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Shortening Osteotomies for Total Hip Replacement in High Congenital Dislocation of the Hip

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ABSTRACT

Total hip arthroplasty (THA) for the treatment of high congenital dislocation of the hip is a complex and technically demanding procedure. The difficulties encountered are due to the variety of anatomic deformities seen in these patients. Morphologic alterations are seen in the acetabulum, femur and the affected side of the pelvis, as well as the soft tissues. The main difficulty remains the restoration of the hip anatomy by recognizing the true position of the acetabulum, implantation of the acetabular cup and the safe reduction of the prosthesis. This is considered essential in order to restore normal hip kinematics and achieve patient satisfaction. Femoral shortening osteotomies have been introduced to facilitate reduction, while avoiding the various complications that are caused by excessive stretching of the soft tissues, such as nerve injuries. Different type of osteotomies have been described, that can be used in the proximal, subtrochanteric or distal femur; each having unique advantages and disadvantages. Familiarity is important in selecting and implementing the proper procedure. Furthermore, awareness of potential complications is imperative in avoiding pitfalls and improving outcomes and patient satisfaction. This article reviews the various types of femoral shortening osteotomies that have been reported in the literature and describes their features along with their technical difficulties and disadvantages. Also reports our experience using the majority of those osteotomies.

KEYWORDS: High Hip Dislocation; Congenital Hip Dislocation; Total Hip Arthroplasty; Femoral Shortening Osteotomy; Shortening Osteotomy.

INTRODUCTION

Achieving proper implant placement, good functional outcomes and patient satisfaction in total hip arthroplasty (THA) for patients with high developmental dysplasia of the hip (DDH) remains a challenge. The procedure is highly technically demanding due to the extent of anatomical deformities. The affected structures include the bone anatomy

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and the soft tissues of both the acetabular and femoral side, encountering femoral deformities, canal stenosis and angulations [1-6]. Hartofilakidis has described two types of high congenital dislocation type C1 where the femoral head is migrated posterosuperiorly and articulates with the false acetabulum and type C2 in which the femoral head lies within the abductor musculature [3,4].

Typically this type of dislocation is characterized by a hypoplastic acetabulum that is narrow, shallow and severely anteverted, while there is a segmental defect of the entire rim [3]. The femoral head is small and lies on a shorter femoral neck that is usually significantly anteverted and results in a smaller femoral offset [2,7-10]. The proximal femur is shorter in these cases, with hypoplasia of the metaphysis and a valgus neck shaft angle resulting in a larger medial cortex [3,6]. The medullary canal is tapered leading to a stenotic isthmic segment and may often present with rotational deformity [2,10-12]. In several occasions the proximal femoral morphology may be further complicated by a residual angulation due to previous femoral osteotomies [3].

To achieve good results, restoration of normal hip biomechanics should be encouraged. This is accomplished by resetting the joint in its physiological position and placing the cup in the true acetabulum [13-15]. A variety of difficulties and complications have been described during these procedures that render anatomy restoration even more challenging. These are mainly due to the tightened soft tissue structures around the high riding hip which in certain situations may even make reduction impossible [16-23].

In order to overcome these challenges femoral shortening osteotomies have been described. These result in femoral shortening and facilitate reduction by reducing the stretching effect posed by contractures [23-25]. A variety of procedures has been described, all having unique advantages and disadvantages. They allow correction of severe deformities and assist in the restoration of the normal anatomy, but they introduced a series of complications that should be held into consideration [12,20,25-28]. The purpose of this article is to review the various femoral shortening procedures as an adjunct to total hip arthroplasty for high dislocation examines their technical difficulties and investigate their advantages and disadvantages.

Total hip arthroplasty considerations in high CDH

The main goal of hip arthroplasty in patients with high congenital dislocation is the restoration of the anatomic hip center. By placing the cup in the true acetabulum besides restoration of normal anatomy, leg length discrepancies may be balanced, while there is restoration of hip biomechanics, improvement in abductor musculature strength and eventually in the gait [13-15]. By restoring hip biomechanics enhanced durability and decreased aseptic loosening and failure rates are expected promoting long-term survival and leading to good long term results [14,29-32].

