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Correction of Coronal Angular Deformity around The Knee Using Temporary Hemiepiphysiodesis by Eight-Plate

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ABSTRACT

Background: Children's idiopathic or trauma-related coronal angular malformation around the knee might impair walking. If it doesn't improve, surgery like temporary hemiepiphysiodesis (TH) with an eight-plate implant is commonly used.

Objective: To evaluate the efficacy, correction velocity, and complications of temporary hemiepiphysiodesis using eight plates for correction of coronal angular deformity around knee.

Patients and methods: This work was a prospective study that had evaluated the use of eight plates for temporary hemi-epiphysiodesis with coronal angular deformity around the knee in 13 children (22 knees) who were operated upon at Menoufia University Hospitals and Helal Insurance Hospital between January 2022 and April 2023.

Results: In valgus group Mechanical axis deviation (MAD) improved in 12 knees representing (92.3%) and only one knee (7.7%) hasn't improved. mechanical lateral distal femoral angle (MLDFA) improved from 81.85±5.3 (range 72-89) pre operatively to 83.31±3.92 after 12 months. Medial proximal tibial angle (MMPTA) improved from 98.08±4.89 (range 92-109) pre operatively to 87.38±2.06 after 12 months. TFA improved from 13.15±0.8 (range 12-15) pre operatively to 6.77±2.01 after 12 months. The rate of improvement of MLDFA was 0.47±0.53, MMPTA was 0.96±0.45 and TFA was 0.59±2.1 per month. In varus group MAD improved in 8 knees representing (88.9%) and only one knee (11.1%) hasn't improved. MLDFA improved from 96.67±5.39 (range 92-110) pre operatively to 90.89±7.22 after 12 months. MMPTA improved from 81.22±1.99 (range 87-84) pre operatively to 88±3.16 after 12 months. Mechanical tibiofemoral angle (TFA) improved from 12±1.66 (range 10-14) pre operatively to 6.89±2.03 after 12 months. The rate of improvement of MLDFA was 0.58±0.39, MMPTA was 0.66±0.3 and TFA is 0.5±0.3 per month.

Conclusion: TH with eight plates is a successful surgery with a low incidence of complications and rebound for coronal angular deformity in patients with open physis.

Keywords: Temporary hemiepiphysiodesis, Coronal angular deformity, MAD, MMPTA, MLDFA, TFA.

INTRODUCTION

Children with a variety of reasons, including idiopathic, posttraumatic, or rickets, frequently have coronal angular deformity around the knee, which can produce aberrant gait and impact nearby joints throughout growth [1,2]. Pathological abnormalities can result in functional impairment, such as incorrect gait, joint discomfort, and a higher incidence of knee osteoarthritis, although physiological deformities frequently go away with growth [3,4].

When these deformities do not resolve spontaneously or worsen, surgical intervention is necessary, with options like temporary hemiepiphysiodesis (TH), permanent hemiepiphysiodesis, corrective osteotomy, transphyseal screw and Ilizarov ring fixator [5,6].

TH, particularly using the eight-plate implant, is a less invasive, predictable, and reversible option, with fewer complications compared to other methods like epiphyseal staples [7-9]. This study aimed to evaluate the efficacy, correction velocity, and complications of temporary hemiepiphysiodesis using eight plates for correction of coronal angular deformity around knee.

PATIENTS AND METHODS

This prospective study included a total of 13 patients (22 knee) with coronal angular deformity who were operated on at Menoufia University Hospitals and Helal Insurance Hospital from January 2022 to April 2023. All patients were evaluated preoperatively through full medical history and clinical examination including gait, deformity, and LLD. Radiological and laboratory investigations were done using follow-up X-rays and bone metabolism profile.

Inclusion criteria: children of both sexes with coronal angular deformity between age of 3 and 12 years with open physis. Specific criteria for varus knee deformity included (MLDFA) of less than 92°, (MMPTA) greater than 85° and children whose mechanical axis of the lower limb deviated into zones 2 or 3 on the medial half of the knee. Specific criteria for valgus knee deformity included MLDFA greater than 85°, MMPTA less than 92°, and mechanical axis of the lower limb deviated into zones -2 or -3 on the lateral half of the knee.

Exclusion criteria: Children with prior knee osteotomies or surgeries, physis injuries, infections, rotational deformities, active rickets, coxa vara, flat foot, or limb length discrepancies.

