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REVIEW ARTICLE

Valgus intertrochanteric osteotomy for femur neck pseudoarthrosis: a simple solution to a complex problem that has stood the test of time

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Abstract

Femoral neck nonunion in young patients has always been a difficult problem to deal with for surgeons. Numerous surgical procedures to address either the biological or mechanical issues at the nonunion have been described and most of them have been associated with variable results. Isolated biological augmentation is often associated with poor results and some techniques like vascularized grafting may require not so commonly available expertise. Valgus osteotomy is aimed to correct the abnormal fracture biomechanics associated with femoral neck fractures. By altering the nature of force transmission across the nonunion, shear forces are converted into compressive forces that lead to rapid osseous union without the need for bone grafting. Though the principles are sound and were described a long time ago, the technical aspects have evolved over time. Various modifications have been described to overcome shortcomings such as limb length discrepancy, reduction of femoral offset, alteration in mechanical axis, and the overall proximal femur anatomy. In this review, we look back at the fundamental principles and recent literature on the results of valgus intertrochanteric osteotomy for femoral neck pseudoarthrosis. We also highlight the important need for accurate preoperative planning and surgical execution. Lastly, we elaborate on the technical improvisations that have happened over time in order to improve functional results and to minimize complications and poor outcome after a valgus osteotomy.

Keywords Valgus intertrochanteric osteotomy · Pseudoarthrosis · Femur neck fracture

Introduction

Nonunion after femur neck fracture is reported in up to 40% patients [1]. While arthroplasty has provided a reliable solution in older patients, the need for hip preservation in younger patients poses complex challenges. Nonunion after a femoral neck fracture is predisposed by a number of mechanical and biological factors. Mechanical factors such as high fracture angle leading to shear forces at the fracture site, small bony segment proximal to the fracture causing challenges in achieving stable fixation, and inferior and posterior cortical comminution compromising fixation strength and varus fixation increase the risk for failure/nonunion. Biological factors such as injury to the capsular arterial blood supply to the femoral head, capsular tamponade, absence of cambium layer of the periosteum, and synovial fluid interference with fracture union have all been implicated. Thus, femoral neck pseudoarthrosis represents issues in both biology and mechanics in the proximal femur and several procedures have been described to address both aspects of the problem [2]. It is debatable whether biology or mechanics is the predominant problem, but given the predictable success of valgisation, osteotomies indicate restoration of mechanics does play a significant role in treating femur neck nonunions. On the other hand, solutions to restore biology like various bone grafting techniques have yielded variable results [3].

The role of osteotomies in treating femur neck nonunions has been well appreciated for a long time. Different types of displacement and angular osteotomies were described. Displacement osteotomies were given up in view of the gross distortion of the proximal femur anatomy and unacceptable limb shortening [4]. Angular osteotomies have been more

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successful and have evolved over time. The most successful of angular osteotomies is the valgus intertrochanteric osteotomy (VITO). The general principles of VITO was first laid down by Friedrich Pauwel [5] and popularized later by Muller [6] for the purpose of treating femoral neck nonunions. Several modifications of VITO have been described in literature, and this article will look to provide a concise review of the biomechanical basis, technical aspects, results, and limitations of VITO.

Biomechanical principles of valgus osteotomy

The fundamental principle behind VITO is conversion of shear forces at the nonunion site into predominantly compressive forces facilitating fracture union. Shear forces have been shown to dominate in intra-capsular femoral neck fractures especially in Pauwel type III injuries. Shear forces are detrimental to union and ultimately lead to the collapse of the fracture into varus resulting in failure of osteosynthesis. VITO helps by making the fracture plane more horizontal and moves it closer to the axis of load transmission across the hip joint, thereby converting the shear to compressive forces across the fracture site.

Recognizing the normal loading patterns of the hip joint will help to understand how exactly VITO works in femur neck pseudoarthrosis. Under normal weight-bearing conditions, the hip joint is subjected to a force "R" which is a sum of two forces, namely, the muscle forces acting across the hip joint (the abductors "M") and the body weight "W." This resultant force R is however not entirely a compressive force because it is not in line with the femoral neck but medial to it (Fig. 1). Thus, femoral neck fractures are inherently subjected to a combination of bending and shear forces apart from compressive forces [7]. The amount of shear increased with verticality of the fracture, thereby increasing the incidence of fixation failures and nonunion.

