Stability of medial opening wedge high tibial osteotomy: a failure analysis

E. M. Nelissen • E. J. van Langelaan •
R. G. H. H. Nelissen

Received: 1 November 2008 / Revised: 16 December 2008 / Accepted: 17 December 2008 / Published online: 3 February 2009
© Springer-Verlag 2009

Abstract Medial opening wedge high tibial osteotomy (HTO) is often used to treat varus gonarthrosis in young, active, highly demanding patients, although it has many pitfalls, which were evaluated in a consecutive cohort of patients. A retrospective analysis of a consecutive series of 45 patients with 49 medial opening HTO for varus gonarthrosis using a spacer plate (Puddu I, Arthrex, USA) were included. A Chi square test was used to study the effect between the wedge size and complications. Complications occurred in 22 knees (45%). There was no significant difference between groups for individual complications; however, when combined, there were significantly more complications in the >10 mm wedge group (Chi square $p=0.05$). The overall complication rate in this series was 45%. The majority were related to intrinsic instability at the osteotomy site (24%) and surgical technique (20%). The evaluated spacer provided inadequate stability.

Résumé Analyse des échecs après ostéotomie tibiale d'ouverture interne. L'ostéotomie tibiale d'ouverture interne HTO est très souvent utilisée dans le traitement des gonarthroses en varus chez le sujet jeune et actif, cependant, il existe beaucoup de pièges. Ceux-ci ont été évalués sur une cohorte de patients consécutifs. Analyse rétrospective d'une

série consécutive de 45 patients ayant bénéficié de 49 ostéotomies internes d'ouverture du tibia pour gonarthrose en varus utilisant une plaque spéciale de type Puddu (Arthrex USA). Le Chi test a été utilisé de façon à évaluer les effets secondaires dus à l'importance de la taille du spacer et ses complications. 45% de complications (22 genoux) sont apparues. Il n'y a pas de différence significative entre les groupes concernant les complications habituelles, cependant il existe un taux significativement plus important de complications si l'ouverture osseuse est supérieure à 10 mm (Chi Square $p=0,05$). Globalement, le taux de complications de cette série est de 45% dont la majorité est secondaire à des problèmes d'instabilité au niveau de l'ostéotomie (24%) ou de la technique chirurgicale (20%). Cette plaque spéciale ne permet pas d'avoir une bonne stabilité de l'ostéotomie.

Introduction

Ever since Coventry's classic report on tibial osteotomy for gonarthrosis in 1965 [5], people suffering from medial, unicompartmental varus gonarthrosis have undergone this type of surgery. After the introduction and better results of unicompartmental joint prosthesis, more treatment options became available.

Currently, there are three possible operative options for treating this degenerative disease in relatively young patients (40–60 years) who have failed conservative treatment: a unicompartmental knee arthroplasty, a total knee arthroplasty or an osteotomy. Most surgeons would deem this type of patient too young for an arthroplasty and choose an osteotomy. In recent years the classic closed wedge osteotomy has given way to the medial opening wedge osteotomy which is said to be more accurate, has the advantage of using a medial approach, and eliminates the

E. M. Nelissen (✉) • R. G. H. H. Nelissen
Department of Orthopaedic Surgery,
Leiden University Hospital (LUMC),
kamer J11-70, Postbus 9600,
2300 RC, Leiden, The Netherlands
e-mail: e_nelissen@yahoo.com

E. J. van Langelaan
Department of Orthopaedic Surgery, Rijnland Hospital,
Leiderdorp, The Netherlands

need for a fibular osteotomy with the risk of peroneal nerve damage and fibular pseudarthrosis [20].

Several different types of osteotomy plates have been designed over the years by various authors. One of these plates, developed by Puddu et al. in the early 1990s, has a small “spacer tooth” incorporated in the plate to provide additional stability to prevent recurrence of the preoperative ‘deformity’ [17, 18]. This study evaluates the postoperative results with this type of fixation in a consecutive series of tibial osteotomies.

