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Surgical Technique

Centralizing the Cemented Exeter Femoral Stem Using the Direct Lateral Approach: Surgical Tips and Radiological Evaluation

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A B S T R A C T

Varus malalignment in total hip arthroplasty has been associated with poor long-term outcomes and complications including abnormal load distribution, endosteal osteolysis, frank loosening, and periprosthetic fractures. Postoperative radiographic assessment was performed on 224 patients from our case series who underwent cemented Exeter total hip arthroplasty using the direct lateral approach alone. No patient had a true varus-aligned stem (ie, $\leq -5°$ on the coronal assessment). We describe our surgical technique, with 4 easily reproducible technical tips to achieve positional consistency of the femoral stem: commencing stem insertion from the piriform fossa entry point, using a femoral stem distal centralizer, aiming the tip of the component to the center of the patella, and placing the thumb between the calcar and inferior neck of the femoral component to prevent the stem from tipping into varus.

Introduction

Total hip arthroplasty (THA) is one of the most successful and frequently performed surgeries resulting in significant health-related quality of life outcome benefits [1]. In England, Wales, and Northern Ireland, the 2019 16th Annual National Joint Registry Report recorded 1,091,892 primary THAs between 1st April 2003 and 31st December 2018 [2]. The steady increase in the number of procedures performed yearly highlights an aging population with an increased incidence of osteoarthritis, thus driving surgical demand. However, despite excellent prosthetic survival rates in the aging population [3], a greater number of younger patients are undergoing THA, with the chances of this cohort of patients having revision surgery being higher. This highlights the importance of optimizing patient, prosthetic, operative, and surgical factors to ensure a successful functional outcome.

With specific regard to the prosthesis, it is well documented that varus placement of the femoral component in THA has been associated with poor outcomes [4-11] and increased complications, for example, aseptic loosening, secondary subsidence, and thigh pain [12-14]. With cemented stems in varus, premature failure has been attributed to stresses in the cement mantle (Gruen zones 3 and 7). Varus alignment leads to an increase in offset and subsequent enhanced lever arm, leading to an increased strain on the lateral (LAT) part of the distal femur and around the tip of the femoral stem [15,16].

For the most part, orientation and positioning of the prosthesis is under surgeon control during stem implantation into the canal. If preoperative planning alignment of the stem is not in varus, but if the postoperative planning alignment is, then malpositioning has occurred. In theory, this should be avoidable with the correct technique. However, external factors such as canal access and preparation, instrumentation, soft-tissue interposition, poor cementation techniques, and surgical experience may all be contributory factors to a poorly aligned prosthesis. The surgical approach may also influence this. While a number of surgical approaches to the hip joint exist, the choice is usually down to

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surgeon preference. Each approach has its unique advantages, disadvantages, and technical intricacies that allow safe and efficient femoral and acetabular reconstruction [17]. Studies analyzing the prosthetic position using various approaches are limited in number, historic, and more focused on comparing the trans-trochanteric and posterior approaches [18-21].

There is limited evidence in the literature assessing radiological outcomes of prosthesis alignment when utilizing the direct LAT approach. We therefore describe our surgical technique for the direct LAT approach and highlight technical tips to achieve radiographic consistency. To strengthen the validity of our technique, we performed radiographic evaluation on all our patients who underwent cemented Exeter THA using the direct LAT approach. Radiological outcomes have been highlighted in the Discussion section.

Surgical technique

The patient is placed in the LAT decubitus position with bolsters over the anterior superior iliac spines and lower lumbar spine to hold the pelvis vertical (sideward). The limb is prepared and draped in the standard fashion; however, care is taken to ensure adequate limb mobilization to facilitate dislocation of the hip and exposure of the acetabulum and the proximal femur.