The resultant force R acts down on the hip center of rotation at an angle of 16° subtended from the sagittal body axis. The femoral shaft axis subtends an angle of 8–10° with the sagittal body axis. So making the fracture plane more horizontal (Pauwel's angle of < 25° as recommended by Muller) brings it perpendicular to the line of the force R resulting in compressive forces across the nonunion (Fig. 2). This is the exact biomechanical basis behind VITO [8]. Once the fracture plane is subjected to continuous compressive forces, the fibrous tissue is rapidly mineralized, angiogenesis and endochondral ossification ensues resulting in a successful outcome.

Initially, Pauwel described two types of VITO (Fig. 3). One was a simple closing lateral wedge osteotomy (V osteotomy), where a predetermined lateral-based wedge is removed depending on the amount of correction needed and the angle of the fixation device. He also described a Y osteotomy, which

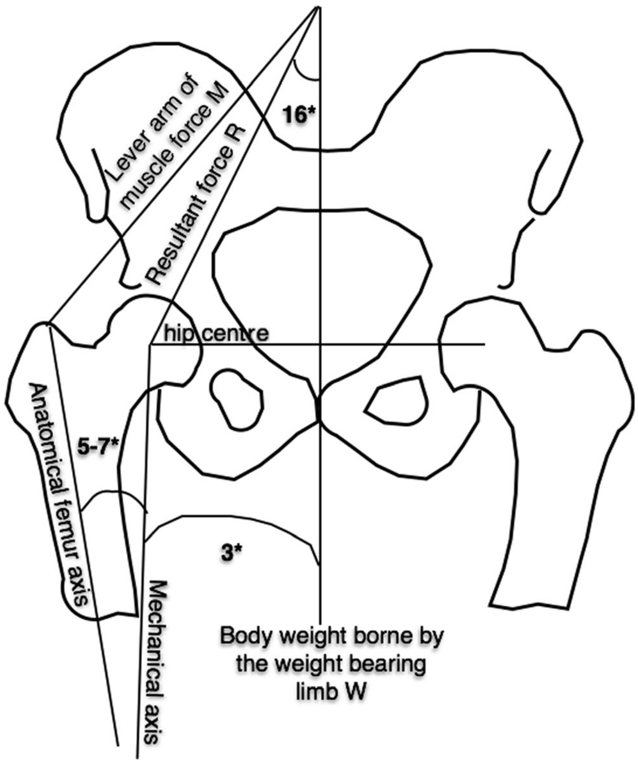


Fig. 1 The different forces acting across the hip joint and its possible effects on healing of a femoral neck fracture

he recommended for cases with severe disturbance to the head–shaft relationship noted by a proximally riding trochanter indicating a negative articulo-trochanteric distance. The Y osteotomy, though useful, compromises the contact at the osteotomy surfaces and results in significant medialization of the shaft to support the femoral head. This can disturb the mechanical alignment and proximal femoral biomechanics. The Y osteotomy is largely given up while conventional techniques of VITO are still based on the V osteotomy[9].

