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The Final Thesis

Treatment of B Type Ankle Fractures

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Declaration

I hereby declare that I have written this dissertation without the unauthorized help of third parties and without the use of other than the stated aids; the thoughts taken directly or indirectly from outside sources are identified and marked as such.

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Furthermore I would like to give a special thanks to my grandmother, who always believed in me and helped me to fulfill my dream of becoming a doctor.

Dedication

I dedicate this work to my fiancé Kejwan Bordbar Jahantighi.

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1. SUMMARY

The master thesis reports a case of a 70 year old male who was presented to the emergency department after an acute ankle injury. After the physical examination and imaging investigation it is demonstrated that the patient has a spiral fibular fracture at the level of the syndesmotic ligaments together with a posterior malleolar fracture or Volkmann fracture. Medially the deltoid ligament is presumably strained. The injury is classified as an AO/OTA 44B3.1 fracture or a Weber B.3.1 fracture. The thesis also addresses the question of whether the posterior malleolar fracture requires mandatory surgery. And if so, which method is the safest for the patient. Three different surgical models are compared in the discussion.

2. INTRODUCTION

2.1. ANATOMY OF THE ANKLE JOINT

The ankle joint is a complex joint in our body that connects the lower leg bones to the foot. It is encased by a joint capsule. Many ligaments and tendons provide not only great mobility but also the necessary stability.

The ankle joint is a hinge joint that consists of two parts:

1. The upper ankle joint is formed by the ends of the tibia and fibula and the adjoining tarsal bone, the ankle bone.
2. The lower ankle joint consists of the talus, the calcaneus and the navicular bone. In between lies the malleolar fork - a bone pit formed by the two knuckles (malleoli) and encompassing the upper ankle joint. [1]

2.2. SUPPORTING FUNCTION OF THE LIGAMENTS

The external ligamentous apparatus is formed by three ligaments: The anterior, medial and posterior external ligaments. They support the ankle joint from the outside. In ankle injuries, it is usually the external ligaments that are affected. The anterior external ligament, called the ligamentum fibulotalare anterius, is most commonly affected (LFTA), followed by the middle external ligament, the ligamentum fibulocalcaneare (LFC). The ligamentum fibulotalare posterius (LFTP) is affected least frequently.

On the inside of the ankle are the inner ligaments of the ankle joint, which are composed of superficial and deeper ligament complexes. The inner ligament complex is also called the deltoid ligament and is one of the strongest ligament complexes in the human body. [2,3]

2.3. STABILIZATION OF THE ANKLE JOINT

In addition, strong connective tissue cords (called the syndesmosis), connect the tibia and fibula and stabilize the ankle joint fork when it is loaded during movement. The syndesmosis is also referred to as a faux joint.

During movement, the force is absorbed by the upper ankle joint via the tibia and fibula and transferred to the lower ankle joint, distributing the force to the entire foot and the ground. [4]

2.4. THE RANGE OF MOTION OF THE FOOT

The lower ankle joint allows the outer edge of the foot to be raised laterally by up to 30° and the inner edge of the foot by up to 60° - also known as pronation and supination. If the ankle joint moves into a position that exceeds the natural range of motion, injury occurs. Supination in particular is the typical movement in accidents caused by twisting an ankle.

The upper ankle joint enables dorsiflexion and plantar flexion, i.e. the raising and lowering of the arch of the foot. This is important for the correct rolling motion during walking. The range of motion when lifting the foot is about 20° to 30° and when lowering the foot even up to 50°.

Dorsiflexion and plantar flexion, as well as pro- and supination, thus allow the ankle joint a wide range of motion, making it highly resilient. It is often the combination of supination and plantar flexion, the so-called inversion, which leads to injuries, e.g. during landings after jumps. [5]

2.5. WEBER B FRACTURE

In 1949 Robert Danis firstly developed the Danis-Weber classification system. Bernhard Georg Weber modified this system after Danis' death in 1972.
At present it is called the Weber ankle fracture classification.
This method is used to describe ankle fractures. It classifies lateral malleolar fractures, with respect to the level of the fracture and additionally with regard to the ankle joint focused on the distal tibiofibular syndesmosis. Between the ages of 20 and 65 years, ankle fractures are the most common fractures with an occurrence of nearly 90 000 per year. [6]
The anatomical classification of Danis-Weber categorizes the fractures according to the site of injury in three types, type A, B and C. Type B accounts for up to 50% of these injuries. [7]
This thesis concentrates on the Weber type B fracture. [8]

