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The role of the intramedullary implant in limb lengthening

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ABSTRACT

Limb lengthening is now an accepted practice in orthopaedic surgery. The principles of distraction osteogenesis have become well established with the use of external fixators, utilizing both monolateral and ring fixators. Corticotomy technique, frame stability, lengthening rate and rhythm all contribute to the formation of bone regenerate and tissues. Complications are however common including pin-site infection, soft tissue tethering from the pins and wires resulting in pain, regenerate deformity from soft tissue forces or fracture following frame removal and patient intolerance of the frames during treatment.

Surgical techniques have changed to try and minimise these complications. The use of intramedullary nails have been used in conjunction with an external fixator or inserted after lengthening has been achieved, to reduce fixator time and prevent regenerate deformity. Implant innovation has led to the production of intramedullary lengthening nails. The initial devices used ratchet mechanisms with rotation of the bone fragments to achieve lengthening (Bliskunov, Albizzia and ISKD). More accurate control of lengthening and a reduction in pain, resulting from the manual rotation of the leg required to achieve the ratchet progression, was achieved by the use of a transcutaneous electrical conduit powered by external high frequency electrical energy (Fitbone).

The most recent implant uses an external remote controller which contains two neodymium magnets. These are placed over the nail on the skin and rotate which in turn rotates a third magnet within the intramedullary nail (Precice). This magnet rotation is converted by a motor to extend or retract the extendible rod. There are multiple nail sizes and lengths available, and early results have shown accurate control with few complications. With such promising outcomes the use of this lengthening intramedullary nail is now recommended as the implant of choice in femoral lengthening. This article is an historical account of the intramedullary device and the impact on limb lengthening.

Introduction of limb lengthening

Over the course of the 20th and early 21st century limb lengthening has become an accepted orthopaedic practice. Codivilla in 1905 published “On the means of lengthening, in the lower limbs, the muscles and tissues which are shortened through deformity” [1]. He highlighted the difficulty of lengthening a limb due to the resistance of the soft tissues and muscles. The forces required to stretch the limbs were considerable which limited the use of skin traction, to overcome this he applied the traction force directly to the skeleton with a calcaneal nail whilst the limb was held in extension and the patient under narcosis. An osteotomy was made in the femur and traction applied to acutely lengthen the limb, a plaster was then applied from pelvis to foot. After a few days a Gigli saw was used to divide the plaster at the level of the osteotomy and further traction applied, with or without narcosis. The gap in the plaster was filled in to maintain the length achieved.

The basic concept of bone osteotomy, acute lengthening and consolidation led to several different distraction devices being produced but all encountered complications due to overstretching, vascular deficiency to the fragments and insufficient fixation of the bone. It was not until after World War II that further interest in limb lengthening techniques provided the principles of today. Following initial concentration on lengthening apparatus, a focus on the biological reaction of the tissues and bone formation led to dramatic improvement in surgical outcomes.

Wagner [2,3] undertook femoral lengthening by placing 4 Shanz pins fixed to a monolateral system, an osteotomy was made with an oscillating saw and the periosteum divided. Gradual traction of approximately 1.5 mm/day was undertaken with one turn of the knob on the lengthening device. Once the desired

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length had been achieved an x-ray was taken. If bone was seen between the bone ends then consolidation was expected and the frame left in situ. However in the majority of patients, especially in adults, bone continuity was absent. This unreliability of bone formation led to bone grafting and osteosynthesis using a special AO-plate being advised, if hyperaemic fibrocartilaginous tissue was present then grafting was deemed not necessary. Wasserstein [4] lengthened with a circular fixator over an unreamed flexible nail. The rate of lengthening was 1–2 mm per day and once the appropriate length was achieved the distraction gap was filled with a slotted tubular allograft.

The aim was to reduce treatment time, increase stability of fixation and ensure proper alignment. This appears to be one of the first documentation of the use of an intramedullary implant.

It was Ilizarov [5–7] in the 1950s who developed arguably the most recognised and accepted circular external skeletal fixation system attached to bone with tensioned wires. His work also highlighted the need to preserve extra-osseous and medullary blood supply with a low energy corticotomy, stable external fixation, a delay (latent period) prior to distraction and a distraction rate of 1 mm per day in frequent small steps in order to stimulate the formation of new bone and soft tissues. Once the lengthening has been achieved a stable neutral frame is maintained and the physiological use of the limb with weight bearing is undertaken to allow the bone to consolidate prior to frame removal. De Bastiani [8] used these principles with a mono-lateral frame fixed with half-pins. Their latent period was longer than Ilizarov's (14 days compared to 5–7 days) to allow callus formation before distraction was undertaken, this coined the term callotasis.

