Growth modulation may decrease recurrence when used as an adjunct to osteotomy in infantile Blount's disease

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Abstract

Background

This study aimed to determine whether the addition of a lateral proximal tibial tension band plate, combined with proximal tibial dome realignment osteotomy, would decrease the recurrence rate in a group of children younger than 7 years with infantile Blount's disease (IBD) and high recurrence risk, defined as a medial physeal slope ≥60°.

Methods

We reviewed the records of 14 children (22 limbs) under the age of 7 years with IBD and a medial physeal slope ≥60° that were treated with a combination of tibial osteotomy and tension band plates (group 2) to determine the recurrence rate and time to reoperation. These results were compared with a matched group of eight children (12 limbs) with IBD and a medial physeal slope ≥60° that were treated previously with tibial osteotomy alone (group 1).

Results

The two groups were matched in terms of age, sex, obesity, Langenskiöld stage, tibio-femoral angle and medial physeal slope. The recurrence rate was 92% (11/12) in group 1 and 77% (17/22) in group 2 (odds ratio 0.31; 95% CI 0.03–3.01, p=0.312). The mean time to reoperation was 2.4 years in group 1 and 1.9 years in group 2 (p=0.319). There were two implant-related complications: one broken screw and one case of epiphyseal fixation failure in the tension band plate group, both in cases of recurrence.

Conclusion

The addition of a lateral tension band plate to a proximal tibial realignment osteotomy may be an option to consider in children younger than 7 years with IBD and a high risk of recurrence. Further research is required to determine recurrence risk in IBD and to develop and evaluate surgical strategies to mitigate this risk with well-designed, multicentre controlled trials.

Level of evidence: Level 4

Keywords: Blount's disease, tibia vara, guided growth, tension band plate, osteotomy, recurrence

Introduction

Infantile Blount's disease (IBD) presents as a progressive multiplanar proximal tibial deformity with onset from the age of walking.[1] The deformity is due to disordered growth in the posteromedial proximal tibial physis.[2] The cause of disordered growth is likely to be multifactorial.[3] Once the diagnosis is confirmed, surgery is indicated.[4]

The risk of recurrence following proximal tibial osteotomy is high and has been reported to be between 41% and 72%.[5-8] It is crucial to attempt to prevent recurrence because repeat osteotomy has been linked to worse outcomes at skeletal maturity.[6,9]

Several authors have identified risk factors that predict recurrence. These include age at surgery, obesity, the severity of deformity, Langenskiöld stage, LaMont type C appearance, and a medial physeal slope (MPS) ≥60°.[5-16] We previously showed that an MPS≥60° was the best predictor of recurrence in our population.[16] Despite the risk factors associated with recurrence being known, surgical strategy selection based on risk stratification has not been extensively investigated. Overcorrection into valgus, medial epiphysiolysis and lateral epiphysiodesis are all strategies that have been employed in an attempt to decrease the recurrence rate.[5,11,17-19] Overcorrection has not been proven to be an effective strategy, medial epiphysiolysis has limited application, and there is a risk of overcorrection and loss of growth potential with permanent epiphysiodesis.[18,20]

Guided growth has become a popular technique to correct long bone deformities in children since the development of the tension band plate.[21] While reports on the use of growth modulation with tension band plates to correct the deformity caused by Blount's

disease have been encouraging, the use of a tension band plates as an adjunct to proximal tibial osteotomy as a strategy to decrease the risk of recurrence has not been investigated.[22-25]

We aimed to investigate whether the addition of a tension band plate to a standard proximal tibial realignment osteotomy could decrease the rate of recurrence after proximal tibial osteotomy in children under 7 years of age with IBD and high recurrence risk.

