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SYSTEMATIC REVIEW

Is eight-plate more effective than reconstruction plate in pediatric guided growth? A systematic review and meta-analysis

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Abstract

Introduction and objectives: Pediatric angular deformities in the lower limb need surgeries that are less invasive to correct deformities and prevent premature degenerative changes in the knee. Partial growth arrest, also known as hemiepiphysiodesis, relies on the growth potential of the unaffected side of the physis to facilitate gradual angular correction. Although recognized as an effective implant for this procedure, eight-plate is an expensive device that increases the economic burden for developing countries. There has been some debate about whether a cheaper implant, reconstruction-plate, is comparable in terms of its efficacy in children with angular deformities. **Methods:** A systematic search was conducted in line with the PRISMA guideline to identify relevant studies through the PubMed, Google Scholar, and Cochrane databases. A total of three studies (181 patients, 339 knees) were included, divided into five meta-analyses, which were processed using Review Manager 5.3. **Results:** Eight-plate and reconstruction-plate offer comparable efficacy in terms of lateral distal femur angle (LDFA) correction ($p = 0.30$, $I^2 = 99\%$, MD 3.38), medial proximal tibial angle (MPTA) correction ($p = 0.27$, $I^2 = 94\%$, MD 4.39), the implant failure rate ($p = 0.28$, $I^2 = 0\%$, OR 0.36), rebound rate ($p = 0.44$, $I^2 = 0\%$, OR 0.44), and complication rate ($p = 0.36$, $I^2 = 0\%$, OR 0.47). **Discussion:** Both internal and external factors should be monitored closely in hemiepiphysiodesis, as they may play a role in the success of the surgery. Internal factors include being overweight and physeal conditions. External factors include plate positioning, screw placement, and the screw tightening technique. Regular follow-up should also be given, as this may minimize the risk of overcorrection and the rebound rate. Reconstruction-plate resulted in comparable efficacy to eight-plate in terms of angular correction, implant failure rate, rebound rate, and complication rate.

Keywords: Eight-plate. Guided growth. Meta-analysis. Reconstruction-plate.

É a placa de oito mais eficaz do que a placa de reconstrução no crescimento guiado pediátrico? Uma revisão sistemática e meta-análise

Resumo

Introdução e objetivos: Deformidades angulares pediátricas nos membros inferiores necessitam de cirurgias menos invasivas para corrigir deformidades e prevenir alterações degenerativas prematuras no joelho. A parada parcial de crescimento, também conhecida como hemiepifisiodese, baseia-se no potencial de crescimento do lado não afetado da fise para facilitar a correção angular gradual. Embora reconhecida como um implante eficaz para este procedimento, a placa de oito é um dispositivo caro que aumenta o ônus econômico para países em desenvolvimento. Tem havido algum debate sobre se um

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implante mais barato, a placa de reconstrução, é comparável em termos de eficácia em crianças com deformidades angulares. **Métodos:** Uma busca sistemática foi conduzida de acordo com a diretriz PRISMA para identificar estudos relevantes através das bases de dados PubMed, Google Scholar e Cochrane. Um total de três estudos (181 pacientes, 339 joelhos) foram incluídos, divididos em cinco meta-análises, processadas usando o Review Manager 5.3. **Resultados:** A placa de oito e a placa de reconstrução oferecem eficácia comparável em termos de correção do ângulo distal lateral do fêmur (LDFA) (p = 0,30, I2 = 99%, MD 3,38), correção do ângulo tibial proximal medial (MPTA) (p = 0,27, I2 = 94%, MD 4,39), taxa de falha do implante (p = 0,28, I2 = 0%, OR 0,36), taxa de rebote (p = 0,44, I2 = 0%, OR 0,44) e taxa de complicações (p = 0,36, I2 = 0%, OR 0,47). **Discussão:** Tanto fatores internos quanto externos devem ser monitorados de perto na hemiepifisiodese, pois podem influenciar no sucesso da cirurgia. Fatores internos incluem sobrepeso e condições da fise. Fatores externos incluem posicionamento da placa, colocação dos parafusos e técnica de aperto dos parafusos. Acompanhamento regular também deve ser realizado, pois isso pode minimizar o risco de supercorreção e a taxa de rebote. A placa de reconstrução apresentou eficácia comparável à placa de oito em termos de correção angular, taxa de falha do implante, taxa de rebote e taxa de complicações.

