SPECIALTY UPDATE

What's New in Limb Lengthening and Deformity Correction

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This update summarizes select articles pertaining to limb lengthening and deformity correction that were published between July 1, 2010 and June 30, 2011.

Limb-Length Discrepancy and Lower Limb Alignment

The minimum threshold for treating limb-length discrepancy is debatable. In the study by O'Brien et al., an imposed discrepancy of >10 mm was perceived by twenty-nine (97%) of thirty normal subjects[1]. In the study by Golightly et al., an inequality of ≥20 mm was associated with progressive radiographic osteoarthritis of the knee[2].

There are subtle differences in lower limb alignment based on sex[3] and ethnicity[4]. Measuring the anatomic axis of the femur and tibia in patients with osteoarthritis with use of limited radiographs of the knee may be less reliable than a full-length weight-bearing radiograph of the lower extremity[5]. A comprehensive monograph on the treatment of limb-length discrepancies was recently published[6].

Pediatric Disorders

Guided Growth and Related Disorders

There are various methods for assessing growth remaining in children. The multiplier method, which is based on the child's chronological age, provides a reasonable estimate of limb length at skeletal maturity among preadolescent children, whereas other prediction methods utilizing skeletal age are more accurate during adolescence[7]. Growth modulation with use of staples, tension band plates, or transphyseal screws remains an attractive option for angular deformity correction in the skeletally immature patient[8,9]. Jung et al. used a mathematical model to evaluate the effect of hemiepiphyseal stapling around the knee on the length of the involved extremity and found that a smaller width of the involved physis, a longer distance between the involved physis and the ankle, and a larger angular deformity tended to increase the effective limb length[10]. Shin et al., in a retrospective study evaluating the efficacy of staples as compared with percutaneous transphyseal screws around the knee, found that both techniques were equally effective for correcting angular deformity and that both techniques had a similar incidence of physeal rebound phenomenon following implant removal (21% overall; twelve of fifty-six)[11]. In a survey of members of the Pediatric Orthopaedic Society of North America (POSNA), sixty-five cases of mechanical failure of titanium nonlocking extraperiosteal plates were reported; failure was often due to a fracture of the cannulated screw as it entered the lateral cortex of the proximal tibial metaphysis[12]. Use of alternatives such as dual plates, stainless steel material, or solid screws was suggested for the at-risk obese patient with Blount disease. Rupprecht et al. reported that temporary medial screw epiphysiodesis of the distal part of the tibia was effective for correcting valgus deformity of the ankle in children with hereditary multiple exostosis[13].

Magnetic resonance imaging (MRI) findings correlated well with histological examination for measuring the extent of physeal bars in an animal model[14]. Novel approaches such as endoscopically aided removal of a distal femoral physeal bar combined with guided growth treatment have been described[15].

Lower Limb Lengthening

Intraoperative arthrography can enhance visualization of the articular surfaces during realignment osteotomy in children with genu varum secondary to achondroplasia[16]. While the

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Taylor Spatial Frame (Smith & Nephew, Memphis, Tennessee) has several advanced features compared with the standard Ilizarov fixator, there may be a slightly slower rate of bone maturation when the newer device is used in children[17]. The use of small-diameter flexible intramedullary nails in combination with the Ilizarov fixator has been associated with a substantial decrease in the duration of external fixation[18,19].

Neuromuscular Disorders

Children with various neuromuscular diseases often have gait abnormalities and lower limb deformities that can interfere with function. On the basis of sagittal T1-weighted MRI scans, Riad et al. reported that limb shortening in patients with spastic hemiplegia originated primarily distal to the knee[20]. Yang et al. reported that, despite some recurrence, functional gains following extension femoral osteotomy and/or gradual distraction with circular external fixation were noted in arthrogrypotic children with flexion contractures of the knee[21]. In addition to distal femoral extension osteotomy and soft-tissue releases, anterior distal femoral epiphysiodesis[22] and the Ilizarov technique with gradual soft-tissue correction[23] are other potential options for addressing flexion deformities of the knee in children with spina bifida and other conditions[24]. Gradual correction with external fixation can also be used to correct excessive tibial torsional and foot deformities in such children[23].

