



LITERATURE REVIEW

A literature review of current surgical treatment for congenital pseudoarthrosis of the tibia

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ABSTRACT

Congenital pseudarthrosis of the tibia (CPT) is an infrequently observed condition. However, it is considered to be one of the most complex ailments in the field of pediatric orthopedics. In cases where a tibial fracture is absent, the conventional treatment approach involves using bracing as a preventive measure against fractures. Various surgical modalities have been proposed for the management of CPT, including intramedullary (IM) rod fixation, external fixators, on-lay grafts, cancellous grafts, periosteal grafts, Paley cross-union, amputation, vascularized fibula grafts, and induced membrane techniques. These modalities can be used in different combinations and permutations. The need for repetitive surgical interventions due to unsuccessful therapeutic outcomes or modifications in secondary treatments can significantly disrupt the childhood experience, resulting in prolonged and recurrent functional limitations. In certain instances, amputation may be required as a primary or secondary treatment modality. This literature review will clarify the current surgical interventions for CPT disease based on a summary of research data. The surgery the patient receives significantly impacts their general health and capacity to heal.



INTRODUCTION

Congenital pseudarthrosis of the tibia (CPT) is a rare medical condition that affects a small proportion of live births, estimated to be around 1 in every 140,000 to 250,000 (Paley, 2021). This disease is a challenging condition to manage in the field of pediatric orthopedics, as noted by Liu *et al.* (2021) and Paley (2012). Identifying the condition at a later stage may present difficulties in differentiating it from alternative causes and addressing more intricate concerns such as significant deformity, discrepancies in leg length, extended contracture, and reduced muscle mass or bone density in the impacted limb, as observed by Miraj and Aprilya (2020). More than 50% of the instances are linked to neurofibromatosis, as Vaidya *et al.* (2019) reported. According to Paley's (2012) findings, a proportion of 10% of individuals exhibit fibrous dysplasia or Campanacci's osteofibrous dysplasia, while the remaining cases are classified as idiopathic.

The underlying mechanisms responsible for the development of CPT remain unclear. The presence of a thickened and adherent periosteum led to the confinement of the tibia and fibula, resulting in atrophy, fracture, and pseudoarthrosis. As per Paley's (2012) theoretical framework based on amputated specimens, it has been suggested that osteolytic fibromatosis served as the underlying etiology of CPT. The observed thickening of the periosteum in individuals with CPT was attributed to heightened myofibroblast proliferation, as per a study encompassing a cohort of ten subjects. As per the research conducted by Paley, it has been discovered that smaller periosteal vessels are constricted and obliterated by the presence of neural-like

cells that surround them. The aforementioned phenomenon ultimately results in subperiosteal bone hypoxia, subsequently leading to non-union, fracture, and resorption.

CPT treatment is complex and frequently challenging, involving both non-surgical and surgical components. Cases presenting with anterolateral bending and the risk of CPT have been treated non-operatively with bracing and prophylactically with bone grafting to delay or prevent the onset of pseudoarthrosis. After experiencing a fracture or the development of pseudoarthrosis, the prevailing surgical interventions include intramedullary rod fixation, circular ring fixation, and vascularized fibular grafting. All these surgical interventions aim to attain osseous union at the location of the pseudoarthrosis (Wang *et al.*, 2021). According to meta-analyses conducted on multicenter studies, the percentage of successful unions without refracture is approximately 50%. The failure to establish a union is recognized as a component of the disorder's inherent progression. Even after it has been established, failure to retain a union results in additional procedures and secondary changes (Paley, 2021). The recurrence of surgical procedures due to unsuccessful therapeutic interventions or secondary modifications can lead to significant disruptions in childhood, prolonged and repeated impairments, and, in certain instances, amputation may be considered a primary or secondary treatment alternative (Paley, 2021). This literature review will clarify the current surgical interventions for CPT disease, considering recent adjustments after past assessments and providing a concise summary of the accumulated research data. In addition, the differences between surgical interventions will also be explained. The right surgical treatment influences the patient's overall health.

METHODS

Data Source

This study is a literature review that employs a comprehensive textual analysis approach in the English language. The articles were selected using the PRISMA methodology (PRISMA, 2023). In May 2023, research papers were systematically searched using three critical databases: Scopus, PubMed, and Google Scholar. Moreover, the selection of documents was conducted in three distinct stages. During the initial phase, articles are chosen by identifying instances of duplication across multiple sources. The subsequent step, known as article selection, involves the examination of the title and abstract. The third phase thoroughly examines the entire article to determine if it mainly addresses the contemporary surgical techniques employed in CPT.