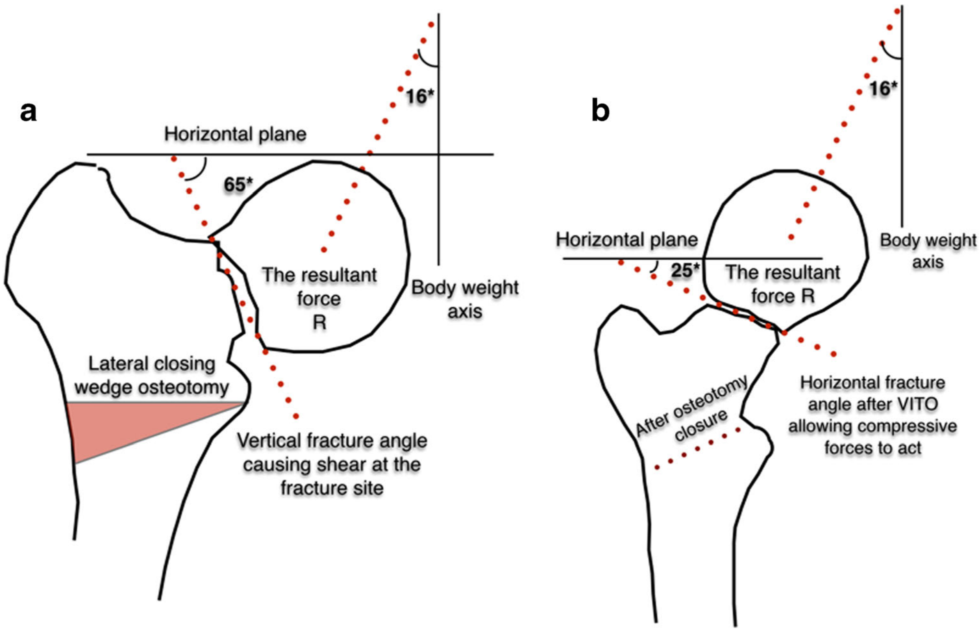
Indications and contraindications (Table 1)

Surgical technique

Preoperative assessment and templating

Careful clinical and radiological assessment is important for correcting all components of the deformity in multiple planes. Limb length discrepancy and coronal, sagittal, and rotational correction needed should be taken into account for planning the osteotomy [10]. AP and lateral x-rays are mandatory for evaluation. AP x-rays should be taken in internal rotation to know the amount of femoral neck available. Use of traction helps to know the mobility of the pseudoarthrosis and to plan the desired amount of correction.

Fig. 2 How a valgisation osteotomy can negate shear forces by repositioning the nonunion more horizontally subjecting it to more favorable compressive forces across the pseudoarthrosis



The goal of surgery is to place the fracture perpendicular to the line of the resultant force R. This requires that the fracture angle is brought to less than 25°. Templating starts with tracing the deformed hip and proximal femur. For accurate templating, we need to know the amount of correction needed (Pauwel's angle minus 25°) and the insertion angle of the implant that is used [11]. Figure 4 shows the steps involved in templating with a 120° blade plate.

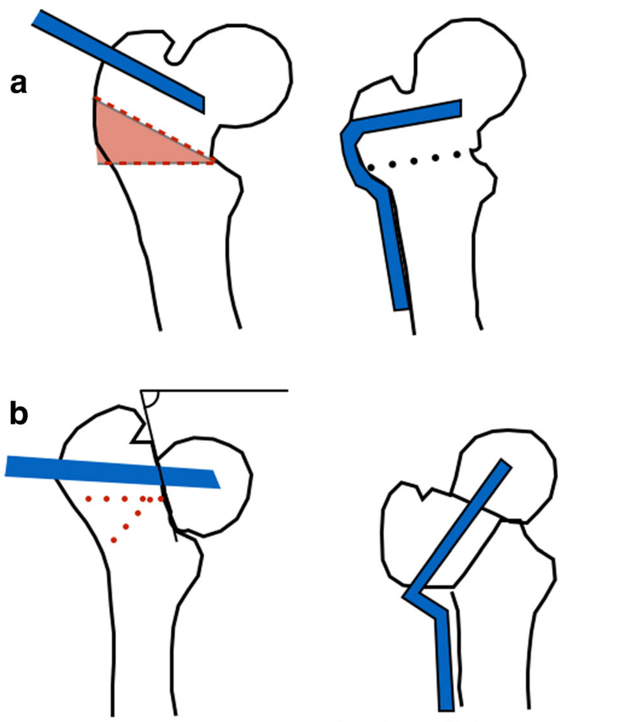


Fig. 3 **a** Pauwel's V osteotomy. **b** Pauwel's Y osteotomy. The Y osteotomy was used when there is gross varus with proximal migration of the shaft

In the illustrated example (Fig. 5), Pauwel's angle is 65°. So the amount of correction needed is (65° − 25° = 40°). The 40° lateral-based wedge is drawn on the tracing paper. The osteotomy should begin at 1.5 cm below the site of blade insertion. The thickness of the lateral wedge is measured in millimeters and would be replicated during the surgery. *Calculation of blade insertion angle:* The supplementary angle for the 120° blade plate is 60° (180° − 120° = 60°). For a 120° blade plate, the angle subtended by the blade plate with the femoral shaft will be equal to the supplementary angle if no correction is needed. Since we need a correction of 40°, the insertion angle of the blade plate to bring about a correction of 40° would be (60° + 40° = 100°). Now the measured amount of lateral based wedge can be removed to make sure that the target fracture angle is achieved and the blade plate sits in line with the femoral shaft.

