Change in angle of depressed medial tibial plateau following extra-articular mechanical realignment surgery in children with Blount’s disease who presented late for treatment

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Abstract

Introduction: The aim of this study was to determine whether any change in degree of medial tibia plateau depression after extra-articular mechanical realignment surgery was observed in children with Blount’s disease who presented late for treatment in their adolescence and young adulthood.

Methods: We retrospectively reviewed the radiographic parameters of 22 patients (32 lower limbs) with Blount’s disease who underwent gradual correction of deformity using a ring external fixator without surgical elevation of the depressed medial tibial plateau at a mean age of 15 (range 10–37) years. Preoperative and postoperative angles of depressed medial tibia plateau (ADMTPs) of the same patient were compared for any significant change. Normally distributed data were analysed using Student’s t-test when comparing two groups or one-way analysis of variance when comparing more than two groups. Skewed data were analysed using Mann–Whitney test.

Results: After extra-articular mechanical alignment surgery, statistically significant improvements in medial tibial plateau depression were seen in the infantile (P = 0.03) and juvenile (P = 0.04) Blount’s subgroups. Change in ADMTP was greater in patients who were operated on at age <17 years, before skeletal maturity (P = 0.001). The improvement was likely due to ossification of unossified cartilage at the posteromedial proximal tibia and the remodelling potential of proximal tibia physis after mechanical realignment.

Conclusion: Improvement of medial tibia plateau depression is possible after mechanical realignment without surgical hemiplateau elevation in cases of infantile and juvenile Blount’s disease that present late for treatment, especially when the operation is performed before 17 years of age.

Keywords: Blount’s disease, deformity, genu varum, orthopaedics, paediatrics

INTRODUCTION

In 1937, Walter Putnam Blount reported progressive tibia vara in young children and the condition was subsequently called Blount’s disease. Langenskiold classified Blount’s disease into six stages based on radiological appearance of the epiphysis and metaphysis.[2‑4] He also grouped them into two distinct entities based on the time of onset of the deformity; children with early-onset Blount’s disease have an age of onset of 4 years or less, where the medial tibial plateau progressively worsens as the child grows older. Children with late-onset Blount’s disease have an age of onset of more than 4 years and generally have less-severe deformity of the medial plateau.[2‑4] Others further classified this condition into infantile (4 years or less), juvenile (5–10 years) and adolescent (11 years or more) Blount’s disease.[5]

Non-operative treatments such as use of braces and orthosis have been described for early-stage infantile Blount’s disease in children aged up to 3 years.[6] If deformity does not resolve, the definitive treatment is surgery. Growth modulation is an
option for mild deformity in children who have not reached skeletal maturity.\[7\] For severe deformity, valgus osteotomy of the proximal tibia with either acute or gradual correction using internal or external fixator may be indicated.\[6\] For deformities associated with significant depression of the postero medial tibial plateau, the current trend of treatment requires medial hemiplateau elevation using intra-articular osteotomies to complement the procedure to correct mechanical alignment.\[8‑10\] Some studies proposed the indication for medial hemiplateau elevation if the angle of depressed medial tibia plateau (ADMTP) is more than 30°.\[10‑13\] However, there are neither recent studies reporting on the natural history of proximal tibia development nor studies validating the actual indication for medial tibia plateau elevation. Proponents of medial tibia plateau elevation surgery claim this surgery is aimed to prevent the development of early osteoarthritis of the knee joint.\[6,10,13\] Nevertheless, medial tibia plateau elevation surgery involves intra-articular osteotomy, which could create an additional insult to the developing proximal tibia physis in a child. The exact timing to do this surgery is controversial. There are many studies describing the technique of medial plateau elevation.\[8,11\] However, there are also no landmark studies in the literature providing evidence that this surgery will reduce the incidence of early osteoarthritis in Blount’s disease.

In our setting, there were many patients with Blount’s disease who presented late for treatment when they were adolescents or young adults. We did not practise medial tibia plateau elevation surgery for these cases because of concern of additional damage to the medial tibia physis and knee joint from this invasive procedure. These children presented with severe deformity of the knee joint. Our approach was extra-articular realignment of the mechanical axis using ring external fixators and monitoring of the medial plateau depression until the patients reached skeletal maturity. The research question was whether the severity of medial tibia plateau depression would change after extra-articular mechanical realignment surgery. The null hypothesis was there would be no change in the ADMTP after extra-articular mechanical realignment surgery.