A longitudinal skin incision is made on the LAT side of the hip in line with the greater trochanter (GT) and proximal femoral shaft. The length of the incision may vary to enable adequate exposure and will be longer in patients with a higher BMI. The subcutaneous fat and superficial fascia are divided in line with the skin incision to expose the fascia lata. The fascia lata is divided longitudinally in line with the skin incision, and the fibers of the tensor fascia lata are split proximally. It is important to expose the femoral insertion of the gluteus maximus tendon to the gluteal tuberosity of the proximal femur posteriorly. The distal division of the fascia lata should always remain anterior to the gluteus maximus tendon insertion. A Charnley or a Norfolk and Norwich retractor is used to retract the deep fascia, taking particular care to place the retractor directly on the edge of the divided fascia (particularly posteriorly), to avoid injury to the sciatic nerve. While the sciatic nerve is not formally exposed, the course of the nerve is felt posteriorly, to ensure that its location along the entire length of the incision is known. The trochanteric bursa is then exposed and divided, stripping it off the GT and abductor insertion. This exposes the abductor tendon, which is then divided in an omega shape from the junction of anterior two-thirds and the posterior one-third of the abductor insertion to the GT extending anteriorly along the abductor tendon and distally, splitting the fibers of the vastus lateralis muscle. The abductors are split proximally using blunt dissection to reduce the risk of injury to the superior gluteal nerve. The hip is dislocated and the femoral neck osteotomized about a finger's breadth above the lesser trochanter, in line with preoperative templating. Acetabular exposure and subsequent implantation of the acetabular component is then undertaken with 20 degrees of anteversion of the component, using the transverse acetabular ligament, in most instances, as a referencing landmark.

Exposure of the proximal femur and piriform fossa is facilitated by placing a Hohmann retractor posterior to the junction of the GT and the proximal femoral shaft. This retractor is placed directly on the bone, to lever the proximal femur anteriorly. The assistant also ensures that the tibia is vertical and pushes on the knee in a downward direction, to lever the proximal femur anteriorly. This allows the surgeon to expose the piriform fossa (posterior and slightly medial to the tip of the GT), which is the correct entry point for the reamer (Fig. 1).

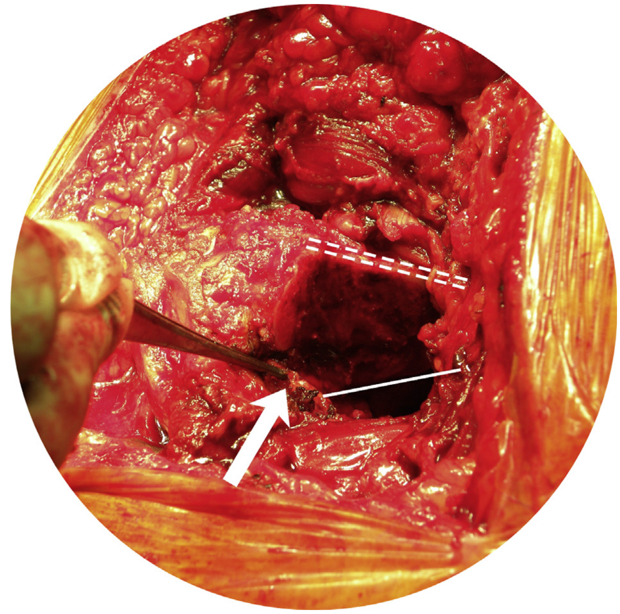

Figure 1. Exposure of the piriform fossa (color). (White arrow—the entry point for the boxed chisel [demarcated by Trethowan], double dashed white line—anterior border, solid white line—the posterior border of the cut femoral neck).

A box chisel is then used to open the femoral medullary canal (Fig. 2). The cancellous bone removed by the box chisel has to be as posterior and LAT as possible and in the correct version (about 5 to 10 degrees of anteversion). If the entry point is correct, then there should be cancellous bone remaining on the anterior femoral neck and no cancellous bone posteriorly. There should only be a thin shell of cortical bone remaining on the posterior femoral neck. The 2 'T' handled rasps (canal reamers) are then inserted sequentially, from the entry point posteriorly and laterally in an anterior direction, aiming for the center of the patella. A Charnley curette is then inserted into the medullary canal to remove the bone laterally from

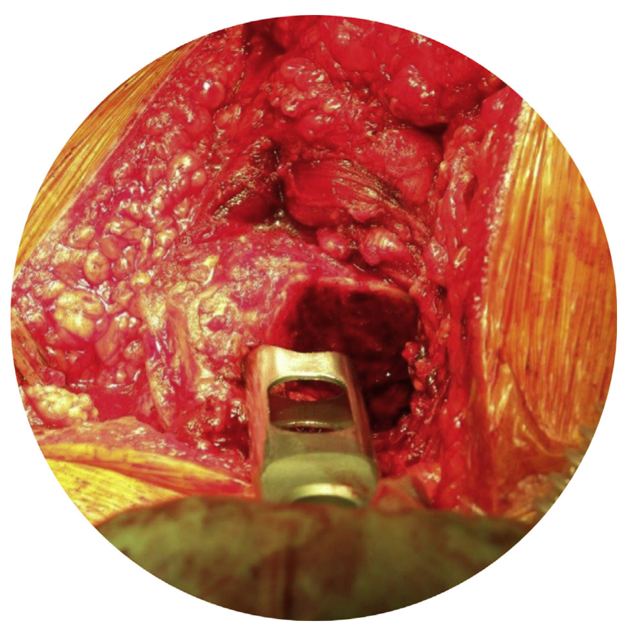

Figure 2. Entry for the boxed chisel (posterior and slightly medial to the tip of the greater trochanter) (color).

