The Efficacy of Guided-Growth Hemiepiphysiodesis Using 8-plate in Management of Knee Deformities in Children near Skeletal Maturity

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Abstract

Background: Angular deformities in children can be physiological or pathological, with the latter requiring surgical correction to prevent functional impairments. Guided growth through hemiepiphysiodesis is a minimally invasive alternative to osteotomies, enabling gradual correction by modulating growth in skeletally immature patients, thus reducing complications.

Objectives: To assess the efficacy of epiphysiodesis using 8 plates in management of deformities in children near skeletal maturity.

Patients and methods: This prospective patient series at Qena University Hospital, Egypt, involved 20 near skeletal maturity children with coronal knee deformities. Guided growth surgery was performed using 3.5–4.5 mm cannulated screws under fluoroscopic guidance. Postoperative care included antibiotics, partial weight-bearing mobilization, and follow-ups at 6, 9, and 12 months.

Results: The mean age was 11.5 ± 1.69 years. 35% were male. 80% had genu valgum and 20% genu varum. Bilateral involvement occurred in 75%. The femoral component was affected in 45%, tibial in 15%, and both in 40%. Preoperative mechanical angles showed a mean mLDFA of 84.2° (right) and 83.25° (left), MPTA of 88.26° (right) and 88.87° (left), and mTFA of 8.13° (right) and 6.84° (left). Postoperative improvement included mLDFA (right: 86.95°, left: 87.08°), MPTA (right: 88.53°, left: 88.27°), and mTFA (right: 1.65°, left: 1.86°). Full correction was achieved in 90% by 18 months, with significant reductions in mTFA (P = 0.0448). Complications included reoperation (5%), persistent pain (5%), and overcorrection (15%).

Conclusion: 8-plate hemiepiphysiodesis effectively corrects knee deformities in children near skeletal maturity with minimal complications.

Keywords: Guided-Growth Hemiepiphysiodesis; Skeletal Maturity; Knee Deformities; 8-plate.

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Introduction

Angular deformities of the lower limb in the pediatric population are a common presentation in orthopedic and pediatric clinics and can be either physiological or true deformities **(Gupta et al., 2020).** Pathologic coronal angular deformities around the knee that do not resolve spontaneously or worsen often require surgical intervention **(Baghdadi et al., 2020).**

Normal lower limb alignment includes equal leg lengths, with the mechanical axis of the leg bisecting the knee when the patient is standing erect with patellae facing forward. This alignment ensures balanced forces on the medial and lateral compartments of the knee and the collateral ligaments, with the patella remaining stable and centred in the femoral sulcus **(Sánchez et al., 2004).**

While physiological deformities typically self-correct with growth, pathological deformities can result in functional impairments such as abnormal gait, joint pain, and an increased risk of osteoarthritis in the knee. Surgical options for correcting angular deformities around the knee include temporary hemiepiphysiodesis, timed permanent hemiepiphysiodesis, corrective osteotomy, and the application of Ilizarov ring fixators **(Smith et al., 2013).**

Guided growth (GG), achieved through physiodesis, allows for the correction of angular deformities in skeletally immature patients by inhibiting growth in a specific segment of the physis. This approach serves as an alternative to osteotomies, reducing the risk of complications **(Bylski-Austrow et al., 2001).**

The aim of this study was to assess the efficacy of epiphysiodesis using 8 plates in management of deformities in children near skeletal maturity.

Patients and methods

This was a prospective patient series that was conducted at the Orthopedic department at Qena university hospital, Egypt involving 20 patients. All patients were children aged 8-16 years old (Tanner stages 2-3), with coronal knee deformities. Patients aged below 8 years old (due to high cartilage-to-bone ratio, increased risk of anesthesia related complications, highly active growth plates which may cause unpredictable bone healing) or with Active infection around knee were excluded from the study.