**METHODS**

We conducted a retrospective study on patients with Blount’s disease who presented late for treatment in their adolescent or young adulthood stage. After we obtained the approval of the Institutional Research Ethics Committee, we searched the hospital database for patients diagnosed with Blount’s disease from 2002 to 2017. All patients aged more than 10 years who had undergone extra-articular deformity correction for Blount’s disease were included. Those who had genu varum secondary to other aetiologies such as trauma, metabolic diseases or skeletal dysplasia were excluded. To reduce the risk of soft tissue complications and further injury to the intra-articular structures, all patients were treated with distraction osteogenesis through a single-level corticotomy at a level just below the tibia tubercle using a ring external fixator, without surgical elevation of the depressed medial tibia plateau. Description of the procedure and type of external fixator used has been reported in our previous publication.\[14\] Clinical information, including patient demographics, treatment details and radiographic images, were collected and analysed. We contacted a few patients for missing information. Patients who were lost to follow-up during treatment were excluded. Lower limb mechanical axis alignment and proximal tibia deformity were evaluated using a standing lower limb plain radiograph. We compared the preoperative radiograph with the postoperative radiograph taken at the last follow-up after frame removal. All radiographic measurements were made by a single investigator (ZHP) who had not been involved in treating the patients, using a digital imaging software system (Picture Archiving and Communication System (PACS); GE Healthcare, Chicago, IL, USA). Standard radiological parameters, including lateral distal femur angle (LDA), medial proximal tibia angle (MPTA), lateral distal tibia angle (LDTA), joint line convergence angle (JLCA) and mechanical axis deviation (MAD), were measured. In addition, we measured the parameters described by Hefny et al.,\[8\] including tibiofemoral angle (TFA), femoral condyle tibial shaft angle (FCTSA) and ADMTP. To further analyse the changes in the medial tibia plateau, we measured three arbitrary additional angles: first, the angle subtended by a line parallel to the lateral tibial plateau and a line connecting the most lateral and the most medial points of the proximal tibia joint line (alpha angle); second, the angle subtended by a line perpendicular to the lateral tibia plateau and the mechanical axis line of the tibia connecting the midpoint of the knee joint to the midpoint of the ankle joint (beta angle); and third, the angle subtended by the mechanical axis line of the tibia and a line connecting the most lateral and the most medial points of the proximal tibia joint line (gamma angle) [Figure 1]. The normal alpha angle is 0°, in which the lateral tibial plateau is at the same height as the medial tibia plateau. The normal beta angle is 0°, in which the line perpendicular to the lateral tibial plateau is parallel to the tibia mechanical axis line connecting the centre of the knee and the ankle joints. The normal gamma angle is 90°, in which the tibia mechanical axis line is perpendicular to both the medial and lateral tibial plateau.

We further subdivided the patients into three groups based on the age of onset for analysis of medial tibia plateau depression as follows: infantile (≤4 years old), juvenile (5–10 years old) and adolescent (≥11 years old) Blount’s disease, noting that patients in the infantile and adolescent groups behave differently as described by Langenskiold and Riska.\[2\]

Normality test was performed on all collected parameters using Shapiro–Wilk test. Parametric data that were normally distributed were analysed using Student’s t-test when comparing two groups or one-way analysis of variance (ANOVA) when
comparing more than two groups. Meanwhile, parametric data that were not normally distributed were analysed using Mann–Whitney test. A $P$ value < 0.05 was significant to reject the null hypothesis of no change in ADMTP after extra-articular mechanical realignment surgery.

**RESULTS**

Seventy-one patients with pathological genu varum were treated during the study period. Twenty-four patients were diagnosed with Blount’s disease and underwent operation when they were more than 10 years old. Two patients were excluded because they were lost to follow-up during treatment and were uncontactable. Eventually, the study sample consisted of 22 patients and 32 lower limbs. There were 12 male and 10 female patients. Ten of them had bilateral knee surgery and 12 had unilateral surgery. The average age of onset of the deformity was 8 (range 1–20) years. There were six patients (10 limbs) with infantile Blount’s disease; ten patients (14 limbs) with juvenile Blount’s disease and six patients (eight limbs) with adolescent Blount’s disease. The mean age of corrective surgery was 15 (range 10–37) years, and the mean duration on external fixator frame was 296 days. The mean duration of follow-up was around 3 years (1195 days).