Patients and methods

From February 2000 until January 2004, 49 medial opening wedge tibial osteotomies were performed for unicompartamental varus gonarthrosis (45 patients, 29 male and 16 female). In 25 patients, the right side was involved, in five patients a bilateral osteotomy was performed in two separate sessions with at least three months between surgical sessions. Mean age at the time of surgery was 48 years (SD 19.9 years) with a range from 29 to 70 years. The implant used was the Puddu I (Arthrex, USA) spacer plate which consists of a spacer plate with variable wedge and non angular stable screws.

An independent observer evaluated the pre- and postoperative long weight bearing anteroposterior (AP) radiographs. The femorotibial angle, the degree of osteoarthritis using Ahlback’s classification method [1], and the presence of consolidation at the osteotomy site were assessed from these radiographs. The radiological consolidation was assessed in both the AP and lateral radiographs, full radiological consolidation was defined as bridging of the osteotomy gap with bone on both sides of the osteotomy, with no radiolucencies around the wedge. Furthermore, the operation report and follow-up notes (presence of pain on weight bearing, postoperative rehabilitation regime) were studied for analysis.

Operative technique and rehabilitation

All operations were performed by four experienced orthopaedic surgeons, all of whom had experience with the medial opening wedge technique, before using the Puddu plate. All patients had general or spinal anaesthesia depending on the patients’ preference, and were operated upon in supine position using the surgical technique described in the Arthrex Opening Wedge Osteotomy brochure.

A tourniquet was inflated to 300 mm Hg of pressure around the mid part of the thigh. The skin incision was placed vertically, on the medial side of the tibia, with a

small hockey stick like curve to the proximal and dorsal side. The periosteum was cut and partially stripped to make room for the osteotomy plate. A 1.6 mm K-wire was drilled under direct fluoroscopic control in an oblique manner and at an angle to the tibial axis aiming for the upper part of the fibular head. When satisfactorily placed, the osteotomy was performed using an oscillating saw for the first part and finished using a chisel under fluoroscopic control. Great care was taken not to damage the lateral cortex. The tibia was manually wedged to the point of desired correction, and the osteotomy plate was positioned and fixed. The osteotomy gap was then filled with Vitoss superficial bone substitute. The mean correction wedge was 10.7 mm (SD 2.31 m). Details on osteotomy wedge data are given in Table 1.

A drain was placed subcutaneously and the wound was closed. A pressure bandage was applied, and was left in situ for 24 hours and then removed together with the drain.

The intraoperative stability at the osteotomy site was assessed by the surgeon, who then determined the postoperative mobilisation regime (immediate partial weight bearing or non-weight bearing). This resulted in five different postoperative regimes with regard to time of mobilisation in the study group. A total of 23 osteotomies were allowed very limited weight bearing up to 15 kg using crutches during the first six to eight weeks. After this period, some patients were allowed to increase weight bearing over a period of two weeks to full weight bearing; in other patients partial weight bearing was continued until there was radiological evidence of progressive osteotomy healing. The other group of 26 patients were kept non-weight bearing for a period of eight to 12 weeks, followed by a period of partial weight bearing and progressive loading which ranged from two to eight weeks.

Results

In 31 of 49 patients (63%) radiological consolidation of the osteotomy occurred. This was marked by bridging of the osteotomy gap with bone on both sides of the osteotomy, with no radiolucencies around the wedge. Radiological evidence of consolidation would often occur much later than clinical consolidation (no more pain on full weight bearing).

In total, 22 (45.8%) osteotomies had one or more complication; these were divided into operation specific (Table 2) and general complications, such as infection and deep vein thrombosis.

One or more broken screws (Fig. 1a) were seen in 10 of 49 osteotomies. Despite these broken screws, only half of these patients had delayed union or pseudarthrosis, and symptoms such as pain during mobilisation. The others