The fracture of the fibula is at the distal extent at the level of the syndesmosis and proximally it could extend some distance. The fractures are usually spiral and the tibiofibular syndesmosis stays intact in most of the cases. In radiographic images like X-Rays, a widening of the distal tibiofibular joint indicates a syndesmotic injury. In the Danis-Weber classification type B the medial malleolus may be fractured as well. The widening of the space between the medial malleolus and the talar dome draws attention to the disruption of the deltoid ligament. The stability of the fracture is dependent on the state of the medial structures the malleolus, the deltoid ligament and the syndesmosis.
The Danis-Weber classification can be further sub-classified as B1 which indicates an isolated fracture. B2 is associated with a medial injury involving the malleolus or the ligament. B3 is defined by a medial lesion and fracture of posterolateral tibia. [9,10]

3. KEYWORDS

Weber B type fracture, ankle fracture, ankle instability, Volkmann fracture, Volkmann triangle, posterior malleolar fracture, stress radiography, bony fixation, internal fixation, posterior buttress plate, posterior-anterior lag screw, anterior-posterior lag screw

4. CLINICAL CASE

4.1 CLINICAL PRESENTATION

A 70 year old male presented to the emergency department at Respublikinė Vilniaus universitetinė ligoninė with a chief complaint of left ankle pain. He had no history of surgery or trauma to the ankle prior to the presenting injury. The physical examination were conducted and the patient was in mild distress but the vital signs were stable. The left ankle showed a decent soft tissue swelling. Over the foot and ankle the sensation was intact and the pedal pulses were palpable as well. During the examination over the distal aspect of the left lateral malleolus, the calcaneofibular and anterior talofibular ligaments tenderness could be felt. Over the medial malleolus pain was also experienced. Due to pain he patient could not walk and bear weight on the left ankle and the passive range of motion was limited as well.

4.2 IMAGING INVESTIGATION

X-Rays of the left ankle, foot and distal part of the lower leg were performed in medial view (Figure 1) and in anterior view (Figure 2). In the medial view (Figure 1) of the X-Ray image of the distal part of the lower leg a white, dense fracture line is visible. This indicates a wedge fracture at the posterior malleolus of the left tibia (red arrow). It is not possible to analyze the state of the fibula in the medial view. The anterior X-Ray image (Figure 2) shows a dense fracture line at the posterior malleolus of the left tibia as well (red arrow). The fibula is clearly depicted next to the tibia. The distal part of the fibula demonstrates an irregularity of the lateral malleolus cortex, which is not displaced (yellow arrow). Just with the radiographic images of the X-Rays it is only possible to assume the diagnosis of a Weber B fracture.

Figure 1. Medial view of left ankle (preoperative). *X-Ray image of the left ankle, foot and distal part of the lower leg in medial view. This image showed a wedge fracture at the posterior malleolus of the left tibia, which is indicated by a red arrow.*

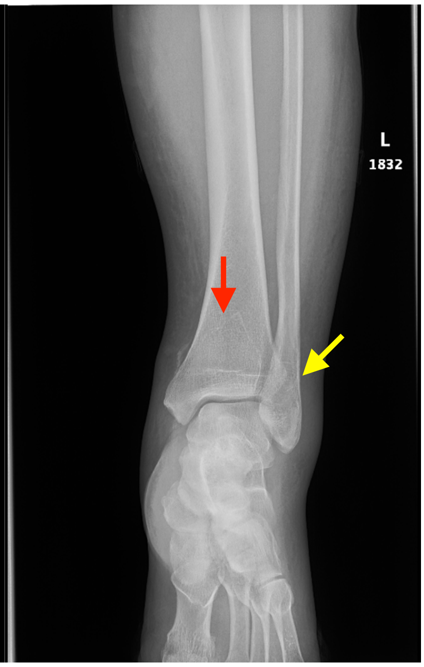

Figure 2. Anterior View of left ankle (preoperative). *X-Ray image of the left ankle, foot and distal part of the lower leg in anterior view. The anterior view indicated a posterior wedge fracture including the posterior malleolus of the tibia. It is characterized by the misty mountain sign (red arrow). Whether the medial malleolus is affected as well, is not visible. An inhomogeneous density above the lateral malleolus of the fibula suggested a possible fracture at this level. (yellow arrow).*