Surgery managed to correct MAD from 94 mm medial to the centre of the knee joint to 9 mm medial to the centre of the knee joint. There was significant improvement in MPTA from 44° to 81° following correction of proximal tibia varus angulation ($P < 0.05$). The mean values of these two parameters remained within the normal limits throughout the period of treatment and follow-up. For other coronal plane alignments that involved the proximal tibia, we noted statistically significant improvement after surgery ($P < 0.05$); TFA improved from 31° varus to 2° valgus, FCTSA improved from 53° varus to 86° varus and JLCA improved from 7° to 2° [Table 1]. We did not notice any obvious difference between the preoperative and postoperative LDFA (88° vs. 87°) and LDTA (88° vs. 90°) [Table 1]. In addition, parameters of medial tibia plateau depression also improved during follow-up. We noted a statistically significant improvement in ADMTP in infantile Blount’s disease from 43° to 32° ($P = 0.03$) and in juvenile Blount’s disease from 35° to 24° ($P = 0.04$). For adolescent Blount’s disease, ADMTP changed from 33° to 23°, but did not achieve statistical significance ($P = 0.09$). Arbitrary additional angles created to analyse medial tibial depression also showed reduced depression after surgery, consistent with the changes of ADMTP mentioned above [Table 2].

We subsequently conducted further analysis to study four possible factors that could have influenced the changes in ADMTP, and these factors included age at surgery, presence of proximal tibia physis, age of onset of Blount’s disease and severity of varus angulation (MAD). To compare the mean changes in ADMTP based on age at surgery, we divided the patients into two groups: ≥ 17 years old (after skeletal maturity) and < 17 years old (before skeletal maturity). We noticed a significant difference in the change of ADMTP, comparing more than two groups. Meanwhile, parametric data that were not normally distributed were analysed using Mann–Whitney test. A $P$ value < 0.05 was significant to reject the null hypothesis of no change in ADMTP after extra-articular mechanical realignment surgery.

**Table 1. Frontal alignment measurement of gradual correction of deformity.**

| Parameter | Normal value | Preoperative | Postoperative | $P$  |
|-----------|--------------|--------------|---------------|-----|
| LDFA (°)  | 85–90        | 88 (6)       | 87 (6.5)      | 0.13|
| LDTA (°)  | 85–93        | 88 (6.5)     | 90 (3)        | 0.47|
| MPTA (°)  | 85–90        | 44 (7–94)    | 81 (50–111)   | <0.001*|
| MAD (mm)  | 3–17         | 94 (14–214)  | 9 (−65 to 112)| <0.001*|
| TFA (°)   | −5           | 31 (10–57)   | −2 (−38 to 27)| <0.001*|
| FCTSA (°) | 90           | 53 (23–77)   | 86 (60–120)   | <0.001*|
| JLCA (°)  | 0–2          | 7 (10.5)     | 2 (3)         | <0.001*|

Normally distributed data are presented as mean (range), and skewed data are presented as median (interquartile range). · Positive MAD values indicate MAD is medial to the knee joint. · Positive TFA indicates varus alignment and negative TFA indicates valgus alignment. *Statistically significant. FCTSA: femoral condyle tibial shaft angle, JLCA: joint line convergence angle, LDFA: lateral distal femoral angle, LDTA: lateral distal tibia angle, MAD: mechanical axis deviation, MPTA: medial proximal tibia angle, TFA: tibiofemoral angle

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**Figure 1:** Illustration shows various measurements used to evaluate medial tibial plateau depression including angle of depressed medial tibial plateau (ADMTP), $\alpha$ angle, $\beta$ angle and $\gamma$ angle.
wherein children evaluated after skeletal maturity had little change in ADMTP compared to the children evaluated before skeletal maturity ($-1.2^\circ$ vs. $-12.5^\circ$, $P < 0.05$). Subsequently, we compared the change in ADMTP between children with radiological evidence of proximal tibia physis and those in whom physis could not be visualised. Presence of lateral proximal tibia physis was chosen to evaluate remodelling potential because in many patients, the medial proximal physis was affected by medial plateau depression and therefore was difficult to visualise. The mean value of change was $-13.6^\circ$ for those with open physis compared to $-6.5^\circ$ for those without physis, which showed a trend of increased change in ADMTP with open physis, but the change was not significant ($P = 0.14$) [Table 3].

