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ADVANCES IN PATELLOFEMORAL SURGERY (L REDLER, SECTION EDITOR)

Femoral Derotational Osteotomies

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Abstract

Purpose of Review Femoral derotational osteotomies are performed to correct residual symptomatic increased femoral torsion in adolescents and adults. Typical indications are anterior knee pain caused by patellar maltracking and patellofemoral instability. There is still no consensus as to what the correct indication is and which surgical techniques lead to the best outcomes in performing a femoral derotational osteotomy.

Recent Findings Good early clinical outcomes have been reported. However, long-term studies and data on return to play are lacking. Surgery often is performed according to the surgeon's experience. There is no evidence to support decisions regarding surgical technique or level of osteotomy.

Summary Femoral derotational osteotomy is the treatment of choice in patients with symptomatic excessive anteversion and torsional malalignment of the femur. Multiple techniques have shown good clinical results with high patient satisfaction. Future studies however must focus on radiographic and clinical assessment to understand different subtypes of torsional deformity and its implication on operative therapy.

Keywords Femoral derotational osteotomy · Femoral anteversion · Knee pain · Hip pain · Patellofemoral instability · Intoeing

Introduction

Rotational deformities with increased femoral anteversion are common and usually self-correcting in children [1]. Femoral version is defined as the angular difference between the axis of the femoral neck and the transcondylar axis of the knee. In most adults, anteversion averages between 10° and 15° [2].

Excessive femoral anteversion can lead to a variety of clinical presentations including anterior knee pain, patellofemoral instability, and an internally rotated gait [3–6, 7•]. When increased femoral anteversion is associated with external torsion of the tibia, a normal foot progression angle can be found [8]. Recent studies additionally demonstrate that increased femoral internal torsion is a risk factor for patellofemoral instability and can result in abnormal patellofemoral contact pressure [4, 7•, 9–11]. Parikh et al. [4] demonstrated that intoeing also results in increased tension of the MPFL, increased forces on the lateral patellar facet, and decreased forces on the medial facet [4].

Increased femoral anteversion additionally can cause gait disturbance with tripping and difficulties with running and increased stress on the anterior labrum in patients with concomitant developmental dysplasia of the hip. Complaints can range from buttock pain due to ischiofemoral impingement to anterior hip pain and labral tears as the forward-facing femoral head places excessive stress on the iliopsoas and labrum [12–14].

Indication

Femoral derotational osteotomy is generally considered for patients with symptomatic excessive anteversion of the femur. The indication is based on the combination of symptoms and clinical and radiological evaluation.

Clinically, femoral anteversion can be measured according to the technique described by Ruwe et al. [15]. The trochanteric prominence angle (TPA) is measured with the patient prone and knee flexed to 90° (Fig.1). The examiner feels for the greater trochanter of the femur and rotates the hip until the

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Fig. 1 According to the technique described by Ruwe et al. [15], femoral anteversion can be measured clinically with the patient prone and knee flexed to 90°. The examiner feels for the greater trochanter of the femur and rotates the hip until the trochanter is most prominent laterally. In this position, the degree of femoral anteversion is estimated as the angle between the long axis of the tibia and a vertical line

Fig. 2 View from the front visualizing the squinting patellae due to increased femoral anteversion

trochanter is most prominent laterally. In this position, the degree of femoral anteversion is estimated as the angle between the long axis of the tibia and a vertical line. Ruwe et al. [15] found this measurement to be more accurate than radiographic measurements.

Clinical examination typically also includes the measurements of internal and external rotation with the hip in both flexion and extension. Internal rotation and external rotation in hip extension. In patients with increased femoral anteversion, internal rotation of the hip far exceeds external rotation. Additionally, while standing, inward pointing of the patellae, described as the "squinting patellae," can be observed (Fig.2).

Imaging

In the literature, various imaging techniques, including radiography, ultrasound, computed tomography, and magnetic resonance imaging (MRI), have been used to assess femoral and tibial torsion [16, 17, 18•, 19•]. Standard conventional radiographic imaging for femoral anteversion includes a Dunn/Rippstein view (Fig.3). As originally described, it is an AP view of the hip with the patient supine and with the hips and knees flexed at 90°, the legs abducted 20° [20]. With cross-sectional imaging techniques, such as CT or MRI, the angle between the femoral neck axis and the distal femur can be measured more reliably (Fig.4). CT and MRI are therefore regarded as the gold standard for measuring torsion in the femur.

