Fixation Systems of Greater Trochanteric Osteotomies: Biomechanical and Clinical Outcomes

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Abstract

The development of cerclage systems for fixation of greater trochanteric osteotomies has progressed from monofilament wires to multifilament cables to cable grip and cable plate systems. Cerclage wires and cables have various clinical indications, including fixation for fractures and for trochanteric osteotomy in hip arthroplasty. To achieve stable fixation and eventual union of the trochanteric osteotomy, the implant must counteract the destabilizing forces associated with pull of the peritrochanteric musculature. The material properties of cables and cable grip systems are superior to those of monofilament wires; however, potential complications with the use of cables include debris generation and third-body polyethylene wear. Nevertheless, the cable grip system provides the strongest fixation and results in lower rates of nonunion and trochanteric migration. Cable plate constructs show promise but require further clinical studies to validate their efficacy and safety.

Osteotomy of the greater trochanter in primary total hip arthroplasty (THA) was strongly advocated by Charnley,[1,2] who observed that it allows for proper hip abductor muscle tensioning and improved hip stability. With the advent of modularity in hip arthroplasty implants, the ability to adjust offset and femoral length with the implant itself allowed for adjustment of soft-tissue tension about the hip without the need for trochanteric osteotomy. In complex primary[3-5] and revision hip arthroplasty,[4-8] however, the need for improved hip joint exposure is facilitated by trochanteric osteotomy.[9] Following the osteotomy, a stable, rigid fixation must be achieved to facilitate union of the bony fragment.

Trochanteric osteotomy fixation systems include monofilament wires, multifilament cables, and cable grip systems. The effectiveness of a wire or cable system in counteracting the destabilizing forces that affect the reattached trochanter depends on the biomechanical properties of the system and its components; these components include fatigue resistance, maximum load capability, and the compressive forces generated by the system. Complications associated with trochanteric osteotomy include wire or cable breakage (Figure 1), debris generation that can result in third-body polyethylene wear, trochanteric fragment migration, and nonunion.

Despite fixation, proximal migration of the osteotomized segment can occur from the contractile activity of the hip abductors (gluteus medius and minimus muscles). Charnley[1,2] showed that the abductors primarily exert shear forces when the hip is flexed and that their proximally directed vector component is a secondary one. These shear forces can be greater than four times body weight and are of paramount importance in the activities of daily living, such as climbing stairs and rising from a chair.[9,10]

Wire Fixation

Systems for reattaching the osteotomized trochanter are conventionally categorized as first, second, or third generation. First-generation monofilament surgical wires have long been used for osseous fixation,[11-13] including fixation of greater trochanteric osteotomies in THA. However, monofilament wires tend to kink during application, compromising the biomechanical integrity of the implant; thus, breakage and loss of trochanteric osteotomy fixation were common, leading to the development of new cerclage systems.[10,14-24]

Various wiring techniques have been described that differ in their ability to resist displacement forces following trochanteric osteotomy. Markolf et al[24] examined displacement as a function of abductor pull, using a device to simulate the proximal pull of the hip abductors on the greater trochanter and the cerclage system. In their comparison of types of wiring techniques, they determined that the Charnley[25] (Figure 2) and Harris[26] techniques resulted in greater resistance to motion, exhibiting a displacement of only 0.7 mm after the third loading cycle, whereas the Amstutz[27] and Coventry[28] techniques had two to three times greater displacement.

Bostrom et al[11] examined the maximum load capabilities of 16- and 18-gauge wire using three different types of knotting techniques (Figure 3). Loaded at a rate of 50 mm of outward strain per minute, the 16-gauge wire failed at a mean of approximately 1,300 N for the square knot and knot twist versus approximately half that value for the uniform symmetric twist method. Results for the 18-gauge wire showed failure rates at a mean of approximately 950 N for the square knot and knot twist versus approximately half that value for the uniform symmetric twist knot[11] (Table 1). These findings confirm that the ultimate strength of the wire construct was primarily dependent on its diameter and on the type of knot used. When wire is to be used for fixation, 16-gauge wire should be utilized, secured with a square knot or knot twist.

