Boomerang proximal tibial osteotomy for the treatment of severe varus gonarthrosis

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Abstract

Purpose The purpose of the study was to review the results of modified infratubercle displacement osteotomy in patients with severe varus gonarthrosis and to determine the factors influencing outcomes.

Methods A total of 177 knees in 133 patients with severe varus gonarthrosis were treated with infratubercle boomerang-shaped osteotomy, stabilised with dual plates. The mean age of the patients was 63.8 years (range 43–80 years), and the mean follow-up period was 61.4 months (range 24–139 months). The factors associated with clinical and survival outcomes were analysed including age, gender, body mass index (BMI), preoperative and post-operative femorotibial angle and femorotibial angle at one year after surgery.

Results Using the Knee Society clinical rating system 149 knees or 84.2 % were rated as having good to excellent results and 21 knees or 15.8 % as having fair to poor results. Overall, the mean preoperative knee score of 33.6 points had improved significantly to 80.7 points at the final follow-up ($p < 0.001$). Using Kaplan-Meier survivorship analysis the five-year survival was 97.1 % with conversion to arthroplasty or second osteotomy as the end point and 89.2 % with a knee score of under 70 points as the end point. The anatomical femorotibial angle at one year after osteotomy had the most significant positive effect on the clinical ($p < 0.001$) and survival outcomes for all end points ($p = 0.002$ for conversion to arthroplasty or second osteotomy and $p < 0.001$ for knee score less than 70 points).

Conclusions The boomerang osteotomy can create adequate valgus alignment in severe varus gonarthrosis. The one-year post-operative knee alignment of 11° valgus provided the most satisfactory results and that between six and 15° valgus the longest survival time.

Introduction

Although the aetiology of degenerative disease of the knee is multifactorial, one of the principal causative and accelerating factors is abnormal stress produced by knee alignment [23, 26]. The valgus high tibial osteotomy has been recognised as an effective procedure for the treatment of varus gonarthrosis confined to the medial compartment [4, 7, 9, 17, 18, 25]. However, Keene and Dyreby demonstrated that the results of valgus osteotomy did not depend on compartmental involvement, but on adequate valgus alignment. The knee with adequate valgus alignment had better clinical results than that with varus alignment, despite bi- or tricompartmental involvement [16]. Moreover, Wagner et al. [28] and Maquet [18] showed that even in gonarthrosis with severe varus deformities satisfactory results could be obtained if adequate valgus alignment had been created and maintained. Neither used the conventional laterally based, closing wedge osteotomy but rather their own techniques. Maquet used barrel-vault supratubercle osteotomy and Wagner et al. used infratubercle displacement osteotomy.

The authors have devised a new technique of valgus osteotomy by refining Wagner et al.'s infratubercle displacement osteotomy and named it "boomerang osteotomy" according to the shape of the osteotomy line. These are: defining the exact level of osteotomy below the tibial tubercle, the boomerang-shaped osteotomy, and fixation with dual plates.

The purpose of the study was to investigate outcomes of modified infratubercle displacement osteotomy in patients with severe varus gonarthrosis and to determine the factors related to outcomes.

The authors postulate that the results of osteotomy would not depend on the number of compartments involved or the degree of associated angular deformities. The valgus osteotomy should yield satisfactory results in bicompartamental gonarthrosis associated with severe varus deformity if adequate valgus alignment can be restored and maintained.

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Materials and methods

A cohort of 133 patients (177 knees) who had modified infratubercle displacement osteotomy for the treatment of severe varus gonarthrosis, performed between 1998 and 2010, were analysed retrospectively. The mean follow-up period was 61.4 months (range 24–139 months). *Inclusion criteria* were patients with severe primary varus gonarthrosis grade IV or V who needed daily non-steroidal anti-inflammatory drugs or opioid drugs. These patients should also have active compliance with the post-operative rehabilitation programme. *Exclusion criteria* were inflammatory joint diseases, post-traumatic osteoarthritis, associated patellofemoral pain, severe limited range of motion (ROM) (flexion < 90°, extension deficit > 20°) and radiographic suggestion of osteoporosis. All patients were operated up on by or under the supervision of the first author. Of the 133 patients, 44 had bilateral knee osteotomy. For bilateral osteotomy, the operations were usually not performed at the same session but after the osteotomy of one side had clinically healed (radiographically no osteotomy line seen and painless full weight-bearing). The mean age at the time of osteotomy was 63.8 years (range 43–80 years). Earlier in the series osteotomy had been performed in patients aged more than 65 years because at that time the national health security programme in our country had not been developed to the point that total knee replacement was covered.

