]. DTFS combined with ankles fracture can be injured without bone involvement at the level of the ankle joint. Partial injury to the DTFS is not identified by radiologists with standard radiographs in the majority of cases. The rate of DTFS injury with injury to the lateral ligamentous complex of the ankle can reach 11 % [22]. For this reason, MSCT is essential in the diagnosis of the DTFS injuries [19, 21]. A syndesmotic clear space of more than 3 mm only can be detected with radiography, and MSCT is reliable in identifying a clear space of 1 mm. However, the diagnostic sensitivity may not be sufficient for partial and dynamic injury to syndesmosis. The clear space may appear only with the external rotation of the foot relative to the fixed tibia in an isolated rupture of the PITFL alone. MRI and diagnostic arthroscopy of the ankle joint can be helpful in the scenario to identify partial injury to the DTFS and dynamic instability [23–26].

Classification of DTFS injury, methods of treatment

DTFS injuries combined with ankle fractures and isolated ligamentous injuries need to specified. In 2016, Van Dijk CN et al. revised the classification of isolated DTFS ruptures and grouped them by timing of injury into acute (up to 6 weeks), subacute (6 weeks to 6 months) and neglected (after 6 months). Acute injuries were divided into stable and unstable. Stable cases included isolated injuries to AITFL, PITFL less common involving the interosseous ligament (IOL) in some instances. Unstable injury to the DTFS included latent dynamic cases with involved IOL and deltoid ligament (DL) and obvious injury to all components of the DTFS and DL. Subacute injuries were divided into recoverable and non-recoverable, and chronic injuries were subdivided depending on the presence of ankle osteoarthritis [27].

Partial stable DTFS injuries are treated conservatively in acute cases. T.L. Miller et al. suggested the protocol for the treatment of acute partial isolated DTFS injuries including rest, ice, elevated position, immobilization with a hinged orthosis without axial loading during the first 2 weeks [28]. The second phase, the 2nd to the 6th week, suggested axial loading with use of the functional brace, training of muscular endurance, strength, restoration of the full range of motion. Muscle balance and proprioception exercises are included in the third phase. Patients can return to normal life 8 weeks after injury with follow-up to be continued up to 6 months to rule out residual instability, heterotopic ossification and formation of a hypertrophic scar at the site of AITFL [27]. Surgical treatment is advocated for complete injury to the DTFS using trans-syndesmosis screws, dynamic fixation with suture buttons, direct restoration with osteosynthesis of evulsion bone fragments or suturing ligaments with or without augmentation. Screw fixation of DTFS ruptures is most common using 3.5 or 4.5 mm 1 or 2 screws passing through 3 or 4 cortical bones. By 2008, Monga et al. reported 97 % of surgeons using screws only to fix the DTFS. For example, 58 % of consultants placed their screws through 3 cortices, 33 % through 4 cortices [29].

It is logical to assume that the rigidity, that is, the resistance to breakage of the metal construct and the resistance to the divergence of syndesmosis can be increased with use of greater screws, diameter and the number of cortices fixed. Biomechanical studies have not identified such a relationship. No statistically significant difference was found by Thompson who compared the stability of fixation with 3.5 and 4.5 mm tricortical screws [30]. Loading was performed for a simulated fracture Weber type C fixed with 3.5 and 4.5 mm screws. Markolf et al. reported the use of 3.5 and 4.5 mm three-cortical and four-cortical screws in a large-scale study. The authors found no statistically significant difference in use of 3.5 and 4.5 mm screws and tricortical and quadricortical fixation in the biomechanical cadaver study perormed in 2013 [31]. Application of external foot torque (internal tibial torque) to a weight-bearing ankle produced the greatest bending displacements of the screws, and should be avoided during rehabilitation to reduce the possibility of screw breakage.

An inverse relationship can be assumed regarding ankle motion after screw fixation since one tricortical screw can get loose faster with greater possibility for the fibular movements as compared to two screws, or a larger diameter screw, or a four-cortical screw. A.C. Peek et al. recommended use of one 4.5 mm three-cortical screw with no implication for screw removal to facilitate a lower risk of breakage, migration, secondary displacement, infection and a lower risk of getting an excessively rigid construct compared to other types of screw fixation [32]. However, there is no convincing statistical confirmation for the algorithm. The literature review on syndesmotic screws is difficult from evidence point of view with many factors affecting clinical and functional result in addition to the diameter, number and length of screws.