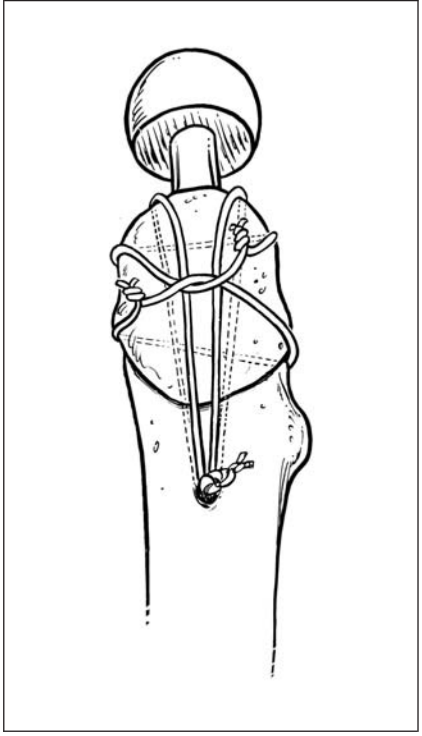
Analysis of studies conducted between 1978 and 1993 reveals an overall wire breakage rate of 22% in 2,910 THAs using various wiring techniques[21,23,26,30-33] (Table 2). Clinically, wire breakage is most often associated with revision surgery,[21] uniplanar osteotomies, simple wire configurations, and cases of trochanteric nonunion. Boardman et al[32] reported that 79.2% of patients with trochanteric nonunion in their study had broken wires. Harris and Crothers[26] evaluated 136 THAs in which none of the trochanters migrated and all united; the wire breakage rate was only 2%.

Trochanteric migration as a result of wire loosening or breakage is a significant complication that can lead

Figure 1

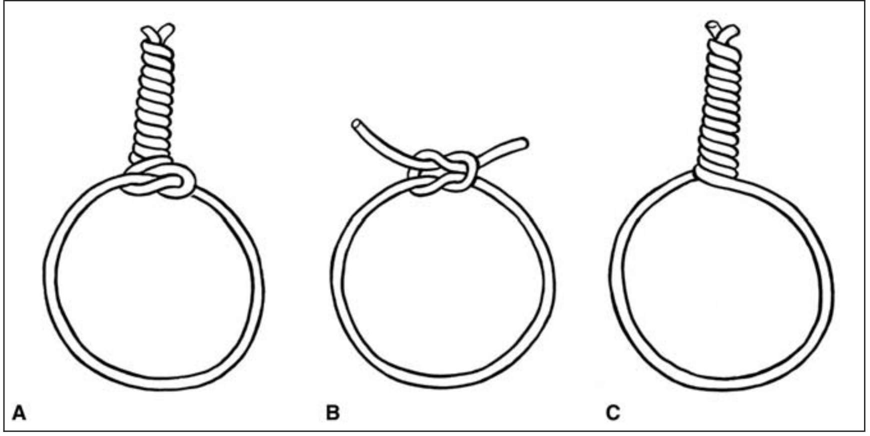
Anteroposterior radiograph demonstrating broken trochanteric fixation wires.

Figure 2



The Charnley wiring technique. The ends of a looped wire are inserted in a hole drilled in the lateral femoral cortex, distal to the edge of the trochanteric osteotomy and below the abductor tubercle. The two ends are passed proximal to the trochanter and through the hip abductor musculature and are finally locked by passing through the eye of the loop. Two transverse wires are placed in the anteroposterior direction via drill holes, one in the proximal femur next to the trochanteric bed and the other in the lesser trochanter. The two wires are crossed during tightening, which results in progressive reduction in slack with each twist.

Figure 3



Knotting techniques. **A,** Knot twist. **B,** Square knot. **C,** Symmetric twist.

to loss of mechanical advantage of the hip abductors. Amstutz and Maki[31] reported a 4.9% trochanteric migration rate in 728 consecutive THAs using a cruciate two-wire technique. They attributed trochanteric migration to osteoporosis and to technical error (eg, small size of the osteotomized trochanteric fragment, poor apposition of bone surfaces, too much contact with acrylic or cortical bone instead of cancellous bone, failure to tighten the wire loops adequately). Rates of trochanteric migration decreased with time as the surgeons modified their technique. In a subsequent study, 712 THAs were evaluated using the same wiring technique with some modifications; the modifications included osteotomy of the trochanter below the trochanteric ridge, advancement of the trochanter, and abrading of the osteotomy surfaces before reattachment.[27] The authors reported a 3.23% rate of trochanteric migration and found an association between this phenomenon and previous osteotomy, osteoporosis, and poor surgical technique.