Sample size justification: This sample size was calculated based on the study conducted by **Vaishya et al., 2018,** where hemi-epiphysiodesis using eight-plate achieved full correction in 91.6% of patients. The sample size was calculated using the following formula:

$$n = \frac{(Z_{\alpha/2} + Z_{\beta})^2 \times (\sigma_1^2 + \sigma_2^2)}{(\mu_1 - \mu_2)^2}$$

Where:

- $Z_{a}/_{2}$ = Z-score for the desired confidence level (e.g., 1.96 for 95% confidence).
- Zβ = Z-score for the desired power (e.g., 0.84 for 80% power).
- μ_1 = the mean preoperative TFA = 22.02°
- μ_2 = the mean postoperative TFA at the end of the follow up = 6.14 ° ± 1.92 °
- σ_1 = The preoperative SD of TFA = ± 5.15 °
- σ_2 = The postoperative SD of TFA = ± 1.92 °.
- n = Sample size = 20.

Methods

All patients underwent thorough history taking, general examination, routine laboratory investigations and clinical evaluation of the affected limbs. Preoperative anteroposterior x-ray films of both lower limbs were obtained. Anatomical alignment is measured from the anteroposterior knee radiographs. The Tibio-femoral angles were measured using a standard plastic 30 cm goniometer and recorded in degrees. Angles greater than 180° represent a valgus alignment, and angles lesser than 180° a varus alignment.

Patients were positioned supine under general anesthesia, with a pneumatic tourniquet applied to the proximal thigh. Fluoroscopic imaging was utilized to localize the targeted physis (distal femur or proximal tibia). A 2–3 cm longitudinal incision was made over the estimated physeal center, followed by fascial division and periosteal exposure through blunt dissection. Under fluoroscopic guidance, a hypodermic needle or guide pin was introduced into the physis, ensuring precise positioning in the midsagittal plane or slightly posteriorly to mitigate the risk of recurvatum. The 8-plate was then cantered over the physis and temporarily stabilized with a hypodermic needle to maintain alignment. One cannulated screw was positioned in the epiphysis and the other in the metaphysis, with placement confirmed via fluoroscopy. Threaded guide wires were inserted through the plate holes in a trajectory parallel to the physis. A cannulated drill (3–5 mm) was employed to create pilot holes, followed by the insertion of self-tapping cannulated screws (3.5 or 4.5 mm, depending on bone dimensions). Once screws were securely tightened, guide wires were removed, and final implant positioning was verified fluoroscopically. After confirming alignment, the wound was routinely closed in layers, the tourniquet was deflated, and a padded dressing was applied to protect the surgical site. **(Said et al., 2023). (Fig.1).**