No clear indications for surgical correction and no true threshold value for pathological internal femoral torsion are reported in the literature. Weinberg et al. [21•] measured tibial torsion and femoral version in 1158 cadavers and assessed for the presence of degenerative joint disease of the hip and knee.

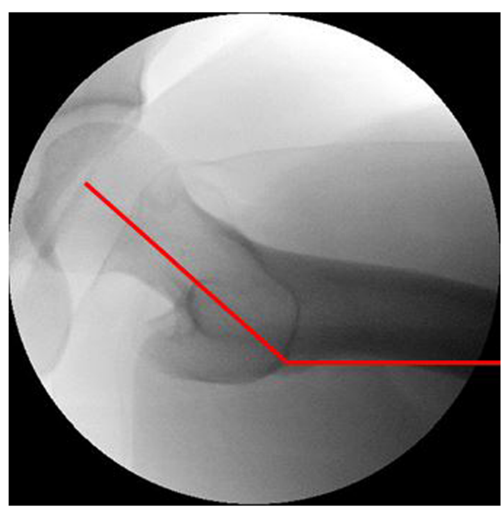

Fig. 3 Radiographic measurement of femoral anteversion according to Rippstein [20] on an anteroposterior (AP) view of the hip with the patient supine and with the hips and knees flexed at 90°, the legs abducted 20°. Anteversion is measured as the angle between the horizontal axis and the axis of the femoral neck (red lines). Reprinted with permission

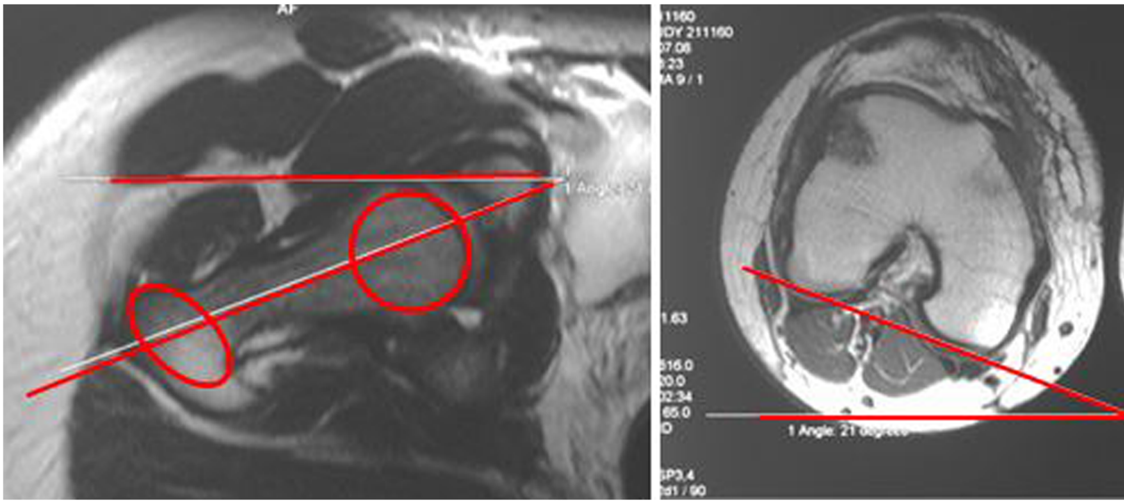

Fig. 4 In the technique described by Waidelich et al. [16], the center of the femoral head on one transverse slice is connected to the center of an ellipse around the greater trochanter on another transverse slice. The axis in the distal part of the femur is a tangent to the posterior condyles on a transverse image. Femoral torsion is assessed by the angle between axes in the proximal and distal parts of the femur. In this case, the femoral torsion added up to 42°

In their study, femoral version and tibial torsion were not associated with hip or knee arthritis. As a clinical conclusion, treatment of femoral anteversion should be based on the symptomatology. In patients free of symptoms, no prophylactic surgery is necessary. We recommend derotation osteotomies in patients with symptomatic patellofemoral malalignment and femoral anteversion greater 25–30°. The goal of the surgery is to correct anteversion to a normal value (15°) by rotating the distal fragment externally, correcting the transverse knee alignment.