For the age of onset, we divided the patients into three age groups: infantile, juvenile and adolescent. Mean changes in ADMTP before surgery and during follow-up were $-11.1^\circ$, $-10.4^\circ$ and $-10.8^\circ$, respectively, and not statistically significant (ANOVA $F = 0.01, P = 0.99$). For severity of varus angulation, we divided the patients into four groups based on MAD as follows: $0$–$5$ cm, $5$–$10$ cm, $10$–$15$ cm and $15$–$20$ cm medial. The changes in ADMTP for these four groups of patients were $-8.5^\circ$, $-6.6^\circ$, $-19.1^\circ$ and $-9.3^\circ$, respectively, and not statistically significant (ANOVA $F = 1.56, P = 0.22$).

**DISCUSSION**

This study has a sample size of 22 patients with Blount’s disease, with an average age of 15 years when they underwent extra-articular mechanical realignment surgery using ring external fixators. As expected, postoperative mechanical alignment was well corrected using this method. Our clinical findings were similar to those of many other studies using gradual correction and ring external fixators to correct severe deformity of Blount’s disease in patients who presented late for treatment.$^{[9,12,14]}$

Our patients with infantile Blount’s disease had a preoperative mean ADMTP of 43$^\circ$, whereas those with juvenile and adolescent Blount’s disease had a preoperative mean ADMTP of 35$^\circ$ and 33$^\circ$, respectively. Patients with infantile Blount’s disease had a trend towards greater preoperative medial tibia plateau depression compared to those with juvenile and adolescent Blount’s disease, but this difference was not statistically significant ($P = 0.06$). This finding may be consistent with the description by Langenskiöld and Riska$^{[2]}$ that early-onset Blount’s disease had more severe medial plateau depression than late-onset cases. Fitoussi et al.$^{[11]}$ studied six infantile Blount’s disease patients who presented late for treatment at an average age of 11 years and reported a preoperative ADMTP of 42$^\circ$. Hefny et al.$^{[10]}$ studied five infantile Blount’s disease patients who also presented late for treatment at an average age of 11.6 years and reported a preoperative ADMTP of 53$^\circ$. Our study had six patients (10 limbs) with infantile Blount’s disease who presented late for treatment at an average age 13.6 years and the preoperative ADMTP was 43$^\circ$. Our study had a higher mean age of onset, but no worsening of medial tibia plateau depression. Although Langenskiöld’s classification described progressive worsening of medial tibia plateau depression up to the age of 10 years, the progression of medial tibia plateau depression for patients with Blount’s disease who seek treatment late in their adolescent years is still not well elucidated in the literature.

### Table 2. Medial tibial plateau depression.

| Blount’s disease | Angle | Angle ($^\circ$), mean (range) | $P$ |
|------------------|-------|-------------------------------|-----|
| Infantile ($n=10$) | ADMTP  | 43 (25–60) | 0.03* |
| $\alpha$ | 19 (10–31) | 6 (1–11) | <0.001* |
| $\beta$ | 18 (8–36) | 4 (–8 to 13) | 0.002* |
| $\gamma$ | 55 (46–67) | 82 (71–98) | <0.001* |
| Juvenile ($n=14$) | ADMTP  | 35 (20–48) | 0.04* |
| $\alpha$ | 15 (4–30) | 8 (1–17) | 0.02* |
| $\beta$ | 23 (10–56) | 0.1 (–17 to 13) | <0.001* |
| $\gamma$ | 58 (24–77) | 89 (77–105) | <0.001* |
| Adolescent ($n=8$) | ADMTP  | 33 (10–56) | 0.09 |
| $\alpha$ | 16 (8–25) | 7 (1–11) | 0.003* |
| $\beta$ | 14 (5–20) | –1 (–13 to 6) | <0.001* |
| $\gamma$ | 64 (56–77) | 91 (83–102) | <0.001* |

$\alpha$, $\beta$ and $\gamma$ angles are shown in Figure 1. Negative $\beta$ angle indicates valgus alignment. *Statistically significant. ADMTP: angle of depressed medial tibia plateau

