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Review Article

Surgical Management of Calcaneal Malunion
跟骨骨折畸形癒合的手術治療

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ABSTRACT

Calcaneal malunion is a common complication after conservative treatment or incorrect surgical treatment of calcaneal fracture. The typical pathoanatomies of calcaneal malunion are subtalar joint incongruity, loss of calcaneal height, arch collapse, varus or valgus deformity of the calcaneus, heel widening and so on. Calcaneal malunion often needs to be treated surgically. The classification of calcaneal malunion and the detailed clinical and radiographical assessment play important roles for surgical option. The main surgical methods include *in situ* subtalar arthrodesis, reconstruction of calcaneal thalamus and subtalar arthrodesis, calcaneal osteotomy with subtalar arthrodesis, corrective calcaneal osteotomy without subtalar arthrodesis. Each option has its different indications, advantages and disadvantages. Thus, the surgical treatment should be individualised.

中 文 摘 要

跟骨骨折畸形癒合是跟骨骨折保守治療或不正確的手術治療之後常見的併發症。常會出現距下關節面不平整，跟骨高度丟失，足弓塌陷，跟骨內外翻，跟骨增寬等典型的病理變化。跟骨骨折畸形癒合往往需要手術治療，畸形癒合的分型和詳細的臨床及影像學評估,在手術方法的選擇上起著重要作用。常見的手术方法主要有距下關節原位融合術，跟骨丘部重建距下關節融合術，跟骨截骨矯形距下關節融合術，保留距下關節的截骨矯形術等。它們各自具有不同的手術適應征及優缺點，需要根據患者的情況進行個體化選擇。

Introduction

The uncertain operative results for severely displaced calcaneal fractures and the complications of nonoperative management are the key reasons why calcaneal malunion develops. Once a severe calcaneal malunion causes the disorder of the motion axis from hindfoot to the whole lower limb, this will result in an abnormal gait with symptoms and dysfunction of the joints and muscles, eventually leading to pain and permanent disability.[1] Thus, calcaneal malunion may be life-altering to patients, not only because it imposes a great symptomatic effect but also because it carries a huge economic burden. Once calcaneal malunion occurs, surgery is always needed to prevent the vicious cycle of pathological changes and to preserve the hindfoot function as far as possible. However, both surgeons and patients should be aware that although surgeries may result in a more functional foot, there is still a considerable amount of disability as indicated by lower functional scores on the 36-Item Short Form Health Survey (SF-36) and American Orthopaedic Foot and Ankle Society hindfoot surveys.[1]

Pathoanatomy and Biomechanics of Calcaneal Malunion

The pathoanatomy of calcaneal malunion can be highly variable and will not only affect the biomechanics and function of the surrounding joints and soft tissues but also the alignment from lower limb to lower lumbar and may even cause neck and head pain. A comprehensive understanding of the pathoanatomic and biomechanical changes of calcaneal malunion will allow the surgeon to formulate the operative treatment. The main pathoanatomy changes can be summarised as follows.

An incongruous facet is known to be a direct cause of arthritis of the subtalar joint by the significant effect on pressure distribution upon load-bearing. The incongruity of the calcaneal facet with abnormal biomechanics will affect the function of ankle joint and transverse tarsal joint in the long term. Hence, anatomic reduction is pursued and displacement greater than 1 mm in calcaneal malunion should be treated surgically.

The decreased height of the calcaneus has significant ramifications since it flattens the talar inclination angle and diminishes the lever arm function of the Achilles tendon, which will decrease the strength of triceps surae muscle and reduce the push-off power

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during gait.[2] The loss of talar inclination assumes the talus in a more horizontal, dorsiflexed position that may result in painful anterior impingement of the talar neck on the anterior tibial plafond and cause a rigid subtalar joint. With a rigid subtalar joint, more load is brought to the lateral column and leads to increased pressure on the lateral mid- and forefoot with lateral shift of the gait line.[3]

Traumatic flatfoot deformity can often be seen in calcaneal malunion, which is essentially caused by traumatic arch collapse without soft tissue factors. However, the long-term deformity will cause the contracture of gastrocnemius muscle and the shortening of Achilles tendon. Thus, the soft tissue balance should not be neglected during correction of the calcaneal deformity. The severe traumatic arch collapse will also oppress the plantar structures and cause an abnormal plantar pressure. We analysed the plantar pressure in 26 cases of calcaneal malunion and found that plantar pressure would be partly transferred from hindfoot to forefoot in calcaneal malunion patients, leading to abnormal gait and ulcers.[4]

A malunited calcaneal fracture with superior translation of the calcaneal tuberosity can also result in calcaneal varus, which will partly transfer the weight-bearing to the lateral side of the foot, significantly altering the hindfoot biomechanics. If severe varus hindfoot persists for a long time, the foot may lose its natural shock-absorbing ability through eversion of the heel in early stance phase and increase the risk of injuries.[5] Calcaneal valgus deformity and heel widening are two other features because of the lateral wall exostosis formed by the united lateral wall blow-out and superolateral translation. The exostosis can cause calcaneofibular impingement, pseudoarticulation formation and peroneal tendinosis, which will change the alignment and weaken the muscle strength of the lower limb.

