CLINICAL ARTICLE

Medial Metaphyseal Slope as a Predictor of Recurrence in Blount Disease

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Objective: This study was aimed to find the radiographic parameter predicting recurrence of stage 2 Blount's disease.

Method: We retrospectively reviewed radiographs of 82 legs from 49 patients diagnosed with stage 2 Blount's disease by Langenskiöld classification who had failed brace treatment and underwent valgus osteotomy between 1998 to 2016. Age ranged from 26 to 47 months. The metaphyseal–diaphyseal angle was measured preoperatively. The medial metaphyseal slope of the proximal tibia and femorotibial angle were measured preoperatively and 3, 6, 12, and 24 months postoperatively in both non-recurrence (group 1) and recurrence (group 2) group. The receiver operating characteristic curve calculated using MedCalc software was used to determine the medial metaphyseal slope predicting risk for recurrence. Statistical analysis was performed using SPSS software.

Results: The mean follow-up time was 4.83 ± 0.38 years. The mean age was 34.57 ± 5.76 in group 1 and 33.2 ± 1.48 in group 2 ($P = 0.258$). The mean preoperative metaphyseal slope was 62.39° ± 9.75° in group 1 and 73.22° ± 6.59° in group 2 ($P = 0.02$). The mean preoperative femorotibial angle (FTA) was −14.31° ± 8.25° in group 1 and −18.89° ± 7.74° in group 2 ($P = 0.1$). The mean preoperative metaphyseal diaphyseal angle (MDA) was 14.75° ± 4.21° in group 1 and 20.11° ±5.16° in group 2 ($P = 0.001$). Demographic data including age, gender, weight, height, and body mass index showed no statistically significant difference between both groups. Out of 82 legs, 9 (10.97%) had recurrence. Preoperatively, the metaphyseal–diaphyseal angle showed statistical significance between both groups. The medial metaphyseal slope showed statistically significant difference between group 1 and group 2 at 3, 6, 12, and 24 months postoperatively. The receiver operating characteristic curve showed that a medial metaphyseal slope more than 70° at 12 months (sensitivity 88.89% and specificity 69.86%) and more than 62° at 24 months postoperatively (sensitivity 100%, specificity 52.3%) was a predictor for recurrence of stage 2 Blount's disease.

Conclusion: Medial metaphyseal slope more than 62° over the 24-month follow-up was associated with recurrence of varus deformity.

Key words: Blount's disease; Corrective valgus osteotomy; Langenskiöld; Medial metaphyseal slope; Recurrence

Introduction

Generally, early treatment of infantile Blount's disease is bracing, although the effectiveness of bracing is still a controversial issue[1]. Surgical management is recommended if correction is not achieved by bracing[2–5]. Currently, the recommendation for progressive infantile Blount's disease is a proximal tibial osteotomy. Recurrence of Blount's disease is diagnosed when the FTA is more than 10° varus at follow-up[6,7]. Preoperative femorotibial angle (FTA) of greater than 10° of varus creates force on the medial side of the knee joint and probably predisposes the patient to medial proximal tibial physeal growth retardation. Tibial realignment is usually recommended for these patients. Early surgical intervention during initial stages of the disease will decrease the incidence of recurrence of deformity and knee pathology at skeletal maturity. Blount[5] and Langenskiöld[8] both stated that if

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correction of the varus deformity is performed to a physiologic valgus position before the age of 8 years in stages 1–4 Langenskiöld, this would result in a permanent cure for the patient. More recent reports by Smith[9], Hofmann *et al.*[10], Schoenecker *et al.*,[11] and Ferriter and Shapiro[12] note a varying frequency of recurrence of varus deformity after initial surgery and suggest that surgical correction should be performed at an early age. Following corrective osteotomy in children at more than 3 years of age with stage 3 Langenskiold, there is a high rate of recurrence[6]. However, performing corrective osteotomy in patients younger than 3 years of age with stage 2 Langenskiold is associated with 10% recurrence[6]. Recurrent deformity in patients younger than 3 years of age with stage 2 Langenskiold may result from multiple factors, such as increasing obesity, age, and staging[13–18]. There is no definite conclusion regarding which factors cause recurrence in this group of patients. Lauren E. LaMont *et al.* evaluated a new modified classification in the recurrence of Blount's disease after surgical intervention for infantile tibia vara and reported that patients with metaphyseal defect slopes that run downward vertically with no upward curvature projecting medially are prone to having a higher recurrence rate[19]. Currently, there are no reports on the preoperative and postoperative medial metaphyseal slope in patients with Blount's disease. The present study examines the correlation of recurrence and the medial metaphyseal slope. This measurement could help orthopaedic surgeons to detect early recurrence of Blount's disease.