Inclusion Criteria

The literature review examines papers that fulfil specific inclusion requirements. These criteria include research articles focusing on contemporary surgical techniques for CPT, articles published internationally to ensure high quality, articles written in English, and articles in full-text format. The exclusion criteria encompassed abstract articles, literature reviews, report-type publications, non-English materials, and articles lacking current information on surgical procedures for CPT.

Tracing Strategy

The user's search query includes the keywords ("current surgical", "Congenital Pseudoarthrosis of Tibia", and "treatment"), found 1,672 articles. The journals were then chosen systematically, resulting in a final selection of nine journals.

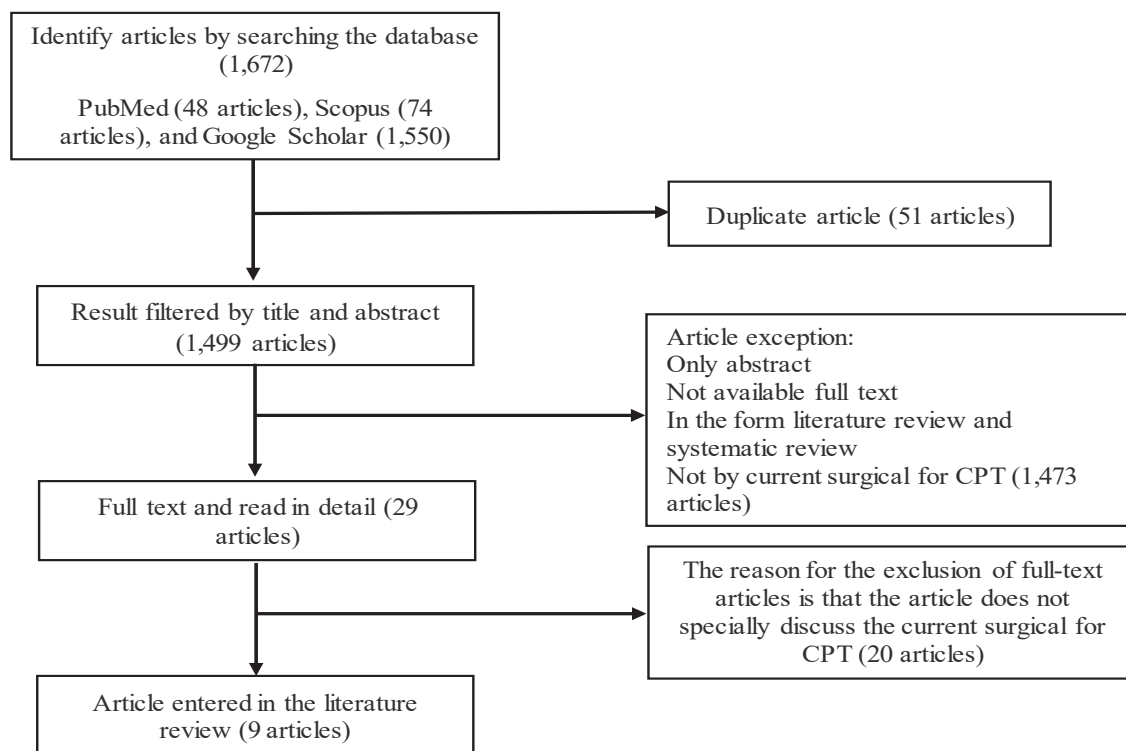


Fig 1. Workflow literature searching



RESULTS

The search found 1,672 articles from 74 Scopus databases, 48 from PubMed, and 1,550 from Google Scholar. A duplicate screening algorithm found 51 articles with similar

material. Based on the title and abstract, a screening procedure was used to uncover 1,473 findings. Twenty papers were found about CPT surgical procedures that lack specificity. This description analyzes nine articles:

