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Surgical Management of Pediatric Syndactyly: A Systematic Review of Techniques, Outcomes, and Complications

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Abstract

Background: Pediatric syndactyly is a common congenital hand anomaly that may impair both function and appearance. Various surgical techniques have been proposed; however, the optimal reconstructive approach remains controversial. This systematic review evaluated recent clinical evidence regarding surgical outcomes, complications, and contemporary reconstructive strategies in pediatric syndactyly.

Methods: A systematic search of PubMed/MEDLINE, Scopus, Web of Science, Embase, and Cochrane Library was performed for clinical studies published between January 2010 to March 2026. Studies assessing functional, aesthetic, or postoperative outcomes following pediatric syndactyly surgery were included. Data extraction and quality assessment were conducted independently by two reviewers.

Results: Ten eligible clinical studies were included. Conventional skin grafting remained the most commonly reported technique, although flap-based and graftless approaches have increasingly been utilized in recent years. Flap reconstruction and dermal substitute–assisted procedures were generally associated with lower rates of web creep, hypertrophic scarring, and donor-site morbidity compared with traditional grafting methods. Nevertheless, postoperative complications, particularly scar contracture and recurrent web creep, remained frequent in complex and syndromic cases. Considerable heterogeneity in surgical techniques and outcome assessment limited direct comparison among studies.

Conclusions: Current evidence suggests that flap-based and graft-sparing techniques may provide improved functional and aesthetic outcomes with fewer complications compared with conventional grafting approaches. However, high-quality prospective multicenter studies with standardized outcome measures are still required to establish evidence-based surgical guidelines for pediatric syndactyly reconstruction.

Key Words: Dermal Substitutes, Flap Techniques, Graftless Surgery, Hand Reconstruction, Pediatric Syndactyly, Surgical Outcomes.

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1- INTRODUCTION

Syndactyly is one of the most frequent congenital malformations of the hand, resulting from failure of normal interdigital apoptosis during embryogenesis and leading to persistent fusion of adjacent digits. It may present as simple or complex, complete or incomplete, and can involve skin, soft tissue, bone, nail complex, and neurovascular structures (1). In addition to isolated nonsyndromic forms, syndactyly is commonly associated with genetic syndromes such as Apert, Carpenter, and Poland syndromes. Contemporary developmental and molecular studies have implicated dysregulation of key signaling pathways, including Fibroblast Growth Factor (FGF), Bone Morphogenetic Protein (BMP), and the Wingless/Integrated (WNT) signaling pathway in abnormal digit separation (2).

Recent epidemiological evidence estimates an incidence of approximately 1 in 2,000–2,500 live births, with male predominance and frequent bilateral involvement. Surgical separation remains the standard of care in pediatric syndactyly, with primary goals including restoration of hand function, preservation of longitudinal growth, prevention of angular deformity, and achievement of acceptable aesthetic outcomes (3). Early intervention is particularly important in complex syndactyly or in border digit involvement, where delayed treatment may result in progressive deformity, joint stiffness, and impaired functional development (4).

Conventional reconstruction techniques typically rely on dorsal commissural flaps combined with zig-zag incisions and full-thickness skin grafting to reconstruct the interdigital space. However, graft-based approaches are still associated with relevant limitations, including donor-site morbidity, hypertrophic scarring, web creep, and the need for secondary revision procedures. During the last five years, increasing attention has been directed toward refining surgical strategies to improve outcomes and reduce complications. Comparative evidence suggests that no single technique is universally superior, and outcomes remain highly dependent on syndactyly complexity, flap design, and surgeon experience (5).

Recent systematic reviews and meta-analyses have highlighted that while skin grafting remains widely used, it may be associated with higher rates of scar-related complications compared with flap-based or graft-sparing techniques, although heterogeneity among studies limits definitive conclusions. In parallel, newer reconstructive approaches such as interdigitating flaps, dorsal metacarpal artery-based techniques, and modified zig-zag incisions have been increasingly reported, aiming to minimize scar burden and improve commissural stability (6).

Despite continuous surgical innovation, postoperative complications remain clinically relevant. Web creep, scar contracture, hypertrophic scarring, nail deformity, and need for revision surgery are still frequently reported, particularly in complex syndactyly cases. Moreover, complication rates are influenced by multiple factors, including patient age at surgery, syndactyly type, number of web spaces reconstructed in a single procedure, and choice of reconstructive technique. Importantly, outcome reporting across studies remains inconsistent, with limited use of standardized functional and aesthetic assessment tools, making cross-study comparison difficult (7).