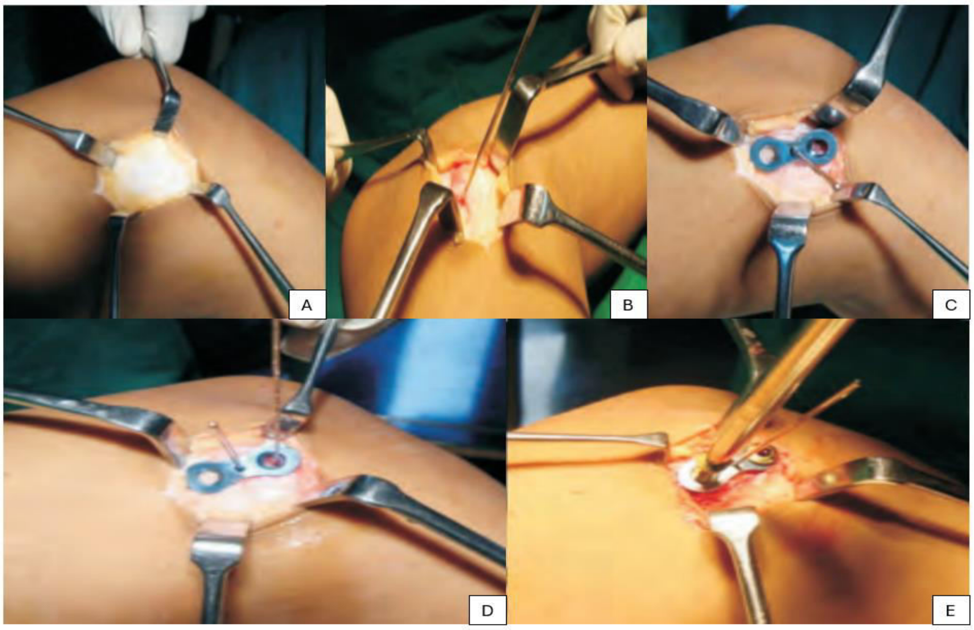

Fig.1. A) A small 2 to 3 cm incision was taken around the physis, B) Fine guide pin insertion into the physis under image intensifier control, C) The plate was passed over the guide pin through its central hole, D) Guide wire for epiphysis was passed with care taken not cross the joint, and E) The self-tapping screws of either 3.5 mm or 4.5 mm diameter (depending upon size of the bone) were passed over the guide wires and tightened.

Postoperatively, patients received prophylactic antibiotics (for 5 days postoperatively). Patients were discharged one day after surgery, partial weight-bearing was allowed in the first two weeks) as patients were instructed to mobilize using crutches with partial weight-bearing on the operated limb. The weight bearing was gradually increasing as tolerated. By the end of the second week, most patients achieved full weight-bearing. For knee motion exercise included early passive and active-assisted motion for 3–7 days as patients began gentle passive and active-assisted range-of-motion (ROM) exercises once the compression bandage was reduced on day 3 or 4. By week 6–8, patients typically progressed to unrestricted activity, provided they exhibited pain-free and near full ROM.

Compliance was evaluated by weekly phone calls and patients re-evaluation at the follow up visits scheduled at 6, 9, and the final assessment at 18 months which included clinical assessments and radiological measurements (Tibio-femoral angle). Implants were removed once the deformity was corrected.

The degree of correction was calculated as the measured value of the mTFA subtracted from the preoperative mTFA. Correction was defined as return of the mTFA to the normal value (<5º). Full correction was defined as the return of mTFA of all the affected limbs to the normal value (<5º) and return of the mechanical axis deviation to the normal value (3-15 mm). Overcorrection was defined as excessive reduction of the mTFA with shifting of varus deformity into valgus with correction or vice versa **(Vaishya et al., 2018; Luís and Varatojo, 2021).**

Ethical approval code: SVU-MED-ORT017-1-24-3-827.

Statistical analysis

The collected data will be coded, processed and analyzed using SPSS program (Version 25) for windows. Descriptive statistics were calculated to include means, standard deviations, medians, ranges, and percentages. For comparison between the pre and postoperative values during follow up, Anova test was used. The Chi square test was used to compare non-continuous data. A p value below 0.05 is considered statistically significant.

Results

The mean age was 11.5 ± 1.69 years. 13 patients (65%) were females. Genu valgum was observed in 16 subjects (80%), while genu varum was present in 4 subjects (20%). 2 patients (10%) involved the right limb, 3 patients (15%) the left limb, and 15 patients (75%) both lower limbs. The femoral component was involved in 9 patients (45%), the tibial component in 3 patients (15%), and both components in 8 patients (40%). **(Table.1).**

Table 1. Demographic data and basal characteristics among included subjects

Variables	Value (N = 20)
Age	11.5 ± 1.69
Gender	
• Male	7 (35%)
• Female	13 (65%)
Deformity	
• Genu valgum	16 (80%)
• Genu varum	4 (20%)
Laterality	
• Right	2 (10%)
• Left	3 (15%)
• Both lower limbs	15 (75%)
Component	
• Femoral	9 (45%)
• Tibial	3 (15%)
• Both	8 (40%)