Palavras-chave: Placa de oito. Crescimento guiado. Meta-análise. Placa de reconstrução.

Keypoints

What is known
- Pediatric angular deformities in the lower limb need surgeries that are less invasive to correct deformities and prevent premature degenerative changes.
- Hemiepiphysiodesis is a well-known procedure for this condition, often with the use of an eight-plate.
- There has been some debate about whether a cheaper implant, reconstruction-plate, is comparable in terms of its efficacy.

What is added
- This is the first meta-analysis to objectively compare the two implants for this condition.
- Reconstruction-plate had comparable efficacy to eight-plate in terms of angular correction, implant failure rate, rebound rate, and complication rate.
- Internal and external factors, as well as perioperative monitoring, are important for treatment success.

Introduction

The most common angular deformities of the lower limbs in children, genu varum and genu valgum, need surgeries that are less invasive to correct deformities and prevent premature degenerative changes in the knee. Surgical treatment depends on the degree of the deformity and the patient's skeletal maturity. Early diagnosis and an accurate choice of treatment is important to prevent the need for more invasive procedures, as osteotomy is linked to a higher risk of complications and a longer recovery. Deformity correction in skeletally immature patients can be achieved through temporary or permanent hemiepiphysiodesis, commonly known as guided growth. In guided growth, deformity correction is achieved by tethering the physis on the convex side of the deformity, while allowing the physis on the concave side of the deformity to continue to grow. The anticipated degree of correction depends on the patient's age and the location of the physis[1,2].

Stapling and transphyseal screws were introduced earlier as a treatment for pediatric angular deformity. However, this has been linked to iatrogenic physeal arrest, implant migration, and irreversibility[3]. Later, a newer treatment, tension-band plates, commonly known as the eight-plate, were adopted by many orthopedic surgeons. The eight-plate is a two-hole plate that is fixed to the deformed bone at the physis, with screws inserted proximal and distal to it. Although recognized as an effective implant for this procedure, the eight-plate is an expensive device that increases the economic burden for developing countries. The price of an eight-plate can reach up to 20 times the price of a reconstruction-plate, making reconstruction-plate use an appealing alternative for healthcare fund providers[3]. There has been some debate about whether the cheaper implant, reconstruction-plate, is comparable in terms of its efficacy in children with angular deformities[4].

To date, there have not been many studies comparing the efficacy of both implants. Through this study, we aim to objectively compare the efficacy and complications of pediatric angular correction using the eight-plate and reconstruction-plate.

Materials and methods

This study was registered in PROSPERO (CRD42023410685). The study design was a meta-analysis of randomized controlled trial and a non-randomized comparative study. A systematic search was conducted based on the PRISMA (Preferred Reporting Items for Systematic

Table 1. PICO table describing inclusion and exclusion criteria

	Inclusion criteria	Exclusion criteria
Population	Pediatric angular deformity of the knee, diagnosed through clinical and radiological studies	Non-human studies Less than six months of follow up
Intervention and comparison	Operative treatment of hemiepiphysiodesis using eight-plate or reconstruction-plate	Non-operative treatment Hemiepiphysiodesis with other types of implant
Outcome	LDFA correction MPTA correction Implant failure rate Rebound rate Complication rate	No outcome mentioned or different outcomes
Publication	Primary research published in English in a peer-reviewed journal	Abstracts, editorials, letters Duplicate publications of the same study/cohort that do not report on different outcomes Conference presentations or proceedings
Design	Randomized controlled trials Cohort studies	Case reports or series Review articles

PICO: population, intervention, comparison, and outcome.