Gruen zones 1 and 2. Sequential rasping is performed to achieve a 'snug-fit,' which would ideally be to the size and offset templated preoperatively.

The trial reduction is then performed doing the usual checks for stability, soft-tissue tension, and equalization of leg lengths. The depth of stem insertion is then marked on the bone with a horizontal line and the vertical direction of insertion, with a vertical line referencing these lines to one of the holes on the neck of the rasp. The stem is then implanted using a third-generation cementing technique using a cement restrictor, a stem holder, and a distal centralizer.

The surgeon places his or her own thumb between the calcar and the inferior neck of the femoral component after it is fully seated in place and holds the thumb there while the cement cures. The surgeon's thumb placed in this position facilitates cement pressurization in the calcar region and prevents the stem from tipping into varus or sinking it deeper than the previously marked horizontal line.

The key to achieving accurate and reproducible femoral stem alignment is to commence stem insertion from the piriform fossa entry point, aiming the tip of the component to the center of the patella. It is also important to implant the component (Fig. 3) in the same position of the final seating of the last rasp used before the trial reduction (in-line with the markings). Once the hip has been reduced, layered closure is then performed taking care to repair the abductor tendon using sutures passing through the bone.

Radiographic evaluation and outcomes

To corroborate our surgical technique, we evaluated all patients who underwent THA using the Exeter cemented femoral hip system, performed by the senior author (D.K.M.) between January 2009 and August 2019 at a district general (Affiliated Teaching) hospital as a consecutive case series. Surgical notes were assessed to ensure that only patients who underwent THA utilizing the direct LAT approach were included. All other surgical approaches were excluded. Any patient undergoing revision arthroplasty and uncemented constructs were excluded. In addition, patients undergoing THA for any indication other than primary hip OA were excluded. A total of 224 patients were subsequently analyzed for this study. All patients had postoperative anteroposterior (AP) and LAT radiographs available for assessment. Both radiographic views were assessed to evaluate the sagittal and coronal alignments of the Exeter stem.

Radiographic assessment and measurements were performed using the framework described by Khalily and Lester [22]. The coronal alignment was determined on the AP view by measuring the angle (α) formed between the long axis of the prosthesis (red line) and the long axis of the femur (yellow line) (Fig. 4), with a positive value corresponding to a valgus tilt and a negative value corresponding to a varus tilt. The neutral alignment of the stem is determined by the central location of the tip in the shaft in relation to the longitudinal axis of the shaft. We defined true varus implantation as femoral stem alignment $\leq -5°$ on radiographic assessment. Sagittal stem alignment was calculated from the angle (β) between the stem axis and the proximal femoral axis in the sagittal plane [18] (Fig. 5). A positive value corresponded with an anterior tilt of the stem tip, with a negative value corresponding to a posterior tilt. Measurements along the coronal plane were more easily reproducible because of standardized anatomical landmarks. Owing to a wide individual variation in the femoral shaft antecurvature, measurements on the sagittal plane were less reproducible. Thus, radiographs were independently reviewed by 3 nonoperating surgeons. Disagreements between reviewers were resolved by consensus. All patients were followed up for a minimum period of 1 year when clinical and radiographic assessment was performed before discharge.

Of the 224 patients, there were 101 males and 123 females. The age range varied from 32 to 92 years, with a mean age of 70.6 years. On AP assessment, 4 patient radiographs depicted perfect neutral alignment at 0°. There were 188 cases with the femoral stem in valgus tilt (range: +0.1° to +4.7°; mean: +1.79°; 95% confidence interval: +1.64° to +1.94°). No patient had a valgus stem position of $\geq +5°$. Thirty-two cases showed varus tilt (range: −0.5° to −3.3°; mean: −1.63; 95% confidence interval: −1.93° to −1.31°). However, as per the framework of Khalily and Lester [22], none of these patients exceed the threshold of $\leq -5°$ to be truly designated to have a varus implanted stem (Table 1 and Fig. 2). On the LAT radiograph

Figure 3. Implanted prosthesis with an appropriate component version (color).