The minimum degree of motion was 0.5 ± 2.18 and the maximum degree of motion was 138.75 ± 3.11. (**Table.2.**) The fluoroscopy time for the included subjects (N = 20) averaged 7.77 ± 2.77 minutes, while the operative time averaged 27.45 ± 11.49 minutes. (**Table.3).**

Table 2. ROM (Degrees) data among included subjects

Variables	**Value (N = 20)**
ROM (Degrees)	
Minimum Degree	0.5 ± 2.18
Max Degree	138.75 ± 3.11

Table 3. Operative data among included subjects

Variables	**Value (N = 20)**
Fluoroscopy time (min)	7.77 ± 2.77
Operative time (min)	27.45 ± 11.49

There were non-significant differences regarding preoperative tibio-femoral angles and measurements at 6 months, 9 months and final measurement except for the right mechanical tibio-femoral angle (mTFA) which show significant reduction from 8.13 ± 4.61 down to1.65 ± 4.09 at final measurement (P = 0.0448). For the right MAD, the preoperative value of 26.17° ± 0.8° significantly decreased to 22.64° ± 0.74° at 6 months, 17.81° ± 4.35° at 9 months, and 9.69° ± 2.91° in the final assessment (P = 0.0001). Pairwise comparisons revealed significant reductions at each follow-up (P1 = 0.004, P2 = 0.0001, P3 = 0.0001, P4 = 0.0001, P5 = 0.0001, P6 = 0.0001).Similarly, for the left MAD, a significant decline was observed from 25.17° ± 3.78° preoperatively to 20.2° ± 2.21° at 6 months, 15.97° ± 3.2° at 9 months, and 9.87° ± 2.93° in the final evaluation (P = 0.0001). All pairwise comparisons showed statistically significant decreases (P1 = 0.001, P2 = 0.0001, P3 = 0.0001, P4 = 0.0003, P5 = 0.0001, P6 = 0.0001). (**Table.4**).

Table 4. Comparison of Tibio-femoral angles and axis deviation preoperatively and through follow up till final assessment among included subjects

Variables	**Preoperative data**	**6 Months Follow up**	**9 Months follow up**	**Final measures (18 months)**	**P-value**
Rt mLDFA	84.2 ± 6.59	85.52 ± 4.51	86.05 ± 3.05	86.95 ± 2.4	0.2634 [F]
	P1= 0.8025, P2= 0.5863, P3= 0.2055, P4= 0.9835, P5= 0.7068, P6= 0.8928				
Rt MPTA	88.26 ± 4.15	88.16 ± 3.04	88.28 ± 2.17	88.53 ± 1.57	0.9836 [F]
	P1= 0.9964, P2= 0.9964, P3= 0.9782, P4= 0.99, P5= 0.9978, P6= 0.9978				
Rt mTFA	8.13 ± 4.61	5.15 ± 3.33	3.27 ± 2.97	1.65 ± 4.09	0.0448* [F]
	P1= 0.4796, P2= 0.0634, P3= 0.0714, P4= 0.6964, P5= 0.7261, P6= 0.99				
Rt MAD	26.17 ± 0.8	22.64 ± 0.74	17.81 ± 4.35	9.69 ± 2.91	0.0001* [F]
	P1= 0.004*, P2= 0.0001*, P3= 0.0001*, P4= 0.0001*, P5= 0.0001*, P6= 0.0001*				
Lt mLDFA	83.25 ± 5.35	84.51 ± 3.05	85.74 ± 2.39	87.08 ± 2.48	0.0658 [F]
	P1= 0.7253, P2= 0.2742, P3= 0.0506, P4= 0.8663, P5= 0.3962, P6= 0.8512				
Lt MPTA	88.87 ± 4.41	88.41 ± 2.9	88.34 ± 1.93	88.27 ± 1.3	0.9065 [F]
	P1= 0.9546, P2= 0.93, P3= 0.9102, P4= 0.9998, P5= 0.9989, P6= 0.9999				
Lt mTFA	6.84 ± 4.69	4.69 ± 3.7	2.41 ± 2.21	1.86 ± 4.97	0.1503 [F]