Blount Disease

Montgomery et al. reported a strong association between vitamin-D deficiency and Blount disease among obese youth, especially boys[25]. In the study by Amer and Khanfour, a high rate of recurrent deformity following gradual deformity correction was noted in children with Blount disease who were more than four years old at the time of presentation[26].

Congenital Lower Limb Deficiencies

Congenital fibular deficiencies have been associated with a wide array of anomalies of the involved extremity besides limb shortening[27,28]. Although a satisfactory clinical outcome can be expected following the use of the Ilizarov technique for limb reconstruction in selected cases of severe fibular hemimelia, complications are common[29]. Birch et al., in a report based on a single institution's experience in the treatment of 104 patients (126 affected extremities) who had fibular hemimelia, reported that patients with three or fewer foot rays were more often managed with amputation rather than limb lengthening[27]. Ulger and Sener reported that rehabilitation training following prosthetic fitting improved function and gait in children with lower limb amputations[30]. Johari et al. reported that children with congenital posteromedial bowing of the tibia who are managed with single-stage lengthening closer to skeletal maturity rather than at a younger age may have fewer complications[31].

Foot and Ankle Disorders

The treatment of pediatric foot and ankle deformities continues to evolve. The use of circular external fixation with gradual correction combined with limited soft-tissue releases has been reported to be effective for correcting relapsed and neglected clubfeet in older children[32,33]. The Taylor Spatial Frame is an emerging tool for the treatment of a variety of multiplanar foot and ankle deformities in children[34-36]. Premature closure of the distal tibial or fibular growth plate may require realignment strategies during growth or at skeletal maturity to reestablish the anatomic relationship of the two bones at the ankle[35,37]. A distal tibial rotational osteotomy for the treatment of symptomatic persistent idiopathic tibial torsion in early adolescence has been reported to improve frontal plane kinematics[38].

Congenital Pseudarthrosis of the Tibia

Despite advances in osteobiologics, congenital pseudarthrosis of the tibia remains a challenging condition to treat. Following extraperiosteal resection of the diseased tibial segment, novel reconstructive approaches such as the use of ipsilateral vascularized fibula[39], contralateral vascularized fibula in infancy[40], split tibia vascularized fibula[41], periosteal fibular flap[42], contralateral onlay tibial cortical grafting[43], temporary cement spacer followed by massive autogenous bone-grafting[44], and local application of bone morphogenetic proteins[45] with systemic administration of bisphosphonates[46] have been reported. While these supplemental procedures may enhance union, typical long-term problems such as refracture, limb shortening, and valgus deformity at the ankle remain unresolved.

Osteogenesis Imperfecta and Related Conditions

Telescopic intramedullary rods are often used for the treatment of osteopenic conditions associated with recurrent fractures and deformities of long bones[47,48]. Cho et al., in a study of children with osteogenesis imperfecta with an intramedullary telescopic rod who were receiving bisphosphonates, noted a persistent fracture risk, especially at less-remodeled fracture or osteotomy sites and at the rod tip[47]. Given the limited torsional stability with these telescopic implants, supplemental external fixation has been advocated for patients who have osteopenic conditions associated with poor healing potential[48]. In older adolescents and adults with lower limb deformities secondary to metabolic bone disease, a fixator-assisted osteotomy stabilized with locked intramedullary nailing is effective for maintaining deformity correction and preventing refractures[49].

Trauma

Pediatric Trauma

Recent literature has focused on preventing and correcting deformity following fractures in children. The use of screw fixation alone for the treatment of displaced femoral neck fractures may not provide adequate stability and was associated with posttraumatic coxa vara in twelve (55%) of twenty-two children in one study[50]. Malunion, especially procurvatum, is a concern after the use of flexible titanium nails for the treatment of pediatric femoral shaft fractures. Divergence of the two nails in the sagittal plane may prevent such deformity[51]. In the report by Ballal et al., fixator-assisted plating combined with realignment osteotomy was used for the treatment of a segmental femoral fracture in a child who had a baseline valgus knee deformity[52]. In the study by Blondel et al., circular external fixation was used for the treatment of tibial fractures in children and demonstrated the potential ability to correct residual deformities in an outpatient setting[53]. Realignment osteotomies of malunited radial neck fractures with intramedullary fixation may improve function[54].