Surgical procedure

The procedure can be performed on a standard radiolucent table or a traction table with the limb in traction. A standard lateral approach is used. The starting point of the chisel is chosen on the anterior two thirds of the greater trochanter to get a satisfactory alignment of the plate with the shaft in the sagittal plane [12]. Violation of the posterior neck cortex should be avoided in order to prevent injury to the retinacular vessels. The chisel is inserted at the templated insertion angle with the shaft. Once the chisel is fully seated to its depth, it is removed and the osteotomy is performed. The proximal and distal limbs of the osteotomy are marked on the lateral cortex

Table 1 VITO—indications and contraindications

Indications	Contraindications
1. Established femoral neck pseudoarthrosis 2. Delayed presentation (> 3 weeks) of a displaced fracture with high Pauwel's angle 3. Primary VITO (in type III Pauwel's fractures)— controversial	Absolute contraindication: 1. Established avascular necrosis with collapse of the femoral head (patchy areas of osteonecrosis without collapse is not an absolute contraindication) Relative contraindications: 2. Advanced age 3. Smoking 4. Osteoporosis 5. Small femoral head (NRR < 0.52) 6. Morbid obesity

according to the thickness of the measured lateral wedge. The osteotomy is done leaving the medial cortex intact. The removed wedge of bone can be used as a graft. The chosen blade plate is inserted fully into the neck. At this point, the blade plate stands off the shaft, which can be brought to the shaft by breaking the medial cortex and abducting the limb. The distal limb of the plate and the femoral shaft can be clamped together and brought to neutral bringing about the desired horizontalization of the fracture plane and valgisation of the proximal femur. Further compression at the osteotomy site can be achieved by using an articulated tension device.

Published results

VITO is the most successful technique reported in the management of femoral neck pseudoarthrosis [13]. The successful results have been replicated time and again with very little modification from its original description (Fig. 6). Several authors have reported excellent results in terms of achieving osseous union, good long-term function with minimal incidence of femoral head osteonecrosis in different patterns of nonunion, and different patient population using different types of implants [14–20]. Easy and reproducible surgical technique, use of regular implants, and presence of good bone quality given the patient population is relatively young and no need for bone grafting make VITO the first choice for treating femoral neck nonunions with reportedly high success rates (Table 2).

Variations in technique

Inter or subtrochanteric osteotomy

The osteotomy is usually performed at a level just proximal to the lesser trochanter. This leaves a bone bridge that is just