Clarke et al[23] reviewed 277 THAs with trochanteric osteotomy fixation using multiple cerclage wires. Trochanteric migration was associated with "severe debility" of the spine or the contralateral hip; the authors attributed fixation failure to patient inability to observe "trochanteric" precautions. Following fixation of the trochanter, the patient should avoid abduction exercises after surgery and adhere to strict postoperative hip precaution protocols.[37] No association with trochanteric migration was found with osteoporosis, previous surgery, age,

Table 1

Properties of Wires and Wiring Techniques

Source	Wire Gauge	Wiring Technique	Fatigue Resistance (N)	Maximum Strength (N)	Compressive Force (N)
Bostrom et al[11]	16	Twist	156	679	—
		Knot twist	356	1,259	—
		Square knot	356	1,357	—
	18	Twist	222	480	—
		Knot twist	400	938	—
		Square knot	400	961	—
Hersh et al[17]	16	Charnley	—	1,380 ± 402	—
Shaw and Daubert[29]	18	Square knot	—	966 ± 7*	17 ± 2*
		Modified square knot	—	790 ± 26	134 ± 9
		Knot twist	—	798 ± 13	115 ± 21
		Twist knot	—	540 ± 24	90 ± 11
		Clinical twist knot	—	494 ± 7	41 ± 9
	20	Square knot	—	682 ± 6	19 ± 2
		Modified square knot	—	543 ± 28	88 ± 10
		Knot twist	—	537 ± 13	46 ± 7
		Twist knot	—	344 ± 7	56 ± 4
		Clinical twist knot	—	344 ± 14	10 ± 3

* All values in Shaw and Daubert[29] were reported in kilogram-force (kgf) and are here converted to N and rounded off.

Table 2

Wire Breakage Rates In Vivo

Source	Number of Total Hip Arthroplasties	Surgical Technique	Wire Breakage Rate	Trochanteric Nonunion
Clarke et al[23]	277	Uniplanar osteotomy	33.2%	9%
Berry and Müller[30]	53 primary, 74 revision hip arthroplasties	Chevron osteotomy with single-wire technique	19% of primary THA, 18% of revision THA	2% in primary and 3% in revision hip arthroplasties
Amstutz and Maki[31]	728	Cruciate 2-wire technique	77%	17%
Harris and Crothers[26]	136	2 horizontal and 1 vertical wire configuration	2%	2%
Boardman et al[32]	1,020	Cruciate: 1 double vertical and 2 crossed horizontal	9%	79.2% of trochanteric nonunion associated with wire breakage
Wroblewski and Shelley[34]	226	Double crossover wire compression spring	4%	None reported
Jenson and Harris[35]	804	2 vertical and 1 transverse	28%	Primary, 1% nonunion; revision, 0% nonunion
Bernard and Brooks[22]	59 revision hip arthroplasties	2 longitudinal and 1 circumferential or transverse; 1 longitudinal and transverse	9%	31%
Schutzer and Harris[21]	188	4-wire configuration had the lowest incidence of wire breakage	27%	79% of the trochanteric osteotomies had healed
Nercessian et al[36]	214	Biplanar osteotomy associated with decreased wire breakage	Overall breakage rate, 14%; 7.3% with biplanar osteotomy, 19% with single-plane osteotomy	6.4% in the biplanar group, 6.2% in the single-plane group

weight, sex, or underlying joint disease process.

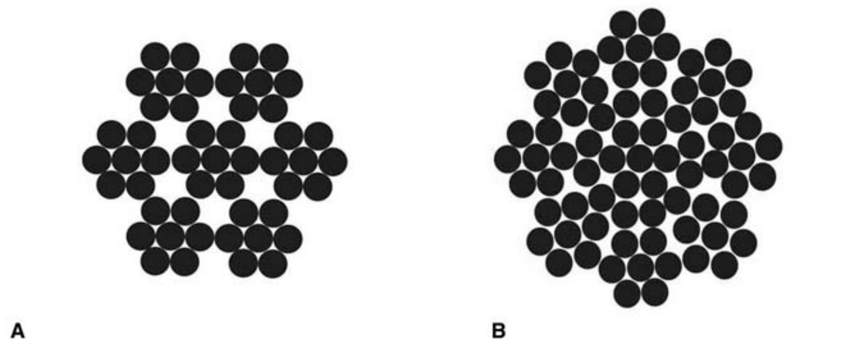
Nonunion after greater trochanteric osteotomy using wires alone in primary THA occurs at rates ranging from zero to 7.9%.[26,31,32,34,35,38,39] Such nonunions have been correlated with male sex, rheumatoid arthritis, and revision surgery,[39] but not with osteoporosis.[27] Rates of incidence of pain ($P < 0.001$), limping ($P < 0.001$), femoral component loosening ($P < 0.005$), and revision of existing components ($P = 0.0225$) were significantly greater in the group with nonunions, and Charnley hip scores were significantly ($P < 0.001$) lower.[39]

Important technical factors leading to trochanteric nonunion include limited surgical experience, small size of the osteotomy fragment, wires wrapped around the lesser trochanter, poorly tightened wires, and reattachment of the trochanter to a primary acrylic bed.[21,27,32] Boardman et al[32] also noted an increase in the rate of nonunions when the primary surgeon was a resident instead of an attending surgeon.