Table 1. Characteristic of article

No.	Source	Destination	Design Method	Sample	Reference for CPT Surgical	Results
1.	Zubair Javaid <i>et al.</i> (2020)	To ascertain the result of CPT managed through the utilization of the Ilizarov fixator.	Prospective cross-sectional study	This study examined patients aged up to 12 years with CPT who had presented to the orthopaedic outpatient department (OPD).	Ilizarov fixator	Ten people had their first surgery, while six had more than two. Three instances (18.75%) needed bone transplants. The distraction broke down the proximal bone at the osteotomy site, causing proximal pseudoarthrosis in one patient.
2.	Enemudo <i>et al.</i> (2023)	The present study aims to elucidate the therapeutic efficacy of the Ilizarov procedure, bone grafting, and administration of bisphosphonate (sodium alendronate) in the management of CPT.	Retrospective study	Over five years, commencing from June 2017 to May 2022, individuals diagnosed with CPT received medical attention at the Delta State University Teaching Hospital located in Oghara, Delta State, Nigeria.	Ilizarov procedure, bone graft, and use of bisphosphonate	Study groups averaged 6–18 years old. LDDs average 7.2 cm but range from 6 to 12 cm. Three patients had one injured limb, tibia, and fibula issues on the same side. Everyone drinks café au lait. Two patients' healing declined after consolidation.
3.	Yalikun <i>et al.</i> (2022)	This investigation aims to evaluate the effectiveness of the Ilizarov method in combination with intramedullary fixation as a therapeutic approach for individuals diagnosed with CPT.	Retrospective study	A total of 18 patients diagnosed with CPT underwent treatment at The First Affiliated Hospital of Xinjiang Medical University between January 2009 and January 2020.	Ilizarov's method combined with intramedullary fixation	In 14 tibia pseudoarthrosis patients, the bones improved independently. One patient had plate fixation, and three received malignant bone grafts and acute compression without a primary union. Both treatments cured the patient. No nerve loss or compartment syndrome was found in this study. Implementing the



4.	Szelerski <i>et al.</i> (2020)	To find out how well the Ilizarov method works for patients with aseptic post-traumatic pseudarthrosis of the tibia and compare it to how well the internal osteosynthesis method works.	A retrospective comparative study	The research examined a cohort of 75 participants who received medical intervention using the Ilizarov method for aseptic post-traumatic CPT during the period spanning from 2000 to 2016.	The two primary methods for bone fracture treatment are the Ilizarov technique and internal osteosynthesis techniques.	Ilizarov treatment averaged 9.1 months. The Ilizarov group had a 100% complete union rate, while the control cohort had only 51.92% ($p < 0,001$). Time-to-union statistics showed Ilizarov patients healed faster (203 days vs. 271 days, $p = 0.091$). Ilizarov therapy had a greater effect on anomalies and limb shortening, especially in higher starting values.
5.	Van Den Heuvel <i>et al.</i> (2020)	The purpose of this study is to report on the use of a vascularized fibula graft in conjunction with a large bone segment allograft.	Retrospective study	Six University Medical Center Utrecht patients who had surgery between November 2007 and July 2018 were retrospectively analyzed.	The utilization of a vascularized fibula graft in conjunction with a bone allograft.	Detachable orthotics had an average weight-bearing time of 3.5 months, ranging from 1.2 to 7.8 months. The consolidation of proximal connections takes 2–10 months. Four of seven grafts fractured the distal anastomosis 6–14 months following surgery. Reoperation cemented the distal anastomosis in 2.8 months, ranging from 2 to 4 months.
6.	Cai <i>et al.</i> (2022)	The purpose of this research study was to assess the efficacy of using transposed gastrocnemius flaps as a treatment for congenital pseudarthrosis of the tibia.	Retrospective analysis study	CPT was identified in nine patients, with an average age of 6.2 ± 3.6 years, who were included in this study. Patients were admitted between March 2013 and March 2018 to our institution.	Intramedullary nails	Anatomical decline in all participants, with a mean bone healing time of 10.1 ± 2.1 months. One patient experienced bone nonunion, no neurovascular injury, and no wound infection. After one and two years post-op, doctors found limb length differences of 3.2 ± 1.8 cm and 4.7 ± 2.7 cm, respectively.



