Posttraumatic ankle osteoarthritis: How initial cartilage lesions, the deltoid ligament and hindfoot alignment affect the outcome of operatively treated ankle fractures
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CHAPTER 1

GENERAL INTRODUCTION
Problem statement and aim of this thesis

The quality of the reduction of intra-articular fractures is of paramount importance for a satisfactory outcome in all joints. According to the most important aspect of conservative or surgical treatment of ankle fractures, is achieving anatomical reduction, thereby restoring the congruity of the mortise. Malunion increases the chance of development of early degenerative joint disease. Other factors that have been recognized to play a role are: ligamentous instability, age, fracture luxation or fracture dislocations, the size of the posterior malleolar fragment and systemic factors that affect bone healing. Not yet fully recognized is the possibly adverse effect of intra-articular cartilage lesions that are often seen after ankle fractures. The vast majority (70-78%) of ankle osteoarthritis is of posttraumatic origin. Among other questions, it remains to be answered, why a significant part of the operative-anatomically reduced ankle fractures still result in posttraumatic osteoarthritis. In this thesis we address the role of the intra-articular cartilage lesions, the role of the deltoid ligament and the role of the alignment of the hindfoot.

Ankle anatomy

The osteology of the ankle joint comprises three bones and three articulars. The tibia and fibula both articulate at their distal ends with the talus. This is the true ankle articulation (Figure 1). The fibula is in contact with the tibia only at a tiny surface extending from the articular surface of the lateral malleolus, and includes a synovial recess of 1cm. This tibio-fibular connection is known as the syndesmosis. The distal part of the fibula is known as the lateral malleolus and extents 1cm more distal than the medial malleolus. The medial malleolus is an apophysis of the distal tibia and consists of two colliculi separated by a groove. The ventral colliculus extents 0.5cm farther than the posterior colliculus. A prominence of the distal tibia on the dorsal aspect is known as the posterior malleolus. The tibia and fibula are tightly bound together thus constituting a ‘fork’: the medial malleolus, tibial plafond and lateral malleolus cover the talus on three sides. The term ankle ‘mortise’
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Figure 1: the bones of the ankle joint seen from ventralateral (left) and posteromedial (right). Images modified from www.anatomy.tv (Primal Pictures Ltd 2013).

Figure 2: the ligamentous structures around the ankle seen from lateral on the left and from medial on the right. In the left image the ligaments are numbered 1) anterior syndesmotic ligament, 2) anterior talofibular ligament, 3) calcaneofibular ligament, 4) lateral talocalcaneal ligament. In the right image the ligaments are numbered 1) anterior tibiotalar ligament, 2) tibionavicular ligament, 3) spring ligament, 4) tibiocalcaneal ligament, 5) posterior tibiotalar ligament. Images modified from www.anatomy.tv (Primal Pictures Ltd 2013)
or ‘mortice’ is therefore not exactly correct. In woodworking terminology, ‘bridle’ joint would be more synonymous. The talus is an intercalated bone with no tendons attached, but firmly bound by ligaments to the tibia, fibula and calcaneus (Figure 2). The talar dome is cylindrical with the convexity in the antero-posterior direction. More accurately, the trochlea is the frustum of a cone with the apex on the medial side. The movement of the talus within the malleoli is hinge-like, permitting rotatory movements in the sagittal plane with, on average 20° of dorsiflexion and 50° of plantarflexion. The talar trochlea is wider anteriorly than posteriorly, giving it a wedge shaped appearance in the transverse plane. 19

On the medial side the deltoid ligament connects the tibia firmly to the posteromedial talus with deep fibres. With superficial fibers the tibia is connected to the navicular bone, the spring ligament and to the calcaneus. 20 The strongest portion of the deltoid ligament are the deep fibers, strictly holding the tibia on top of the talus, allowing a minimum of relative movement. 21 The tibia and fibula are bound together by three structures, from ventral to dorsal: the anterior tibiofibular ligament, the interosseous membrane, and the posterior tibiofibular ligament, together the syndesmotic complex. The posterior syndesmotic ligament consists of two layers, the superior band and the deep band, also named transverse ligament. This component is very strong and thick, acting as a posterior labrum. 18 On the lateral side, the fibula is attached to the talus by the anterior and posterior talofibular ligaments and to the calcaneus by the calcaneofibular ligament.