Surgical Techniques and Results

Numerous techniques at the proximal [22•, 23–25], diaphyseal [26, 27•, 28–32], or distal femur [7•, 33•, 34–36] have been reported with good results. Proximal intertrochanteric osteotomies are usually secured with angle blade plates, distal metaphyseal osteotomies are usually secured with locking plates, whereas diaphyseal osteotomies are typically secured with an intramedullary rod (Fig. 5).

The literature provides no evidence whether a proximal, mid-shaft, or distal location of the osteotomy is preferable.

The authors' preferred method for femoral correction is a distal supracondylar derotational osteotomy [7•]. Our experience includes over 100 patients with idiopathic or secondary excessive femoral anteversion corrected with a distal osteotomy and fixed with a locking plate. The use of a locking plate and fast healing of the metaphyseal osteotomy allow exact derotation and rapid full-weight bearing and return to normal activities [7•, 33•].

The medial aspect of the distal femur is exposed through a subvastus approach [7•]. After incising the subcutaneous tissue, the vastus medialis muscle is elevated and dissected from the intermuscular septum. Care has to be taken not to injure the medial patellofemoral ligament at the distal end of the exposure. Under image intensifier, the position of the osteotomy and plate are determined on the anteromedial femur. The use of two Schanz screws proximal and distal to the planned osteotomy facilitates derotation (Fig. 6a). The osteotomy is performed perpendicular to the femoral shaft with drill holes followed by an oscillating saw (Fig.6a). The oscillating saw is used to score the cortex prior to making the osteotomy to aid in visualizing the amount of derotation (Fig. 6b). Derotation of the distal fragment is then performed using the Schanz screws as joysticks to the desired amount of correction (Fig.6b). The use of an image intensifier is recommended to confirm no unintended deformity is introduced in the sagittal or coronal plane. Finally, fixation of the osteotomy is performed with a locking plate [6].

In a follow-up study with a minimum follow-up of 12 months after combined reconstruction of the MPFL and femoral derotation osteotomy, significant improvement of knee function and good patient satisfaction was found. No re-dislocation of the patella occurred [7•].

Dikschas et al. [33•] published similar good clinical results in 30 patients after supracondylar femoral derotation osteotomy for anterior knee pain, patellofemoral instability, or femoroacetabular impingement.

Hinterwimmer et al. [34] reported their technique of supracondylar femoral derotation osteotomy for patellofemoral malalignment. The author performed a biplanar osteotomy with resection of an anterior wedge to enhance primary fixation stability and osseous consolidation by increased bone-to-bone contact. However, they did not report follow-up data of their technique.