7.	Liu <i>et al.</i> (2022)	The objective of this investigation is to analyze the fundamental effect of the "telescopic rod" within a comprehensive surgical strategy for the treatment of CPT in the pediatric population.	Retrospective study	Treatment of 15 Crawford type IV CPT patients from January 2017 to May 2018 using surgical method and telescopic rod. The average age of surgery participants was 43.3 months, ranging from 16 to 126 months.	Combined surgical technique and the telescopic rod	Follow-up averaged 37.3 months for all patients with main unions. Typical primary unions lasted 4.5 months. The average limb length difference in nine LLD patients (60%) was 1.1 cm. The sample had ankle, proximal tibia, telescopic rod, and epiphyseal plate tethering. Aftercare showed no refraction.
8.	Shannon <i>et al.</i> (2021)	The purpose of this study is to evaluate the initial outcomes of the Paley cross-union technique using only internal fixation and no external fixation.	Retrospective study	The study reports 39 CPT cases in 36 Paley cross-union protocol patients. This procedure included internal fixation, bone transplantation, zoledronic acid infusion, and BMP-2 insertion.	Rod exchange (Fassier-Duval nail, SLIM rod, Malleable EVOS plate).	One patient with persistent fibular pseudoarthrosis had a scheduled rod exchange, whereas the other was asymptomatic. No patient experienced a refractory extension after seven years. The most prevalent issue was 66.7% Fassier-Duval (FD).
9.	Westberry <i>et al.</i> (2018)	A study was conducted (Level IV evidence) to examine the indications and outcomes of amputation in the context of CPT.	Retrospective study	The study comprised 17 amputation patients with a mean age of 4.5 years (0.7 to 9.2 years) who met the inclusion criteria. The mean clinical follow-up length was 11.1 years, ranging from 2.1 to 18.4.	Amputation	Three Boyd's and one below-knee amputation were performed on four individuals. The BKA transtibial amputation was done four times. After Byod surgery, 4 of 13 pseudoarthrosis patients did not unite, necessitating additional surgeries. After recent follow-ups, 12 of 13 pseudoarthrosis patients had radiographic healing.



DISCUSSION

CPT has been a challenging orthopedic surgery problem until recently due to its uncertain etiopathogenesis, low incidence, and resistance to treatment. NF-1 is linked to inflammation by several studies (Vanderstappen *et al.*, 2015). CPT is complicated and often requires surgery and non-surgery. After a fracture or pseudoarthrosis, intramedullary rod fixation, circular ring fixation, and vascularized fibular grafting are common surgeries. These surgeries aim for a bony union at the pseudoarthrosis. All surgeries risk problems, including non-union and refracture. If a prosthesis assists the patient more, amputation may be considered in 8% to 33% of patients with poor functional results after treatment (Wang *et al.*, 2021).

Ilizarov Surgery for Congenital Pseudarthrosis of Tibia (CPT)

Zubair Javaid *et al.*, (2020) used an Ilizarov fixator during CPT surgery on 16 prospective cross-sectional patients aged 2–7. All patients had preoperative leg length differences (LLD) of 2–10 cm. Ten primary and six secondary surgeries were performed on sixteen individuals. Remaining LLD, malalignment, and delayed bone repair plagued eight patients. Retransplantation was needed for three patients. The Ilizarov approach has successfully corrected LLD, angular abnormalities, and ankle deformities. In Cho *et al.* (2008) Ilizarov surgery, 20 of 23 patients fractured. Advanced apical malalignment may occur after the union. An 11-year-old girl with osteotomy and distraction to stretch her proximal tibial bone developed osteolysis instead. Many theories explain distal tibial pseudoarthrosis, including hypertrophied ossified and cohesive periosteum that causes bone resorption, fractures, and pseudoarthrosis. The removal of hamartomatous tissue is an essential part of the treatment, but Paley D (2019) notes that

its usefulness in promoting bone repair and refracture prevention is questionable.

Enemudo *et al.* (2023) treated five CPT patients aged 6–18 using the Ilizarov surgery, bone grafting, and bisphosphonates. Two patients had hypertrophic cardiomyopathy, whereas three had atrophy. The union performs well in four areas and relatively in one. Regeneration problems include ankle flexion stiffness and length decrease. The individual had an atrophic non-union, as most researchers have concluded. Enemudo *et al.* (2023) stated that Umebese and Mobash (2005) found sclerotic CPT in 80% of patients. The pseudoarthrosis joint was resected and treated with an intramedullary nail without bone grafting. Bone grafts or BMP are needed to induce bone union in atrophic CPT after removing the pseudo-joint and dysplastic periosteum. As previously shown, atrophic CPT requires inhibiting osteoclast cell activity to establish bone union (Eisenberg and Vuillermin, 2019; Paley *et al.*, 1992). Bone grafts were used to aid docking site tissue regeneration in this study. Eisenberg and Vuillermin (2019) used BMP and bone grafts, while Paley *et al.* (1992) used bones. The study inhibited osteoclast cells using bisphosphonates (BP). Paley *et al.* (1992) managed CPT with BP due to significant outcomes. All participants recovered from LLD with the Ilizarov technique. This study found that two patients integrated numerous generations of loss. Leg length disparity resolved up to 12 cm, impossible with other treatments. The Ilizarov procedure helped Plawecki *et al.* (1990) treat three CPT patients. The authors concluded that this method can treat LLD and axial malalignment simultaneously.