After an orthopedic consultation further investigations were ordered to confirm the diagnosis and to further classify the fracture. CT (computer tomography) scans were performed, which are visible in Figure 3 - Figure 8. The computed tomographic scan in medial view (Figure 3) confirms the posterior wedge fracture of the posterior malleolus. It seems that the posterior malleolus is slightly displaced as well. This image indicates that the posterior malleolus fragment includes a portion of the articular surface of the distal tibia. The posterior wedge fracture is called Volkmann fracture or Volkmann triangle. [11] It is a special form of ankle fracture, a wedge-shaped bone fracture in the are of the distal joint surface of the tibia. [12] It is a loose intra-articular fragment which can be called as Trimalleolar fracture as well. [13] Figure 4 and 5 show axial views of the left ankle in transverse planes. Both images validate a fracture of the posterior malleolus and support the the assumption of a lateral malleolus fracture.

Figure 3. Computed tomographic scan in medial view of the left ankle (preoperative). *It confirmed the posterior wedge fracture of the posterior malleolus, which was slightly displaced (red arrow). The fibula is not visible.*

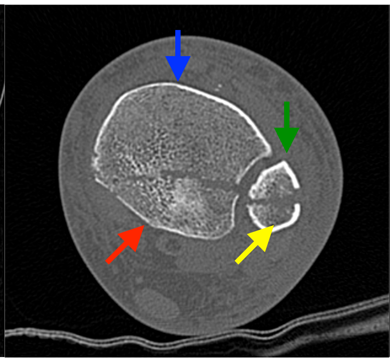

Figure 4. Computed tomographic scan in axial view of the left ankle (preoperative). *On the left side the tibia is shown (blue arrow) and on the right the fibula (green arrow). This image confirmed the fracture of the posterior malleolus (red arrow) and validated the lateral malleolus fracture (yellow arrow).*

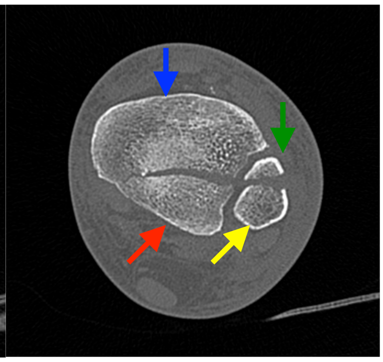

Figure 5. Computed tomographic scan in axial view of the left ankle (preoperative). *It showed the tibia (blue arrow) and the fibula (green arrow). Similar to Figure 1, this image underlined the posterior malleolus fracture (red arrow) and supported the theory of the lateral malleolus fracture (yellow arrow).*

3D computed tomography scan images of the left ankle were taken, to detect all fracture components, to assess the impaction and to aid preoperative planning (Figure 6, 7 and 8). Figure 6 shows the spiral fracture of the fibula, which is at the level of the syndesmosis. It is important to assess the integrity of the deltoid ligament in order to estimate the stability. Therefore the medial clear space (MCS) needs to be measured. It is the distance between the medial malleolus and medial talus. It is important that the foot stays in neutral position and not in plantarflexion. In plantar flexion the medial clear space appears wider. A rupture of the deltoid ligament leads to a lateral talar shift and an increase of the medial clear space. It is abnormal when the medial clear space is > 4 mm. [14] In figure 6 it seems that the medial clear space is slightly increased. Whether the deltoid ligament is ruptured is difficult to say.

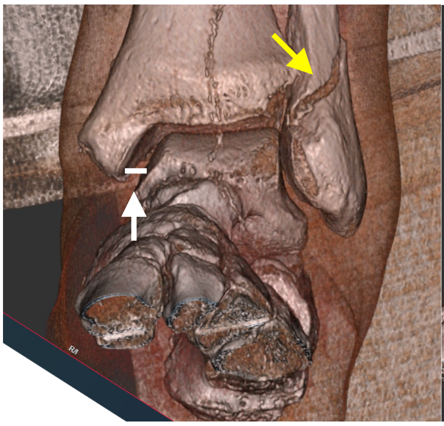

Figure 6. 3D computed tomography scan of the left ankle in anterior view (preoperative)*. The yellow arrow points to the spiral fracture of the fibula, which was at the level of the syndesmosis, whether the fracture is displaced or not was not visible. The anterior view did not show any fracture of the tibia. The distance between the medial malleolus and medial talus seemed to be increased.*

