Ankle fractures

Šalinović, Dinko

UNIVERSITY OF ZAGREB

SCHOOL OF MEDICINE

Dinko Šalinović

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Mentor of the graduate thesis: Ivan Dobrić, MD, PhD

Abbreviations:

L4: Lumbar vertebra 4

L5: Lumbar vertebra 5

S1: Sacral vertebra 1

S2: Sacral vertebra 2

CT: Computed tomography

MRI: Magnetic resonance imaging

ORIF: Open Reduction and Internal Fixation

Table of contents:

1. Summary

Title: Ankle Fractures

Key words: Ankle Fractures, AO classification, Lauge-Hansen classification, ORIF

Ankle fractures are described by different classification systems. The two classifications that are used are the AO classification and the Lauge-Hansen Classification. Anatomical and mechanical considerations show the different outcomes after an injury to the ankle and the problems associated with them. The paper does not only explain fractures of the bones of the ankle joint, but also the damage to soft tissues like ligaments and capsules. The physiology and pathoanatomy are described including the importance of joint stability and congruity. Included are also the treatment options, which describe the immediate management before surgeries, treatment options that are non-surgical, as well as postoperative management. Surgical procedures are shown and which approach is used for the different types of fractures.

2. Preface

Ankle fractures are part of everyday life. Approximately 15% of all injuries of the ankle are ankle fractures. They develop after forces that act on the ankle joint during movements. The first mechanism is by foot supination, where the forefoot is inverted, the hindfoot adducted and the ankle is rotated inward. The second mechanism, which is exactly opposite to the first mechanism, is by foot pronation. The treatment depends on the severity of the injury and includes non-surgical approaches and surgery.

2.1. Anatomy

The foot hast two surfaces. The dorsal surface is the upper part of the foot and the plantar surface is the surface of the sole of the foot. The ankle joint, which is also called talocrural joint (1), is a hinge joint that allows for several movements. When the foot moves upwards it is called dorsiflexion and when the foot moves downward it is referred to as plantarflexion. Two other movements are eversion, when the foot moves laterally and inversion, when the foot moves medially.
The ankle joint consists of bony parts, ligaments, muscles, as well as tendons, arteries, veins and nerves which run through it.

2.1.1. Bones

The bones, which make up the ankle, are the tibia, fibula and talus. The medial border of the ankle joint consists of the medial malleolus which is a part of the distal tibia. The lateral border consists of the lateral malleolus which is a part of the distal fibula. Together they make up the ankle mortise, or the talus mortise. The mortise is in rectangular shape and forms like an arch over the talus. The talus is located under the tibia and fibula. (1)

2.1.2. Ligaments

There are several important ligaments in the ankle joints. The medial aspect of the ankle joint is stabilized by the deltoid ligament. It is fan shaped and consists of two parts. The superficial part comprises the tibiocalcaneal band and the deep part consists of the deep anterior talotibial ligament and the deep posterior talotibial ligament. Laterally we have the lateral ligament which is made up of three portions being the anterior talofibular ligament, the calcaneofibular ligament and the posterior talofibular ligament. Two other ligaments, which are not part of the ankle joint, but are important for the stability are the syndesmotic ligament in the syndesmosis of the distal tibia and fibula and the interosseous membrane which spans all space between the tibia and fibula. Although they are not within the ankle joint they provides great stability, because they fixe the tibia to the fibula and thereby provide strength to the tibiofibular part of the joint. All the ligaments that surround the talocrural joint are helping to form the joint capsule. (2)

2.1.3. Tendons

Unlike ligaments, which attach bones to other bones, tendons attach muscles to bones and are an important part of the joint. They both consist of small fibers of a material, which is called collagen. And the strength of a tendon or ligament is determined by its thickness. The muscles and tendons around the ankle joint are important for the functional movement of the joint. The most important tendon in the ankle joint is the Achilles' tendon. It attaches the triceps surae muscle, consisting of the gastrocnemius muscle and the soleus muscles, which are the two calf muscles, to the calcaneal tuberosity. The posterior tibialis tendon runs posteriorly to the medial malleolus and attaches the posterior tibialis muscle to the navicular tuberosity, the medial, intermediate and lateral cuneiforms and into the bases of the second to fourth metatarsals. The anterior tibialis tendon attaches the anterior tibialis muscle to the medial cuneiform, more specifically to the medial and plantar surface of the medial cuneiform and the medial base of the first metatarsal bone of the foot. The two fibularis tendons, the fibularis longus tendon and the fibularis brevis tendon originate from their muscles respectively. They both run behind the lateral malleolus. The fibularis longus tendon then continues under the foot and inserts into the plantar side of the medial cuneiform and the base of the first metatarsal. After the fibularis brevis passes behind the lateral malleolus it passes above the tendon of the fibularis longus and inserts into the tuberosity of the base of the fifth metatarsal bone and sometimes also into the dorsal aponeurosis of the fifth metatarsal bone. (1) (3)