Directly reducing the hip in the true acetabulum often requires extensive force and will pose excessive stresses to both the bone and soft tissues [16-23]. The resulting lengthening may lead to several implications such as limb length inequalities and nerve injuries. Lengthening of the limb by > 2 cm often causes abnormal gait, while > 4 cm increases the risk for nerve injuries which have been reported ranging from 0.8% to 11.3% [16-22,33]. Furthermore tightness due to stretching of the periarticular soft tissues such as the abductors, may subsequently lead to joint stiffness and implant loosening [23].

These difficulties are further complicated in Hartofilakidis C2 type of dislocation where the femoral head is migrated approximately 18mm higher than in C1 types [34]. In addition it has been demonstrated by Xenakis et al. in their study employing CT scan measurements, that almost half of the patients with unilateral and bilateral dislocation have a longer leg in the affected side. A longer extremity leads to higher stresses in the soft tissues during reduction increasing the possibility of complications, patient dissatisfaction and legal implications [35]. Thus it becomes clear that there is a need to equalize limbs and reduce stresses in order to avoid traction injuries when restoring the normal hip anatomy.

Addressing the problem

A variety of techniques have been employed with success in assisting with the restoration of hip anatomy. Femoral shortening osteotomies are historically the most commonly used solution to solve the problem of leg length inequality protecting from nerve injuries and facilitating reduction [23-25]. These involve shortening of the femur to decrease reduction stresses and control length while also allowing for correction of rotational deformities [36-38]. They can be performed in various levels such as the proximal femur, subtrochanteric region, mid shaft or distal femur [5,26,36-41]. There is no general consensus regarding the choice of osteotomy and typically authors select their method depending on their experience [36,42,43]. Subtrochanteric types of osteotomies have all been used with success, while they are generally preferred than other osteotomy planes [13,26,33,36,43,44].

Types of shortening osteotomies

Proximal femoral osteotomy: A method to achieve femoral shortening has been described by Paavilainen, which involves either the resection of the proximal femur coupled with a trochanteric slide osteotomy or a segmental metaphyseal resection depending on the deformity [21]. In general the resection level is decided after preoperative planning depending on the required lengthening. The stem is chosen based on the shape of the femur distal to the osteotomy. The femur is cut in the metaphysis distal to the tip of the greater trochanter and the medial part is removed. If the soft tissues are tight a more distal resection may be required than anticipated. In such cases the distal transfer of the greater trochanter is performed. Following placement of the prosthesis, the greater trochanter is concavely shaped and is advanced distally on the diaphysis in order to tighten the abductor muscles.

The tendinous part of the gluteus medius may need to be released to facilitate the distal trochanter slide. Fixation of the greater trochanter is performed using screws to reduce the risk of non-union, while the stem acts as an intramedullary nail to stabilize the osteotomy [45]. Using this method lengthening of the limb may be possible for up to 5 cm. This type of resection can be performed in hips with a previous high Schanz osteotomy. The resection is usually performed at the level or below the previous Schanz osteotomy. Patients that were previously treated with a low Schanz osteotomy need special consideration, as this method may not provide sufficient lengthening. In these cases a metaphyseal segmental resection of the angular part of the previous osteotomy can be performed. The resection levels estimating length and rotational corrections are preoperatively planned and the osteotomy is performed in a step cut manner in order to be rotationally stable. In such cases a long stem may be necessary and the osteotomy should be optimally at the level of the porous coating. Metaphyseal segmental resection generally limits lengthening to 3 cm.

Proximal femoral osteotomies have been shown to overcome the difficulties posed by the high dislocated hip and allow for correction of remaining deformities by preceding procedures. However, there are several disadvantages coupled with such procedures. The amount of proximal resection markedly reduces the metaphyseal bone stock rendering the use of cementless components unsuitable [46]. Furthermore, when considering that candidates for total hip arthroplasty in this patient group are more likely to be younger active individuals, the use of cemented components is a particular issue that may lead to failure of the components [47]. In addition prosthetic loosening in this age group has been reported relatively high, and an insufficient bone stock may compromise further operations [46,48,49]. Another disadvantage tied to these procedures is the inherent risk of trochanteric non-union due to abductor muscle pull and insufficient bone bed at the site of fixation [40]. This danger is particularly high in cases of high dislocation where the abductor mechanism is fixed under sufficient tension [45,50].

