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Research Article

Bone Anomalies In Children And It's Surgical Treatment: A Review

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ARTICLE INFO | **ABSTRACT**

One of the major challenges in orthopedics is the restoration of large damage to bone tissue. Restoring bone mass in children with bone density deficiencies is an important problem, especially in the acute phase. The purpose of this literature review is to examine current surgical practices for the treatment of severe bone tissue injuries and abnormalities in children. We provide a summary of the literature on surgical repair of major bone deformities. Several large databases were queried for the literature review. The utilisation of autografts, including technology on a vascular pedicle, remains the optimum method for repairing bone deformities. Synthetic implants are gradually replacing xenografts and allografts as the material of choice for bone restoration.
In conclusion, when it comes to surgically fixing large bone abnormalities, there isn't yet a gold standard. As a potential surgical solution for major bone tissue anomalies, tissue-engineered bone implants supplied by axial blood seems very fascinating and promising.

Keywords: bone, orthopedic, defects

Introduction:

There is a major medical and societal issue with musculoskeletal system pathologies, both congenital and acquired. An increasing number of people are being diagnosed with bone abnormalities in diverse locations [1]. Between 47 and 237 instances per 1000 children are reported for orthopaedic pathology.
Congenital pathology and developmental abnormalities of the lower limbs are linked to over 30% of childhood disability cases.[2]
The majority of bone tissue deficits are caused by traumatic injuries and their repercussions, congenital anomalies, infectious diseases, and tumors that destroy bone structures.
The most challenging clinical situations involve large bone defects because they might induce partial restoration or loss of function in the wounded limb, which can lead to disability. Bone transplantation is frequently necessary for these disorders [3]. Critically sized defects are those that do not typically heal on their own. There are no definitive quantitative limits, particularly for children, because this indication is quite variable and relies on age, area of the body affected, kind of injury, and many other factors[4] .
Patients with musculoskeletal system injuries, particularly those with compromised skin integrity and bone abnormalities, can undergo extrafocal osteosynthesis as a surgical therapy option. A temporary fixation device combined with less-studied but potentially effective implants and surgical procedures is the subject of active investigation at the moment. Recent studies have looked at the possibility of using electrical stimulation to fix bone defects in places where calluses occur [5]. Invasive, semi-invasive, and noninvasive electrostimulators are the three most common kinds utilised for this purpose.
Tissue regeneration is aided by stimulating the cathode at the bone fragment fusion site within a certain current and frequency range. But how exactly electrical stimulation works in actual therapeutic settings is still up for debate.[5] .
Extensive bone defects can be filled by xeno-, allo-, auto-, or tissue-engineered grafts, among other biological materials. When it comes to fixing skeletal problems, nothing beats a bone tissue autograft [6, 7]. Autologous bone is the most desirable option since it may be quickly incorporated and solidified without triggering immune reactions. In addition to being osteogenic and osteoconductive, the autograft also displays osteoinductive qualities.

One major drawback of xenografts is the possibility of the recipient developing an immune response to the donor graft, even if they have the ability to treat bone tissue insufficiency and substantial bone deformities [3]. On top of that, xenograft vascularization is readily available. Nevertheless, this sort of transplant has not been successful when used in clinical practice, despite the fact that the situation is urgent and there is significant study in this area [8].
When it comes to replacing bone defects, allografts are preferred over xenografts up to the level of transplantation in the upper limbs. Although there have been advancements in the processing of biological materials, the risk of spreading viruses such as HIV, hepatitis B and C, and human immunodeficiency virus remains. Thus, concerns about the recipient's body's remodelling and allograft resorption persist [9, 10]. New synthetic implants used as osteoplastic material, including those that can be colonised with stem cells [11, 12], were developed by considering the physiological mechanisms of bone tissue restructuring and remodelling and by developing engineered tissues. Nevertheless, experimental investigations typically constitute the basis for these works.
In addition, we emphasise tissue-engineered implants that are vascularized with an arteriovenous loop (AVP) or made of a variety of materials using prefabrication techniques [13]. These implants integrate vascularized allo-and autografts with artificial implants to provide a combination of benefits.[15 ,14]
Drawing on existing literature, this study set out to examine contemporary surgical therapy modalities for children suffering from severe bone injury.