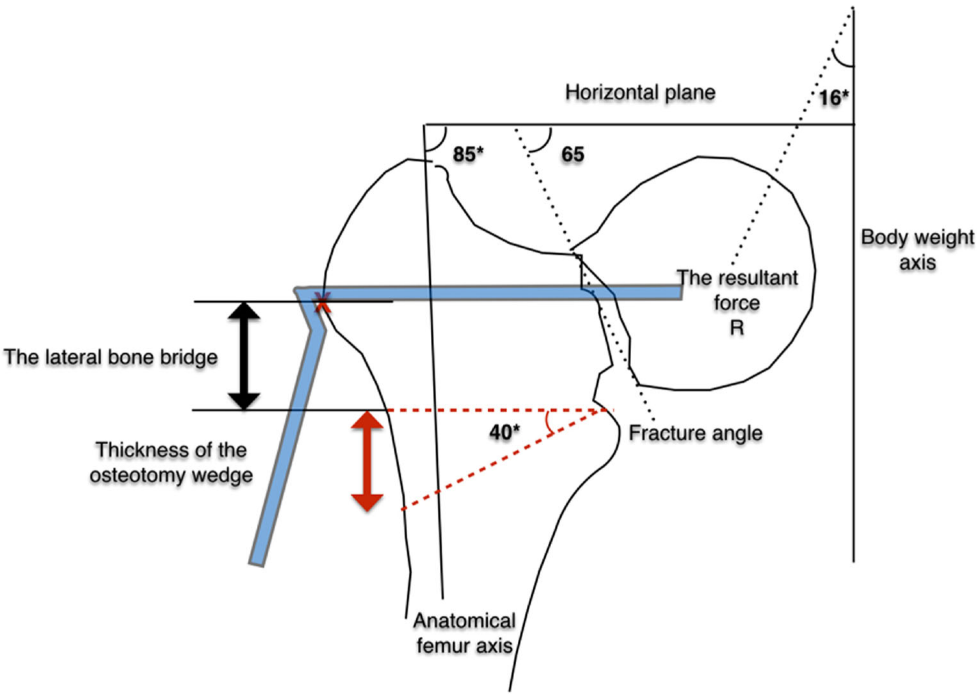


Fig. 4 Pre-operative planning with a 120° blade plate: The blade insertion angle is calculated based on the supplementary angle + the degree of correction (fracture angle − 25°). Tracings are made to calculate the thickness of the lateral wedge and to confirm the degree of correction after the planned osteotomy

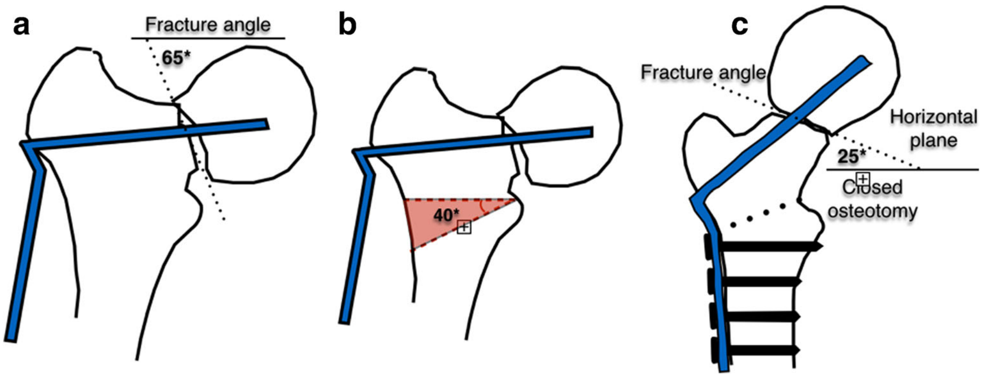


Fig. 5 Steps of VITO using a 120° double-angled blade plate

adequate between the implant footprint and the osteotomy. An intertrochanteric osteotomy provides excellent bony contact between cancellous bony surfaces leading to predictable healing of the osteotomy. The only problem is iatrogenic failure of the bone bridge which can lead to lateral wall insufficiency and instability at the osteotomy site [21]. For this reason, subtrochanteric osteotomies have been described. While failure of the bone bridge is less common with subtrochanteric osteotomy, osteotomy healing and difficulty in controlling the proximal fragment due to muscular forces is a concern.

Full wedge or half wedge

Ununited femur neck fractures lead to a shortened limb and achieving limb length equalization is always a desired goal with VITO. Valgisation in principle improves leg length but removing a full thickness lateral wedge of bone can compromise the ability to achieve limb length equalization and can also significantly alter the mechanical axis of the limb. Careful preoperative planning with regard to templating and implant choice is required to avoid or minimize these problems. In spite of meticulous planning, limb length discrepancy of up to 1 cm is common after a full-thickness lateral-wedge osteotomy [11]. To avoid the problem, half-wedge and no-wedge techniques have been described (Figs. 7 and 8) [22]. The half-wedge technique minimizes the bone removed at the proximal femur and helps improve limb length equalization at the expense of less bony contact between osteotomy surfaces. The no-wedge sliding technique is done with an oblique osteotomy to allow the osteotomy surfaces to slide against each other which brings the correction. The sliding osteotomy requires medialization of the shaft. While this may be acceptable for smaller corrections, large corrections can be difficult to perform without significant medialization of the femoral shaft. This may affect the contact at the osteotomy surfaces and also alter the mechanical axis.