Familiarity with the subtleties of the radiographic assessment of the distal part of the humerus is helpful when treating elbow trauma in children. The lateral capitellohumeral and Baumann angles remain essentially unchanged during early childhood[55]. A variety of osteotomies are available for addressing posttraumatic cubitus varus. Medialization of the distal fragment, with or without a step-cut osteotomy, avoids the lateral prominence of the distal part of the humerus[56,57]. While internal rotation correction is not warranted because of the limited remodeling potential, correction of the hyperextension humeral deformity has been recommended for patients more than ten years old[58].

Adult Trauma

Lower Extremity Trauma

Injudicious reaming of the tibial shaft can lead to extreme local hyperthermia, with a rare but catastrophic complication of segmental bone and soft-tissue necrosis. Seven such limbs were salvaged with bone transport with use of circular external fixation[59]. Patients with complex femoral fractures associated with polytrauma are at risk for pulmonary complications. External fixation for immediate and definitive fixation has been successfully used for damage-control orthopaedics and for the prevention of the secondary hit phenomenon[60-62]. The role of external fixation in the treatment of pilon fractures continues to be studied. In one study, two-stage open reduction and internal fixation was compared with limited internal fixation combined with external fixation for the treatment of closed tibial plafond fractures[63]. The functional outcomes were similar, although radiation exposure and the prevalence of superficial soft-tissue infection were higher with external fixation. In the study by Kapoor et al., indirect reduction with use of an ankle-spanning Ilizarov fixator for the treatment of high-energy pilon fractures, with removal of the calcaneal ring approximately four weeks postoperatively to allow ankle motion, resulted in satisfactory healing in the majority of patients[64]. Patzkowski et al. reported that the use of a newly designed ankle-foot orthosis combined with intensive physical therapy can further enhance function patients requiring limb salvage following a combat-related wound[65].

In the biomechanical study by Mercer et al., the stiffest construct for spanning external fixation for the stabilization of traumatic knee dislocations was achieved when half-pins were placed anterolaterally on the femur and two connecting rods were used[66]. In the study by Levy et al., a staged protocol involving the initial use of a spanning external fixator followed by vascular repair and ligament reconstruction demonstrated satisfactory clinical and functional outcomes in patients sustaining traumatic knee dislocation with an associated vascular injury[67].

Upper Extremity Trauma

A prospective randomized multicenter study on the treatment of unstable distal radial fractures suggested that dynamic external fixation resulted in better restoration of radial length and wrist mobility as compared with static external fixation[68]. In the study by Wilcke et al., wrist function recovered more rapidly after volar locked plating than after external fixation, but functional outcomes were similar at one year postoperatively[69]. Burg et al. reported that minimally invasive treatment of osteoporotic distal humeral fractures with closed reduction and ring fixation is a viable alternative to internal fixation or elbow arthroplasty in the older patient[70]. Blonna et al. reported that, in comparison with traditional external fixation, a hybrid technique that combined osteosutures and external fixation was associated with better clinical outcomes when used for the treatment of proximal humeral fractures in the elderly[71].

Bone and Soft-Tissue Defects

Chaddha et al. reported that, despite multiple complications, use of the Ilizarov technique of bone transport for the treatment of massive bone defects (average, 8.9 cm) was associated with an ultimate union rate of 92% (twenty-three of twenty-five)[72]. In the study by Parmaksizoglu et al., early limb lengthening via callus distraction after acute shortening for the treatment of traumatic below-the-knee amputations and severe open tibial fractures was associated with similar outcomes compared with a delayed strategy[73]. Investigators comparing bone transport and compression-distraction treatment with use of monolateral fixation favored compression-distraction because of a lower rate of complications[74]. However, the extent of bone loss should be considered when choosing between the two options.

