

Gradual Deformity Correction with a Computer-assisted Hexapod External Fixator in Blount's Disease

Pieter H Mare¹, Leonard C Marais²

ABSTRACT

Aim: To evaluate the results in terms of correction and complications from gradual correction with a computer-assisted hexapod circular external fixator in a mixed cohort of children with Blount's disease.

Materials and methods: A retrospective review was performed of the correction and complications of 19 children (25 limbs) with recurrent infantile (IBD) and late-onset Blount's disease (LOBD) treated by gradual correction with a hexapod external fixator. The correction was measured by the medial proximal tibial angle (MPTA), anatomic posterior proximal tibial angle (aPPTA) and anatomic tibio-femoral angle (TFA). Obesity was present in 76% (19/25) of cases. Fifteen limbs were classified as infantile Blount's disease and 10 limbs as late-onset Blount's disease. The mean age was 12.5 years (range 7–17 years).

Results: The mean pre-operative MPTA of 59° (SD 13°, range 33–79°) was corrected to a mean of 86° (SD 5°, range 77–93°). The mean pre-operative aPPTA of 64° (SD 14°, range 33–84°) was corrected to 79° (SD 6°, range 70–90°). The median pre-operative rotation of 15° internal rotation was corrected to normal (0–15° of external rotation). Eight out of 25 limbs had severe deformities with varus or procurvatum greater than 40° or both. The mean pre-operative TFA of 28° varus (SD 13°, range 4–53°) was corrected to 1.8° valgus (SD 6°, range 14° varus to 13° valgus). The median follow-up was 19 months (range 6–67 months). The alignment after correction was "good" in 55% (11/20), "acceptable" in 35% (7/20) and "poor" in 10% (2/20).

The median duration for correction was 16 days (IQR 11–31 days, range 7–71 days). The median number of prescribed correction programmes was 1 (IQR 1–2, range 1–5). The mean total time in the frame was 136 days (SD 34 days, range 85–201 days).

All patients developed minor pin track infections that resolved with oral antibiotics (Category 1 complications). Four patients developed complications that necessitated modification of the treatment plan (Category 2 complications). In two cases, treatment objectives could not be achieved (Category 3 complications). Two patients treated before skeletal maturity developed recurrent genu varum.

Conclusion: Gradual correction with a computer-assisted hexapod external fixator may be a useful technique for correcting recurrent IBD or LOBD even in children with severe deformities. The results of gradual correction were similar in the two groups. While complications occur, most can be mitigated by timely intervention during the correction phase of treatment. Recurrence remains a concern if correction is performed before skeletal maturity.

Level of evidence: 4.

Keywords: Blount's disease, External fixation, Gradual correction, Hexapod, Tibia Vara, Tibial osteotomy.

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INTRODUCTION

Blount's disease results in a multi-planar deformity of the proximal tibia due to disordered growth of the posteromedial proximal tibial physis.¹ While the aetiology is multifactorial, there is an association with obesity.² The typical deformity consists of varus, procurvatum, internal rotation and shortening in the tibia. Blount's disease is classified according to the age at onset into infantile (IBD) and late-onset Blount's disease (LOBD).^{1,3–5} In IBD, there may be an intra-articular deformity consisting of a down-sloping medial tibial articular surface that results in knee instability.³ Distal femoral varus, valgus or internal torsion deformity, as well as distal tibial valgus or hindfoot deformity, may be associated with Blount's disease.^{6–10} A comprehensive assessment of all aspects of the lower extremity deformity is essential.