The purposes of this study are: (i) to determine the differences in demographic data between recurrence and non-recurrence groups; (ii) to establish radiographic parameters that predict recurrence of stage 2 Blount's disease; and (iii) to determine the cut-off angle of the medial metaphyseal slope predicting recurrence of Blount's disease at different time intervals after surgery.

Materials and Methods

Following approval by the research ethical committee of the hospital, the charts and radiographs of 82 legs diagnosed with stage 2 Blount's disease by Langenskiöld between 1998 and 2016 were chosen for the study, all of which had failed brace treatment. Children included in the data collection did not have any other orthopaedic or medical problems that were related to their lower extremities, had received no previous treatment, and had at least 2 years of follow-up visits with full length lower extremity radiographs.

Inclusion criteria were: (i) age between 2 and 4 years with stage 2 Blount's disease; (ii) the patients underwent the dome osteotomy operation at proximal tibia and fibular; and (iii) postoperative follow-up for at least 2 years.

Exclusion criteria were: (i) patients with other disease that may affect bone growth and lead to misinterpretation; (ii) patients with lower limb deformity; and (iii) incomplete medical records and radiographic data. The good quality of the AP view can be determined by the position of the tibial spine, which must be at the same position of the intercondylar notch of femur. The fibular head is 0.5 cm to 1.5 cm below the tibial plateau and ¼ of the fibula head overlaps the tibia.

There were 49 patients; 35 were bilateral and 14 unilateral (2 cases were bilateral with stage 2 on one side and stage 3 on other side). The surgical procedures were dome osteotomy of the proximal tibia and fibula in all patients.

Surgical Technique

The surgery was carried out using general anesthesia in the supine position. Osteotomy of the fibular was carried out using a 3-cm longitudinal incision along the posterior edge of the fibular approximately 5 cm distal to the fibular head. The tibia was approached using a straight longitudinal incision just lateral to the tibial crest. A dome osteotomy was completed parallel to the joint line; the apex of the dome osteotomy was perpendicular to the axis of the tibia and at the level of the distal aspect of the tubercle. The tibial osteotomy was slightly overcorrected and stabilized using two crossed Kirschner wires. At the stage of data collection, the patients were divided in two groups: Group 1 was the non-recurrence group (the knees become normal without deformity after single osteotomy); Group 2 was the recurrent group with recurrence of varus deformity defined by femorotibial angle (FTA) greater than 10° varus. They required further corrective osteotomy so that the axis of the knee was in a normal position. The recorded data included patients' age, sex, BMI, affected side, Langenskiöld stage, preoperative FTA, postoperative FTA of 3, 6, 12, and 24-month interval after the surgery. The measurements included, preoperative metaphyseal-diaphyseal angle (MDA), preoperative medial metaphyseal slope (MPS), and postoperative MPS 3, 6, 12 and 24 months after surgery.

Medial Metaphyseal Slope Measurement

The medial metaphyseal slope (MPS), measured by AP radiograph, was an angle that formed between two lines. The first line was drawn between the most medial point of medial distal metaphysis and the most medial point of the proximal metaphysis. The second line was drawn between the most medial point of the proximal metaphysis and the most lateral point of the metaphysis. The medial metaphyseal slope was used to identify the severity of Blount disease. (Fig. 1).

Preoperative radiographs of the lower extremity were classified by Langenskiöld. Standing AP and lateral radiographs of bilateral knees were obtained. The FTA and MPS in group 1 and group 2 at the preoperative period and at 3, 6, 12 and 24-months postoperatively were measured and calculated.