Surgical technique:

All patients underwent general anesthesia under radiolucent table, supine position under tourniquet control above knee. Within 30 minutes before onset of surgery, preoperative antibiotics prophylaxis (first

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generation cephalosporins according to child weight) was administered. The dissection was performed using fluoroscopic guidance through a 2-3 cm long incision focused on the physis, passing through fascia and across muscles while leaving the periosteum intact. Prior to putting the 8-plate, a needle was introduced through the perichondrial ring to pinpoint the physis (which was validated fluoroscopically). Threaded guide pins were placed into the center of the plate's holes under fluoroscopic supervision. A drill bit measuring 3.2 mm was used over the guide wire. Then, two 4.5-mm screws were used. The screw length was verified with fluoroscopy to be almost midline. Following wound closure, a compression bandage was enough; no casts were required.

Ambulation was started immediately post-operatively as pain tolerating. Evaluation of the wound was done at first week. Removal of stitches was done at second week. Follow up X-ray was done every three months for recording the evaluating angles (MAD, MMPTA, MLDFA, and TFA). Follow up continued till full correction then removal of hardware was performed.

Ethical approval:

The Research Ethics Committee of the Menoufia Faculty of Medicine gave its ethical approval to this investigation. The parent of each participant gave their written, informed permission. Throughout its implementation, the study complied with the Helsinki Declaration.

Statistical analysis

IBM SPSS software version 28.0 was used to analyze the data; quantitative data were characterized by range, mean ± SD, while qualitative data were displayed as frequencies and percentages. For data that was regularly distributed, the Bonferroni Post-Hoc Test and ANOVA with repeated measurements were employed; for data that was abnormally distributed, the Friedman test and Dunn's Post-Hoc Test were utilized. At the 5% threshold, significance was established.

RESULTS

In valgus group, the MAD has improved post-operatively in 12 patients representing (92.3%) and only one patient (7.7%) hasn't improved even after 12 m post-operatively. The complete correction was achieved after 9 and 12 m post-operatively. These results were highly statistically significant regarding both preoperative and (3, 6, 9 and 12 m) postoperative MAD. In varus group, the MAD has improved post-operatively in (8/9) representing (88.9%) and only one patient (11.1%) hasn't improved even after 12 m post-operatively. The complete correction was achieved after 9 and 12 m post-operatively. These results were highly statistically significant, regarding both preoperative and (3, 6, 9 and 12 m) postoperatively MAD **(Table 1)**.

Table (1): Distribution of the studied cases according to MAD (n = 22)

MAD	Pre-operative		After 3 months		After 6 months		After 9 months		After 12 months		Fr	P
Valgus	**(n = 13)**		**(n = 13)**		**(n = 13)**		**(n = 13)**		**(n = 13)**		47.646*	<0.001*
Zone -3	11	84.6	1	7.7	1	7.7	1	7.7	1	7.7		
Zone -2	2	15.4	10	76.9	0	0.0	0	0.0	0	0.0		
Zone -1	0	0.0	2	15.4	12	92.30.	0	0.0	0	0.0		
Zone 0	0	0.0	0	0.0	0	0.0	12	92.3	12	92.3		
p_0			0.107		0.004*		<0.001*		<0.001*			
p1					0.215		<0.001*		<0.001*			
Sig. bet. Periods					p_2=0.018*, p_3=0.018*, p_4=1.000							
Varus	**(n = 9)**		**(n = 9)**		**(n = 9)**		**(n = 9)**		**(n = 9)**		31.680*	<0.001*
Zone 0	0	0.0	0	0.0	0	0.0	8	88.9	8	88.9		
Zone 1	0	0.0	0	0.0	8	88.9	0	0.0	0	0.0		
Zone 2	2	22.2	8	88.9	0	0.0	0	0.0	0	0.0		
Zone 3	7	77.8	1	11.1	1	11.1	1	11.1	1	11.1		
p_0			0.371		0.025*		<0.001*		<0.001*			
p1					0.180		0.002*		0.002*			
Sig. bet. periods					p_2=0.074, p_3=0.074, p_4=1.000							

IQR: Inter quartile range. SD: Standard deviation. Fr: Friedman test, Sig. bet. periods was done using Post Hoc Test (Dunn's).

