Trends in Guided Growth for Correction of Angular Deformities around the Knee: Past, Present, and Future

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Abstract

The principles of guided growth have been followed in orthopaedics since historic times . The bent tree braced to a stake to make it grow upward and straight is the first reference to the principles of growth modulation in the annals of orthopaedic history

Keywords: Guided Growth, Epiphysiodesis, Hemiepiphysiodesis, growth modulation, eight plate, genu varum, genu valgum, deformity correction, pediatric orthopaedics, growth plate

Introduction

Techniques for guided growth for angular deformities around the knee have been employed since the 1930's when Phemister described his bone block technique which achieved a complete arrest of the growth plate. The technique of guided growth has evolved since those times to minimally invasive, safe, and reversible methods to achieve modulation of growth.

Definition and Principle

Growth modulation or epiphysiodesis is defined as a process, procedure, intervention, or action designed to change, alter, modify, or guide the growth and development of the axial or appendicular skeleton in whole or part in a skeletally immature individual.

Principle of growth modulation is the cessation or deceleration of the natural growth across a growing point or a group of growing points to balance, correct, or overcorrect deformities or discrepancies of the axial or appendicular skeleton.

The Annals of Guided Growth History

The reversed bone block technique (Phemister 1933)

The Phemister technique of guided growth entailed inserting a crania-caudally reversed bone block consisting of the Epiphseal bone, physeal plate, and metaphyseal bone (Fig. 1) which was harvested subperiosteally from the medial and lateral aspect of the distal femur or the proximal tibia [1]. Once the procedure is performed, the elevated periosteum is sutured over the block.

The technique fell into disrepute due to the permanence of the growth arrest and also due to the fact that the bone block would often get dislodged leading to fragility fractures and significant morbidity.

Percutaneous growth plate curettage and physeal violation (Bowen 1984)

Percutaneous growth plate curettage technique [1] described by Bowen underwent successive modifications over a span of 30 years. Principally, this technique entailed a permanent violation of the peripheral physeal growth plate on the medial and lateral sides with the help of various instruments including curettes, chisels, and drill bits (Fig. 2). In the absence of dynamic imaging, the technique included a 3 cm incision centered over the physis with subsequent violation of the growth plates and the use of dye for radiological confirmation.

The technique and its modifications are extremely popular and are still in practice when a permanent growth arrest is desired. Extreme care needs to be taken, as not to violate the central growth plate as this may lead to a "fish-tail" deformity [2].

Periphyseal stapling (Blount 1949)

The technique of periphyseal stapling includes a temporary cessation of growth of the physeal plate by the application of 3 stainless steel staples placed in a circumferential pattern (Fig. 3) converging in the center over the medial and/or the lateral side of the end of a growing bone, most commonly, the distal femur and the proximal tibia [1].

The concept may be considered as the first form of temporary and reversible epiphysiodesis procedure described in the literature. Although the method gained popularity, issues such as staple expulsion due to the smooth surface of

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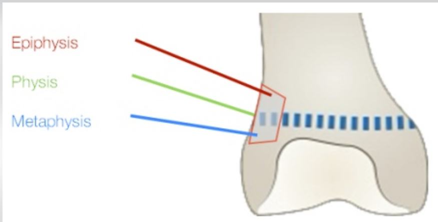

Figure 1: The Phemister reversed bone block.

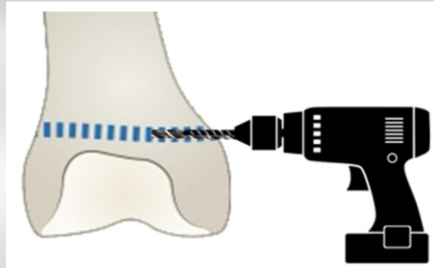
Figure 2: The Percutaneous growth plate physeal violation technique.


Figure 3: The periphyseal stapling technique.

the ends and bottle cork phenomenon during physeal growth due to the convergent design of the ends lead to failure in many cases, including the series of blount.

The percutaneous metaphyseal-epiphyseal screw technique (Metaizeau 1998)

The technique described by Metaizeau [3] consists of inserting two crossed 6–7 mm screws inserted from the metaphysis to the epiphysis while crossing the physis obliquely (Fig. 4).

The screws are inserted using a guide pin and need to be placed in a way that the medial and lateral screws do not interject and are reasonably centered over the physis in the coronal plane.

Song et al. [4] stated that screw diameter (6 mm or more) screw trajectory and the presence of at least 4 threads of each screw in the physis are important determinants for success in this surgery. Multiple authors have reported a lag period of at least 6 months before the correction commences [3,4]. (Fig. 5).

