

GUEST EDITORIAL

What's New in Limb Lengthening and Deformity Correction

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This review summarizes selected articles regarding limb lengthening and deformity correction that were published in 2019 and early 2020. Our goal was to select articles that encapsulate a broad spectrum of pathologies and interventions, investigated at a variety of institutions. These articles evaluate current practice techniques as well as describe innovations and emerging frontiers within our subspecialty.

Congenital Limb Deficiencies

Congenital limb deficiencies in children are an ongoing subject of intense study because of the psychosocial effects of the diagnosis, difficult early treatment decisions (amputation versus reconstruction), and the technical execution of challenging lengthenings and multiple procedures throughout childhood. Mano et al. performed a novel investigation in which children with congenital limb deficiencies were asked to draw whole body portraits, and their knowledge of basic anatomy was evaluated¹. The children with congenital limb deficiencies were equivalent to controls with respect to visuo-spatial body knowledge, but they demonstrated less lexical-semantic knowledge (i.e., affected children were less familiar with general terms for body parts). Gettys et al. reported that children with a congenital limb deficiency and scoliosis had a high rate of clinically important intraspinal pathology on magnetic resonance imaging (MRI) and high rates of neuro-surgical intervention, and therefore recommended that screening spine MRI be performed whenever the 2 entities coexist².

In a retrospective investigation involving children with congenital femoral deficiency, monolateral external fixation lengthening was compared with motorized intramedullary nail limb lengthening (MILL). Despite similar lengthening parameters, the MILL group had lower complication rates and better range of motion at the end of distraction and at consolidation³.

In another recent study, staged reconstruction and amputation were compared in the treatment of Achterman-Kalamchi Type-II (severe) fibular hemimelia. Despite clear

socioeconomic differences between those undergoing reconstruction versus amputation, psychosocial adjustment and health-related quality of life were comparable between the groups and achieved near-normal values for age⁴. A report on a staged approach to fibular hemimelia (systematic utilitarian procedure for extremity reconstruction [SUPER]ankle then lengthening) suggested durable results in most patients at an average of 9 years of follow-up⁵.

A novel staged-reconstruction strategy for Jones Type-IV tibial deficiency (distal tibial-fibular diastasis, absence of ankle mortise, shortening) was described by Ernat and colleagues⁶. The technique included soft-tissue distraction, tibiotalar fusion, and later tibial lengthening, and resulted in functional independence at skeletal maturity in 2 patients.

Litrenta et al. reviewed the treatment of congenital tibial deficiency, describing an incidence of 1 per million, noting a broad spectrum of involvement and unknown etiology, and reporting that associated pathologies are common⁷. The authors described that the overriding goal is to create a stable limb capable of independent ambulation, usually through amputation and prosthetic fitting. Fundamental to surgical decision-making is knee stability and extensor-mechanism function. In those with a functional knee joint, proximal cross-union of the tibia and fibula and distal amputation are most successful. Limb lengthening and foot centralization, in select cases, can be performed, but multiple surgeries, the high risk of complications, and unknown functional results must be addressed carefully with the family.

Guided Growth

A retrospective investigation of the screw divergence angle in plate + screw tension-band constructs was performed, in order to investigate whether greater or less screw divergence resulted in a superior correction rate for hemiepiphysiodesis about the knee⁸. Although there are biomechanical reasons that either screw configuration could result in superior correction, both appeared equivalent, and the authors suggested finite-element

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WHAT'S NEW IN LIMB LENGTHENING AND DEFORMITY CORRECTION

analysis as a means of further investigation of all potential variables.

Several groups have reported on the use of guided growth for the proximal part of the femur with cannulated screws (medial proximal femoral hemiepiphyodesis) to correct coxa valga in patients with neuromuscular hip subluxation⁹. Although largely successful in the slow correction of neck-shaft deformity and migration percentage, physeal growth “off the screw” was common after approximately 2 years and resulted in difficulty with screw exchange.

Metaizeau et al. described a new technique of guided growth in the transverse plane, involving percutaneous cannulated screws and a cable around the distal femoral physis to effect slow distal femoral derotation¹⁰. Transverse-plane correction occurred at about 1.2° per month, although small amounts of recurvatum were introduced in 8 of 20 knees, and stiffness requiring formal knee manipulation under anesthesia occurred in 6 of 20 knees.