2.1.4. Muscles

The muscles of the ankle joint are like mentioned above the two calf muscles gastrocnemius and soleus muscles. Other muscles are the posterior tibialis muscle, the anterior tibialis muscle, the fibularis longus and brevis muscles. The gastrocnemius and the soleus muscle make up the triceps surae muscle. The gastrocnemius muscle has two heads. The lateral head originates from the lateral femoral epicondyle and the medial head originates from the medial femoral epicondyle and then they both insert into the calcaneal tuberosity via the Achilles' tendon. They are both innervated by the sacral spinal nerves S1 and S2 via the tibial nerve. Theirs action is to plantar flex the talocrural joint as well as flexion of the knee joint. The soleus muscle has its' origin in the head, neck and posterior surface of the proximal fibula and the soleal line of the tibia. It receives its' innervation from the tibial nerve, too and its' action is the same as in the triceps surae muscle. The posterior tibialis muscle originates in the interosseous membrane at the adjacent borders of the fibula and the tibia. It inserts via the tibialis posterior tendon into the navicular tuberosity, the medial, intermediate and lateral cuneiforms and into the bases of the second trough forth metatarsal bones. It is innervated by the lumbar spinal nerves L4 and L5 via the tibial nerve. The main actions of the tibialis posterior muscle are plantar flexion in the talocrural joint, inversion or supination of the subtalar joint and support of the transverse and longitudinal arches of the foot. The tibialis anterior muscle has its' origin in the upper two thirds of the lateral surface of the tibia, the superficial crural fascia and the interosseous membrane. It inserts into the medial and plantar surface pf the medial cuneiform and into the medial base of the first metatarsal bone. The lumbar spinal nerves L4 and L5 innervate the tibialis anterior via the deep fibular nerve. The actions of the tibialis anterior are to dorsiflex the talocrural joint and to inverse or supinate the subtalar joint. The fibularis longus muscle originates in the fibula, to be more precise in the head and the proximal two thirds of its' lateral surface and inserts into the plantar surface of the medial cuneiform and the base of the first metatarsal. The innervation is supplied by the lumbar and sacral spinal nerves L5 and S1 via the superficial fibular nerve and the actions of the fibularis longus muscle are to plantarflex the talocrural joint, to evert or supinate the subtalar joint and to support the transverse arch of the foot. After the fibularis brevis muscle arises in the lateral surface of the distal half of the fibula and the intermuscular septum it inserts into the tuberosity of the base of the fifth metatarsal. The innervation is supplied, like in the fibularis longus muscle, by the lumbar and sacral spinal nerves L5 and S1 via the superficial fibular nerve. It enables the muscle to plantarflex the talocrural joint and to evert or pronate the subtalar joint. (3)

2.1.5. Arteries

Arterial blood is initially comes from the anterior tibial artery, the posterior tibial artery and the fibular artery. The anterior tibial artery supplies the anterior compartment of the leg and the dorsum of the foot with oxygenated blood. After it descends to the foot through the anterior compartment of the leg it becomes the dorsalis pedis artery at the level of the inferior extensor retinaculum. The dorsalis pedis artery then descends anteromedially and passes through the first interosseous space where it divides into the plantar, lateral tarsal and arcuate arteries. Together they supply the dorsal muscles of the foot. It also sends small branches through the first dorsal interosseous muscles, where it becomes the deep plantar artery, which supplies the plantar arch. Additionally, the anterior tibial artery sends a branch, which is called the medial malleolar artery to supply the medial malleolus. The next important artery is the posterior tibial artery. It descends down the leg in the posterior compartment of the leg. At the level of the flexor retinaculum it divides into the medial and lateral plantar arteries. Together those two arteries supply the medial and lateral plantar surface of the foot, respectively, with oxygenated blood. The last important artery is the fibular artery. After it descends through the posterior compartment of the leg it sends branches supplying the posterior part of the lateral malleolus, as well as perforating branches through the distal part of the interosseous membrane between the tibia and fibula into the anterior compartment of the leg. There it becomes the lateral malleolar artery supplying the anterior part of the lateral malleolus. (2) (1)