Soft-tissue and bone-healing problems may arise during bone transport, especially at the docking site. A technique involving a reverse sural flap was described for the treatment of soft-tissue problems in the distal third of the leg with an overlying circular fixator[75]. This sural artery-based fasciocutaneous flap was transposed anteromedially with the patient in the prone position. The Ilizarov fixator also has been used to gradually close traumatic soft-tissue defects[76]. Hatzokos et al. reported that healing time at the docking site following the application of demineralized bone matrix and autologous bone marrow was equivalent to that after autologous cancellous bone grafting and was superior to that after closed compression alone[77]. The use of arthroscopic debridement of the docking site to enhance osseous healing was reported by Robinson et al.[78].

Malunion/Nonunion

Buijze et al. reported on a single surgeon's experience with twenty-nine of 152 eligible patients who underwent reconstruction with debridement of infected and necrotic tissues, external fixation, and soft-tissue coverage followed by autologous bone-grafting for the treatment of complex malunion or nonunion of the tibia or femur[79]. After a median duration of follow-up of twenty years, all available patients were able to bear full weight with persistent osseous healing, despite functional limitations. A clamshell osteotomy with intramedullary stabilization for the correction of complex diaphyseal malunions of the femur or tibia was recently described as an alternative to more conventional techniques[80].

Upper Extremity Reconstruction

The mechanical axes of the wrist are oriented obliquely to the anatomic axes, with the primary direction being one of radial extension and ulnar flexion[81]. Distal radial osteotomies for the treatment of malunited fractures[82] and Madelung deformity[83] with acute biplanar correction can restore anatomic alignment. External fixation with gradual lengthening and deformity correction continues to be utilized for the treatment of a variety of congenital and acquired conditions related to the humerus[84], forearm[85], and hand[86,87].

The functional range of elbow motion necessary for the performance of contemporary tasks such as using a cellular phone or a computer may be greater than previously reported[88]. Surgical release of posttraumatic elbow contracture with[89] or without[90,91] a hinged external fixator has been reported to be effective for improving elbow mobility. However, gains in health status and disability scores following open elbow contracture release may not correlate with improvement in function[90].

Lower Extremity Reconstruction

Ilizarov Hip Reconstruction

Pelvic support osteotomy combined with femoral lengthening and realignment (the Ilizarov hip reconstruction) is a comprehensive solution for the treatment of hip instability associated with limb shortening secondary to various etiologies. In the study by Gursu et al., a lower complication rate and a higher satisfaction rate were noted for patients who underwent such reconstruction for the treatment of the sequelae of hip infection as compared with those who underwent the procedure for the treatment of long-standing hip dislocation[92].

Total Hip Arthroplasty

The assessment of limb length is pertinent both before and after total hip arthroplasty. Meermans et al. reported that, for the assessment of preoperative limb-length discrepancy in patients with osteoarthritis of the hip, the interteardrop line was a reliable pelvic reference and the center of the femoral head was a dependable femoral marker on an anteroposterior pelvic radiograph[93]. Benedetti et al. reported that, for the evaluation of the effects of limb lengthening after a total hip arthroplasty, a limb-length discrepancy of <20 mm did not substantially affect hip kinetics[94].

Total Knee Arthroplasty

There are concerns regarding the outcome of total knee arthroplasty in patients who have undergone a previous high tibial osteotomy. Two recent intermediate-term studies suggested that a previous high tibial osteotomy did not influence the function or survival of a total knee replacement[95,96]. Patients with skeletal dysplasia typically have anatomic variances and osseous deformities. While special considerations regarding implant selection and ligament balancing must be made during total knee arthroplasty, short-term results have revealed consistent improvements in terms of pain and function in such individuals[97]. Patients with persistent hindfoot valgus deformity who undergo total knee arthroplasty are predisposed to postoperative lateral deviation of the mechanical axis that can negatively impact the longevity of the implant[98].

Periprosthetic fractures following total knee arthroplasty can be a challenging problem, especially in elderly patients with multiple medical comorbidities and osteopenia. An Ilizarov external fixator is a potential option for the treatment of such fractures around implants, allowing for the restoration of alignment, stable fixation with rapid mobilization, and osseous healing[99].