Definitive percutaneous epiphyodesis (PE) was compared with temporary epiphyodesis (TE) with medial and lateral plates (distal part of the femur and/or proximal part of the tibia)¹¹. Correction of limb-length discrepancy was greater in the PE group, although the differences did not meet traditional thresholds for statistical significance. Complication rates were higher in the TE group, because of unplanned reoperation for coronal malalignment, notwithstanding the need for routine implant removal.

Lawing et al. examined factors associated with late follow-up and overcorrection when guided growth techniques are employed¹². In a retrospective series of 112 patients, they reported a late follow-up rate of 39%, which was associated with overcorrection, obesity, and a primary language other than English, highlighting the need for close and appropriate patient education and communication with patients undergoing guided growth. A review article was also published pertaining to guided growth¹³.

Dysplasia and Tumors

Cirstoiu et al. described current treatment options for bone defects after resection of extremity bone sarcomas, including modular endoprosthetic reconstruction, bone-graft reconstruction, bone transport, resection arthrodesis, and rotation-plasty¹⁴. Specific concerns with bone transport included infection risk and immunosuppression, possible tumor cell activation, regenerate fracture, muscle contractures, implant failure, nonunion, malalignment, and high psychological burdens.

Jang et al. describe a small group of patients with “proximal tibial dysplasia” associated with congenital pseudarthrosis of the tibia, who underwent lengthening either with a transphyseal distraction or an osteotomy directly next to the physis¹⁵. Those with lengthening through the physis had a lower healing index (faster healing) than

those with metaphyseal corticotomy. The authors acknowledge that this technically demanding surgery (transphyseal distraction) was developed for particularly severe cases of proximal tibial dysplasia associated with congenital pseudarthrosis, best done near maturity.

Ko et al. reported on a series of extensive lengthenings among 14 patients with achondroplasia and 1 patient with hypochondroplasia, comparing complications by bone segment and whether the patient had simultaneous bilateral femoral lengthenings and separate bilateral tibial lengthenings (transverse technique), or crossed lengthenings (simultaneous femoral and contralateral tibial, followed later by the opposite)¹⁶. Humeral lengthenings were associated with significantly fewer complications and quicker healing than lower-extremity lengthenings, and the authors also found that humeral lengthening aided in perineal self-care. The crossed lengthenings had a greater incidence of malalignment and leg-length discrepancy compared with the transverse technique.

Memeo et al. described the use of a protocol for sequentially injecting bone marrow aspirate concentrate in patients with achondroplasia during distraction osteogenesis for the treatment of delayed union¹⁷. The concentrate was injected in multiple areas of poor regenerate, and the site was manipulated to improve penetration. The authors did not describe the influence of frame stability, implying that the concentrate acted alone to improve healing.

Singer and Johnston reported the results of 34 patients treated with the Charnley-Williams procedure for congenital pseudarthrosis of the tibia, who were followed to skeletal maturity¹⁸ (mean follow-up of 11.9 years after the initial surgery). The authors considered patients whose fibula was not treated to have had inferior results. Thirteen of the 34 patients experienced fracture after a period of union, 10 of whom healed on retreatment. All 6 patients who did not have fibular surgery had poor results and requested amputation.

Foot and Ankle

A “round table discussion” was conducted pertaining to tibiotalar calcaneal arthrodesis in patients with and without diabetes¹⁹. Patient outcome measures, including the Grimby scale, Lower Limb Activity Scale, and visual analog scale (VAS) for activity, were used in 2 papers from the same series of 47 patients by Morasiewicz et al.^{20,21} that reported clinical results as well as physical activity levels after ankle arthrodesis. While ankle arthrodesis was found to be effective using either external or internal fixation, better outcome scores were reported in the external-fixation group.

Chappell et al. reported on circular fixator use for concurrent tibial and hindfoot deformity correction and distal tibial lengthening in a series of 19 patients²². For distal tibial deformity, a technique was described for dome osteotomy creation using a single circular ring as well as a 5-hole Rancho

WHAT'S NEW IN LIMB LENGTHENING AND DEFORMITY CORRECTION

cube (Smith & Nephew) to “trace out” the osteotomy prior to fixation with cannulated screws²³.

The infected neuropathic ankle presents a further management conundrum. Tomczak et al. presented a series of 7 such cases managed with a hybrid technique of circular external fixation and an intramedullary nail coated with antibiotic cement²⁴. A silicone tube filled with antibiotic bone cement was placed over a standard hindfoot nail, and after cement setting, the tube was incised and removed.