Yalikun *et al.* (2022) treated 18 CPT patients with the Ilizarov technique and intramedullary fixation. The results indicate a 39.2-month follow-up average. The study found that 14 individuals had primary bone union at



the pseudoarthrosis location, and four had secondary surgery. Agashe *et al.* (2012) retrospectively studied 15 CPT patients. The researchers used Ilizarov and intramedullary rodding. The patients' progress was tracked for 4.5 years. Fourteen individuals had bone unions, with a 6.7% fracture rate. Mathieu *et al.* (2008), found that 10 CPT patients who got a combination of the above therapies had a 10% refractory rate after four years. In CPT patients, intramedullary fixation and the Ilizarov approach have been shown to avoid fractures (Borzunov and Chevardin, 2016; Horn and Steen, 2013; Pannier, 2011). This strategy can improve stability, congruity, and direct extension. El-Rosasy (2020) recommends combining the two procedures since it reduces the fracture rate from 68% to 29%.

Szelerski *et al.* (2020) state that the Ilizarov technique combines intramedullary fixation and internal osteosynthesis methods such as internal fixation plates and nails. The post-traumatic effects of Ilizarov surgery are examined in this study. The Ilizarov group had a 100% union rate, while the control group had 51.92%. The data demonstrate that the Ilizarov group had a bone union in 203 days, compared to 271 days for the control group. The Ilizarov cohort had a more substantial effect on deformity and limb shortening. The Ilizarov procedure was only used on people with higher baseline values. The retrospective analysis of patients with one or more risk factors for impaired fracture healing and those without such factors showed no significant difference in union length. Tsang tested nail exchange for chronic paronychia. Union occurred in 69% of instances, with a median time of 8.7 months (Tsang *et al.*, 2016). Harshwal and Sankhala (2014) tested monolateral external fixators for pseudoarthrosis. The median bony

union success rate was 91,9% after five months. The examples above show that CPT has only one best method. Identifying non-union causes and choosing a therapy strategy that fits the pathological mechanism is crucial to treatment success (Szelerski *et al.*, 2020).

Liu *et al.* (2022) tested surgical methods on 15 CPT type IV Crawford patients. Telescopic rods, intramedullary rods, autogenous iliac bone graft wrapping, pseudoarthrosis excision, Ilizarov's fixator, and tibia-fibular cross union were used. The data showed that all individuals achieved primary union after 37.3 months of follow-up. The average first union lasts 4.5 months. The average LLD length was 1,1 cm in 60% of cases. Proximal tibial valgus was seen in three patients and ankle valgus in one. Six telescopic rod displacement instances and two epiphyseal plate anchoring were recorded. Over the monitoring period, no fractures were found during this investigation.

Grill *et al.* (2000) found a 75% first CPT cure. The intramedullary rod procedure was recommended to prevent refracture. El-Rosasy (2020) found that Ilizarov's external fixation and an intramedullary rod reduced fracture incidence to 29%. Johnston found that 23 CPT cases were treated with bone grafting and intramedullary rod fixation. The initial treatment effectiveness was 87%; however, 12% had persistent non-union. Researchers have shown that intramedullary rods improve CPT healing, prevent refracture, and maintain the mechanical axis. Thabet *et al.* (2008) found that surgically removing the problematic periosteum and transferring detached bone, tibial intramedullary rods, and Ilizarov external fixators can speed fracture healing and reduce relapse. The surgical procedure is widely accepted as a realistic and effective treatment for the medical problem.