2.1.6. Veins

The foot receives venous drainage from both superficial and deep veins. The latter usually accompany their respective arteries, which are internal to the deep fascia. Superficial veins do not accompany arteries and run subcutaneously. The main way of venous drainage in the foot is through superficial veins, which receive venous blood from both deep and small superficial veins. In the dorsum of the foot both the dorsal digital veins and the plantar digital veins drain together into the dorsal metatarsal veins, which then become the dorsal venous arch of the foot. This venous arch then drains into the dorsal venous network, which in the end becomes the anterior tibial vein. The anterior tibial vein passes anteriorly to the ankle joint, which it drains, and ascends into the leg. On the plantar side we can differentiate again between deep and superficial veins. The plantar digital veins drain into the plantar venous arch, which drains blood both into the posterior tibial vein and the fibular vein and they run posteriorly to the medial and lateral malleoli, respectively, accompanying their respective arteries. The superficial drainage from the plantar venous network drains by two ways. The first way is, when it drains around the medial border of the foot and together with some of the veins from the dorsal medial arch’s medial border into the medial marginal vein, which then forms the great saphenous vein. It runs superficially in front of the medial malleolus and then ascends into the leg. The second way is when the plantar venous network drains around the lateral part of the foot. There it combines with some of the veins of the lateral portion of the dorsal venous network and together they form the lateral marginal vein, which becomes the small saphenous vein. It then runs superficially in front of the lateral malleolus ascending then into the leg. (1)

2.1.7. Nerves

The nerves running through the ankle and innervating it and the foot are the tibial nerve, common fibular nerve, which consists of the deep and superficial fibular nerves, the sural nerve and the saphenous nerve. The tibial nerve originates from the sciatic nerve. At first it passes the popliteal fossa lying on the popliteus. Then it descends on the tibialis posterior and ends under the flexor retinaculum of the foot, which is a fibrous band that spans from the medial malleolus to the calcaneus and forms together with bony grooves ways for tendons of the flexor muscles, where it divides into medial and lateral plantar nerves. It innervates the posterior muscles of the leg, which are involved in plantarflexion and inversion of the foot. The common fibular nerve is a continuation of the sciatic nerve, too, and is created when the sciatic nerve bifurcates at the apex of the popliteal fossa. After that it passes at the medial aspect of the biceps femoris muscle and continues posteriorly of the head of the fibula. After that it turns around the neck of the fibula and divides into its' two branches deep and superficial fibular nerves. They both form between the neck of the fibula and the fibularis longus. It then penetrates the deep fascia in the distal third of the lower limb, where it becomes subcutaneous. The superficial fibular nerve sends motor innervation to the fibularis longus and brevis muscles, which act to plantarflex the talocrural joint and to evert or pronate the subtalar joint and sensory innervation to the anterior surface of the distal third of the leg and the dorsum of the foot. The deep fibular nerve descends on the interosseous membrane after it goes through the extensor digitorum longus muscle and then traverses the distal portion of the tibia, where it enter the dorsum of the foot. Motor innervation is given to the anterior muscles of the leg and dorsum of the foot and sensory innervation is send to the skin of the 1^{st} interdigital cleft. The saphenous nerve carries only sensory branches, which innervate the skin of the medial aspect of the foot and ankle. It originates from the femoral nerve and makes its' way through the femoral triangle and adductor canal. In the end it descends alongside the great saphenous vein. The last important nerve is the sural nerve, which originates from both the tibial and the common fibular nerves. Before it goes superficially in the middle of the leg it first passes between the heads of the gastrocnemius muscle. Later it descends next to the small saphenous vein and passes to the lateral side of the foot after going under the lateral malleolus. It also only carries sensory fibers which innervate the skin of the lateral areas of the foot and leg and the posterior part of the leg. (1)

2.2. Congruity

There is full congruity in the ankle joint, meaning from full dorsiflexion to full plantar flexion. We can look at the articular surfaces of the tibia and talus as being cones, which have their base laterally. This means that when the ankle moves, it spins around its own lateral base. The lateral malleolus is therefore very important, because it stabilizes the lateral talar base, and enables full movement of the talus.