Table 1 Patient data

Patient	Gender	Wedge size	Mobilisation (weeks)		Number of screws	Complication
			NWB	PWB		
1	M	7.5	8			
2	F	7.5	12			
3	M	7.5		6		
4	F	7.5	8	6		
5	F	7.5		6		
6	F	7.5		8		Pseudarthrosis
7	F	7.5		8		Lat cortex #
8	F	7.5		8		
9	F	9		8		
10	F	9	8		Plate	Lat plateau #
11	M	9	8			
12	M	10		8		Superficial infection
13	M	10	8	6		
14	F	10	8			Pseudarthrosis
15	M	10	8			
16	F	10	8	6		Pseudarthrosis
17	M	10		8		
18	M	10	8			
19	M	10		6		
20	M	10	8	6		
21	F	10		8		
22	M	10	6			
23	M	10	6			
24	F	10	6	8	1	Lat cortex #
25	M	10	8	6		
26	M	10	8	4	Plate+1	Lat cortex ++pseudarthrosis
27	F	10	6		1	Lat cortex #
28	M	10	6			Lat plateau #
29	M	10		6		
30	F	11		6		
31	M	11		6		
32	F	11		6		Pseudarthrosis
33	M	12.5		8	2	Pseudarthrosis
34	M	12.5		8		Pseudarthrosis
35	F	12.5	6		1	Lat cortex ++deep infection
36	M	12.5		6	2	Lat cortex #
37	M	12.5		6	3	Lat cortex ++pseudarthrosis
38	M	12.5		8	2	Pseudarthrosis
39	M	12.5		8	1	Lat plateau #
40	M	12.5	6	2	Plate	Lat cortex ++pseudarthrosis
41	M	12.5		6		
42	M	12.5	6	2	1	Pseudarthrosis
43	M	12.5		6		
44	M	12.5		6		
45	M	12.5	8	6		
46	M	12.5	8	6		
47	M	15	6	2		
48	M	17.5	8	6		Lat cortex #
49	M	17.5	8			Pseudarthrosis

M male, *F* female, *NWB* non-weight bearing, *PWB* partial weight bearing

Table 2 Operation specific complications

Complication	PWB	NWB	Total	Percentage of total
Failure of implant (osteotomy plate broken)	0	3	3	6.1%
Broken screws/ total used	9	6	15/198	7.5%
Osteotomies with broken screws	5	5	10	20.8%
Infraction of tibial head (lateral plateau)	1	2	3	6.1%
Lateral cortical fracture	4	5	9	18.4%
Pseudarthrosis	5	6	11	22.4%
Total complications	11	11	22	45.80%

NWB non-weight bearing, *PWB* partial weight bearing

healed without problems. There were 11 pseudarthroses, defined as absense of bridging of the osteotomy gap with bone on both sides of the osteotomy, and radiolucencies around the wedge on the one year postoperative radiograph. A lateral cortical fracture (Fig. 1b) was seen in nine out of

49 cases (18.4%). This was not often obvious at the time of operation, but became more apparent after a few weeks. There was no significant relation between the size of the wedge used, mobilisation regime, and the occurrence of lateral cortical fractures (Tables 1 and 2).

Fig. 1 Complications. **a** Broken screws. **b** Lateral cortical fracture. **c** Infraction fracture of the lateral tibia plateau. **d** Fracture of the Puudu I osteotomy plate

Infraction fracture of the lateral tibia plateau (Fig. 1c) was seen three times, probably resulting from wedging in combination with a relatively short osteotomy. Fracture of the Puddu I osteotomy plate (Fig. 1d) was seen in three cases.

To analyse the effect of the mobilisation regime, a distinction was made between patients that were allowed no weight bearing (NWB group) for the initial postoperative weeks and patients that were allowed partial weight bearing (PWB group) immediately. There was no significant relation between the mobilisation regime and the complication rate (Table 2), although the more conservative mobilisation regimes showed a trend towards fewer complications.

To study the effect of the wedge size on the postoperative osseous complications, two groups (less than or equal to 10 mm and >10 mm were defined). Four osseous complication groups were defined: none, tibial plateau fracture, pseudarthrosis at osteotomy site, and a combination of the latter two.

For each patient, pre- and postoperative anatomical mechanical axes and MPTA (medial proximal tibial angle) as defined by Brown et al. [24] were measured. Using this data, our patient group was divided into a group with complications and one without complications, and we calculated the change in these two parameters after osteotomy.

In general, the osteotomies in which complications occurred seemed to have a higher degree of correction when compared to the osteotomies without complications. For details see Table 3.