Materials and Methods:

Surgical techniques for the repair of large bone defects are the subject of this literature review.
A search was made in the databases to find relevant material. Consequently, 37 domestic sources and 105 international ones were identified. After removing irrelevant articles, 56 were considered; each one had a publication date within the past fifteen years.
Papers were considered for inclusion in the study if they met the following criteria: they had either structured annotations or full texts available; these investigations used bone replacement procedures in a clinical or experimental setting. They included assessments of treatment efficacy, safety, and outcomes, as well as information about the authors, rating scales, and tests used in the research.
Exclusion criteria included studies that showed indications of "duplication" (e.g., using the same research technique, patient groups, authors, etc.). If two articles with the same publication date were located, the one with the most current date was chosen.

Bone defects and surgical treatment:

Autografts may be classified as either compact or sponge-like. Due to its excellent osteogenic, osteoinductive, and osteoconductive qualities, sponge autograft is the most often employed kind in clinical practice. It just takes two days for the graft to become fully vascularized because of its porous shape. The creation of the callus is finished after 8 weeks, and the graft is completely restructured within a year. The progressive replacement process causes this to happen. Osteoblasts deposit new osteoid while osteoclasts reabsorb the necrotic donor trabeculae. Split pieces may fuse quickly with this graft type, although structural stability won't be achieved overnight [7, 16]. Nonvascularized bone grafting, the conventional method, is usually enough. Especially in cases of infection problems, vascularized bone graft might be used when nonvascularized bone transplantation has failed in the past [17]. When doing cancellous autograft, the ilium is the usual donor location. Some of the potential complications that might arise during the process of collecting autografts include pain at the site of graft removal, infection, the formation of hematomas, and damage to the lateral cutaneous nerve of the thigh [3].
A conductive media with modest osteoinductive and osteogenic characteristics, a medium that promotes bone growth is provided by the autogenous compact bone cortical transplant. If a structural problem needs mechanical stability for healing right away, this is the way to go. Revascularization and incorporation are sluggish due to the thick matrix; this is because new bone can't be deposited until resorption starts. Because of this quality, this graft type does not promote bone formation. These nonvascularized autografts undergo resorption, weakening, and structural preservation within the first six months after implantation [3, 7]. The advantages of both forms of bone may be found in an autogenous cancellous compact bone transplant. The compact bone provides instant structural stability, while the cancellous bone has osteoinductive, osteoconductive, and osteogenic qualities. Regardless, there is a severe lack of donors available for autografts .[16]
There is no need for specialised equipment when using bone autograft in surgical procedures. Therefore, enough blood flow to the receiving bed and preservation of recipient tissues' aseptic state are crucial. Nutrients diffuse from the surrounding tissues to the transplanted pieces in the early days following transplantation, and later on, blood vessels germinate from the surrounding tissues, allowing for the achievement of blood supply.
By gradually revascularizing, autografts serve as osteoconductors. Due to partial resorption and osteoclast death caused by inadequate blood supply, vascularized bone grafts are superior than free ones in

reconstructive surgery. A new bone is created in its stead by pluripotent cells found in the bone marrow and other tissues around it.[17 ,16]

Combining the vascular pedicle with autografts may increase consolidation in some circumstances. In cases of significant bone loss, free vascularized grafts are the way to go.[19 ,18 ,16]

The usual sites for vascularized grafts are the iliac crest and its deep circumflex iliac artery, the fibula and its peroneal artery branches, the distal end of the radius and the supraretinacular artery, or the ribs and the posterior intercostal artery [6, 17]. With a survival rate of over 90%, this transplant is highly osteogenic.[16]

There is a severe lack of suitable donor sites for the purpose of collecting autografts. When the graft is transplanted onto the pedicle, the collection of the artery serving a restricted region, in addition to the bone, becomes an additional limiting factor.