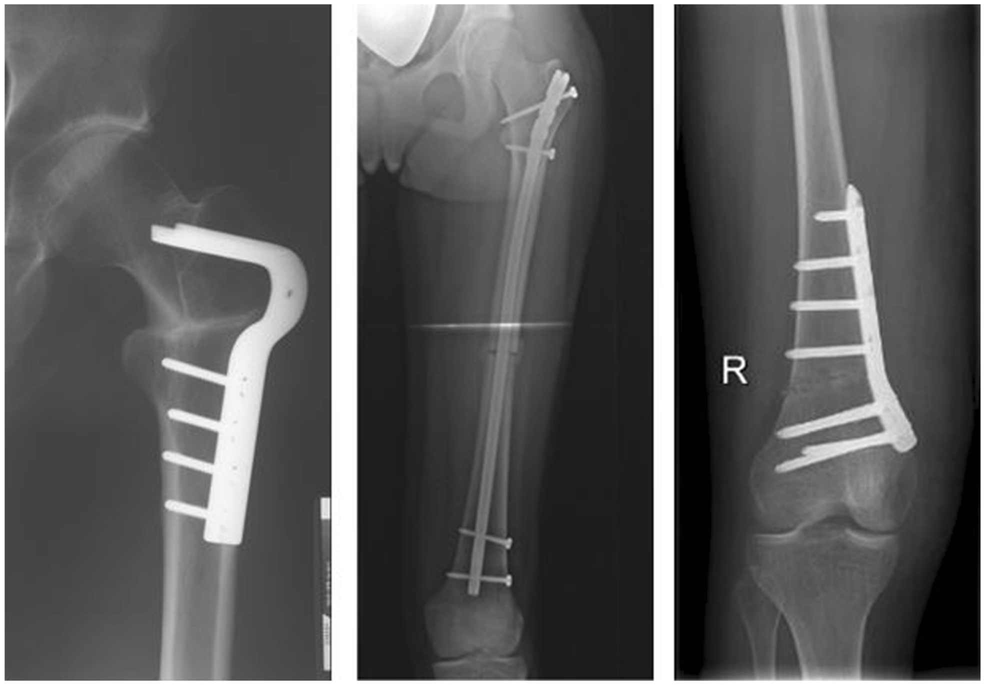

Fig. 5 Typical techniques of femoral derotational osteotomies. Proximal intertrochanteric osteotomy secured with an angle blade plate, diaphyseal osteotomies secured with an intramedullary rod, and distal supracondylar osteotomy secured with a locking plate

Diaphyseal Osteotomy

The technique of diaphyseal osteotomies has been reported by several authors [26, 27•, 28–32] typically using interlocking screws. Stambough et al. [27•] reported results of 28 consecutive patients between 2013 and 2014 who underwent derotational osteotomy about an antegrade intramedullary nail. Two complications were noted in their series (9%). One patient required a femoral exchange nailing at 9 months after the index operation for a symptomatic, aseptic femoral nonunion. At 1-year minimum follow-up, 78.5% subjects demonstrated a mean significant improvement of 13 points for International Knee Documentation Committee Score.

Mei-Dan et al. [31] described a minimally invasive single-incision technique based on an intramedullary saw that enables an inside-out osteotomy, preserving the periosteum and biological activity in the local bone and soft tissue to promote faster fracture healing. In the experience of the authors, the use of an expandable nail with abutment of the inner cortex makes interlocking unnecessary. The authors however also reported difficulties with saw insertion and advancing the saw down the canal. Additionally, Mei-Dan et al. [31] stated that "current intraoperative measurement techniques need refinement."

In a letter to the editor, Matuszewski PE and Herzenberg JE [32] raised concerns about the described technique. They propose that reaming in unfractured bone may increase intramedullary pressure with the risk of pressurization of bone marrow contents into the circulation. The risk for fat/air embolism, pulmonary embolism, hypotension, oxygen desaturation, and mortality may therefore be increased. The authors therefore recommended pre-drilling at the level of the osteotomy prior to reaming to allow ventilation of the canal (decreasing the risk of fat embolism) and to allow emergence of the reamings at the osteotomy level [32].

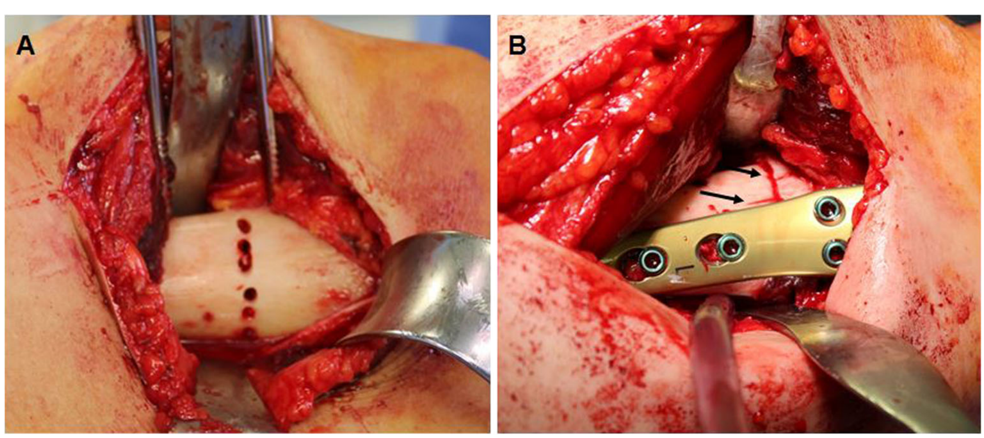

Fig. 6 Intraoperative photograph demonstrating the two Schanz screws inserted into the femur proximal and distal to the planned osteotomy in order to facilitate derotation. The osteotomy was performed with drill holes and with an oscillating saw (**a**). Fixation with a locking plate after a femoral derotation osteotomy. The degree of the desired correction is visualized by the small vertical cuts (black arrows) (**b**)

Proximal Osteotomy

Osteotomies of the proximal femur can be performed either on the inter- or subtrochanteric level. The major advantage of intertrochanteric osteotomies is the possibility to additionally correct varus/valgus and flexion/extension deformity. The most common indication for intertrochanteric osteotomies has been hip dysplasia. In recent years however, reorientation of the acetabulum has become the treatment of choice to treat hip dysplasia. In general, the indication for intertrochanteric osteotomies has diminished over the last 20 years. In the literature, there are only few studies about the results of inter- or subtrochanteric derotational osteotomies available. Most published studies report results of intertrochanteric osteotomies in patients with cerebral palsy.