Subtrochanteric osteotomy

The disadvantages of the proximal femoral osteotomy led to the popularization and more frequent use of the subtrochanteric osteotomy. These osteotomies allow shortening of the femur and restoration of rotational deformities, while they have been used with success to correct angular deformations [13,23]. Frequently used types of subtrochanteric osteotomies include the transverse, oblique, step cut and double chevron (V-shape) [13,21,23,26,30,36,40-42,51-55].

When compared to the proximal femoral osteotomies these remove the least amount of bone while they are mostly performed at the level of the deformity [13]. They thus preserve the precious metaphyseal bone stock and allow the use of cementless components. On the other hand, subtrochanteric osteotomies have been blamed for violating the proximal femoral anatomy, rendering problematic the use of a modern taper stem with proximal fitting. A transverse subtrochanteric osteotomy is relatively easier and technically simpler than a V-shaped or a step cut, but the latter have more torsional stability allowing the use of a shorter stem [13,56].

Transverse subtrochanteric osteotomy

Following the exposure to the hip the first osteotomy is performed in these cases in the femoral neck according to preoperative planning. Preparation of the femoral canal with reaming or broaching is than performed [52]. Exposure to the subtrochanteric area is achieved through splitting or elevating a part of the vastus lateralis [44]. A drill hole is made as a marker in either side of the osteotomy to ensure proper rotation. The first transverse subtrochanteric osteotomy is performed about 2 cm to 3 cm distal to the lesser trochanter. A prophylactic cerclage wire is applied to the proximal and distal femoral fragment then the trial femoral component is placed

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in the proximal femoral fragment and reduction is performed. If reduction is not achieved, either release of soft tissues or repeating the femoral neck osteotomy and impacting the implant deeper in the metaphysis may help resolve the issue [44]. Gentle traction is then applied to the distal femur and the amount of bone that overlaps the two femoral fragments corresponds to the required amount of shortening [52]. The second osteotomy is performed and the distal fragment is prepared with reaming or broaching in case the distal part of the stem is not accommodated easily. Press fit at the distal fragment is essential for rotational stability. The reduction of both fragments follows. A 6 to 7 holes plate with unicortical screw osteosynthesis is used to secure rotational stability of the two fragments.

Fixation can be augmented at the site of the osteotomy with strut autografts and wires by using the fragments of the osteotomized femur [43,44]. Morselised bone graft from the reaming can also been used to augment and enhance union of the osteotomy. In case where longer stems can be used they can act as intramedullary nails [50,57]. The transverse type of resection offers the smallest contact area than other subtrochanteric osteotomies but it is easier to perform and may offer a more uniform contact [58]. Nonetheless bone cutting blocks are available, and can be used in order to assist in obtaining parallel and proper osteotomies.

Oblique subtrochanteric osteotomy

Femoral osteotomy with this technique is achieved through two oblique cuts. This procedure was initially described by Reikeras as an alternative to the original transverse osteotomy that could provide higher torsional stability [22]. Following placement of the acetabular cup, the femoral canal is sequentially reamed to the desired size. The proximal cut of the osteotomy is performed in an upwards lateral direction at approximately 45° to the longitudinal plane and 1cm distal to the lesser trochanter. A second cut is performed distal and parallel to the first. Both fragments are reduced using a trial component [22]. The osteotomy site can be secured with cables although it may not be required [59]. Our preferred method of fixation is plate with unicortical screws, which adds to the stability of the construct and it is relatively easy to perform. If the osteotomy is not congruent morselized bone can be used for augmentation.