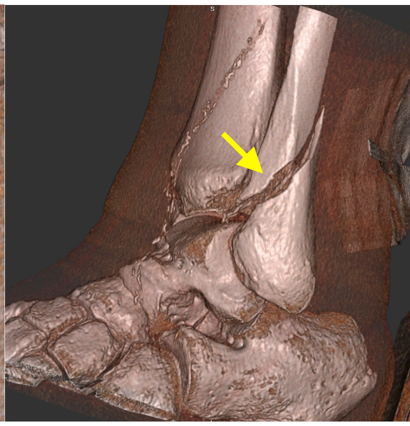

Figure 7. 3D computed tomography scan of the left ankle in lateral view (preoperative). *The lateral view confirmed the nature of the fracture, which was spiral and demonstrated that the fibula fracture was on the level of the sydesmosis. The lateral malleolus was slightly displaced due to the fracture in the fibula. This indicated an unstable fracture.*

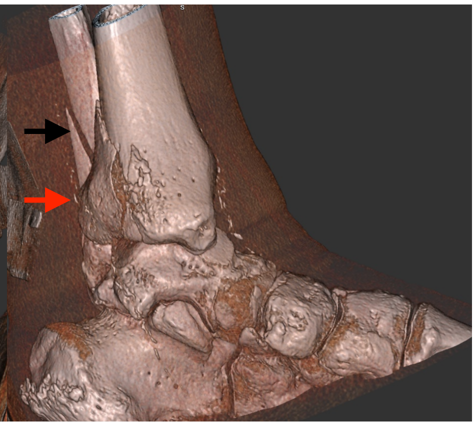

Figure 8. 3D computed tomography scan of the left ankle in posterior medial view (preoperative). *The red arrows points to the Volkmann fracture. This view confirmed, that the medial malleolus was not affected by the injury and was intact. The black arrow indicated the fibula fracture. The level of the fibula fracture was not visible.*

A displacement of the lateral malleolus is not visible in this image. A tibial injury is not seen as well. Figure 7 shows the spiral fracture of the fibula and a modest displacement of the lateral malleolus. The posterior medial view of the left ankle in figure 8 shows the posterior wedge fracture of the posterior malleolus and the fibula fracture as well.

4.3 FINAL DIAGNOSIS

The radiographic investigations indicate that the patient has a spiral fibular fracture at the level of the syndesmotic ligaments together with a posterior malleolar fracture or Volkmann fracture. Medially the deltoid ligament is not torn, but presumably strained. The injury is classified as an AO/OTA 44B3.1 fracture. [15] In combination with the findings of the radiographic images, the clinical presentation of the patient and the AO/OTA classification the diagnosis of a Weber B.3.1 fracture is confirmed. The deltoid ligament belongs to the most important static stabilizers of the ankle. A lateral malleolar fracture along with a strained deltoid ligament is defined as an unstable type of injury and requires surgical treatment. [16]

4.4 TREATMENT

After the operation X-Ray images of the left ankle, foot and distal part of the lower leg were performed in medial (Figure 9) and anterior (Figure 10) view. The given radiographic images show that the patient underwent an open reduction, internal fixation operation with a posterolateral approach. The lateral malleolus was fixated with a neutralization 1/3 tubular plate and six lag screws. [17] It is indicated that the operation was conducted posterolateral in order to fixate the Volkmann fracture. The Volkmann fracture needs to be reduced and fixed. A posterior 1/3 tubular buttress plate is used to simplify the reduction. Five lag screws were used to reduce and fixate the fracture. The talus, the tibia and the fibula are perfectly aligned and the medial clear space is in a normal range (< 4 mm). [18] The patients left leg is casted in order to bring the foot in the right position and to make sure the fractures and incisions heal properly. There is no indication for the fixation of the syndesmotic ligaments.

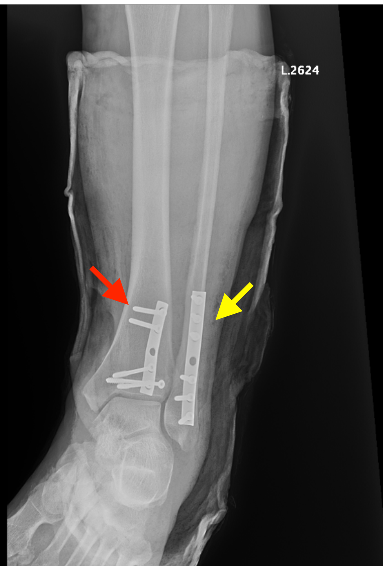

Figure 9. X-Ray image of the left ankle, foot and distal part of the lower leg in medial view (postoperative)*. This image showed the bony fixation of the tibia and fibula. It was not clearly visible where the tibial and fibula plates were placed and how many screws were used. The patients' foot was casted.*

