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Abstract	In arthritis of the varus knee, a high tibial osteotomy (HTO) redistributes load from the diseased medial compartment to the unaffected lateral compartment.

We report the outcome of 36 patients (33 men and 3 women) with 42 varus, arthritic knees who underwent HTO and dynamic correction using a Garches external fixator until they felt that normal alignment had been restored. The mean age of the patients was 54.11 years (34 to 68). Normal alignment was achieved at a mean 5.5 weeks (3 to 10) post-operatively. Radiographs, gait analysis and visual analogue scores for pain were measured pre- and post-operatively, at one year and at medium-term follow-up (mean six years; 2 to 10). Failure was defined as conversion to knee arthroplasty.

Pre-operative gait analysis divided the 42 knees into two equal groups with high (17 patients) or low adductor moments (19 patients). After correction, a statistically significant ($p < 0.001$, *t*-test,) change in adductor moment was achieved and maintained in both groups, with a rate of failure of three knees (7.1%), and 89% (95% confidence interval (CI) 84.9 to 94.7) survivorship at medium-term follow-up. |

At final follow-up, after a mean of 15.9 years (12 to 20), there was a survivorship of 59% irrespective of adductor moment group, with a mean time to conversion to knee arthroplasty of 9.5 years (3 to 18 95% CI ±2.5).

HTO remains a useful option in the medium-term for the treatment of medial compartment osteoarthritis of the knee but does not last in the long-term.

High tibial osteotomy (HTO) was initially developed to manage deformity arising from poliomyelitis and rickets. Jackson first described its application to the management of degenerative arthritis of the knee.[[1]] It has since become an established treatment for medial compartment osteoarthritis (OA) of the knee.[[2-10]] The advances in unicompartmental (UKA) and total knee arthroplasty (TKA) have been accompanied by a decline in the use of HTO.[[17]] This has occurred despite a

Cochrane database review which shows no significant benefit of UKA over HTO in the management of medial compartment osteoarthritis of the knee in terms of gait analysis, pain scores or function.[[7]] Favourable outcomes in carefully selected patients show that it remains a useful treatment for medial compartment OA.[[8-10]]

Biomechanically, HTO redirects the forces away from the diseased medial compartment with the aim of stopping the progression of the OA and delaying the need for arthroplasty of the knee.[[1,7]] The techniques of HTO include dome, lateral closing wedge and medial opening wedge osteotomy with or without bone graft.[[7]] A medial opening wedge osteotomy has the advantage of avoiding structures on the lateral side which include the common peroneal nerve. Fixation is by internal fixation or external fixation with progressive distraction.[[12,13]]

Difficulties with HTO include estimating and achieving the appropriate degree of correction, and intrinsic problems with pre-operative planning using radiographs.[[14-17]] The ideal weight-bearing axis and the degree of angular correction remain difficult to define.[[16]] This is highlighted by various studies which report correction of the weight-bearing axis to a range between 3° and 10° of valgus.[[16-20]]

Fujisawa, Masuhara and Shiomi[[21]] defined a point through which the mechanical axis should pass: this is 30% to 40% of the way across the width of the lateral plateau measured from the centre of the knee: this gave the best results in their series. A modified Fujisawa point was described by Jakob and Murphy,[[22]] based on the extent of medial compartment arthritis. They advised that the axis should be more neutrally aligned, closer to the anatomical axis of the tibia, in patients with mild arthritis. However, as the arthritis progressed, the angular correction should move closer towards the Fujisawa point.[[22]]

Prodromos et al[6] first introduced the concept of high and low adductor moment around the knee, defining a high adductor moment as higher than 4% body weight × height, and a low adductor moment below this value. They reported gait analysis before and after HTO in patients with initially low or high adductor moments around the knee, and described better outcomes in patients with a low adductor moment.[6]

We reviewed a series of 42 knees with medial compartment arthritis in 37 patients who had undergone HTO using the Garches external fixator (Orthofix, Verona, Italy). When the patient deemed their correction complete, we used gait analysis and radiological measurements to assess the outcome. We report the medium and long-term outcomes.

Patients and Methods

Between 1993 and 2001, 36 patients (33 men and 3 women) underwent HTO using a Garches external fixator. Of the 42 HTO procedures presented, 31 were unilateral, 10 bilateral and one revision HTO. Over this period there were 47 HTO procedures, but 5 have been excluded from this study due to incomplete data..