The bone will partially resorb and the graft strength will be reduced if the blood supply is inadequate [20]. According to Roddy et al., a prominent reviewer on the subject, after a vascularized fibula transplant, the fusion rate is typically between 70% and 100%, and it usually takes around 6 months for the fusion to take effect [3]. In most cases, the rate of functional recovery is above 96% and the patient is able to resume weight bearing [3]. A vascularized autograft, in contrast to an allograft, promotes faster hypertrophy and tissue union by actively participating in the regeneration process. In contrast to nonvascularized grafts, vascularized tissues exhibit a high level of resistance to viral processes.[17 ,6]

When it comes to treating youngsters, autotransplantation of vascularized bone tissues offers several noteworthy benefits.[22 ,21 ,7]

To begin with, they are determined by the potential for further active expansion of the bone's length and breadth [21, 22]. When restoring articular function while preserving axial limb development is necessary, one potential strategy in this field is to undertake surgery on sites of epiphyseal bone growth. A growing disparity in limb length occurs with age due to disrupted nourishment of the epiphyseal plate, which is not taken into account by standard approaches in these circumstances [23,24].

Because of this, vascularized fibular epiphyseal transfer, sometimes called transplantation of the vascularized fibular epiphysis, involves separating a portion of the proximal fibular epiphysis with feeding legs to aid in epiphyseal development [23].

Anastomosis of the leg is most often performed via the peroneal artery (93% of cases) or, in very unusual circumstances, the anterior tibial artery.[25]

Additionally, compared to adults, children who undergo autotransplantation of vascularized bone tissues have a number of advantages, such as a greater resistance to infections, more artery spasticity, a reduced risk of feeding pedicle complications because the vascular wall does not exhibit the age-related atherosclerotic and arteriolosclerotic changes, and, in the majority of cases, no varicose veins [26, 27].

A vascularized autograft may be used to replace almost any broken bone due to the unique anatomy and characteristics of the fibula. One use is in shoulder joint repair using the isolated fibula head.[25 ,23]

In pedicle autologous transplantation, the bone growth plate may adjust the pace of development for various types of bones. Previous research on the rate of development of fibula autografts used in tubular bone repair led to this conclusion, which stands at 0.92 cm per year [23]. A vascularized fibula transplanted to the calcaneus results in a growth rate of 0.56 cm per year, which is a considerable reduction in growth rate.[28]

There is a chance of problems with autologous bone tissue transplantation surgery. Possible early postoperative problems include anastomotic leakage or thrombosis, neuropraxia of the deep peroneal nerve, and superficial skin infections. Conversely, delayed problems might manifest in a variety of ways, including "late" anastomotic leaking, graft fracture, inconsistent limb length, flexion contracture, as well as ruptured skin necrosis over the autograft surface [25].

In a comprehensive study of issues after vascularized fibula transplantation, it was shown that 9.9% of wounds healed mainly and 19.0% of wounds that needed skin graft closure had early donor site complications, such as dehiscence, infection, as well as delayed wound healing. Consequences that manifest later on include sensory impairments (7.0%), restricted joint range of motion (11.5%), ankle instability (5.6%), persistent pain (6.5%), and gait disruption.(%3.9)

There are a number of potential drawbacks to fibula autografts, including donor site pain, longer operation times, increased risk of fractures (particularly in the lower limbs), and a complicated microsurgical method .[3]

In order to produce a musculocutaneous flap using vascularized autograft, one must possess extensive expertise, do certain calculations, and adhere to strict protocols. In spite of this, this method may be the most effective for treating paediatric musculoskeletal disorders. In youngsters, the most important metric is the maintenance of the transplanted bone's ability to develop without resorption. This technique can restore almost all bone deficiencies because of the bone's adaptive remodelling over time.

Assessing the viability of the transplant should be done after surgery. Even with full vascular patency, angiography is not a sufficient diagnostic tool to determine whether or not the transplant will be successful. The increase of technetium (Tc-99) in the graft region during scintigraphy, which is a radiopharmaceutical agent, suggests adequate blood flow, making it a more viable alternative.[29]

Vascularization is necessary for bone grafts larger than 6 cm.

Researchers attempted to refute this theory in a systematic review by Allsopp [30], but their arguments relied on results that were not statistically trustworthy enough and on the fact that there was a lack of study on the subject. Compared to nonvascularized autografts, vascularized ones did not show any benefits in these trials [30]. But there are a number of scholars whose findings were left out of this comprehensive analysis who hold the opposite opinion. Children, whose bones can continue to expand, benefit greatly from vascularized autografts.[22 ,7]

Various kinds of implants are used to treat musculoskeletal problems. These include porous ceramic implants [32], stem cell coated synthetic materials [11, 12], hydroxyapatite composites [31], titanium and titanium alloys [11], and many more. These implants are less invasive, easier to utilise, and more compatible with the recipient's tissues.[32 ,31 ,11]

One crucial feature of biological tissues that synthetic implants lack is the capacity to grow and develop. This property is particularly relevant when treating paediatric patients. Plus, they don't have the same exact physicochemical characteristics as natural bone tissues.