Hip and Knee

Limb-reconstruction techniques continue to find applications in the management of complex articular pathology. Dumlao et al. described the management of a chronic, traumatic posterior hip dislocation in an 8-year-old boy by open reduction, interpositional grafting, femoral shortening, and stabilization with articulated iliofemoral external fixation²⁵. Articulated hip distraction was also described by Papachristos et al. for the management of idiopathic femoral-head osteonecrosis, augmented by core decompression and grafting²⁶.

The role of the posterior proximal tibial angle (PPTA), commonly referred to as “tibial slope” in non-reconstruction literature, is increasingly recognized for its role in knee stability. In a cadaveric study, the authors compared the effects of axial force across a newly implanted anterior cruciate ligament (ACL) graft in 10 knees, varying flexion angle and PPTA²⁷. They demonstrated a strong linear relationship between graft force and PPTA, concluding that a low PPTA (“high slope”) may contribute to ACL graft failure. The group also reported on the effect of PPTA on the posterior cruciate ligament (flatter slope was associated with graft failure)²⁸.

Takahashi et al. performed a meta-analysis on the role of knee-joint distraction in the management of degenerative osteoarthritis, concluding that it may represent a treatment option²⁹. The 3 studies included in the analysis all originated from the same research group, and it is unclear whether patient cross-over is acknowledged or accounted for.

Mayer et al. reported comparable radiographic outcomes for 41 patients treated for Blount disease with Ilizarov or Taylor Spatial Frame (Smith & Nephew) external fixation, with an average patient age of 9.6 years³⁰.

Upper Limb

Circular-fixation techniques play a key role in the management of Monteggia-spectrum injuries. A case of infected ulnar nonunion and a 2.5-cm osseous defect was managed with the application of circular fixation, distal osteotomy, and retrograde ulnar transport to fill the defect, followed by a second ulnar osteotomy and lengthening in order to reduce the radial head³¹. Notably, no radial fixation was used in order to allow pronation and supination during the extended treatment course. Gallone et al. reported on 20 children managed with corrective ulnar osteotomy and lengthening

with unilateral external fixation for chronic Monteggia injuries (3 to 38 months from injury to treatment), extensively reporting a number of radiographic and functional parameters³². The level of the osteotomy significantly influenced radial-head reduction success.

Ulnar lengthening is also central to the management of forearm deformity due to multiple hereditary exostoses, which disproportionately affects ulnar longitudinal growth, leading to forearm deformity, radial-head dislocation, and functional impairment. Thirty-three patients (average age, 10.4 years) were included in a study by Li et al.³³, who used either unilateral or circular external fixation for lengthening. Patient age, ulnar diameter at the osteotomy site, and body mass index (BMI) were found to affect the bone-healing index, although only age achieved significance. Concurrent exostosis removal and lengthening percentage were nonsignificant.

In patients with distal radial deformity with shortening, Guan et al. described a technique for bifocal distal radial osteotomy, consisting of acute angular correction distally and external fixator lengthening more proximally. They reported results among 8 patients managed with the technique³⁴.

Trauma

The use of external fixation in pediatric fracture management has been employed by surgeons who are constrained by the physis for fixation options, seek to maintain motion during the initial healing period, and wish to minimize periosteal blood-supply disruption. Korobeinikov and Popkov reviewed the use of external fixation for juxta-articular and periphyseal fractures, in both upper and lower extremities, in children in Kurgan, Russia³⁵. Most frames were removed within 30 days of injury (elbow, wrist, knee, ankle), and full motion was routinely achieved within 30 days of frame removal.

A group in Hanover, Germany who treated an adult with a floating knee injury utilized the time between initial stabilization (damage control) and definitive treatment to construct custom, 3D-printed external fixators through which an anatomic reduction could be maintained through the existing half-pins³⁶. The authors discuss that such a technique could lessen the increased operative time and complication rates at definitive osteosynthesis, as damage-control frames with poor alignment can increase such complications.

Rohilla et al. evaluated the quality of regenerate with bone transport in cases of infected tibial nonunion, comparing monolateral rail fixators and circular fixators³⁷. At 3 and 6 months, regenerate was similar, but at 12 months, the rail-fixator group appeared to have a significantly higher grade of mineralization. The authors postulate that a monolateral frame may be inherently less stable, and the resultant small increase in strain could favorably accelerate maturation.