Studies of the association between other factors and trochanteric nonunion have not revealed any significant difference with regard to type of osteotomy[36] or wiring technique.[30]

The great majority of THAs in which trochanteric osteotomy is used are revision THAs. Schutzer and Harris[21] examined 188 revision THAs in which wires were used for trochanteric reattachment; they noted 3% nonunions and 4% delayed unions. Technical errors (eg, reattaching the trochanter directly to cement, poor wire or mesh placement)

Figure 4



Multifilament cable system configurations. **A,** 7 × 7. **B,** 19 × 8 × 7.

were causes for most of the nonunions. In a review of 59 cases of THA with trochanteric osteotomies that required revision, Bernard and Brooks[22] found that all nonunions that underwent additional revision with wires failed to unite after the second revision; pain was relieved in less than half of these THAs. Hodgkinson et al[40] examined 59 revision THAs performed before and after the implementation of the crossed-wire configuration using a compression spring; these authors reported a significantly ($P = 0.001$) higher rate of union using the compression spring.

Although the use of wires has decreased with the availability of cable and cable grip constructs, there are still situations in which they may be preferred. Some authors are hesitant to use cables because of the incidence of cable fraying and generation of debris. During revision for cables that have frayed, it may be necessary to use wires to avoid further debris generation that could lead to third-body polyethylene wear. When wires are to be used for trochanteric fixation, the literature supports the use of multiple wires in at least two planes, such as with the Charnley and Harris techniques. The wires should be 16-gauge and fixed with a knot twist or square knot technique. If cement is used, an effort should be made to realign the trochanter so that there is bone-on-bone contact and only limited contact with the cement mantle. The bone edges should be abraded before fixation, and the wires should be checked for sufficient tightness.

Several of the authors cited above have stated the need for proper surgical technique and patient selection when using wire constructs. These conditions may be more important than the type of fixation used. Wires should be used with caution in patients who have had prior failure of wire constructs.

Cable Fixation

Second-generation multifilament cables were first used for trochanteric reattachment in 1977 by Dall and Miles.[10] Whereas monofilament wires are made only of stainless steel or cobalt-chrome alloy, multifilament cables are also available in titanium. Cables are constructed in several configurations—for example, 8 bundles of 7 monofilament strands surrounding a central bundle of 19 monofilament strands, or 7 bundles of 7 monofilament strands (Figure 4). The material composition of these cables and their configuration have combined to offer more resistance to deforming forces and provide better compression at the osteotomy site.[10,14-22]

Clinical studies have compared cable fixation to the more traditional wiring techniques.[41-43] MacDonald et al[42] evaluated 45 extended trochanteric osteotomies performed in revision THAs at a minimum 2-year follow-up and found a mean of 2.8 mm of trochanteric migration with the wire configuration and 0.3 mm with the cable technique, a difference that was statistically significant ($P = 0.025$). Studies of cable[43] and two-plane cable[41] constructs have reported no trochanteric migration in the early postoperative period.

Maximal compression perpendicular to the plane of the osteotomy minimizes both shear and rotational deforming forces. Shaw and Daubert[29] examined the compressive forces generated by wire and cable cerclage systems. They showed that titanium cables achieved mean compression forces of 260 N, compared with a range of 11 to 136 N for the 18-gauge wire and 10 to 89 N for the 20-gauge wire, depending on the type of knot used (Tables 1 and 2). Compared with wires, multifilament cables provide a stronger construct at the osteotomy interface.

Cables cannot be used in the same fashion as monofilament wires. Whereas wires can be tied into tight knots and tend not to unravel, cables cannot be tied into a secure knot; the cables will unravel, and fixation will be lost. To solve this problem, cable sleeves are used. The cables are threaded through the sleeves and tensioned, and then the sleeve is crimped to hold the fixation. In addition, cables should not be crossed. Some micromotion will occur between the crossed cables, which will cause debris generation and potential third-body wear. Finally, the cables do not hold fixation as well when threaded through a cement mantle.

Even when placed properly, however, there is still a significant rate of complications accompanying the use of cable systems. Kelley and Johnston[33] evaluated 322 THAs in the early 1990s; they found a 12%

wire breakage rate and a 43% cable breakage rate. They also reviewed the results of wire fixation and cable fixation; nonunion rates were 15% and 8%, respectively. In contrast, Hop et al[15] found an opposite trend in nonunion rate between cable fixation (19.7%) and wire fixation (14%). Despite the conflicting results, both studies advised against the use of cable-only constructs because of potential complications related to metal debris. For these reasons, and because of the development of the cable grip systems, the cable-only construct is generally reserved for repair of an extended trochanteric osteotomy.