Statistical analysis was performed using the receiver operating characteristic (ROC) curve and Medcalc software, version 17.6 (MedCalc Software bvba, Ostend, Belgium) to evaluate the cut-off angle from each postoperative period that was predisposed to recurrence cut-off angle was selected from values that had the highest sensitivity and specificity.

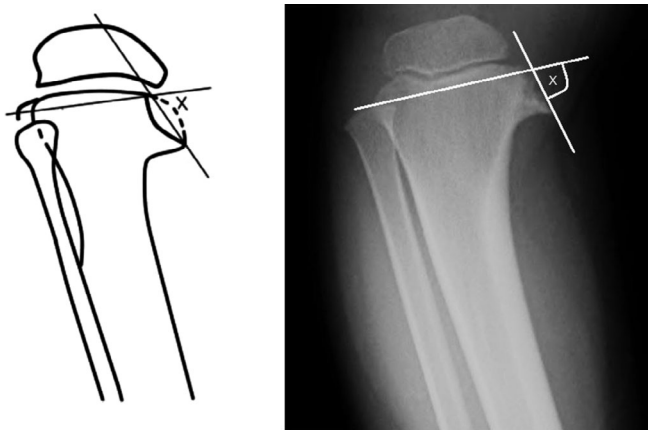

Fig. 1 Medial metaphyseal slope angle (X): an angle forms between line 1 and line 2. Line 1 was drawn between the most medial point of the medial distal metaphysis and the most medial point of the proximal metaphysis and line 2 was drawn between the most medial of the proximal metaphysis and the most lateral point of the metaphysis.

The two-tailed *t*-test for continuous variables and the χ^2-test for dichotomous variables were analyzed using SPSS software, version 18 (SPSS, Chicago, IL, USA). A *P*-value of $P < 0.05$ was considered statistically significant.

Results

Demographic Study

Patients were divided into two groups: a non-recurrence group (group 1) and a recurrence group (group 2). Seventy-three legs were in group 1 and 9 legs were in group 2. In this study, the follow-up time of the patients ranged from 2 to 13 years with the mean follow-up time of 4.83 ± 0.38 years. Demographic data included age, gender, weight, height, and body mass index (BMI). Radiographic data included the femorotibial angle, the metaphyseal-diaphyseal angle, and the medial metaphyseal slope before surgery (Table 1). The mean preoperative MPS was 62.39° ± 9.75° in group 1 and 73.22° ± 6.59° in group 2 (P = 0.02). The mean age was 34.57 ± 5.76 years in group 1 and 33.2 ± 1.48 years in group 2 (P = 0.258). The mean preoperative FTA was −14.31° ± 8.25° in group 1 and −18.89° ± 7.74° in group 2 (P = 0.1). The mean preoperative MDA was 14.75° ± 4.21° in group 1 and 20.11° ±5.16° in group 2 (P = 0.001).

Femero–Tibial Angle

After postoperative correction at 3-months follow-up, the FTA in group 1 ranged from −5° to −32° with a mean of 14.85° ± 6.56° and in group 2 ranged from 10° to 23° with a mean of 14.00° ± 4.82° (*P*-value 0.532).

At 6-months follow-up, the FTA in group 1 ranged from 0° to 30° with a mean of 13.78° ± 6.25° and in group 2 ranged from 1° to 19° with a mean of 10.89° ± 5.51° (*P*-value, 0.207).

At 12-months follow-up, the FTA in group 1 ranged from 2° to 27° with a mean of 12.62° ± 5.53° and in group 2 ranged from −2° to 14° with a mean of 7.22° ± 5.09° (*P*-value, 0.007).

At 24-months follow-up, the FTA in group 1 ranged from −1° to 24° with a mean of 9.50° ± 5.69° and in group 2 ranged from −5° to 13° with a mean of 4.44° ± 5.48° (*P*-value, 0.028) (Table 2).