Choice of implant

Different implants can be used for VITO (refer to Table 2). Blade plates are popular since they remove less bone, leave a small footprint, and offer better rotational stability. Implant with a higher angle is preferred to limit the amount of undesired medialization of the femoral shaft. Blade plates however require a more exact surgical technique and offer less intraoperative flexibility. Wrong blade trajectory can compromise the alignment and contact at the osteotomy site. Screw devices are modular and easy to use. Like the blade plate, it can achieve comparable correction but screws remove a lot more bone, which is an important factor to consider. They are rotationally less stable than the blade plate and often needs to be used with a derotation screw. Using a double-angled blade plate may cause undesired medialization of the shaft (Fig. 9). This can be avoided by using a blade length that is 10–15 mm longer or

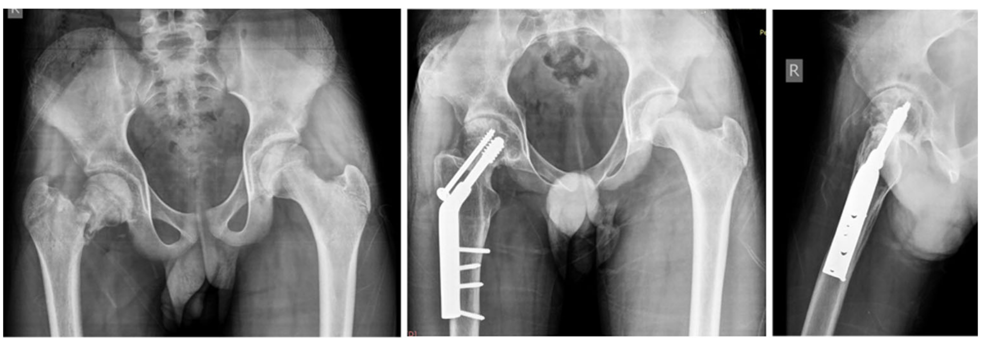


Fig. 6 Case example of a 17-year-old male with a 9-month-old femoral neck pseudoarthrosis. Valgisation was done with a 135° SHS. Union was achieved in 6 months. His Harris hip score was 83

Table 2 Note: This data is mandatory. Please provide.

Reference	*N*	Mean follow-up (year)	Union rate, *n*/total (%)	AVN, n/total (%)	Implant	Functional outcome
Marti et al.	50	7.1	43/50 (86)	22/50 (44%)	DABP	HHS—91
Anglen et al.	13	2	13/13 (100)	2/13 (15)	DABP	HHS—93
Wu et al.	32		32/32 (100)	2/32 (6)	SHS ± subtrochanteric osteotomy	NA
Kalra et al.	22	2.5	20/22 (85)	2/22 (9)	DABP	75%: good to excellent results
Sringari et al.	20	2	18/20 (90)	nil	DABP	NA
Magu et al.	48	6	44/48 (94)	2/48 (4)	DABP	HHS—86.7
Khan et al.	16	2.5	14/16 (87)	nil	SHS: 120°	HHS—88
Said et al.	36	3.5	35/36 (97)	5/36 (13)	Single-angled blade plate: pre-bent 130°	NA
Sen et al.	22	3.2	21/22 (97)	5/22 (22)	DABP + non-vascularized fibula	66%: good to excellent results
Gadegone et al.	41	2.75	39/41 (95)	7/41 (17)	SHS (110° – 130°) + non-vascularized fibula	HHS—90.9
Gavaskar et al.	11	1	11/11 (100)	nil	SHS (subtrochanteric osteotomy) no wedge	Oxford—40
Gupta et al.	60	3.5	56/60 (93)	4/60 (6)	SHS, 130° + subtrochanteric osteotomy	HHS—87.5
Varghese et al.	32	5	29/32 (91)	13/32 (44)	DABP	HHS—82
Yuan BJ, et al.	32	1.8	31/32 (97)	7/32 (22)	DABP	NA
Abdelazeem, et al.	22	3.8	22/22 (100)	nil	Contoured 4.5-mm DCP + iliac graft + subtrochanteric osteotomy	HHS—89.6

DABP: double-angled blade plate; *SHS*: sliding hip screw; *HHS*: Harris hip score; *NA*: not available

a single angled blade plate/sliding hip screw. Pre-bent double-angled DCS and contoured dynamic compression plates have also been reported in literature with successful results [23, 24].