Vascularized Fibula Graft for Congenital Pseudarthrosis of Tibia

Van Den Heuvel *et al.* (2020) used a combination of a large allograft and an intramedullary vascularized fibula transfer to do CPT surgery on six patients. Vascularized fibula grafts without bone stabilization extend non-weight bearing. The study's mean follow-up was 5.4 years. The mean duration for carrying unlimited weight with a detachable orthotic device was 3.5 months. Within ten months, all proximal connections were consolidated. Four of the seven grafts fractured at the distal anastomosis between 6 and 14 months postoperatively. The distal anastomosis was cemented 2.8 months after the reoperation. A patient needed lower limb removal below the knee. Weiland *et al.* (1990) and Gilbert A. (1995) used a vascularized fibular graft and a large, detachable weight-bearing allograft and found the technique possible in 1.2 to 7.8 months. Compared to the vascularized fibula graft without substantial allograft support, complete load-bearing capacity may require 18–24 months (Kalra, 2012). Stefani *et al.* sources imply that large allografts and intramedullary vascularized fibula transfers may improve CPT.

Intramedullary Fixation for Congenital Pseudarthrosis of Tibia

Cai *et al.* (2022) used intramedullary nails. All participants achieved anatomical reduction, with bone healing taking 10.1+2.1 months on average. No neurovascular damage or wound infection was seen in one patient with a bone non-union. Lower extremity length disparities ranged from 3.2 to 1.8 cm at one year and 4.7 to 2.7 cm at two years post-operation. Two patients received intramedullary nail replacement; eight had good functional and radiological results. Tibia repair uses intramedullary nailing and the Ilizarov procedure. The Ilizarov pooling rate ranges from 32% to 85%.

Multicenter research found that the Ilizarov procedure best manages CPT by restoring stable fixation and length (Grill *et al.*, 2000). However, this approach has limitations, such as recurring fractures, axial deformities, and pin infections. The treatment of fractures with intramedullary rod fixation is standard. CPT data shows 12%–75% success rates with this approach. This approach's procedures are stable, cost-effective, and subcutaneous pin-end infection-free. Intramedullary fixation is best for maintaining alignment during growth and preventing recurrent fractures. Contralateral epiphysiodesis can correct leg length discrepancies under 5cm. The Ilizarov treatment may be appropriate for leg length differences above this level (Cai *et al.*, 2022).

Paley Cross-Union for Congenital Pseudarthrosis of Tibia

Shannon *et al.* (2021) found 39 cases of CPT in 36 patients who received the Paley Cross-Union protocol, which included internal fixation, bone grafting, ZA infusion, and BMP-2 insertion. 39 CPT events formed a horizontal connection with the fibula at the tibia. Two people had fibular pseudoarthrosis. No fractures were observed throughout the seven-year follow-up. Most cases (66.7%) involved the Fasier-Duval (FD) trunk migrating across the physis to the metaphysis. Ohnishi *et al.* (2005) examined 73 instances using diverse procedures. These protocols included Ilizarov fixation for 26 patients, vascularized fibula grafting for 25, combining the two for 7, intramedullary rods with free bone grafting for 6, grafting and grafting for 5, and different treatment protocols for four others. The study found CPT unification in all Ilizarov fixation patients except four resistant ones.

Of 25 patients treated with a free vascularized fibula graft, 22 achieved CPT unification, with one refractory. All fibula graft and Ilizarov



fixation patients achieved CPT unification. Intramedullary therapy has been used to achieve and maintain fusion, with mixed results. Pharmaceutical adjuncts such as BMP-2, BMP-7, and bisphosphonate (ZA) have been used in CPT treatment. Lee *et al.* (2006) treated five CPT fracture patients with BMP-7, allograft, intramedullary rodding, and external fixation. The group averaged six years old and had 14 months of follow-up. The poor healing environment of CPT fractures is still caused by inadequate recombinant human BMP-7 use. ZA was given to chronic periodontitis patients by Dobbs *et al.* (2004) and Schindler *et al.* (2008) to regulate osteoclast function and aid bone fusion. After bone graft removal, bisphosphonates cannot prevent resorption.

Amputation for Congenital Pseudoarthrosis of Tibia

Amputation was used to treat CPT by Westberry *et al.* (2018). The study included 17 amputation patients who met eligibility requirements and had an average age of 4.5 years during the operation. This study's median clinical follow-up was 11.1 years, and its median radiographic follow-up was 9.1 years. Approximately 2.2 surgeries are performed before amputation. Three individuals received Boyd amputations; one got BKAs as their initial surgery. Thirteen patients had Boyd amputations during the research. Rush's retrograde tibial shaft and local autograft stabilized pseudoarthrosis. A transtibial amputation (BKA) was performed on four individuals. Four of the 13 patients assessed after Boyd's surgery had persistent pseudoarthrosis non-union, requiring a second treatment. A recent follow-up found that 12 of 13 pseudoarthrosis patients had radiographic healing. One with continuous pain, the other with refractory agony. Surgeons and treatment centers disagree on pediatric CPT amputation criteria.

