International Journal of Research in Orthopaedics
Kadam TS et al. Int J Res Orthop. 2020 Sep;6(5):1123-1129
http://www.ijoro.org

DOI: http://dx.doi.org/10.18203/issn.2455-4510.IntJResOrthop20203741

Case Report

A controlled diaphyseal expansion osteotomy for the implantation of a wagner cone prosthesis in a stenotic femoral canal encountered in a polio limb: a case report of the technique

Tushar S. Kadam*, Mohan M. Desai

Department of Orthopaedics, Seth G. S. Medical College and King Edward VII Memorial Hospital, Mumbai, Maharashtra, India

Received: 10 June 2020
Accepted: 13 July 2020

***Correspondence:**
Dr. Tushar S. Kadam
E-mail: tushar23.kadam@gmail.com

ABSTRACT

Dysplastic hips pose a significant technical challenge to arthroplasty surgeons. Such deformed hips might be encountered either in congenital and developmental conditions or as sequel of neuromuscular disorders (like poliomyelitis), following infections, or after childhood surgical procedures of the hip. The scientific literature, focussing on total hip arthroplasty (THA), for coxarthrosis in patients with residual poliomyelitis, is relatively rare. Several anatomical distortions seen in dysplastic femurs are described, one of which includes an undersized diaphysis with a stenotic medullary canal. We present a case of a 28 years old male with residual poliomyelitis who underwent a cementless THA for a non united transcervical neck of femur fracture. The patient had an extremely narrow medullary canal which posed a formidable difficulty in the procedure. This was overcome by a novel diaphyseal expansion osteotomy, which enabled the implantation of Wagner Cone prosthesis. This technique, which has hitherto not been described in the literature, can significantly facilitate the implantation of an appropriately sized stem in an undersized femur while at the same time ensuring a good long-term result.

Keywords: Arthroplasty, Femur, Osteotomy, Poliomyelitis

INTRODUCTION

Hip dysplasia secondary to developmental disorders like Legg-Calvé-Perthes disease, Developmental Dysplasia of the Hip (DDH) or Slipped Capital Femoral Epiphysis (SCFE) often leads to osteoarthritis in adulthood.[1] Similarly, neuromuscular disorders like poliomyelitis can lead to degenerative hip changes either as a sequel of the disease process or independent of the neurological condition.[2]

Poliomyelitis is a viral disease that invades the nervous system leading to paralysis. Coordinated vaccination programmes have reduced the global caseload >99%. Post-polio syndrome (PPS) is a condition afflicting polio survivor many years after the initial attack. It is characterised by progressive muscle weakness, fatigability (both generalised and local muscular fatigue) and muscle atrophy. Although rarely life threatening, it can significantly hamper the activities of daily living.[3] Previously, it was considered that degenerative joint diseases are rare in patients with PPS because the forces acting across joints in the paralytic limbs were thought to be lower than normal.[2] However, muscular imbalances may still contribute to joint degeneration. The relative weakness of the gluteus medius and minimus alongside normal strength in the hip flexors and adductors leads to the subluxation of the hip with subsequent painful arthritis.[4,5] Additionally, although patients with residual paralysis are less active, they may develop degenerative arthritis in the contralateral (normal) hip. This may be caused by leg length discrepancy, pelvic obliquity or due to severe deformities in the affected hip.[2,4,5]

Possible treatment options for such degenerated, painful hips in patients with PPS include osteotomy (periacetabular or femoral) and THA.[4] An osteotomy is suitable for hips with less advanced arthritis in young adults. For those with advanced changes, the best option is usually THA.[1,2,4,5] Research on hip replacement in patients with PPS is scanty and limited to individual case reports and case series. However, the literature shows that although technically challenging, predictable and consistent results can be obtained in these patients with THA.[2,4,6]

The dysplastic changes in the native hip, studied extensively by Haddad et al, vary widely in terms of their severity and presentation thus leading to several technical challenges. The changes, discussed further ahead, distort the shape of the proximal femur.[1]Additionally, Sugano et al also reported increased anteversion and neck shaft angle with higher grades of dysplasia leading to a valgus appearance of such hips on radiographs due to an anteverted femoral neck.[7] The intra operative scenario may be further exacerbated due to previously done procedures like arthrodesis, corrective osteotomy or resection arthroplasty with soft tissue scarring adding to the complexity.[4]

