Proximal femoral varus osteotomies in childhood-development of osteosynthesis materials

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Abstract— Proximal femoral osteotomies are one of the most commonly used surgical techniques and play an important role in the spatial correction of the hip joint in a number of pediatric orthopedic disorders such as Legg-Calve-Perthes disease, Slipped capital femoral epiphysis, Developmental dysplasia of the hip, osteoarthritis, etc.[14,21,23,28,30,31]

The development of orthopaedic osteosynthesis for fixation of bone fragments includes the use of Kirschner wires, intraosseous nail plates, AO-plates with fixed angle, external fixators, etc. Over time, many of the techniques and osteosynthesis materials have fallen into disuse and have remained only of historical significance.

The purpose of this study is to follow how osteosynthesis fixation devices for varus osteotomies in the proximal femur have historically evolved and developed from the beginning to the present.

Keywords— Proximal femoral osteotomies, varus osteotomies, osteosynthesis devices

1. INTRODUCTION

Proximal femoral osteotomies are one of the most commonly used surgical techniques and play an important role in the spatial correction of the hip joint in a number of pediatric orthopedic disorders such as Legg-Calve-Perthes disease (LCPD), Slipped capital femoral epiphysis (SCFE), Developmental dysplasia of the hip (DDH), osteoarthritis, etc.[14,21,23,28,30,31]

In pediatric orthopedics, the goal of proximal femoral osteotomies (PFOs) is to change the existing pathologic anatomic substrate to achieve optimal joint congruency and prevent mid- and long-term hip damage.[32]

The technique for performing these osteotomies is also largely determined by the used osteosynthetic devices. Nowadays, the stability of osteosynthesis has become a basic requirement, using the proven principles of the Swiss Osteosynthesis Association (OA) and its the osteosynthesis devices.

The contribution of the Bulgarian orthopaedic and traumasurgeons is not small.[3]

2. Techniques of PFO and osteosynthetic materials used for fixation

In 1835, H.V. Bouvier in Paris, France, described the first varus subtrochanteric osteotomy of the proximal femur in a child with congenital dysplasia of the hip.[12]

In 1950, Pauwels' osteotomy marked the beginning of the varus proximal femoral osteotomy (VPFO). With his research, Friedrich Pauwels laid the foundation for subtrochanteric osteotomies. The principles he reported are the basis of all the varization proximal femoral osteotomies that are still performed today. This osteotomy was performed as early as 1940. Pauwels' principles are: 1) compressive forces are the magnitude that stimulate callus formation, 2) distraction forces limit bone formation, and 3) cutting forces harm and stop callus formation.[33,34,35,39,40]

In this osteotomy, a wedge with a medial base is extracted from the intertrochanteric region of the proximal femur, with the tip of the wedge angled equal to the magnitude of the varus correction required. The two sheared surfaces are then well adapted to each other. The disadvantage of this surgical technique is the greater shortening. The shortening can be reduced if, after the osteotomy, a wedge is not extracted, but the distal fragment is medialized and adducted and the medial part of the proximal fragment is positioned at the central part of the distal incision surface.

Pauwels with its varization osteotomy, aims to balance the forces acting on the femoral neck, i.e. converting distraction and cutting forces into compression ones.[10,33,34,35,39,40] (Fig.1)

The development of orthopaedic osteosynthesis for fixation of bone fragments goes through the use of Kirschner wires, intraosseous nail plates, AO-plates with fixed angle, external fixators, etc.

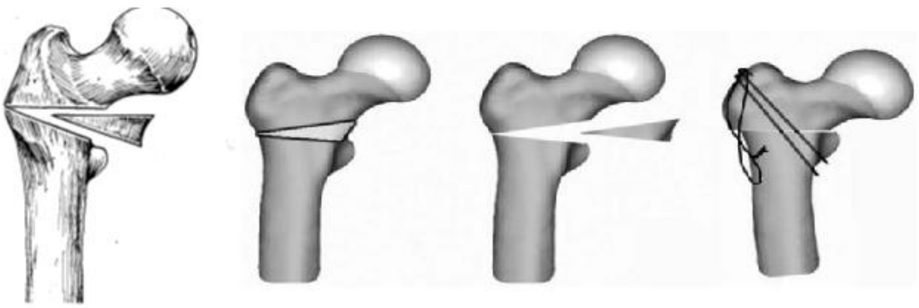

Fig.1 Pauwels's proximal femoral varus osteotomy

Osteosynthesis materials for fixation of the two fragments in VPFO can be grouped into 6 groups:

I. Osteosynthesis with K-wires

Fixation with K-wires and cerclage - In 1982, Brunner and Weber used K-wires and cerclage as osteosynthesis material for stabilization in variable proximal femoral osteotomy, based on Pauwels principles of cerclage. Based on these, Brunner and Weber present a simple, inexpensive, and efficient method of osteosynthesis for performing VPFO in children. Using K-wires and cerclage, conversion of tensile forces of the proximal femur into compressive forces acting at the osteotomy site is achieved. K-wires act as guides and neutralize cutting and rotational forces.[13,39] Fig.2

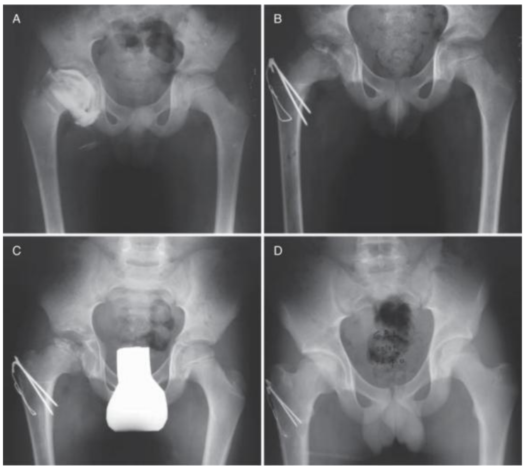

Fig.2 Fixation with K-wires and cerclage

The operative technique was osteotomy of the proximal femur in the intertrochanteric region with removal of an average of 150 medial open bony wedges. Minimal medialization of the femoral diaphysis was performed before the bone wedge was placed laterally to preserve the aligned mechanical axis. After the osteotomy was performed, 2 Kirschner wires (2.0-2.5mm) were passed through the trochanter major, passing through the osteotomy and penetrating the medial cortex of the distal fragment. The level of osteotomy, reposition, and placement of the Kirschner wires were performed under X-ray guidance (C-arm). A transverse hole is made on the lateral cortex of the distal fragment and a 1.0 mm flexible steel wire is passed through it. The wire is bent into the shape in Figure 8 (figure of eight), with the end of the wire anchored proximally over the Kirschner wires in the trochanter major, then tensioned and tied. To avoid their migration, the proximal end of the Kirschner's wires are curved upward and driven into the cartilage of the trochanter major. The postoperative period involves wearing cast immobilization until bony fusion occurs.

Osteosynthesis with 4 K-wires according to Tönnis - This technique for fixation of the two bone fragments by 4 K-wires was first performed by Tönnis in 1976. After removal of the medial bone wedge from the intertrochanteric area, a K-wires is passed along the axis of the femoral neck to determine the anteversion. The proximal bone fragment is placed in the desired varus position. With the help of 4 crossed wires, the two fragments are fixed to each other. This technique remains of historical value as fixation of the fragments and maintaining them in the required position is extremely difficult even with additional cast immobilization.[47] (Fig.3)

Fig.3 Tönnis- Two K-wires from lateral and distal to proximal and medial and 2 K-wires from lateral and proximal to medial and distal /through trochanter major/

II.Osteosynthesis with rigid plate and screws:

1) Osteosynthesis with AO- plates - The AO-plates are introduced in 1960 by AO (Arbeitsgemeinschaft für Ostesynthesefrage) and are still the main surgical procedure used for fractures, revision surgery and corrective osteotomies. Due to its fixed-angle

shape, successful placement depends on careful planning, accurate orientation in all planes and precise preparation of the canal for the blade of the plate.

The operative technique is a modern version of the classic Müller technique of 1984.

The Cannulated Pediatric Osteotomy System (CAPOS) is most commonly used. The system includes 90^0 paediatric plates of 3.5 and 4.5 mm and instrumentation with guides and chisels. The osteosynthesis system also has 115^0 microplates for children up to 2 years, 80^0 and 100^0 plates for adolescent age.