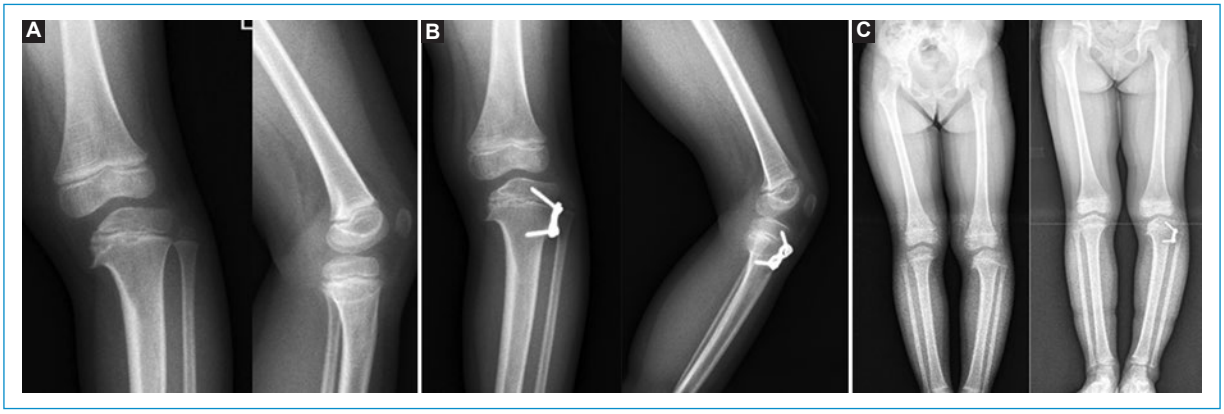

Figure 1. Plain knee X-Ray of a patient with blount disease, treated with emiepiphysiodesis using reconstruction-plate. **A:** before surgery. **B:** at seven months follow-up. **C:** comparative scanogram *(courtesy of Maharjana MA)*.

Reviews and Meta-Analyses) guideline from September 2022 to March 2023 to identify relevant studies through the PubMed, Google Scholar, and Cochrane databases. The following keywords were used: "eight-plate" AND "reconstruction plate" AND "guided-growth" AND "outcome".

The titles and abstracts of the articles found were then manually scanned and reviewed by each of the authors. The full text of relevant articles was subsequently extracted and carefully selected according to the following inclusion criteria: (1) studies including a comparative design for eight-plate versus reconstruction-plate in pediatric angular deformity of the knee, whether in retrospective, prospective, as well as randomized controlled and observational studies; (2) studies reporting a clinically and/or radiologically desirable outcome with either continuous or dichotomous variables; (3) studies in English with any publication year. Exclusion criteria were adult patients, patients with trauma, malignancy, a history of previous surgery, and patients receiving other treatment methods. Duplicate publications, noncomparative studies, non-human in vivo and in vitro studies, and articles in languages other than English were also excluded. The inclusion and exclusion criteria are described in the Population, Intervention, Comparison, and Outcome (PICO) table below (Table 1). Critical appraisal was then performed on potential studies based on the

Figure 2. Plain knee X-Ray of a patient with post-traumatic genu valgum, treated with hemiepiphysiodesis using reconstruction-plate. **A:** before surgery. **B:** at nine months follow-up. **C:** comparative scanogram *(courtesy of Maharjana MA).*

Table 2. Studies included in the analysis

No.	Reference	Journal	Study design	Level of evidence
1	Jamil et al. (2021)	Malaysian Orthopaedic Journal	Cohort Retrospective	III
2	Ghaznavi et al. (2022)	The Archives of Bone and Joint Surgery	Cohort Retrospective	III
3	Park et al. (2017)	Journal of Orthopaedic Science	Cohort Retrospective	III

Joanna Briggs Institute (JBI) Checklist for Systematic Reviews and Research Syntheses.

Extracted data was collected under the basic characteristics and outcomes using designated tables in Microsoft Excel (Microsoft Corp., Redmond, WA, USA) for all of the studies identified and included. When the data was available, a quantitative analysis was performed using Review Manager (RevMan, computer program ver. 5.3, the Cochrane Collaboration, 2014; The Nordic Cochrane Center, Copenhagen, Denmark). Outcomes were presented in the form of forest plots. The mean difference for continuous outcomes and an odds ratio (OR) for dichotomous outcomes with a 95% confidence interval (CI) was calculated in each study. A fixed-effects model was used when heterogeneity (I^2) was < 50%, whereas a random-effects model was used when heterogeneity was > 50%.