In 2010, Manjoo et al. reported 106 patients with injured syndesmosis treated with positional screws and found that the OMAS-score (Olerud-Molander Ankle Score) was significantly higher in patients with broken, loose or removed screws (85 ± 3) than in the group with intact positional screws (70 ± 6) [33]. The second group demostrated narrowing of the free tibio-fibular space of an average 1 mm in comparison with the first group. This indicated excessive compression of syndesmosis with use of positional screw and a significantly worse functional result can be expected if the compression is not eliminated by removing the screw or with breaking / loosening of the metal construct. In 2013, Gardner et al. concluded that the use of two 4.5 mm four-cortical screws necessitated the removal to avoid extremely rigid fixation and persistent limitation of the range of motion [34].

Screws are normally placed 2-3 cm above the joint line at an angle of 20-30 degrees in anterior-to-posterior manner. Removal of screws does not affect the functional result of treatment with use of tricortical screws [35, 36]. The use of a single screw, regardless of the diameter and the number of cortices, is accompanied by statistically homogeneous results. The use of two 4.5 mm four-cortical screws is the only rigid fixation option that requires routine removal of implants at 8 to 16 weeks. The use of trans-syndesmosis fixation is controversial. Many authors agree that trans-syndesmosis fixation is not required for a fracture of the posterior malleolus or a fracture of the anterior malleolus of the fibular notch to avoid associated complications.

The use of any kind of transindesmosis fixation and application of a bone clamp is a risk factor for malposition and malreduction. J. Franke reported 252 patients with ankle fractures and a DTFS rupture whose postoperative MSCT revealed malreduction in

82 cases (39 %) with 64 (25 %) being associated with fibular malposition in the tibial notch [37]. In 2017, M.A. Miller et al. published a study conducted at the University of Mississippi Medical Center, Jackson, MS, USA that included 198 ankle fractures involving the posterior malleolus. In total, 151 patients were initially positioned supine, 27.2 % of whom required operative stabilization due to syndesmotic instability of the DTFS detected intraoperatively with the Cotton test and external rotation stress test. 47 patients were treated prone using the posterolateral approach. All patients underwent posterior stabilization with one case (2.1 %) requiring a positional screw. The need for trans-syndesmosis fixation was 13 times less with surgery prone and posterior stabilization provided [38]. M.A. Miller and Bartonijek et al. recommended to avoid trans-syndesmosis fixation in all cases when technically available, with transosseous injuries (Volkman fracture, Chaput fracture or Vagstaffe fracture). In 2015, Bartonijek et al. suggested that osteosynthesis of a broken posterior malleolus involving the posterior wall of the fibular notch is practical to restore the stability of syndesmosis from the posterolateral approach and eliminate the need for trans-syndesmosis fixation in 95 % of cases [39].

M.J. Gardner suggested that osteosynthesis of bony components of syndesmosis is capable to restore the normal anatomy of the fibular notch and stabilize syndesmosis to a greater extent than positional screws [40]. Another group of researchers relies more on improved trans-syndesmosis fixation than on attempts to avoid it. Y. Shimozono and C. Colcuc reported significantly better results with use of trans-syndesmosis fixation. The use of suture buttons for trans-syndesmosis fixation allowed for accelerated rehabilitation due to earlier weight-bearing and movements in the ankle and helped to avoid implant failure and loss of reduction [41, 42].

Although button fixation has been shown to be the best option for solving all of the above problems accurate reduction of fibular fracture and accurate reduction of syndesmosis is the most important surgeon associated factor in the treatment of DTFS ruptures.