Ankle fractures

Sir Percivall Pott (Figure 3) wrote in 1768: “... the fibula breaks in the weak part already mentioned, that is within two or three inches of its lower extremity. When this happens, the inferior fractured end of the fibula falls inward toward the tibia, that extremity of the bone which forms the outer ankle is turned somewhat outward and upward, and the tibia having lost its proper support, and not being of itself capable of steadily preserving its true perpendicular bearing, is forced off from the astralagus * inwards, by which means

* Astralagus is the old anatomic name for the talus
the weak bursal, or common ligament of the joint is violently stretched, if not
torn, and the strong ones, which fasten the tibia to the astralagus and os calcis,
are always lacerated, thus producing at the same time a perfect fracture and
a partial dislocation, to which is sometimes added a wound in the integu-
ments, † made by the bone at the inner ankle.” 22 This is one of the first injury
pattern descriptions of the ankle in Western literature. It is this early de-
scription that preserves the eponym of Pott’s fracture for ankle fractures. The
French usually prefer their own eponyms, and in this case it is quite justified.
In France, ankle fractures are referred to as “Dupuytren” and “Maisonneuve”
fractures, the former is located distally, the latter is located in the proximal
fibula. Guillaume Dupuytren (Figure 3) was among the first to use cadaver
experiments to produce ankle fractures by outward movement of the foot. 23
Jules Germain Maisonneuve (Figure 3) was the first to recognize the impor-
tance of external rotation as common fracture mechanism. He also recognized
the ligamentous lesions that accompany ankle fractures and described the

* Os calcis is the old anatomic name for the calcaneus
† Integuments are the soft layers covering the joint, i.e. the capsule and skin
high fibular fracture that bears his name. Dupuytren was the greater surgeon, but Maisonneuve truly understood the pathogenesis of ankle fractures. Many different fractures around the ankle exist, but only a specific sort of fractures is called ankle fracture. Tibial plafond fractures caused by a hammering (“pilon” in French) of the talus by axial force, are not ankle fractures. Talus fractures are also not considered ankle fractures. Ankle fractures are fractures of either the lateral, the medial or the posterior malleolus, or combinations thereof, caused by rotation, abduction or adduction of the talus. As Maisonneuve described, next to interruption of bony continuity, ruptured ligaments around the ankle contribute to instability of the joint and need to be recognized. On the medial side, a ruptured deltoid ligament is the equivalent of a medial malleolus fracture. A lateral malleolus fracture is commonly an oblique fracture, between the anterior and posterior tibiofibular ligaments. However, together with a lateral malleolus fracture, the syndesmotic ligaments may also rupture. Most often the anterior tibiofibular ligament yields first in case of external rotation. If the posterior tibiofibular ligament ruptures, there is a marked instability, allowing diastasis between the tibia and fibula. However, the posterior ligament is strong, resulting in avulsion of the posterior malleolus in most cases.

Ankle fracture classifications

Among some residual archaic eponymic designations for ankle fractures, today two classification systems are commonly used: the Lauge-Hansen system (Fig 4), commonly perceived as difficult, and the Weber system (Fig 5), perceived as easy. The Weber system has been incorporated in the AO nomenclature (Fig 6). The Belgian surgeon Robert Danis (1949) and subsequently the Swiss surgeon Bernhard Georg Weber (1972) classified ankle fractures by the radiographic anatomical features. More specifically, they described the level of the fracture from the distal tip in its relationship to the syndesmosis. Weber type A fractures are below the syndesmosis. They correspond to the Lauge-Hansen supination-adduction fractures. Type B fractures are at the level of the syndesmosis. They correspond to the Lauge-Hansen supi-
Figure 4: The Lauge-Hansen ankle classification consists of two terms, one to describe the position of the foot - in supination or in pronation - and another to describe the movement of the talus in the mortise - abduction, adduction or external rotation - plus stages 1 to 4 to indicate the different structures that fracture or rupture. Images modified from www.radiologyassistant.nl (original by Robin Smithuis).

Figure 6: The Weber classification consists of three types of ankle fractures. Weber A is an infrasyndesmotic fibular fracture. Weber B is an transsyndesmotic fibula fracture. Weber C is a suprasyndesmotic fibula fracture. The medial and posterior injuries have to be separately mentioned. Images modified from www.radiologyassistant.nl (original by Robin Smithuis).
Type C fractures are above the syndesmosis. They include Lauge-Hansen pronation-external rotation and pronation-abduction fractures. The AO group used the Weber system as the basis of a comprehensive fracture classification, consisting of groups and subgroups to include 27 fracture types. An alternative is to describe ankle fractures on the basis of the number of malleoli fractured. Although this excludes useful information, it has been shown to be of prognostic value. The Lauge-Hansen system has been reported to have a poor interobserver reliability, because of its limitation as a predictor of soft-tissue damage associated with ankle fractures, and leaving too many fractures unclassifiable.
Ankle fracture treatment

The most important Dutch contribution to fracture treatment, around 1850, has probably been the invention of the plaster cast on a roll. Operative treatment only matured at the turn of the 19th century thanks to radiography, antiseptic wound treatment and the development of anesthesia. In the first half of the 20th century, many complications frequently associated with peri-articular fractures could still not be prevented. It was the Arbeitsgemeinschaft für Osteosynthesefragen, founded in 1958, that have changed the entire approach of fracture treatment. Uniform fracture registration and teaching of principles like anatomical reduction, stable internal fixation and early mobilization of joints, have had a great influence on treatment regimens worldwide.