p: p value for comparing between the studied period

p_0: p value for comparing between pre-operative and each other periods

p_1: p value for comparing between After 3 month and each other periods

p_2: p value for comparing between After 6 month and After 9 month

p_3: p value for comparing between After 6 month and After 12 month

p_4: p value for comparing between After 9 month and After 12 month

*: Statistically significant at $p \leq 0.05$

In valgus group, the MLDFA improved gradually and highly statistically significantly from 81.85 ± 5.30 pre-operatively to become 87.15 ± 1.95 after 12 m post-operatively. In varus group, the MLDFA improved gradually and highly statistically significantly from 96.67 ± 5.39 pre-operatively to become 90.89 ± 7.22 after 12 m post-operatively **(Table 2)**.

Table (2): Comparison between the different studied periods according to MLDFA (n = 22)

MLDFA	Pre-operative	After 3 months	After 6 months	After 9 months	After 12 months	F	P
Valgus	**(n = 13)**	**(n = 13)**	**(n = 13)**	**(n = 13)**	**(n = 13)**		
Min. – Max.	72.0 – 89.0	76.0 – 89.0	80.0 – 88.0	83.0 – 89.0	83.0 – 90.0	9.648*	<0.001*
Mean ± SD.	81.85 ± 5.30	83.31 ± 3.92	84.77 ± 2.55	86.31 ± 1.84	87.15 ± 1.95		
p_0		0.006*	0.007*	0.007*	0.009*		
p_1			0.011*	0.008*	0.011*		
Sig. bet. Periods			p_2=0.007*, p_3=0.014*, p_4=0.051				
Varus	**(n = 9)**	**(n = 9)**	**(n = 9)**	**(n = 9)**	**(n = 9)**		
Min. – Max.	92.0 – 110.0	92.0 – 110.0	90.0 – 110.0	87.0 – 110.0	87.0 – 110.0	22.497*	<0.001*
Mean ± SD.	96.67 ± 5.39	95.11 ± 5.67	93.11 ± 6.37	91.44 ± 7.07	90.89 ± 7.22		
p_0		0.011*	0.003*	0.002*	0.001*		
p1			0.001*	0.001*	<0.001*		
Sig. bet. Periods			p_2=0.001*, p_3<0.001*, p_4=0.051				

IQR: Inter quartile range SD: Standard deviation
F: F test (ANOVA) with repeated measures, Sig. bet. periods were done using Post Hoc Test (adjusted Bonferroni)
p: p value for comparing between the studied period
p_0: p value for comparing between pre-operative and each other periods
p_1: p value for comparing between After 3 month and each other periods
p_2: p value for comparing between After 6 month and After 9 month
p_3: p value for comparing between After 6 month and After 12 month
p_4: p value for comparing between After 9 month and After 12 month
*: Statistically significant at $p \leq 0.05$

In valgus group, the MMPTA improved gradually and highly statistically significantly from 98.08 ± 4.89 pre-operatively to become 87.38 ± 2.06 after 12 m post-operatively. In varus group, the MMPTA improved gradually and highly statistically significantly from 81.22 ± 1.99 pre-operatively to become 88.0 ± 3.16 after 12 m post-operatively **(Table 3)**.

Table (3): Comparison between the different studied periods according to MMPTA (n = 22)

MMPTA	pre-operative	After 3 months	After 6 months	After 9 months	After 12 months	F	P
Valgus	**(n = 13)**	**(n = 13)**	**(n = 13)**	**(n = 13)**	**(n = 13)**		
Min. – Max.	92.0 – 109.0	90.0 – 103.0	88.0 – 97.0	85.0 – 93.0	85.0 – 92.0	45.904*	<0.001*
Mean ± SD.	98.08 ± 4.89	95.0 ± 3.85	92.15 ± 2.79	89.31 ± 2.25	87.38 ± 2.06		
p_0		<0.001*	<0.001*	<0.001*	<0.001*		
p1			<0.001*	<0.001*	<0.001*		
Sig. bet. periods			p_2<0.001*, p_3<0.001*, p_4=0.003*				
Varus	**(n = 9)**	**(n = 9)**	**(n = 9)**	**(n = 9)**	**(n = 9)**		
Min. – Max.	78.0 – 84.0	80.0 – 86.0	80.0 – 88.0	80.0 – 90.0	80.0 – 90.0	42.063*	<0.001*
Mean ± SD.	81.22 ± 1.99	83.33 ± 1.87	85.11 ± 2.26	87.11 ± 2.85	88.0 ± 3.16		
p_0		0.001*	<0.001*	<0.001*	<0.001*		
p1			<0.001*	<0.001*	<0.001*		
Sig. bet. periods			p_2<0.001*, p_3<0.001*, p_4=0.035*				