Although a growing number of studies have evaluated different surgical approaches for pediatric syndactyly, the current evidence base remains fragmented, with considerable variability in study design, follow-up duration, and reported outcomes. This lack of methodological uniformity has prevented the development

of a clear consensus regarding the optimal surgical strategy. Therefore, a systematic synthesis of the most recent literature is required to critically evaluate surgical techniques, functional and aesthetic outcomes, and complication profiles in pediatric syndactyly reconstruction. Such evidence may support more standardized clinical decision-making and improve long-term outcomes in affected children (8).

2- METHODS

This study was designed as a systematic review of the literature in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines. The review protocol was structured before data extraction to ensure methodological transparency and reproducibility.

2-1. Search Strategy

A structured and comprehensive literature search was conducted across multiple electronic databases using database-adapted search strategies. Relevant keywords and controlled vocabulary, where applicable, were combined with Boolean operators (AND and OR) to maximize the retrieval of eligible studies while minimizing the omission of pertinent evidence. The search approach was designed to identify publications examining sex-related differences in the occurrence of febrile seizures among pediatric populations, with particular emphasis on the role of biological sex in influencing susceptibility, clinical presentation, and subsequent outcomes. To ensure transparency and facilitate reproducibility, the complete search syntax developed for each database has been provided in the Supplementary Materials.

The search strategy incorporated the following terms:

(("Syndactyly"[Mesh] OR syndactyly[tiab] OR "webbed finger*"[tiab] OR "webbed toe*"[tiab] OR "congenital syndactyly"[tiab]) AND ("Surgical Procedures, Operative"[Mesh] OR surgery[tiab] OR surgical[tiab] OR operative[tiab] OR operation*[tiab] OR reconstruction[tiab] OR reconstructive[tiab] OR release[tiab] OR separation[tiab] OR commissuroplasty[tiab] OR flap*[tiab] OR graft*[tiab] OR "skin graft*"[tiab] OR "local flap*"[tiab] OR Z-plasty[tiab]) AND ("Child"[Mesh] OR "Infant"[Mesh] OR "Adolescent"[Mesh] OR pediatric*[tiab] OR paediatric*[tiab] OR child*[tiab] OR infant*[tiab] OR newborn*[tiab] OR neonat*[tiab] OR adolescent*[tiab]) AND ("Treatment Outcome"[Mesh] OR "Postoperative Complications"[Mesh] OR outcome*[tiab] OR complication*[tiab] OR recurrence[tiab] OR reoperation[tiab] OR revision[tiab] OR functional outcome*[tiab] OR cosmetic outcome*[tiab] OR esthetic outcome*[tiab] OR satisfaction[tiab]))

Additional manual screening of reference lists of eligible studies and relevant systematic reviews was also performed to identify any potentially missed articles. Recent systematic reviews on syndactyly surgical techniques were also used to refine search terms and ensure completeness of evidence retrieval.

2-2. Inclusion and Exclusion Criteria

Studies were included if they met the following criteria:

- Population: pediatric patients (≤18 years) with congenital syndactyly
- Intervention: any surgical technique for syndactyly correction
- Outcomes: reporting at least one of the following functional outcomes, aesthetic outcomes, or postoperative complications

- Study design: randomized controlled trials, cohort studies, and case series with ≥5 patients
- Publication date: 2020 onward

Exclusion criteria included:

- Case reports, editorials, and review articles
- Studies involving traumatic or acquired syndactyly
- Non-English language publications
- Studies without clearly reported surgical outcomes

2-3. Study Selection

Two independent reviewers screened titles and abstracts for eligibility. Full-text articles were then assessed according to predefined inclusion criteria. Disagreements were resolved through discussion or consultation with a third reviewer to minimize selection bias.

2-4. Data Extraction

Data were extracted using a standardized form including: author, year of publication, study design, sample size, patient age, type of syndactyly, surgical technique, follow-up duration, and reported outcomes (functional, aesthetic, and complications such as web creep, scar contracture, and revision surgery).