A series of 14 patients with aseptic long-bone nonunion (femur or tibia) were treated with open debridement and compression with a magnetic expandable lengthening nail (in reverse)³⁸. Interestingly, the nails were programmed to shorten

WHAT'S NEW IN LIMB LENGTHENING AND DEFORMITY CORRECTION

an average of 9.5 mm and actually shortened 6.7 mm, the bone was actually shortened by an average of 3.1 mm, and the locking bolts at the telescopic end were observed to bend an average of 2.5°. Union was achieved in 13 of the 14 cases.

Bone Defects

The management of bone defects continues to be a subject of interest in the orthopaedic literature. A common theme among 5 retrospective clinical investigations was the need for complete eradication of infection at the beginning of treatment through radical debridement³⁹⁻⁴³.

Borzunov and Shastov³⁹ reviewed posttraumatic defects of the tibia and forearm; they encountered poor bone regenerate during bone transport, solved by altering the mechanical environment. The authors employed 4 methods: secondary corticotomy, temporary compression through the poor regenerate, and compression performed acutely or gradually at the docking site, all of which were reported to be successful. The small and diverse sample makes it difficult to know which method to use.

In a review of 86 patients treated with bone transport for defects of >8 cm, Catagni et al. showed that trifocal treatment (with 2 lengthening sites) shortened fixator duration and was associated with better results compared with bifocal treatment (with 1 lengthening site), despite a longer operative time in the trifocal group⁴⁰. The authors reported that the reduction in fixator duration was responsible for fewer complications.

Fifteen cases of deep femoral infection resulting from intramedullary fixation of closed femoral fractures were resolved with staged treatment, including radical defect excision, marrow debridement and continuous canal irrigation for 1 to 3 weeks, parenteral antibiotic administration, and subsequent monolateral bifocal bone transport⁴¹. Infection-free union was reported in all cases.

An L-shaped partial corticotomy was used for 8 cases of focal tibial osteomyelitis⁴². Hemiacortotomy with preservation of intact and uninvolved posterior tibial bone was described. The deficits averaged 8 cm after debridement, with the duration of circular external fixation averaging 169 days. The authors proposed that, in instances in which the infected defect is incomplete, posterior cortical and periosteal preservation may reduce fixator duration.

Conversely, Hosny and Ahmed queried the need for extensive debridement when managing chronic osteomyelitis in the pediatric population⁴³. A range of techniques were employed in their series of 36 patients.

Limb Lengthening

In a retrospective review of 107 femoral lengthenings using the PRECICE (NuVasive) motorized intramedullary nail, the authors compared antegrade and retrograde femoral lengthening techniques, finding “excellent” results with both. Knee motion was preserved in more patients in the antegrade than in

the retrograde group⁴⁴. The indications listed for retrograde lengthening were a narrow proximal femoral isthmus, large proximal soft-tissue envelope, or planned simultaneous distal femoral deformity correction.

Our group evaluated the use of motorized internal lengthening nails compared with external fixation in a series of humeral lengthenings⁴⁵. While the lengthening parameters were comparable, motorized lengthening mitigated pin-site complications and allowed for repeat lengthenings via reuse of the implant. The ability for greater proportional lengthenings of the humerus was again demonstrated in a case report that involved a 15-year-old male patient after proximal humeral physal arrest, in whom just over 10 cm of length was achieved in a single lengthening, 100% of the prior humeral length⁴⁶.

It is evident now that multiple groups are working on motorized internal lengthening plates, to provide an all-internal solution for situations in which intramedullary nailing is contraindicated. Gaudreau et al. provided an ex vivo description of a prototype plate consisting of a cylindrical major segment 18 mm in diameter, capable of generating up to 735 N of distraction force⁴⁷.

Cyclic, axial dynamization to promote osteotomy healing, popularly known as the “accordion technique,” was evaluated in an ovine model by Reich et al.⁴⁸. Their model used unilateral rather than circular external fixation, with 1,200 cycles per day of 0.2, 0.4, and 0.8-mm amplitude. Another animal-based model examined osteogenesis as well as the adaptive morphology of muscle tissue⁴⁹. Canine tibiae were lengthened by 3 mm per day for 10 days, with histological examination being performed both at distraction completion and after 3 months. Interestingly, histological differences were observed in muscle tissue when fixation was augmented with intramedullary stabilization compared with no intramedullary stabilization.