According to Müller , resection of bone wedges is not necessary in children under 15 years of age, and although fragments angled in the shape of an open lateral wedge create a significant gap, it heals quickly. Because of the stable fixation, Müller does not recommend postoperative cast immobilization and reports that fusion usually occurs in 5 to 8 weeks.[1,38]

Technique of AO-plate insertion: a Kirschner wires is inserted into the femoral neck through the most laterally protruding area of the greater trochanter, also called tuberculum innominatum. The direction in which it is driven should make an angle with the perpendicular to the femoral diaphysis equal to the amount of varization required. The magnitude of the femoral anteversion must also be taken into account, with the blade of the plate being introduced into the medial femoral neck region. The chisel-guide should be impaled no more than the length of the blade of the plate to be inserted. X-ray control in AP and lateral profile for the position of the guide is mandatory. Before the osteotomy is performed, 2 K-wires are placed in the proximal and distal fragments to help achieve the desired anteversion, which is calculated preoperatively. The osteotomy is then performed, after which the guide chisel is hammered and the blade of the AO-plate is driven into the shaped bony bed. To achieve the desired anteversion, the proximal fragment is rotated and the achieved correction is preserved by fixing the plate to the femoral diaphysis with screws. **(Fig.4)**

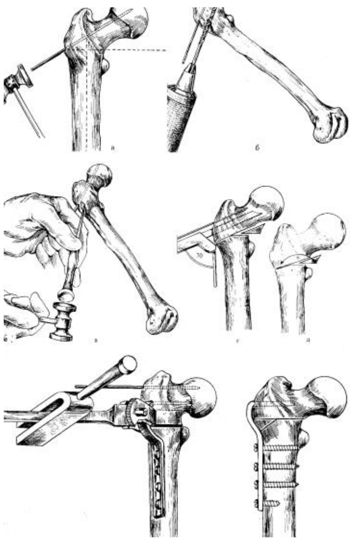

Fig.4 Osteosynthesis with AO- plates

The Altdorf clamp for varus and derotative osteotomies - The version for the hip is a modification of the Becker angle clamp created by Wagner and comes in 3 sizes (9, 10.5, and 12 mm).[49]

The proximal end of the clamp is biconcave and forms a 130° angle with the rest of the plate. Distally, there are 2 holes in the plate for fixation to the femoral stem and one proximal hole for insertion of a locking screw in the proximal fragment. Alonso, Lovell, and Lovejoy reported good results with this clamp and compiled a list of its advantages: fewer complications especially with regard to lateral protrusion because the clamp is placed through the shear surface; and reduced risk of damage to the trochanteric apophysis and prevention of unwanted rotation. They found that most complications were in patients older than 8 years of age, so they recommended the plate for children younger than that.[9] (**Fig.5)**

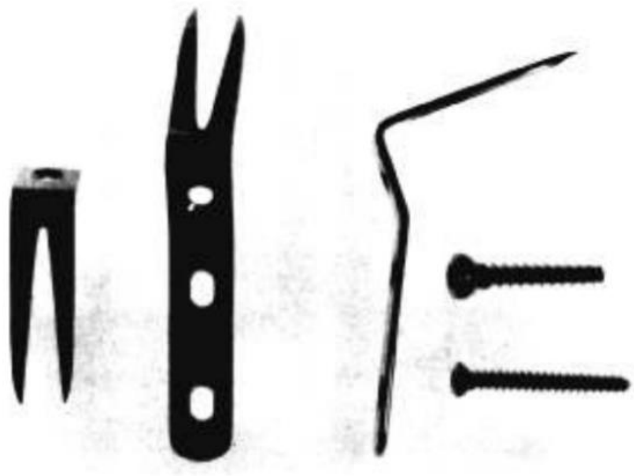

Fig.5 The Altdorf clamp for varus and derotative osteotomies

3) Richard's hip screw

Richard's hip screw is a modified osteosynthetic device, based on the principle of the rigid AO- plate. The difference is that in Richard's hip screw the proximal part is a screw and a barrel.

Operative technique : A standard posterolateral approach to the femur is used. A guide wire is passed along the axis of the femoral neck under X-ray control. This wire is used to mark the axis of the femoral neck and is a proximal landmark to assess the degree of anteversion present.

After the osteotomy, it is necessary to pass the barrel and screw through the osteotomized surface to obtain the desired varization.