2.3. Stability

Each ankle joint carries half of a person`s weight and therefore stability is very essential during movements. The main components that make the ankle joint very stable are the bones and the ligaments. Not only the rigidity of the bones makes the ankle joint very stable, but also the form. Proximally the ankle consists of the tibia and fibula, which embrace the talus on the top and on the sides, thus providing stability and limiting movement in those planes. Further stability to the tibia and fibula is provided by their interosseous membrane, the anterior and posterior tibiofibular ligaments and the syndesmotic ligaments. The joint capsule and the medial and lateral collateral ligaments also increase the stability. The medial side of the ankle joint is basically stabilized by medial malleolus and the deltoid ligament. On the lateral part the lateral malleolus and the lateral collateral ligament prevent displacement of the joint laterally and through the lateral collateral ligament it also prevents anterior displacement. Limitations to the inversion of the talocrural joint are provided by the calcaneofibular ligament and prevention of rotatory and posterior subluxation of the talus is provided by the posterior talofibular ligament.

2.4. Epidemiology

Approximately 15% of all injuries of the ankle are ankle fractures. 187 in 100000 persons sustain an ankle fracture per year. Male develop ankle fracture twice as often as females. While the age distribution in males is under 50 years where fractures are most common, this is above 50 years in females. (10)

2.5. Physiology

Even though the distal tibiofibular joint is very stable, there is still some minimal movement during walking. When a person starts to walk force is transmitted from the talus to the lateral malleolus, which after that goes back to the tibia by means of the interosseous membrane. The lateral malleolus thereby carries approximately 15% of the body weight. As mentioned above, ligaments give additional stability during movement of the joint, which is enabled by the muscles of the lower leg.

2.6. Pathoanatomy

We can distinguish between two types of injuries. One is injury of the ligaments and the other of the bones. If one or both of those two components are altered by an injury we would have a resultant instability and disruption of congruity in the ankle joint. If there is only a minimal change in the ankle joint as a result of an injury, this would have great effect on the biomechanics. The lateral malleolus has a great role in the development of incongruity and instability after an injury, because even a small positional change of the fibula could result in a great change of the contact between the articular surfaces of the tibia and talus. For example, if the lateral malleolus was shifted in its' vertical axis by 2°–4°, the talus would be displaced laterally by 2 mm and if the lateral malleolus was displaced posteriorly by 2-3 mm it would mean a 10° shift in the vertical axis of the talus. That means that if the axis of the lateral malleolus is changed in any plane it would have a huge influence on the surface contact in the ankle joint, which would become smaller. As a result, the surface pressure, which is usually evenly distributed over the talus, would be greater, because we would have a smaller contact surface between the tibia and talus. Clinically this means that degenerative changes of the joint would develop much faster. Injury to the medial side is biomechanically not as significant as the lateral side so it will not be mentioned. (2) (4)

2.7. Classification by mechanism of injury

According to Lauge-Hansen we can differentiate between two mechanisms of injury. The first mechanism is by foot supination, where the forefoot is inverted, the hindfoot adducted and the ankle is rotated inward. The second mechanism, which is exactly opposite to the first mechanism, is by foot pronation. Thereby the forefoot is everted, the hindfoot abducted and the ankle rotated outward. Furthermore the position of the foot during the time of the injury is important as well. When the foot is supinated during the injury the medial ligaments are in a relaxed state, which means that the lateral portion of the ankle is damaged first and then the medial one. In opposite, when the foot is pronated at the time of injury the lateral ligaments are relaxed. Therefore the medial portion is injured first and after that the lateral one. (5)

In the supination-adduction injury the lateral ligament can torn and there can also be an avulsion fracture going transversely through the fibula which is located distally to the syndesmosis. Additionally, if the force is strong enough, a medial malleolar vertical fracture can develop with the medial portion of the dome of the talus being subluxated. Sometimes the posterimedial tibia can also be fractured by that mechanism. The dome of the talus is can be damaged in two different ways, which are on its's lateral or medial side. (6)