The mean age at the time of surgery was 54.1 years (34 to 68 with 95%CI ±3.3). The mean BMI was 27.8 kg/m^2 (22.3 to 37.5 and 95%CI ±1.07): 9 had a normal BMI (18.5 kg/m^2 to 25 kg/m^2), 21 were overweight (BMI 25 kg/m^2 to 30 kg/m^2), and 6 were obese (BMI > 30 kg/m^2). The surgery was carried out by three surgeons (PBMT, CWJ, DG), using the same agreed technique and instrumentation. Local approval was obtained from our clinical governance board for the study.

Outcome measures included short- to medium-term gait analysis, revision to an arthroplasty and a scale of 0 to 10 (best to worst) visual analogue scores (VAS) for pain. In addition, the long-term need for revision to an arthroplasty was identified.

Pre-operative assessment

All patients were reviewed in a clinic (PBMT, CWJ, DG) pre-operatively where the range of knee flexion was measured and plain long-leg standing anteroposterior radiographs were taken in a standard fashion. This involved the patient removing all footwear and, if necessary, placing blocks underneath the shortened side to equalise the leg lengths and enable the patient to extend both knees fully. With both patellae facing forward a scaled weight-bearing anteroposterior radiograph of both legs, including both hip and knee joints, was taken. Measurement of the mechanical axis was obtained from these radiographs by the senior authors (PBMT, CWJ, DG). The mechanical axis of the femur was defined as a line passing distally from the centre of the femoral head to the centre of the intercondylar notch. The mechanical axis of the tibia was defined as a line passing from the centre of the proximal tibia to the centre of the ankle joint. The angle formed where the two lines intersected constituted the mechanical axis.

Gait analysis was carried out on all patients pre-operatively using a force plate and video imaging. The gait laboratory consisted of a 10-metre walkway with two video cameras and a force platform embedded in the floor to calculate kinetics of gait and the knee adductor moment. The minimum, maximum, and mean adductor moments were measured for both knees. The walking speed was 1 m/s.

Surgery

The surgeons used a standardised protocol for application of the Garches fixator and the corticotomy. The Garches device is a T-shaped external fixator. The horizontal proximal clamp is applied anteriorly and holds three horizontally inserted bone screws, which converge towards the posterior cortex of the proximal tibia. The vertical component has a distal clamp, which holds two vertically disposed bone

screws sited in the midshaft of the tibia. The horizontal and vertical parts are joined by a pivot screw which is loosened to allow the angle between the parts to be changed, or tightened to lock the angle. The vertical part is telescopic and allows up to 4cm of lengthening. A telescopic screw set to one side of the vertical strut acts as the motor.. If the motor is lengthened with the pivot locked, but the vertical telescopic part unlocked, then the fixator will lengthen. If the pivot and vertical telescopic part are unlocked then the fixator can lengthen and change angle simultaneously.

The Garches external fixator is applied to the tibia guided by intraoperative x-ray image intensification. Using the Garches template to ensure correct pin placement, the three proximal pins are inserted 20mm below the tibial plateau and the two distal pins are inserted into the midshaft of the tibia. The proximal pins, when correctly placed, are closest to tibial plateau posteriorly, due to the slope of the tibial plateau..

A 20 mm transverse incision is made over the proximal tibia, level with the distal end of the tibial tubercle. An osteotome with a 10 mm blade is used to do a horizontal subperiostial corticotomy in the lateral and anteromedial cortices leaving the posterior cortex intact. The Garches fixator is then assembled and attached to the five bone pins. With the clamps and the angle pivot screw tightened, the lengthening-locking screw is loosened and the motor screw used to lengthen the fixator by 4mm, to put the tibia under tension. A medial 20 mm vertical incision is then made over the postero-medial corner of the tibia, through which the osteotome is used to perform a horizontal corticotomy across the posterior cortex of the tibia. As the posterior corticotomy is completed, joining the lateral and anteromedial corticotomies, it springs apart slightly due to the tension created by pre-lengthening the fixator. The screw motor is taken off and the pivot loosened. The corticotomy is complete if the

pivot can be rocked 10° or more. If it is felt that there is, as result of an intact fibula, insufficient movement at the osteotomy site intra-operatively, then a fibula osteotomy is performed. The screw motor is now put back on and used to compress the corticotomy.