There was only one acute deep infection which was treated with IV antibiotics (Flucloxacilline). This resulted in pseudarthrosis requiring subsequent revision surgery with removal of the plate at one year, and finally consolidation. There was one superficial wound infection which healed with oral antibiotics. All patients received 0.3 cc subcutane-

ous low-molecular-weight heparin (LMWH), for the first six postoperative weeks. No deep vein thrombosis occurred.

Discussion

The aim of this retrospective study of high tibial opening wedge osteotomies was to evaluate complications at the osteotomy. The high failure rate (45%) seen with this implant and technique has also been reported by others [21, 23]. Some authors however report good medium- or long-term clinical and radiological results using this or a similar implant and technique [5, 9, 12, 17, 18].

In our series there was no relation between presence of pseudarthrosis and the occurrence of intraoperative complications such as lateral cortical fractures. We could find no correlation between preoperative value of anatomical axis and postoperative complications. This is consistent with previous publications by Leutloff et al. [15].

With regard to correction, there were significantly more complications in the large wedge group when comparing wedges larger or smaller than 10 mm (F 1.49 vs 3.3; $p=0.069$). This might indicate that the osteotomy has to be performed earlier when the varus deformation is still minimal, although Bhan et al. could find no relation between short-term results and degree of correction [22]. Additionally, we could not find a relation between the mobilisation regime (weight- or non-weight bearing) and complication rate.

The figures presented here are a clear indication of the problems surgeons encounter in treating unicompartmental knee osteoarthritis in an ever younger patient population. These patients often suffer from pains limiting their very active lifestyle and are by no means candidates for hemi- or total knee arthroplasty. The only operative option left in this group of patients (40–65 years, active and demanding lifestyle) seems to be a medial opening wedge high tibial

Table 3 Correction vs complication

Wedge	No complication					Complication				
	#	Av axis Δ (deg)	SD	Av MPTA Δ (deg)	SD	#	Av axis Δ	SD	Av MPTA Δ	SD
7.5	6	-3.1	1.35	4.7	2.62	2	-5.1	0.42	-1.4	4.1
9	2	-4.2	3.11	0.3	2.4	1	-4.4	0	3	0
10	11	-3.7	4.59	5.6	2.59	7	-6.6	3.77	6.23	6.43
11	2	10.7	na	7.3	na	1	-5	0	8.5	0
12.5	5	-3.3	2.3	4.23	3.3	9	-4.9	4.35	7.1	4.23
15	1	na	0	na	0	0	na	na	na	na
17.5	0	na	na	na	na	2	-8.7	9.4	7.1	7.14

number of osteotomies, Av axis Δ average anatomical axis change after osteotomy, Av MPTA Δ average MPTA change after osteotomy, na not available, SD standard deviation, MPTA medial proximal tibial angle

osteotomy. Osteotomies seem to have many advantages over an arthroplasty, i.e. no implant loosening and participation in sports is less of a problem. Wear problems related to artificial joint replacement are not an issue. Infection and haematoma are general complications but are less detrimental than in prosthetic replacement.

There are however some major pitfalls which are often not recognised. In analysing our failures we defined five key points which we think are responsible for the success or failure of the medial opening wedge high tibial osteotomy.

First, the mechanical theory states that in a healthy knee the mechanical axis runs through the centre of the knee, giving an equal distribution of weight on both compartments. In a knee suffering from varus gonarthrosis however, the mechanical axis is shifted medially, leading to an increased load on the medial compartment. This causes the arthrosis to progress. Changing the leg's alignment by performing an opening wedge osteotomy aims to overcorrect the mechanical axis which results in a reduced and more natural loading pattern [13, 16]. Several authors have partially or totally disagreed with this theory and claim that not the mechanical, but the dynamic axis is of more importance [4, 8, 10, 19]—which theory is correct is still a matter of discussion. Patient outcome studies show that a large number of patients who have undergone an opening wedge osteotomy would have the same procedure again. This means that the clinically satisfactory (medium term) results many authors have claimed with various osteotomy techniques cannot be ignored [11, 12].