Results

A total of three studies (181 patients, 339 knees) were included, divided into five forest-plot analyses. All of the studies used have a retrospective study design (Level III evidence) (Table 2). Critical appraisal based on the Joanna Briggs Institute Scoring System showed that none of the studies had more than four invalidity criteria.

The sample age ranged from three to 16 years old, with males comprising most of the study population (male: female = 54.7%:45.3%). Eight-plate was used in 153 knees (45.13%), while 186 knees were treated with reconstruction-plate (54.87%). Syndromic as well as idiopathic genu valgum and genu varus were included in the analysis. The distal femur was the most common region for plate application (281 knees/82.89%). The time to implant removal varies from five to 68.5 months, and the follow-up time ranged from seven to 104 months after implant removal. Body Mass Index (BMI) ranged from 18.7 – 28 in both groups (Tables 3 and 4).

For lateral distal femur angle (LDFA) correction, two studies were included in the analysis, with a total of 93 patients treated with eight-plate and 123 patients treated with reconstruction-plate. Eight-plate and reconstruction-plate offer comparable efficacy in terms of

Table 3. General characteristics of the studies included in the analysis

No.	References	Sample size	Implant selection		Pathology	Mean age (years)		Sex		Region	Time to implant removal	Follow up
			8-plate	Recon plate		8-plate	Recon plate	8-plate	Recon plate			
1	Jamil et al. (2021)	17 patients (27 knees)	24	3	Down's syndrome: 2 Idiopathic genu valgus: 2 Tibia vara: 23	4 (3-6)		F = 5 (29.4%) M = 12 (70.6%)		Distal femur: 4 Proximal tibia: 23	20.5 months (13.75-25.5 months)	12-104 months after implant removal
2	Ghaznavi et al. (2022)	109 patients (212 knees)	90	122	Idiopathic genu valgum in all patients	11.9 ± 5 (9-16)		F = 58 (53.2%) M = 51 (46.8%)		Distal femur in all patients	11.3 + 3 months (5-18 months)	32.9 + 15.1 months (7-74 months)
3	Park et al. (2017)	55 patients (100 knees)	39	61	Idiopathic genu valgum: 15 Rickets: 14 Multiple osteochondromatosis: 11 Blount disease: 8 Post-traumatic: 6 Others: 7	7.5	8.6	F = 9 (45%) M = 11 (55%)	F = 10 (28.6%) M = 25 (71.4%)	Distal femur: 65 Proximal tibia: 35	Time to angular correction: 13.7 months (12.7-31.3 months) in 8-plate and 19.7 (11.4-68.5 months) in Recon plate	14 months (12-20 months) after implant removal

Table 4. Characteristics of study outcomes

No.	References	Mean BMI (kg/m^2)		Outcome measurements									
				LDFA correction		MPTA correction		Failure rate		Rebound rate		Complication rate	
		8-plate	Recon plate	8-plate	Recon plate	8-plate	Recon plate	8-plate	Recon plate	8-plate	Recon plate	8-plate	Recon plate
1	Jamil et al. (2021)	26 (25-28)		0.67°/month		0.71° / month		8.3%	33.3%	8.3%	0%	-	
2	Ghaznavi et al. (2022)	22.4 ± 1.8		8° ± 3.7°	7.9° ± 3.5°	2.7° ± 3.7°	2.1° ± 3.4°	0%	0.8%	-		1.1%	3.3%
3	Park et al. (2017)	18.7	22.7	9° (1.03°/month)	9.9° (0.77°/month)	7.1°	9°	0%	1.6%	0%	3.3%	2.6%	3.3%

Figure 3. Plain scanogram and knee X-Ray of a patient with rachitic genu valgum, treated with bilateral hemiepiphysiodesis using eight-plate. **A:** before surgery. **B:** after surgery *(courtesy of Maharjana MA).*

Figure 4. Plain post-operative scanogram and knee X-Ray of a patient with idiopathic genu valgum, treated with distal femur and proximal tibia hemiepiphysiodesis using eight-plate *(courtesy of Maharjana MA).*

LDFA correction (I^2 = 99%; weighted mean difference (WMD) 3.38; 95% CI, –3.06 to 9.82; p = 0.30). In the analysis for medial proximal tibial angle (MPTA) correction in 235 patients, both implants also showed comparable efficacy (I^2 = 94%; WMD 4.39; 95% CI, –3.47 to 12.26; p = 0.27).