Medial Metaphyseal Slope

After postoperative correction at 3-months follow-up, the medial metaphyseal slope in group 1 ranged from 28° to 88°

TABLE 1 Demographic data of the patients in both groups

Patient characteristics	No recurrence (N = 73) (Mean ± SD [Minimum–Maximum])	Recurrence (N = 9) (Mean ± SD [Minimum–Maximum])	*P*-value
Gender			
Male	29 (90.6%)	3 (9.4%)	0.659
Female	16 (84.2%)	3 (15.8%)	
Age (month)	34.57 ± 5.76 (26–47)	33.2 ± 1.48 (31–35)	0.258
Body mass index (kg/m^2)	25.07 ± 4.16 (17.25–33.93)	25.84 ± 5.93 (21.34–35.61)	0.717
Weight (kg)	22.71 ± 4.82 (13–36)	22.56 ± 6.45 (14–30.8)	0.734
Height (cm)	94.97 ± 6.23 (81–109)	93 ± 8.51 (81–105)	0.528
Femero–tibial angle (FTA, °)	−14.31 ± 8.25 ((−39)–0)	−18.89 ± 7.74 ((−31)–(−9))	0.119
Metaphyseal–diaphyseal angle (MDA, °)	14.75 ± 4.21 (1–24)	20.11 ± 5.16 (13–30)	0.001
Medial metaphyseal slope (MPS, °)	62.39 ± 9.75 (36–81)	73.22 ± 6.59 (62–81)	0.02

TABLE 2 Femorotibial angle and medial metaphyseal slope between two groups 3, 6, 12, and 24 months after surgery

	No recurrence (n = 73) (Mean ± SD [Minimum–Maximum])	Recurrence (n = 9) (Mean ± SD [Minimum–Maximum])	P-value
Femero–tibial angle (°)			
3 months	14.85 ± 6.56 (−5–32)	14.00 ± 4.82 (10–23)	0.532
6 months	13.78 ± 6.25 (0–30)	10.89 ± 5.51 (1–19)	0.207
12 months	12.62 ± 5.53 (2–27)	7.22 ± 5.09 ((−2)–14)	0.007*
24 months	9.50 ± 5.69 ((−1)–24)	4.44 ± 5.48 ((−5)–13)	0.028*
Medial metaphyseal slope (°)			
3 months	59.95 ± 13.83 (28–88)	70.44 ± 11.52 (55–85)	0.037*
6 months	61.18 ± 14.67 (31–88)	72.67 ± 8.35 (61–86)	0.030*
12 months	59.27 ± 17.66 (18–90)	76.33 ± 7.26 (63–88)	0.001*
24 months	52.88 ± 26.82 (0–91)	72.56 ± 7.74 (63–86)	0.025*

* P-value of P < 0.05 was considered statistically significant.

with a mean of 59.95° ± 13.83° and in group 2 ranged from 55° to 85° with a mean of 70.44° ± 11.52° (P-value, 0.037).

At 6-months follow-up, the medial metaphyseal slope in group 1 ranged from 31° to 88° with mean of 61.18° ± 14.67° and in group 2 ranged from 61° to 86° with a mean of 72.67° ± 8.35° (P-value, 0.030).

At 12-months follow-up, the medial metaphyseal slope in group 1 ranged from 18° to 90° with mean of 59.27° ± 17.66° and in group 2 ranged from 63° to 88° with a mean of 76.33° ± 7.26° (P-value, 0.025).

At 24-months follow-up, the medial metaphyseal slope in group 1 ranged from 0° to 91° with mean of 52.88° ± 26.82° and in group 2 ranged from 6° to 86° with a mean of 72.56° ± 7.74° (P-value, 0.025) (Table 2).

Table 3 reveals the ROC curve analysis by MedCalc software of the patients in groups 1 and 2 at 3, 6, 12, and 24-month intervals after surgery. The medial metaphyseal slope at 3 months are more than 71 (sensitivity, 55.56; specificity, 79.17), at 6-months are more than 59 (sensitivity, 100; specificity, 41.54), at 12-months are more than 70 (sensitivity, 88.89; specificity, 69.86), and at 24-months are more than 62 (sensitivity, 100; specificity, 52.31). Figures 2 and 3 show ROC curves from different time intervals. The MPS values at 12 and 24 months clearly show the association with recurrence in stage 2 Blount's disease (Table 3) (Fig. 2).

Intraobserver agreement was done with the intraclass correlation coefficient (ICC) of FTA of 0.94 and intraclass correlation coefficient (ICC) of MPS of 0.86.