Payne et al. [24] reported the results of 51 osteotomies in 27 patients with idiopathic femoral anteversion over a 15-year period. Thirty-four derotational osteotomies in 17 patients were performed using a supracondylar technique with crossed-pin fixation. Sixteen osteotomies in 11 patients (10 patients in prone, 1 patient in supine position) were performed using an intertrochanteric osteotomy and blade-plate fixation. The authors report that intertrochanteric osteotomy allowed more accurate correction of the intoeing deformity and decreased the need for postoperative immobilization. Today, however, the disadvantages of the distal osteotomy are no longer present, since locking plates allow immediate mobilization and weight bearing.

Another study by Huber et al. [23] assessed bone healing and complication rate following subtrochanteric rotational osteotomy fixed with a locking compression plate. In their follow-up, no complications were found; all osteotomies healed without secondary loss of correction. Fixation with a locking plate allowed simultaneous bilateral correction and immediate full weight bearing with crutches, with a minimal risk of implant failure [23].

MacWilliams et al. [37•] performed a multicenter retrospective study, which included 25 patients with idiopathic femoral anteversion who underwent femoral derotational osteotomy. All patients had completed pre- and postoperative gait analyses. The authors found reduced gait pathology and improvements in hip rotation and foot progression after derotational osteotomy [37•].

Anatomical Considerations

Georgiadis et al. [18•] pointed out that the terms “femoral anteversion” and “femoral torsion” have often been used interchangeably in the orthopedic literature, yet they represent distinct anatomical entities. Anteversion refers to the anterior tilt of the femoral neck, whereas torsion describes rotation of the femoral shaft. Since treatment of femoral neck deformity may be different than diaphyseal deformity, the authors recommend using terms that differentiate these morphologies. They suggest that when referring to transverse plane rotation of the femur and its surgical treatment, that “version” be used for rotation localized proximal to the lesser trochanter and “torsion” be used for rotation localized distal to the lesser trochanter [18•].

A wide range of the standard values for femoral torsion has been reported in the literature. In most adults, anteversion averages between 10° and 15°. In a radiographic study performed by Decker et al. [38], the anteversion of 211 healthy femurs was measured using torsion difference CTs according to the technique published by Jend [39]. The authors found mean values differed between 17.8° and 22.7° in women and 15.3° and 21.4° in men. Descriptions of various measurement techniques have been published, using transverse or oblique and single or superimposed image slices. The techniques also use different anatomical landmarks for measurement. Kaiser et al. [40•] compared the feasibility of six different CT-based measurement techniques (Waidelich, Murphy, and Yoshioka on transverse images and Hernandez, Jarrett, and Yoshioka on oblique images) for establishing an indication for derotational osteotomy in the cases of patellar instability or femoral fracture. The authors found that femoral torsion values depend on the measurement technique. When derotational osteotomy is being considered, it is essential to use different threshold values depending on the measurement technique. With regard to intraobserver and interobserver agreement, techniques that use superimposed images or an oblique image in their study appeared to be preferable for measuring femoral torsion. The authors recommend the technique described by Waidelich et al. [16] because of its high intra- and interobserver agreement and the availability of norm values in the literature (Fig.4).

A CT-based rotational analysis by Waisbrod et al. [41•] analyzed anatomic location of abnormal femoral anteversion. They measured femoral anteversion using the lesser trochanter as an additional landmark. Their results show that about two thirds of torsional changes occur distal to the lesser trochanter. The authors conclude that their results provide a considerable indication for a subtrochanteric osteotomy to address correction of femoral rotational deformity at its anatomical origin.