IQR: Inter quartile range SD: Standard deviation
F: F test (ANOVA) with repeated measures, Sig. bet. periods was done using Post Hoc Test (adjusted Bonferroni)
p: p value for comparing between the studied period
p_0: p value for comparing between pre-operative and each other periods
p_1: p value for comparing between After 3 month and each other periods
p_2: p value for comparing between After 6 month and After 9 month
p_3: p value for comparing between After 6 month and After 12 month
p_4: p value for comparing between After 9 month and After 12 month
*: Statistically significant at $p \leq 0.05$

In valgus group, the TFA was improved gradually and highly statistically significantly from 13.15 ± 0.80 pre-operatively to become 6.77 ± 2.01 after 12 m post-operatively. In varus group, the TFA improved gradually and highly statistically significantly from 12.0 ± 1.66 to become 6.89 ± 2.03 after 12 m **(Table 4)**.

Table (4): Comparison between the different studied periods according to TFA (n = 22)

TFA	pre-operative	After 3 months	After 6 months	After 9 months	After 12 months	F	P
Valgus	**(n = 13)**	**(n = 13)**	**(n = 13)**	**(n = 13)**	**(n = 13)**		
Min. – Max.	12.0 – 15.0	10.0 – 13.0	8.0 – 13.0	6.0 – 13.0	5.0 – 13.0	85.100*	<0.001*
Mean ± SD.	13.15 ± 0.80	11.08 ± 0.95	9.46 ± 1.20	7.77 ± 1.79	6.77 ± 2.01		
p_0		<0.001*	<0.001*	<0.001*	<0.001*		
p_1			<0.001*	<0.001*	<0.001*		
Sig. bet. periods			p_2<0.001*, p_3<0.001*, p_4=0.002*				
Varus	**(n = 9)**	**(n = 9)**	**(n = 9)**	**(n = 9)**	**(n = 9)**		
Min. – Max.	10.0 – 14.0	9.0 – 12.0	7.0 – 12.0	5.0 – 12.0	5.0 – 12.0	23.104*	<0.001*
Mean ± SD.	12.0 ± 1.66	9.89 ± 0.93	8.56 ± 1.42	7.33 ± 2.0	6.89 ± 2.03		
p_0		0.014*	0.003*	0.001*	0.001*		
p_1			0.002*	0.001*	<0.001*		
Sig. bet. periods			p_2=0.001*, p_3<0.001*, p_4=0.035*				

IQR: Inter quartile range SD: Standard deviation
F: F test (ANOVA) with repeated measures, Sig. bet. periods was done using Post Hoc Test (adjusted Bonferroni)
p: p value for comparing between the studied period
p_0: p value for comparing between pre-operative and each other periods
p_1: p value for comparing between After 3 month and each other periods
p_2: p value for comparing between After 6 month and After 9 month
p_3: p value for comparing between After 6 month and After 12 month
p_4: p value for comparing between After 9 month and After 12 month
*: Statistically significant at $p \leq 0.05$

In valgus group, the rate of improvement of MLDFA was 0.47 ± 0.53 per month, MMPTA was 0.96 ± 0.45 per month and TFA was 0.59 ± 0.21 per month. In varus group, the rate of improvement of MLDFA was 0.58 ± 0.39 per months, MMPTA was 0.66 ± 0.30 per month and TFA was 0.50 ± 0.30 per months **(Table 5).**

Table (5): Descriptive statistics of the studied cases according to improvement and % of improvement

	Valgus (n = 13)	Varus (n = 9)
MLDFA		
Improvement	5.31 ± 6.17	5.78 ± 3.49
Rate of improvement/ month	0.47 ± 0.53	0.58 ± 0.39
MMPTA		
Improvement	10.69 ± 5.65	6.78 ± 2.86
Rate of improvement/ month	0.96 ± 0.45	0.66 ± 0.30
TFA		
Improvement	6.38 ± 2.29	5.11 ± 2.93
Rate of improvement / month	0.59 ± 0.21	0.50 ± 0.30

CASE PRESENTATION

Case 1: An 11-year-old female with no significant past medical history presented with a varus deformity that began at the age of 8 **(Figure 1A, 1B)**.