	P1= 0.619, P2= 0.1444, P3= 0.2596, P4= 0.7819, P5= 0.9215, P6= 0.9895				
Lt MAD	25.17 ± 3.78	20.2 ± 2.21	15.97 ± 3.2	9.87 ± 2.93	0.0001* [F]
	P1= 0.001*, P2= 0.0001*, P3= 0.0001*, P4= 0.0003*, P5= 0.0001*, P6= 0.0001*				

Rt mLDFA: Right mechanical Lateral Distal Femoral Angle, Rt MPTA: Right Medial Proximal Tibial Angle, Rt mTFA: Right mechanical Tibiofemoral Angle, Lt mLDFA: Left mechanical Lateral Distal Femoral Angle, Lt MPTA: Left Medial Proximal Tibial Angle, Lt mTFA: Left mechanical Tibiofemoral Angle, Rt: Right, Lt: Left.. F: Anova test. P1 = Preoperative measurements vs 6 Months Follow up, P2 = Preoperative measurements vs 9 Months follow up, P3 = Preoperative measurements vs final assessment at 18 months, P4 = 6 Months Follow up vs 9 Months follow up, P5 = 6 Months Follow up vs final assessment at 18 months, P6 = 9 Months follow up vs final assessment at 18 months.

On the right side, there was a significant increase in the degree of correction which was 3.07 ± 1.75 in 6 months, 4.53 ± 3.22 at 9 months and 6.93 ± 5.94 at final follow up (P = 0.016). Within the following months, there was significant difference regarding the degree of correction at 6 months and at the final follow up (P = 0.0124). On the left side, there was a significant increase in the degree of correction which was 2.59 ± 1.24 in 6 months, 4.17 ± 2.9 at 9 months and 6.12 ± 5.09 at final follow up (P = 0.0103). Within the following months, there was significant difference regarding the degree of correction at 6 months and at the final follow up (P = 0.0074). The full correction was achieved in 4 (20%) patients at 9 months postoperatively compared to 18 (95%) patients (P < 0.001). (**Table.5**).

Table 5. Comparison of degree of correction through follow up till final assessment among included subjects

Variables	Preoperative data	6 Months Follow up	9 Months follow up	Final measures (18 months)	P-value
Degree of correction					
Rt	-	3.07 ± 1.75	4.53 ± 3.22	6.93 ± 5.94	0.016* [F]
	P1= 0.5056, P2= 0.0124*, P3= 0.1673				
Lt	-	2.59 ± 1.24	4.17 ± 2.9	6.12 ± 5.09	0.0103* [F]
	P1= 0.344, P2= 0.0074*, P3= 0.2006				
Full correction	-	-	4 (20%)	19 (95%)	< 0.001* [X]

Rt: Right, Lt: Left. F: Anova test, X: chi square test. P1 = 6 Months Follow up vs 9 Months follow up, P2 = 6 Months Follow up vs final assessment at 18 months, P3 = 9 Months follow up vs final assessment at 18 months.

Reoperation was needed in 1 patient (5%) and persistent pain was in 1 patient (5%). Overcorrection occurred in 3 subjects (15%), while no patients of infection, implant breakage, or wound healing issues were reported (0%). Wound healing within 2 weeks was achieved in all subjects (100%). **(Table. 6).**

Table 6. Complications occurring among included subjects

Variables	Value (N = 20)
Reoperation	1 (5%)
Infection	0 (0%)
Persistent pain	1 (5%)
Overcorrection	3 (15%)
Implant breakage	0 (0%)