Although a study by Bicanic et al described several osteotomies which aid in restoring the biomechanics of the prosthetic hip in patients with native dysplasia.[8] The technique described by us is a novel method which hasn't been described in the past. It is suitable for a narrow, stenotic femoral canal encountered in a dysplastic femur which is classified as a Type V femoral deficiency according to the American Academy of Orthopaedic Surgeons (AAOS) Classification System for Femoral Deficiency.[9,10]

CASE REPORT

A 28 years old Indian male, with a childhood history of poliomyelitis of the left lower limb and subsequent residual paralysis of the limb presented to us with complaints of left hip pain. Despite the residual paralysis of the left lower limb, he could ambulate without any walking aid. He had a short-left limb and could walk with a slight limp due to the leg length discrepancy. The other limb had functional motor power and the patient was gainfully employed. The patient had no complaints of hip pain till he suffered a trivial fall leading to a transcervical neck of femur fracture on the left side. This was managed conservatively in a separate hospital and at the time of presentation, the patient had features of non union of the transcervical fracture with persistent hip pain. Furthermore, the patient was bedridden with significant limitation of his daily routine. On examination, all movements of the affected side were painful. The patient had a flexion, abduction and external rotation deformity of the left lower limb with a limb length discrepancy of 5 cm between the two sides. The paralyzed left limb could not be effectively evaluated because of the femoral neck fracture; however, because the patient used to ambulate independently prior to injury, we considered the minimum muscle strength on the left side to be grade 3/5 (according to the Medical Research Council grading system). The contra lateral right side had muscle strength of grade 5 in all major proximal muscle groups. His knee was stiff, with a range of 0 to 20º, with neither pain nor tenderness. He had scars on the anterior aspect of his thigh proximally and the lateral aspect of the thigh distally. These were due to previous surgeries done in childhood, the exact details of which were unavailable (Figure 1).

Figure 1: Shortened and atrophic left lower limb with an external rotation deformity.

The radiographs showed a dysplastic left hip with pelvic obliquity. The femoral canal was stenotic, with narrowing of both external and internal diameters of the canal- an AAOS Type V femur (Table 1).

Table 1: American Academy of Orthopaedic Surgeons (AAOS) Classification System for Femoral Deficiency.

Classification	Description
I	Segmental defects (loss of the femoral cortical shell)
II	Cavitary defects with loss of cancellous bone and intact cortex
III	Combined segmental-cavitary defects
IV	Femoral malalignment (angular or rotational)
V	Femoral canal stenosis (narrowing or obliteration)
VI	Femoral discontinuity

Source: Brown et al.[10]

However, it must be noted that in our case the external diameter of the femur was also small (Figure 2A and B). A computed tomography scan revealed the internal diameter at the metaphyseal level to be 13.3 mm which decreased to 8mm closer to the isthmus. The femoral head was calculated to have a diameter of 40 mm (Figure 3). Due to the poor bone quality and doubtful vascularity of the femoral head, we ruled out fixation of the fracture. Instead, a THA was planned for the patient. The long term results of the Wagner Cone prosthesis are encouraging, hence this prosthesis was selected.[11,12] However, challenges were anticipated in view of the dysplastic changes and for this reason, we carried out a saw bone simulation of our expansion osteotomy technique using the Synthes™ Wagner Cone trial reamers and a trial stem (Figure 4A-D).This simulation was done on a saw bone model. The material properties of a saw bone model are different from those of a native bone; nevertheless, this simulation depicts the mechanism of the proposed osteotomy.

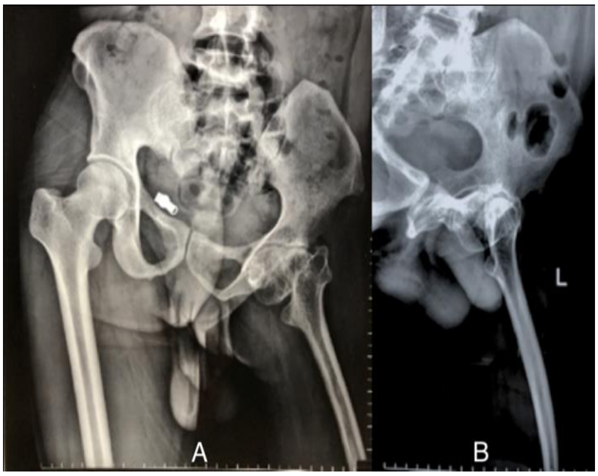

Figure 2: Radiographs showing a stenotic femoral canal on the left side. Also note the pelvic obliquity. A: antero-posterior view; B: frog-leg lateral view.