Once the diagnosis of Blount's disease is made, the treatment involves surgery typically. Various surgical options are available depending on the patient characteristics, the deformities present, and the surgeon's training and preference. These include guided growth, acute correction through a proximal tibial osteotomy, with or without internal fixation, and acute elevation of the medial

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joint surface by osteotomy. Complications of tibial osteotomies are rare but serious and include compartment syndrome, vascular injury and peroneal nerve palsy. The Ilizarov method of deformity correction through the principle of distraction osteogenesis with mechanical hinges and circular fixation

has been applied to Blount's disease successfully.^{9,11} Gradual correction through a proximal tibial metaphyseal osteotomy alone or in combination with acute or gradual medial joint elevation osteotomy has become more sophisticated with the development of computer-assisted hexapod circular external fixators.¹² While the procedure is complicated and patient compliance is essential, gradual correction presents a unique opportunity to mitigate complications during deformity correction. Timely intervention may offset permanent impairment when a setback is encountered. The development of classification systems to describe the "difficulties" encountered during gradual correction with circular fixators has been helpful to anticipate and prevent permanent complications.^{13–15}

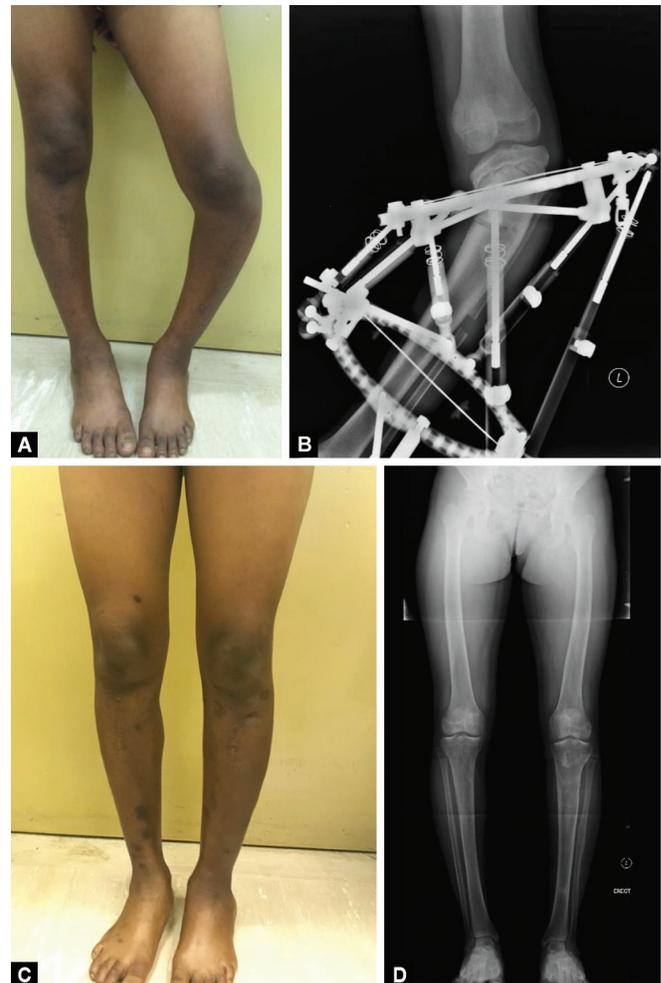
This retrospective observational study describes our experience with gradual correction using a hexapod external fixator in a subset of patients with Blount's disease. Our objectives were to determine the pre-operative tibial deformity and analyse the clinical outcome of surgery in terms of the correction and incidence of complications.

MATERIALS AND METHODS

The sample comprised all children with Blount's disease treated with gradual correction and hexapod external fixation through a proximal tibial and midshaft fibula osteotomy by our Paediatric Orthopaedic Unit in an academic hospital between 2013 and 2019 (Fig. 1). These patients were identified through a database at the unit. We included children ≥ 7 years with recurrent IBD without medial joint line depression (or after previous medial elevation osteotomy with recurrent metaphyseal deformity) and those with LOBD where the magnitude of deformity was greater than could be corrected with guided growth (considering the amount of growth remaining) or where severe obesity made guided growth undesirable due to the risk of failure. The normal angle of depression of the medial plateau (ADMP) has been described as 20–30°.¹⁶ Children with IBD and medial joint line depression $>30^\circ$ and knee instability were managed by simultaneous medial elevation, lateral epiphysiodesis and acute correction through a proximal tibial osteotomy and mid-shaft fibula osteotomy.¹⁷