Table 3

Properties of Cables and Cable Grips

Source	Cerclage System	Maximum Strength (N)
Hersh et al[17]	Cable	1,300 ± 402
	Cable grip	1,900 ± 459
McCarthy et al[14]	1.6-mm cable	2,400
	2.0-mm cable	2,800
Shaw and Daubert[29]	Titanium cable	1,027 ± 15*

* Reported in Shaw and Daubert[29] in kilogram-force (kgf) and here converted to N and rounded off.

Cable Grip Fixation

Dall and Miles[10] introduced the third generation of fixation, a trochanteric grip system consisting of an H-shaped gripping apparatus that supplements the multifilament cables. These grip constructs were reported to be better than wires and cables at capturing the greater trochanter and resisting peritrochanteric destabilizing forces, thus preventing trochanteric escape.[10]

The Dall-Miles cable grip system using 1.6-mm cables was initially reported to have a 6.2% breakage rate; after the authors switched to 2.0-mm cables, this rate was reduced to 3.1%.[10] They also found that cable breakage was not seen after bone union. The results of numerous follow-up studies using the Dall-Miles cable system have varied according to surgical technique. Ritter et al[20] reported a 32.5% cable breakage rate when the cables were threaded through the cement mantle of the femoral prosthesis, and Silverton et al[18] experienced a 22% cable breakage rate. McCarthy et al[14] reported a 10% cable breakage rate with no significant difference between cases with stainless steel and Vitallium cables. When assembling the cable grip constructs, these authors[14] varied the placement of the cable through the bridge in the grip. The cable was either pulled through the anterior side of the grip and around the medial aspect of the proximal femur, or it was pulled through the posterior side and around the lateral aspect of the bone. They found that cables positioned posterolaterally broke approximately 23 times more often than did those placed anteromedially.

Hersh et al[17] compared the relative strengths of orthopaedic wires, cables, and the cable grip system under quasistatic loading conditions (Tables 1 and 3). The cable grip systems withstood 1.5 times the maximum load of the cable or wire alone. The loads required to induce 1- or 2-cm trochanteric displacements also were examined. The cable grip system required almost twice the load of the cable or wire alone to cause a 1-cm displacement (1,397 N versus 771 N and 757 N, respectively) and 2 to 2.5 times the load of the cable or wire to cause a 2-cm displacement (1,900 N versus 757 N and 1,100 N, respectively).

The cable grip system also is associated with certain complications. Dall and Miles[10] reported a nonunion rate of 5.4% with one horizontal 1.6-mm cable, 4.8% nonunion with two horizontal 1.6-mm cables, and 1.5% nonunion with two horizontal 2-mm cables. In the last group, fibrous union occurred in 3.1% with "slight positional loss." Ritter et al[20] reported a 38% nonunion rate in 40 THAs. Of the 15 nonunions, 11 (73%) were in THAs in which there was no cable breakage. Silverton et al[18] reported a 25% nonunion rate with the use of the cable grip system and reported no difference in four versus two cables. McCarthy et al[14] reported a 0.9% nonunion rate using the cable grip system and found a statistically significant correlation between nonunion and posterolateral positioning of the cables. The nonunion rate was significantly less when cable fixation was directly to host bone as opposed to cement or allograft bone. Prior history of nonunion was also a statistically significant (P = 0.046) factor in the failure of the trochanteric fragment to heal after a second reattachment procedure.

Silverton et al[18] reported a 47% incidence of cable fraying and fragmenting with the Dall-Miles cable grip system and a 17% incidence of migrating metallic debris. In another study of the cable grip system, McCarthy et al[14] noted an 18% rate of unraveling. Third-body wear of the polyethylene liner has been noted to occur following breakage of cables and multifilament cable grip constructs.[16,18,33,44] Compared with cable configurations, monofilament wire configurations are associated with significantly (P = 0.0001) less metallic debris and with reduced migration of such debris into the articulation; typically, such debris results in volumetric wear and osteolysis.[15,33] Nevertheless, Hop et al[15] noted that there have been no reports of a sig-

Figure 5

Anteroposterior radiograph demonstrating a Dall-Miles cable grip.

Figure 6

Anteroposterior radiograph demonstrating a cable plate used for fixation of the osteotomized greater trochanter.

nificant difference in revision rates between wire and cable configurations. Because of this fact, and taking into account the higher ultimate strength of the cable systems as well as the significant rates of wire breakage and other complications with wire fixation, we favor use of the cable grip construct (Figure 5).