Two studies looked at improving regenerate formation via pharmacological augmentation. Teriparatide, the bioactive component of parathyroid hormone, was delivered to patients after bone-transport docking via 8 weeks of a daily subcutaneous injection⁵⁰. Sixteen patients were randomized, with 8 receiving treatment. Bone mineral density (BMD) was measured via dual x-ray absorptiometry (DXA) scanning at 8 weeks post-treatment; the treated group demonstrated significantly higher BMD. Functional outcome scores were also measured, but results comparing the groups were not reported, and the duration of frame treatment was not reported. Akçay et al. used vitamin E during mandibular distraction osteogenesis in a rabbit model⁵¹. Vitamin E was delivered intraperitoneally in the treatment group daily for 7 days. Following animal sacrifice, DXA measurement of regenerate demonstrated significant increases in BMD in the experimental group compared with the control group.

Practical Management and Technique

A practical and simple approach to leg positioning for circular frame application, utilizing a radiolucent triangle and

WHAT'S NEW IN LIMB LENGTHENING AND DEFORMITY CORRECTION

U-bolster, is detailed in the *Annals of the Royal College of Surgeons of England*⁵². In a randomized, single-blinded study, Subramanyam et al. concluded that there is no role for antiseptic preparations in routine frame pin care⁵³. One hundred and fourteen patients (2,363 pin sites) were randomized to either no preparation, chlorhexidine, povidone-iodine, or silver sulfadiazine. Participants were predominantly being treated for open or closed fracture (61%), and most frames were applied to the leg (62.3%). Neither the antiseptic preparation type nor performance of daily dressing changes appeared to affect the pin-site infection rate. Additionally, a review article published in *Injury*⁵⁴ details evidence pertaining to the diagnosis and management of pin-track infection, and highlights the absence of high-quality (Level I to III) evidence guiding care.

Finally, an "Ethics in Practice" article in *JBJS*, by Randall et al., presents the case of an 11-year-old girl with mild knee valgus resulting in mild mechanical-axis deviation (zone 2)⁵⁵. Guided growth was performed. The authors use the case as the basis for a discussion about the merits of deformity-correction surgery with mainly "aesthetic" indications. This article high-

lights the importance of a holistic approach, shared decision-making, and the importance of medical ethical principles in the application of our incredibly specialized skill set.