TABLE 3 Associated criterion, area under the ROC curve sensitivity and specificity of FTA and MPS at 3, 6, 12, and 24-month intervals after surgery

	Area under the ROC curve (AUC)	Sensitivity	Specificity	Associated criterion	95% CI for AUC
FTA					
3 months	0.564	66.67	62.50	≤13	0.45–0.67
6 months	0.615	88.89	35.38	≤15	049–0.73
12 months	0.756	55.56	84.93	≤7	0.65–0.85
24 months	0.726	66.67	73.85	≤5	0.61–0.82
MPS					
3 months	0.698	55.56	79.17	>71	0.59–0.79
6 months	0.732	100	41.54	>59	0.62–0.83
12 months	0.832	88.89	69.86	>70	0.73–0.90
24 months	0.732	100	52.31	>62	0.62–0.83

FTA, femorotibial angle; MPS, medial metaphyseal slope; ROC, receiver operating characteristic.

Discussion

Previous studies reported rates of recurrence of varus deformity in Blount's disease ranging from 10% to 100%[6,7,17,18]. The rate of recurrence may be decreased by performing the initial surgery at an early age[14,20]. The only two prognostic factors that could be identified in evaluating the recurrence deformity were patient's age and Langenskiöld stages at the initial osteotomy[11]. Ferriter and Shapiro[12] found a difference, with a recurrence rate of 76% in limbs operated on initially at an age older than 4.5 years versus a 31% recurrence rate in limbs operated on before 4.5 years. Although we corrected the deformity at an early stage, 10% of patients developed recurrence of the deformity. Recurrence in the limbs operated on at an early age is reported in many published studies[6,7]. Factors associated with recurrence in limbs operated on at an early age are weight, age, staging, and MPS[7,13–18]. It is well recognized that BMI is one of the risk factors of the disease[21,22]. However, there is no report that BMI is one of the risk factors for recurrence. In this study, BMI and age showed no statistical significance in either group.

The time course of progression versus resolution of infantile Blount's disease had not been well documented. Several authors have stated that if untreated, the disease is uniformly progressive.

In our study, we found significantly higher MPS preoperatively in recurrence patients, although both groups were Blount's stage 2. A higher medial metaphyseal slope is significantly related to recurrence of the deformity[7]. Our study also found that the MPS were different between the recurrence and non-recurrence groups. In the recurrence group, MPS was not decreased over the 24-month follow-up period, while the MPS of the non-recurrent patients decreased significantly. Our results agreed with the previous study of Kaewpornsawan that MPS < 59°was related to lower recurrence of deformity[7]. Kling *et al.*[23] reported that MPS greater than 60° was always associated with recurrent varus deformity after tibial osteotomy. Our result was also compatible with the finding of LaMont[19] that patients with metaphyseal defect sloping downward vertically with no upward curvature projecting medially were prone to having higher recurrence rate (Figs 4 and 5). From our study, the ROC curve showed that an MPS more than 70° at 12 months (sensitivity