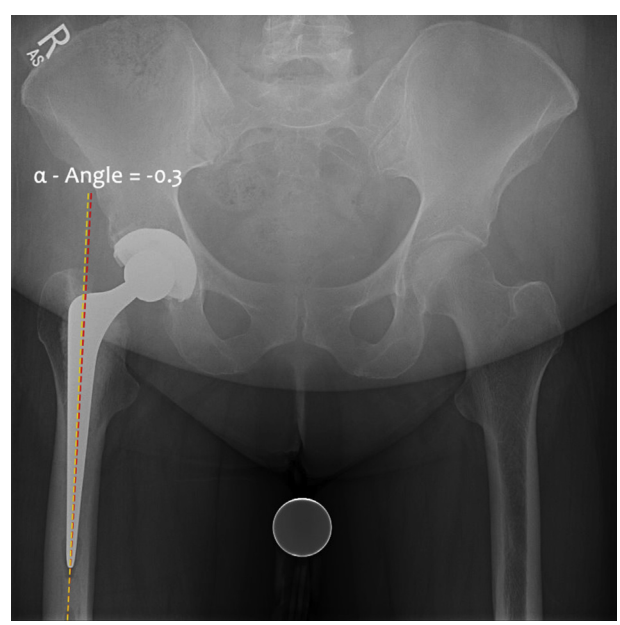

Figure 4. Coronal stem alignment (α-angle) using an anteroposterior radiograph (color). (Red line—the long axis of the prosthesis, yellow—the long axis of the femur).

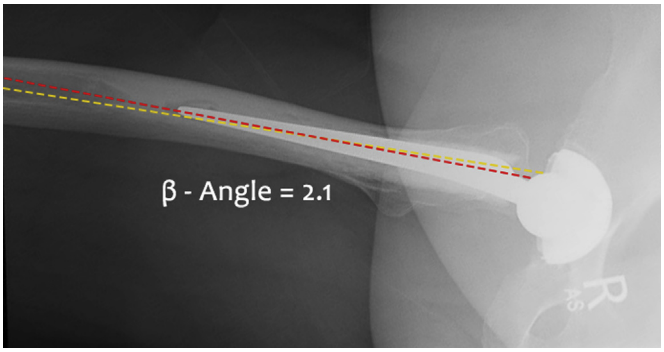

Figure 5. Sagittal stem alignment (β-angle) using lateral radiographs (color). (Red line—the long axis of the prosthesis, yellow—the long axis of the femur).

assessment, 3 patient radiographs were again depicted to have neutral alignment at 0°. One hundred seven patients had an anterior tilt (range: +0.2° to +6.2°; mean: +2.68°). One hundred fourteen patients had a posterior tilt (range: −0.1° to −5.1°; mean: −1.94°) (Table 2). True extended implantation, that is, an anterior tilt >+5°, occurred in 8 patients. One patient had true flexed implantation, that is, a posterior tilt <−5°. Figure 6 demonstrates a scatterplot diagram of all 224 patients, showing no patient exceeding the threshold of ≤−5° to be deemed a varus-aligned stem. All of the postoperative radiographs did show a cement mantle of at least 2 mm in all Gruen zones. At 1-year, follow-up imaging showed a well-implanted femoral stem in all cases.

Discussion

This single-surgeon case series explores surgical technical tips that prevent malalignment of the femoral stem of a hip prosthesis. It highlights radiologic consistency with excellent femoral stem positioning when performing cemented THA utilizing the direct LAT approach.

THA is one of the most successful and cost-effective interventions in modern medicine [23-25]. It offers significant pain relief as a treatment modality and improves function in patients suffering from osteoarthritic or inflammatory pathology. Functional outcomes, whether satisfactory or not, after a THA are often multifactorial. The thresholds for undertaking surgery have changed with modern medical practice, and therefore, more patients are being offered THAs. Advances in medicine leading to an increased life expectancy coupled with a greater number of younger patients undergoing THA highlight the need to achieve long-term implant survivorship. Implant longevity is again multifactorial, affected by the choice of implant, cementation, prosthetic alignment, patient and surgeon factors, and so forth. However, it is well established that appropriate femoral stem placement is thought to be a vital prosthetic factor, with varus-positioned stems leading to poor outcomes [4-11] and increased complications [12-14].