The osteotomy is performed prior to insertion of the guide wire. Once the exact position of the guide wire is achieved, it is reamed along it and the insertion of the locking screw follows. The appropriate plate is selected to give the desired cervical-diaphyseal angle (CDA). With the reduction osteotomy, medialization of the femoral shaft is also achieved, which relieves the adductor musculature. The plate is fixed to the femoral diaphysis with screws.[50] **Fig.6**

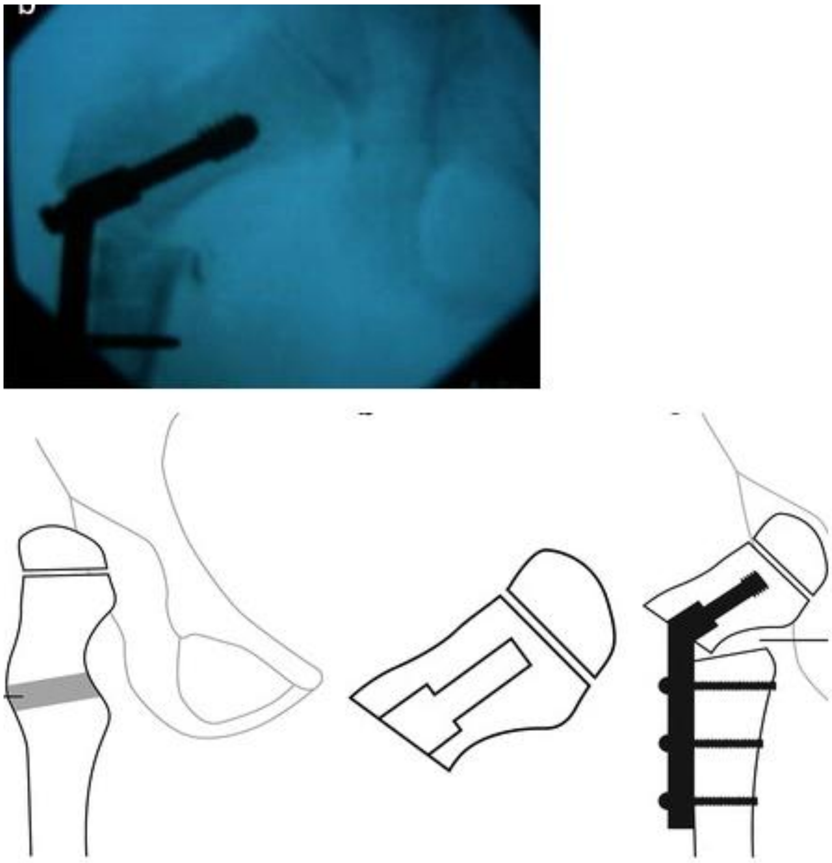

Fig.6 Richard's hip screw

III. Varus osteotomy with an anteriorly placed locking plate

Anterior plate placement along the proximal fragment is determined by the bony groove. The angle of varus adjustment corresponds to the position of the plate and femoral neck. The proximal 2 holes are made into the groove. The first bicortical screw is placed loosely to allow manipulation of the plate. The path of the second screw is prepared with a drill. The plate is temporarily rotated upward after which, the intertrochanteric osteotomy is easily performed. The plate is returned, after which the second screw is inserted. Varus correction is automatic or achieved after resection of the bone wedge after pulling the plate to the anterior surface of the femoral diaphysis. The reposition is stabilized with the placement of the distal screws.[32] **Fig.7**

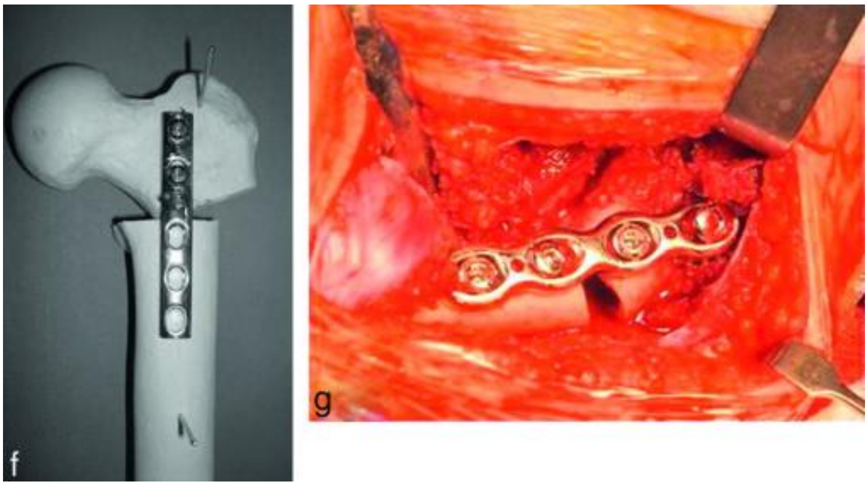

Fig.7 Varus osteotomy with an anteriorly placed locking plate

IV.Intramedullary osteosynthesis in VPFO:

1). Blade of Holevich

In the middle of the 20th century prof. Yanaki Holevich introduced and used the "blade with a hole" as an osteosynthesis device for retention of varus and derotational osteotomies in children with congenital luxation of the hip. The "blade" is a bilaterally tapered osteosynthesis device with a hole in the blade its proximal end is made in 7 sizes with 1mm differences in width and 5mm in length. The accuracy of the direction in which the "blade" is driven is an important point of the operation. It must be at an inclination to the femoral diaphysis corresponding to the required varization and it must be positioned exactly in the sagittal plane, i.e. one blade must be directed ventrally and the other dorsally. The tip is driven immediately above the insertion of m. vastus lateralis. The tip should not reach the site where the osteotomy is to be performed. The femoral metaphysis is then penetrated along the posterior margin of m. vastus lateralis. The level of the osteotomy is noted and performed. The femur is adducted to the extent that the femoral condyle lies exactly along the path of the "blade". In this position, the "blade" is tapped into the distal segment, all the time being held in the anterior-posterior position with the forceps, and the assistant maintains the femur in the horizontal position. A control radiograph is taken. A hip spica cast is placed for 45 days.[4] (Fig. 8)

2). Osteosynthesis by Holevich- Vladimirov (blade) - in the 80s of the 20th century prof. Holevich and prof. B. Vladimirov introduced a new osteosynthesis tool and technique to achieve the VPFO in older children. Operative technique with the Holevich-Vladimirov "blade"- a special "blade" is driven into the proximal part of the trochanteric region under an inclination. Its axis makes an angle with the longitudinal axis qual to the magnitude of the required varization. A special guide is used for this purpose.

Once the "blade" is driven 3-4 cm, a transverse intertrochanteric osteotomy is performed. The distal fragment is then adducted and medialized, and the proximal fragment is varizated until the axes of the "blade" and femoral diaphysis are alined.

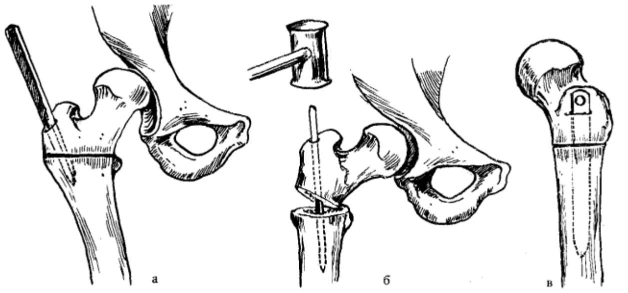

Fig.8 Blade of Holevich

The "blade" is then impaled into the medullary canal until the distal end of its pedicle notch sinks into the spongiosis of the greater trochanter. The diaphysis is drilled through the orifice of the guide, and a special pin is inserted through the hole made and passed through the two cortical layers and the orifice of the "blade" . Essentially this osteosynthesis method adopts and uses the advantages of the Holevich "blade" and Küntscher intramedullary osteosynthesis.[5,29] (**Fig.9)**

V. External fixator

To achieve and maintain varus correction in proximal femoral osteotomies, in addition to the use of internal osteosynthesis devices, external fixators are also applied. This modality is primarily used in patients with neuroorthopedic disorders such as cerebral palsy[17,44,51] and myelomeningocele[16] , in which the bones are smaller and softer. For this purpose, Schanz pins are used, which are inserted percutaneously through the medial and lateral cortex of the bone. The proximal pins are positioned 1 cm distal and parallel from the proximal growth zone. Distal pins are placed at a level below the trochanter minor and in a direction perpendicular to the femoral diaphysis. The intertrochanteric osteotomy is performed through a minor approach. The rotation is corrected first. A small medial displacement of the distal fragment allows the femoral neck to tilt into varus. A wedge resection is required in older children. These pins lock to the external fixator which maintains the achieved correction.[20] (Fig.10)