High Tibial Osteotomy

Despite advances in total knee arthroplasty, the use of high tibial osteotomy to address medial compartment osteoarthritis in active adults continues to generate interest. The biomechanical benefit of realignment via high tibial osteotomy for the treatment of medial compartment osteoarthritis was evaluated with use of a computational knee model in a study of thirty patients[100]. The external knee adduction moment during stance phase, medial compartment load, and medial-to-lateral compartment load ratio were substantially improved postoperatively. Sterett et al. reported that, with a survival rate of 91% at seven years, microfracture combined with high tibial osteotomy could delay knee replacement in active patients with varus gonarthrosis[101]. Hui et al., in a study of 455 consecutive patients who underwent lateral closing-wedge high tibial osteotomy for the treatment of medial compartment osteoarthritis, reported that the probability of survival at five, ten, and fifteen years was 95%, 79%, and 56%, respectively[102]. An age of less than fifty years, normal body mass index (BMI), and anterior cruciate ligament (ACL) deficiency were independent factors associated with improved long-term survival following high tibial osteotomy.

Various techniques are available for the performance of high tibial osteotomy. An opening-wedge technique with rigid fixation is gaining popularity[103,104]. El Assal et al. reported an average time to union of 12.4 weeks following Page: 13 opening-wedge corrections of up to 14 mm that were performed with internal fixation and without bone graft[105]. Good short-term results have also been reported following opening-wedge high tibial osteotomy with locked plates[106]. In the study by Song et al., complications following opening-wedge high tibial osteotomy were similar to those following the closing-wedge technique, although obesity remained an independent predictive risk factor for postoperative complications[107].

The ideal candidate and timing for high tibial osteotomy remain controversial. In the study by Niemeyer et al., the severity of medial cartilage damage and partial-thickness defects of the lateral compartment as noted on preoperative arthroscopy did not appear to influence clinical outcome three years following high tibial osteotomy[108]. Masrouha et al., in a study of active young adults (less than twenty-five years old) who had constitutional tibia vara, reported that opening-wedge correction resulted in satisfactory outcomes two years postoperatively[109]. Kim et al. performed a clinical study to examine the role of high tibial osteotomy in patients with varus alignment without medial compartment knee arthrosis who were undergoing ACL reconstruction[110]. As the stability and functional scores after ACL reconstruction were not adversely affected by primary varus alignment, a concomitant high tibial osteotomy may not be necessary in the absence of medial compartment arthritis or varus thrust. In the cadaver study by Kendoff et al., incremental increases in valgus correction affected the length and strain on the posterolateral bundle of the ACL[111]. Thus, the authors recommended that, if necessary, the high tibial osteotomy should be performed prior to ACL reconstruction.

Foot and Ankle

Deformity Analysis and Correction

Weight-bearing radiographs along with clinical evaluation are imperative when treating foot and ankle deformities. Naviculocuboid overlap, anteroposterior talonavicular coverage, and anteroposterior talus-first metatarsal angles measured on weight-bearing radiographs are reliable and valid indicators for assessing frontal plane hindfoot deformities[112]. The hindfoot alignment view is often used for assessing the relationship of the long axis of the hindfoot and tibia. In the study by Frigg et al., the varus-valgus alignment noted on this radiograph in patients with an ankle or tibiotalocalcaneal fusion was correlated with pedographic load distribution[113]. A tibiocalcaneal angle of 5° to 10° valgus was associated with a physiologic gait pattern.

Circular external fixation allows gradual correction of complex foot and ankle deformities with minimally invasive methods. Deformities related to a variety of etiologies such as post-burn contractures[114], chronic unreduced fracture-dislocation of the ankle[115], neurologic disorders[116], and others[117] can be effectively treated with this strategy. However, one needs to be prepared for potential problems, including pin-track infections, hypoesthesia[117], and recurrence of deformities[116].

Charcot Arthropathy

This potentially limb-threatening condition is often seen in patients with diabetes and can be associated with peripheral sensory neuropathy, osteopenia, joint instability, and skin ulceration. A circular external fixator can be effectively used for deformity correction and arthrodesis in such patients[118,119].