Dichotomous variables were also analyzed, where a fixed effects model was used in three forest plots. For implant failure rate, three studies were included in the analysis, comprising 153 patients in the eight-plate group and 186 patients in the reconstruction-plate group. Both implants were proved to have a comparable implant failure rate (I^2 = 0%; OR 0.36; 95% CI, 0.06 to 2.28; p = 0.28).

The rebound rate of angular deformity was analyzed through a total of 63 patients treated with the eight-plate and 64 patients treated with the reconstruction-plate. There are two patients in the eight-plate group with rebound and two patients in the reconstruction-plate group with rebound. The forest plot analysis showed a comparable rebound rate between the two procedures (I^2 = 0%; OR 0.44; 95% CI, 0.05 to 3.58; p = 0.44).

The last analysis differentiates the rate of complications between patients treated with the eight-plate and the reconstruction-plate. Through 129 patients treated with the eight-plate and 183 patients treated with the reconstruction-plate, it was found that the rate of complications did not vary significantly (I^2 = 0%, OR 0.47; 95% CI, 0.09 to 2.36; p = 0.36). Park et al. (2017), found one implant failure (screw breakage) in his study of the reconstruction-plate group, and one superficial infection in both groups. Ghaznavi et al. (2022) recorded five complications in total, where the eight-plate group had a case of screw loosening, and the reconstruction-plate group had a screw loosening, two overcorrections, and one screw breakage.

Discussion

The use of reconstruction-plate in the treatment of pediatric angular deformity of the knee is recognized (Figs. 1 and 2). However, research comparing it with the widely-recognized eight-plate has not been discussed often. The use of reconstruction-plates has been acknowledged to be an innovative surgical implant compared to older osteotomy techniques in terms of surgical duration, complications, and the invasiveness of the procedure[6]. The successfulness of the reconstruction-plate was also addressed in another study by Ghaffari (2020), where a modulated growth of eight degrees bilateral genu valgum without previous intervention was treated with a distal femoral and proximal tibial two-hole reconstruction-plate and achieved complete correction at eight months, when the implant was removed[7]. Another study also mentioned the successful correction of 86% of angular deformity using reconstruction-plate with a failure rate in 10% of the subjects, with screw failure or plate failure[8]. In another study with a bigger sample, it was found that 61.5% of varus knees and 85.2% of valgus knees were able to be corrected with a two-hole reconstruction-plate. Correction failure in the study was bigger in varus knees compared to valgus knees (38.5% vs. 14.8%). This study divided the physis of the patients into normal physes and sick physes, and the complication rate was significantly higher in sick physes (81.8% vs. 18.2%), where rebound and implant failure were only found in the sick physis group[3].

Various factors are attributed to the hardware failure, patients' factor, and technical factors. Suggested patients' factors may include obesity combined with sick physis, which may cause abnormal growth motion of the physis. This suggested factor was shown in the Jamil et al. (2021) study where the screw failure happened in a 13-year-old boy with a BMI of 32. Technical factors may include the small screw diameter and poor plate contouring. To prevent against hardware failure, the author suggests a three-hole plate instead of two-hole to increase screw divergence. Proper screw tightening by alternating tightening may provide better plate attachment to the bone. To avoid rebound, a proposed technique of 3°-5° overcorrection with the eight-plate may be used[1]. In regard to the complications for both methods, Park et al. (2017) recorded one patient with a BMI of 37.8 kg/m^2. A research paper by Burghardt et al. reported that the eight-plate implant failure consisted of a screw breakage and a combination of Blount disease with high BMI as the suspected cause. Multiple studies suggested that cannulated screws were reported to be weaker than a solid cortical screw. However, in his study, the screw that was broken was the cortical screw, which had the same diameter as the cannulated screw. Hence, the strength of the cortical screw and cannulated screw need to be studied in more detail to decide which one is better for applying hemiepiphysiodesis[2,9].

Soft tissue infection is another complication described in literature, where Park et al. suggested that soft tissue infection was caused by the thickness of the reconstruction-plate impacting patients' knee motion. Certain measures can be taken to prevent soft tissue problems, such as proper tightening of the screws and optimal contouring of the plate to provide proper plate to bone contact[2].