(1A)

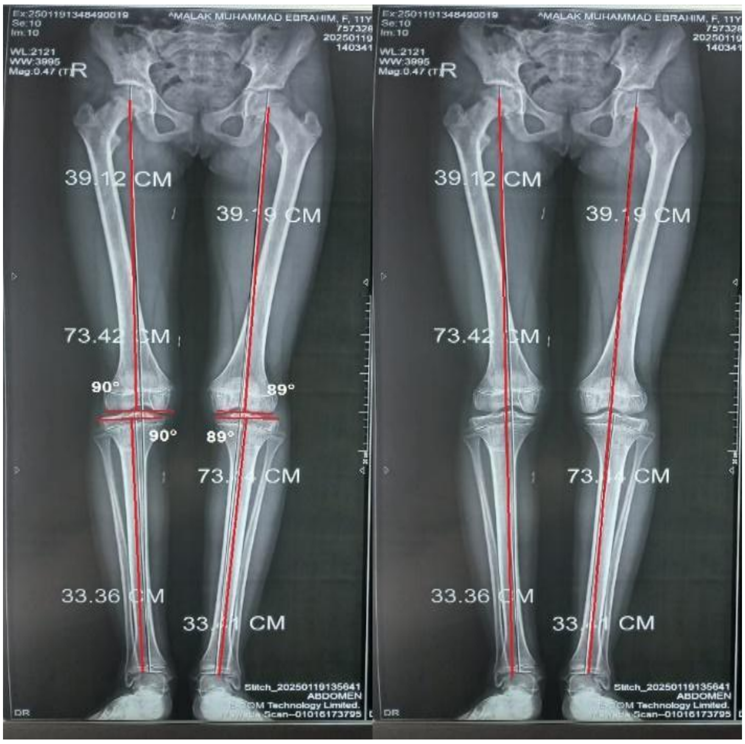
(1B)

Fig. (1): (A) pre-operative clinical photo of the varus deformity and (B) preoperative scanogram of the varus deformity

Right lower limb MAD = Zone +2 / MLDFA = 93 / MMPTA = 84

Left lower limb MAD = Zone +2 / MLDFA =92 / MMPTA = 81

(2A)



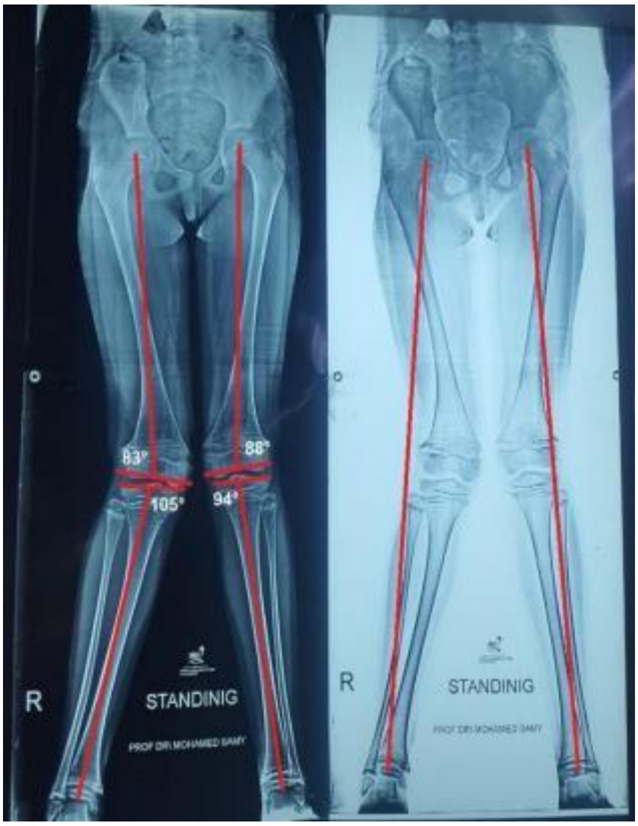
(2B)

Fig. (2): (A) post-operative clinical photo after removal of eight-plate and (B) scanogram after removal of the eight-plate.