Rupture of DTFS in patients with diabetes mellitus is of special concern. Lack of protective sensitivity in diabetes patients (and with other types of peripheral neuropathy in rare cases) can lead to serious consequences, breakage and migration of metal fixators, loss of reduction, development of Charcot arthropathy, infection and even loss of the limb. A different treatment algorithm is used for the cohort of patients. The strongest fixator is used to protect soft tissues, and indications for primary arthrodesis are significantly expanded. A set of (3–4) four-cortical screws of increased diameter or at least 2 suture buttons with the plate are used to fix syndesmosis. The use of posterolateral approach can reduce the risk of infection, necrosis of the wound edges and prevent the divergence. Primary Ilizarov external fixation is a reasonable alternative in such a situation. Primary arthrodesis with the Ilizarov frame or panarthrodesis with interlocking nailing can be considered for the fracture occurred secondary to Charcot's arthropathy[43].

Evaluation of intraoperative reduction of DTFS

Intraoperative assessment of DTFS reduction is difficult. AP radiographic view or a view with an internal rotation of 15° have been shown to be insufficient and the findings can be misleading. High frequency of malpositions in the sagittal plane and rotational asymmetry necessitates intraoperative assessment of the fibular position in the plane in comparison with the contralateral side [44]. True lateral radiographs can be used to assess fibula positioned relative to the tibia in the sagittal plane. Radiographs of the contralateral side are practical for adequate assessment. Anteroposterior tibiofibular ratio, a new reliable measure to assess syndesmotic reduction was described by S. Grenier in 2013. The method is essential for intraoperative judgement of the fibular station. True lateral radiographs were used to mark the anterior edge of the tibia and the intersection point of the anterior fibular edge and the metaphyseal border. If the line is extended to the posterior cortex of the tibia on the true lateral view the point of intersection of the anterior edge of the fibula and the metaphyseal line should divide this line in half (Fig. 4) [45].

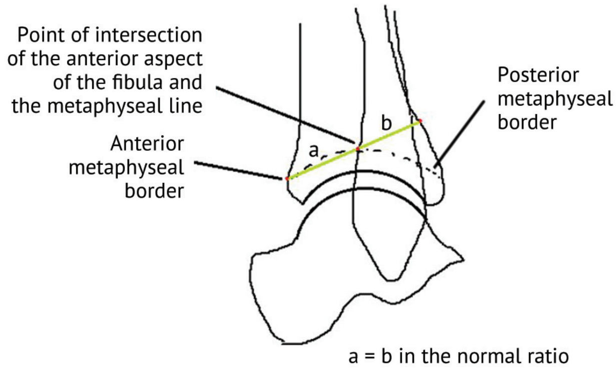

Fig. 4 The use of a lateral radiograph for judging reduction of DTFS in the sagittal plane (diagram)

The use of both AP and lateral radiographs of the contralateral side is imperative with MSCT to be produced after surgery [40]. Many researchers suggest that the open reduction of DTFS under visual control and osteosynthesis of concomitant transosseous injuries significantly reduce the risk of malposition [9, 35, 40].

DISCUSSION

Inadequate reduction of displacement with fibular malposition is one of the main reasons of poor outcomes of DTFS ruptures including those with ankle fractures. Adequate preoperative diagnosis and planning (MSCT), open reduction of the displaced DTFS, fixation of concomitant transosseous injuries, rejection of unreasonable trans-syndesmosis fixation, the use of suture button facilitate lower risk of iatrogenic malreductions and poor functional results. DTFS has a variable anatomical structure that makes radiological diagnosis of DTFS ruptures, intraoperative X-ray monitoring and postoperative assessment of the reduction difficult.

H. Claude Sagi et al. prospectively evaluated results of treatment of 68 patients with ankle fractures and injury to the DTFS at a minimum of 2-year follow-up. The patients underwent postoperative MSCT, functional outcome scoring using the Olerud-Molander Ankle Score (OMAS) and the Short Form Musculoskeletal Assessment (SFMA) questionnaires. Twenty-seven (39 %) of 68 injuries were malreduced when compared with the contralateral uninjured syndesmotic joint using MSCT and were not suspected radiologically. Malreduction was associated with translational asymmetry of the fibula in 64 % of cases (Fig. 5), rotational asymmetry in 28 % and inadequate reduction of the fibula fracture in 8 %. Iatrogenic complication developed in 44 % of closed reduction of displacement and fixation and in 15 % of open fixation of syndesmosis.