Step-cut subtrochanteric osteotomy

This procedure achieves femoral shortening with a Z shaped or step-cut osteotomy following preparation of the femur with reamers and broaches. The osteotomy comprises of one longitudinal cut that is placed in the middle of the femur and two half transverse cuts [23]. The proximal cut is on the lateral side of the femur and the distal cut lies on the medial side [23]. Preoperative planning is important to assess the amount of shortening and plan the cuts. The distance between the lesser trochanter and the medial transverse cut should be about 2 cm to 5 cm. While the amount of shortening can be calculated by subtracting, 3 cm to 4 cm which is a safe amount for a high dislocation to be reduced, from the original distance of the head above the true acetabulum [23]. Femoral derotation can be performed with this technique but requires additional steps [23]. In cases of severe anteversion, a rasp is positioned in the desired anteversion and a proximal longitudinal half cut is performed in the midline. Then a second distal longitudinal half cut is performed in the midline after the femur is rotated externally and the patella is in neutral position. These two osteotomies are rotated on their axis to correct the rotational deformity.

Correction of angulation deformities is possible such as after a previous Schanz osteotomy. Typically fixation is achieved with insertion of the stem and it is secured with cable or cerclage wires [23]. Additional plate fixation is usually not required [5,23]. These osteotomies have great rotational stability they provide, however, inferior press fit contact and the stem may subside into varus [40]. Thus the osteotomy must be congruent circumferentially [37,57,60]. Another advantage is the high contact surface that is directly related to the length of the longitudinal cut. It is however technically demanding to perform and may not achieve proper contact [58].

Double Chevron (V-shape) subtrochanteric osteotomy

This technique employs a double V-shaped osteotomy to achieve shortening. After the initial exposure this technique requires a trochanteric osteotomy in order to access the acetabulum, as was originally described by Becker and Gustillo [13]. A femoral neck osteotomy follows. When the acetabular cup is properly seated, preparation of the femur is performed with reamers and broaches followed by exposure of the anterior part of the proximal femur. The osteotomy is then centered anteriorly if no derotation is required or laterally if it is necessary [13].

The tip of the osteotomy is located approximately 3 cm distal to the lesser trochanter and around 1 cm proximally than its distal limbs essentially forming a 180° mirrored "V". A distal similar

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osteotomy is marked at the required shortening length. A line is marked connecting the two apexes and multiple drill holes are made along the lines previously marked. The osteotomy is separated with an osteotome proximally then distally and along the midline [13]. The proximal and distal fragments are approximated and impacted with the rasp in place. The intercalary fragments are placed over the osteotomy site and secured with cable wires. The procedure is concluded with proper tensioning of the abductor mechanism and greater trochanter fixation [13]. A double chevron technique provides a larger surface area for fixation potentially reducing non-unions while its shape facilitates reduction [61]. It is however technically difficult to perform in order to achieve congruence among the fragments. The use of specially made devices such as cutting blocks may allow to perform accurate cuts and a more congruent osteotomy [62].

Distal femoral osteotomy

Distal femoral osteotomy as an adjunct to hip arthroplasty for high congenital dislocation has been initially described by Koulouvaris et al [38]. Their approach utilized a traditional diaphyseal transverse osteotomy distal to the stem. The level of the osteotomy is related to the length of the used plate in that the first screw of the plate must be at least 2 cm from the stem. This osteotomy can be used to simultaneously correct knee valgus deformities if necessary [38]. Intraoperative correction of such deformities is possible by adjusting the shape of the resection. In these cases, an osteotomy is performed in the supracondylar area, as in the case of correcting the valgus knee. It is performed with the typical open wedge technique. Following reduction the osteotomy is secured either with a limited contact plate and screws, or a blade plate. Modern supracondylar anatomical plates can also been used for valgus knees [38]. This technique avoids the pitfalls of the proximal and subtrochanteric osteotomies when considering non-union, intraoperative fractures while being relatively simple and achieving good fixation [38]. Reduction of the hip joint is somehow laborious with this type of osteotomy. Another disadvantage is the need for a second approach increasing the amount of trauma.

Biomechanical studies

Stable fixation at the site of the osteotomy is of great importance in order to avoid potential pitfalls, such as fractures of the fragments, femoral stem instability, poor stem fixation or osteotomy non-unions [63]. Several studies have examined the various factors that may affect the quality of fixation, as the geometry of the cut, type of fixation and stem structural characteristics [63-67]. Step cut and oblique osteotomies have been regarded as superior to other types with respect to rotational stability [23,30,37]. This has also been demonstrated by Cascio et al, who reported that the transverse osteotomy is inherently weaker in torsion while resistance depends solely on the type of fixation [64]. In their study, however, the increase in torque for the step cut was approximately 10% higher than the transverse and the existence of stress risers was established.