It is true that in a large study comparing the eight-plate (tension-band plate) with other more conventional methods, such as percutaneous screws, stapling, and osteotomies, the efficacy of the tension-band plate has been proven[10]. Jamil et al. (2021) stated that the eight-plate is less invasive, reversible,

easily inserted, and removed with minimal damage to the physis and periosteum (Figs. 3 and 4). In a patient with a sick physis, such as skeletal dysplasia or Blount disease, the correction rate of hemiepiphyiodesis with the eight-plate may be slower, but the rate of hardware failure is no different when compared to the reconstruction-plate[10]. The rate of correction in patients treated with an eight-plate shows an auspicious result where the average MPTA and LDFA correction is 8.6° while the studies included in this meta-analysis only correct MPTA and LDFA at 7.6 and 8-9, respectively[11]. Furthermore, a study by Boero et al. (2011) mentioned that the rate of correction might be slower in pathological physis due to physeal compromise (e.g. in dysplasias and endocrinopathies), resulting in the need for early intervention and possible repeated treatment procedures[12]. In a larger study of 135 physes, the success rate reached 94.06% with no rebound complications or risk factors[13]. In a study by Martinez et al., the eight-plate was proven to provide better correction compared to screw and suture (0.54° vs 0.45° per month, p = 0.33)[14].

Despite its advantages, the eight-plate is five times more expensive than the reconstruction-plate. Patient satisfaction combined with cost-effective treatments will lead to a well-organized and effective environment for every aspect of the healthcare industry, from patients, healthcare providers, and governments, who play a significant role in funding treatments[1]. Our findings suggest that the reconstruction-plate offers similar efficacy in angular correction as well as a comparable rebound, complication, and implant failure rate. This study has several limitations: (1) All three studies included in the analysis were of level III evidence. However, we have ensured that these studies were of high quality and eligible to be included in this meta-analysis; (2) The heterogeneity of some analysis was > 50%, and this may contribute to analysis bias. This issue may be the result of the different patient characteristics in the two studies involved, where Jamil et al. (2021) also included syndromic conditions with more correction-resistant sick physes whereas the sample in Ghaznavi et al. (2022) was exclusive to idiopathic conditions. The mean age also varies, where Jamil et al. (2021) included younger patients up to three years of age, while the youngest sample in the study by Ghaznavi et al. (2022) had a mean age of 11.9 years old. This leads to our recommendation to apply these results with caution, especially in young patients with syndromic deformities. However, this study also has several advantages: (1) To our knowledge, this is the first meta-analysis to objectively compare eight-plate and reconstruction-plate for pediatric guided growth; (2) Outcomes were thoroughly assessed, in terms of several outcome measures, aiming to describe as many aspects as possible to be considered in treating such cases. It is hoped that this study could serve as an influential bridge to future research with larger sample sizes and some cost analysis, as well as a clinical guideline for choosing surgical therapeutic approaches for pediatric patients receiving guided growth treatment.

Conclusion

Reconstruction-plate offers comparable efficacy to eight-plate in terms of angular correction, implant failure rate, rebound rate, and complication rate.

Authors' contribution

Anak Agung Ngurah Krisna Dwipayana and Sherly Desnita Savio: Performed the selection of literature to be included in the study, performed systematic and meta-analysis, and discussed with the other authors about how to formulate the discussion and conclusion. Read and approved the final manuscript.

Made Agus Maharjana: Supervision of the literature selection, discussed with the other authors about how to formulate the discussion and conclusion. Read and approved the final manuscript.

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Conflicts of interest

None.

Ethical disclosures

Protection of human and animal subjects. The authors declare that no experiments were performed on humans or animals for this study.

Confidentiality of data. The authors declare that no patient data appear in this article. Furthermore, they have acknowledged and followed the recommendations as per the SAGER guidelines depending on the type and nature of the study.

Right to privacy and informed consent. The authors declare that no patient data appear in this article.

Use of artificial intelligence for generating text. The authors declare that they have not used any type of generative artificial intelligence for the writing of this manuscript, nor for the creation of images, graphics, tables, or their corresponding captions.

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