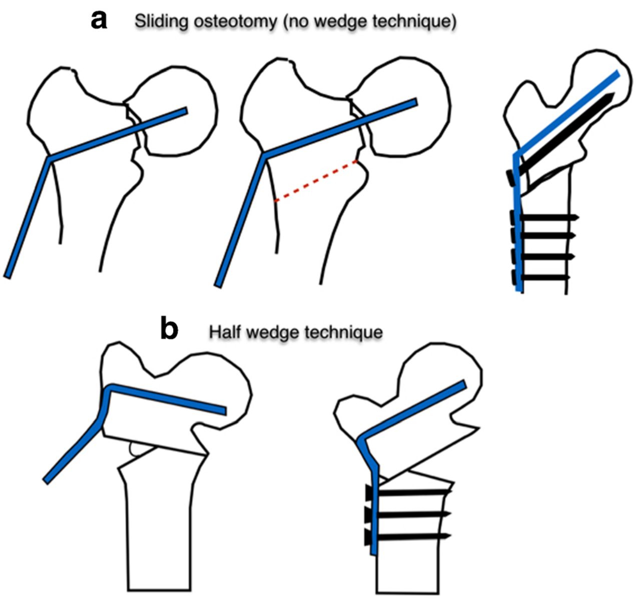


Fig. 7 **a** Sliding osteotomy (no wedge): This technique relies on an oblique osteotomy made at an angle corresponding to the degree of correction required. The osteotomy surfaces slid against each other achieving necessary valgisation with minimal translation. **b** A half wedge was described to minimize bone resection and improve limb length equalization

Problems and complications

Failure at the nonunion site is the most common problem after VITO. Reasons cited for failure include poor surgical

Fig. 8 Case example of a 30-year-old male who successfully underwent VITO using a no wedge technique

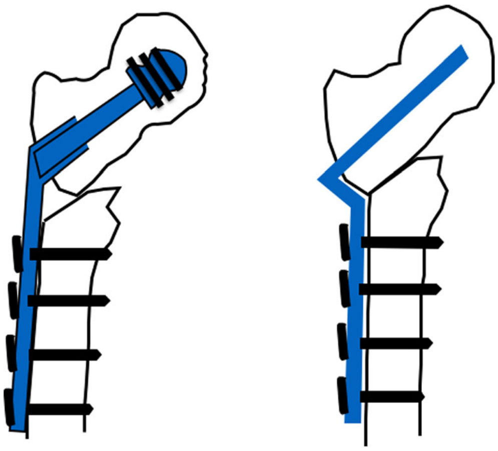


Fig. 9 How a SHS prevents alteration in the mechanical axis compared to a double-angled blade plate by preventing medialization

technique with inadequate valgisation, shorter length, or poor position of the blade/screw in the head. Loss of fixation due to failure of the lateral bone bridge and sagittal plane deformity also has been reported. Another important predictor for failure is inadequate bone stock due to neck resorption. A neck resorption ratio (NRR) of (< 0.52) was associated with more failures in the series reported by Varghese and colleagues [13]. NRR is calculated as a ratio of available femoral neck at the nonunion and the length of the normal femoral neck on the opposite side (Fig. 10). Failures at the osteotomy site are less common but have been reported in chronic smokers and obese patients.

Excess valgisation of the femoral head has been reported to increase the incidence of avascular necrosis of the femoral head (AVNFH). Valgisation of 15° more than the normal contralateral side has been shown to increase joint reaction forces and kinking of the posterior retinacular vessels [13]. Occurrence of AVNFH leads to rapid deterioration of hip function necessitating total hip replacement (THA). Excessive valgisation also leads to more distortion of the