While there is evidence to support that the Exeter stem may be tolerant of varus malalignment, with no difference at 5-year Oxford Hip Scores [26,27], these studies are limited by their duration of follow-up, that is, midterm clinicoradiological follow-up at 5 years. It may very well be that the Exeter stem is a more forgiving stem when placed in varus; however, changes associated with malalignment and subsequent aseptic loosening are not usually evident at this early stage. Ebramzadeh et al. [28] assessed long-term outcomes (21-year follow-up) using survival analysis in 836 cemented femoral components. They noted that there was a higher predilection for progressive loosening, cement fractures, and radiolucent lines at the stem-cement or bone-cement interfaces in varus-aligned stems (≥5°of varus) compared with those in neutral or valgus. These findings were independent of the implant material (titanium or stainless steel) [28]. Jaffe and Hawkins [4] assessed femoral stem survivorship at 15 years and noted a 37.5% failure rate of stems implanted in varus subsequently requiring revision arthroplasty.

A retrospective study by Gruen et al [29] analyzing sequential radiographs highlighted medial midstem pivoting as a mode of failure (mode II). It is caused by weak proximal calcar support and a lack of thin distal cement support associated with varus implantation. Furthermore, a biomechanical analysis by Floerkemeier et al. [15] showed that aligning the stem in an excessive varus position leads to an increased strain in the medial part of the proximal femur (increased lever arm) and around the distal tip of the stem—areas where the cement mantles are inadequate. With these increased forces, particularly on the medial calcar, there is a higher risk of intraoperative and postoperative fractures [16,30]. It is therefore important to maintain a cement mantle >2 mm circumferentially [28,31], but particularly in the proximomedial part of the femur. Malaligned stems (which may lead to a direct contact of the prosthesis with the bone) or stems implanted with cement defects may also provide a route through which wear particles can migrate to the endosteal surface of the femur [32,33]. This leads to localized endosteal osteolysis, frank loosening of the prosthesis, and periprosthetic femoral fractures [32]. Varus malalignment also results in abnormal load distribution, theoretically leading to cortical hypertrophy in Gruen zones 3 and 5, which may lead to thigh pain [34,35]. The use of a hollow femoral distal centralizer ensures a homogeneous cement mantle without implant-bone impingement and allows subsidence of the stem.

The surgical approach to the hip is usually dictated by the surgeon's preference. Robinson et al. [20] compared the posterior and LAT transtrochanteric approaches in THAs and found no significant difference in the prosthetic alignment. Similarly, Vicar and Coleman [21] compared the anterolateral, transtrochanteric, and posterior surgical approaches in 269 THAs. One of their outcome measures involved radiographic evaluation of femoral positioning, which showed no significant difference in component alignment.

It is worth noting that since the publications of these papers in the 1980s, not only has the surgical technique been refined but also both prosthetic implants have been upgraded. In addition, cementation techniques have also evolved. Collectively, these are all significant contributory factors affecting the prosthetic alignment. Variation in the femoral stem tip position was assessed by Vaughan et al. [19] while comparing radiographs of polished, tapered Exeter THA, inserted via the anterolateral or posterior approach. They

Table 1
AP radiographic assessment.

Position on AP	Range	Mean	95% CI	Number of cases
Neutral	0°	0°	-	4
Valgus tilt	+0.1° to +4.7°	+1.79°	+1.64° to +1.94°	188
Varus tilt	−0.5° to −3.3°	−1.63°	−1.93° to −1.31°	32

CI, confidence interval.

Table 2
Lateral radiographic assessment.

Position on LAT	Range	Mean	95% CI	Number of cases
Neutral	0°	0°	-	3
Anterior tilt	+0.2° to +6.2°	+2.68°	+2.40° to +2.96°	107
Posterior tilt	−0.1° to −5.1°	−1.94°	−2.14° to −1.74°	114

CI, confidence interval.

