CLINICAL ARTICLE

Do Different Tibial Osteotomy Techniques Affect Sagittal Alignment in Children with Blount Disease?

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Objective: To determine the radiographic outcomes following dome or wedge-shaped proximal tibial osteotomy in the management of infantile Blount disease with a particular interest in sagittal alignment of the knee joint.

Method: Medical records of patients with Langenskiöld stage 2 Blount disease (aged ≤5 years) who underwent surgical correction between January 2005 and November 2019 were retrospectively identified. Patients with metabolic bone disease, bone tumors, prior traumatic fractures, congenital anomalies, inadequate plain films, and incomplete medical documents were excluded. Patient characteristics (e.g. age, gender, and body mass index [BMI]) and surgical characteristics (e.g. side, type of surgery, and follow-up times) were recorded. Antero–posterior (AP) and lateral knee radiographs were analyzed. Data were categorized by surgical technique as dome-shaped proximal tibial osteotomy or wedge-shaped proximal tibial osteotomy. The femorotibial angle (FTA) was used to evaluate the correction angle in varus deformities. Sagittal alignment of the lower limbs using the posterior tibial slope (PTS) angle was measured postoperatively at 3, 6, 12, and 24 months, and at the final follow-up visit.

Results: The present study included 72 surgeries of 46 patients who had undergone proximal tibial osteotomy. Twenty-nine (63%) were male. The mean age of patients at the time of surgery was 34.50 months (range, 26–47). The mean weight was 23.11 ± 4.98 kg (mean ± SD); the mean height was 95.33 ± 6.36 cm, and the mean BMI was 25.32 ± 4.36 kg/m^2. The mean duration of follow up was 4.77 ± 2.78 years. Sixty-four patients (88.90%) received dome-shaped proximal osteotomy of the tibia, while 8 (11.10%) received wedge-shaped proximal osteotomy of the tibia. The average FTA of the total correction measured was $29.32° \pm 7.98°$. The demographic data of the two groups were not significantly different for gender, age, BMI, side follow-up times, and the total correction of varus deformities. In the dome-shaped osteotomy group, the mean correction of the FTA was $29.59° \pm 7.45°$. The mean degree of the PTS angle was 6.50° at 3 months, 6.38° at 6 months, 5.32° at 12 months, 5.17° at 24 months, and 5.53° at the final follow-up visit. In the wedge-shaped proximal tibial osteotomy group, the mean correction of the FTA was $27.25° \pm 11.77°$. The PTS was 6.00° at 3 months, 7.50° at 6 months, 7.00° at 12 months, 5.40° at 24 months, and 5.57° at the final follow-up visit. No significant difference was observed in the radiological outcome between surgical techniques.

Conclusion: Dome and wedge-shaped proximal tibial osteotomies did not demonstrate significant differences in the PTS angle in children with Blount disease.

Key words: Blount disease; Dome-shaped proximal tibial osteotomy; Posterior tibial slope; Wedge-shaped proximal tibial osteotomy

Introduction

Blount disease is a disorder of growth and development of the posteromedial proximal tibia causing 3D varus deformity[1,2]. Proximal tibial varus and internal tibial torsion are also common manifestations. Clinical features that often present include bowing of the leg and lateral thrust gait. The pathophysiological mechanisms are unclear. It is more frequently observed in obese infants and in black ethnic

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groups[3–5]. Gushue *et al.* described the adaptation of musculoskeletal around the knee to provide stability in overweight children[6]. The recent published literature has classified the disease into infantile or early-onset (0–10 years) and adolescent or late-onset (>10 years)[3]. The Langenskiöld classification system has been widely used to stage the severity of infantile Blount disease.

The inter-observer and intra-observer reliability of the classification system was assessed among residents, surgeons, and pediatric orthopaedic surgeons by Erkus *et al.*[7]. The results indicated excellent agreement and were not influenced by the level of experience. Moreover, the classification can be a predictive factor for recurrence of the deformity and early osteoarthritis[8]. Antero–posterior (AP) and lateral knee radiographs are obtained to assess and categorize the severity of disease. When diagnosis has been delayed, CT and MRI should be used to evaluate physeal bar formation[9]. If the patients are older than 4 years, the pathology becomes more aggressive; MRI would be an imaging option. However, the data on whether MRI is useful as the prognostic value have not been labeled[3]. Long-term varus malalignment can result in osteoarthritis of the knee[10].