Materials and methods

We reviewed our paediatric orthopaedic database and identified all children with IBD under the age of 7 years with a high risk for recurrence treated at our tertiary hospital between 2010 and 2018 with at least 18 months follow-up. IBD was diagnosed by observing progressive proximal tibial deformity, typical changes on standing AP and lateral knee radiographs and a tibial metaphyseal diaphyseal angle (MDA) >16°. High risk of recurrence was defined as a metaphyseal slope angle (MPS) ≥60°.[12,13,16] We excluded eight children (ten limbs) who had less than 18 months follow-up. We also excluded children older than 7 years because these cases were frequently complicated by knee instability due to medial plateau depression and were treated with medial elevation osteotomy and definitive lateral epiphysiodesis.

In children under 7 years with IBD, it was our practice to perform multiplanar deformity correction through a metaphyseal proximal tibial dome osteotomy. We aimed to correct the coronal alignment into physiological valgus, while simultaneously correcting the internal rotation and procurvatum to normal. The normative data published by Salenius and Vankka were used as a reference (diaphyseal tibio-femoral angle between 5° and 6°±4°).[26] Pragmatically, we aimed to correct the tibio-femoral angle to between 5° and 10° valgus alignment. During the study period, our practice changed to include the use of a lateral proximal tibial eight-plate (Orthofix, McKinney, Texas, USA), in addition to immediate proximal realignment osteotomy, in children where the MPS≥60° *(Figure 1a–d)*. We compared a subgroup of the initial patients who had an MPS≥60° and were treated with tibial osteotomy alone, with the latter patients who had the additional eight-plate. The two groups were compared in terms of demographics, obesity and disorder severity to ensure they were matched in terms of recurrence risk. Severity was assessed by the Langenskiöld stage, metaphyseal–diaphyseal angle (MDA), anatomic tibio-femoral angle (TFA) and medial physeal slope (MPS). Radiographic measures were obtained on standing AP long cassette radiographs. If these were not available, standing AP knee radiographs that included sufficient tibial and femoral diaphysis to allow measurements were used. The postoperative measurements were obtained from supine AP knee radiographs.

The outcome measures were the recurrence rate and time to repeat surgery. Recurrence was defined as progressive varus ≥10° varus TFA. All recurrent cases required repeat operation. Procedures that were needed to correct alignment and restore knee stability were tibial osteotomy and medial joint line elevation. If medial growth was observed, the eight-plates were removed. If there was no medial growth, a lateral proximal tibial Phemister epiphysiodesis was performed.

Surgical technique

All cases were treated by immediate multiplanar deformity correction through a low energy proximal tibial dome osteotomy.[27] An oblique incision from proximal medial to distal lateral was made to access the proximal tibia. The orientation of the incision allowed easy access to the medial metaphysis should medial elevation osteotomy be required at recurrence. A section of 5–10 mm of the midshaft fibular diaphysis was resected through a longitudinal incision with a fine oscillating saw before deformity correction. The tibial osteotomy was pre-drilled in the AP plane and completed with curved and straight osteotomes. Varus, internal rotation and procurvatum were corrected acutely, and we aimed to achieve an AP tibio-femoral angle of 5–10° valgus. The congruent corresponding bone surfaces at the osteotomy contributed to stability so that, with the addition of an above-knee cast, internal fixation was not necessary. Closed system suction drains were used routinely, and wounds were closed with absorbable suture material. In group 2, an additional incision was made over the lateral proximal tibial physis. Initially, we used a longitudinal incision but have since transitioned to a transverse incision as we found the scar to have an improved cosmetic appearance. An eight-plate of appropriate length plate and screws was selected and inserted under fluoroscopic guidance according to the standard surgical technique.[28] The corrected position was assessed clinically and confirmed under fluoroscopy. The radiolucent diathermy cable spanned between the centre of the hip to the ankle was useful to assure realignment of the axis to neutral or valgus at the knee. The limb was maintained in an above-knee cast (synthetic polyester cast tape) for six to seven weeks. Weight-bearing ambulation was initiated between eight and twelve weeks postoperatively.