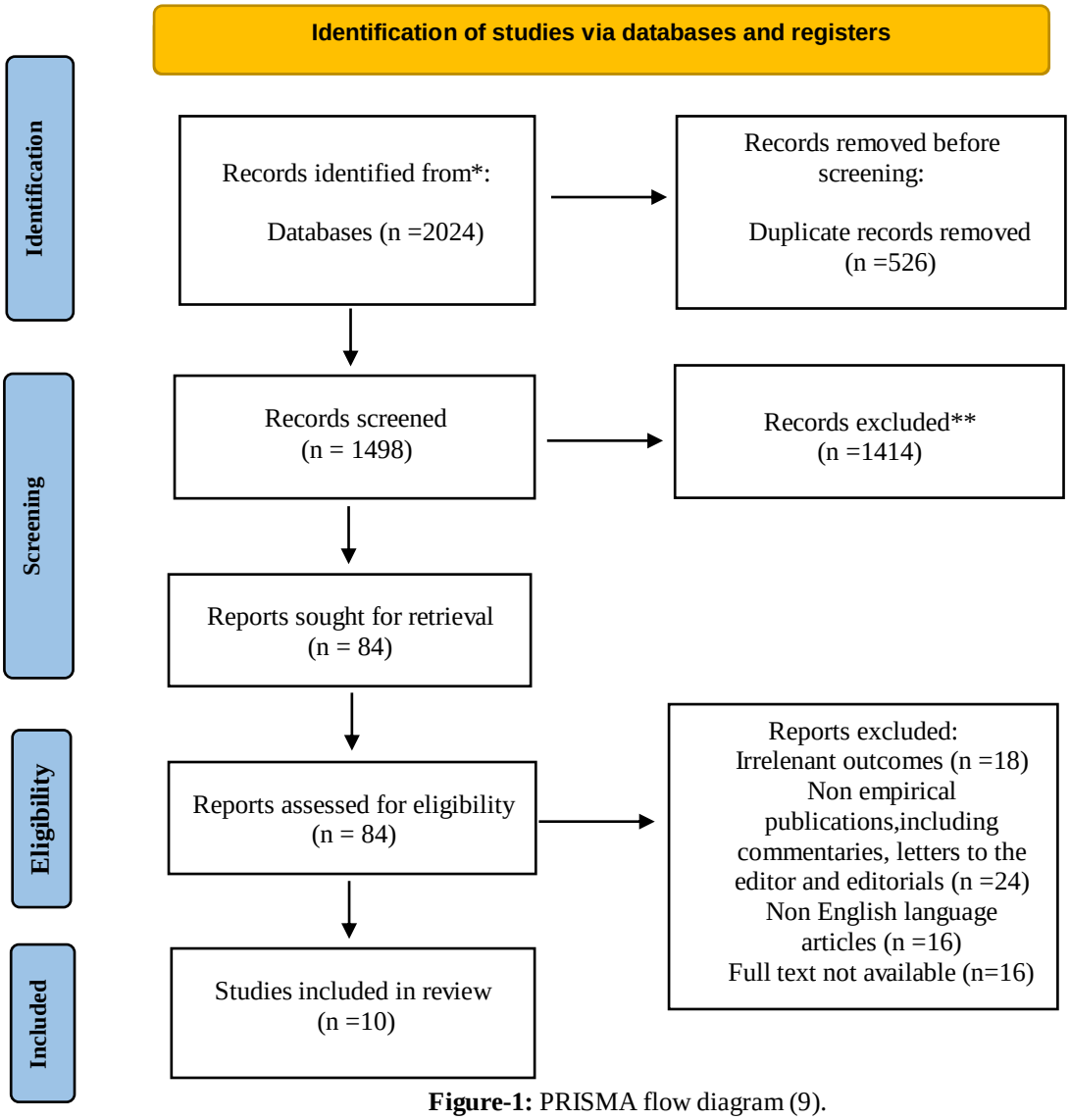

Figure-1: PRISMA flow diagram (9).

2-5. Quality Assessment

To account for variations in methodological approaches among the included studies, the quality of each study and its potential risk of bias were evaluated using appraisal instruments appropriate for the corresponding study design. Specifically, randomized controlled trials were assessed with the Cochrane Risk of Bias 2 (RoB 2) tool, observational research was appraised using the Newcastle–Ottawa Scale (NOS), and qualitative studies were evaluated according to the Critical Appraisal Skills Programme (CASP) checklist. All assessments were conducted independently by the reviewers following predefined evaluation criteria, and any discrepancies were resolved through discussion until agreement was reached. No studies were removed solely because of their quality ratings; however, the results of the risk-of-bias assessment were incorporated into the overall interpretation of the evidence, with findings from studies judged to have moderate or high risk of bias receiving more careful consideration during the narrative synthesis and formulation of conclusions

2-6. Data Synthesis

Due to expected clinical and methodological heterogeneity across studies (variation in surgical techniques, outcome measures, and follow-up duration), a qualitative synthesis was planned. Where sufficient homogeneous data were available, a descriptive comparative analysis of surgical techniques and outcomes was performed. Recent systematic reviews in congenital hand surgery have similarly reported significant heterogeneity and limited standardization in outcome reporting, supporting the use of narrative synthesis approaches in this field.