Eversion-abduction injuries can be further divided into supination-eversion, pronation-abduction and pronation-eversion injuries. In supination-eversion injuries the foot is supinated and externally rotated. The orders by which injuries occur are by 4 steps. At first, the anterior syndesmotic ligament is torn or a Wagstaffe fracture develops, which is an avulsion of the anterior fibula. Then there is a fibular spiral fracture located at the joint or superior to it. After that the anterior tibiofibular ligament ruptures with or without an avulsion fracture at its' insertion. The last step is when the force of the injury reaches the medial portion of the joint, where the deltoid ligament ruptures with or without an avulsion fracture of the medial malleolus. Pronation-abduction injuries consist of three consecutive steps. The first step is a deltoid ligament rupture with or without an avulsion fracture at its' insertion into the medial malleolus. The second step is a syndesmotic ligament rupture with or without an avulsion fracture. The third step is a dome fracture combined with an oblique fibular fracture located at the level of the syndesmosis or above it. The first step of pronation-eversion injuries is the same as in pronation-abduction injuries. In the second step the anterior tibiofibular ligament ruptures with or without avulsions at insertion sites. Then the fibula fractures at the level of the syndesmosis or above it together with the interosseous ligament. At last, the ankle mortise is destabilized by a posterior tibial tubercle fracture or a posterior tibiofibular ligament rupture. (7)

2.8. Evaluation of injury

Before the decision of treatment of an injury the degree and type of damage to the ankle has to be assessed. This is done by both clinical reasoning and by radiological finding. By radiological findings the extent of congruity and stability can be evaluated.

First of all the history of how the injury happened has to be found out, e.g. how the strength of the force that led to the injury. Another factor is if the patient was able to walk after the injury happened, which is a point that influences the decision making in so far, that the patient will most probably not require surgery, because walking is an indication of sufficient stability in the joint. When the patient was injured during an accident involving cars or motor bicycles, it is most probable that the injury is unstable enough to require surgery. In the physical examination the physician has to look for signs of injury, a probable displacement of bones, which is always an indicator of instability, and if there is any instability in the ankle joint. Signs such as ecchymosis, swelling and local tenderness are important indicators of injury. If the patient has only unilateral signs medially or laterally it is most commonly a stable injury, but if signs span over the whole joint it should raise suspicion of an unstable injury. Instability is examined, either when the patient is conscious, or if the patient does not tolerate the pain well under anesthesia. If the talus moves abnormally in the ankle mortise, it leads the physician to the suspicion of an unstable injury. Anteroposterior, lateral and mortise views are the standard, when assessing an injury radiologically by x-ray. The significance of the mortise view is to visualize the inferior tibiofibular syndesmosis and the picture is taken with the ankle joint rotated internally by 15°. Computed tomography (CT) is only used in the assessment of congruity of the distal tibiofibular joint. Magnetic resonance imaging (MRI) is almost never used, because the above mentioned modalities are enough for the assessment of an injury. (2) (8)

2.9. Radiological evaluation

It is important to discuss the varying radiological findings of the different locations of the joint, because they differ in ther presentations.

2.9.1. Medial complex

There are several significant aspects to consider in medial complex injuries, which are fragment size, direction of the fracture, if there is an articular comminution present, how much the fracture is displaced and if there is a posterior fracture present. Inversion injuries cause vertical fractures in which there is a medial tibial articular comminution. Incongruity is always present in laterally displaced injuries. The mortise is almost always unstable, when there are avulsion fractures at or below the level of the joint and if a lateral or posterior injury causes displacement. In medial malleolar fractures without displacement after a lateral injury the joint is usually stable. (2)

2.9.2. Lateral complex

When assessing the lateral complex it is essential visualize the degree of displacement and the shape of the fracture of the fibula. If there is a visible break or displacement of the tibiofobular line, the physician should be alerted. A tear of the syndesmotic ligaments is usually present when there is a lateral displacement or shortening of the lateral malleolus and also when an avulsion fracture of the syndesmotic ligaments is present. On the lateral view shortening and posterior displacement of the fibula can be presented as well as a posterior subluxation of the talus, which can be combined with a tear of the posterior tibiofibular ligament or a fracture of the tibial lip. Another indicator, that is less important, is the location of the fibular fracture, which can be located at or above the syndesmosis. A spiral fracture in the vicinity of the syndesmosis is associated with low-energy rotation injuries and high-energy forces lead to comminuted or oblique fractures. (2)

2.9.3. Posterior tibial process

In posterior tibial process injuries it is important to assess the location of the fracture and the size of it. The posterior tibial fragment of the fracture can be bound to the distal fragment of the same fracture via the posterior syndesmotic ligament. As with many other fractures sizes of the fractured parts in avulsion fractures may vary. It can range from small avulsions of the posterior part of the tibia to big fragments which are triangular in shape in fractures of the Volkmann triangle. The size of the fragment is dependant of the force of the injury. Low-energy forces are usually associated with small avulsion fractures and large fractures are cause by injuries with much higher forces. But the ankle joint can also be unstable even if there is no fracture, as in disruption of the syndesmotic ligaments, because it tears the tibia away from the fibula. (2)

2.10. Classification by AO

The AO classification of ankle fractures categorizes the types of fractures depending on the position on the fibula. There are three main categories, which are type A fractures, which are located below the syndesmotic ligament, type B fractures, which are positioned at the level of the syndesmosis and type C fractures, where the fracture is above the syndesmotic ligament. Those three types are further divided into subtypes.