Surgical Technique

Pre-operative deformity analysis was performed by clinical examination and a radiological assessment as described by Paley and Tetsworth.¹⁸ The procedure was performed under tourniquet control in the supine position on a radiolucent table. One centimetre of the fibula diaphysis was resected subperiosteally to avoid premature consolidation. All patients were treated with the TLHex external fixator (Orthofix Srl, Verona, Italy). Two methods of frame mounting were used: a frame was either configured or built pre-operatively using the software available for the TLHex system; or the rings were mounted orthogonally to the reference and moving segments intraoperatively. The magnitude of procurvatum is difficult to estimate clinically and mounting the rings in the correct rotation may also be challenging. Prebuilding the frame facilitates correct frame position and fixation because the rings are fixed in the correct relationship to each other, and the longer distal tibial (moving segment) becomes an additional guide to the frame position. The proximal and distal rings were fixed to the tibia with a tensioned transverse wire in each ring, respectively. The proximal wire was placed just distal to the knee capsular insertion, anterior to the fibula and distal to the growth plate. Rotation was assessed clinically and the correct coronal and sagittal plane orientations

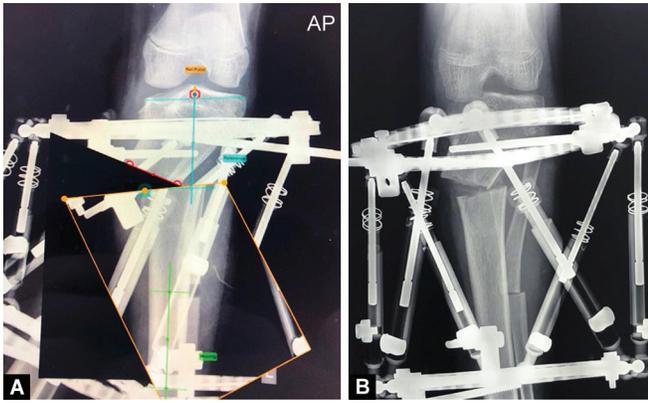


Figs 1A to D: (A) Clinical picture of the lower limbs of an 11-year-old girl with recurrent Blount's disease on the left; (B) Post-operative AP radiograph of the knee with the external fixator applied and the osteotomy visible; (C) Clinical picture of the lower limbs at skeletal maturity; (D) Standing long-film AP radiograph of the lower limbs at skeletal maturity

were confirmed on fluoroscopy. Two 6 mm diameter half pins were inserted and fixed to each ring to complete fixation. The half pins were inserted parallel to the rings and perpendicular to the bone segment and to each other. A low-energy tibial osteotomy was performed approximately 1 cm from the most distal proximal half-pin according to the technique described by De Bastiani et al.¹⁹ All half pins were hydroxyapatite-coated. The pin tracks were dressed by occlusive gauze dressings soaked in chlorhexidine gluconate in 70% alcohol.

A lateral proximal tibial epiphysiodesis was performed in all children with IBD if treated for recurrent deformity following a previous tibial osteotomy and if significant growth remained. The children with IBD and LOBD treated near skeletal maturity did not require a lateral epiphysiodesis.

Post-operative X-rays were taken to reassess the deformity and evaluate the frame mounting. The TLHex software was used to calculate the deformity correction program (www.tlhex.com) (Fig. 2). Our aims for the final medial proximal tibial angle (MPTA) and posterior proximal tibial angle (PPTA) were 87° and 81°, respectively, and we also included 15° external tibial rotation. The amount of



Figs 2A and B: (A) Screen-captured image showing the planned correction during the deformity correction planning process from the HEX-ray module of the TLHEX application software (www.tlhex.com); (B) AP radiograph of the knee and proximal tibia and fibula depicting the limb after gradual correction

lengthening was calculated based on the estimated LLD at maturity in unilateral cases. In bilateral cases, lengthening was calculated to ensure the moving segment clears the reference fragment during the correction. Pin-track care was started after a week as a daily routine of pin cleaning with chlorhexidine gluconate in 70% alcohol. The pin tracks were not routinely dressed after the initial post-operative period.