In the early years of ankle fracture surgery, the medial malleolus was considered the main column of the ankle mortise. Hence, displaced bimalleolar fractures were treated by open reduction and fixation of the medial malleous in conjunction with closed reduction of the fibular fracture. In 1977 Yablon published a widely quoted paper in which was stated that the talus ‘follows’ the fibula in ankle fractures, pointing towards the lateral malleolus as the key to ankle stability. Recently the tide has turned again, as the medial malleolus has regained its popularity as the most important structure to assure mortise congruity and stability after anatomical reduction and fixation.

The conservative treatment of closed, stable, non-displaced ankle fractures, and of some minimally displaced fractures has proven to be successful. The current indications for operative treatment of ankle fractures are: open fractures, fracture displacement of more than 2mm, lateral malleolar shortening by more than 2mm or rotation by over 5 degrees, any lateral talar shift, bimalleolar and trimalleolar fractures, syndesmotic disruption, and instability based on stress views. Open anatomical reduction and internal fixation with lag screws and a plate on the fibula and screws on the medial side, is generally considered the treatment of choice for most fractures. In some cases additional reduction and fixation of a posterior malleolus fragment is necessary, as is the placement of a syndesmotic screw.
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Results of ankle fracture treatment

Conservative treatment of apparently stable ankle fractures leads to good clinical and radiological results in 95% of the cases. The failures may have been caused by missed unstable fractures. This is not fully understood. Alternatively, the cartilage lesions occurring together with ankle fractures may cause these failures. Open treatment, leading to better results for unstable fractures, comes with the price of surgical complications. However the reported complication rates are relatively low: 0.34% pulmonary embolisms, 1.44% wound infections, 0.82% revision surgery and 0.96% need for fusion or prosthesis within five years. Approximately 80-90% of the operatively treated patients have excellent short-term results. However at 10 years follow-up or longer, some report only 52% good-to-excellent results. Because of the widely held assumption - that the quality of the fracture reduction is of paramount importance for a satisfactory long-term outcome - the question remains, why a significant part of the operatively anatomically reduced fractures still result in posttraumatic osteoarthritis. Radiographic changes are common after 10 years in about 70-75% of the cases. In general, posttraumatic arthritis is reported to occur in 14% to 50% of all operatively treated ankle fractures. In ankle fracture treatment, the role of the intra-articular cartilage lesions that are often seen after ankle fractures, the role of the deltoid ligament, and the role of coronal plane alignment of the hindfoot are unknown.

Outline of this thesis

In order to quantify the existing knowledge about the influence of cartilage lesions, the deltoid ligament ruptures and hindfoot alignment on the long-term outcome after operatively treated ankle fractures, a systematic literature review was undertaken, of which the results are presented in chapter 2. Because of the lack of information on the role of accompanying initial cartilage lesions after ankle fractures, a cross-sectional long-term follow up study of operatively treated ankle fractures, in which the cartilage lesions have been described at the time of fracture management, was performed. The results are presented in chapter 3. Unknown is the exact role deltoid ligament ruptures
play in ankle fractures. Instability of the mortise occurs when the deltoid ruptures together with a lateral malleolus fracture. How to best diagnose a deltoid ligament rupture and whether to address the ligament with open suturing is not established yet. Chapter 4 consists of a narrative review of the diagnosis and treatment of deltoid ligament lesions that accompany ankle fractures. How the ruptured deltoid ligament effects the long-term outcome of ankle fracture treatment has not been clarified yet. In chapter 5 we present the results of a long-term follow up study of ankle fractures with a deltoid ligament lesion. Chapter 6, 7 and 8 are devoted to malalignment of the ankle in the coronal plane. The measurements in the coronal plane are dependent on image properties and observer reliability. In the literature a wide variation of nomenclature, measurement methods and normal ranges can be found. In chapter 6 a radiologic study is presented in which we point to the importance of whole lower leg images when measuring the varus or valgus of the distal tibia. Additionally a standardized measurement method is described as are the inter- and intra observer reliabilities. The influence of alignment of the distal tibia in the coronal plane on the ankle joint and congruency has not been studied yet. Hypothetically the ankle joint is influenced by varus and valgus malunions after fracture. In chapter 7 and 8 the results are presented of a biomechanical study, in which the tibio-talar pressures are measured after creating varus and valgus malalignment in the distal tibia and fibula.

References

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