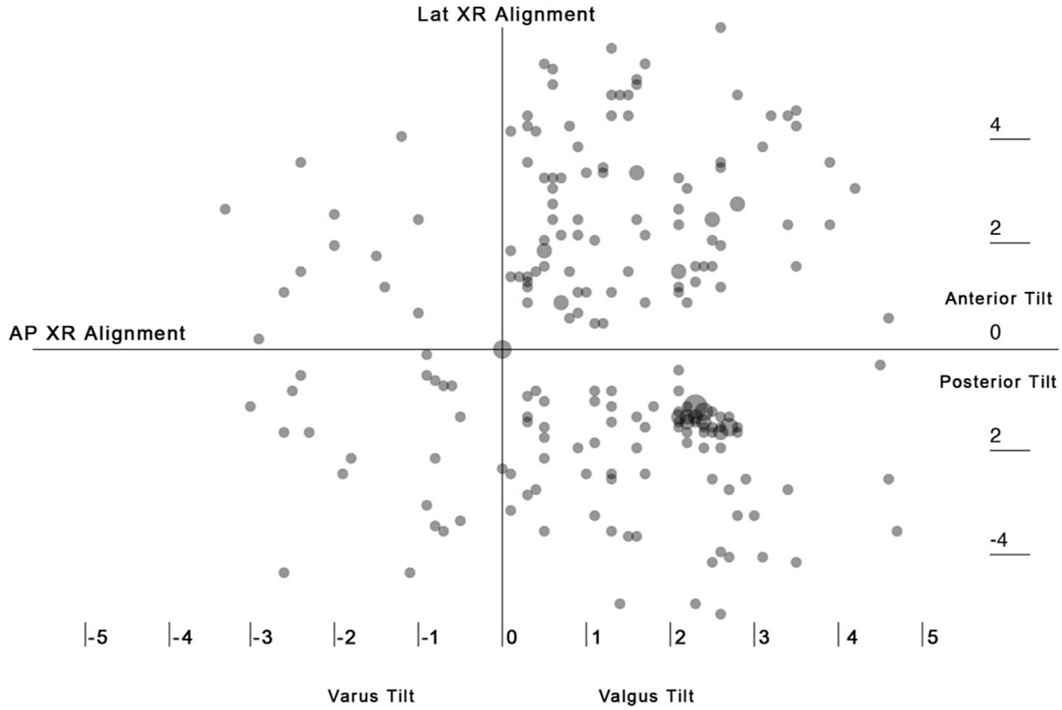

Figure 6. Scatterplot diagram depicting the stem position on AP and lateral views.

showed a significant difference in the sagittal tip position only ($P = .01$), but not in the coronal plane. THAs inserted with the anterolateral approach in their series showed a deviation toward the posterior cortex. They attribute this to the cuff of glutei that can lever the proximal stem anteriorly causing an anterior entry point and a posterior stem position. More recently, Jain et al. [18] concluded no statistically significant difference in the positioning of the femoral stem in the sagittal plane by either trochanteric osteotomy or posterior approach to the hip in their case series of 50 patients. Our case series highlights a fairly even distribution of femoral stems positioned with an anterior tilt (107) and a posterior tilt (114). True extended implantation, that is, an anterior tilt $>5°$, occurred in 8 patients. Only 1 patient had true flexed implantation, that is, a posterior tilt $< -5°$. As far as the authors are aware, this is the first study that highlights excellent stem positioning, with no varus alignment of $\leq -5°$ using the direct LAT approach.

We emphasize four crucial steps to achieve a well-aligned prosthesis, that is, a well-exposed piriformis entry point to facilitate stem insertion, the use of a prosthetic stem distal centralizer, aiming the tip of the femoral component to the center of the patella and finally placing the thumb between the calcar and the inferior neck of the femoral component while the cement cures to prevent the stem from tipping into varus or sinking further into the canal.

Intraoperatively, it is important to recognize the variation in the position of the GT, which may be more medially or laterally positioned in some patients (trochanteric lateroversion). Wang et al. [36] assessed coronal alignment and noted that excessive variation in GT lateroversion was a risk factor for femoral stem varus and varus positioning was always accompanied by inadequate canal filling. A recent study by Thangaraj et al [37] showed that failure to recognize increased GT thickness may lead to insufficient LAT broaching resulting in misaligned femoral components. It is important to note that varus positioning may sometimes be attributable to femoral pathology, particularly coxa vara deformity—and this is not necessarily a technical failure but rather a consequence of associated morphological traits, that is, an increased femoral offset, greater trochanteric overhang, and the height and lower canal flare index [38]. This reiterates the importance of preoperative planning and templating.

The authors recognize the limitations of the study including the absence of clinical and functional outcomes from our case series; however, there is sufficient evidence in the available literature correlating varus stem alignment with poor outcomes. We also recognize that femoral stem assessment was performed by 3 nonoperating surgeons in a bid to reduce bias by the operating surgeon evaluating his own work. While there was no statistical method to evaluate intraobserver and interobserver variability, the radiographic framework used has been validated by Khalily and Lester [22]. Clinicoradiographic assessment after variation in implant choice and long-term follow-up were also not assessed. The authors are aware of the follow-up burden on patients this would impose, which will contribute to the difficulties in maintaining research follow-up.