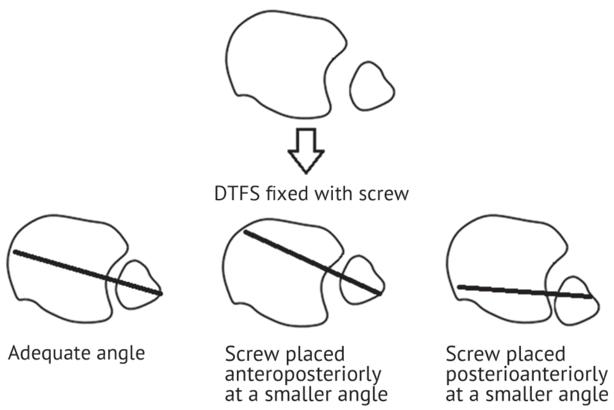

Fig. 5 Variants of fibular malreduction at the DTFS level due to the positional screw placed at the wrong angle

The functional result of treatment at 2 years postsurgery was significantly different in patients with malreduced syndesmosis. The result scored 12 ± 10.6 on the SFMA scale in patients with anatomical reduction and 27 ± 23.3 in malreduction group with differences being statistically significant. The outcomes measured with the Olerud-Molander questionnaire showed statistically significant differences and scored 72.7 ± 22.5 in the anatomical reduction group and 46.3 ± 28.5 in malreduction cases [47]. Open reduction of the DTFS ruptures led to a lower risk of malreduction and improved functional results [47].

Malreduction of syndesmosis with placement of a bone clamp and a positional screw is common. In 2013, A.N. Miller et al. reported a cadaver study and suggested that application of a bone clamp for ruptured DTFS with insufficient visualization can dramatically increase the risk of anterior or posterior fibular displacement and rotational asymmetry and onward placement of the positional screw can aggravate the displacement. To test the hypothesis the authors used 14 cadaveric tibiae with the syndesmotic components intersected and the bone clamp placed at an angle of 0, 15, 30 degrees relative to the sagittal axis with the positional screw mounted at an angle of 15 and 30 degrees with an entry point either laterally or posterolaterally. MSCT was performed at each stage. The authors failed to achieve adequate reduction of the displaced DTFS with any of the stations. The bone clamp and positional screw are normally placed anteriorly at an angle of 15–30° and the series demonstrated that such a station of ruptured DTFS led to external rotation of the fibula and excessive compression of syndesmosis with varying degrees of anterior translation of the fibula in all cases. The clamp and the screw placed at an angle of 0° led to the fibula translated posteriorly with rotation and excessive compression impaired to a lesser extent.

The angle of 0° appeared to be the statistically superior station causing less impairment in the DTFS. The limitation of this study is simulation of isolated ligamentous injury to the DTFS. It can be assumed that the syndesmotic screw used for intra-incisura tibia fractures can cause translation of the fibula towards the fracture due to lack of support. The study revealed the lack of technical ability to adequately address the displacement in the DTFS using a bone clamp. The authors recommended open stabilization of displaced DTFS to reduce the risk of malreduction [48]. So how not to miss a DTFS injury and how to treat it correctly? Rule of thumb is to use MSCT at the slightest suspicion of a DTFS injury. MSCT scan can help to avoid a missed rupture of the DTFS or a Volkman fracture, a Chaput fracture and a Vagstaffe fracture. The second rule is to first address bone structures and then consider repair of the DTFS. With osteosynthesis of three malleoli in trimalleolar fractures, the DTFS fixation may not be required in most cases. The third rule is to judge the contralateral limb. The fourth rule is to visualize syndesmosis from at least one side. The fifth is, a „just in case“ screw is not required with no radiological signs of instability. And the sixth, suture buttons are more preferable than screws.