There are few contraindications to the use of cable grips. If the trochanteric fragment has no soft-tissue attachments, then it is devoid of blood supply and the implant does not need to be placed. In addition, an intact medial cortex just distal to the lesser trochanter must be present for fixation. When cementless femoral implants are used in conjunction with a greater trochanteric osteotomy, and if there is medial bone loss from the femur, the wires should not be in contact with the prosthesis; such contact can lead to premature wire failure and the generation of third-body metallic debris.

Cable Plate Systems

Fourth-generation cable grip systems are now reaching the market; the hope is that the cable fraying and breakage that has occurred with previous systems will be reduced. These implants use the 19 × 7 multifilament pattern and have some potential advantages over the traditional cable grip system, including the ability to tighten and then retighten the cables as needed. Different-sized plates are also available, allowing the placement of transverse cables below the level of the lesser trochanter, thereby theoretically decreasing the incidence of trochanteric migration or rotation. Placing transverse cables below the level of the lesser trochanter also allows the surgeon to use extra cables in situations with extended trochanteric osteotomies. Because of the larger size of some of these implants (Figure 6), the possibility exists for hardware irritation and hip abductor weakness. In the only clinical study of these systems published to date, Barrack and Butler[45] compared a fourth-generation cable plate to wires, cables, and the cable grip system; they noted significantly lower incidences of cable breakage ($P < 0.025$) and trochanteric nonunion ($P < 0.05$) with the cable plate. Although the cable plate group had a lower incidence of limp and demonstrated increased strength, these differences were not significant. Long-term clinical outcomes studies on these new devices may facilitate the decision process for the optimal fixation system for trochanteric osteotomies. At the present time, these devices seem to be most clinically applicable for management of trochanteric nonunions or fractures.

There are potential disadvantages to the cable plate systems. They are difficult to use with small fragments or with osteopenic bone. In addition, failure of the construct likely will require a revision to remove the hardware. Also, a more extensive dissection is necessary to use these systems, and they are more expensive than wires or cables with sleeves.

The advancement of orthopaedic implant design likely will provide further options for the fixation of the trochanter. With the increased use of locking plates, it is likely that an implant using this technology will be available for use in the future. To our knowledge, there have been no studies or reports of locking plates being used for this application.

Extended Trochanteric Osteotomy

First described by Wagner[46] and later popularized by Younger et al[47] for the removal of well-fixed femoral components in cases of revision THA, the extended trochanteric osteotomy has proved to be a useful tool in providing adequate surgical exposure for both revision and complex primary cases.[3,7,43] The extended trochanteric osteotomy facilitates implant and cement removal, the correction of proximal femoral deformity, access to the femoral diaphysis for component placement, and improved exposure of the acetabulum while providing a relatively large surface area for healing of the osteotomized segment.[3] In addition to allowing for the efficient removal of femoral implants, this technique reduces the likelihood of femoral fracture, femoral perforation, and cement retention seen with more limited approaches.[6]

The indications for the extended trochanteric osteotomy include revision of well-fixed cemented and cementless femoral components, removal of a loose femoral component with a well-bonded cement mantle, cases of proximal femoral deformity in both revision and primary settings, and cases in which increased acetabular exposure is deemed necessary.[5,7] A contraindication for extended trochanteric osteotomy is femoral component revision in which the revision implant will be cemented because extrusion of cement into the osteotomy site may hamper healing.[5]

The osteotomy can be performed before hip dislocation, after dislocation with the femoral component still in place, or after stem removal.[8] Osteotomy before hip dislocation is recommended when dislocation is difficult or when there is concern of an intraoperative fracture secondary to extensive heterotopic ossification or significant femoral component subsidence. Otherwise, most authors report performing the osteotomy after dislocation. The ideal length of the osteotomy, tailored to each individual patient, is determined preoperatively. The osteotomized fragment should be long enough to provide maximal exposure of the femoral canal and allow a minimum of two cerclage cables around it for later fixation. Typically, an osteotomy 12 to 15 cm in length (measured from the tip of the greater trochanter) satisfies these criteria.[5,8]

The extended trochanteric osteotomy is most commonly performed through a posterolateral approach to the hip, which allows adequate exposure of the posterolateral cortex of the proximal femur.[8,48] Approximately 5 to 10 mm of the posterior border of the vastus lateralis is dissected away from the linea aspera, allowing anterior reflection of the muscle while preserving its innervation. An oscillating saw is then used to make a longitudinal cut, starting at the posterior aspect of the greater trochanter and extending distally along the femur to the preoperatively planned length (Figure 7, A). Next, using either the oscillating saw or a high-speed burr, a smooth U-shaped end to the osteotomy should be fashioned, limiting the stress riser effect associated with a transverse distal cut. Finally, the posteromedial cortex can be cut the length of the segment, completing the extended trochanteric osteotomy. Once the lateral and medial cortices have been osteotomized, broad osteotomes are inserted laterally to ease the osteotomy open, allowing the greater trochanter and the lateral cortical segment of the proximal femur to be reflected anteriorly, in continuity with the attached muscles.[5,8,48]