Summary

This single-surgeon case series highlights technical tips using the direct LAT approach that prevent malalignment of the femoral component of the prosthesis. It reinforces the notion that despite variations in hip approaches, positional consistency can be easily achieved with the direct LAT approach. Our series revealed no true varus alignment of $\leq -5°$ on coronal assessment. There are 4 main learning points highlighted in this study that are easily reproducible, to achieve a well-aligned stem: commencing stem insertion from the piriform fossa entry point, using a prosthetic stem distal centralizer, aiming the tip of the component to the center of the patella, and placing the thumb between the calcar and the inferior neck of the femoral component to prevent the stem from tipping into varus or sinking further into the canal. We also recommend the use of preoperative templating for identification of mechanical references including femoral offset and optimize the position of the implant to re-establish hip biomechanics.

Conflict of interests

The authors declare there are no conflicts of interests.

References

[1] Shan L, Shan B, Graham D, Saxena A. Total hip replacement: a systematic review and meta-analysis on mid-term quality of life. Osteoarthritis Cartilage 2014;22(3):389.

[2] NJR. National joint registry - 16th Annual Report (2019). https://reports.njrcentre.org.uk/Portals/0/PDFdownloads/NJR%2016th%20Annual%20Report%202019.pdf; 2019. [Accessed 17 May 2020].

[3] Evans JT, Evans JP, Walker RW, Blom AW, Whitehouse MR, Sayers A. How long does a hip replacement last? A systematic review and meta-analysis of case series and national registry reports with more than 15 years of follow-up. Lancet 2019;393(10172):647.

[4] Jaffe WL, Hawkins CA. Normalized and proportionalized cemented femoral stem survivorship at 15 years. J Arthroplasty 1999;14(6):708.

[5] Devitt A, O'Sullivan T, Quinlan W. 16- to 25-Year follow-up study of cemented arthroplasty of the hip in patients aged 50 years or younger. J Arthroplasty 1997;12(5):479.

[6] de Beer J, McKenzie S, Hubmann M, Petruccelli D, Winemaker M. Influence of cementless femoral stems inserted in varus on functional outcome in primary total hip arthroplasty. Can J Surg 2006;49(6):407.

[7] Kobayashi S, Eftekhar NS, Terayama K. Predisposing factors in fixation failure of femoral prostheses following primary Charnley low friction arthroplasty. A 10- to 20-year followup study. Clin Orthop Relat Res 1994;(306):73.

[8] Dunn AW. Total hip arthroplasty: review of long-term results in 185 cases. South Med J 1982;75(8):937.

[9] Pellicci PM, Salvati EA, Robinson HJ. Mechanical failures in total hip replacement requiring reoperation. J Bone Joint Surg Am 1979;61(1):28.

[10] Gill TJ, Sledge JB, Orler R, Ganz R. Lateral insufficiency fractures of the femur caused by osteopenia and varus angulation: a complication of total hip arthroplasty. J Arthroplasty 1999;14(8):982.

[11] Munuera L, Garcia-Cimbrelo E. The femoral component in low-friction arthroplasty after ten years. Clin Orthop Relat Res 1992;279:163.

[12] Eingartner C, Heigele T, Volkmann R, Weise K. Long-term results of an uncemented straight femoral shaft prosthesis. Hip Int 2006;16(1):23.

[13] Evola FR, Evola G, Graceffa A, et al. Performance of the CLS Spotorno uncemented stem in the third decade after implantation. Bone Joint J 2014;96-B(4):455.

[14] Kandel L, Kligman M, Sekel R. Distal femoral stem tip resection for thigh pain complicating uncemented total hip arthroplasty. Five patients followed up for 6-10 years. Hip Int 2006;16(3):210.

[15] Floerkemeier T, Gronewold J, Berner S, et al. The influence of resection height on proximal femoral strain patterns after Metha short stem hip arthroplasty: an experimental study on composite femora. Int Orthop 2013;37(3):369.

[16] Kutzner KP, Freitag T, Donner S, Kovacevic MP, Bieger R. Outcome of extensive varus and valgus stem alignment in short-stem THA: clinical and radiological analysis using EBRA-FCA. Arch Orthop Trauma Surg 2017;137(3):431.