Measurements

Radiographs taken as weight-bearing films were reviewed before surgery, after frame removal and at the latest follow-up to identify cases with recurrent deformity. Measurements taken included the anatomic tibio-femoral angle (TFA), the medial proximal tibial angle (MPTA) and the anatomic posterior proximal tibial angle (aPPTA). The tibial torsion was assessed clinically by an estimation of the intermalleolar axis and foot-thigh angle. The leg length discrepancy was evaluated clinically and radiologically on standing long leg films when available. Recurrence was defined as an MPTA decrease of greater than 10°.

The TLHex software programme data were reviewed for the magnitude of deformity correction as well as the number and duration of correction schedules. The total time in the frame was also recorded.

The outcome in terms of alignment at the latest follow-up was assessed as "good" if the TFA was measured as 1–11° valgus.²⁰ "Acceptable" alignment was if the TFA was between 0 and 9° varus as we found that patients were satisfied with the cosmetic appearance of the limb and declined further intervention. Valgus alignment with a TFA >11° valgus or varus alignment with a TFA ≥10° varus was categorised as "poor" alignment.

Complications were classified using the system described by Cherkashin et al.¹⁵ Category 1 complications required no alteration in the treatment plan, no return to the operating theatre and did not affect the treatment outcome. Category 2 complications necessitated modifications in the treatment plan or a return to the operating theatre, but the eventual outcome was not affected. Category 3A complications resulted in a failure to achieve treatment goals. Category 3B complications resulted in a failure to achieve the treatment goals and a worsening of the condition or development of new pathology.¹⁵

Statistical Analysis

Statistical analysis was performed using Jamovi version 1.2.18.0 open-source software.²¹ Normally distributed continuous variables were reported as means with standard deviations (SD) and ranges. Non-parametric data were reported as medians with interquartile ranges (IQR), as well as entire ranges. Categorical variables were reported as percentages and numbers. 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. The Mann-Whitney 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 $p < 0.05$.

RESULTS

Nineteen children (26 limbs) with Blount's disease were identified who were treated by gradual correction with a hexapod external fixator. The median follow-up was 19 months (IQR 13–41), with a range of 6–67 months. Sixty-three percent (12/19) of the children were female. One limb was excluded due to incomplete post-operative radiological records; thus, 25 limbs were included for analysis. The mean age was 12.5 years (range 7–17 years). Fifteen limbs had IBD and these children had a mean age of 11.2 years (range 7–14 years) at treatment. Ten limbs had LOBD and these children had a mean age of 14.5 years (range 11–17 years) at treatment. Obesity was present in 76% (19/25) of cases overall, 73% (11/15) in the IBD cases and 80% (8/10) in the LOBD cases ($p = 0.702$). Bilateral Blount's disease was present in 13 children but gradual bilateral correction was indicated only in six children. Five out of the six (83%) of the bilateral cases requiring gradual correction were treated by staged surgery. Gradual correction was the first procedure in 28% (7/25) of limbs. All the children with infantile Blount's disease were treated for recurrent deformity after previous surgery (15/15), while gradual correction was the primary surgical procedure in 70% (7/10) of the late-onset cases. The median tibial varus deformity was 22° (IQR 19–35°, range 13–57°), median tibial procurvatum was 20° (IQR 7–25°, range 9° recurvatum to 68° procurvatum) and the median internal tibial torsion was 15° (IQR 0–20°, range 0–49° internal torsion). Eight out of 25 limbs had severe deformities with >40° varus or procurvatum or both.

Two cases of distal femur malalignment were treated with guided growth (one case of IBD with distal femur valgus and one case of LOBD with distal femur varus). Lateral proximal tibial epiphysiodesis was required in 4/15 IBD limbs for children treated between the age of 7 and 9 years. No lateral proximal tibial epiphysiodesis was performed in the 9/10 limbs with LOBD that were treated near skeletal maturity. In the remaining LOBD limb of a 12-year-old boy with unilateral LOBD, a lateral epiphysiodesis was considered but not performed due to an open medial proximal tibial physis at the time of frame removal.

The median correction duration was 16 days (IQR 11–31 days, range 7–71 days). The median number of correction programs was 1 (IQR 1–2, range 1–5). The mean total time in the frame was 136 days (SD 34 days, range 85–201 days).