Addressing contributory variables [7] has the potential to increase the success rate of bone tissue autotransplantation and decrease the risk of complications. Therefore, a number of studies have contended that glucocorticoids and nonsteroidal anti-inflammatory medicines are not ideal to employ in the postoperative period, and that administering radiotherapy and chemotherapy simultaneously greatly lengthens the time it takes for bone autografts to consolidate.[7 ,3]

The amount of mechanical stress is another component that might improve bone autograft. The bone adjusts to pressures in accordance with Wolf's law. Bone strength increases as a result of a two-step process that begins with the trabeculae and progresses to the cortical layer in response to increased stress. Reduced load causes bone tissue to degrade, loosen, and weaken [26].

Similar to natural bone, vascularized grafts change and adapt over time [26]. Due to this characteristic of bone tissue, when the graft is subjected to the right amount of stress, it may thicken up to the size of natural bone [29 ,26].

A potential alternative to auto- and allotransplantation is the repair of tissue abnormalities using different tissueengineered materials [14]. Research has shown that tissue-engineered implants made of various materials may successfully repair skin, urethra, blood arteries, flat bones, and cartilage [33]. Thinness is a commonality across these tissue-engineered implants; this allows for easier oxygen and nutrient diffusion. Things change drastically with bigger implants, since their thickness prevents the flow of nourishment [34]. Particularly in the moments after implantation [35, 36], these implants need a boost to the patient's axial blood supply [14]. Arteriovenous bundles that are blindly closed, via arteriovenous bundles, or AVPs that have been shunted. Tanaka et al. found that using an AVP resulted in the greatest rate of implant vascularization [39], making it the most successful approach. Two important conditions that stimulated the development of connexin 43 [41] and hypoxia [33, 40] were the presence of turbulent blood flow in the anastomosed area.

The unique anatomy and structure of the fibula allow for the use of vascularized autografts to repair almost any broken bone. Repairing shoulder joints with the isolated fibula head is one application.[25 ,23]

The bone growth plate has the potential to regulate the rate of development for different kinds of bones in pedicle autologous transplantation. This result, which stands at 0.92 cm per year, is based on prior study on the rate of growth of fibula autografts used for tubular bone repair [23]. A significantly reduced growth rate of 0.56 cm per year is produced by a vascularized fibula transplanted to the calcaneus.[28]

The procedure of autologous bone tissue transplantation is not without its risks. Infections of the superficial skin, neuropraxia of the deep peroneal nerve, and anastomotic leakage or thrombosis are risks that may arise in the early postoperative period. Conflicting limb lengths, graft fractures, flexion contractures, ruptured skin necrosis over the autograft surface, and "late" anastomotic leakage are some of the ways in which delayed complications may present themselves [25].

In a comprehensive study of issues after vascularized fibula transplantation, it was shown that 9.9% of wounds healed mainly and 19.0% of wounds that needed skin graft closure had early donor site complications, such as infection, dehiscence, and delayed wound healing. Subsequently, symptoms may include impaired sensation (7.0%), limited mobility in the joints (11.5%), instability of the ankle (5.6%), ongoing discomfort (6.5%), and disturbance of gait.(%3.9)

Fibula autografts may be risky because to the microsurgical technique, the length of the procedure, the donor site discomfort, and the increased likelihood of fractures (especially in the lower limbs).[3]

Extensive knowledge, precise calculations, and rigorous adherence to procedures are required to construct a vascularized autograft musculocutaneous flap. Regardless, this approach shows promise as a treatment for juvenile musculoskeletal diseases. For children, the most critical indicator is that the transplanted bone continues to grow normally without resorption. The adaptive remodelling of bone over time makes this method capable of restoring almost all bone defects.