CONCLUSION

Injury to the DTFS is one of the most controversial topics among ankle injuries due to difficulties of diagnosis, difficulties of stable and anatomically adequate fixation, different fixation approaches to posterior malleolus fractures, options for partial and dynamically unstable injuries and the important role of syndesmotic injury in the development of post-traumatic ankle arthritis. Nevertheless, several important trends can be identified in the development of orthopaedic practice for DTFS injuries. Firstly, an anatomical restoration of incisura fibularis is required in all cases with associated injury to the bones in a Volkman fracture, less often a Chaput fracture and a Vagstaffe fracture. Secondly, an open reduction of DTFS and repair of incisura fibularis is essential for interposition of the interosseous ligament with small bone fragments that complicate reduction and can cause reduction errors with application of a bone clamp. Flexible fixation with Tight Rope buttons can accelerate rehabilitation and reduce the risk of the reduction loss in cases of isolated ligamentous injury to the DTFS. Much more rigid fixation and a longer period of time with no full weight-bearing are required for injury to the DTFS with peripheral neuropathy (with prolonged DM or other causes) in comparison with routine DTFS injuries. Definitive fixation of DTFS in complicated trimalleolar fractures has not yet been determined. There is a trend to expand indications for posterolateral approach, anatomical reduction and stable fixation of all types of intra-incisura fractures regardless of the size of the fragment avoiding routine anterior-to-posterior fixation with the preferred use of elastic fixation using suture buttons. There are no randomized studies comparing the use of trans-syndesmosis fixation and osteosynthesis of the posterior malleolus in trimalleolar fractures but the available cohort studies indicate the equal value.

REFERENCES

1. Felson D.T. The epidemiology of osteoarthritis: Prevalence and risk factors. In: Kuettner K.E., Goldberg V.M., editors. *Osteoarthritis Disorders*. Rosemont (IL), American Academy of Orthopedic Surgeons, 1995, pp. 229-237.
2. Andersen M.R., Frihagen F., Hellund J.C., Madsen J.E., Figved W. Randomized Trial Comparing Suture Button with Single Syndesmotic Screw for Syndesmosis Injury. *J. Bone Joint Surg. Am*., 2018, vol. 100, no. 1, pp. 2-12. DOI: 10.2106/JBJS.16.01011.
3. Ewers B.J., Dvoracek-Driksna D., Orth M.W., Haut R.C. The extent of matrix damage and chondrocyte death in mechanically traumatized articular cartilage explants depends on rate of loading. *J. Orthop. Res*., 2001, vol. 19, no. 5, pp. 779-784. DOI: 10.1016/S0736-0266(01)00006-7.
4. Thompson R.C. Jr., Oegema T.R. Jr., Lewis J.L., Wallace L. Osteoarthrotic changes after acute transarticular load. An animal model. *J. Bone Joint Surg. Am*., 1991, vol. 73, no. 7, pp. 990-1001.
5. Llinas A., McKellop H.A., Marshall G.J., Sharpe F., Kirchen M., Sarmiento A. Healing and remodeling of articular incongruities in a rabbit fracture model. *J. Bone Joint Surg. Am*., 1993, vol. 75, no. 10, pp. 1508-1523. DOI: 10.2106/00004623-199310000-00012.
6. Lovász G., Llinás A., Benya P.D., Park S.H., Sarmiento A., Luck J.V. Jr. Cartilage changes caused by a coronal surface stepoff in a rabbit model. *Clin. Orthop. Relat. Res*., 1998, no. 354, pp. 224-234. DOI: 10.1097/00003086-199809000-00027.
7. McKinley T.O., Rudert M.J., Koos D.C., Brown T.D. Incongruity versus instability in the etiology of posttraumatic arthritis. *Clin. Orthop. Relat. Res*., 2004, no. 423, pp. 44-51. DOI: 10.1097/01.blo.0000131639.89143.26.
8. Weening B., Bhandari M. Predictors of functional outcome following transsyndesmotic screw fixation of ankle fractures. *J. Orthop. Trauma*, 2005, vol. 19, no. 2, pp. 102-108. DOI: 10.1097/00005131-200502000-00006.
9. Miller A.N., Carroll E.A., Parker R.J., Boraiah S., Helfet D.L., Lorich D.G. Direct visualization for syndesmotic stabilization of ankle fractures. *Foot Ankle Int*., 2009, vol. 30, no. 5, pp. 419-426. DOI: 10.3113/FAI-2009-0419.
10. Sagi H.C., Shah A.R., Sanders R.W. The functional consequence of syndesmotic joint malreduction at a minimum 2-year follow-up. *J. Orthop. Trauma*, 2012, vol. 26, no. 7, pp. 439-443. DOI: 10.1097/BOT.0b013e31822a526a.
11. Andersen M.R., Frihagen F., Hellund J.C., Madsen J.E., Figved W. Randomised Trial Comparing Suture Button, with Single Syndesmotic Screw for Syndesmosis Injury. *J. Bone Joint Surg. Am*., 2018, vol. 100, no. 1, pp. 2-12. DOI: 10.2106/JBJS.16.01011.
12. Laflamme M., Belzile E.L., Bédard L., van den Bekerom M.P., Glazebrook M., Pelet S. A prospective randomized multicenter trial comparing clinical outcomes of patients treated surgically with a static or dynamic implant for acute ankle syndesmosis rupture. *J. Orthop. Trauma*, 2015, vol. 29, no. 5, pp. 216-223. DOI: 10.1097/BOT.0000000000000245.