Figure 10. X-Ray image of the left ankle in anterior view (postoperative)*. It showed the fixation of the Weber fracture B 3.1. The operation was conducted from the posterior approach where a plate was positioned on the tibia. The posterior malleolus was fixated with five screws (red arrow). The fibula was fixated with a plate as well (yellow arrow). Six screws were used to adjust the lateral malleolus. The patient' foot was casted.*

4.5. OUTCOME AND FOLLOW-UP

After two months the patient came for the follow-up and additional X-rays were taken (Figure 11 and 12). The cast is not necessary anymore and the patient is able to stand by himself. Figure 12 shows that the fractures from the patient are healed and there is no abnormality visible compared to the right leg.

Figure 11. Radiographic image of left ankle in medial view (follow-up after two months). *The patients foot was not casted anymore and he was able to stand by himself. The screws were not removed and the fracture seemed to be healed.*

Figure 12. Radiographic image of left ankle in anterior view (follow-up after two months). *Both lower legs were visible. The fractures healed and the left leg did not show any abnormality compared to the right leg.*

5. DISCUSSION

Ankle fractures happen frequently and publications have drawn attention to the fact that Weber B fractures of the fibula are the most common type. [19] The bony and ligamentous parts of the injury require a complete understanding of the anatomy, before the management can be planned. The decision whether the talus is stable or unstable is difficult to make. If the talus is stable, a non-operative management can be considered. How to determine the stability of a Weber B fracture is debated in several papers. [14]

Weber B fractures including a posterior malleolus fracture are analyzed regarding surgical treatment. [20] Axial imaging computed tomographic scans are of big importance to classify the fracture, to rule out differential diagnosis and to create a treatment plan in order to reduce and fix the posterior malleolus. Several paper present the fixation of the posterior malleolus by emphasizing the posterolateral approach. [21]

The major question is, should the posterior malleolus be fixed or not? The posterior malleolus is a part of the articular surface of the distal tibia. A fragment in this area can cause a disbalance of the articular congruity. Some hospitals ignore the posterior malleolar fracture and others fix them anatomically to restore stability. According to issued studies, surgeons perform posterior malleolar fixation, when 20%, 25%, 30% or a greater proportion of the articular surface of the tibial plafond is affected. [22] The bigger the posterior malleolar fragment gets, the more the contact pressure at the tibiotalar articulation increases. [23] The stability of the joint is dependent on the medial and lateral malleoli. As long as they are intact the stability of the joint is not affected. Some long term studies where conducted, to emphasize the role of the posterior malleolus. [24]

The fracture of the lateral malleolus needs a surgical reduction and fixation like the previously discussed patient case. The posterior malleolus will heal as well, even without a surgical approach. It just needs a proper period of immobilization. The reason why the posterior malleolus does not need a fixation is, because the posteroinferior tibiofibular ligament is the connection between the distal fibula and the posterior malleolus. An intercalated fragment could be a reason for an inaccurate reduction. [25] The single fixation of the lateral malleolus can lead to a shift of the posteroinferior tibiofibular ligament and even a small degrees of dislocation has an impact on the healing length of the posterior syndesmotic osseous ligamentous component and results ultimately in posterolateral talar instability. When the posterior malleolus is not fixed surgically, it is more likely that the

patient has a prolonged period where the joint should not be loaded or stressed compared to cases where the posterior malleolus is operated. The patients can bear full weight through the ankle after a shorter period of time and therefore they can return to daily activities and work earlier. [26] As already indicated, the reduction of the posterior malleolus must be accurate when it is treated surgically. Incorrect reduction will lead to problems in reducing the fibula during the operation, as well as to the occurrence of degenerative changes in the future. [27,28] Before the permanent fixation of the fibula, the reduction should be checked with the provisional fixation of the posterior malleolus. It is strongly advised to make pre- and post-operative computed tomographic scans to ensure the quality of the operation. [29] Depending on the results, early revision may be required, because it prevents osteotomy. [30,31]
Another argument for the posterior malleolar fixation is because of the tibiofibular syndesmosis. Firstly, due to the posterior malleolar fixation the distal fibula is reduced to the correct length. This reduction occurs through the posteroinferior tibiofibular ligament. Additionally it guarantees an accurate length and strength of this ligament and the distal tibiofibular joint. Therefore a stabilization of the syndesmosis is not required. The fixation of the fibular fracture restores the majority of the strength of the distal tibiofibular joint and a syndesmosis fixation with screws or a tightrope is associated with a poor outcome. [32] So the posterior malleolus fixation has multiple advantages like reconstruction of the articular surface of the tibia, accurate fibular length correction, preventing a false union and recreating the stability of the syndesmosis. [33]