Lengthening for Brachymetatarsia

Acute or gradual metatarsal lengthening can be performed to restore length and alignment in patients with brachymetatarsia. Various pitfalls associated with metatarsal lengthening along with preventive and management strategies have been outlined[120]. In the study by Giannini et al., one-stage metatarsal lengthening with allograft interposition and intramedullary Kirschner wire fixation was used for twenty-nine patients (fifty metatarsals) with congenital brachymetatarsia and was associated with a mean gain of 13 mm and low morbidity[121]. Lee et al. noted similar outcomes following distraction osteogenesis for the treatment of first and fourth brachymetatarsia[122]. Despite eventual healing in all forty-eight patients (seventy-four metatarsals), stiffness of the metatarsophalangeal joint and malalignment of the lengthened metatarsal was noted in a few cases in each group.

Oncologic Reconstruction

Children with larger bone cysts may be predisposed to limb shortening as adults, possibly related to the effect on the adjacent growth plate[123]. There are several options for addressing large bone defects following resection of malignant tumors[124-126]. Various biologic and prosthetic options such as allograft, extracorporeally radiated autograft, vascularized allograft with plate fixation, and custom diaphyseal implants have been utilized for joint-preserving reconstruction following diaphyseal resection of bone tumors[125]. In the study by Hariri et al., one-stage reconstruction with vascularized fibular grafts was associated with superior functional results in comparison with the results of a two-stage approach following resection of metadiaphyseal tumors of the lower extremity[124]. Distraction osteogenesis with hemicallotasis[127] and medial transport of the ipsilateral fibula[128] are other innovative techniques for addressing tibial bone defects following tumor resection. Distal femoral growth arrest following a cemented proximal femoral endoprosthetic replacement in a child with Ewing sarcoma also has been reported[129].

What's New in Limb Lengthening and Deformity Correction

Postoperative Complications and Their Treatment

In order to avoid injury to vital structures and to allow early detection of neurovascular compromise in patients undergoing external fixation, vigilance during the intraoperative and postoperative periods is warranted. Placement of a "retro-fibular wire" via a safe corridor in the distal part of the tibia can provide greater crossing angles and increased stability for fine-wire circular external fixation[130]. Radial nerve injury following external fixation of the humerus[131] and the use of ultrasound for localizing the site of nerve injury during humeral lengthening[132] have been reported.

While the use of hydroxyapatite-coated half-pins has substantially decreased pin-track infections, pin-related problems associated with external fixation continue to be a source of concern. Further improvement in the design of osseous anchors, such as the use of iodine-supported titanium half-pins[133] and different pin-care regimens, continues to be investigated[134].

Soft-tissue problems are often encountered in patients being managed with distraction osteogenesis. While investigators continue to search for ways to prevent muscle fibrosis[135], innovative surgical techniques to address knee contractures with use of a combination of soft-tissue releases and hinged external fixation are being utilized[136]. Ankle valgus deformity secondary to proximal migration of the fibula following tibial lengthening has been associated with poor regenerate formation and distal fibular nonunion[137].

Poor bone formation during limb lengthening and deformity correction can negatively impact clinical outcome. Besides autologous bone-grafting and innovative instrumentation, several biologic, chemical, and mechanical solutions are being investigated to enhance bone formation and to shorten the consolidation phase of distraction osteogenesis[138]. Some of these potential ancillary methods include the use of autologous bone-marrow grafting combined with demineralized bone matrix[77], mesenchymal stem cells[139,140], bone morphogenetic proteins[141], bisphosphonates[142], thrombin peptide[143], erythropoietin[144], and low-intensity pulsed ultrasound stimulation[145].

New Tools and Techniques

Picture Archiving Systems/Preoperative Planning Software

With the transition in technology toward digital radiography and picture archiving and communication systems (PACS), surgical planning software programs are also gaining popularity. Digital measurements of lower limb length and alignment based on full-length radiographs of the lower extremity via PACS are similar to those obtained with use of conventional hard-copy radiographs[146]. While the level of accuracy and reliability for making measurements from digital radiographs is quite high, there is still some variability[147].

Computer-aided preoperative planning for lower limb deformity correction based on computed tomographic (CT) scan-derived data appears promising[148]. Other software programs have been utilized for osteotomies of the proximal part of the femur and the pelvis[149], the distal part of the humerus[150], the olecranon[151], and the distal part of the radius[152].