Normandin et al. observed progressive screw curvature if screws of 4 mm diameter were used and recommended that threat diameter, thread morphology, and screw length were important determining factors in the success of this procedure [5].


Figure 4: The percutaneous metaphyseal-epiphyseal screw technique.

Periphyseal compression screw plate (Stevens 2007)

As a significant advancement to the Blount's stapling technique and with consideration of the complications associated with technique, Steven's [6] described the technique of using a periphyseal plate known as the 8 plate.

The technique is based on the principles of strong metaphyseal and epiphyseal anchorage, up to 20° of screw mobility in the coronal plane to avoid compression injury to the physis and the use of a single plate placed sagittally over the physis with no obvious advantages of 2 plates over a singular plate [6].

Other authors have reported contrary results as regard the use of a single plate, [7] leading to 4 screw constructs as well as plates with hinges which have a better stability and occupy a wide portion of the physis in the sagittal plane.

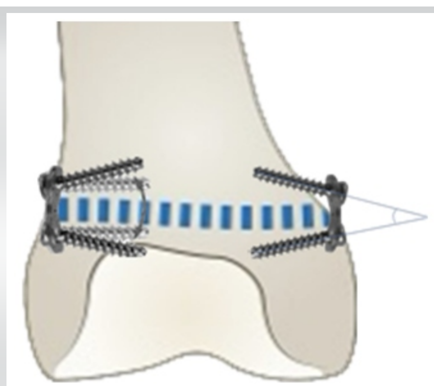
Figure 5: The periphyseal compression screw plate technique.

Technique of Periphyseal Compression Screw Plate Technique

Patient assessment

The process typically begins with a thorough assessment of the patient's condition, which may involve physical examinations, imaging studies (X-rays, MRI, or CT scans), and specialized gait analysis to evaluate the nature and severity of the skeletal deformity.

Planning

Based on the assessment, the orthopedic surgeon develops a treatment plan tailored to the patient's specific needs. This may include determining the location and orientation of the guided growth implant as well as the amount of correction needed.

Surgical procedure

Guided growth procedures are usually performed as minimally invasive surgeries, often using fluoroscopic guidance. A small incision is made near the affected growth plate, and a tension band plate or another type of implant is inserted in close proximity to the physis growth plate (Fig. 6a-d).

Implant selection

The implant used in guided growth procedures is designed to provide controlled tension to the growth plate,

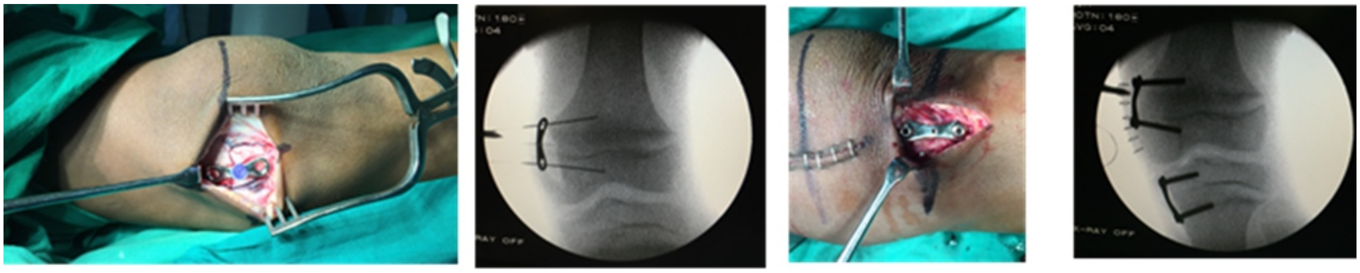

Figure 6: (a-d) The technique of periphyseal compression screw plate technique.

slowing down, or hastening the growth on one side of the bone to gradually correct the deformity. The implant's tension can be adjusted over time to fine-tune the growth modulation.

Post-operative follow-up

Following the procedure, the patient may be monitored regularly with clinical evaluations and imaging studies to assess the progress of growth modulation and ensure that the correction is occurring as intended (Fig. 7a and b).

Removal of implant

Once the desired correction is achieved, the implant is typically removed in a relatively simple daycare procedure.

Issues with Guided Growth Procedures

It is important for both the orthopedic surgeon and the patient's caregivers to be aware of these potential complications and to closely monitor the child's progress during and after the guided growth procedure. Regular follow-up visits and imaging studies can help to ensure that any issues are promptly identified and addressed. (Fig. 8)

Some of the complications associated with guided growth using the 8-plate technique include [8-14] as follows:

Over correction

There is a risk of overcorrection when using the 8-plate technique, which can lead to the opposite angular deformity. This can occur if the plates are left in place for too long or if too much correction is attempted at once.