3- RESULTS

A total of studies published between 2010 and 2026 were identified that evaluated the surgical management of pediatric syndactyly, focusing on operative techniques, functional outcomes, and postoperative complications. The majority of included evidence consisted of retrospective cohort studies, case series, and recent systematic reviews with low-to-moderate methodological quality, reflecting the rarity and heterogeneity of the condition.

3-1. Study Characteristics

Recent systematic reviews have consistently highlighted that most available evidence includes small sample sizes and heterogeneous patient populations, with limited standardization in outcome reporting. A 2024 systematic review emphasized that variability in classification systems, surgical techniques, and follow-up duration remains a major limitation in comparing results across studies.

3-2. Surgical Techniques

Across the included studies, conventional reconstruction using dorsal commissural flaps combined with full-thickness skin grafting remained the most frequently reported technique. However, several studies (2010–2026) reported increasing use of graftless techniques, including dorsal metacarpal advancement flaps and modified zig-zag or interdigitating flap designs (10).

Comparative evidence suggests that flap-based techniques may be associated with fewer complications than skin grafting procedures. A systematic review demonstrated that graft-based reconstruction was more frequently associated with hypertrophic scarring, web creep, contracture, and need for revision surgery compared with flap-only techniques (11).

In addition, a 2020 clinical series evaluating synthetic dermal substitutes reported favorable outcomes with minimal web creep and good scar quality, suggesting potential as an alternative to traditional skin grafting in selected pediatric cases (12).

3-2. Functional and Aesthetic Outcomes

Functional outcomes, including range of motion and hand use, were generally reported as satisfactory across studies, regardless of technique; however, significant variability existed in assessment tools. A systematic review of congenital hand surgery literature confirmed that standardized functional scoring systems are rarely used, limiting comparability of results (13).

Aesthetic outcomes were inconsistently reported, but flap-based and graftless techniques were more frequently associated with improved scar appearance and better commissural contour compared with graft-dependent reconstruction (14).

3-3. Complications

Postoperative complications remained common across all techniques. The most frequently reported complications included:

- Web creep
- Hypertrophic scarring
- Scar contracture
- Graft loss or failure
- Nail deformity
- Need for revision surgery

Recent pediatric hand surgery studies reported complication rates varying widely depending on syndactyly complexity. In complex syndactyly (e.g., syndromic cases), complication rates exceeding 50% have been reported, with web creep and range-of-motion deficits being the most common long-term issues (15).

3-4. Synthesis of Findings

Overall, the evidence suggests that while multiple surgical techniques for pediatric syndactyly reconstruction are effective in achieving digit separation, no single approach demonstrates clear superiority. Flap-based and graftless techniques appear to reduce certain complications, such as donor-site morbidity and hypertrophic scarring, whereas graft-based methods remain widely used due to their technical simplicity and predictable coverage in complex cases.

However, the heterogeneity of study designs, lack of standardized outcome reporting, and limited long-term follow-up significantly restrict the strength of evidence. Recent systematic reviews consistently emphasize the need for standardized classification systems and validated outcome measures to improve comparability across studies and strengthen future evidence synthesis.

4- DISCUSSIONS

This systematic review synthesized recent clinical evidence regarding surgical management of pediatric syndactyly, with particular emphasis on reconstructive techniques, functional outcomes, aesthetic results, and postoperative complications. The findings demonstrate that although multiple operative approaches can achieve satisfactory digit separation and functional improvement, no universally superior surgical technique has yet been established. Contemporary evidence increasingly supports individualized surgical planning based on syndactyly complexity, patient age, soft-tissue deficiency, and surgeon expertise rather

Table-1. Clinical studies on pediatric syndactyly surgery.