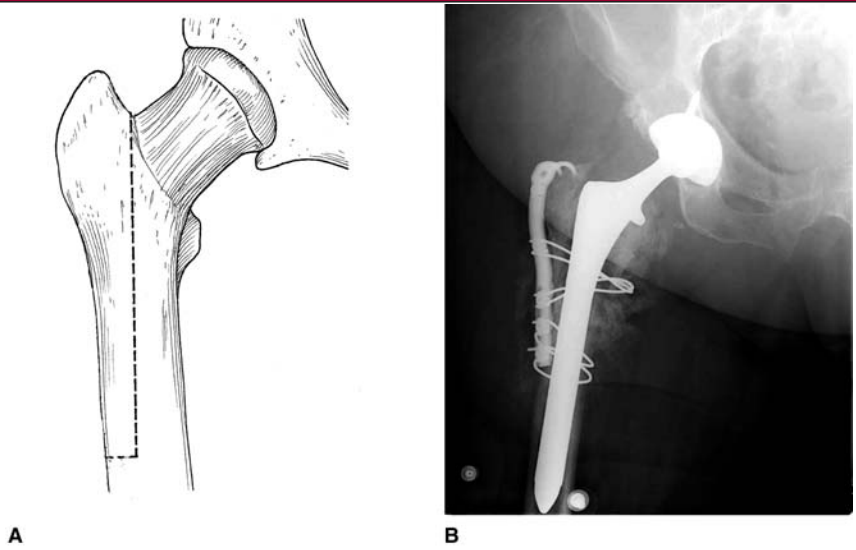
On completion of the revision or complex primary THA, the osteotomy is reduced onto its bed on the posterior aspect of the femur. Proper reapproximation of the osteotomized segment is important to avoid subsequent impingement. Once the fragment is reduced and positioned, fixation is achieved with the use of two to four evenly spaced cerclage wires or cables passed submuscularly around the osteotomy segment and proximal femoral diaphysis from posterior to anterior[5,8,48] (Figure 7, B).

The most proximal cerclage wire or cable is most commonly passed through a drill hole in the lesser trochanter or placed just distal to the lesser trochanter, in an attempt to counteract the forces pulling the osteotomized segment proximally. The most distal cerclage wire or cable is typically passed 2 to 3 cm proximal to the distal end of the osteotomy. The number of wires or cables spaced evenly between these two points depends on the length of the extended trochanteric osteotomy segment. A wire is usually placed distal to the osteotomy site to prevent propagation of a femoral fracture during placement of the femoral stem. This wire may be removed after placement of the stem at the discretion of the surgeon. Typically, the most distal cerclage wire or cable is tightened securely, the middle wires or cables tightened slightly less securely, and the most proximal wire left relatively loose to avoid segment fracture, especially at the junction of the greater trochanter and the lateral cortex where the bone is thin and weak.[5,48] Once the osteotomy is reduced and secure, the hip is taken through a complete range of motion to assess component stability and soft-tissue tension and to ensure a lack of bony impingement.

Postoperative precautions after an extended trochanteric osteotomy include toe-touch weight bearing for the first 6 to 8 weeks. This is followed by progression to weight bearing as tolerated. Active hip abduction also is prohibited for the first 6 weeks postoperatively.

Complications associated with the extended trochanteric osteotomy are similar to those seen with other greater trochanter osteotomy techniques, including intraoperative and postoperative fracture, nonunion, malunion, and fragment migration. Clinical series evaluating the efficacy of the extended trochanteric osteotomy in revision THA have demonstrated that the rates of incidence of nonunion and proximal segment migration are markedly lower with this technique than with standard and sliding osteotomies.[5,48]

Figure 7



A, Extended trochanteric osteotomy. A longitudinal cut is made starting at the posterior tip of the greater trochanter and extended distally along the femur to a preoperatively planned length. The medial and lateral cortices are osteotomized, and the trochanter is reflected anteriorly to gain exposure. **B,** Anteroposterior radiograph demonstrating repair of the extended trochanteric osteotomy with a cable plate. (Radiograph courtesy of Robert Barrack, MD.)