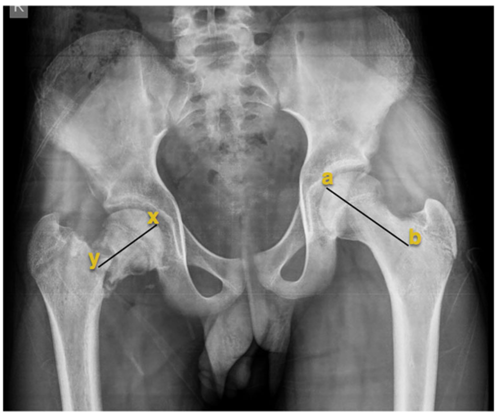


Fig. 10 The neck resorption ratio (NRR) is calculated by dividing the longest length of the femoral head–neck fragment on the nonunion side and the length of the intact femoral neck measured until the intertrochanteric line

proximal femoral anatomy that may complicate THA. Barei and colleagues showed excellent union rates with a mean Pauwel's angle of 47° (23° − 67°). They were able to preserve the proximal femur anatomy and biomechanics better with lower valgisation, yet achieving union rates comparable to published results [2].

Another universal problem after VITO is altered gait [25]. Limp can be either due to excess valgisation leading to decreased femoral offset or limb length discrepancy. This effect is more pronounced in patients with a major degree of neck resorption. Reduction of femoral offset of up to 45% compared to the opposite side has been reported.

VITO however well done does alter the mechanical axis of the lower limb. The alteration is more pronounced in high degree of corrections. The mechanical axis is shifted laterally after VITO and this leads to lateral compartment overload and premature degenerative changes at the knee joint (Fig. 11). During VITO, it is important to lateralize the shaft to avoid

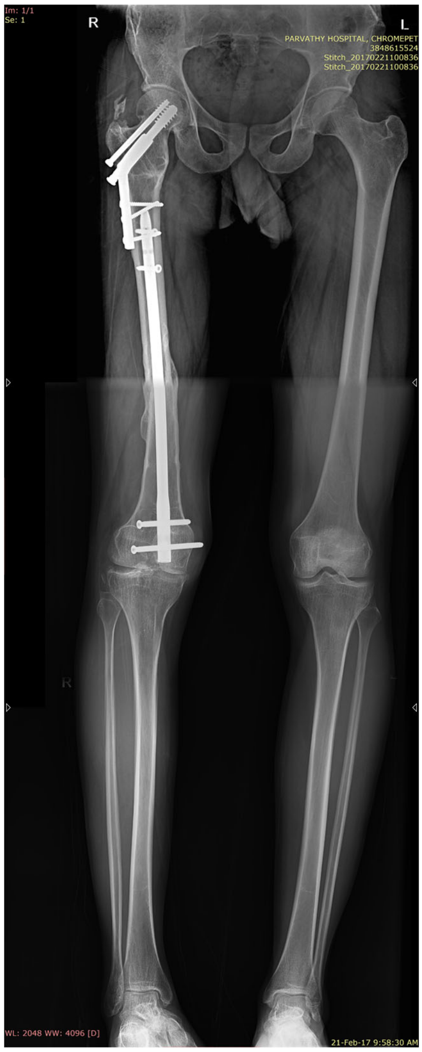


Fig. 11 Case example on a 26-year-old male shows evidence of knee lateral compartment arthritis 3 years post VITO

lateral shift of the mechanical axis. This can be done easily using a DHS compared to a double-angled blade plate. If a double-angled blade plate is used, it is important to use a blade length that is 15 mm longer than the measured length to allow space for lateralization.

Disturbed proximal femoral anatomy and altered mechanical axis can lead to difficult THA when required. THA after VITO is often more complex and requires more surgical time, meticulous pre-operative planning and templating, and the need for modular implants [26]. This can be avoided by doing the osteotomy at a proximal level without disturbing the distal anatomy, avoiding sagittal plane malalignments, and preventing excessive valgisation and medialization of the femoral shaft.

Summary

VITO is the most successful technique reported for treating femoral neck nonunions. VITO acts by improving the loading characteristics at the nonunion site subjecting it to predominantly compressive forces that help to achieve osseous union without the need for bone grafting. The technique is simple, can be performed with routine implants, and has produced predictably successful results in 85–100% of patients in published results. Careful pre-operative planning and a meticulous surgical execution can help prevent or minimize limb length discrepancy and interfere less with mechanical axis and femoral offset. Excess valgisation does not offer any advantage with regard to fracture union and should be avoided to prevent poor function, AVNFH, and joint degeneration.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

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