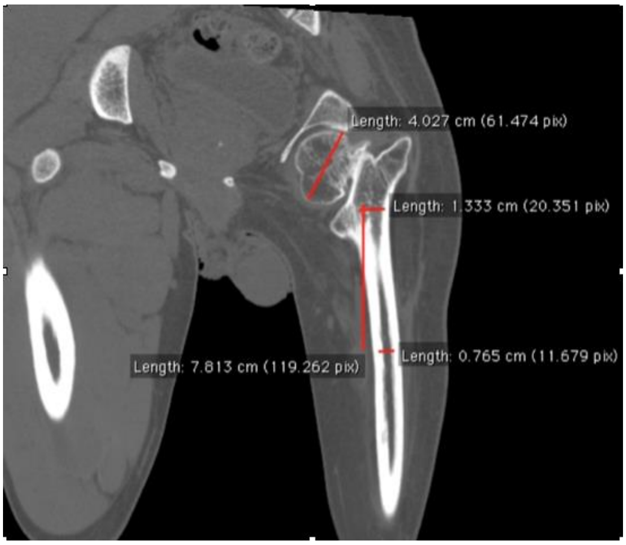

Figure 3: Coronal section of the CT scan showing the neck of femur non-union and the stenotic proximal femur.

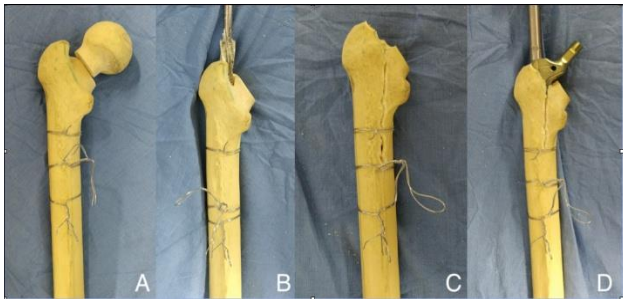

Figure 4: A saw bone simulation of the diaphyseal expansion osteotomy technique. A: a saw bone model with an osteotomized neck to replicate the intra operative scenario. Note the placement of the stainless steel wire cerclages. B: manual reaming carried out using the implant specific tapered conical reamers (Synthes™). C: the formation of linear cracks as the diaphysis starts to expand. D: the insertion of the trial stem. Note the opening up of the linear fissures; however, the wire cerclages prevent any catastrophic crack displacement while simultaneously allowing the insertion of an appropriate sized stem.

The osteotomy technique

The Wagner Cone prosthesis has eight longitudinal flutes which impart a high degree of rotational stability while also ensuring good osseointegration.[4,11] This requires a firm fit between the inner cortex of the femur and the middle third of the prosthesis. It is not sufficient for the stem tip to merely sit firmly in the medullary canal.[4] However; the expansion of a misshapen, stenotic femoral canal can be an arduous task. The external diameter of the femur constitutes the limit up to which the canal can be safely enlarged. The reamers (flexible or rigid) are used to widen the canal, working on the principle of creation of micro fractures of the inner cortex; in contrast, broaches and rasps achieve this by impaction of the cancellous bone.[10]

The diaphyseal expansion osteotomy is based on the principle that an expansion of the medullary canal such that it approximates the external diameter of the femur or even exceeds it is clearly not possible without creating macro fractures in the femur. Nonetheless, it may be required, in order to prevent the implantation of a loose and undersized prosthesis. Although loose implants may achieve rotational stability after initial subsidence, the patients are likely to have limb length inequality, joint instability and undesirable joint mechanics which affect the gait of the patient, while also aggravating the wear.[13]

It is a well-known strategy to use a prophylactic cerclage with a steel wire, controlled cable systems or, more recently, using a braided polyblend suture to prevent intra operative fractures.[14-16] Based on this idea, the senior author conceptualized a technique to achieve a controlled expansion of the medullary canal using multiple 18 gauge monofilament stainless steel wires (Synthes™- 0.8 mm) which are flexible enough to allow the longitudinal cracks to open up in a controlled manner.[17] The wire loops are placed at multiple locations along the expected length of the implant to ensure that uncontrolled catastrophic crack propagation doesn't occur. The last loop should be placed slightly distal to the expected endpoint of the stem. Controlled cable systems would not allow this opening.[15,18] We do not know whether the braided polyblend suture would allow it. The steel wires are moderately tightened prior to reaming and firmly fixed after the final insertion of the stem. We had no device to accurately measure the amount of tension imparted to each wire loop which was based on the experience of the senior author.