Statistical analysis

Statistical analysis was performed using jamovi version 1.2.18.0 open-source software.[29] Continuous variables were reported as mean (standard deviation [SD], range) or median (interquartile range [IQR], range), and categorical variables as number and percentages. The Shapiro–Wilk test was used to analyse the distribution of data. Normally distributed data were compared with the use of the unpaired Student's t-test, whereas the Mann–Whitney U test was used for non-parametric data. Categorical data were analysed using the chi-squared test unless the expected value in any cell was below 5 when Fisher's exact test was used. All tests were two-sided, and the level of significance was set at $p<0.05$. Binomial logistic regression was used to determine the odds ratio (OR) and 95% confidence interval (95% CI) of the primary outcome measure.

Results

We identified eight children (12 limbs) that were treated with a tibial osteotomy alone (group 1) and 14 children (22 limbs) that were treated with a tibial osteotomy combined with a lateral proximal tibial tension band plate (group 2). A comparison of the descriptive treatment and outcome data is summarised in *Table I*. The follow-up duration for group 1 was longer than that of group 2. The groups were matched for obesity, severity as measured by the Langenskiöld stage, MDA, TFA and MPS.

In both groups, the mean TFA as measured on postoperative radiographs was within the physiological valgus range. The mean TFA on the first standing films (within 12 weeks postoperatively) was in less valgus, but still within the physiological valgus range in both groups.

The recurrence rate in group 1 was 92% compared to 77% in group 2 where a tension band plate was used as an adjunct to tibial osteotomy with an OR of recurrence of 0.31 (95% CI 0.03–3.01, p=0.312). The time to reoperation was similar between the two groups.

There were two tension band plate-related complications: one metaphyseal screw breakage and one of epiphyseal screw pull-out. In both of these cases, recurrence occurred. There were no cases of vascular injury, peroneal nerve injury, compartment syndrome or infection.