The presence of a stress riser in the osteotomy may lead to either bone resorption areas or propagate cracks that will lead to failure of the fixation [64]. These stress risers have been recognized to be the points where the transverse and longitudinal cuts meet [64]. This is consistent with previous reports, while a similar pattern was noted in a recent study [63,68]. In that study stress risers formed and cracks propagated in all non-grafted subjects and in two subjects from the cable and strut grafting group [63].

This may be indicative that extramedullary stabilization may be required to avoid failure of the constructs. Nevertheless, they concluded that strut graft and cable fixation did not have a significant contribution to stability although the former had higher stiffness values than the latter [63]. Another study examining the hypothesis whether transverse osteotomies require further extramedullary fixation demonstrated that stability was related to the cross sectional geometry of the prosthesis; and that there is no need for additional extramedullary support as strut grafts, cables or z-osteotomies [58]. This partly explains the common belief that cylindrical stems with higher friction area have better stabilizing characteristics. These types of stems when combined with a step cut osteotomy may enhance stability at the site of resection [23,30,37]. This effect has been recently examined in a biomechanical study and the authors concluded that in the clinical setting neither osteotomy type nor prosthetic design was superior to another [69]. Despite their conclusion, some individual significant data was noted which however was not deemed clinically important. Their data and conclusion was consistent with another biomechanical study that compared 4 different types of osteotomies [63]. They noted however that when cyclic loading was applied the mean stiffness was higher in the oblique osteotomy group than the step-cut group when a conical prosthesis was used [69]. They believe the reason for the significant difference in mean stiffness between groups was the higher failure loads of the oblique osteotomy groups. Furthermore higher stiffness values were noted for the conical

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prosthesis versus the cylindrical prosthesis without the difference being significant; a finding that may suggest that the latter is not superior as previously thought [22,30,70]. In addition, other authors reported that a cylindrical stem provides better stability than a rectangular tapered stem [67]. This controversy noted among studies although they all agree that neither prosthetic design is superior to another, is probably related to the individual prosthetic design; while another factor that has been exhibited to be able to influence stability is a larger implant cross sectional area at the level of the resection 63. Nevertheless previous reports demonstrated good results with both prosthetic designs [22,40,58,71].

Osteotomy vs non-osteotomy

Two recent studies sought to compare the outcomes of total hip replacement for high dislocation with and without femoral osteotomy [72,73]. In the osteotomy group a transverse subtrochanteric technique was performed. In both of these studies there was an increase in the functional score after the operation. In one study functional score improvement was slower in the non-osteotomy group when compared to the osteotomy group [73]. They attributed slower rehabilitation to soft tissue tightness, which improved considerably during the last follow up. There was a significantly shorter operative time and lower blood loss in the non-osteotomy group in both studies. In the first study, 17.24% of the patients in the non-osteotomy group had an intraoperative fracture and 47.37% in the osteotomy group [72]. In the second study there was only one intraoperative fracture in the osteotomy group accounting for 5% of total [73]. All fractures healed without compromise in both groups. There was only one delayed union of the osteotomies noted, while the rest healed fully [73]. Nerve injuries were noted in both studies, which occurred at the non-osteotomy group. Two femoral nerve injuries (6.90%) were noted in the first study [72]; while three patients (13.64%) were found to have femoral nerve palsies in the second study [73].

Regarding limb length both studies recorded higher postoperative discrepancies in the osteotomy group. One study noted that the non-osteotomy group had fewer patients with > 2 cm length discrepancy, which could potentially cause abnormal gait than the osteotomy group [72]. The other study noted that while the initial lengthening was more in the non-osteotomy group, the discrepancy at the last follow up was considerably lower than the osteotomy group [73]. This initial lengthening is thought to be due to pelvic obliquity that when tissue tension decreased, there was a decrease in the discrepancy [73]. They both concluded that satisfactory results were achieved with either approach while each had its unique advantages and disadvantages, such as operative time, extent of tissue trauma, type of complications, rehabilitation [72,73]. Thus non-osteotomy THA can be considered in cases were lengthening is less than 4cm and is related to fewer intraoperative fractures, lower operative time and less blood loss and potentially fewer patients with postoperative limp. However, it is technically more difficult to perform than a transverse osteotomy and may lead to more nerve injuries while it may require a markedly increased rehabilitation [72,73].