The patient was operated by the senior author under general anaesthesia in a lateral decubitus position using the posterolateral approach. An extensile exposure is needed for placing the prophylactic cerclage wires. All precautions were taken to prevent an iatrogenic fracture during rotation of the limb. Similarly, meticulous attention was paid to prevent excessive traction or stretch injury to the sciatic nerve and to avoid any iatrogenic injury to the acetabulum. The superior wall of the acetabulum was found to be deficient and was built up using an auto graft from the femoral head. This was fixed using 4 mm screws (flying buttress graft), an important step to contain the cement. The pelvic obliquity, a major concern, was compensated for during acetabular reaming in order to recreate a normal cup position. Care is needed while using the Transverse Acetabular Ligament (TAL) as a landmark for cup positioning in dysplastic hips with distorted acetabula. A 43mm constrained cup (LINK® Lubinus® Cemented Acetabular Cup) was used (Figure 5).

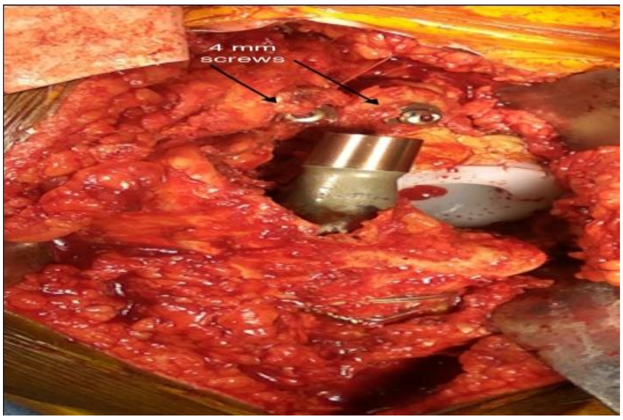

Figure 5: Intra operative picture showing the Link® Lubinus® cemented acetabular cup and the Wagner Cone prosthesis. (Black arrows show the two 4mm screws used to fix the bone-graft.)

The femur was prepared for reaming by placing multiple 0.8 mm stainless steel monofilament wires (Synthes™) over the expected length of the Wagner Cone stem, which was 115 mm in our case. The last wire loop was placed slightly distal to the expected end point of the stem and all loops were moderately tightened. The stem is available in sizes from 13 to 24 mm (with a distal taper design) with various horizontal offsets and two neck shaft angles (125º and 135º). The smallest size is 13 mm, which was equal to the internal diameter of the femur at the level of the lesser trochanter in our patient. However, it was still necessary to ream the canal because the prosthesis was deemed too proud for reduction. Hence, the diaphyseal expansion osteotomy was carried out to enlarge the narrow canal, which was only 8 mm wide at a point about 10cm distal to the lesser trochanter. The graduated tapered conical reamers specific to the system were inserted to the appropriate penetration depth as measured from the head centre mark on the reamer. This was followed by the insertion of a trial stem. After trial reduction, we made sure that the soft tissue tension was moderate in order to prevent any traction injury to the sciatic nerve. It is important to note that as the broader portion of the stem engages the inner cortex of the femur, the longitudinal splits are likely to open; however, the procedure is safe due to the prior applied stainless-steel wire cerclages spanning the entire length of the stem. After insertion of the final prosthesis, all cerclage loops are maximally tightened. Additionally, we also applied a Narrow 4.5 mm DCP plate in neutralization mode spanning the femoral segment to prevent any late opening of the osteotomy and late displacement due to torsional or angulatory forces. This is because of the fact that the circumferential wire cerclages, on their own don't provide enough resistance to torsional and angulatory forces.[18] the entire procedure was carried out under IITV guidance (Figure 6).