The outcome of deformity correction was measured after frame removal. The mean pre-operative MPTA of 59° (SD 13°, range 33–79°) was corrected to a mean of 86° (SD 5°, range 77–93°). The mean pre-operative aPPTA of 64° (SD 14°, range 33–84°) was corrected to 79° (SD 6°, range 70–90°). The median pre-operative rotation of 15°

internal rotation was corrected to normal (0–15° of external rotation). The median lengthening was 1 cm (IQR 1–1 cm, range 0.5 cm shortening to 3.5 cm lengthening). We were able to measure the pre- and post-operative TFA accurately in 80% (20/25) of cases. The mean TFA of 28° varus (SD 13°, range 4–53°) was corrected to 1.8° valgus (SD 6°, range 14° varus to 13° valgus). A comparison of the pre- and post-operative data between IBD and LOBD is summarised in Table 1. The alignment after correction was “good” in 55% (11/20), “acceptable” in 35% (7/20) and “poor” in 10% (2/20). Of the two cases with poor alignment, one was due to overcorrection of the tibial deformity to an MPTA of 93° which resulted in a valgus tibiofemoral alignment. The second case with poor alignment was due to a combination of tibial and distal femoral varus malalignment. In this case, the MPTA was under-corrected (MPTA = 80°) and distal femoral varus alignment resulted from malreduction during plate fixation of a distal femur fracture sustained during gradual correction of the tibia.

Two patients had recurrent genu varum. One patient with IBD who was operated on at the age of 7 years developed recurrence that occurred despite percutaneous lateral epiphysiodesis (that was performed at frame removal) and required a repeat osteotomy. Another patient with LOBD treated at the age of 12 had 8° recurrent proximal tibial varus at the latest follow-up but it was combined with progressive distal femoral varus; this resulted in an unacceptable anatomic TFA of 15°. Lateral epiphysiodesis was considered but not performed due to an open medial proximal tibial growth plate at frame removal.

Complications

All patients developed a Category 1 complication in the form of minor pin track infection that resolved with increased frequency of pin track care and oral antibiotics (Checketts-Otterburn grade I and II).²²

Four patients developed Category 2 complications. The deformity correction in one patient was not completed due to a proximal ring mounting error. The patient had to return to the operating theatre during deformity correction for adjustment of the orientation of the proximal ring. Deformity correction continued uneventfully after that with “good” alignment achieved.

In another case, complete translation of the moving segment occurred in relation to the reference segment due to the osteotomy being too distal (Paley osteotomy rule two).²³ An additional run of the programme was utilised in order to translate the axis of the reference segment (Paley osteotomy rule three) so that the osteotomy surface of the moving segment overlapped at least 50% of the reference segment.²³ When poor regenerate was observed on sequential X-rays, the patient was returned to the operating theatre for iliac crest autograft. The osteotomy healed without further complication. Two patients developed Checketts-Otterburn grade III pin track infection of the proximal transverse tensioned wire that resolved after wire removal.

There was poor alignment in two limbs (8%), and these were classified as Category 3 complications. One was due to tibial overcorrection (MPTA of 93°) and was classified as a Category 3A complication. Inadequate deformity correction in the second patient was due to an under-corrected tibia (MPTA of 80°). This patient also sustained a spiral distal femur fracture due to a fall during the consolidation phase of treatment. The distal femur was treated by open reduction and plate fixation with a residual varus deformity (mechanical lateral distal femoral angle of 94°, opposite side 83°), resulting in varus malalignment and a Category 3B complication.

A comparative analysis of the correction, results and complication rates is summarized in Table 2.

DISCUSSION

The aim was to determine the outcome of hexapod external fixator-assisted gradual deformity correction of the tibia in children with Blount's disease. The severity of the deformity, the correction and the incidence of complications were measured and recorded. A good or acceptable deformity correction was accomplished in 90% of cases, with two cases subsequently developing recurrent deformities. All patients developed Category 1 complications and four patients developed Category 2 complications. These complications did not compromise the goals of treatment due to timely interventions during the correction period. Two patients developed Category 3 complications.