Complications during leg lengthening however still remain. Paley [9] has divided these into problems, obstacles and true complications that remain after lengthening has been completed. Soft tissue complications relate to muscle contractures, joint subluxation and dislocation and both neurologic and/or vascular injury. The regenerate bone may deviate during lengthening as a result of muscle pull, prematurely or delay in ossification and potentially deform or fracture following frame removal. Pin-site problems include local and deep infection, and soft tissue tethering with associated pain are common scenarios. Residual joint stiffness can be a persistent complication.

Modification of surgical techniques have therefore been geared towards reducing fixator time, to reduce soft tissue complications and joint stiffness but maintain good bone alignment and prevent deformity or fracture of the new bone regenerate. Intramedullary implants have been used in combination with external fixators and more recently with advanced technology as fully implantable lengthening devices to achieve these goals.

A combination of external fixation and an intramedullary nail

Paley et al. [10] first presented the concept of combining femoral lengthening with an intramedullary nail in situ in 1997. They high-light the long duration of external fixator treatment until sufficient regenerate healing and the keenness of patients to have the frame removed as soon as possible. Their comparative review confirms the advantages of lengthening over a nail (LON) with early fixator removal, protection against fracture and deformity and earlier rehabilitation with reduced joint complications. They also demonstrated statistically faster consolidation time of the regenerate even after intramedullary reaming, hypothesising that the revascularisation of the endosteal blood supply, with better stability provided by the nail and earlier functional loading results in excellent bone consolidation. The surgical technique involves accurate positioning of the fixator wires or pins to avoid contact with the nail, to reduce risk of cross contamination and intramedullary sepsis. The antegrade nail is locked proximally at time of insertion and after lengthening was achieved locked distally with concomitant ex-fix removal (Fig. 1). They confirmed that the cost of treatment and estimated blood loss was higher than the control "classical lengthening" group. They also demonstrated no significant change in mechanical axis following long lengthening segments along the anatomical axis (as directed by the nail).

The benefits of this technique must be balanced with the risk of deep infection. The rate varies from 0 to 20% in the literature [10–20], the higher percentage relates to occurrence in a small prospective randomised clinical study [20]. Deep infection developed in 3 of 28 patients which responded to nail removal and reaming. They were all stated to be heavy smokers and not compliant with pin care instructions. Song et al. [16] demonstrated a higher risk of osteomyelitis with a previous history of infection or open fracture and state that this should be taken into consideration when choosing the method of lengthening.

An alternative technique has been proposed by Rozbruch et al. [21]. In this case the limb is lengthened and then once lengthening has been completed the nail is inserted with frame removal. The frame construct is applied to enable the intramedullary nail to be inserted later without contact between the internal fixation and external fixation pins and wires. A locked reamed intramedullary nail is inserted across the regenerate bone and the frame removed. There are several advantages using this technique in comparison to LON including the ability to insert a full-length large-diameter nail which offers more stability. Without the use of concomitant internal and external devices the infection rate is theoretically lower. If a pin tract infection occurs during lengthening this may be

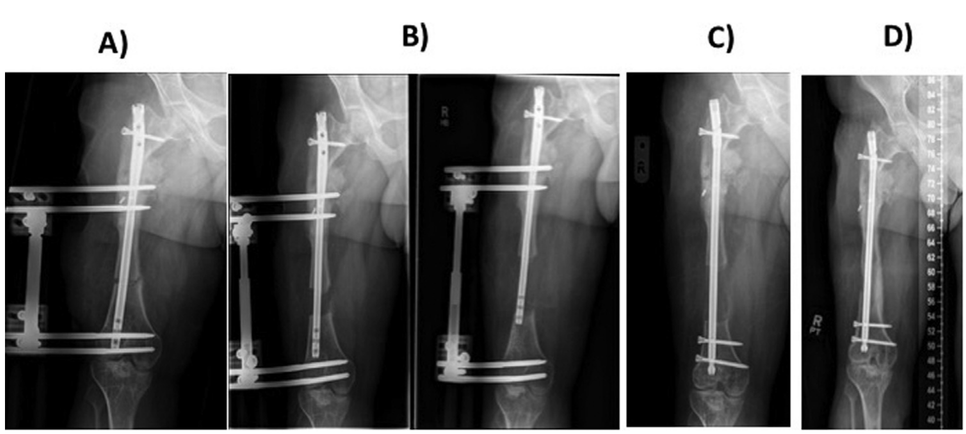

Fig. 1. Lengthening over a nail. a) Initial Construct lengthened over a humeral nail; b) Lengthening until the nail disengages with distal fragment; c) Exchange to a femoral nail with removal of external fixator; d) Bone consolidation.

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