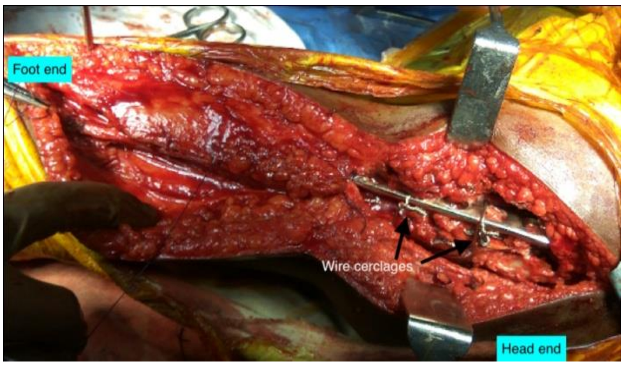

Figure 6: Intra operative picture, taken during wound closure, showing the wire cerclages and the 4.5 Narrow DCP. Note the extensile exposure required. (Black arrows show the wire cerclages.)

The rehabilitation program started on postoperative day two with emphasis on bedside range of motion exercises for the first 48 hours. From day three, the patient was allowed to walk toe touch weight bearing with crutches for support. Isometric exercises for other muscle groups such as the hip abductors and hip flexors began after day three. He gradually transitioned from partial weight bearing using two crutches, to walking with one cane over a period of six months. The limb length discrepancy was reduced to 2.8 cm and was compensated for by using a shoe raise. Excessive and overzealous correction carries the risk of sciatic nerve injury. The patient was followed at intervals of six weeks, three months, six months and one year. At the latest follow up, after one year (Figure 7A and B), the patient was ambulatory without any support with the pain component of the Harris Hip Score at 44 points (no pain or ignores pain). He has been able to resume his pre injury occupation. The follow up radiographs at one year reveal good osseointegration of the cementless stem with an uneventful union of the osteotomy (Figure 8 A and B).

Figure 7: Picture taken at one year follow up. A: note the residual limb length discrepancy which was compensated using a shoe raise. B: healed skin incision.

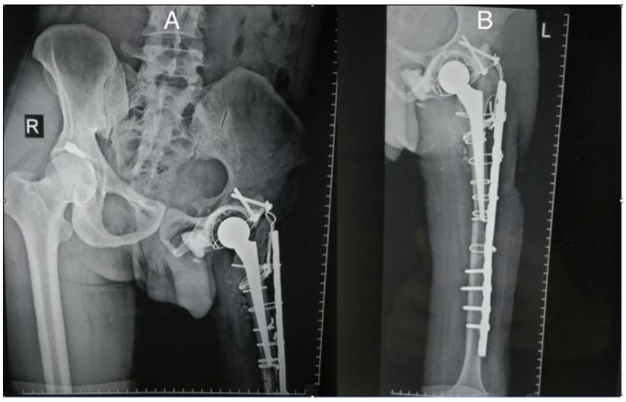

Figure 8: Postoperative radiographs at one year follow up. A: pelvis with both hips. B: full length femur.

DISCUSSION

Orthopaedic surgeons are often reluctant to perform THA in patients of residual poliomyelitis. Their major concerns, regarding hip replacement in limbs afflicted with poliomyelitis, are about increased risk of complications, especially postoperative instability and dislocation in limbs with weak muscle tone and the technical challenges encountered in dealing with the dysplastic femur and acetabulum.[4,6] The published literature, pertaining to this topic, is scanty with all projects either being individual case reports or small series.

A major study by Yoon et al in 2013 evaluated 10 hips in patients with residual poliomyelitis for four parameters - the Harris Hip Score, radiographic outcomes, complications (like dislocation) and the limb length discrepancy after recovery. The patients were analysed over a minimum follow up period of three years (mean of seven years). This study incorporated both paralytic and contralateral (non paralytic) limbs. The authors concluded that dysplastic arthritis of the hip is more prevalent on the paralytic side, whereas, overuse induced degenerative arthritis of the hip is more likely on the non paralytic side. Additionally, they noted that, in experienced hands, cementless THA is likely to have good results, although patients may need to be warned about mild persistent residual pain and limb length discrepancy in some cases.[4]Another noteworthy study, by Sobron et al in 2017, assessed 5 hips with paralytic poliomyelitis. They demonstrated good results with improvement in patient satisfaction. Moreover, the authors noted that although certain factors like preoperative weakness, muscle pain, limb length discrepancy and residual limp could compromise the clinical results; these should neither be considered as contraindications for the procedure nor as a sign of failure.[6]