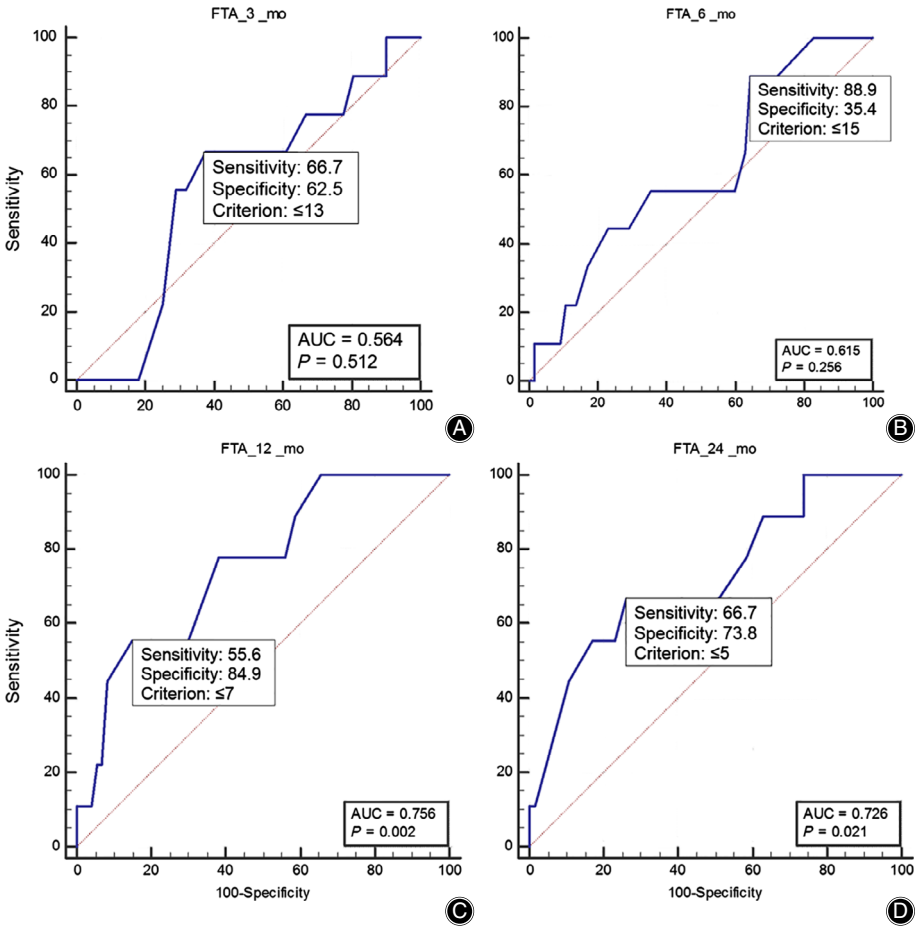

Fig. 2 Receiver operating characteristic (ROC) curve for femero–tibial angle: (A) 3 months postoperative, (B) 6 months postoperative, (C) 12 months postoperative, and (D) 24 months postoperative.