Second, the type of implant used is a determinant for success of the osteotomy. A number of studies have reported on stability of various implants [6, 20, 23]. These studies have also shown that it is not the axial but the torsional loading which presents problems. Most implants are able to cope with the axial loading during midstance of gait but fail to resist the torsional loads which accompany these and thus fail. This suggests that to withstand the forces directed upon an osteotomy we need to have a very rigid osteotomy plate and rigid fixation of the screws in the bone before partial or full weight bearing is allowed. Most newly designed plates aim for more stability, mostly by using angle-stable screws.

The third key point is the postoperative mobilisation regime. Should the postoperative regime be standardised or should it be personalised and thus different for each case? A 65-year-old female with a weight of 70 kg and an osteotomy with a 7.5 mm wedge is very different from a 45-year-old male weighing 90 kg and having a correction wedge of 17.5 mm. The latter calls for an individualised postoperative regime. In this series no differences in complications between the different postoperative regimes were seen. Whether weight bearing is related to more complications in tibial osteotomies has never been investi-

gated. In a systematic Cochrane review this was not addressed [2]. Further studies on the effect of mobilisation on opening wedge osteotomies should be performed to investigate which regime is preferable. The weight of the patient and size of correction are likely to have influence on the stability. In this study the larger corrections seemed to have more complications.

The fourth factor for failure or success of the opening wedge tibial osteotomy is the amount of tibial wedge fill with either bone or a bone substitute. Several different materials and their use in high tibial osteotomy as either a wedge or filler have been investigated, but no conclusive advice about the function or necessity of a bone substitute or wedge filler has been made [7, 11]. No clinical studies have investigated the importance of the type of spacer (monoblock versus small particles) used in open wedge osteotomy. In general a more rigid monoblock spacer with a low porosity (e.g. Otis, Z.I du Monge, France; 25% porosity) is preferred in order to gain more stability and obtain faster consolidation. However, spacers which consist of small, separate particles with high porosity (e.g. Vitos, Orthovita, USA; 88–92% porosity) which are impacted, might give better consolidation. Randomised clinical trials might answer this question.

Finally, several authors have stressed the importance of an intact lateral cortex in the medial opening wedge osteotomy [21, 23]. Once there is a break in the lateral cortex or infraction of the lateral tibial head, the stability is severely weakened. Fluoroscopy to check the lateral tibial cortex is obligatory during surgery. If there is doubt postoperatively, a CT scan should be made to check the integrity of the lateral cortex and tibial plateau. If the lateral cortex is damaged, the need for additional stability should be considered [14].

In conclusion, the open wedge tibial osteotomy is a technically demanding surgical procedure with some pitfalls. The Cochrane review on osteotomy for treating knee osteoarthritis by Brouwer et al. [2] showed no significant difference in comparing open wedge tibial osteotomy with another operative treatment (other technique of HTO/ unicompartmental joint replacement). There is no evidence to show whether an osteotomy is more effective than conservative treatment [25], and the results so far do not justify any conclusion about effectiveness of specific surgical techniques. The high complication rate in this study was consistent with the results of other authors who have used the Puudu I plate in opening wedge osteotomies [3, 21, 23].

In our series the Puudu I plate is inadequate for fixation of opening wedge osteotomies, which is in contrast to other authors who have reported good results [6]. Our study led us to abandon the Puudu I plate for medial opening wedge osteotomy.