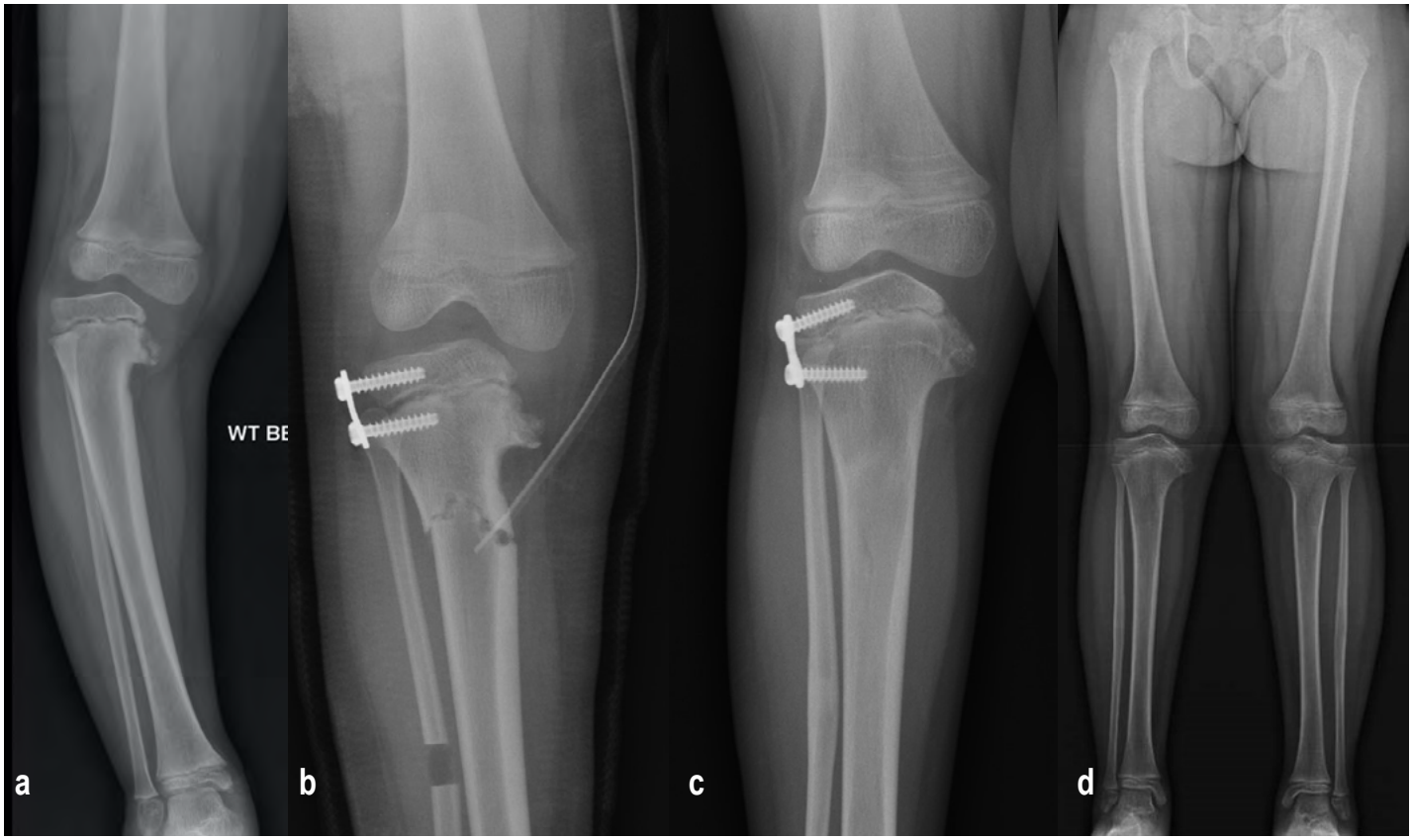

Figure 1. a) Standing AP radiograph of the right knee of a 4-year-old girl – the medial physeal slope (MPS) was measured as 70°; b) Postoperative AP radiograph in long leg cast immobilisation; c) Standing AP radiograph one year postoperatively demonstrating divergence of the tension band plate screws and mild overcorrection prior to removal of the implant – the Harris line shows the extent of growth; d) Bilateral standing AP radiograph three years after the initial procedure demonstrating maintenance of correction

Subgroup analysis in group 2 showed that the median age of the children that did not recur was 4 years (i.e., between 4 and 5 years), compared to a median age of 5 years in the children that did have recurrent deformity (p=0.177). The mean TFA of the children that did not recur was 22° (SD 13°, range 10–40), compared to a mean of 33° (SD 14°, range 15–65) in the recurrent group (p=0.121). The Langenskiöld stage was a median of stage 3 in the group without recurrence, and stage 4 in the group with recurrence (p=0.292).

Discussion

We aimed to determine whether the addition of a lateral proximal tibial tension band plate to a proximal tibial realignment osteotomy could decrease the rate of recurrence in children under the age of 7 years with IBD and a high risk of recurrence.