Treatments include conservative and surgical management. Braces are recommended in patients younger than 3 years with stage 2 Langenskiöld[3,11]. Even if the age of the patients is less than 4 years, osteotomy would be recommended, particularly in obese children[3]. Surgical intervention becomes necessary if conservative treatment is not able to achieve an anatomical alignment or the degree of varus has continuously progressed[3,12]. Surgical correction should begin early to decrease the recurrence of deformity, particularly in children >4 years of age[13,14].

A study published by Janoyer on patients with Blount disease showed the high recurrence rate after osteotomy associated with age older than 4 years and physeal bar formation[3]. Stage 3 Langenskiöd or bilateral involvement has been associated with a greater risk of the recurrence of deformities[14,15]. Approximately 80% of surgeries were successful in children under the age of 4 years[3]. Age and race (black *vs* not black) were not associated with mortality.

Montgomery *et al.* retrospectively studied the relation between vitamin D level and risk of Blount disease in obese patients. Patients who had serum 25-hydroxyvitamin D levels <16 ng/mL were considered vitamin D-deficient and those with levels > 16 ng/mL were not. They found that factors associated with the disease were body mass index (*OR*, 1.03; 95% *CI*, 1.01–1.06; $P = 0.01$), vitamin D levels (*OR*, 7.33; 95% *CI*, 2.09–25.54; $P = 0.002$), and gender (*OR*, 8.16; 95% *CI*, 1.74–38.37; $P = 0.01$)[16].

Radiographic parameters measuring alignment, including femorotibial angle (FTA), metaphyseal diaphyseal angle (MDA), deformity angle (DA), medial and posterior proximal tibial angle (MPTA/PPTA), and mechanical axis deviation (MAD), are used to evaluate surgical outcomes. Several operative techniques are available to manage Blount disease.

The techniques included dome-shaped osteotomy, open-wedge osteotomy, closed-wedge osteotomy, and spiked-osteotomy, which were mostly selected based on surgeon preference. Many surgical techniques have been reported for treatment of Blount disease, including a single-stage double osteotomy[17], step cut "V" osteotomy[18], fibulectomy with Z osteotomy[19], and hemiepiphysiodesis[20]. The multiaxial correction system (MAC) external fixator has also been proposed to reduce the number of intraoperative and postoperative complications[21]. The patients who were operated on with MAC showed similar results for radiographic parameters and adverse events after surgery compared to other external fixators[21,22]. Cherkashin *et al.* developed a complication classification system for severe Blount disease treated with circular external fixation and gradual deformity correction based on clinical and radiographic outcomes of surgery. They concluded that 88% of patients reached their treatment goals by using the classification scheme[23].

The recent systematic study of temporary hemiepiphysiodesis and their complications were reviewed. The varied outcomes were noted for different subtypes of Blount disease. Eight-Plate guided growth should be considered the first choice of treatment. Osteotomy might be considered when hemiepiphysiodesis fails[20]. However, Oto *et al.* did not support surgery in obese patients with severe adolescent Blount disease[24]. Postoperative complications of surgery include vascular complications, focal nerve palsies, loss of alignment, wound infection, compartment syndromes, and posterior angulation at the osteotomy site[25,26]. The disease can cause social and psychological problems, including difficulty with education, social discrimination, low self-esteem, and stress both for patients and their family. Few studies have reported on the effect of osteotomy techniques on sagittal alignment[27–29]. The purpose of the present study is to evaluate the radiographic outcomes of dome or wedge-shaped proximal tibial osteotomy, with a particular focus on sagittal alignment of the knee joint.

Materials and Methods

General Information

The medical records of patients with Langenskiöld stage 2 Blount disease diagnosed between January 2005 and November 2019 were retrospectively analyzed. The inclusion criteria were: (i) patient aged under 5 years; (ii) Langenskiöld stage 2; (iii) proximal tibial osteotomy had been performed; (iv) two pediatric orthopaedic surgeons (P.M. and P.E) performed all surgeries; and (v) AP and lateral knee radiographs were obtained preoperatively and postoperatively. The exclusion criteria were: (i) patients who had underlying factors that might affect bone quality, such as metabolic bone disease, thalassemia, bone tumors, prior traumatic fractures, or congenital anomalies; and (ii) patients who were lost to follow up or for whom there were inadequate plain films and incomplete medical documents.