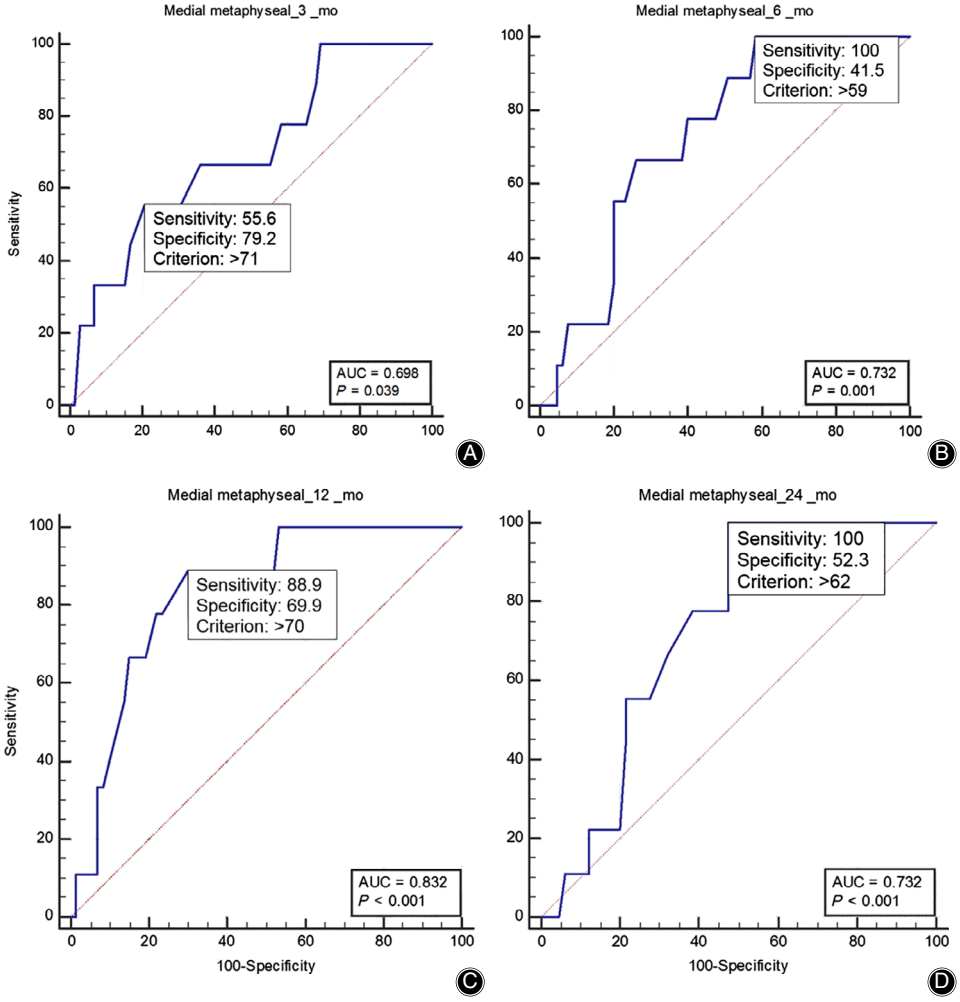

Fig. 3 Receiver operating characteristic (ROC) curve for medial metaphyseal slope: (A) 3 months postoperative, (B) 6 months postoperative, (C) 12 months postoperative, and (D) 24 months postoperative.

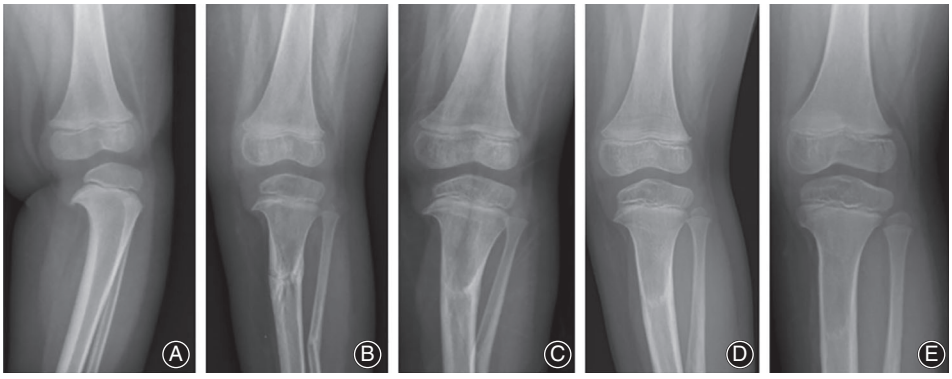

Fig. 4 The change of metaphysis in non-recurrence group: (A) preoperative, (B) 3 months postoperative, (C) 6 months postoperative, (D) 12 months postoperative, and (E) 24 months postoperative.

88.9% and specificity 69.9%) and 62° at 24 months postoperatively was a good predictor for recurrence in stage 2 Blount's disease.

We also found that preoperative MDA may be another significant predictor of recurrence. However, postoperative MDA varied depending on the degree of proximal tibial correction. Thus, postoperative measurement was not included.

A limitation of this study was the selection bias due to the nature of retrospective study.

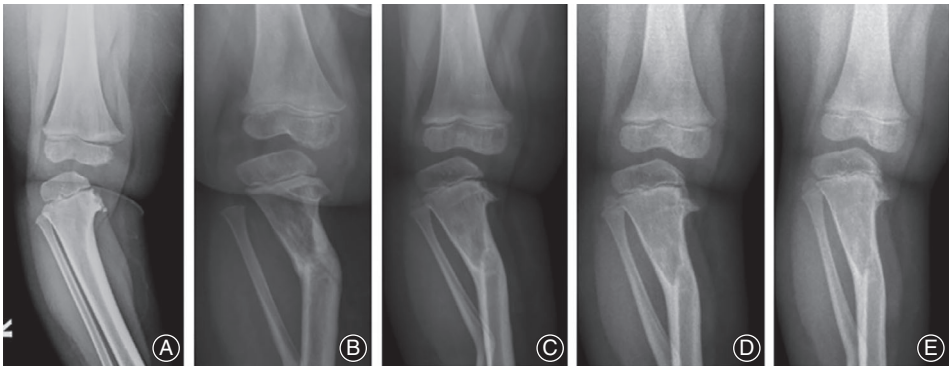

Fig. 5 The change of metaphysis in recurrence group: (A) preoperative, (B) 3 months postoperative, (C) 6 months postoperative, (D) 12 months postoperative, and (E) 24 months postoperative.

Conclusion

A medial metaphyseal slope of more than 62° at 24 months follow-up was associated with recurrence of the deformity.

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