When children under 7 years present with severe IBD, selecting a surgical strategy is challenging because while further medial growth is unlikely, growth arrest is not inevitable. Three techniques have been described to decrease recurrence risk: overcorrection, medial epiphysiolysis and lateral epiphysiodesis.[5,11,17-19] Corrective proximal tibial realignment osteotomy aims to unload the medial physis during weight-bearing, so that the 'sick' physis may resume growing under normal weight-bearing loads. The aim of overcorrection beyond the physiological range is to compensate for knee instability (due to medial joint depression and lateral ligament laxity) during weight-bearing and therefore to ensure that the mechanical axis is corrected to a lateral position at the knee.[19] The lateral mechanical axis deviation, in theory, decreases the compressive forces over the medial physis. There is conflicting data about the effectiveness of overcorrection in preventing recurrence. When assessing the evidence for overcorrection, it is essential to note whether authors describe the anatomic TFA (or shaft–shaft angle) or the mechanical TFA (or hip–knee angle). Another complicating factor is that the immediate postoperative radiograph is non-weight-bearing after the osteotomy and does not reflect the extent of knee instability.[1,8] Loder and Johnston recommended overcorrection to >5° of the mechanical TFA as a strategy to decrease recurrence risk.[11] Schoenecker et al. suggested that realignment to within 5° of neutral was sufficient.[10] The only investigation specifically evaluating the effect of overcorrection was a study by Eamsobhana et al. in 2014 on children with Langenskiöld stage 2 IBD which failed to demonstrate an advantage to overcorrection beyond a TFA of 15° valgus alignment.[20] Langenskiöld advised against overcorrection of the deformity, as he stated that excessive valgus did not remodel reliably.[5] Therefore, we aimed to correct the limb to a valgus anatomic TFA of 5–10° in the above-knee cast as measured on an AP non-weight-bearing radiograph.

Medial epiphyseolysis, first reported by Beck et al., is another technique that may reduce the risk of recurrence.[17] Andrade and Johnston reported that 26% of 27 limbs treated with a combination of valgus osteotomy and medial epiphysiolysis had a normal mechanical alignment (0°±5°) at latest follow-up.[18] This study was limited by selection bias, and the authors acknowledge that adequacy of epiphysiolysis may be challenging to confirm intraoperatively, as there is no well-defined bar.[4,18] Our previous experience with this procedure was unsatisfactory, and it was not part of our surgical strategy. Lastly, definitive lateral epiphysiodesis will prevent recurrent deformity at the cost of any potential growth.[5] Should growth resume medially after proximal tibial realignment, progressive overcorrection would result. Temporary

Table I: Comparative analysis of descriptive and treatment data of group 1 (tibial osteotomy alone) and group 2 (tibial osteotomy and tension band plate)

Variable	Group 1 Tibial osteotomy 8 children (12 limbs)	Group 2 Tibial osteotomy and eight-plate 14 children (22 limbs)	p-value
Age[a]	5 (5–5)	5 (4–6)	0.398
Sex	88% female (7/8)	71% female (10/14)	0.486
Obesity (BMI > 95th centile)	50% (4/8)	29% (4/14)	0.440
Langenskiöld stage[b]	4 (4–5)	4 (3–4)	0.126
MDA[c]	38°±10°	34°±9°	0.241
TFA[d]	32°±9°	31°±14°	0.845
MPS[e]	70°(65°–75°)	66° (65°–70°)	0.507
Postoperative			
TFA[f]	10° valgus (9°–12° valgus)	8° valgus (5°–10° valgus)	0.101
TFA weight-bearing	5° valgus (5° varus to 10° valgus)	2° valgus (5° varus to 5° valgus)	0.332
Follow-up[g]	7 (6.2–8)	3.5 (2.2–5.7)	**0.002**
Recurrence rate	92% (11/12)	77% (17/22)	0.389
Reoperation			
Time to reoperation[h]	2.4±1.4	1.9±1.0	0.319
Lateral epiphysiodesis	83% (10/12)	68% (15/22)	0.439
Tibial osteotomy	92% (11/12)	59% (13/22)	0.061
Medial elevation	58% (7/12)	59% (13/22)	1.000

a: age in years as median and interquartile range; b: Langenskölld stage as median and interquartile range; c: tibial metaphyseal diaphyseal angle; d: tibio-femoral angle; e: medial physeal slope; f: post-operative TFA in cast; g: follow-up in years as median and interquartile range; h: time to reoperation in years as mean with standard deviation

lateral epiphysiodesis with a tension band plate was, therefore, an attractive option to potentially prevent or delay recurrence after proximal tibial realignment without the risk of permanent growth arrest or progressive overcorrection.