VI. Techniques and osteosynthetic devices with the possibility of targeted intraoperative varus correction:

1) The apparatus of Ivan Iliev

Ripstein's method was used to determine the anteversion and varus values of the femoral neck preoperatively on native radiographs. After specifying the necessary correction, the lateral approach to the hip joint is used to expose the femur. A special Iliev's apparatus is placed on it, with the proximal part fixed to the trochanteric region and the distal part fixed to the femoral shaft.. The two arms of the apparatus are connected to each other and an intertrochanteric osteotomy is performed. By rotating the two arms of the apparatus relative to each other, the anteversion and varus are adjusted to predetermined values. Two parallel Kirschner wires are inserted, penetrating through one cortical layer of each fragment, as a marker for rotation. Osteosynthesis can be performed with a Holevich's osteosynthesis blade , allowing stable fixation of both fragments in the desired position. The sharpened blade is driven into the apex of the trochanteric region by tapping into the bony groove of the femoral diaphysis after the osteotomy. The sharpened surfaces of the blade are fixed into the cortical walls of the bone. The correcting apparatus of Iliev is then removed. A hip spica is placed for 45 days.[6] (**Fig.11)**

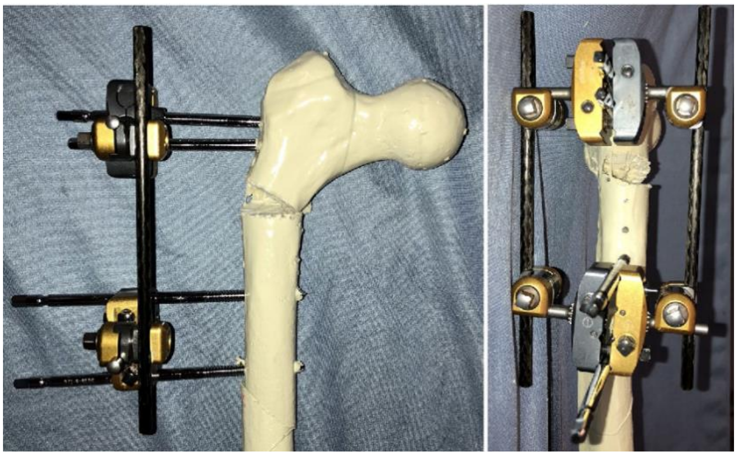

Fig.10 External fixator for VPFO

Fig.11 The apparatus of Ivan Iliev

2) Osteotomy and fixation with LCP Ped. Hip Plate - Since 2008, Synthes has introduced a new system - LCP Pediatric Hip Plate - for stable fixation of varus, valgus and derotated osteotomies and fractures of the proximal femur. The system was designed with the basic principles of AO ASIF : a) optimal adaptation to the bone anatomy in children and adolescents; b) stable fixation, reducing the risk of loss of correction intra- and postoperatively; c) spare the bone blood supply by limiting contact between the plate and the bone; and d) early mobilization. The LCP Pediatric Hip Plate System consists of a plate with three proximal and three distal holes (in the case of 2.7 mm plates, the holes are two). Two locking screws in the plate to the femoral neck and one, also locking, calcaneal screw fix the proximal fragment. Three distal screws fix the plate to the diaphysis. The design allows the distal screws to be locking or standard cortical for compression. Depending on the size of the fragments, the weight of the child and the age, plates with a hole width of 2.7; 3.5; 5.0 mm are used, with three different thicknesses. The plates are universal for left and right proximal femoral compression. Two different surgical techniques can be used for the implantation of the plate: fixed and calculated cervical-diaphyseal angle.

Operative technique: the femur is approached from lateral. To determine the anteversion, a K-wire is slid along the anterior aspect of the neck and fixed in the epiphysis. Both plate guides are placed parallel to the wire. The guides do not reach the physis. Below them, a special instrument determines the site of the osteotomy. The plate is inserted and the guides are replaced successively with two locking screws. After drilling, also with a guide, the calcareous screw is inserted. The plate is fixed to the diaphysis with locking screws, the most distal of which is placed monocortically.[2] (**Fig.12)**

Fig.12 Osteotomy and fixation with LCP Ped. Hip Plate

3. DISCUSSION

The historical review of osteosynthesis devices and techniques in PFO demonstrates the great variety. Each has its advantages and disadvantages, and their use is logically justified for the time of their appearance.