Post-operative management

Patients were mobilised bearing fully weight-bearing from day one: the external fixator remained locked for two weeks. The pivot and telescope screws were then loosened and the motor was lengthened by the patient at a rate of 0.5 mm per day. Patients were followed up weekly for pin-site care and monitoring of the degree of correction. When the patient felt that the correction had offloaded the medial compartment of their knee, and the alignment felt 'normal' for them, the pivot screw was locked. The gait analysis was then repeated. In the early part of this series the motor was removed at this point, but following some loss of correction in one patient, the motor was left in place for subsequent patients. Serial radiographs were obtained to assess the healing of the regenerate in order to determine when the external fixator could be removed. Once sufficient ossification had occurred, the pivot screw of the fixator was slackened and the osteotomy site was manually stressed by applying valgus and varus force to the knee. If no relative movement between the two parts of the fixator could be detected the fixator was removed.

Post-operative assessment

Further assessment of pain, function, radiological alignment and gait analysis were carried out post-operatively after a year and at medium-term follow-up (2 to 10 years: mean six years). The results of gait analysis were further examined according to whether the knees had a high or low adductor moment.[[6]] Those knees with a pre-operative peak adductor moment of less than 4% body weight × height were defined

as being in the low adductor group: those above 4% body weight × height were in the high adductor group.

All the patients' records and electronic notes were reviewed again in February 2013 to determine the number of patients who had subsequently undergone a total knee arthroplasty.

Statistical analysis

All data analysis was performed using SPSS Statistics v22.0 (IBM Corp., Armonk, New York) except for Kaplan-Meier survivorship, which was calculated using the statistical package R v3.0.2 (R Foundation, Vienna, Austria). Descriptive statistics were used to describe the study population: independent sample t-tests were used to analyse continuous variables and chi-squared testing was carried out to analyse categorical variables. Statistical significance was assumed at $p < 0.05$. Chi-squared analysis was used to compare the survival curves between the two groups, $p < 0.05$ was considered significant.

Results

Short- to medium-term results

The mean clinical follow-up was six years (2 to 10). The mean time from surgery to when the patient felt the knee alignment had been restored to normal was 5.5 weeks (3 to 10 95%CI ±0.62). The external fixator was in place for a mean of 12.0 weeks (8 to 21 95%CI ±0.91).

Patients were first evaluated as a single group and then according to whether they had a high or low pre-operative adductor moment (Table I).. 36 patients (42 knees) with a mean age at the time of surgery of 54.1 years (34 to 68 with 95%CI ±3.3).) were included in the analysis. Of these 19 patients (21 knees) were in the low adductor moment group (mean age 53.4 years; 38 to 68 95%CI ±4.6) and 17 patients

(21 knees) in the high adductor moment group (mean age 54.9 years; 34 to 67 95%CI

± 5.1).

Table I. Summary of radiological alignment and peak adductor moments in the whole cohort and divided into high and low adductor groups pre- (pre-op) and post-operatively (post-op) (*t*-test used for statistical analysis, $p < 0.05$ for significance)

	Radiological alignment (deg) +varus, -valgus		%age Peak adductor moment		
	Pre-op	Post-op	Pre-op	1 year Post-op	6-year Post-op
Total Mean	+8.6	+1.44	3.98	2.06	2.71
Range	+3 to +17	-11 to 16	0.32 to 7.956	0.06 to 4.68	0.03 to 5.9
95%CI	±1.76	±2.11	±0.38	±0.53	±0.49
p (wrt pre-op)		0.001		<0.001	< 0.001
High Adductor Group Mean	+10.4	+1.22	4.91	2.26	2.82
Range	+6 to +17	-11 to +16	4.05 to 7.96	0.06 to 4.68	0.31 to 5.6
95%CI	±1.9	±3.04	±0.4	±0.77	±0.71
p (wrt pre-op)		0.009		<0.001	.<0.001
Low Adductor Group Mean	+6.9	+1.69	3.06	1.81	2.60
Range	+3 to +15	-9 to +12	0.32 to 3.98	0.93 to 4.47	0.03 to 5.9
95%CI	±2.5	±2.87	±0.37	±0.73	±0.69
p (wrt pre-op)		0.036		0.008	0.272

Analysis was also undertaken considering the cohort as a whole as the distribution of adductor moments fell within a normal distribution (Fig. 1).