The patients were divided into two groups: group 1 included patients who underwent dome-shaped proximal tibial osteotomy and group 2 included those who underwent wedge-shaped tibial osteotomy.

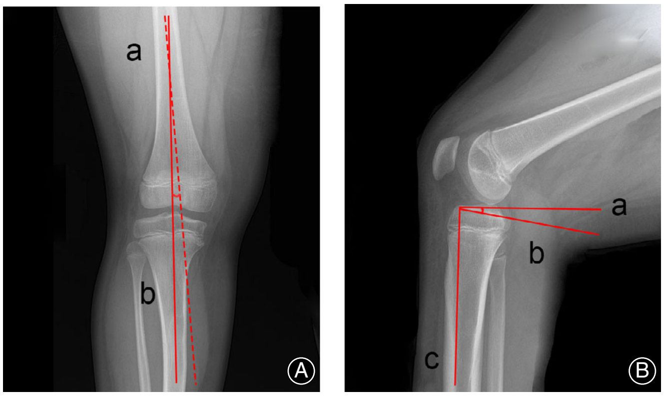

Fig. 1 (A) The femorotibial angle is obtained on the antero–posterior radiograph by measuring the angle between the longitudinal axis of the femoral shaft (a, dotted line) and the longitudinal axis of the tibial shaft (b, solid line). (B) The posterior tibial slope is obtained on the lateral knee radiograph by measuring the angle between an axis drawn perpendicular to the anatomical axis of the tibia (a) and a line parallel to the tibial plateau (b).

Patient characteristics (e.g. age, gender, and body mass index [BMI]), and surgical characteristics (e.g. side, type of surgery, and follow-up times) were recorded. AP and lateral knee radiographs were evaluated. The FTA was preoperatively calculated to identify the total degree of valgus correction. Sagittal alignment of the knee using the PTS was retrospectively evaluated 3, 6, 12, and 24 months after surgery, and during the final follow-up visit. The data were categorized into wedge-shaped and dome-shaped groups. The authors performed all measurements (Figs. 2 and 3).

Measurement

Femorotibial Angle

The FTA, an important parameter in the coronal alignment of the knee joint, is used to detect a varus or valgus deformity. The FTA is defined as the angle between the femoral longitudinal axis and the tibial longitudinal axis[30]. In Fig 1A, the anatomical axis of the femur is calculated from the center of the femoral diaphysis 10 cm proximal to the joint line, and the center of the femoral metaphysis 4 cm proximal to the joint line (a). The anatomical axis of the tibia was established using the center of the tibial metaphysis 4 cm distal to the joint line and the center of the tibial metaphysis 4 cm distal to the joint line. (b) The FTA was used to identify varus and valgus malalignment.

Posterior Tibial Slope

The PTS is used to evaluate outcomes of knee joint surgery, particularly in adults. The angle was defined as the angle between a line perpendicular to an anatomical longitudinal axis of the tibia (a) and a line drawn tangential to the tibial plateau (b)[31]. The anatomical axis of the tibia was determined by a line passing through the midpoints of two transverse lines across the tibia (c). The proximal line was drawn just below the anterior tibial tubercle and the distal line was created 10 cm below the proximal line (Fig. 1B). The mean PTS angle is 6°–14° in a normal knee.

Statistical Analysis

Differences in age, BMI, follow-up time, total degree of valgus correction, and the postoperative slope of the tibial plateau in dome and wedge-shaped osteotomies were calculated by Mann–Whitney *U*-test and Student *t*-test. The χ^2-test was applied to compare gender and side between the groups. SPSS software (version 18; SPSS, Chicago, IL, USA) was used for statistical analysis. A *P*-value less than 0.05 was set as statistically significant.