Discussion

Guided growth for coronal plane knee deformity has historically been used for knee valgus and knee varus correction. Recently, its indications have expanded to address deformities in other lower and upper extremities, including hallux valgus, hindfoot calcaneus, ankle valgus and equinus, rotational abnormalities, knee flexion, coxa valga, and distal radius deformity **(Cappello, 2021).**

Various pathologies affect growth in the long bones of the lower extremities, causing aesthetic and functional issues, with angular deformities in the coronal plane being a major contributor to knee osteoarthritis due to overload (**Sepúlveda and Ferrada, 2021).** Hemiepiphysiodesis, particularly using temporary methods like stapling, transphyseal screws, and tension band plates, is a reversible approach for correcting angular deformities in children with significant growth potential **(Shah, 2020). Stevens et al. (2007)** introduced the use of tension band plates, known as eight-plates, which are associated with fewer implant-related complications and easier implantation.

Guided growth using 8-plates corrects angular deformities by leveraging the principles of asymmetric physeal growth modulation. The 8-plate, acting as a tension band, is secured with screws across the physis, partially restricting growth on one side while allowing the unrestrained side to continue normal growth. This creates a controlled differential growth rate, leading to gradual realignment of the limb over time. As growth progresses, the convex side of the deformity elongates while the concave side slows, promoting progressive correction without disrupting normal bone development. Once the desired alignment is achieved, plate removal allows resumption of symmetric growth, preventing overcorrection and ensuring long-term biomechanical stability **(Lohith et al., 2024).**

This study assessed the efficacy of eight-plate hemiepiphysiodesis in managing coronal plane knee deformities in 20 children near skeletal maturity at Qena University Hospital, Egypt.

The mean age was 11.5 ± 1.69 years, with 7 males (35%) and 13 females (65%). Genu valgum was observed in 16 patients (80%), and genu varum in 4 patients (20%). Bilateral involvement occurred in 15 patients (75%), with 2 (10%) affecting the right limb and 3 (15%) the left limb.

Dai et al. (2021) evaluated 101 knees treated with eight-plate hemiepiphysiodesis and reported a mean age of 10.1 years, with a higher incidence of genu valgum (94%), similar to our findings. **Özdemir et al. (2021)** also found a predominance of genu valgum, though their cohort showed a male majority (59.7%), contrasting with our female-majority sample.

In our study, the femoral component was affected in 9 patients (45%), the tibial component in 3 patients (15%), and both in 8 patients (40%). This distribution aligns with previous studies that emphasize the femur's larger growth plate and significant role in knee alignment, particularly in genu valgum and varum **(Coppa et al., 2022; Patel and Nelson, 2020; Shim et al., 2024)**.

Range of motion (ROM) analysis revealed minimum motion of 0° in 95% of patients and maximum ROM of 140° in 85%. The gradual improvement in ROM can be attributed to deformity correction and soft tissue adaptation **(Johnson, 2024; MacWilliams et al., 2011; Umre et al., 2022).**

The average fluoroscopy time was 7.77 ± 2.77 minutes, and operative time was 27.45 ± 11.49 minutes. These results are consistent with studies by **Dai et al. (2021), Vaishya et al. (2018), and Zajonz et al. (2017),** which reported average operative times of 25–30 minutes per limb.

Preoperative mechanical angles on the right side showed a mean mLDFA of 84.2 ± 6.59°, MPTA of 88.26 ± 4.15°, and mTFA of 8.13 ± 4.61°. On the left side, the mean mLDFA was 83.25 ± 5.35°, MPTA 88.87 ± 4.41°, and mTFA 6.84 ± 4.69°. At the final follow-up, the right mLDFA improved to 86.95 ± 2.4°, MPTA to 88.53 ± 1.57°, and mTFA to 1.65 ± 4.09°, while the left mLDFA was 87.08 ± 2.48°, MPTA 88.27 ± 1.3°, and mTFA

1.86 ± 4.97°. Full correction was achieved in 19 subjects (90%) by 18 months.