A fixed cavovarus deformity is rare in calcaneal malunion, which may occur by the contracture and scarring of the posterior tibialis muscle, flexor hallucis longus (FHL) and flexor digitorum longus because of the compartment syndrome misdiagnosed in an acute injury.[6]

The Classification of Calcaneal Malunion

Nowadays, the widespread acknowledged classifications of calcaneal malunion are the Stephens and Sanders classification system and the Zwipp and Rammelt classification system. They are of great help in determining the appropriate treatment.

The Stephens and Sanders classification system is based on coronal computed tomography at the level of the posterior facet and divided into three types. Type I is characterised as a lateral wall exostosis with normal hindfoot alignment. Type II exhibits a lateral wall exostosis, subtalar arthritis and hindfoot malalignment of less than 10°. Type III malunion may have more extensive and severe subtalar arthritis than Type II with greater than 10° of hindfoot malalignment, which can result in an angular deformity caused by hindfoot varus or valgus (Figure 1).[7] However, this system is based solely on coronal CT images, and it cannot demonstrate hindfoot height or talar inclination. Moreover, we noticed that it was difficult to determine the extent of cartilage damage and preoperative plan by this classification to calcaneal malunion within 1 year after injury because the development of severe subtalar arthritis depended on not only the extent of cartilage damage but also on the duration and degree of weight-bearing after injury.[8]

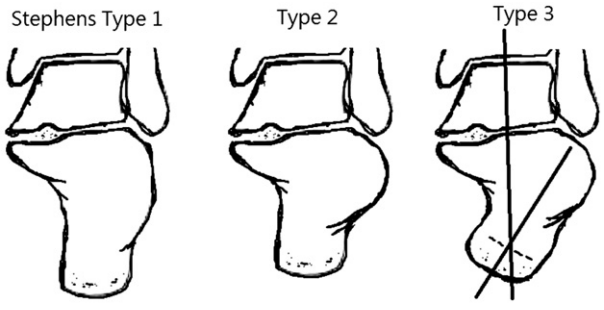

Figure 1. The Stephens and Sanders classification system of calcaneal malunion.

The Zwipp and Rammelt classification system includes five types. Type I is characterised as subtalar incongruence with arthritis but normal calcaneal shape. Type II exhibits the heel varus or valgus. Type III is loss of hindfoot height and Type IV is characterised as translation of calcaneal tuberosity without varus or valgus. In Type V, the talar tilt or dorsiflexion past neutral is the main feature.[9] This classification emphasises the potential issues that may exist after a traumatic injury, which has great significance in selecting the appropriate treatment methods.[8] However, calcaneal malunion with normal subtalar joint is not involved in this classification.

Clinical and Radiographic Evaluation

Detailed clinical evaluation of the malunion can provide important information for the surgeons to formulate the treatment plan. The chief complaint of pain is always the main reason for a patient to seek medical help. It may be challenging to identify the causes of the pain. Pain in the anterior ankle is commonly caused by impingement of the anterior ankle. Patients may have difficulty in dorsiflexion of the ankle, and forced ankle dorsiflexion may reproduce the pain. Plantar pain is mainly due to the traumatic arch collapse that oppresses the plantar structures or plantar exostosis from the malunited calcaneus. In the long term, the heel pad may be atrophic. Pain in the medial heel may be the consequence of tibia nerve or FHL tendon problems. Tinel's sign may be noted in tibial nerve problems and in patients with FHL tendon problems, and pain may be reproduced by passive motion of the hallux. Pain in the lateral heel is mainly due to subtalar arthritis, calcaneofibular impingement or peroneal tendinosis.[5] Symptomatic subtalar arthritis will limit the hindfoot inversion and eversion; thus, the patients may find it difficult to walking on uneven ground. The pain caused by calcaneofibular impingement is secondary to the lateral wall exostosis. The patients may complain of difficulty in shoe wearing as heel widening. In peroneal tendinosis patients, the palpation along the course of the peroneal tendons may reproduce the symptoms. The malunion of depressed calcaneal fracture can also result in posterior ankle impingement pain. It is mainly caused by the posterior calcaneal bone spike formed just behind the posterior facet, which may be aggravated by forced ankle plantarflexion.[10] The tarsal tunnel syndrome caused by calcaneal malunion, however, is rare. Manasseh et al[11] reported a case of tarsal tunnel syndrome caused by a small fragment just under the nerve in the tarsal tunnel causing pain, tingling and sensory hypoaesthesia along the branches of the posterior tibial nerve. Thus, in calcaneal malunion, the fragments under tarsal tunnel require special attention.

On physical examination, the hindfoot alignment should be compared with the normal contralateral side. The calcaneal varus is the most commonly encountered deformity. However, the true position of the calcaneal tuberosity may be masked in the presence of hindfoot oedema or heel widening as it may appear rectus but actually remains in varus when evaluated radiographically.[12] Moreover, care should be taken when dealing with hindfoot varus caused by forefoot deformity, and Coleman block test can distinguish them.[13] Changes in alignment may be more apparent on walking, and gait analysis should also be also performed. The