Miner et al[7] reviewed 192 consecutive revision THAs in which an extended trochanteric osteotomy was used for improved exposure. The authors reported 2 cases of nonunion (1.2%) and 1 case of malunion (0.6%) among 166 patients at a minimum 2-year follow-up. Clinical evaluation of these patients showed that pain and walking scores improved from a mean of 6.5 preoperatively to 9.8 postoperatively on the Merle d'Aubigné and Postel scale. Based on these findings, the authors concluded that the extended trochanteric osteotomy is a useful tool for the removal of well-fixed femoral components, with predictable postoperative healing and excellent functional outcomes.

Similar successful outcomes were shown by Mardones et al[49] in their review of 74 revision THAs. The authors demonstrated that at a mean follow-up of 2 years, 73 of the 74 osteotomies had healed uneventfully; there was 1 nonunion. Of these 73, 68 healed with no evidence of segment migration; the other 5 cases healed with <5 mm of migration.

Management of Complications

Marked functional changes have been noted to occur following proximal trochanteric fragment migration of >2 to 3 cm, including considerable weakness in the hip abductor musculature.[50] Other clinical studies indicate that trochanteric displacements of approximately 5 to 20 mm lead to an unstable fixation construct with subsequent failure and result in significant gait alterations, such as a Trendelenburg limp.[17,31,50] It is therefore important to recognize quickly the development of nonunion or migration of the osteotomized fragment. When early breakage of the fixation occurs, migration should be suspected. To avoid the development of these complications, many surgeons institute postoperative "trochanteric" precautions in addition to standard hip precautions. These additional precautions include no active abduction and no single-leg stance on the affected side for 6 weeks. To our knowledge, there have been no studies documenting the effectiveness of these precautions.

Management in the setting of early migration or symptomatic nonunion, with or without cable breakage, is revision of the fixation. Revising constructs in which cables have broken is especially important to prevent polyethylene wear resulting from third-body debris generation. Revising such constructs could prevent the need for revision of otherwise well-functioning THA components. In addition, the actual wires or cables can migrate into the joint, causing severe damage to the components. Asymptomatic wire breakage can be observed, but if the wires begin to migrate, they should be removed.

During revision surgery, as much of the fixation construct as possible should be removed. The bed of the trochanter should be prepared by removing all fibrous tissue from the edges of the osteotomy and ensuring the presence of bleeding surfaces. Repeat fixation with a cable grip construct should be performed. Repeat wire fixation has a high failure rate.[22] The implementation of trochanteric precautions is important to reduce recurrence of the nonunion. In addition, restricted initial weight bearing[26] with use of crutches for 8 weeks postoperatively has been associated with fewer nonunions.

Asymptomatic nondisplaced fibrous nonunion is not an indication for surgical revision. This should be evaluated with serial radiographs to ensure that there is no migration; however, surgery should not be considered unless the patient becomes symptomatic.

Trochanteric bursitis after THA is more common in the setting of trochanteric osteotomy. This is often a difficult problem to manage, and treatment success is variable. When this diagnosis is suspected, an injection of lidocaine can be given to confirm it. Corticosteroid with lidocaine may be injected to treat the inflammation. Multiple injections are contraindicated because of the increased risk of infection with each additional injection.

If pain does not improve after one or two injections, removal of the trochanteric hardware may be indicated. Blood tests should be obtained to rule out infection. The patient should be cautioned that removal of the hardware may not completely eliminate pain. Bernard and Brooks[22] removed hardware from 36 patients; pain was relieved in only half of them. When trochanteric nonunion or migration is present, the fixation should be revised as described above.

Summary

Trochanteric osteotomy is a surgical technique that is used primarily in complex primary and revision THAs. Various devices such as wires, cables, and cable grip systems can provide stable and rigid fixation. Although the material properties of cables and cable grip systems are superior to those of monofilament wires, the surgeon must consider such potential complications as debris generation and third-body polyethylene wear should the cable break. Although all systems are adequate in achieving trochanteric union and positive clinical results, we favor the cable grip system, which can provide the strongest fixation and result in lower rates of nonunion and trochanteric migration. Positive clinical outcomes are also dependent on patient selection because such factors as previous hip surgery and comorbid conditions (eg, contralateral hip or spine disease) may affect the decision to use trochanteric osteotomy and the subsequent choice of implant. The newer cable plate constructs are promising, but further clinical studies are needed to validate their efficacy and safety.

References

Evidence-based Medicine: There are 2 level II study (references 14 and 34), 6 level III studies (references 15, 23, 33, 36, 37, and 45), 26 level IV studies (references 1-3, 7, 9, 14, 16, 18, 20-22, 25-27, 30-32, 35, 38-43, 49, and 50), and 2 level V studies (28 and 47). The remainder are reviews, biomechanical studies, case reports, or descriptions of technique.

Citation numbers printed in **bold type** indicate references published within the past 5 years.

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