Right lower limb MAD = Zone 0 / MLDFA = 90 / MMPTA = 90

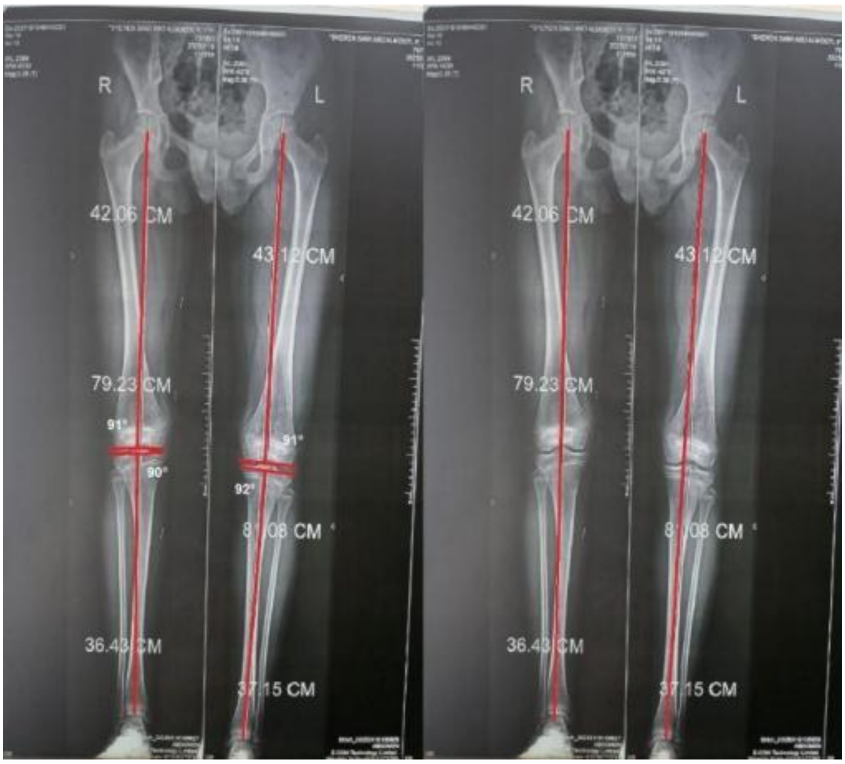
Left lower limb MAD =Zone 0 / MLDFA = 89 / MMPTA = 89

CASE 2: A 10-year-old female with no notable past medical history presented with a valgus deformity that started at the age of 8.



(3A) **(3B)**

Fig. (3): (A) pre-operative clinical photo of the varus deformity and (B) preoperative scanogram of the deformity
Right Lower limb MAD = Zone -3 / MLDFA = 83 / MMPTA = 105
Left lower limb MAD = Zone -2 / MLDFA = 88 / MMPTA = 94



(4A) **(4B)**

Fig. (4): (A) post-operative clinical photo after removal of the eight plate and (B) scanogram after removal of the eight-plate.
Right lower limb MAD = Zone 0 / MLDFA = 91 / MMPTA = 90
Left lower limb MAD = Zone 0 / MLDFA = 91 / MMPTA = 92

DISCUSSION

This prospective cohort study involved 13 children (22 knees) with coronal angular deformity around the knee, aiming to evaluate the efficacy, correction velocity, and complications of temporary hemi-epiphysiodesis using 8-plates. The valgus group consisted of 3 males (37.5%) and 5 females (62.5%), while the varus group included 3 males (60%) and 2 females (40%). The mean age in the valgus group was 8.88 ± 3.23 years (range 3-12), and in the varus group, it was 8.20 ± 3.96 years (range 3-12). One knee in the valgus group had a history of proximal tibial fracture, and another had Down syndrome.

In this recent study, post-operative mechanical axis deviation (MAD) improvement was observed in 12 of the 13 knees in the valgus group (92.3%), with only one (7.7%) didn't improve at 12 months. Complete correction was observed at 9 to 12 months post-surgery, with highly significant results (P ≤ 0.001) in both pre operative and post operative MAD at 3, 6, 9, and 12 months. In the varus group, MAD improved in 8 of 9 knees (88.9%), with the same time frame for complete correction. The results were statistically significant (P ≤ 0.001) at all time points.