There were 120 women and 13 men; 92 right knees and 85 left knees were involved. Preoperative bipedal standing anteroposterior, lateral and patella skyline radiographs were assessed. The anatomical femorotibial angle (FTA) was used for measurement of knee alignment. Using Ahlbäck radiographic classification [1], 63 knees (35.6 %) were grade IV and 114 knees (64.4 %) were grade V. All knees had radiographic evidence of arthrosis in the lateral compartment; 134 knees had full extension and 43 knees had flexion contracture ($\leq 20^\circ$). The mean knee flexion was 124.2° (range 90° – 150°). Of the patients, 34 (48 knees) were considered obese [body mass index (BMI) $\geq 30 \text{ kg/m}^2$]. The mean preoperative FTA was 13.4° (range 0° – 32°). One hundred and twenty knees (67.8 %) had a preoperative FTA more than 10° . To evaluate the clinical outcomes the Knee Society clinical rating system was used [12, 13]. The mean Knee Society clinical score was 33.6 points (range 10–70 points) preoperatively.

Surgical technique Firstly, the fibula is osteotomised obliquely at the middle third of the fibular shaft, through a separate lateral incision. Thereafter, a skin incision is made from just above Gerdy's tubercle to the tibial tuberosity laterally, extending along the tibial crest for about 10 cm. The soft tissues at the proximal tibia are detached medially and laterally to expose the tibial condyle. A boomerang-shaped osteotomy is made just below the tibial tubercle, beginning with an oblique osteotomy approximately 60° to the lateral border of the tibia, running to the point

just below the tibial tubercle. From this point the osteotomy runs just above and parallel to the pes anserinus, beneath the medial collateral ligament (Fig. 1a). The distal fragment is then laterally displaced and the sharp edge of the lateral corner of the proximal fragment is impacted into the medullary canal of the distal fragment. Simultaneously, the FTA is realigned by applying valgus force, aiming at 10° – 15° valgus. The knee alignment is controlled intraoperatively using an image intensifier (Fig. 1b). The correction is temporarily fixed with a 2.2-mm Kirschner wire and then stabilised with double five-hole semi-tubular plates (Synthes, Bettlach, Switzerland) laterally under compression using a tension device. Additionally, a three or four-hole dynamic compression plate (DCP) is placed anteromedially (Fig. 1c). Early in the study a single semi-tubular plate was used, and later double semi-tubular plates were used instead to prevent implant failure. A rigid plate narrow plate was not used because this plate pulls the bony fragments to the plate, resulting in loss of correction. In contrast, the double semi-tubular plate allows itself to conform to the bony fragments, maintaining the corrected alignment. When an anosteotomy is done below the tibial tubercle there is a strong tension force ventrally, produced by the pull of patellar ligament on the proximal fragment and by gastrosoleus muscles on the distal fragment, running a risk of nonunion. To medially support and resist anterior tension, a three or four-hole DCP is placed anteromedially.

Range of movement exercises and straight leg quadriceps/hamstring muscle strengthening exercises were begun on the second post-operative day. Partial weight-bearing (10 kg) was started on the third post-operative day. Generally, full weight-bearing was started ten to 12 weeks after osteotomy, depending on radiographic evidence of bridging callus. In the presence of laxity of collateral ligaments, the knee was immobilised in a knee splint for walking post-operatively. A cylinder cast was then applied for four weeks after suture

Fig. 1 Infratubercle boomerang osteotomy. The boomerang-shaped osteotomy just below the tibial tubercle (a). The sharp edge of the proximal fragment is laterally displaced and impacted into the distal fragment (b). The realigned FTA is stabilised with double semi-tubular plates laterally and a 3- or 4-hole DCP anteromedially (c)

removal at ten days after surgery. Afterwards, a valgus knee splint was used during walking until the coronal plane laxity spontaneously recovered, which normally took about three months after surgery (Fig. 2).