13. De-Las-Heras Romero J., Alvarez A.M.L., Sanchez F.M., Garcia A.P., Porcel P.A.G., Sarabia R.V., Torralba M.H. Management of syndesmotic injuries of the ankle. *EFORT Open Rev*., 2017, vol. 2, no. 9, pp. 403-409. DOI: 10.1302/2058-5241.2.160084.
14. Van den Bekerom M.P., Haverkamp D., Kloen P. Biomechanical and clinical evaluation of posterior malleolar fractures. A systematic review of the literature. *J. Trauma*, 2009, vol. 66, no. 1, pp. 279-284. DOI: 10.1097/TA.0b013e318187eb16.
15. Van Dijk C.N., Longo U.G., Loppini M., Florio P., Maltese L., Ciuffreda M., Denaro V. Classification and diagnosis of acute isolated syndesmotic injuries: ESSKA-AFAS consensus and guidelines. *Knee Surg. Sports Traumatol. Arthrosc*., 2016, vol. 24, no. 4, pp. 1200-1216. DOI: 10.1007/s00167-015-3942-8.
16. Shah A.S., Kadakia A.R., Tan G.J., Karadsheh M.S., Wolter T.D., Sabb B. Radiographic evaluation of the normal distal tibiofibular syndesmosis. *Foot Ankle Int*., 2012, vol. 33, no. 10, pp. 870-876. DOI: 10.3113/FAI.2012.0870.
17. Lui T.H., Ip K., Chow H.T. Comparison of radiologic and arthroscopic diagnoses of distal tibiofibular syndesmosis disruption in acute ankle fracture. *Arthroscopy*, 2005, vol. 21, no. 11, pp. 1370. DOI: 10.1016/j.arthro.2005.08.016.
18. Harper M.C. An anatomic and radiographic investigation of the tibiofibular clear space. *Foot Ankle Int*., 1993, vol. 14, no. 8, pp. 455-458. DOI: 10.1177/107110079301400805.
19. Ostrum R.F., De Meo P., Subramanian R. A critical analysis of the anterior-posterior radiographic anatomy of the ankle syndesmosis. *Foot Ankle Int*., 1995, vol. 16, no. 3, pp. 128-131. DOI: 10.1177/107110079501600304.
20. Ebraheim N.A., Lu J., Yang H., Mekhail A.O., Yeasting R.A. Radiographic and CT evaluation of tibiofibular syndesmotic diastasis: a cadaver study. *Foot Ankle Int*., 1997, vol. 18, no. 11, pp. 693-698. DOI: 10.1177/107110079701801103.
21. Ebraheim N.A., Lu J., Yang H., Rollins J. The fibular incisure of the tibia on CT scan: a cadaver study. *Foot Ankle Int*., 1998, vol. 19, no. 5, pp. 318-321. DOI: 10.1177/107110079801900509.
22. Hopkinson W.J., St Pierre P., Ryan J.B., Wheeler J.H. Syndesmosis sprains of the ankle. *Foot Ankle Int*., 1990, vol. 10, no. 6, pp. 325-330. DOI: 10.1177/107110079001000607.
23. Oae K., Takao M., Naito K., Uchio Y., Kono T., Ishida J., Ochi M. Injury of the tibiofibular syndesmosis: value of MR imaging for diagnosis. *Radiology*, 2003, vol. 227, no. 1, pp. 155-161. DOI: 10.1148/radiol.2271011865.
24. Takao M., Ochi M., Oae K., Naito K., Uchio Y. Diagnosis of a tear of the tibiofibular syndesmosis. The role of arthroscopy of the ankle. *J. Bone Joint Surg. Br*., 2003, vol. 85, no. 3, pp. 324-329. DOI: 10.1302/0301-620x.85b3.13174.
25. Elgafy H., Semaan H.B., Blessinger B., Wassef A., Ebraheim N.A. Computed tomography of normal distal tibiofibular syndesmosis. *Skeletal Radiol*., 2010, vol. 39, no. 6, pp. 559-564. DOI: 10.1007/s00256-009-0809-4.
26. Beumer A., Valstar E.R., Garling E.H., Niesing R., Ranstam J., Löfvenberg R., Swierstra B.A. Kinematics of the distal tibiofibular syndesmosis: radiostereometry in 11 normal ankles. *Acta Orthop. Scand*., 2003, vol. 74, no. 3, pp. 337-343. DOI: 10.1080/00016470310014283.
27. Amendola A., Williams G., Foster D. Evidence-based approach to treatment of acute traumatic syndesmosis (high ankle) sprains. *Sports Med. Arthrosc. Rev*., 2006, vol. 14, no. 4, pp. 232-236. DOI: 10.1097/01.jsa.0000212329.32969.b8.