Seitlinger et al. [42•] measured femoral torsion on MRI at different levels in patients with abnormally high or low femoral torsion and compared the results with healthy volunteers. To assess femoral torsion in their study, four lines were drawn: a line through the center of the femoral head and neck, a second line through the center of the femur at the top of the lesser trochanter, a third line tangent to the posterior aspect of the distal femur just above the attachment of the gastrocnemius, and a fourth line tangent to the posterior condyles [42•]. As results of their measurements, the authors conclude that all three levels of the femur contribute to the total femoral torsion. The authors additionally found a different pattern among patients with high torsion and patellar instability. Patients with patellofemoral problems showed a lack of external torsion in the femoral shaft in patients and high femoral torsion. As the attachment of the quadriceps muscle is mainly located on the femoral shaft, this could be an explanation for an increase in lateral force on the patellofemoral joint [42•]. The authors recommend that the level of torsional deformity should be respected when planning a derotational osteotomy. As multilevel measurements of femoral torsion have not yet found their way into clinical practice, the clinical relevance of the results of the study remains unclear.

Liebensteiner et al. [43•] found that the morphology of the trochlea is significantly related to femoral anteversion. In their study, increased femoral torsion was associated with a flatter, more dysplastic trochlea. This was particularly true for increased torsion located at the distal femur.

Paley [44] has emphasized that derotational osteotomies of the femur can cause malalignment in the frontal plane, because the mechanical and anatomical axes are different. No specifications of the amount of change at different levels were provided however.

A study by Nelitz et al. [45•] analyzed the effects of torsional osteotomies on frontal plane alignment with a 3D computer model, created from CT data of a human cadaver femur. Virtual torsional osteotomies of 10°, 20°, and 30° were performed at proximal, mid-shaft, and distal levels of the femur. The change of the frontal plane alignment was expressed by the mechanical lateral distal femoral angle (mLDFA).

Proximal external derotational osteotomies tended to result in an increased varus angulation, while distal external derotational osteotomies tended to result in an increased valgus angulation. As a clinical consequence of their study, the authors concluded that torsional osteotomies have an increased risk of unintentional implications on frontal plane alignment. Torsional osteotomies can induce a clinically relevant change of frontal plane femoral malalignment, especially in patients with an increased antecurvatum angle of the femur [45•].

Conclusion

Femoral derotational osteotomy is the treatment of choice in patients with symptomatic excessive anteversion and torsional malalignment of the femur. As increased femoral torsion is a risk factor for patellofemoral instability, torsional osteotomy has to be considered as an isolated MPFL reconstruction might not be sufficient, as it does not address the underlying pathology [7•].

In the literature, there are only few reports describing the results of femoral derotational osteotomies in otherwise healthy patients, whereas there are numerous publications regarding the treatment of torsional deformities and intoeing in children with cerebral palsy. Overall, with different techniques, good clinical results with good patient satisfaction can be achieved.

Reviewing the literature, there is no clear evidence to support the level at which to perform the osteotomy. Surgery often is performed according to the surgeon's experience. It seems logically consistent that hip surgeons prefer a proximal, trauma surgeons an intramedullary, and knee surgeons a supracondylar osteotomy. Others argue that the correction should be performed in the region of the complaints or where it can possibly be combined with additional procedures. In the author's experience, a supracondylar osteotomy and fixation with a locking plate is a safe procedure with the possibility of early mobilization and full weight bearing. Additionally, the degree of correction can be performed more accurately compared to the intramedullary osteotomy. When the osteotomy is combined with surgical dislocation of the hip however, a proximal approach seems reasonable. There is no evidence of the superiority of one surgical technique over the other.

A lot of questions concerning the topic of torsional deformities and the operative correction remain unanswered:

How important is the level of the osteotomy?

Should the pattern of torsion distribution determine the level of the osteotomy?

What is the threshold at which the osteotomy should be the primary treatment in patients with patellofemoral instability?

Depending on the level of the osteotomy, derotational osteotomy results in different changes of muscle attachments on the femur. What is the implication of the corrected muscle attachment on clinical outcome and gait?

Future studies are necessary to answer these questions in this highly interesting field of orthopedic surgery.

Compliance with ethical standards

Conflict of interest Manfred Nelitz declares that he has no conflict of interest.

Human and animal rights and informed consent This article does not contain any studies with human or animal subjects performed by any of the authors.

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