Statistical analysis Binary logistic regression was used to determine the factors associated with good to excellent results. Two end points of failure were evaluated: conversion to arthroplasty or second osteotomy and knee score of under 70 points. The Kaplan-Meier survivorship analysis was used for each end point. The Cox proportional hazards regression model was used to determine the factors associated with the survival. Because the knees with satisfactory clinical results and longer survival time after osteotomy were reported as having an FTA between six and 15° valgus [6, 22, 27, 30], a log-rank test was used to compare the survival curve of FTAs at one year after surgery of six to 15° valgus with that outside the range. A two-sided p value of <0.05 was considered to indicate statistical significance. Statistical analysis was performed with SPSS for Windows software (version 13.0). For analysis of the survival with 95 % confidence interval (CI) Stata software (version 12) was used.

Results

At the final follow-up, for the clinical results 83 knees were rated as excellent, 66 as good, 17 as fair and 11 as poor. A total of 149 knees or 84.2 % were rated as having good to excellent results and 21 knees or 15.8 % as having fair to poor results. Of 120 knees with a preoperative FTA of more than ten degrees of varus, 101 knees (84.2 %) had good to excellent results. Overall, the mean preoperative knee score of 33.6 ± 13.6 points improved significantly to 80.7 ± 14.1 points ($p < 0.001$) at the final follow-up. The mean pain score improved from 13.9 ± 8.1 points preoperatively to 42.8 ± 8.4 points at the last follow-up study ($p < 0.001$). There were 58 knees (32.8 %) with no pain, 104 (58.7 %) with mild pain and 15 (8.5 %) with moderate pain.

The mean FTA was turned from $13.4 \pm 5.8^\circ$ varus preoperatively to $11.2 \pm 3.7^\circ$ valgus post-operatively ($p < 0.001$) and to $7.6 \pm 7.2^\circ$ valgus at one year after surgery ($p < 0.001$). The mean FTA at the final follow-up was $7.7 \pm 8.7^\circ$ valgus which was not different from that at one year after surgery ($p = 0.889$). The FTA of the group with no or mild pain was $8.6 \pm 7.9^\circ$ valgus, and that of the group with moderate pain was $2 \pm 11.3^\circ$ varus ($p < 0.001$). The FTA of the group with good to excellent results was $8.4 \pm 7.4^\circ$ valgus, and that of the group with fair to poor results was $3.8 \pm 13.3^\circ$ valgus ($p = 0.022$). There were 120 knees with a preoperative FTA of under ten degrees with a mean of $16.1 \pm 4.9^\circ$ varus, which was turned to $7.2 \pm 8.9^\circ$ valgus at the last follow-up ($p < 0.001$). The knee osteotomy did not change the knee flexion. The mean preoperative flexion angle was $124.2 \pm 13.4^\circ$ and that at the final follow-up was $124.2 \pm 11.8^\circ$ ($p = 0.697$). After surgery the number of knees with flexion

contracture was decreased: 42 (23.7 %) of 177 knees preoperatively and 12 (6.8 %) at the final study had flexion contracture ($p < 0.001$).