Following the application of inter- and subtrochanteric PFO, an increase in the occurrence of various complications- metal notching, loss of correction, wound infection, hematoma formation, femoral neck fractures, heteroectopic ossification, and metal breakage, has been reported in the literature.[41,45,50]

Fixation with K-wires and wire cerclage is an affordable and effective method of osteosynthesis, technically feasible, which converts compressive forces into cutting forces and thus potentiates bone fusion at the osteotomy site. Its comparative instability and lack of possibility of precise correction are its main disadvantages. The same disadvantages apply to Tönnis osteosynthesis, which necessitates the use of additional cast immobilization in both methods.[47]

Tivchev P. reported on 300 intertrochanteric osteotomies performed, in children in which only 4 K-wires were used for fixation according to the method of Tönnis, recording not a single complication.[8]

In their study, Maranho D and Pagnano R (2014) performed VPFO in 20 patients with Perthes disease using K - wires and cerclage as osteosynthetic material. The mean age of the patients was 7.4 +- 2.3 years and the mean follow-up was 10 +- 4.3 years. To evaluate the effectiveness of the osteosynthesis material, they monitored the neck-shaft angle (NSA) value and its change over time radiographically. The reduction of NSA when the VPFO was performed preoperatively and immediately postoperatively averaged 14.3^0. Compared with the immediately measured postoperative NSA value with the follow-up and final measurements, the NSA increased by 7.0^0 on average. The authors reported no cases of OM problems or other complications during follow-up; only 1 patient developed a peri-implant femoral fracture 17 years after surgery. In conclusion, the authors express a positive assessment of the effectiveness of OM in VPFO.[36]

The ideal osteosynthesis material should be simple, inexpensive, result in bone fusion, and should confer stability to maintain the correction without external immobilizing agents. Cerclage and K-wires cover the first 3 criteria,[48] but do not achieve lasting mechanical stability of the proximal femur. For this reason Engel, E. E., Volpon, J. B., & Shimano, A. C. (1997) are not convinced to what extent cast immobilization can maintain the desired position.[18]

The Holevich's blade is an osteosynthesis device that until about 10 years ago was commonly used for fixation of bone fragments after varus and derotation PFO. With it, the ease of performance of the surgical technique, the sharp "learning curve" and the affordability of the implant are too seductive for the surgeon. Its major disadvantages such as injury to the apophysis of the greater trochanter, inaccuracy of correction, lack of rotatory stability, the need for cast immobilization, and lack of certification for its use have slowly but surely removed it from orthopaedic practice. Even the refinement of the idea, in the form of the Holevich-Vladimirov osteosynthesis, failed to stop this process, further potentiated by the chronological coincidence with the introduction of the new osteosynthesis devices of the AO group. In 1972, at the first national congress of orthopaedics in Varna, a team of authors - Ivanov, Holevich, Petrov, Vladimirov - presented the results of 207 operated hip joints and found the revalgization values for the Holevich blade - 27.6^0, while for other osteosynthesis methods, which do not affect the apophysis of the trochanter, the revalgization value was 17.7^0, or a difference of 9.9^0. In his doctoral work Iliev, on the basis of 1113 operated joints, gives a value of revalvization with the blade of Holevich- $14,35^0$, and for other osteosynthesis means- $9,5^0$, or a difference of $4,8^0$.[7]

With regard to the use of external fixators in VPFOs, Handelsman et al. reported a study in which 28 children with neuroorthopedic conditions (20-CCP, 6-spina bifida, 1-neonatal meningitis, and 1-sacral agenesis) underwent VPFOs (36 TBS) with an external fixator. The authors reported the removal of external fixators at a mean of the 10th postoperative week after radiographic confirmation of osseous fusion at the osteotomy site (4-17 weeks), and reported no available evidence of femoral epiphyseal avascular necrosis after a mean follow-up of 6,6years. (3-15y). Three complications were reported during external fixator use : infection in 1 of the pin sites (1 case); skin injury (1 case) and bone nonunion (1 case).[20]

Patient tolerance to the use of external fixators in VPFO has been confirmed by other authors using them in patients with Perthes disease and SCFE.[15,24]

The problem with the use of external fixators in VPFO is related to infection around the screws or K - wires, which occur postoperatively. Grill reported an incidence of infection around the screws or K-wires of 70% (20 Orthofix + 7 Ilizarov), suggesting that the high incidence of infection is due to the prolonged healing period and the tension of the screws against the bone and soft tissue.[19,24]

In 1982, Beauchesne R, Miller F, Moseley C published their article describing the technique of AO-plate application in VPFO and its application in 157 hip joint in 101 children. No postoperative immobilization or restraints were assigned to the patients. As many as 14 complications occurred in 11 patients. The use of preoperative antibiotics reduced the infection rate from 12% to 0%, which was significant. All osteotomies were healed by postoperative week 16, and there were no nonunions or problems with OM or avascular necrosis. In conclusion, the authors reported stable fixation of the bone fragments, which enabled retention of the correction in all desired planes.[11]