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References

- Mano H, Fujiwara S, Haga N. Body knowledge in children with congenital lower limb deficiency. *Pediatr Int*. 2019 Feb;61(2):158-65. Epub 2019 Feb 7.
- Gettys FK, Carpenter A, Stasikelis PJ. The role of MRI in children with congenital limb deficiencies with associated scoliosis. *J Pediatr Orthop*. 2020 May/ Jun;40(5):e390-3.
- Szymczuk VL, Hammouda AI, Gesheff MG, Standard SC, Herzenberg JE. Lengthening with monolateral external fixation versus magnetically motorized intramedullary nail in congenital femoral deficiency. *J Pediatr Orthop*. 2019 Oct;39(9):458-65.
- Birch JG, Paley D, Herzenberg JE, Morton A, Ward S, Riddle R, Specht S, Cummings D, Tulchin-Francis K. Amputation versus staged reconstruction for severe fibular hemimelia: assessment of psychosocial and quality-of-life status and physical functioning in childhood. *JB JS Open Access*. 2019 Apr 5;4(2):e0053.
- Kulkarni RM, Arora N, Saxena S, Kulkarni SM, Saini Y, Negandhi R. Use of Paley classification and SUPERankle procedure in the management of fibular hemimelia. *J Pediatr Orthop*. 2019 Oct;39(9):e708-e717.
- Ernat JJ, Wimberly L, Samchukov ML, Cherkaskin AM, Birch JG. Staged reconstruction for type IV tibial deficiency (distal tibiofibular diastasis): a report of 2 cases. *JBJS Case Connect*. 2019 Dec;9(4):e0088.
- Litrenta J, Young M, Birch JG, Oetgen ME. Congenital tibial deficiency. *J Am Acad Orthop Surg*. 2019 Mar 15;27(6):e268-79.
- Eltayeb HH, lobst CA, Herzenberg JE. Hemiepiphysiodesis using tension band plates: does the initial screw angle influence the rate of correction? *J Child Orthop*. 2019 Feb 1;13(1):62-6.
- Hsieh HC, Wang TM, Kuo KN, Huang SC, Wu KW. Guided growth improves coxa valga and hip subluxation in children with cerebral palsy. *Clin Orthop Relat Res*. 2019 Nov;477(11):2568-76.
- Metaizeau JD, Denis D, Louis D. New femoral derotation technique based on guided growth in children. *Orthop Traumatol Surg Res*. 2019 Oct;105(6):1175-9. Epub 2019 Jul 26.
- Borbas P, Agten CA, Roskopf AB, Hingsammer A, Eid K, Ramseier LE. Guided growth with tension band plate or definitive epiphysiodesis for treatment of limb length discrepancy? *J Orthop Surg Res*. 2019 Apr 11;14(1):99.
- Lawing C, Margalit A, Ukwuanu G, Sponseller PD. Predicting late follow-up and understanding its consequences in growth modulation for pediatric lower limb deformities. *J Pediatr Orthop*. 2019 Jul;39(6):295-301.
- Journeau P. Update on guided growth concepts around the knee in children. *Orthop Traumatol Surg Res*. 2020 Feb;106(1S):S171-80. Epub 2019 Oct 25.
- Cirstoiu C, Crețu B, Serban B, Pantzi Z, Nica M. Current review of surgical management options for extremity bone sarcomas. *EFORT Open Rev*. 2019 May 10; 4(5):174-82.
- Jang WY, Choi YH, Park MS, Yoo WJ, Cho TJ, Choi IH. Physeal and subphyseal distraction osteogenesis in atrophic-type congenital pseudarthrosis of the tibia: efficacy and safety. *J Pediatr Orthop*. 2019 Sep;39(8):422-8.
- Ko KR, Shim JS, Chung CH, Kim JH. Surgical results of limb lengthening at the femur, tibia, and humerus in patients with achondroplasia. *Clin Orthop Surg*. 2019 Jun;11(2):226-32. Epub 2019 May 9.
- Memeo A, Verdoni F, Ingrassia C, Rossi L, Pedretti L, D'Amato RD, Peretto L, Mineo GV. Mesenchymal stem cells as adjuvant therapy for limb lengthening in achondroplasia. *J Pediatr Orthop B*. 2019 May;28(3):221-7.
- Singer D, Johnston CE. Congenital pseudarthrosis of the tibia: results, at skeletal maturity, of the Charnley-Williams procedure. *JB JS Open Access*. 2019 Jun 20;4(2):e0004.
- Carpenter B, Thomas J, Brigido SA, Cooper MT. Tibio-talar-calcaneal fusion in the diabetic and nondiabetic patient: an update on surgical techniques. *Foot Ankle Spec*. 2019 Apr;12(2):172-4.
- Morasiewicz P, Dejne M, Kulej M, Dragan SL, Konieczny G, Krawczyk A, Urbański W, Orzechowski W, Dragan SF, Pawik Ł. Sport and physical activity after ankle arthrodesis with Iliarov fixation and internal fixation. *Adv Clin Exp Med*. 2019 May;28(5):609-14.
- Morasiewicz P, Dejne M, Orzechowski W, Urbański W, Kulej M, Dragan SL, Dragan SF, Pawik Ł. Clinical evaluation of ankle arthrodesis with Iliarov fixation and internal fixation. *BMC Musculoskelet Disord*. 2019 Apr 11;20(1):167.
- Chappell TM, Ebert CC, McCann KM, Hutchinson BL, Rodriguez-Collazo E. Distal tibial distraction osteogenesis-an alternative approach to addressing limb length discrepancy with concurrent hindfoot and ankle reconstruction. *J Orthop Surg Res*. 2019 Jul 30;14(1):244.
- Chatterton BD, Bing A. A novel technique for supramalleolar osteotomy of the tibia using a circular frame. *Ann R Coll Surg Engl*. 2019 May;101(5):373-4. Epub 2019 Mar 11.
- Tomczak C, Beaman D, Perkins S. Combined intramedullary nail coated with antibiotic-containing cement and ring fixation for limb salvage in the severely deformed, infected, neuroarthropathic ankle. *Foot Ankle Int*. 2019 Jan;40(1):48-55. Epub 2018 Sep 28.
- Dumlao PIE, Javier J, Sumpaico CE. Open reduction capsular arthroplasty using a modified Codivilla-Hey Groves-Colonna procedure augmented with tensor fascia lata graft, supported by Iliarov hinged external fixator in a patient with chronic traumatic posterior hip dislocation. *BMJ Case Rep*. 2019 Aug 26;12(8):e229926.
- Papachristos IV, Rankine J, Giannoudis PV. Hip arthrodiastasis combined with core decompression and diamond concept for postcollapse femoral head avascular necrosis. *BMJ Case Rep*. 2019 Aug 13;12(8):e231081.