The Kaplan-Meier survivorship analysis revealed a five-year survival of 97.1 % (95 % CI 92.3–98.9 %; 88 knees) with a conversion to arthroplasty or second osteotomy as the end point (Fig. 3a) and 89.2 % (95 % CI 82.9–93.3 %; 87 knees) with a knee score of less than 70 points as the end point (Fig. 3b). **Predictors of the clinical results:** Using a binary logistic regression model to determine the factors affecting the clinical results, the FTA at one year after osteotomy ($p < 0.001$, odds ratio = 1.235, 95 % CI 1.133–1.346) was the significant predictive factor for the results. From the curve estimation regression, the FTA at one year after osteotomy (after complete healing of the osteotomy) was significantly correlated with knee score at the last follow-up, and the FTA of 11° valgus was associated with the highest knee score ($R^2 = 0.489$, $p < 0.001$) (Fig. 4). Age ($p = 0.293$), sex ($p = 0.100$), BMI ($p = 0.767$), pre- ($p = 0.625$) and (immediate) post-operative alignment ($p = 0.062$) were not significant factors for the results. **Predictors of survival:** The Cox hazards regression model revealed that only one-year post-operative knee alignment and complications were the survival predictors for each end point. With conversion to total knee replacement or second osteotomy as the end point, the one-year post-operative FTA ($p = 0.002$, hazard ratio = 1.232, 95 % CI 1.080–1.407) was significantly associated with the probability of early failure. Similar results were found with the knee score of less than 70 points as the end point; the one-year post-operative knee alignment ($p < 0.001$, hazard ratio = 1.182, 95 % CI 1.117–1.252) was the factor associated with survival. Age, sex, BMI, pre- and (immediate) post-operative alignment were not significant factors for each of the two survival end points. With conversion to total knee replacement or second osteotomy as the end point, the p value for age was 0.537, sex 0.712, BMI 0.238, preoperative FTA 0.798 and post-operative FTA 0.534. With the knee score of less than 70 points as the end point, the p value for age was 0.138, sex 0.097, BMI 0.936, preoperative FTA 0.900 and post-operative FTA 0.594. At five years, the survival of the knees with a one-year FTA of six to 15° valgus was 100 % and those with alignment outside that range was 94.3 %, when conversion to total knee replacement or second osteotomy was the end point. Using a log-rank test, this was found to be significantly different ($p = 0.027$). The same finding was found when the knee score of less than 70 points was the end point: 100 % five-year survival for the knees with a one-year FTA of 6–15° valgus and of 81.2 % for knees with alignment outside that range ($p < 0.001$).

Complications Complications occurred in 25 knees, but no post-operative deaths or severe complications. One case of soft tissue infection developed six months after surgery. The infection resolved after plate removal and administration of

Fig. 2 **a** A 75-year-old woman with bilateral severe varus gonarthrosis (Ahlbäck V) associated with coronal plane instability. Preoperative radiographs of the right (**b**) and left (**c**) knees show severe varus gonarthrosis. Radiographs of the right (**d**) and left (**e**) knees made at 6 years after surgery show adequate valgus knee alignment and marked improvement of subchondral and metaphyseal area. Clinical appearance at 6 years after surgery indicated she had excellent clinical results. At the last clinical examination, the right knee score was 85 points and the left one 91 points

intravenous antibiotics. All nerve injuries (one peroneal nerve and six nerves to extensor hallucis longus) spontaneously recovered three months after surgery. One case of nonunion with broken plate underwent total knee arthroplasty. Only two of the 12 knees with hypervalgus (FTA > 20°) underwent opening wedge varus osteotomy because of pain.

Discussion

After the study of Bauer, high tibial osteotomy has been generally believed to be limited to varus osteoarthritis

Ahlbäck grade III without radiographic evidence of arthrosis in the lateral compartment [3]. Insall et al. found inferior results of closing wedge high tibial osteotomy in treating varus gonarthrosis with an FTA of more than ten degrees varus [14]. These beliefs may be true for laterally based closing wedge osteotomy. One should not extrapolate to other types of proximal tibial osteotomy. The current closing wedge high tibial osteotomy cannot treat severe varus osteoarthritis because it cannot create and maintain valgus alignment until the osteotomy heals. The medial opening wedge osteotomy may correct severe varus alignment but a high incidence of patella infera was reported [29]. Moreover,

Fig. 3 **a** Kaplan-Meier survival analysis (and 95 % CI) for the knees after boomerang proximal tibial osteotomy with arthroplasty or second osteotomy as the end point. **b** Kaplan-Meier survival analysis (and 95 % CI) for the knees after boomerang proximal tibial osteotomy with knee score of < 70 points as the end point

there was a significant increase in patellofemoral pressures after medial opening wedge osteotomy of only ten millimetres and a larger osteotomy resulted in a greater increase [15]. The preliminary results of this study have supported the authors' hypothesis that the results of osteotomy might not depend on the presence of lateral compartment involvement, the severe degrees of osteoarthritic change and associated angular deformities. The valgus osteotomy can yield satisfactory results in bicompartamental gonarthrosis associated with severe varus deformity if adequate valgus alignment can be restored and maintained. In this study all of the 177 knees were Ahlbäck grade IV or V with radiographic evidence of lateral compartment involvement. One hundred and twenty knees were associated with an FTA of more than ten degrees of varus. In this group the mean preoperative knee alignment of $16.1 \pm 4.9^\circ$ varus could be turned to $7.2 \pm$

Fig. 4 Curve estimation regression for the correlation between FTA at 1 year after osteotomy and the knee score at the last follow-up ($R^2 = 0.489$, $p < 0.001$). The 1-year post-operative FTA of 11° valgus was associated with the highest knee score. FTA femorotibial angle, negative = valgus, positive = varus

8.9° valgus at the last follow-up, and 101 of them (84.2 %) had good to excellent results.