[17] Petis S, Howard JL, Lanting BL, Vasarhelyi EM. Surgical approach in primary total hip arthroplasty: anatomy, technique and clinical outcomes. Can J Surg 2015;58(2):128.

[18] Jain K, Subramanian S, Hodgkinson J, Hemmady M. Comparison of femoral stem alignment in primary total hip replacement by transtrochanteric and posterior approach. Pol Orthop Traumatol 2013;78:115.

[19] Vaughan PD, Singh PJ, Teare R, Kucheria R, Singer GC. Femoral stem tip orientation and surgical approach in total hip arthroplasty. Hip Int 2007;17(4):212.

[20] Robinson RP, Robinson HJ, Salvati EA. Comparison of the transtrochanteric and posterior approaches for total hip replacement. Clin Orthop Relat Res 1980;(147):143.

[21] Vicar AJ, Coleman CR. A comparison of the anterolateral, transtrochanteric, and posterior surgical approaches in primary total hip arthroplasty. Clin Orthop Relat Res 1984;188:152.

[22] Khalily C, Lester DK. Results of a tapered cementless femoral stem implanted in varus. J Arthroplasty 2002;17(4):463.

[23] Crawford RW, Murray DW. Total hip replacement: indications for surgery and risk factors for failure. Ann Rheum Dis 1997;56(8):455.

[24] Liang MH, Cullen KE, Larson MG, et al. Cost-effectiveness of total joint arthroplasty in osteoarthritis. Arthritis Rheum 1986;29(8):937.

[25] Jonsson B, Larsson SE. Functional improvement and costs of hip and knee arthroplasty in destructive rheumatoid arthritis. Scand J Rheumatol 1991;20(5):351.

[26] Hossain M, Thomas G, Beard D, Murray D, Andrew G. The consequences of varus implantation of a taper-slip cemented femoral stem. Orthopaedic Proc 2012;94-B(SUPP_XXI):105.

[27] Takada R, Whitehouse S, Hubble M, et al. Does varus or valgus alignment of the exeter stem influence survival or patient outcome in total hip arthroplasty? A review of 4126 cases with a minimum follow-up of five years. Orthop Proc 2019;101-B(SUPP_6):22.

[28] Ebramzadeh E, Sarmiento A, McKellop HA, Llinas A, Gogan W. The cement mantle in total hip arthroplasty. Analysis of long-term radiographic results. J Bone Joint Surg Am 1994;76(1):77.

[29] Gruen TA, McNeice GM, Amstutz HC. "Modes of failure" of cemented stem-type femoral components: a radiographic analysis of loosening. Clin Orthop Relat Res 1979;141:17.

[30] Banerjee S, Pivec R, Issa K, Harwin SF, Mont MA, Khanuja HS. Outcomes of short stems in total hip arthroplasty. Orthopedics 2013;36(9):700.

[31] Jasty M, Maloney WJ, Bragdon CR, O'Connor DO, Haire T, Harris WH. The initiation of failure in cemented femoral components of hip arthroplasties. J Bone Joint Surg Br 1991;73(4):551.

[32] Anthony PP, Gie GA, Howie CR, Ling RS. Localised endosteal bone lysis in relation to the femoral components of cemented total hip arthroplasties. J Bone Joint Surg Br 1990;72(6):971.

[33] Mirza SB, Dunlop DG, Panesar SS, Naqvi SG, Gangoo S, Salih S. Basic science considerations in primary total hip replacement arthroplasty. Open Orthop J 2010;4:169.

[34] Gustke K. Short stems for total hip arthroplasty: initial experience with the Fitmore stem. J Bone Joint Surg Br 2012;94(11 Suppl A):47.

[35] Ritter MA, Fechtman RW. Distal cortical hypertrophy following total hip arthroplasty. J Arthroplasty 1988;3(2):117.

[36] Wang H, Gu J, Liu X, et al. Variation in greater trochanteric lateroversion: a risk factor for femoral stem varus in total hip arthroplasty. Hip Int 2020;30:33.

[37] Thangaraj R, Wilson-Theaker W, Kumar A, Oakley J. Difference in trochanteric thickness between well-aligned and malaligned polished collarless stem. J Clin Orthop Trauma 2019;10(1):117.

[38] Murphy CG, Bonnin MP, Desbiolles AH, Carrillon Y, Aït Si Selmi T. Varus will have varus; a radiological study to assess and predict varus stem placement in uncemented femoral stems. Hip Int 2016;26(6):554.