The posterior malleolar fixation (Volkmann fragment) has the aim to restore the articular surface of the tibial plafond, maintain joint stability and achieve utmost functional recovery. This goal can be achieved by three different posterior malleolar fixation methods. The first method is to use posterior-anterior lag screws via the posterolateral approach. The second method is the usage of anterior-posterior lag screws with the posteromedial approach. Lastly a posterior buttress plating can be used as well for the fixation.

Using the posterolateral approach gives the advantage to have an easy access to the fracture site with direct visualization and reduction of the posterior fragment. Fundamental concept in fracture surgery is the anatomical reduction of articular surfaces. Anatomical reduction takes place in 83% of posterior malleolar fractures, when the direct reduction method is used

compared to the standard indirect reduction method using anteroposterior screws, where only 27% of the posterior fractures are reduced. [34]
It is possible to use the same incision for the fixation of the posterior and medial malleoli using the posteromedial approach. [35] But it limits the visualization of the posterior malleolar fragment. [36] In between the posterior malleolus fragment gaps interposition of soft tissue or loose osseous fragments is accumulated, which leads to technical difficulty to achieve anatomical reduction and fix small comminuted fragments. [37]

The majority of the orthopedic surgeons recommend to undergo a posterior malleolar fixation operation, when the size of the posterior malleolar fracture is bigger than 25%. Recent studies have shown that the posterior malleolus prevents the posterior displacement of the talus and is important in the tibiotalar load propagation. [38]
In a computational study the biomechanical efficiency of the mentioned fixation methods is compared in simulated posterior malleolar fractures greater than 25%. The study analyzed that the usage of the posterior buttress plate is the most stable fixation method in comparison to posterior-anterior or anterior-posterior lag screws. It was observed that the plate resisted the upward displacement more effectively than posterior-anterior or anterior-posterior lag screws. Anterior-posterior lag screws are the least stable fixation methods in this study. [39] According to a previous study by Bennett et al., where the fixation strength of one-third tubular posterolateral plate and anterior-posterior lag screws were compared in cadaveric models, using the posterior buttress plating showed less displacement during cyclical loading in comparison to anterior-posterior lag screws. [40] A Chinese literature came to the conclusion that the fixation of the posterior malleolus using a distal radius plate is superior in achieving the fracture reduction. [41] Additionally another clinical study by O´Connor et al. showed improved clinical and radiographic outcomes using a posterior plate for the posterior malleolar fixation. [42] So all in all it can be said that according to the majority of the studies the posterior plate remains the strongest implant for the fixation of the posterior malleolar fracture, the posterior-anterior lag screw is the second most stable method. Using the anterior-posterior lag screw is the least favorite technique.

6. CONCLUSION

Displaced and unstable Type B fractures require surgical fixation. A mischaracterized ankle fracture may lead to further harm and putting the patient at bigger risk for the development of post-traumatic osteoarthritis. Surgeons perform posterior malleolar fixation, when 20%, 25%, 30% or a greater proportion of the articular surface of the tibial plafond is affected. Different surgical techniques can be used for the fixation of the fragment. Many biomechanical and clinical studies have proven that using a posterior buttress plating is the most stable fixation implant with minimum amount of relative micro-motion and vertical displacement. Following the second most stable method the posterior-anterior lag screw. The least stable fixation construct is the anterior-posterior lag screw.

In conclusion, it is important to note that surgeons should choose the appropriate approach based on their experience in order to reach the best possible outcome for their patients.

7. RECOMMENDATIONS

Unstable Type B ankle fractures require surgical fixation in order to prevent the development of post-traumatic osteoarthritis. Displaced posterior malleolar fractures that involve between or more than 20-30% of the distal articular tibial surface should be operated via the posterolateral approach with buttress plates. The posterolateral approach gives good visualization of the fracture and leads to achieve a good reduction and fixation.

Although several studies have shown that fixating the posterior malleolar fracture with buttress plating using the posterolateral approach is the most stable construct, the surgeons preference and experience should be taken under consideration.

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