WHAT'S NEW IN LIMB LENGTHENING AND DEFORMITY CORRECTION

- 27.** Bernhardtson AS, Aman ZS, Dornan GJ, Kemler BR, Storaci HW, Brady AW, Nakama GY, LaPrade RF. Tibial slope and its effect on force in anterior cruciate ligament grafts: anterior cruciate ligament force increases linearly as posterior tibial slope increases. *Am J Sports Med.* 2019 Feb;47(2):296-302. Epub 2019 Jan 14.
- 28.** Bernhardtson AS, Aman ZS, DePhillipo NN, Dornan GJ, Storaci HW, Brady AW, Nakama G, LaPrade RF. Tibial slope and its effect on graft force in posterior cruciate ligament reconstructions. *Am J Sports Med.* 2019 Apr;47(5):1168-74. Epub 2019 Mar 21.
- 29.** Takahashi T, Baboolal TG, Lamb J, Hamilton TW, Pandit HG. Is knee joint distraction a viable treatment option for knee OA? a literature review and meta-analysis. *J Knee Surg.* 2019 Aug;32(8):788-795.
- 30.** Mayer SW, Hubbard EW, Sun D, Lark RK, Fitch RD. Gradual deformity correction in Blount disease. *J Pediatr Orthop.* 2019 May/June;39(5):257-62.
- 31.** Kliushin NM, Stepanenko P, Mekki WA. Treatment of forearm diaphyseal defect by distraction compression bone transport and continued distraction for radial head reduction: a case study. *Chin J Traumatol.* 2019 Oct;22(5):304-7. Epub 2019 Jun 15.
- 32.** Gallone G, Trisolino G, Stilli S, Di Gennaro GL. Complications during the treatment of missed Monteggia fractures with unilateral external fixation: a report on 20 patients in a 10-year period in a tertiary referral center. *J Pediatr Orthop B.* 2019 May;28(3):256-66.
- 33.** Li Y, Han B, Tang J, Chen M, Wang Z. Identification of risk factors affecting bone formation in gradual ulnar lengthening in children with hereditary multiple exostoses: a retrospective study. *Medicine (Baltimore).* 2019 Feb;98(5):e14280.
- 34.** Guan J, Ruan H, Yin J, Chai Y, Kang Q. Bifocal osteosynthesis to treat radial shortening deformity with dislocation of the inferior radioulnar joint. *BMC Musculoskelet Disord.* 2019 Oct 10;20(1):440.
- 35.** Korobeinikov A, Popkov D. Use of external fixation for juxta-articular fractures in children. *Injury.* 2019 Jun;50(Suppl 1):S87-94. Epub 2019 Mar 29.
- 36.** Liidakis E, Bruns N, Macke C, Krettek C, Omar M. [3D-printed template-assisted reduction of long bone fractures]. *Unfallchirurg.* 2019 Apr;122(4):286-92. German.
- 37.** Rohilla R, Sharma PK, Wadhvani J, Rohilla S, Beniwal R, Singh R, Devgan A. Prospective randomized comparison of quality of regenerate in distraction osteogenesis of ring versus monolateral fixator in patients with infected nonunion of the tibia using digital radiographs and CT. *Bone Joint J.* 2019 Nov;101-B(11):1416-22.
- 38.** Fragomen AT, Wellman D, Rozbruch SR. The PRECICE magnetic IM compression nail for long bone nonunions: a preliminary report. *Arch Orthop Trauma Surg.* 2019 Nov;139(11):1551-60. Epub 2019 Jun 19.
- 39.** Borzunov DY, Shastov AL. Mechanical solutions to salvage failed distraction osteogenesis in large bone defect management. *Int Orthop.* 2019 May;43(5):1051-9. Epub 2018 Jun 23.
- 40.** Catagni MA, Azzam W, Guerreschi F, Lovisetti L, Poli P, Khan MS, Di Giacomo LM. Trifocal versus bifocal bone transport in treatment of long segmental tibial bone defects. *Bone Joint J.* 2019 Feb;101-B(2):162-9.