Table 1: Summary and comparative analysis of the pre- and post-operative descriptive characteristics of our patient cohort

Variable	Infantile Blount's disease (n = 15)	Late-onset Blount's disease (n = 10)	p value
Age ⁱ	11.2 (7–14)	14.5 (11–17)	<0.001 ^{vi}
Obesity [% (n)]	73% (11)	80% (8)	0.702 ^{vii}
Bilateral	87% (13)	60% (6)	0.126 ^{vii}
Previous surgery	100% (15)	30% (3)	<0.001 ^{vii}
<i>Pre-operative</i>			
TFA ⁱⁱ	–30° (–4° to –53°)	–26° (–15° to –42°)	0.482 ^{vi}
MPTA ⁱⁱⁱ	57° (69° to 37°)	61° (74° to 33°)	0.544 ^{vi}
aPPTA ^{iv}	60° (84° to 33°)	69° (83° to 45°)	0.135 ^{vi}
Internal rotation ^v	15° (0° to 30°)	14° (0° to 49°)	0.333 ^{viii}
<i>Post-operative (after frame removal)</i>			
TFA ⁱⁱ	1.2° (–14° to 13°)	2.4° (–5° to 10°)	0.761 ^{vi}
MPTA ⁱⁱⁱ	86° (77° to 92°)	87° (82 to 93°)	0.956 ^{viii}
aPPTA ^{iv}	79° (70° to 89°)	79° (70° to 90°)	0.857 ^{vi}

(i) Mean age in years (range); (ii) Mean tibio-femoral angle (TFA) (range), negative values denote varus alignment; (iii) Mean medial proximal tibial angle (MPTA) (range); (iv) Mean anatomic proximal posterior tibial angle (aPPTA) (range); (v) Median internal rotation (range); (vi) Student's *t*-test; (vii) Chi-squared test; (viii) Mann-Whitney *U*-test

Table 2: Summary and comparative analysis of the correction, results and complication rate of gradual correction in our patient cohort

Variable	Infantile Blount's disease n = 15	Late-onset Blount's disease n = 10	p value
Correction			
Program number ⁱ	1 (1–5)	2 (1–3)	0.822 ^{vi}
Correction days ⁱⁱ	19 (11–71)	14 (7–33)	0.337 ^{vi}
Total days ⁱⁱ	136 (85–180)	137 (91–201)	0.925 ^{vii}
Results (n = 20)			
Good ⁱⁱⁱ	50% (5)	60% (6)	
Acceptable ^{iv}	30% (3)	40% (4)	0.327 ^{viii}
Poor ^v	20% (2)	0% (0)	
Complications [% (n)]			
Category 1	100% (15)	100% (10)	
Category 2	27% (4)	0% (0)	0.075 ^{viii}
Category 3A	7% (1)	0% (0)	0.229 ^{viii}
Category 3B	7% (1)	0% (0)	

(i) Median (range); (ii) Mean total days in external fixator (range); (iii) 1° valgus to 11° valgus tibio-femoral angle (TFA); (iv) 0–9° varus TFA; (v) >11° valgus, >9° varus; (vi) Mann–Whitney U-test; (vii) Student's t-test; (viii) Chi-squared test

This cohort consisted of a mixture of recurrent IBD and LOBD with the mean age comparable to other studies on similar mixed cohorts.^{11,15} A high proportion of the children in this cohort (76%) had a BMI >95th centile, comparable to other studies.^{11,15,24} The magnitude of deformity (13–57° varus, 9° recurvatum to 63° procurvatum) was similar to the studies by Stanitski (10–55° varus) and Cherkashin (2–48° varus, 11° recurvatum to 48° procurvatum).^{11,15} Correction to a mean MPTA and aPPTA of within 1–2° to the reference means was achieved although there was substantial variation around this mean due to the two cases with poor alignment.¹⁸ “Good” or “acceptable” alignment in 90% of cases was accomplished when evaluating the correction as measured by the TFA.