Results

A total of 72 surgeries in 46 patients with Blount disease were identified; 29 patients (63%) were male (Table 1). The mean age at surgery was 34.50 months (range, 26–47). The mean weight was 23.11 ± 4.98 kg (mean ± SD); the mean height was 95.33 ± 6.36 cm, and the mean BMI was 25.32 ± 4.36 kg/m^2. The mean postoperative FTA correction was 29.32° ± 7.98°. The mean duration of follow-up was 4.77 ± 2.78 years. A total of 64 (89%) cases underwent dome-shaped and 8 (11%) had wedge-shaped osteotomy.

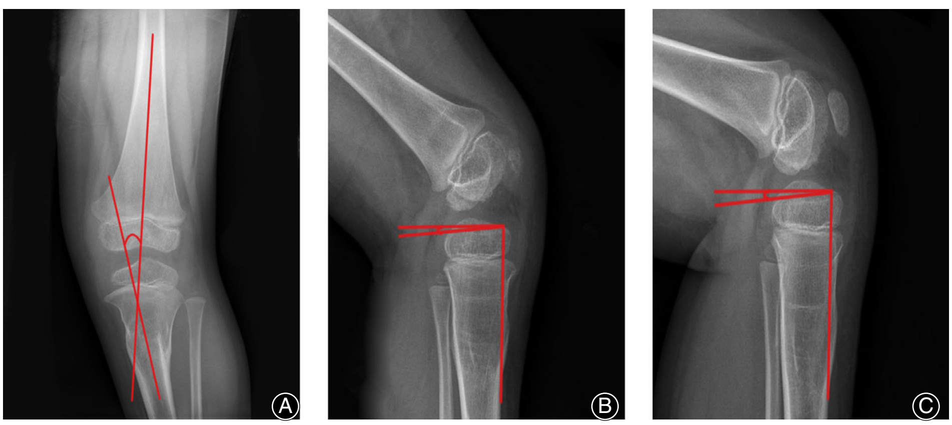

Fig. 2 (A) Antero–posterior preoperative radiograph of the knee. The figure shows the radiograph of the patient with a varus deformity. The femorotibial angle of the patient with a varus deformity measured 20°. (B, C) Lateral postoperative radiographs of the knee. The figure shows the radiographs of the patient following dome-shaped proximal tibial osteotomy. The posterior tibial slope angle at 12 and 24 months after surgery measured 2° and 8°, respectively.

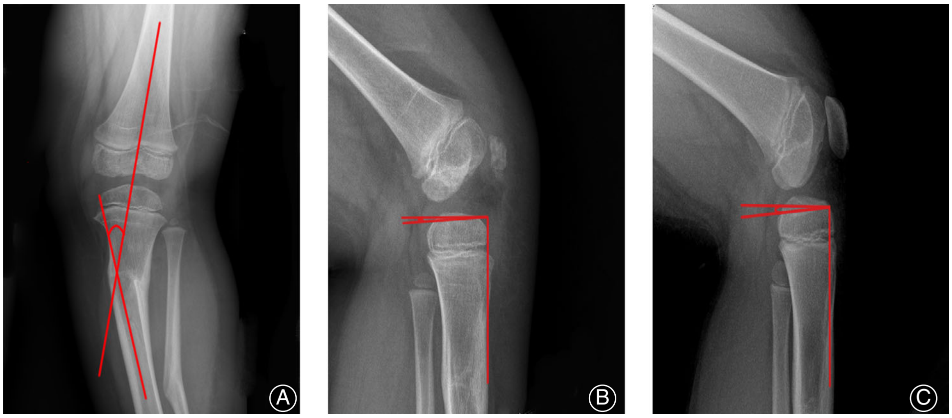

Fig. 3 (A) Antero–posterior preoperative radiograph of the knee. The figure shows the radiograph of the patient with a varus deformity. The femorotibial angle of the patient with varus deformity measured 15°. (B, C) Lateral postoperative radiographs of the knee. The figure shows the radiographs of the patient following wedge-shaped proximal tibial osteotomy. The posterior tibial slope angle at 12 and 24 months after surgery measured 8° and 9°, respectively.