Complications

Several complications have been described that are related to the femoral shortening osteotomies. One of the most important complications reported is intraoperative fracture due to manipulation during stem insertion [20,25,26]. The prevalence reported in the literature and ranges from 5% to 22% [16,20,25,26,44]. The unique anatomy of the femur with the stenotic femoral canal plays an important role in this part as it is quite narrow at the distal femoral opening. At the point of stem insertion fissures may develop that will propagate to the shaft [16,26,37,41,74-76]. A useful strategy in these cases is the reinforcement of the distal femoral insertion with a cerclage wire [44].

Another major complication is the non-union at the site of the osteotomy ranging around 2.8% to 29% [12,19,28,55]. Many factors contribute in osteotomy site healing, such as contact area and stability, periosteum status and the type of bone. Stability is one the major causes as movement across the site of the osteotomy may lead to nonunion [64]. This may happen when the strain at the junction exceeds minimal induction strain which is required for healing, which subsequently leads to bone resorption in order to reduce the strain [64,77]. In this regard a uniform contact should be sought to avoid abnormal loads around the geometry of the osteotomy, while a larger contact area may increase healing potential [64,78,79]. Periosteal stripping may occur at the time or resection which may affect periosteal osteoblastic activity [80]; while care should be taken to avoid stripping the blood supply during exposure of the proximal femur, which may promote healing of the osteotomy [44].

Non-unions and fractures at the level of the osteotomy may lead to stem subsidence and varus angulation [26,36,40]. This will eventually affect the rotational stability of the construct

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leading to potential failure and subsequent pain [26,36,40]. These issues can be decreased by careful and proper implant positioning and stable fixation. Furthermore, a tendency in bringing the stem into varus has been reported with step cut osteotomies, due to inferior press fit [40]. In order to avoid such complication complete stem contact must be achieved [37,57,60].

Nerve injury is another complication, which despite shortening osteotomy can still occur [19,28,55,81]. The reported incidence ranges from 5% to 11.3% [19,22]. The offending mechanism in these cases is still excessive stretching. It is generally reported in the literature that acute limb lengthening 2 cm to 4 cm increases the risk for nerve injuries [16,24,33,75,82,83]. Other factors may be associated with nerve damage as has been previously demonstrated, such as trauma either direct or indirect, the operative approach and the time of operation [84].

Vascular injuries although quite rare may still occur [85,86]. However, there is no substantial information in the literature regarding vascular injuries in THA for congenital hip dislocation. Nevertheless vessel injuries may result from a variety of causes such as direct damage from misplaced retractors, protruding screws or extraction of components [87,88]. Dupark classified injuries occurring during THA as penetrating trauma, pressure trauma and also mentioned injuries occurring due to elongation or torsion [89]. The latter may typically occur during forceful reduction maneuvers as is the case with high congenital dislocation. Although typically osteotomies decrease the required force and manipulation effort to reduce the hip, contractures around the hip still have to be taken into consideration which may lead to undesired stresses and potentially such injuries [16-23].

Limb length discrepancy is also common complication following femoral osteotomies. This procedure may result in significant shortening of the operated leg [27]. This is mainly due to the amount of resection required to reset the joint. Preoperative planning and less than planned resection or successive resection may reduce the risk of excessive shortening by keeping the resection to a minimum [59].

CONCLUSION

Total hip arthroplasty in patients with high congenital dislocation is a complex and technically demanding procedure. Surgical skills and experience team work is needed. The unique challenges set by the deformed anatomy can be overcome with careful preoperative planning and preparation. Femoral osteotomies allow the correction of such deformities, and help avoid certain complications. Their use comes with great advantages but also with several disadvantages which can be avoided with careful implementation and experience, while several osteotomies require higher surgical skills. In conclusion femoral shortening osteotomy is a feasible procedure that can produce good outcomes when properly executed.

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