- 41.** Liu C, Zhang X, Zhang X, Li Z, Xu Y, Liu T. Bone transport with a unilateral external fixator for femoral infected nonunion after intramedullary nailing fixation: a case control study. *Medicine (Baltimore).* 2019 May;98(20):e15612.
- 42.** Lou TF, Wen G, Wang CY, Chai YM, Han P, Yin XF. L-shaped corticotomy with bone flap sliding in the management of chronic tibial osteomyelitis: surgical technique and clinical results. *J Orthop Surg Res.* 2019 Feb 12;14(1):47.
- 43.** Hosny GA, Ahmed AA. Infected tibial nonunion in children: is radical debridement mandatory? *Injury.* 2019 Feb;50(2):590-7. Epub 2018 Oct 29.
- 44.** Calder PR, McKay JE, Timms AJ, et al. Femoral lengthening using the Precice intramedullary limb-lengthening system: outcome comparison following antegrade and retrograde nails. *Bone Joint J.* 2019 Sep;101-B(9):1168-76.
- 45.** Morrison SG, Georgiadis AG, Dahl MT. Lengthening of the humerus using a motorized lengthening nail: a retrospective comparative series. *J Pediatr Orthop.* 2019 Sep 23. Epub 2019 Sep 23.
- 46.** Cheng SDJ, Wong KPL. Distraction osteogenesis of the humerus: a case of 100% humeral lengthening in a short duration without permanent complications. *BMJ Case Rep.* 2019 May 15;12(5):12.
- 47.** Gaudreau J, Mekhail M, Hamdy R, Villemure I. Remote-controlled internal lengthening plate for distraction osteogenesis in pediatric patients. *Expert Rev Med Devices.* 2019 Apr;16(4):333-9. Epub 2019 Apr 1.
- 48.** Reich KM, Tangl S, Heimel P, Lettner S, Ignatius A, Claes LE, Pfeil J, Janousek A, Redl H. Histomorphometric analysis of callus formation stimulated by axial dynamisation in a standardised ovine osteotomy model. *Biomed Res Int.* 2019 Feb 12;2019:4250940.
- 49.** Popkov AV, Kononovich NA, Filimonova GN, Gorbach EN, Popkov DA. Bone formation and adaptive morphology of the anterior tibial muscle in 3-mm daily lengthening using high-fractional automated distraction and osteosynthesis with the Ilizarov apparatus combined with intramedullary hydroxyapatite-coated wire. *BioMed research international.* 2019;2019:3241263.
- 50.** Wagner F, Vach W, Augat P, Varady PA, Panzer S, Keiser S, Eckardt H. Daily subcutaneous teriparatide injection increased bone mineral density of newly formed bone after tibia distraction osteogenesis, a randomized study. *Injury.* 2019 Aug;50(8):1478-82. Epub 2019 Jun 3.
- 51.** Akçay H, Kuru K, Tatar B, Şimşek F. Vitamin E promotes bone formation in a distraction osteogenesis model. *J Craniofac Surg.* 2019 Nov-Dec;30(8):2315-8.
- 52.** Awad F, Jennison T, Hughes A. Radiolucent triangle and U-bolster for lower leg positioning for circular frame application. *Ann R Coll Surg Engl.* 2019 Jan;101(1):76. Epub 2018 Aug 16.
- 53.** Subramanyam KN, Mundargi AV, Potarlanka R, Khanchandani P. No role for antiseptics in routine pin site care in Ilizarov fixators: a randomised prospective single blinded control study. *Injury.* 2019 Mar;50(3):770-6. Epub 2019 Jan 23.
- 54.** Guerado E, Cano JR, Fernandez-Sanchez F. Pin tract infection prophylaxis and treatment. *Injury.* 2019 Jun;50(Suppl 1):S45-9. Epub 2019 Apr 1.
- 55.** Randall RM, Balch Samora J, Shannon C, Humbyrd CJ. Ethical considerations in limb lengthening and deformity correction: do aesthetics matter? *J Bone Joint Surg Am.* 2019 Aug 7;101(15):1428-31.