TABLE 1 Demographic data and characteristics of patients with Blount disease

Demographics	Value
Surgical techniques (cases [%])	
Dome-shaped osteotomy	64 (88.90)
Wedge-shaped osteotomy	8 (11.10)
Gender (cases [%])	
Male	29 (63.00)
Female	17 (37.00)
Age (months, [mean ± SD, range])	34.50 ± 5.40 (26–47)
Weight (kg, [mean ± SD, range])	23.11 ± 4.98 (13–36)
Height (cm, [mean ± SD, range])	95.33 ± 6.36 (81–109)
BMI (kg/m^2, [mean ± SD, range])	25.32 ± 4.36 (17.25–35.61)
Laterality (cases [%])	
Left	38 (52.80)
Right	34 (47.20)
Follow-up time (years, [mean ± SD, range])	4.77 ± 2.78 (0.25–12.00)
Valgus correction (°, [mean ± SD, range])	29.32 ± 7.98 (11–49)

There were no significant differences between groups in terms of gender, age, BMI, side, follow-up time, and total correction of varus deformities (Table 2).

Dome-Shaped Proximal Tibial Osteotomy

The mean age of patients undertaking dome-shaped osteotomy was 34.23 months (range, 26–47). The mean weight was 22.53 ± 5.16 kg, the mean height was 94.67 ± 6.11 cm, and the mean BMI was 25.44 ± 4.38 kg/m^2. The mean correction of FTA was 29.59° ± 7.45°. The mean duration of follow up was 4.96 ± 2.87 years (Table 2). The mean PTS angle was 6.50° at 3 months, 6.38° at 6 months, 5.32° at 12 months, 5.17° at 24 months, and 5.53° at the last follow-up visit (Table 3).

Wedge-Shaped Proximal Tibial Osteotomy

The mean age of patients in the wedge-shaped osteotomy group was 33.33 months (range, 28–45). The mean weight was 24.02 ± 3.46 kg, the mean height was 98.83 ± 7.11 cm, and the mean BMI was 24.22 ± 4.42 kg/m^2. The mean correction of the FTA was 27.25° ± 11.77°. The mean duration of follow up was 3.38 ± 1.30 years (Table 2). The mean PTS angle was 6.00° at 3 months; 7.50° at 6 months, 7.00° at 12 months, 5.40° at 24 months, and 5.57° at the last follow-up visit. There is a discrepancy in the number of cases between each follow-up period because the films were inadequate or unavailable in some cases. There was no statistically significant difference in tibial slope between the two groups at any measured time interval (Table 3).

TABLE 2 Comparison of demographic data and characteristics of dome and wedge-shaped osteotomy group

Demographics	Dome	Wedge	*P*-value
Gender (cases (%))			
Male	26 (65.00)	3 (50.00)	0.66
Female	14 (35.00)	3 (50.00)	
Age (months, [mean ± SD, range])	34.23 ± 4.93 (26–47)	33.33 ± 6.28 (28–45)	0.41
Weight (kg, [mean ± SD, range])	22.53 ± 5.16 (13–36)	24.02 ± 3.46 (20.50–30.00)	0.69
Height (cm, [mean ± SD, range])	94.67 ± 6.11 (81–107)	98.83 ± 7.11 (91–109)	0.50
Body mass index (kg/m^2, [mean ± SD, range])	25.44 ± 4.38 (18.21–35.61)	24.22 ± 4.42 (17.25–30.61)	0.14
Laterality (cases (%))			
Left	34 (53.10)	4 (50.00)	1.00
Right	30 (46.90)	4 (50.00)	
Follow-up time (years, [mean ± SD, range])	4.96 ± 2.87 (0.25–12.00)	3.38 ± 1.30 (1–5)	0.13
Valgus correction (°, [mean ± SD, range])	29.59 ± 7.45 (14–49)	27.25 ± 11.77 (11–43)	0.60

TABLE 3 Postoperative posterior tibial slope (PTS) angle of dome and wedge-shaped tibial osteotomy at 3, 6, 12, and 24 months and the final follow-up visits (mean ± SD)