28. Walley K.C., Hofmann K.J., Velasco B.T., Kwon J.Y. Removal of Hardware after Syndesmotic Screw Fixation: A Systematic Literature Review. *Foot Ankle Spec*., 2017, vol. 10, no. 3, pp. 252-257. DOI: 10.1177/1938640016685153.
29. Gardner R., Yousri T., Holmes F., Clark D., Pollintine P., Miles A.W., Jackson M. Stabilization of the syndesmosis in the Maisonneuve fracture – a biomechanical study comparing 2-hole locking plate and quadricortical screw fixation. *J. Orthop. Trauma*, 2013, vol. 27, no. 4, pp. 212-216. DOI: 10.1097/BOT.0b013e31825cfac2.
30. Markolf K.L., Jackson S.R., McAllister D.R. Syndesmosis fixation using dual 3.5 mm and 4.5 mm screws with tricortical and quadricortical purchase: a biomechanical study. *Foot Ankle Int*., 2013, vol. 34, no. 5, pp. 734-739. DOI: 10.1177/1071100713478923.
31. Manjoo A., Sanders D.W., Tieszer C., MacLeod M.D. Functional and radiographic results of patients with syndesmotic screw fixation: implications for screw removal. *J. Orthop. Trauma*, 2010, vol. 24, no. 1, pp. 2-6. DOI: 10.1097/BOT.0b013e3181a9f7a5.
32. Miller T.L., Skalak T. Evaluation and treatment recommendations for acute injuries to the ankle syndesmosis without associated fracture. *Sports Med*., 2014, vol. 44, no. 2, pp. 179-188. DOI: 10.1007/s40279-013-0106-1.
33. Peek A.C., Fitzgerald C.E., Charalambides C. Syndesmosis screws: how many, what diameter, where and should they be removed? A literature review. *Injury*, 2014, vol. 45, no. 8, pp. 1262-1267. DOI: 10.1016/j.injury.2014.05.003.
34. Thompson M.C., Gesink D.S. Biomechanical comparison of syndesmosis fixation with 3.5- and 4.5-mm stainless steel screws. *Foot Ankle Int*., 2000, vol. 21, no. 9, pp. 736-741. DOI: 10.1177/107110070002100904.
35. Dingemans S.A., Rammelt S., White T.O., Goslings J.C., Schepers T. Should syndesmotic screws be removed after surgical fixation of unstable ankle fractures? A systematic review. *Bone Joint J*., 2016, vol. 98-B, no. 11, pp. 1497-1504. DOI: 10.1302/0301-620X.98B11.BJJ-2016-0202.R1.
36. Miller M.A., McDonald T.C., Graves M.L., Spitler C.A., Russell G.V., Jones L.C., Replogle W., Wise J.A., Hydrick J., Bergin P.F. Stability of the Syndesmosis after Posterior Malleolar Fracture Fixation. *Foot Ankle Int*., 2018, vol. 39, no. 1, pp. 99-104. DOI: 10.1177/1071100717735839.
37. Manway J.M., Blazek C.D., Burns P.R. Special Considerations in the Management of Diabetic Ankle Fractures. *Curr. Rev. Musculoskelet. Med*., 2018, vol. 11, no. 3, pp. 445-455. DOI: 10.1007/s12178-018-9508-x.
38. Bartoníček J., Rammelt S., Tuček M., Naňka O. Posterior malleolar fractures of the ankle. *Eur. J. Trauma Emerg. Surg*., 2015, vol. 41, no. 6. DOI 10.1007/s00068-015-0560-6.
39. Gardner M.J., Graves M.L., Higgins T.F., Nork S.E. Technical Considerations in the Treatment of Syndesmotic Injuries Associated with Ankle Fractures. *J. Am. Acad. Orthop. Surg*., 2015, vol. 23, no. 8, pp. 510-518. DOI: 10.5435/JAAOS-D-14-00233.
40. Shimozono Y., Hurley E.T., Myerson C.L., Murawski C.D., Kennedy J.G. Suture Button versus Syndesmotic Screw for Syndesmosis Injuries: A Meta-analysis of Randomized Controlled Trials. *Am. J. Sports Med*., 2019, vol. 47, no. 11, pp. 2764-2771. DOI: 10.1177/0363546518804804.
41. Colcuc C., Blank M., Stein T., Raimann F., Weber-Spickschen S., Fischer S., Hoffmann R. Lower complication rate and faster return to sports in patients with acute syndesmotic rupture treated with a new knotless suture button device. *Knee Surg. Sports*