2.10.1. Type A

As already mentioned, type A fractures are located below the syndesmotic ligament. They are subdivided into A1 and A2 groups. Group A1 injuries consist of isolated lateral fractures which are created by inversion or adduction forces. Those injuries either involve a complete or incomplete tear of the lateral ligament or an avulsion fracture of the fibula. There is no damage to the syndesmotic ligament meaning that the ankle is still stable. Group A2 injuries are caused, the inversion force continues. Thereby the anterior capsule ruptures through which the fibular avulsion fracture can be displaced and the talus can subluxate. If an even stronger inversion force is applied the talus subluxates out of the mortise. This kind of injury is unstable. A medial malleolar vertical fracture happens if an additional axial force acts on the ankle during the inversion injury with concurrent damage to the tibial and medial talar articular cartilages. The last phase is a posteromedial tibial fracture.

2.10.2. Type B

Type B injuries are subdivided into three groups. They consist of a fracture of the fibula at the level of the syndesmosis, with increasing severity of the injury from group to group. Group B1 injuries consist of isolated lateral malleolus fractures. The fracture is still stable even if the syndesmotic ligament ruptures, because the medial complex is undamaged. In B2 injuries both the lateral and medial malleoli are injured. Additionally the anterior syndesmotic ligament is ruptured meaning that the ankle mortise is highly unstable. B3 injuries are characterized by the trias of medial, lateral and posterior damage. Both the tibia and the fibula are fracture and there is a rupture of the posterior syndesmotic ligament, which is important for stability. This means that the injuries in this group cause a great instability.

2.10.3. Type C

Type C injuries are fractures of the fibula located anywhere above the syndesmosis. They can be both stable and unstable and can be divided into three subtypes. C1 injuries are simple fracture of the fibula, which can be spiral or oblique with or without medial injury. C2 type injuries are characterized by comminuted fractures of the fibula, and medial or posterior injuries can also be present. C3 injuries consist of injuries to the proximal fibula, such as a fracture or a dislocation. There can also be a concurrent injury to the medial and posterior portion.

2.10.4. Isolated fracture of the medial malleolus

When comparing this injury with the Lauge-Hansen classification, we can say that the isolated fracture of the medial malleolus is the same as the first stage of the Lauge-Hansen Classification. This means that there is only an avulsion fracture of the medial malleolus with damage to the deltoid ligament. The ankle can be considered as stable, but incongruous.

2.11. Comparison between the Lauge-Hansen classification and the AO classification

The main goal of the classification system in general is to guide the physician about how to treat the injuries of patients and to be able to predict which consequences injuries could have. There is not a perfect classification system, because no injury is the same, but classifications can at least put some of the similar appearing injuries into groups. Considering the Lauge-Hansen classification it is important to mention, that it only describes the mechanism of injury, but it does not really help in the decision on how to treat the injuries, which is not useful in everyday clinical practice. It also does not cover unusual fracture patterns, because it only describes some of the possible outcomes after an injury. This is a great disadvantage, because there are a lot of possible variations of injuries. An advantage of this classification is that it signifies the important relationship between injuries of the ligaments and the resulting stability or instability of the joint. It also shows the sequence at which the injuries occurred.

The AO classification of ankle fractures on the other hand categorizes ankle fractures depending on the position of the fracture on the fibula. A problem in this classification is, that it describes, that fibular fractures, which are more proximal also cause more instability in the ankle joint and have a worse outcome than the others, which is not always true. A advantage of the AO classification is that it is much broader than the Lauge-Hansen classification.

The similarities of both classifications are that they present the order of how the injury happened and they both stress the impact of injury of ligaments which cause instability. A problem of both is that they do not predict the treatment for all fractures, but in the end for both classifications similar treatments are used, such as open or closed treatment.