On the other hand, McNerney NP et al. conclude that there are some difficulties and existing trauma in the use of AO - plates in children. In addition, they report an increased risk of avascular necrosis of the femoral head with the use of this OM.[37]

James A. Webb et al. followed the clinical and radiologic outcomes after performing a VPFO in children using the Richards hip screw. In their follow-up, the authors included 72 patients in whom 81 VPFOs were performed with the Richards screw. The patients were divided into 3 groups according to their diseases: PD, DDH and CP, respectively. The mean clinical and radiological follow-up was 69 months, with a minimum of 32 months. On average, NSA decreased by 340 postoperatively, and hip migration rate decreased by 43%. The authors reported no postoperative complications, except in 1 patient who was found to have proximal fragment rotation and loosening that led to reoperation. In conclusion, they reported that the Richards screw was easy to place, relatively atraumatic, and OM , which did not require placement of a hip spica cast. To prevent loosening and rotation of the proximal fragment, the authors advised the use of an additional anti-rotation screw.[25]

Compared to AO -plates, nail-plates (Richard's screw for the Hip) are a less traumatic OM and are more familiar to most orthopaedic surgeons because of the similarities to the DHS technique, used for pertrochanteric fractures in older patients. The disadvantages of these OMs are loss of stability, risk for loss of position, and increased incidence for the use of a hip spica cast postoperatively. A simple modification of the technique, namely the placement of 1 oblique screw along the course of the neck through the superior lateral opening of the plate, results in increased stability of fixation and a limitation in the use of a lumbosacral cast postoperatively.[52]

The advantages of AO devices: the AO - plate followed by the LCP pediatric hip plate, such as accuracy of preoperative planned correction, stability of fixation, no need for cast immobilization, allowing early postoperative verticalization and ambulation, are the main driving forces that necessitate their use in recent years. These qualities are particularly pronounced in LCP paediatric hip plates, which additionally allow sparing of bone blood supply and do not impair bone fusion.

The LCP Ped hip plate system showed an improvement in fixation strength and stability through the use of locking screws , in addition to a reduction in the degree of loosening in osteoporotic bones.[27,41]

LCP plates have a low lateral profile, which prevents the problem of metal prominence seen with AO - plates.[50] It also reduces the risk of disruption of periosteal blood supply by the reduced plate-bone contact made by the locking screws.[26]

Fixation stability is another advantage of LCP plates in children with low bone mechanical properties characteristic of neuromuscular diseases, compared with the results of using angle-fixation plates in a number of follow-up studies. [41,50]

The lack of medialization and subsequent change in proximal femoral biomechanics could be considered a disadvantage of LCP plates. This disadvantage has been addressed by the use of an instrument that can be applied intraoperatively to improve hip biomechanics as described by Joeris et al. [26]

Normally, no cast immobilization is placed postoperatively after the use of LCP plates in VPFO. Several cases of postoperative complications of plaster immobilization in children with CP such as femoral fractures and decubital wounds have been described in the literature.[22,42] Avascular necrosis is another serious complication that occurs after PFO reported in the literature.[46]

In contrast, Joeris et al. did not report any cases of subsequent avascular necrosis after PFO with LCP plate in their study, which was also found by Samarah O. et al.[26,43]

Samarah et al. demonstrate that LCP Ped Hip plates are safe osteosynthesis devices for PFO fixation. The plates proved their stable fixation in osteoporotic bones. With accurate planning, appropriate sizing of the plates, and stabilization of the fragments with locking screws, minor complications are obtained with the use of this osteosynthesis implant.[43]

The main "disadvantages" of these techniques are their relatively high cost and the slow "learning curve", requiring a well-prepared and trained team of specialists to use them.

4. CONCLUSION

The most of osteosynthesis fixation materials and techniques for corrective proximal femoral osteotomies have remained of historical value. This is due to their disadvantages as well as the advances in modern implantology. Thanks to the ongoing collaborative work of orthopaedic surgeons and osteosynthesis companies, the weaknesses of the older osteosynthesis methods have largely been overcome, giving the advantage to date to the more modern ones, especially the LCP paediatric hip plates. In their face, orthopaedic surgeons engaged in this type of surgery find a reliable means of bone fixation that increases the quality and peace of mind of their work and, more importantly, the satisfaction of their patients and their families.

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