Several factors predisposed the children in both groups to recurrence; these included age >4 years, Langenskiöld stage >III or IV, and MPS≥60°.[6-13,16] Correction was achieved through proximal tibial dome osteotomy in both groups to physiological valgus on the first postoperative radiograph. The first weight-bearing TFA, while still within the normal valgus range and comparable between the two groups, was less than that measured on the postoperative radiograph. This joint instability may be due to medial tibial plateau depression, lateral collateral ligament attenuation or a combination of the two factors.

The high recurrence rate in both groups is indicative of the severe impairment of growth potential that exists in children with severe IBD. The 92% recurrence rate in the osteotomy only group was similar to the findings of Kling et al. and Kaewpornsawan, who both reported a 100% recurrence rate associated with an MPS≥60°.[12,13] With the addition of the tension band plate in group 2, the recurrence rate was 77%. Because the effect size is possibly small and our patient numbers limited, our study was not sufficiently powered in terms of the recurrence rate. Our study was similarly underpowered for subgroup analysis in terms of age and severity. Additional research is required to further define recurrence risk in Blount's disease. We were also unable to confirm a difference in the time to reoperation between the two groups. Procedures that were required at reoperation included medial elevation osteotomy, proximal tibial realignment osteotomy and lateral epiphysiodesis. These were performed in similar frequency in both groups. The recurrence rate remains very high in this patient group despite the addition of the tension band plate. For this reason, we routinely perform medial elevation osteotomy, lateral epiphysiodesis and proximal tibial realignment osteotomy as the primary procedure from the age of 7 years. Before the age of 7 years, even the slim chance of preventing recurrence was deemed worthwhile when considering the inevitable loss of longitudinal growth with definitive epiphysiodesis. For this reason, we continue using the lateral tension band plate in addition to tibial osteotomy in children with an MPS≥60°.

Besides the small size of our study and resultant insufficient power, there were several other limitations. We did not have standing long leg films that included the entire lower limb in all cases and this may have affected the accuracy of the TFA measurements. We compared the group of children treated with tension band plate combined with proximal tibial osteotomy with a historical control group where only a proximal tibial osteotomy was used, which opened the study to potential selection bias. However, our analysis revealed that the children in both groups were matched in terms of risk factors for recurrence. The numbers in this study are low, but its findings are important because these patients represent a small subgroup of children with IBD with very high recurrence risk. While it is recommended that the treatment of children with IBD is individualised, this is the first study that has attempted to risk-stratify children with IBD and evaluates a treatment strategy accordingly. It is also the first study to assess the effect of an additional tension band plate, with proximal tibial realignment osteotomy, on recurrence rate in children with IBD and high recurrence risk. Despite this surgical strategy, the recurrence rate remained high, and further research is required both to quantify recurrence risk and to identify additional interventions that can reduce the risk of recurrence and the need for reoperation.

Conclusion

The addition of a lateral tension band plate has demonstrated a low complication rate, and in the absence of another strategy that may effectively decrease recurrence rate, may be an option to consider in children younger than 7 years with IBD and a high risk of recurrence. Further research is required to determine recurrence risk in children under 7 years with IBD and to develop surgical strategies to mitigate this risk accordingly.

Ethics statement
The authors declare that this submission is in accordance with the principles laid down by the Responsible Research Publication Position Statements as developed at the 2nd World Conference on Research Integrity in Singapore, 2010. Ethical approval (BCA268/15) was granted by the University of KwaZulu-Natal Biomedical Research Ethics committee. All procedures were in accordance with the ethical standards of the responsible committee on human experimentation (institutional and national) and with the Helsinki Declaration of 1975, as revised in 2008.

Declaration
The authors declare authorship of this article and that they have followed sound scientific research practice. This research is original and does not transgress plagiarism policies.

Author contributions
PHM: Study design, data capture, data analysis and interpretation, first draft preparation, manuscript revision
DMT: Study conceptualisation, manuscript review
LCM: Study design, data analysis and interpretation, manuscript preparation and revision

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