In line with our study **Winanto and Ismiarto, (2022)** assessed Mechanical Lateral Distal Femoral Angle (MLDFA), Medial Proximal Tibia Angle (MPTA), and Mechanical Axis Deviation (MAD) Value in Young Adults in North Sumatera. Their study revealed that the average mechanical lateral distal femoral angle (MLDFA) was 87,93 º ±2,16 º. The average medial proximal tibia angle (MPTA) was 86,28 º ±2,26 º. The average mechanical axis deviation (MAD) was 1.56±1,48 mm.

A study by **Luís and Varatojo, (2021)** conducted radiological assessment of lower limb alignment. Their study reported that the normal mLDFA range is approximately 87° ± 3° while the standard MPTA value is around 87° ± 3°.

These findings align with **Boero et al. (2011),** who reported full correction in idiopathic patients within 11 months and longer durations in pathological patients. Similarly, **Dai et al. (2021)** reported a 94.06% correction rate with a mean duration of 13.26 months.

Significant reductions in mTFA were observed, particularly on the right side, from 8.13° preoperatively to 1.65° post-correction (P = 0.0448). The degree of correction significantly increased over time, reaching 6.93 ± 5.94 on the right side and 6.12 ± 5.09 on the left side at the final follow-up. **Kumar et al. (2016)** noted similar findings, with eight-plates showing a statistically better correction rate for mLDFA compared to staples.

The significant increase in the degree of correction over time on both sides can be explained by the gradual growth modulation mechanism of 8-plate hemiepiphysiodesis. This technique selectively slows down the growth on the convex side of the deformity, allowing the concave side to catch up, leading to progressive realignment. As the treatment continues, the correction becomes more pronounced, with the most significant changes occurring as growth slows closer to skeletal maturity. This explains the significant differences between the 6-month and final follow-up, as the correction mechanism takes more time to fully influence bone remodeling and achieve substantial realignment **(Boero et al., 2011; Dai et al., 2021)**.

Complications included reoperation in 1 patient (5%), persistent pain in 1 patient (5%), and overcorrection in 3 patients (15%). No infections, implant breakage, or wound healing issues were observed. These results are consistent with studies by **Boero et al. (2011), Dai et al. (2021), and Zajonz et al. (2017),** which reported low complication rates.

The occurrences of overcorrection highlight the importance of precise plate placement and close follow-up to avoid excessive growth modulation **(Kemppainen et al., 2016; Vaishya et al., 2018).**

Limitations: The primary limitations of our study include the relatively small sample size, which may limit the generalizability of the findings, and the absence of a control group for comparison. Future studies with larger cohorts, longer follow-up periods, and randomized control designs are needed to validate and expand upon these findings.

Conclusion

The use of 8-plate hemiepiphysiodesis for managing coronal plane knee deformities in children near skeletal maturity proved to be an effective and safe technique, demonstrating significant improvements in angular deformities with a high success rate and minimal complications. Most participants achieved satisfactory correction within 18 months, with significant reductions in tibio-femoral angles and consistent improvement in mechanical alignment across follow-up periods. Complications were minimal, with no infections or implant-related issues, and wound healing was achieved in all patients. This method offers a reliable, minimally invasive approach for correcting deformities in growing children while preserving growth potential and maintaining joint function.

List of abbreviations

Abb	Full term
GG	Guided Growth
Lt	Left
Lt mLDFA	Left Mechanical Lateral Distal Femoral Angle
Lt MPTA	Left Medial Proximal Tibial Angle
Lt mTFA	Left Mechanical Tibiofemoral Angle
mTFA	Mechanical Tibio-Femoral Angle
ROM	Range Of Motion
Rt	Right
Rt mLDFA	Right Mechanical Lateral Distal Femoral Angle
Rt MPTA	Right Medial Proximal Tibial Angle
Rt mTFA	Right Mechanical Tibiofemoral Angle

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