Computer Navigation

Computer navigation is a potential means for improving surgical safety and accuracy. Manzotti et al. reported that while computer-assisted surgery was more effective for minimizing limb-length discrepancy during total hip arthroplasty, the surgical time was prolonged compared with the control group[153]. In the study by Iorio et al., accurate correction of mechanical axis alignment and minimal unintentional change in the posterior slope following opening-wedge high tibial osteotomy was noted in association with computer navigation[154]. Finally, the case report by Kang et al. illustrated the use of computer navigation during the surgical resection of a physeal bar in a child with premature growth arrest of the distal part of the tibia[155]. It remains to be determined if the increased cost and longer operative times are justified by the advantages of this new technology in orthopaedics.

Intramedullary Lengthening Devices

Interest in and experience with the use of internal lengthening nails have grown in the last decade. Although external fixation is avoided, other challenges associated with such devices have become apparent. Three studies examined difficulties associated with the only current Food and Drug Administration (FDA)-approved internal lengthening device. Burghardt et al. evaluated the mechanical failures of the Intramedullary Skeletal Kinetic Distractor (ISKD) (Orthofix, Verona, Italy) in a study of 180 patients (242 limb segments)[156]. In all, fifteen ISKD devices failed in twelve patients; the failures included ten device fractures. Following unplanned interventions, the lengthening goal was finally achieved in all twelve patients. In another study, substantial difficulties were noted in forty-five (65%) of sixty-nine patients undergoing lengthening with use of the ISKD device[157]. However, successful femoral lengthening was achieved in fifty-two (90%) of fifty-eight patients whereas tibial lengthening was achieved in only five (45%) of eleven patients. In a third study, insufficient bone regenerate developed in eight (23%) of thirty-five patients undergoing femoral lengthening with use of the ISKD device[158]. Important risk factors for poor bone formation were a lengthening rate of >1.5 mm/day, an age of thirty years or more, smoking, and lengthening of >4 cm. Distraction problems associated with the ISKD device were related mostly to internal malfunction of the lengthening mechanism.

Intramedullary lengthening with use of a different device (FITBONE; WITTENSTEIN intens GmbH, Igersheim, Germany) was retrospectively analyzed by Krieg et al. in a study of thirty-two patients[159]. Lengthening was successful in thirty (94%) of the thirty-two patients, with faster healing in the femur than in the tibia. Implant-related problems were noted in five instances. As the intramedullary lengthening devices become

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more reliable in terms of their mechanical integrity and control of the distraction rate, their popularity may increase.

Hybrid Techniques

Hybrid techniques combine external and internal fixation, primarily to minimize time in external fixation. Fixator-assisted nailing is an effective method for addressing lower limb deformities secondary to metabolic bone disease[49]. The accuracy of deformity correction and clinical outcome following distal femoral osteotomy with use of external fixation was comparable with fixator-assisted plating, although the operative time was longer with supplemental internal fixation[160].

In the study by Sun et al., lengthening over a nail was compared with classic lengthening of the tibia with use of external fixation alone[161]. Although faster healing with less axial deviation and callus subsidence was seen with lengthening over a nail, a higher prevalence of equinus contracture was noted. In the study by Chen et al., tibial lengthening over a small-diameter humeral nail was successfully performed in a group of patients with poliomyelitis[162]. When an intramedullary nail is already in place, lengthening over the nail can be performed without removal of the nail[163]. In children, lengthening over small-diameter flexible nails can decrease the duration of external fixation[18].

Upcoming Events

Specialty Day of the Limb Lengthening and Reconstruction Society (LLRS) will be held at the Annual Meeting of the American Academy of Orthopaedic Surgeons (AAOS) on February 11, 2012, in San Francisco, California. The Annual Scientific Meeting of the LLRS will be held on July 27 and 28, 2012, in Cincinnati, Ohio. A workshop on "Essentials in Deformity Correction" is planned for July 28, 2012, in Cincinnati, Ohio. Details are available at the LLRS web site: www.llrs.org.

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