The duration of correction (mean 16 days, range 7–71 days) reflected the complexity of the deformity with some children requiring multiple deformity correction programmes and those undergoing lengthening requiring more prolonged correction. The total duration of frame application (136 days, range 85–201 days) was similar to that described by Cherkashin et al. (average 130 days for Infantile and 152 days for Adolescent Blount's disease), but longer than the reports by Feldman (approximately 102 days) and Stanitski (84 days without lengthening, 118 days with lengthening).^{11,12,15} There was caution exercised when planning frame removal with a following of the adage: ‘rather a month too late than a day too early’.

Several authors have described a simultaneous medial tibial plateau elevation osteotomy (either acute or gradual) with the proximal tibial osteotomy for gradual correction, and with a low rate of complications.^{25–30} In our unit, children with demonstrable knee instability in full extension and an ADMP >30° were treated with simultaneous medial joint line elevation, proximal tibial osteotomy and acute correction combined with lateral proximal tibial epiphysiodesis. This strategy was chosen due to the potential risk of deep infection at the elevation osteotomy or even septic arthritis when proximal tibial external fixation, with a high incidence of pin track infection, is combined with peri-articular osteotomies. This decision was supported by our observation of two major pin track infections at the proximal tibial reference wire in this study.

The classification described by Cherkashin et al. provides a pragmatic framework to evaluate difficulties encountered during

treatment.¹⁵ Superficial pin track infection that resolved on oral antibiotics was a universal Category 1 complication, similar to the experience of Feldman et al. and Eidelman et al.^{12,31} Of the four cases with Category 2 complications, two were due to major pin track infections that resolved without further sequelae after wire removal. The third Category 2 complication occurred in a child with severe deformity (MPTA of 37°, aPPTA of 36°). The extent of the procurvatum was underestimated and the proximal ring was mounted anterior side-up. The posterior struts could not lengthen sufficiently to complete the deformity correction due to the proximal ring malalignment. This complication may have been prevented had a pre-built frame been used in application. The final Category 2 complication was due to a complete translation of the moving segment on the reference fragment during deformity correction. The osteotomy was too far distal in relation to the apex of the deformity. A check-up programme was run to correct the translation at the cost of residual axis translation and Iliac crest autograft was required to achieve union. This complication could have been avoided by ensuring the proximal ring and fixation elements were placed as proximal as possible (without penetrating the distal knee joint capsule), allowing for the osteotomy site to be as close as possible to the apex of deformity. We failed to achieve the goals of the procedure in two patients; one resulted from tibial over-correction and the other was a combination of tibial under-correction and distal femur malunion.

During follow-up, two patients developed recurrent genu varum. One case was ascribed to a failed lateral epiphysiodesis in a child with IBD. The second was due to a combination of mild recurrent tibial varus and progressive concomitant distal femoral varus in a 12-year-old boy with LOBD. A timely lateral epiphysiodesis may have prevented this complication. A lateral proximal tibial epiphysiodesis is essential when further medial growth is unlikely, such as after previous IBD recurrence, or in the child with LOBD and severe obesity treated when significant growth remains. Follow-up until skeletal maturity is essential to monitor for recurrence as the failure rate of lateral epiphysiodesis is between 12 and 15%.³²

There are several limitations to this study. Incomplete records did not permit a comparison of frame mounting accuracy between the ‘pre-built’ and ‘rings-first’ methods of frame application. Clinical

assessment of leg length discrepancy was also not available due to missing medical records. Full-length radiographs were insufficient for analysis of the mechanical TFA as an outcome variable and we had to use the anatomic TFA as measured on weight-bearing knee X-rays to assess limb alignment. While not all of these children were followed to skeletal maturity, we were able to determine and evaluate the correction and complication rate of gradual correction with a hexapod external fixator for this cohort. Further research is required to determine the recurrence rate and long-term outcome of Blount's disease treated by gradual correction with external fixation.

CONCLUSION

Gradual correction with a computer-assisted hexapod external fixator may be a useful technique for correcting recurrent IBD or LOBD even in children with severe deformities. The results of gradual correction were similar between these two groups. While complications are common, most can be mitigated by timely interventions during the correction phase of treatment. Recurrence remains a concern if correction is performed before skeletal maturity.

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