A study by **Alagamy *et al.*** **[10]** found that in 38 patients with genu-valgum deformity, MAD was corrected from 34.3 ± 14.3 mm to 7.9 ± 5.3 mm, with a statistically significant improvement (P= 0.0001). **Oner *et al.*** **[11]** reported significant MAD differences before and after surgery for both genu valgum and genu varum, with 81.8% of genu varum deformities and 79.5% of genu valgum deformities achieving a neutral mechanical axis.

In this current study, the rate of improvement per month for medial lateral distal femoral angle (MLDFA) in the valgus group was 0.47 ± 0.53, achieving complete correction after one year post-operatively, while the varus group showed a rate of 0.58 ± 0.39. The MLDFA improved significantly in both groups (P ≤ 0.001), with the valgus group improving from 81.85 ± 5.30 to 87.15 ± 1.95 after one year, and the varus group improved from 96.67 ± 5.39 to 90.89 ± 7.22.

In line with our findings, **Alagamy *et al.*** **[10]** reported MLDFA improvement from 79.9 ± 3.18° to 89.5 ± 2.55° (P < 0.001) in a cohort of 38 patients with genu-valgum deformity. **Guzman *et al.*** **[12]** also showed improvement in MLDFA from 78.7° to 83.7° in 25 patients (47 knees) with idiopathic genu valgum.

Burghardt *et al.* **[13]** conducted a study on 39 genu valgum and 4 genu varum patients, reporting a correction of MLDFA by 10 degrees (range 1–18) and MMPTA by 7.78 degrees (range 0–14).

In this current study, MMPTA in the valgus group improved significantly from 98.08 ± 4.89 preoperatively to 87.38 ± 2.06 after one year (P ≤ 0.001), while in the varus group, it improved from 81.02 ± 1.99 to 88.0 ± 3.16.

The rate of improvement per month for MMPTA in this study was 0.96 ± 0.45 in the valgus group and 0.66 ± 0.30 in the varus group, with maximal improvement achieved after one year. **Oner *et al.*** **[11]** similarly reported significant differences in MMPTA before and after surgery in both groups.

Özdemir *et al.* **[14]** observed a mean correction rate of 0.94 ± 0.43° per month in femoral valgus deformity and 0.94±0.49° per month in tibial varus deformity in 77 patients. **Stevens** **[15]** reported an average MLDFA correction of 9.0° in the 8-plate group, while **Boero *et al.*** **[16]** reported a correction of MLDFA by 7° ± 7.2° degrees in 134 patients.

In this current study, there was a complete correction in tibiofemoral angle (TFA) from 13.15 ± 0.80 to 6.77 ± 2.01 in the valgus group, and from 12.0 ± 1.66 to 6.89 ± 2.03 in the varus group (P ≤ 0.001). The rate of improvement per month for TFA in the valgus group was 0.59 ± 0.21 and 0.50 ± 0.30 in the varus group, with maximal improvement at one-year post-surgery.

In studies by **Guzman *et al.*** **[12]**, **Das *et al.*** **[17] and Kulkarni *et al.*** **[18]**, TFA correction was also achieved, with a similar range of improvement. **Rajput *et al.*** **[19]** reported a correction rate of 1.5° per month in 16 knees, with 4 cases of overcorrection.

Complications:

Regarding complications, in this study, there was noted premature epiphyseal closure in one patient who refused revision osteotomy. **Zhen *et al.*** **[20]** reported complications such as screw loosening and wound infection in 3.4-4% of cases. **Danino *et al.*** **[21]** found no hardware failures in 372 physes of 206 patients with idiopathic angular deformities. However, **Stevens** **[15]** reported a higher incidence of superficial infections (16%) compared to **Adawy *et al.*** **[22]** (7%). **Park *et al.*** **[23]** emphasized that tibial varus deformities are associated with a higher complication rate compared to femoral deformities.

CONCLUSION

TH with eight plates is a successful technique for genu angular deformity with a minimal risk of complications and rebound.

LIMITATIONS

Single center study with limited number of patients included may weaken the strength of the results from the multivariate analyses. There was lack of long-term follow-up duration to assess complications after plate removal. Additionally, we did not contrast the results of eight-plate hemiepiphysiodesis with those of other devices.

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