[[Fig 1]]

[[FigCap]]The distribution of peak adduction moments during walking (mean speed of 1 m/s).

A positive value indicates that the ground reaction force passed medial to the centre of the knee joint, a zero value that the ground reaction force passed between the tibial spines and a negative value that the ground reaction force passed lateral to the centre of the knee.

The values in brackets show the mean radiological alignment pre-operatively and at final follow-up. All pre-operative values were positive, indicating varus alignment.

The adductor moment, degree of radiological coronal alignment and pain were measured pre-operatively, post-operatively, at a year, and then at medium term follow-up (mean six years; 2 to 10). After 1 year the adductor moment decreased in both the high (p < 0.001, *t*-test) and low (p = 0.008, *t*-test) adductor groups. Pre-operatively, the low adductor moment group had a mean varus deformity radiologically of 6.9° (3° to 15° varus), which improved to a mean of 1.69° (12° varus to 9° valgus) varus post-operatively. The high adductor moment group had a mean pre-operative varus deformity of 10.4° (6° to 12° varus) which improved to a mean 1.22° (16° varus to 11° valgus) of varus post-operatively. There is no correlation between the radiological alignment and the peak adductor moment (r^2<0.001). However, a greater degree of angular correction was seen in the high adductor group (*p* = 0.019) compared with the low adductor group. Considering the cohort as a whole, a mean radiological correction of 7.2° was required for the 'normalisation' of the patients adductor thrust

Following the protocol described earlier, the alignment of the mechanical axis was corrected to a mean 1.4° of varus (95%CI ±2.1). Overall there were 23 knees aligned in varus and 19 in valgus. There was no significant difference between these two groups in terms of conversion to arthroplasty (chi-squared, p = 0.428) or length of follow-up (chi-squared, p = 0.724).

After the correction of the alignment had been completed, the peak adductor moment when walking at 1 m/s had reduced (p <0.001). Pre-operatively, the high adductor group had a mean peak adductor moment of 4.91 (4.05 to 7.96), which improved to 2.26 at one year, and was maintained at 2.82 (0.51 to 3.3) at final follow-up (mean six years). Similarly the low adductor group had pre-operative mean adduction moment of 3.06 (0.063 to 3.5), which had improved to 1.81at one year and

was maintained by final follow-up (mean six years) at 2.6 (0.06 to 3.7), but this was not statistically significant (p>>0.05) with respect to pre-operative values. ~~(Fig. 2).~~

~~[[Fig 2]]~~

~~[[FigCap]]Comparison between mean maximum adduction moments during walking pre-operatively, one year post-operatively and at medium term follow-up (mean six years). The values in brackets show the mean radiological alignment pre-operatively and at final follow-up. All values are positive and thus represent a varus alignment; a negative value would represent a valgus alignment (error bars represent 95% confidence intervals).~~

Considering the whole series without separation into adductor moment groups, the mean pre-operative adductor moment was 3.98, which improved to 2.03 (p<0.001) one year post-operatively to the position the patient felt was normal. This had slightly deteriorated to a mean of 2.71 at final follow-up, but with a statistically significant sustained improvement (t-test, p < 0.001).

Pain relief

The dynamic correction of the mechanical axis was stopped when the patient reported that the knee felt normally aligned. The mean pre-operative VAS for pain was 7.63 (4 to 10, ±0.47) and improved to a mean of 3.74 (0 to 8.5, ±0.88) post-operatively at mean six-year follow-up. Similar results were seen in the low and high adductor moment groups with mean pre-operative scores of 7.60 (4 to 10, ±0.75) and 7.67 (5 to 10, ±0.59), and post-operative pain scores of 3.79 (0 to 8, ±1.24) and 3.69 (0 to 8.5, ±1.29), respectively. The improvement in VAS scores was statistically significant (p < 0.001, t-test), which was repeated in low and high groups separately; but there was no statistical difference between the groups themselves (p>>0.05). Post-operatively,

30 patients (36 knees) were able to walk between one and four miles, 15 patients (20 knees) having no limitations to their mobility at medium-term follow-up.