Secondly, with regard to the anticipated technical challenges, a combination of improved prosthesis design and a novel surgical technique can help to overcome this problem. Acetabular dysplasia may pose challenges like acetabular insufficiency or the formation of a secondary socket. These patients might require the use of acetabular augmentation devices.[13] Literature also advocates optimal component positioning as the key to prevent dislocation.[2,6] Also, patients with paralytic limbs could benefit from the use of a constrained cup because of the increased risk of subluxation.[5] The dysplastic femur has a spectrum of abnormal features such as a small deformed head, posteriorly displaced greater trochanter, stenotic medullary canal and excessively anteverted, short femoral neck.[1] Modern implant designs can help to tackle the altered proximal femoral morphology. Modular implants like the S-ROM prosthesis allow distal plus proximal anchorage and modification of the antetorsion.[13] Currently, the Wagner cone prosthesis is considered as the implant of choice for patients with dysplastic coxarthrosis.[12] The Wagner cone prosthesis is made of a Protasul-64 titanium alloy rough blasted with corundum. The design features that make it suitable for dysplastic femurs are eight longitudinal flutes (also called ribs) distributed around the circumference and the length of the stem that ensure rotational stability and good osseointegration; a high conical taper permitting axial (taper lock) or vertical stability; a cylindrical design that allows selection of an appropriate anteversion to correct torsional abnormalities; a smaller horizontal offset which is required in dysplastic hips.[11] Furthermore, studies show good long term results with the Wagner cone prosthesis when used in complex primary hip replacements with survival rates of 98.04% with a minimum 2 year follow up and 91.5% after a mean follow-up of 11.5 years.[11,12]

An osteotomy of the femur for diaphyseal ectasia was first described by Ganz et al. in a case of revision hip arthroplasty with extreme ectasia of the femur secondary to loosening of a long Wagner stem. This was a form of a canal reduction osteotomy done for a markedly expanded medullary canal and it involved making multiple longitudinal splits in the femur, to expand it, followed by tightening all the pieces over the prosthetic stem.[19]

Another study by Perka et al. added a corrective three dimensional osteotomy comprising of a subtrochanteric de-rotation and, if needed, a shortening component within the framework of a THA to allow the implantation of an uncemented stem with a rectangular cross section.[12,20] However, it had a high rate of intraoperative complications (femur fracture) although, according to the authors, these complications did not adversely affect the survival of the prosthesis. Similarly, an extensive description of various available osteotomy procedures for dysplastic femur was given by Bicanic et al. Single plane longitudinal split osteotomy is known to revision hip arthroplasty surgeons.[8] It is used to extract well fixed femoral stems and works on the principle of expansion of the femoral canal allowing for easier component removal.[10] This osteotomy is done from outside-in and may thus compromise the periosteal blood supply.

CONCLUSION

The technique, described by us, is based on the above literature and aims to solve the formidable problem of inserting a prosthetic stem in a narrow, stenotic canal with a small external diameter. It has the advantage of superior healing because it is performed from inside out with the help of graduated reamers. Multiple linear cracks are created within the cortex (from inside out) with all fragments secured by stainless steel wire cerclages. This allows for expansion of the stenotic canal while also maintaining the biological potential of the multiple split osteotomies due to intact periosteal supply and muscular attachments. In order to allow the cracks to open, we recommend using an 18-gauge monofilament wire of 0.8 or 1 mm (Synthes™) since the fixation provided by these is comparatively less rigid. To the best of our knowledge a diaphyseal expansion osteotomy, such as this, has not been previously described in the scientific literature. THA is one of the treatment options to tackle coxarthrosis in patients with residual poliomyelitis. The diaphyseal expansion osteotomycan be useful to tackle the undersized, stenotic medullary canal encountered in dysplastic hips. Additional studies with long-term follow up will help to build further consensus.

Funding: No funding sources
Conflict of interest: None declared
Ethical approval: Not required

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Cite this article as: Kadam TS, Desai MM. A controlled diaphyseal expansion osteotomy for the implantation of a wagner cone prosthesis in a stenotic femoral canal encountered in a polio limb: a case report of the technique. Int J Res Orthop 2020;6:1123-9.