References

- Ahlback S (1968) Osteoarthritis of the knee. A radiographic investigation. *Acta Radiol Diagn (Stockh) Suppl* 277:7–72
- Brouwer RW, Jakma TSC, Bierma-Zeinstra SMA, Verhagen AP, Verhaar JAN (2005) Osteotomy for treating knee osteoarthritis. *Cochrane Database Syst Rev* 1:CD004019
- Brouwer RW (2006) Unicompartmental osteoarthritis of the knee: diagnosis and treatment of malalignment. Doctoral Thesis, Erasmus University, Rotterdam, 17 May 2006
- Catani F, Marcacci M, Benedetti MG, Leardini A, Battistini A, Iacono F, Giannini S (1998) The influence of clinical and biomechanical factors on the results of valgus high tibial osteotomy. *Chir Organi Mov* 83(3):249–262
- Coventry MB (1965) Osteotomy of the upper portion of the tibia for degenerative arthritis of the knee. A preliminary report. *J Bone Joint Surg Am* 47:984–990
- Dorsey WO, Miller BS, Tadjé JP, Bryant CR (2006) The stability of three commercially available implants used in medial opening wedge high tibial osteotomy. *J Knee Surg* 19(2):95–98
- Gao TJ, Lindholm TS, Kommonen B, Ragni P, Paronzi A, Lindholm TC (1997) Stabilization of an inserted tricalcium phosphate spacer enhances the healing of a segmental tibial defect in sheep. *Arch Orthop Trauma Surg* 116(5):290–294
- Harrington IJ (1983) Static and dynamic loading patterns in knee joints with deformities. *J Bone Joint Surg Am* 65(2):247–259
- Papachristou G, Plessas S, Sourlas J, Levidiotis C, Chronopoulos E, Papachristou C (1974) Deterioration of long-term results following high tibial osteotomy in patients under 60 years of age. *Int Orthop* 30(5):403–408
- Johnson F, Leitzl S, Waugh W (1980) The distribution of load across the knee. A comparison of static and dynamic measurements. *J Bone Joint Surg Br* 62(3):346–349
- Koshino T, Murase T, Takagi T, Saito T (2001) New bone formation around porous hydroxyapatite wedge implanted in opening wedge high tibial osteotomy in patients with osteoarthritis. *Biomaterials* 22(12):1579–1582
- Valenti JR, Calvo R, Lopez R, Cañadell J (1990) Long term evaluation of high tibial valgus osteotomy. *Int Orthop* 14(4):347–349
- Maquet P (1980) The biomechanics of the knee and surgical possibilities of healing osteoarthritic knee joints. *Clin Orthop Relat Res* 146:102–110
- Miller BS, Dorsey WO, Bryant CR, Austin JC (2005) The effect of lateral cortex disruption and repair on the stability of the medial opening wedge high tibial osteotomy. *Am J Sports Med* 33(10):1552–1557
- Leutloff D, Tobian F, Perka C (2001) High tibial osteotomy for valgus and varus deformities of the knee. *Int Orthop* 25(2):93–96
- Papachristou G (2004) Photoelastic study of the internal and contact stresses on the knee joint before and after osteotomy. *Arch Orthop Trauma Surg* 124(5):288–297
- Puddu G, Fowler PJ, Amendola A (1998) Opening wedge osteotomy system by Arthrex surgical technique. Arthrex, Naples, FL
- Puddu G, Cipolla M, Franco V (1999) A plate for open wedge tibial and femoral osteotomies. In: Congress the of International Society of Arthroscopy. Knee Surgery and Orthopaedic Sports Medicine, Washington, DC
- Shaw JA, Moulton MJ (1996) High tibial osteotomy: an operation based on a spurious mechanical concept. A theoretic treatise. *Am J Orthop* 25(6):429–436
- Spahn G, Wittig R (2002) Primary stability of various implants in tibial opening wedge osteotomy: a biomechanical study. *J Orthop Sci* 7(6):683–687
- Spahn G (2004) Complications in high tibial (medial opening wedge) osteotomy. *Arch Orthop Trauma Surg* 124(10):649–653
- Bhan S, Dave PK (1992) High valgus tibial osteotomy for osteoarthritis of the knee. *Int Orthop* 16(1):13–17
- Stoffel K, Stachowiak G, Kuster M (2004) Open wedge high tibial osteotomy: biomechanical investigation of the modified Arthrex Osteotomy Plate (Puddu Plate) and the TomoFix Plate. *Clin Biomech (Bristol, Avon)* 19(9):944–950
- Brown GA, Amendola A (2000) Radiographic evaluation and preoperative planning for high tibial osteotomies. *Oper Tech Sports Med* 8(1):2–14
- Zhang W, Moskowitz RW, Nuki G, Abramson S, Altman RD, Arden N, Bierma-Zeinstra S, Brandt KD, Croft P, Doherty M, Dougados M, Hochberg M, Hunter DJ, Kwoh K, Lohmander LS, Tugwell P (2008) OARSI recommendations for the management of hip and knee osteoarthritis, part II: OARSI evidence-based, expert consensus guidelines. *Osteoarthritis Cartilage* 16(2):137–162