Traumatol. Arthrosc., 2018, vol. 26, no. 10, pp. 3156-3164. DOI: 10.1007/s00167-017-4820-3.
42. Franke J., von Recum J., Suda A.J., Grützner P.A., Wendl K. Intraoperative three-dimensional imaging in the treatment of acute unstable syndesmotic injuries. *J. Bone Joint Surg. Am*., 2012, vol. 94, no. 15, pp. 1386-1390. DOI: 10.2106/JBJS.K.01122.
43. Grenier S., Benoit B., Rouleau D.M., Leduc S., Laflamme G.Y., Liew A. APTF: anteroposterior tibiofibular ratio, a new reliable measure to assess syndesmotic reduction. *J. Orthop. Trauma*, 2013, vol. 27, no. 4, pp. 207-211. DOI: 10.1097/BOT.0b013e31826623cc.
44. Sagi H.C., Shah A.R., Sanders R.W. The functional consequence of syndesmotic joint malreduction at a minimum 2-year follow-up. *J. Orthop. Trauma*, 2012, vol. 26, no. 7, pp. 439-443. DOI: 10.1097/BOT.0b013e31822a526a.
45. Candal-Couto J.J., Burrow D., Bromage S., Briggs P.J. Instability of the tibio-fibular syndesmosis: have we been pulling in the wrong direction? *Injury*, 2004, vol. 35, no. 8, pp. 814-818. DOI: 10.1016/j.injury.2003.10.013.
46. Miller A.N., Barei D.P., Iaquinto J.M., Ledoux W.R., Beingessner D.M. Iatrogenic syndesmosis malreduction via clamp and screw placement. *J. Orthop. Trauma*, 2013, vol. 27, no. 2, pp. 100-106. DOI: 10.1097/BOT.0b013e31825197cb.
47. Monga P., Kumar A., Simons A., Panikker V. Management of distal tibio-fibular syndesmotic injuries: a snapshot of current practice. *Acta Orthop. Belg*., 2008, vol. 74, no. 3, pp. 365-369.

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Information about the authors:

1. Dmitry A. Nikiforov – nikiforovmd@gmail.com;
2. Mikhail A. Panin – Candidate of Medical Sciences, panin-mihail@yandex.ru, SPIN code: 5834-3500;
3. Victor G. Protsko – Doctor of Medical Sciences;
4. Rami D. Borgut – Candidate of Medical Sciences;
5. Rasul N. Aliyev – Candidate of Medical Sciences.