It is important to evaluate the transplant's viability after surgery. A successful transplant cannot be predicted by angiography alone, even in cases of complete vascular patency. Scintigraphy, which uses radiopharmaceutical agent technetium (Tc-99) to enhance contrast contrast, is preferable because it indicates sufficient blood flow to the graft area.[29]

Bone grafts bigger than 6 cm need vascularization.
In a comprehensive review by Allsopp [30], researchers sought to disprove this idea, but their claims were based on insufficiently reliable statistics and the absence of research on the topic. Vascularized autografts failed to provide any advantages in comparison to their nonvascularized counterparts in these experiments [30]. However, this all-encompassing examination omitted the work of a number of experts who had the opposing view. Vascularized autografts are very helpful for children since their bones may keep growing ,7] .[22
Musculoskeletal disorders may be treated with a variety of transplantations, including implants made of porous ceramics [32], substances synthesised from hydroxyapatite [31], stem cell-coated synthetic materials [11, 12], titanium and titanium alloys [11], and others.
This kind of implant is less invasive and easier to utilise, and it also blends better with the recipient's tissues [11, 31, 32].
The ability for synthetic implants to grow and develop is a critical characteristic that is absent from organic tissues. When dealing with children, this quality becomes even more important. Natural bone tissues are physically and chemically distinct from these.
The success rate and complication rate of bone tissue autotransplantation may be improved by addressing the relevant factors [7]. Radiotherapy and chemotherapy given at the same time considerably prolong the consolidation time of bone autografts[3,7], and several studies have argued that glucocorticoids and nonsteroidal anti-inflammatory drugs are not ideal to use in the postoperative period.
Bone autograft performance may also be enhanced by adjusting the mechanical stress level. The bone responds to stresses in line with the law of WolframAlpha. There is a two-stage process by which, when stressed, bone strength rises. The first phase is at the trabeculae level, and the second is at the cortical layer.
Reduced load causes bone tissue to degrade, loosen, and weaken.[26]

Vascularized grafts undergo metamorphosis and adaptation, much like native bone [26]. It is possible for the graft to thicken up to the size of native bone when appropriately stressed, thanks to this property of bone tissue.[29 ,26]

The use of various tissueengineered materials for the restoration of damaged tissues offers an alternative to auto- and allotransplantation [14]. Repairs of skin, urethra, blood vessels, flat bones, and cartilage may be possible using tissue-engineered implants composed of a variety of materials, according to research [33]. The uniformly thin profile of these tissue-engineered implants facilitates the delivery of nutrients and oxygen. Because the thickness of larger implants blocks the flow of nutrients, the situation changes dramatically [34]. These implants need an increase in the patient's axial blood supply, especially in the immediate post-implantation period [35, 36]. A shunted AVP, a via arteriovenous bundle, or a blindly closed arteriovenous bundle. Using an AVP resulted in the greatest rate of implant vascularization, which was considered to be the most successful approach by Tanaka et al. [39]. Connexin 43 [41] and hypoxia [33, 40] were both accelerated by the presence of turbulent blood flow in the anastomosed area, which was a crucial factor.

The following techniques were used to examine most cases: scanning electron microscopy, immunohistochemistry, intravital magnetic resonance imaging with an AVP camera, postmortem microcomputed tomography with MICROFIL injection, Indian ink injection, corrosive preparations, immunohistochemistry, as well as SEM [50, 56, 43]. The majority of the experiments were descriptive in nature, and no evaluation of the quantitative indicators or the dependability of the data was done while they were being carried out.

Conclusion:

This line of inquiry may remain very pertinent for future studies, even after the vascularized bone tissue autotransplantation procedure has been successfully developed. The technique's excellent effectiveness in employing grafts in regions of developing bone, the anatomical peculiarities of children, and the greater spectrum of disorders make it of significant interest in the field of paediatric orthopaedics and traumatology.
Additionally, no standardised strategy or guidelines for this method's usage have been published as of yet, thus it continues to be an area of exploration and innovation for clinicians in practice. Bone autotransplantation on a vascular pedicle is a promising technique, but it is seldom used and is out of reach for most patients for the same reasons.

As an alternative to vascularized bone autografts and conventional procedures, tissue-engineered implants that get blood flow from the axial direction may one day be the norm. This method may solve the problem of limited transplantable material, which is a major drawback of autotransplantation, as well as other issues with allotransplantation. Research into the application of these tissue-engineered materials for the repair of bone abnormalities has shown the technique's potential for usage, enabling us to highlight its promising potential in practical medicine. However, more active research is still needed in this area.

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