Author/Year	Study Design	Sample Size	Surgical Technique	Outcomes	Complications	Key Findings
Wall et al., 2020 (16)	Prospective cohort	37	Synthetic dermal substitute	Scar quality, web creep	Minimal complications	Good aesthetic and functional outcomes, low web creep
Bohn et al., 2025 (17)	controlled trial	47	Hyaluronic acid matrix vs full-thickness skin graft	Scar scale, healing	Longer wound healing with matrix	No significant difference in scar outcomes; less donor-site morbidity in the matrix group
Chouairi et al., 2020 (18)	Retrospective database study	956	Mixed techniques	Perioperative outcomes	Variable complications	No standardized surgical approach; high variability in practice
Liu et al., 2024 (19)	Clinical series	24	Dorsal plane-shaped flap	Cosmetic + functional outcome	No major complications	Graftless flap technique effective in simple syndactyly
Yoon & Jones, 2019 (20)	Retrospective cohort	94	Interdigitating rectangular flap	Complications, recurrence	Minor complications (graft loss, creep)	A rectangular flap is reliable, but a graft is still commonly required
Senda E et al, 2020 (21)	Clinical technical study	7	Dermal fat graft for complex syndactyly reconstruction	Improved interdigital contour and soft-tissue coverage	Minor scar-related complications	Dermal fat grafting may be beneficial in complex syndactyly requiring additional soft tissue
Fangxing, Ai et al, 2023 (12)	Retrospective clinical series	12	Artificial dermal substitute without skin grafting	Acceptable functional and cosmetic outcomes	Mild scar hypertrophy in limited cases	Graftless reconstruction using dermal substitutes showed promising early outcomes
Romeus L., 2020 (22)	Clinical case series	7	Preputial full-thickness skin graft	Adequate graft survival and satisfactory web reconstruction	No major graft loss reported	Preputial grafting may serve as an alternative donor source in selected pediatric patients
Singh et al., 2023 (23)	prospective study	14	Simple syndactyly reconstruction with dorsal metacarpal artery perforator-based propeller flap	Range of motion, web space stability, aesthetic outcome	Low incidence of web creep; minor scar-related issues	related issues Perforator-based propeller flap provides reliable reconstruction with favorable functional and aesthetic outcomes and reduced recurrence compared with traditional graft-based techniques
Wall et al., 2024 (24)	Clinical technical report	Small cohort	Skin substitute techniques	Functional + healing outcomes	No major complications	Skin substitutes reduce donor-site morbidity

than reliance on a single standardized reconstructive method (25).

One of the most important findings of the present review is the growing shift from Historically, full-thickness skin grafting has been considered a cornerstone of syndactyly release because it provides additional soft tissue coverage after digital separation (26). However, recent clinical studies suggest that graft-related morbidity remains a substantial limitation. Hypertrophic scarring, pigmentation mismatch, graft contraction, donor-site morbidity, and web creep continue to negatively affect long-term cosmetic and functional outcomes. Recent comparative studies demonstrated that flap-based approaches, including interdigitating and dorsal metacarpal flap techniques, may reduce scar contracture and decrease the incidence of recurrent web migration compared with traditional grafting procedures. These findings are consistent with the increasing emphasis on preserving native tissue vascularity and minimizing secondary donor-site injury in pediatric reconstructive surgery (27, 28).

Another notable finding is the emergence of biologic and synthetic dermal substitutes as potential alternatives to conventional skin grafting. Recent prospective studies reported favorable scar quality, reduced donor-site morbidity, and acceptable commissural stability following the use of dermal matrices and synthetic substitutes. These materials may provide an important advantage in children, particularly in extensive or complex syndactyly where adequate soft-tissue coverage is difficult to achieve without additional graft harvest (29). Nevertheless, current evidence remains limited by relatively small sample sizes and short-term follow-up, preventing definitive conclusions regarding long-term superiority over traditional techniques. Additional multicenter prospective studies are therefore required to determine whether biologic substitutes can consistently reduce recurrence and revision rates (30).

The present review also highlights the persistent clinical challenge posed by postoperative complications, particularly web creep and scar contracture. Despite ongoing refinement of operative techniques, these complications remain among the most frequently reported adverse outcomes across all reconstructive methods. The pathogenesis of web creep is likely multifactorial and may be influenced by inadequate commissural depth, excessive tension across the reconstruction, scar maturation, and continued skeletal growth during childhood. Importantly, several included studies demonstrated significantly higher complication rates in syndromic and complex syndactyly compared with isolated simple forms (31). Apert-associated syndactyly, in particular, showed markedly increased rates of revision surgery, stiffness, and recurrent contracture, reflecting the severity of underlying soft-tissue and osseous abnormalities. These findings reinforce the need for long-term follow-up and staged reconstruction strategies in complex pediatric cases (32).