The causes of pain in varus osteoarthritis can be attributed to abnormal overload in the medial compartment. The abnormal overload stimulates pain receptors in subchondral bone. The injured cartilage releases inflammatory mediators causing painful synovitis [8]. If the load progressively increases, the knee becomes more varus which in turn causes painful overstretching of soft tissues [28] and subchondral microfracture [21]. As a result subchondral bone cyst and sclerosis develop, producing painful intraosseous hypertension [2]. Therefore, if the abnormal overload is eliminated by realignment osteotomy, pain should subside. This has been evidenced by the results of our study. At the last follow-up study the knees with no or mild pain had a mean FTA of $8.6 \pm 7.9^\circ$ valgus and those with moderate pain had $2 \pm 11.3^\circ$ varus ($p < 0.001$). The one-year post-operative FTA had significant influence on the results ($p < 0.001$, odds ratio = 1.235, 95 % CI 1.133–1.346) and the survival of knee osteotomy for each end point (conversion to total knee replacement or second osteotomy as the end point: $p = 0.002$, hazard ratio = 1.232, 95 % CI 1.080–1.407; knee score of less than 70 points as the end point: $p < 0.001$, hazard ratio = 1.188, 95 % CI 1.122–1.259). Moreover, the five-year survival of the knees with valgus alignment of six to 15° at one year after surgery was 100 % for each end point.

Our study has shown that immediate post-operative knee alignment had no effect on the results and the survival, but that of the one-year osteotomy did. The immediate post-operative knee alignment did not correspond to the one-year

post-operative alignment, because partly it was non-weight-bearing film. The FTA after surgery might change over the period of osteotomy healing, depending on the bone quality for bone-screw interface and healing. After osteotomy healing the FTA (one year after surgery) did not significantly change until the final follow-up, as shown in our study. The knee alignment one year after the osteotomy did not change over the time until the last follow-up either between six and 15° valgus or outside this range. Yasuda et al. showed that over the course of ten years the FTA at one year after surgery with adequate valgus overcorrection was constant and that with inadequate valgus progressively lost correction [30]. It might be possible that because of the short period of follow-up in our study the FTA outside the range six to 15° valgus did not deteriorate with time.

In our study preoperative FTA was not the risk factor for failure ($p = 0.625$), because the boomerang osteotomy could correct severe varus angulation adequately. Preoperative FTA more than nine degrees varus was reported to be a risk factor for failure in closing wedge high tibial osteotomy [11]. With closing wedge high tibial osteotomy, the proximal cut of the osteotomy is limited and must be at least two centimetres below the level of the joint to decrease the risk of plateau fracture or unstable fixation [5].

Although the osteotomy in this study was done below the tibial tubercle, the nonunion rate (one in 177 knees or 0.6 %) was not definitely different from that of other reports, in which the osteotomy was done above the tibial tubercle (0–4.8 %) [10, 19, 20, 24]. The infratubercle osteotomy has advantages over the supratubercle osteotomy in that it provides more bone for stabilisation and does not change the patellar position.

Limitations of our study are its retrospective nature and short-term follow-up; for five-year-survival only 50 % of knees could be evaluated. Long-term follow-up is therefore needed to obtain more accurate outcomes.

Conclusion

The boomerang osteotomy can provide satisfactory results for the patients with severe osteoarthritic knees associated with marked varus deformity. This type of treatment is safe and reliable. Redistribution of the load by maintaining adequate valgus alignment is the key to achieve satisfactory outcomes. The one-year post-operative knee alignment of 11° valgus provided the most satisfactory results and that between six and 15° valgus the longest survival time.

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

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