### Table 3. Comparison between mean changes of ADMTP based on various factors.

| Factor | $n$ | Total change in ADMTP ($^\circ$), mean (range) | $P$ |
|--------|-----|---------------------------------------------|-----|
| Age of onset (yr) | | | |
| $1$–$4$ | 10 | $-11.1$ (–37 to 19) | 0.99 |
| $5$–$10$ | 14 | $-10.4$ (–29 to 3) | |
| $>11$ | 8 | $-10.8$ (–34 to 0) | |
| ANOVA | $F=0.01$ | | |
| MAD (cm) (medial) | | | |
| $0$–$5$ | 8 | $-8.5$ (–29 to 0) | 0.22 |
| $5$–$10$ | 10 | $-6.6$ (–27 to 19) | |
| $10$–$15$ | 8 | $-19.1$ (–37 to 3) | |
| $15$–$20$ | 6 | $-9.3$ (–24 to 3) | |
| ANOVA | $F=1.56$ | | |
| Age during surgery (yr) | | | |
| $<17$ | 27 | $-12.5$ (–37 to 19) | <0.05* |
| $\geq17$ | 5 | $-1.2$ (–6 to 3) | |
| Student’s $t$-test | | | |
| Presence of physis | | | |
| Yes | 19 | $-13.6$ (–37 to 19) | 0.14 |
| No | 10 | $-6.5$ (–34 to 3) | |
| Student’s $t$-test | | | |

*Statistically significant. ADMTP: angle of depressed medial tibia plateau. ANOVA: analysis of variance test for parametric data using $F$ statistics, MAD: mechanical axis deviation.
We did not perform surgical elevation of medial tibia plateau in all patients, and therefore, we did not expect any significant improvement in medial tibia plateau depression. However, our study showed an unexpected improvement in ADMTP after extra-articular mechanical realignment surgery. The improvement in ADMTP was statistically significant in the infantile and juvenile subgroups ($P < 0.05$), but not in the adolescent subgroup ($P = 0.09$). These findings were significant enough to reject the null hypothesis of no change in ADMTP after extra-articular mechanical realignment surgery. Potential for improvement in ADMTP seemed to vary according to the age at surgery. Patients who had attained skeletal maturity (age $\geq 17$ years) had little change in ADMTP compared to children who did not reach skeletal maturity (age $< 17$ years). In addition, there was a trend towards more improvement in ADMTP in children with open proximal tibia physis compared to those without physis, although the difference was not statistically significant ($P = 0.14$). Our results indicated that during the growth spurt in adolescents, there is more potential for radiological reduction in ADMTP. One potential reason is that the space created by the depressed medial tibial plateau might not actually be a true defect. Our findings support previous magnetic resonance imaging studies that showed that this space might be occupied by unossified cartilage.\[15-17\] In addition, our study made a clinical observation that this unossified cartilage over the posteromedial tibia plateau has the ability to ossify over time, especially after mechanical realignment.

Surgery performed for our patients was aimed at correcting alignment to obtain normal mechanical axis and offload pressure to the medial knee joint. Theoretically, offloading pressure to the medial knee joint results in growth and remodelling of the medial tibia physis, as described by Delpech’s law, which results in ossification of the unossified cartilage.\[17\] We postulated that many of our patients were operated on when they were near skeletal maturity, and therefore, after surgery, the cartilage might have been well ossified, resulting in an apparently lower ADMTP on radiograph. The findings of our study indicate the unpredictable remodelling potential of the proximal tibia physis in skeletally immature children with Blount’s disease during adolescence. The most appropriate timing to perform hemiplateau elevation is still subject to debate, given the notoriously unpredictable remodelling potential of the proximal tibia physis, especially in children with infantile and juvenile Blount’s disease.

Our study included patients with Blount’s disease who presented late for treatment in their adolescence and young adulthood, and these are not commonly covered in previous literature. One of the limitations of this study is the small sample size, as it is difficult to get a big sample size from a single institution. Another limitation is the potential recall bias regarding the age of onset of deformity. In addition, many lateral radiographs of the knee, especially those taken before 2010, were not aligned to the proximal tibia, and this precluded measurement and evaluation of sagittal plane deformity. Finally, we also did not have magnetic resonance imaging, arthrography or ultrasonography to provide more information on the non-bony structures over the knee joint.

In conclusion, this study analysed 22 patients (32 affected limbs) with Blount’s disease, who presented late for treatment and who underwent extra-articular correction of deformity to realign the mechanical axis. Our results showed a significant improvement in ADMTP after mechanical realignment in the infantile and juvenile subgroups. This change reflects the remodelling potential of the medial tibia physis after mechanical realignment for children with infantile and juvenile Blount’s disease when they approach adolescence. The remodelling potential is greater in children who were operated on at below 17 years of age, before they reach skeletal maturity.

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Conflicts of interest
There are no conflicts of interest.

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