2.12. Treatment

Two kinds of treatment apply for injuries to the ankle, which are casting to stabilize the foot until the fractures have healed and surgery. Treatment options obviously vary from fractures type to fracture type and therefore the different types of fractures by the AO classification will be discussed.

2.12.1. Type A

Type A injuries are avulsion fractures of the fibula. The ankle is most commonly stable because the medial complex is not damaged. The treatment depends on displacement or non-displacement of the fracture and if there is damage to the medial complex. If the avulsion fracture is not displaced and the medial complex is not injured, then a walking cast is used for 6-8 weeks so that the fibula has time to heal. Indications for a surgical procedure are when the fracture is not stable, when closed reduction does not resolve the displacement and when the soft tissues are greatly damaged. Another factor is when the medial malleolus is fracture and displaced. The last indicator for surgery is a medial osteochondral fracture.

2.12.2. Types B and C

Both types are described in this paragraph because the management is more or less the same. If instability is still assumed, which was not confirmed radiologically, the patient must be examined. This is done under anesthesia. By that the ankle is moved to see if there is any instability and then additional radiological images are done. Stable ankles without or with small displacement are treated non-operatively, usually with a below the knee walking cast until the fracture has healed. Types B1 and C1 fall under this category. When the injury involves the other two types of B and most of the C types the approach is different. Ecchymoses, swelling and tenderness which involve the whole joint leads to the suspicion of joint instability, as well as radiological results. The treatment option for those unstable fractures is mostly by surgery in order to prevent incongruity and malunion. If the injury involves a medial malleolar fracture it is an imperative to surgically treat the injury otherwise the fracture will not heal properly. If the medial malleolus is not fractured but the deltoid ligament is ruptured, the approach is similar, because it also causes ankle mortise insufficiency.

2.12.3. Isolated malleolar fracture

Isolated malleolar fractures are treated conservatively, if there is no displacement of the avulsion fracture, but displaced fractures should be treated surgically.

2.13. Surgery

All fracture types that require surgery should be treated as soon as possible, but there are reasons, which influence the decision on when a surgery will be performed. If a patient has an acute skin condition involving the ankle, the surgery should be performed after the resolution of the skin condition, because otherwise the skin could become necrotic afterwards. Another factor is the general status of a patient. The patient should be stable and the patients' chronic diseases should be monitored, e.g. when dealing with patients with diabetes an endocrinologist should be asked for advice, because diabetes could influence the healing process.

As in the other limbs surgeries a tourniquet should be applied before the surgery begins in order to decrease the loss of blood.

2.13.1. Incisions

An anterolateral incision is used to expose the lateral malleolus. It is favored because the skin behind the fibula is much thinner than on the anterior aspect. The thin skin can lead to skin necrosis much more easily. Additionally an incision must not be positioned on the skin and subcutaneous tissue exactly over the bone, because if necrosis occurs there would not be any skin left to cover the implant. In anterolateral incisions it is important to recognize and prevent damage to the superficial peroneal nerve as it is in close vicinity to the incision.

When performing a surgery on the medial malleolus a medial incision is performed. In the case that the surgeon wants to expose a vertical fracture an anteromedial incision is used. The skin on the medial side is also very thin, but there are fewer problems involved in healing due to the posterior tibial artery, which supplies a sufficient amount of blood. In medial incisions the saphenous nerve must be identified to prevent injury during the procedure. For avulsion fracture only small incisions are performed anteromedially. A posteromedial incision is used for medial malleolus fractures which are combined with a posteromedial fracture.

Posterolateral incisions are performed when dealing with a fibular fracture which is associated with a big posterolateral fragment.

2.13.2. Open Reduction and Internal Fixation

Open Reduction and Internal Fixation is a surgical procedure in which the affected fractured bone is exposed. After it a displaced fracture is reduced to its' original anatomical position screws and plates are applied to fix the bone.

2.13.2.1. Type A injuries

In type A fractures both the medial and the lateral complex can be fractured. When the lateral complex injury is an avulsion fracture the methods of choice are a tension band wire or a screw, because they will assure static compression. A tension band is usually used in osteoporotic bones or when the fracture consists of small fragments. Small osteochondral fragments should be removed and large osteochondral fragments are to be replaced and repaired with articular pins, when dealing with lateral talar dome fractures.