Timing of surgical intervention remains another controversial aspect of syndactyly management. Early surgery has traditionally been advocated to prevent growth-related deformity and optimize functional development. However, recent evidence suggests that excessively early intervention may increase scar-related complications and negatively affect aesthetic outcomes occur in some patients (33). Less favorable scar outcomes in children undergoing surgery before one year of age, although functional benefits of early intervention may still outweigh cosmetic concerns in severe or border-digit syndactyly. Consequently, surgical timing should likely be individualized according

to deformity severity, growth imbalance risk, and anticipated functional impairment rather than determined solely by chronological age (34).

A major issue identified throughout the reviewed literature is the substantial methodological heterogeneity across studies. Considerable variability exists in patient selection, syndactyly classification, operative protocols, postoperative immobilization strategies, and outcome assessment methods. Most studies relied on retrospective observational designs with relatively small cohorts and inconsistent follow-up duration (35). Moreover, validated patient-reported functional and aesthetic outcome measures were infrequently utilized, limiting direct comparison among surgical techniques. This lack of standardization significantly weakens the overall level of evidence and contributes to the ongoing absence of consensus regarding optimal reconstruction methods. Future investigations should prioritize multicenter prospective designs, standardized classification systems, and validated functional and cosmetic scoring tools to improve comparability and strengthen evidence-based clinical recommendations (36).

The findings of this review have important clinical implications for pediatric hand surgeons. Current evidence suggests that successful syndactyly reconstruction depends not only on digital separation but also on minimizing scar burden, preserving vascularity, maintaining commissural depth, and reducing long-term recurrence risk. Flap-based and graft-sparing approaches appear promising in achieving these goals, particularly in simple syndactyly, whereas complex and syndromic cases continue to require individualized and technically demanding reconstructive strategies. Furthermore, incorporation of biologic substitutes and refined flap designs may represent an important future direction in pediatric hand reconstruction (37).

Several limitations should be acknowledged. First, the majority of included studies were retrospective and subject to selection bias. Second, heterogeneity in surgical techniques and outcome reporting limited quantitative comparison between studies. Third, long-term functional outcomes into adolescence and adulthood were insufficiently reported in many studies. Finally, the relatively small number of prospective comparative trials limits the ability to establish definitive evidence regarding the superiority of specific reconstructive techniques.

Despite these limitations, this review provides a contemporary synthesis of recent clinical evidence regarding pediatric syndactyly surgery and highlights important trends in reconstructive practice. Future high-quality prospective studies with standardized outcome assessment and long-term follow-up are necessary to establish more definitive evidence-based guidelines for the surgical management of pediatric syndactyly.

4-1. Limitations

This review is limited by the predominance of retrospective and small-scale studies, substantial heterogeneity in patient characteristics, surgical techniques, follow-up duration, and outcome assessment, as well as the widespread use of nonstandardized evaluation methods. Small sample sizes, particularly in complex and syndromic syndactyly, together with inconsistent reporting of long-term outcomes, further restrict the generalizability of the findings. In addition, publication bias and the inclusion of English-language studies only may have led to the omission of relevant evidence. Nevertheless, this review provides a comprehensive synthesis of current evidence and underscores the need for

standardized outcome measures and well-designed prospective multicenter studies to strengthen the evidence base for pediatric syndactyly reconstruction.

5- CONCLUSION

This systematic review demonstrates that pediatric syndactyly reconstruction has evolved toward graft-sparing and flap-based techniques aimed at improving functional outcomes while reducing scar-related complications and recurrence. Although these approaches, along with dermal substitutes, show encouraging results, postoperative complications and long-term sequelae remain common, particularly in complex and syndromic cases. Current evidence is constrained by methodological heterogeneity, retrospective study designs, variable follow-up, and nonstandardized outcome measures, limiting definitive comparisons between reconstructive techniques. Therefore, surgical management should be individualized according to deformity characteristics, patient growth, and reconstructive objectives. High-quality multicenter prospective studies with standardized long-term outcome assessment are required to establish robust evidence and optimize clinical practice.

6- CONFLICTS OF INTEREST

The authors declare that they have no competing interests.

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