Fibular osteotomy

Fibular osteotomy was required in 11 knees (10 patients). These patients were older (p=0.3), with a mean age of 57 years (41 to 67), than those who did not need fibular osteotomy (mean age 53 years, 34 to 67). Those with high adductor moments had a higher incidence of fibular osteotomy, but.there was no statistical difference between the two adductor groups (p = 0.28, chi squared) There was a reduction of mean maximum adductor moment from 4.49to 1.80 (p<.001, t-test) at one year for those who had undergone fibular osteotomy compared with 3.8 to 2.2 (p=0.0014, t-test) in those who had not. At a mean of six years' follow-up, the mean adductor moment was 1.01 for those with a fibular osteotomy and 2.45 for those without. This difference was significant (p = 0.002, t-test). There was no significant difference between the two groups overall (p<0.001, chi-squared). Fibular osteotomy enabled a greater mean radiological correction (p<<0.001)) from 11.25° varus (10° to 12°) to 2.5° valgus (5° varus to 11° valgus). In the absence of fibular osteotomy, the mean correction (p=0.0023)was 7.87° varus to 2.65° varus. There was no statistical significance between the two groups (p = 0.085, chi-squared). However, the fibular osteotomy group tended to show a greater degree of valgus correction (p=0.091, chi=squared) but this was not significant (p=0.091, chi=squared).

Failures and complications

Four knees were converted to TKA, representing a failure rate of 9.5%, with an 89% survivorship (95% CI 84.9 to 94.7) at a mean of six years. Three of the failures were in the low adductor group. The mean time to conversion was 4.6 years (3 to 7). One of these patients, who had a proximal pin-site infection, which needed surgical

debridement while the external fixator was in place, subsequently developed an infected TKA. The radiographs taken immediately before the TKA showed a small bony cavity at the site of a bone screw which, in retrospect, is likely to have persisted because of continuing sub-clinical infection. The same organism was present in the pin-site infection and later in the infected TKA.

13 patients (17 knees) required antibiotic treatment for pin-site infection. There were no cases of septic arthritis, nerve injury or venous thrombo-embolism.

Long-term follow-up

To complete follow-up analysis, all patient records were reviewed at a mean of 16 years (12 to 20). Three patients (three knees) had died of unrelated causes and 32 patients (39 knees) remained alive. Of those who had died, one patient (one knee) had undergone revision to a TKA three years after the HTO and two had needed no further surgery for ten and 17 years between HTO and death. Of the remaining 32 patients (39 knees), 13 HTOs were converted to TKA at a mean of 9.5 years (3 to 18, 95%CI ±2.5). A total of 26 HTOs were still functioning, giving a Kaplan-Meier survivorship Mean Time To Failure of 14.8 years (95% CI ±1.6) and a survivorship of 59 % (95% CI ±39%) at the meanfollow-up average of 16 years (Fig. 3).

[[Fig 2]]

[[FigCap]]Kaplan-Meier curve of survivorship for all patients

Low adductor group

There were 18 patients (21 knees) in the low adductor group with a mean follow-up of 16 years (12 to 20). Of these, seven knees were converted to TKA at a mean of 8.7 years (3 to 15). Two patients died in this group without conversion to TKA with their HTO surgery lasting 10 years and 18 years, respectively, without revision. If those patients who died without further surgery are included in the calculation for the low

adductor group at mean follow-up of 16 years, 14 knees (67%) did not have their HTO revised to an arthroplasty (Fig. 4).

[[Fig 3]]

[[FigCap]]Weibull curve of survivorship comparing high and low adductor moment groups, no statistical difference in (chi squared, p=0.88)

High adductor group

There were 17 patients (21 knees) in the high adductor group with a mean follow-up of 16 years (12 to 20). In all, seven knees needed conversion to TKA after a mean interval of 10.3 years (3 to 18). One patient in this group who died 18 years after the HTO had not required revision to a TKA. This represents a survivorship of 68% for the high adductor group at mean 16 years follow-up (Fig. 4). There was no statistical difference in long-term outcome between the high and low adductor group (chi squared, p = 0.88).