Under correction

Conversely, there is a risk of undercorrection, where the desired correction is not achieved. This can occur if the plates are removed too early or if the growth modulation is not adequate to achieve the desired correction.

Implant-related complications

There can be complications related to the 8 plates themselves, such as migration or loosening of the plates, which can lead to irritation of the surrounding soft tissues or inadequate correction of the deformity.

Physeal injury

The 8-plate is applied across the physis (growth plate), and there is a risk of physeal injury during placement or removal of the plates, which can lead to growth disturbances or premature physeal closure.

Infection

Although uncommon, there is a risk of infection associated with any surgical procedure, including the placement of 8-plates.

Nerve or vascular injury

There is a potential risk of injury to

Figure 7: (a and b) Results of guided growth using a periphyseal compression plate technique for genu valgum deformity in a case of multiple epiphyseal dysplasia.

Figure 8: (a and b) Results of guided growth using a periphyseal compression plate technique for genu varum deformity in a case of vitamin D-resistant rickets.

nerves or blood vessels during the surgical placement or removal of the 8-plates.

Malalignment

In some cases, malalignment of the extremity can occur, leading to functional impairment or the need for additional corrective procedures.

Compromised correction in the presence of bone deformity

In cases where there is a significant bony deformity, the 8-plate technique may not be able to fully correct the deformity, necessitating more complex surgical interventions.

Residual leg length discrepancy (LLD)

Even with successful correction of angular deformities, there can be persistent LLD due to differential growth rates of the affected bones. This may require further management such as epiphysiodesis or limb lengthening procedures.

The Future of Guided Growth Procedures

Future technologies for guided growth in angular deformities continue to evolve, driven by advancements in orthopedic surgery, biomechanics, and medical technology. These innovative approaches aim to enhance the precision, safety, and outcomes of guided growth procedures [15-19].

Some technologies which are predicted to be the game changers in the future include as follows:

Patient-specific 3D-printed implants

Customized 3D-printed implants designed to fit the patient's anatomy can offer tailored correction for angular deformities. The use of 3D printing technology allows for precise, patient-specific implant fabrication based on pre-operative imaging, potentially reducing the risk of implant-related complications and optimizing correction outcomes [15].

Magnetically driven growth modulation

Magnetic internal lengthening devices and magnetically controlled implants represent a promising avenue for guided growth in angular deformities. By utilizing magnetic forces to modulate growth at the physis, these technologies offer non-invasive, adjustable, and reversible correction, with potential benefits in terms of reduced surgical invasiveness and increased control over the rate and direction of correction

Implantable sensors for real-time monitoring

Integration of implantable sensors within growth modulation devices could enable real-time monitoring of the mechanical environment at the physis. These sensors may provide valuable data on growth rates, biomechanics forces, and tissue response, facilitating personalized adjustments and optimizing the modulation process

Bioresorbable implants with controlled release of growth modulators

Bioresorbable implants capable of controlled release of growth modulators, such as growth factors or biologically active substances, represent an innovative approach to guided growth. These implants may offer the potential for more targeted and dynamic modulation of bone growth, promoting optimal correction while minimizing the risk of long-term implant-related complications.

Computer-assisted surgical planning and navigation

Advanced computer-assisted techniques, including pre-operative planning software and intraoperative navigation systems, enable precise localization of the physis and accurate implant placement. Integration of imaging data with computerized modeling and navigation may enhance the accuracy and reproducibility of guided growth procedures.

These emerging technologies and techniques showcase the ongoing innovation in the field of guided growth for angular deformities, with a focus on personalized, minimally invasive, and dynamically adjustable approaches. As the research and development in this area continue to expand, it is important to conduct further clinical studies and longitudinal follow-ups to evaluate the safety and efficacy of these novel interventions.

Summary

In conclusion, the treatment of angular deformities around the knee has evolved significantly over the years, with guided growth emerging as a less invasive and more effective option for patients.

Recent studies have shown promising results with guided growth procedures, and the future of this field holds great potential for further advancements in technology and surgical techniques. By continuing to innovate and improve upon current practices, we can expect to see even better outcomes for patients with angular deformities around the knee in the years to come.

Conclusion

The concept of guided growth and its applications in the immature skeleton has evolved significantly over the last decade . As more lucidity has set in, with regards to growth plate physiology, the aberrations of growth and the understanding of the pathology of various growth disorders , specific tweaks in the technique of guided growth have evolved with a more focused outcome.

Declaration of patient consent: The authors certify that they have obtained all appropriate patient consent forms. In the form, the patient has given his consent for his images and other clinical information to be reported in the Journal. The patient understands that his name and initials will not be published, and due efforts will be made to conceal his identity, but anonymity cannot be guaranteed.
Conflict of Interest: NIL; **Source of Support:** NIL

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