Follow-up time (months)	Dome	Wedge	Total	*P*-value
3	6.50 ± 3.08 (*n* = 6)	6.00 ± 2.31 (*n* = 4)	6.30 ± 2.67(*n* = 10)	0.66
6	6.38 ± 2.88 (*n* = 8)	7.50 ± 0.71 (*n* = 2)	6.60 ± 2.59 (*n* = 10)	0.79
12	5.32 ± 3.97 (*n* = 22)	7.00 ± 4.36 (*n* = 3)	5.52 ± 3.96 (*n* = 25)	0.40
24	5.17 ± 3.27 (*n* = 30)	5.40 ± 1.67 (*n* = 5)	5.20 ± 3.08 (*n* = 35)	1.00
Last follow-up	5.53 ± 2.83 (*n* = 53)	5.57 ± 2.30 (*n* = 7)	5.53 ± 2.75 (*n* = 60)	0.97

Discussion

Several operative techniques are available to manage Blount disease. The techniques include dome-shaped osteotomy, open-wedge osteotomy, closed-wedge osteotomy, and spiked-osteotomy, which were mostly selected based on surgeon preference. Age more than 3 years at first visit and the presence of severe deformity may predispose patients to treatment failure. Postoperative complications include focal nerve palsies and compartment syndrome[25,26]. The purpose of this study was to determine the radiographic outcomes following dome or wedge-shaped proximal tibial osteotomy in the management of infantile Blount disease, with a particular focus on sagittal alignment of the knee joint.

Surgical Outcomes of Dome versus Wedge-shaped Proximal Tibial Osteotomy

Kaewpornsawan *et al.* retrospectively reviewed children with infantile Blount disease who underwent dome-shaped osteotomy with surgical fixation pins and concluded that early surgical intervention was beneficial[32]. Recurrence of deformities has been reported following dome-shaped osteotomy. However, overcorrection into valgus alignment does not appear to reduce the recurrence of varus deformity[9]. Studies of wedge tibial osteotomy have reported impressive outcomes with few complications and good alignment restoration[33,34]. Various parameters are used to evaluate the effectiveness of surgery for Blount disease. These include the deformity angle (DA), the femorotibial angle (FTA), the medial and posterior proximal tibial angle (MPTA/PPTA), mechanical axis deviation (MAD)[9,35–39], and the metaphyseal–diaphyseal angle (MDA)[18,38,39]. Feldman *et al.* promoted gradual tibial deformity correction because they found an increased PPTA in patients with acute correction[38]. Jones *et al.* reported that a postoperative MAD range of −5° to +5° has been associated with patient satisfaction and could be useful for planning surgery[39].

Effect of Varus Correction on Posterior Tibial Slope Angle

Our objective was to identify whether the correction of coronal plane deformities led to sagittal malalignment. The radiographic technique of interest was PTS. Several studies report changes in multiple axis deviation of the knee after high tibial osteotomy, but there is little research on change in the PTS after proximal tibial osteotomy in a pediatric population[34]. This might because of the difficulty in measuring unossified bone in premature skeletons. The mean PTS angle is 6°–14° in a normal knee and does not vary with age or gender, but most studies have been conducted in skeletally mature patients[40–43]. We observed a slightly decreasing PTS angle over the follow-up period. No significant differences in PTS were detected between the two groups. We observed a slight decrease in PTS angles at the final follow-up, with mean PTS of 5.53° for dome and 5.57° for wedge osteotomy.

Two published meta-analyses have reported an increase in the tibial slope following open-wedge high tibial osteotomy (HTO). Nha *et al.* reviewed the published literature to determine the effects of open and closed wedge HTO on the sagittal profile of the knee. Patients that received the open technique showed a mean increase of PTS compared to other groups[44]. Wu *et al.* reported similar findings and suggested that slope alteration can be explained by the anatomic geometry of the proximal tibia[27]. Increasing valgus correction was correlated with increased slope degree after dome and wedge-shaped osteotomy but was not correlated with the degree of varus deformities preoperatively[28,29]. In contrast, Mozella *et al.* found no alteration in sagittal alignment of the knee following medial-opening tibial osteotomy[45]. However, all of these reports were conducted in older age groups compared to our study.

Limitations

Our study had some limitations. First, the wedge-shaped group sample was small compared with the dome osteotomy group. Second, the study was a retrospective review and sample selection was not random. Third, some of the X-rays could not be evaluated because most of the patients were younger than 30 months had round ossification centers.

Conclusion

In our study, dome and wedge-shaped proximal tibial osteotomies did not show significant differences in PTS change after 24 months of follow-up.

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