Circular arc nailing for stable fixation of hindfoot fusions

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Extended Article

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Abstract

In stance, the human body's centre of gravity is retained perpendicularly within the contact area of the feet with the ground. This surface forms a so-called "supporting polygon". Compared to other species within the mammals, due to bipedalism, this polygon is very small. The smaller the polygon, the more critical is the equilibrium in statics, walking and running. It thus appears evident that the osteo-articular axes of the foot must respond to a very precise alignment in relation to the centre of gravity of the body to not falling out of equilibrium. Stability of stance is active, by means that multiple bones and adaptive joints are powered by 10 extrinsic muscles which adapt constantly a precarious mechanical construct.

In case of fusing joints, the muscular and articular mechanism does not fully work anymore and the mentioned "active stabilization" gets cut-off. Eventual osteo-articular malalignment of e.g. fused hindfoot may then cause instability, disability and pain. The key to avoid such disability goes through minute operative alignment of the critical joints to be fused. If painful articular destruction involves both the upper ankle and the subtalar joint, the hindfoot must be placed in a very precise position beneath the tibia allowing for uneventful function of the midtarsal and forefoot joints. This includes a perfect plantar foot in relation to the axis of the lower leg and a slight external rotationallowing for rolling over the medial edge of the foot during walking.

Considering the exact anatomy of the weight-bearing hindfoot it appears that the trans-articular bony alignment of the heel to the distal tibia follows an arc: the posterior facet of the subtalar joint is located posterior and lateral to the tibio-talar facet of the upper ankle joint. The calcaneal tuberosity which is the fulcrum of heel strike is located posterior and lateral to the posterior facet of the subtalar joint.The bone trabeculae within the calcaneus, the talus and the distal tibia demonstrate and witness the orientation of physiological stress by means of a circular arc. It then appears opportune to fix e.g.tibio-talo-calcaneal arthrodesis in respect to the particular osteo-articular orientation of the hindfoot.

A novel circular shaped nail had been designed to fix anatomically tibio-talo-calcaneal arthrodesis. Following the aforementioned considerations of statics and anatomy, this fixation means follows sharply the functional stresses about the hindfoot. The technique starts by realigning the hindfoot as desired after mobilizing the upper and lower ankle (subtalar) joints. The knee joint must be prepped to achieve optimal orientation. The aligned bones are fixed temporarily with Kirschner wires and checked radiologically. Using an adequate guide which is fixed to the hindfoot and lower leg percutaneously, acircular arc borehole is drilled and milled starting at the lateral aspect of the heel (tuber calcanei), crosses the calcaneus and the posterior facet of the subtalar joint, the talus, the center of the tibio-talar joint and the distal metaphysis of the tibia. The nail, is then impacted into the achieved bony canal applying gentle blows. The nail will be guided on its whole path by the bone which acts mechanically as “form-fit”.

The clinical results of our series of 45 cases (21 women and 24 men) between 30 and 84 years of age suffering post-traumatic, metabolic (diabetes) inflammatory (RA) and congenital conditions demonstrated an overall union rate of 93%. 2 non-unions (1 ankle, 1 subtalar joint) were observed without necessitating further surgery. 3 superficial surgical site infections were registered which made a local flap coverage necessary in 2 patients due to local skin break-down. No deep infection did occur. There were 2 implant removals, one was not related to hindfoot nailing. At the time of follow-up, the AOFAS Ankle/Hindfoot Score was 57 (median) from a maximum of 86 points. The self-assessment via the Foot Function Index improved from preoperative 155 points to 62.5 postoperatively (median values, $p<0.001$, Wilcoxon test).

On the basis of our results with a high rate of successful fusion and patient’s satisfaction where the hindfoot reduction was maintained until definite healing in the vast majority of cases the novel circular arc nail represents a viable and safe option for tibio-talo-calcaneal arthrodesis with a limited complication portfolio.