Medial complex injuries, if they are simple, are repaired by screw fixation. Two or more malleolar screws are used for that or cancellous lag screws. In the case of tibial articular crush injuries a bone graft should be placed above it to repair the articular surface and if there are small fragments, they should be removed. The same procedure is used in the treatment of a crushed medial talar dome. Comminuted vertical fractures of the tibia are fixed by a buttress plate. Multiple Kirschner wires are used for bone fragments which are too small to be fixated by screws.

2.13.2.2. Types B and C

The first step in the surgical procedure of treating type B and C lateral complex injuries is the anatomical reduction of the fibula because the length of the fibula has to be reconstructed. This is done by ORIF. Transverse fractures of the diaphysis of the tibia are repaired by a tension band plate and a neutralization plate and interfragmental screws are used to treat spiral and comminuted fractures. Metaphyseal fibular fractures are most commonly comminuted or spiral fractures. Those fractures are either fixed by Kirschner wires or by interfragmental compression, which is done by putting a neutralization plate posteriorly or posterolaterally, which is then fixed by lag screws.

After the restoration of the fibular length the surgeon turns his attention to posterior malleolar avulsion fractures. Small avulsion fractures do not require surgical treatment, but large ones do. If the fragments of the avulsion fracture are greater than 33% of the articular surface, then surgical correction is indicated. (9) In thick fragments of posterior fractures a retrograde cancellous screw is used. It is screwed in from the anterior surface of the tibia to the posterior fragment of the malleolus. In thin fragments of the fracture the screw is inserted posterolaterally.

After the steps mentioned above the surgeon should inspect the syndesmosis. The distal tibiofibular joint should be in its' anatomical position after the other fractures and injuries have been dealt with. If there are any large avulsion fractures in the distal tibiofibular joint, they must be repaired by screws. A syndesmotic screw is placed above the distal tibiofibular joint, if the interosseous membrane and anterior and posterior ligaments are torn. The screw has to be removed after 6 to 8 weeks though.

In fractures of the medial complex the tool of choice are Kirschner wires. The medial ligaments are not usually repaired. Avulsion fractures of the medial malleolus are treated with Kirschner wires in the case of a small fragment and for large particles are a malleolar screw is used.

2.13.3. Closure of the wound

Before the wound of the surgery is sutured, the surgeon will decide if a suction drain should be placed and the decision depends on the amount of bleeding after the procedure. For that an active drain is most commonly used. The suction drain consists of a bottle in which there is negative pressure and a rubber tube. On one end of the rubber tube is a sharp metallic needle, which is inserted from inside the wound to the outside where it penetrates the skin in order to drain the surgical wound after primary closure, and on the other end of the rubber tube are tiny holes, which serve as means of fluid drainage from the wound. After placement of the rubber tube the sharp metallic needle is removed and the negative pressure bottle is attached to the rubber tube to allow drainage. The advantages of active drains are that blood pools, pockets of air and dead space from the wound are removed. By this the risk of infection and inflammatory process is reduced. Also very important is that the pain levels are lowered, because there is less swelling which could compress nerves. The prevention of swelling also improves the healing process, because blood vessels are not compressed by the swelling and hematoma formation. There is reduced formation of ecchymosis, contraction of tissues, scar and adhesion development.

After the placement of the suction drain the wound is sutured by primary closure. The first step is to place absorbable sutures subcutaneously, which brings the soft tissues together. After that non-absorbable sutures are used to suture the skin, which are removed later on. The surgical wound should not be sutured too tightly medially or laterally, because it could lead to compression of the ankle due to the combined effect of the tightness of the suturing and the swelling after the procedure.

2.14. Postoperative management

Immediately after the surgery is performed a splint should be applied to stabilize the ankle at a right angle, because otherwise an equinus deformity will develop. The leg should also be elevated to decrease edema formation. The splint can be removed approximately on the fourth day to allow the patient to exercise, but it has to be applied again after the exercise.

Early motion can be begun when the surgeon decides that the implants for internal fixation are stable. This is usually after 4 to 6 weeks and includes only partial weight-bearing. Full weight-bearing can be started by twelfth week, meaning that the patient is healed.

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5. Biography

Dinko Šalinović was born on 06.12.1988 in Zagreb, Croatia. He spent his whole life in Munich, Germany, where he first went to the Fromund Schule primary school and after that he attended the Teodolindengymnasium high school. He enrolled in the University of Zagreb Medical school in the academic year 2010/11.

It was his lifelong dream to become a doctor and to help people in their most difficult times of their lifes.

Now finally in 2016 his dream to become a medical doctor will come true and he will do his best in his future carreer.