Discussion

HTO for the treatment of OA was popularised by Coventry.[[15]] The ideal angular correction for the best long-term outcome is unclear.[[16,17,23]] Poor results have been reported where under-correction of the deformity has occurred.[[4]] Even when a specific angle of correction has been planned pre-operatively, it has been reported that optimal correction of the limb axis measured from post-operative radiographs is not achieved in 20% of HTOs.[[24]] This may be due to difficulty in standardising the x-rays: rotational mal-alignment may affect the perceived deformity. It has also been shown that there is no correlation between knee alignment and pain[[18,25]] and therefore static correction of angular deformity alone may not be reliable. It has been reported from dynamic assessment of gait that standing radiographs do not correlate

with predicted joint loads across the knee.[[5,26]] There may be other compensatory mechanisms which reduce the load in some patients.[[27]]

Navigation for HTO has been shown to improve the accuracy of correction but it remains unproven if this gives a better clinical outcome. It certainly gives no information about what the optimal correction should be.[[28-30]]

With the lack of consensus about the optimal treatment, our rationale was that with an external fixator we could tailor the correction to the individual and dynamically correct the mechanical axis. Gait analysis provides a dynamic assessment of the effect of deformity on the forces through the knee. Dynamic callotasis combined with gait analysis allows a progressive, accurate method of correction to a point where the patient feels that their alignment is 'normal'. This avoids the inaccuracies of radiographs and attempts to address the other compensatory mechanisms of the knee. Our results showed that we achieved a wide range of correction from 6° varus to 11° valgus with survivorship comparable to that reported in the published literature.[[1-11]]

We had an 89% survivorship at six years and a 59% survival at a mean of 16 years in both low and high adductor groups. This is better or comparable to other published retrospective studies. A report on 106 HTOs at ten to 22-year follow-up identified a 39% survival at 15 years.[[31]] Berman et al[[2]] retrospectively reviewed a series of 35 patients undergoing HTO using staple fixation, with a mean follow-up of 8.5 years (3.8 to 15.1). A total of 22 patients (57%) had good results: nine patients (26%) needed TKA at a mean of 4.7 years post HTO. Patients were assessed pre-operatively using long-leg radiographs but gait analysis was not used. Those with favourable results were less than 60 years old, had less than 12° pre-operative angular deformity and had isolated unicompartmental disease.

In a retrospective review of 107 patients with OA of the knee treated by valgus HTO using staples, Rudan and Simurda,[[3]] noted comparable results in patients under and over the age of 60 years at the time of surgery. They reported 79.6% good results up to nine years and 70% good results at ten to 15 years, with a revision rate of 10.9%. Holden et al[[32]] reviewed 45 patients (51 knees) achieving good to excellent results in 70% of patients at ten years. Published long-term results from the Finnish National Registry on 3195 knees revealed 89% survivorship at five years and 73% at ten years using joint arthroplasty as the endpoint.[[31]]

The main factors thought to affect long-term outcome unfavourably include correction of valgus of less than 7°, a high adduction moment, obesity, and an age of more than 55 years.[[34,35]] Our study does not show a poorer outcome with a smaller angular correction. In fact our correction angle was a mean 1.44° of varus, but this seemed to have no adverse effects on the overall outcome. When we compared our knees in varus alignment against those in valgus, there was no significant difference in the outcome in terms of revision (p = 0.428) or follow-up (p = 0.724).

Overall peak adduction moments were decreased post-operatively and compared favourably with the findings of Prodromos et al.[[6]] In our study the peak adductor moments for the high and the low adductor moment groups at final clinical review were lower than those reported in the normal control group of Prodromos et al.[[6]] All our early failures within six years were in the low adduction moment group, and long-term survival did not seem to be related to a high adduction moment, although the later failures were all in this group.

Other predictors of success included patients less than 60 years of age[[4]] and a BMI of less than 27.5kg/m^2. We found no association with BMI but accept that the

number of patients may be too small to permit accurate analysis. The mean age in the low adductor and high adductor groups were 53. and 54.9 years, respectively: the low adductor group had more patients less than 60 years of age but both groups had a similar age distribution. We found no statistical significance between age and outcome, consistent with Rudan and Simurda.[[3]]

We acknowledge the limitations of this retrospective study and the absence of long-term gait analysis or functional scoring in the surviving patients.

In conclusion, treating osteoarthritis of the medial compartment of the knee using this technique gives a satisfactory outcome at a mean of six years and a 59% (95% CI 59.6 to 68.9) survival at a mean of 16 years.

Supplementary material
A figure showing stills from video imaging recording gait analysis is available alongside the online version of this article at www.bjj.boneandjoint.org.uk

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Supplementary material

[[Fig a]]

[[FigCap]]Gait analysis showing pre-operative malalignment (top left), adductor moment (top right), Garches external fixator *in situ* (bottom left) and the post-correction alignment (bottom right).