Some consider amputation an extreme treatment, while others support it as self-care (Vander *et al.*, 2008). McCarthy & Noonan (2008) describe CPT amputation indications. These include unsuccessful bone union after three surgeries, a leg length disparity above 5 cm, pseudoarthrosis-induced distal toe deformity, and secondary function loss. Edvardsen (1973) pioneered pseudoarthrosis fusion following amputation. The paper describes Boyd's amputation and pseudoarthrosis osteosynthesis for a 10-year-old boy patient who had had previous surgery to achieve union. Removing dysplastic bone, coaptating normal bone, reducing foot-induced torsional strain on the tibia, and developing an early load-bearing end-bearing leg all help to get the bones to join. One in six Syme's amputation patients had radiographic pseudoarthrosis, according to Guille *et al.* Similar findings were found in prior research.

The absence of refraction after union defines CPT success. Over a century of surgical procedures to treat CPT have yielded less than 50% union without refracture. The author's research found that purposeful cross-union of the tibia and fibula had a 100% success rate, with 36 out of 36 cases demonstrating positive results over 13 years. Choi *et al.* (2011) used 4-in-1 osteosynthesis to achieve cross-union in CPT with 100% success at 7.4 years. Vaidya *et al.* (2019) scored 100% in their study. Liu *et al.* (2022) studied a comparable topic. Two recent studies found 100% effectiveness in cross-union CPT treatment utilizing modified versions of the above methods at four years. The CPT cross-union altered how to combat this vile childhood disease. Cross-union should be implemented as the standard of care for CPT because its success rate ranges from 50 to 100 percent. Inefficient and obsolete practices should be progressively eliminated (Paley, 2021).



The surgery known as CPT is difficult. Congenital tibial pseudoarthrosis is treated with a focus on union, alignment, preventing relapse, and limb length difference, all while keeping joint function. Accessible surgeries include:

- The Ilizarov methods.
- Intramedullary rod fixation.
- Circular ring fixation with allograft and BMP.
- Vascularized fibular grafting.
- Paley cross union.
- Amputation.

However, surgical procedures often cause non-union, refracture, and other problems. Amputation may be essential for patients when multiple therapies fail. Each strategy is unique; thus, various approaches may be needed.

This literature review has a few limitations, such as the fact that it only looks at 9 papers. It means that only a few journals that don't cover all kinds of CPT operations are chosen. So, more research needs to be done on several procedures that are outside this literature review study. Also, CPT surgeries are done not only with one type of surgery but also with a mix of different types. So, it's still hard to say whether one surgery is better. In cases of congenital pseudoarthrosis, there is no set procedure for surgery. Still, some types of surgery need to consider how the process affects the child and the rest of the family.

CONCLUSION

The management of CPT through surgical intervention is a complex procedure. As mentioned above, researchers use various surgical techniques for CPT, including the Ilizarov fixator, vascularized fibula grafts, intramedullary fixation, Paley cross-union, and amputation. Not all of the above procedures are carried out alone, but some are performed

by combining 2 to 3 methods to get better surgical results with minimal complications. The Ilizarov fixator is used to lengthen and compress the bone at the fracture site after a lot of diseased bone and soft tissue have been cut away. Ilizarov can handle problems with pseudoarthrosis, LLD, and parts of the foot. Both ipsilateral and contralateral techniques for vascularized fibula grafts are adequate, as these aid in the healing of the tibia. Intramedullary nails are easy, inexpensive, and simple to carry out repeatedly. Vascularized fibula patches, BMP, or BP, can also be used in this method. Problems with this method include the chance of stiffness in the ankle from long-term fixation of the tibiotalar and subtalar joints, immobilization after intramedullary rods, and re-fracture after the rods are taken out. The Paley cross-union method starts with a pre-operative injection of ZA acid to protect the tibia, fibula, and autogenous bone graft from hyper-osteoclastic cell resorption in CPT. And finally, the amputation process is done to save people who are hard to heal and have had several failed attempts to join their limbs together. Various factors, such as the underlying mechanism of the disease, biological factors, and union factors, determine the selection of a surgical procedure. There is currently no established protocol for surgical intervention in cases of congenital pseudoarthrosis. Nonetheless, specific surgical approaches necessitate consideration of the impact of the intervention on both children and family members.

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