Adolescent Bunions: Treatment Options and Technical Pearls for the Distal Percutaneous Osteotomy

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Abstract: Juvenile hallux valgus is a complex condition that is associated with multiple forefoot abnormalities and can be accompanied by a flexible flat foot. Initial treatment remains conservative with large toe box shoes, pain control, stretching, taping, or spacers. When indicated, surgical treatment is controversial because of the greater than 100 described surgical procedures and a historically high prevalence of recurrence. However, more recent reviews of surgical techniques for juvenile bunions show less recurrence than previously reported. The percutaneous distal metatarsal osteotomy is one procedure that offers many advantages to correcting adolescent hallux valgus deformities including minimal scar, immediate weight bearing, and effectiveness at correcting the deformity in a reproducible manner. The purpose of this paper is to review the management of juvenile/adolescent bunions and share technical pearls for the successful treatment with a percutaneous distal metatarsal osteotomy.

Key Concepts:

- Due to an increased dysplastic metatarsal articular angle, juvenile bunions are complex deformities and are not “younger” versions of the adult bunion.
- Lesser toe deformities may accompany the obvious hallux valgus deformity.
- Historically high rates of recurrence for surgical treatment are decreasing with improved techniques such as percutaneous distal metatarsal osteotomy.

Introduction

Juvenile/adolescent bunions (hallux valgus) are considered by some to be distinct from adult bunions. The appearance of hallux valgus with lateral deviation and pronation are similar, but the cause is not completely understood.[1] It is a complex condition that involves many portions of the forefoot. Mosca summarized these deformities to include obligate valgus deformity of the hallux in relation to the first metatarsal head > 15 degrees. Other anatomic features listed next may or may not be present. These include valgus deformity of the first metatarsal head with lateral positioning of the articular surface causing malorientation of the first metatarsophalangeal (MTP) joint (high distal metatarsal articular angle [DMAA]), lateral subluxation of the hallux on the first metatarsal head (first metatarsophalangeal joint incongruity), and hallux valgus with lateral deviation of the interphalangeal joint.[2] There can be pronation of the great toe and lesser toe deformities. Hallux valgus can be accompanied by a flexible flat foot.[3,4] Studies have demonstrated that the DMMA is more often increased in juvenile bunions when compared with adult deformities. The metatarsal joint is congruent but dysplastic and in valgus orientation. In the midfoot, metatarsus primus varus is always present with an adducted first metatarsal and malorientation of the first metatarsal medial cuneiform. Although the deformity is centered on the medial great toe, the forefoot, midfoot, hindfoot, and ankle may be affected.[2]

Juvenile/adolescent bunions present as early as age 10 years and even earlier in some studies. Frequency in the pediatric population has been reported to be similar to adults at around 3.5%, although Geissele and Stanton reported a prevalence as high as 36%.[3,5] Similar to the adult population, females have a higher prevalence, with studies reporting ratio ranges from 3:1 to 15:1 female-to-male.[3,6] Maternal inheritance is seen in over 70% of cases.[2] Unlike adults, shoe wear, such as high heels and narrow shoes, contribute less to the development of bunions in the pediatric population, leading to the conclusion that there may be a genetic factor.[6] Unfortunately, to date there is no identified specific gene or inheritance pattern associated with juvenile/adolescent bunions, although many patients report other family members also have bunions.[4] Tight Achilles tendons can increase the transfer of pressure to the medial forefoot. The growth plate of the first metatarsal is proximal; therefore, with growth, the width of the forefoot will increase. Calluses or irritation form along the medial aspect of the first MTP joint from shoe rubbing as well as the plantar aspect of the ball of the foot due to altered foot pressure. Other irritating areas include rubbing between the great toe and second toe from the pressure caused by the valgus deformity.

Evaluation

A host of unique and variable anatomic features must be appreciated and require three-dimensional understanding of the complex deformity to plan and execute the most appropriate surgical management for the adolescent bunions. Evaluation begins with a thorough history and physical exam as well as identifying the presence, location, and precipitating factors for pain. When there is pain, it is often over the medial eminence from shoe pressure. Patients may also complain of radicular pain from pressure on the dorsomedial cutaneous nerve branch of the superficial peroneal nerve.[1] On physical exam, the forefoot, midfoot, and hindfoot should be examined. In the forefoot, the alignment of the hallux should be evaluated as well as alignment of the lesser toes and inspection of the skin for callosities. In the midfoot, assessing the motion of the first metatarsal-medial cuneiform joint is important as it is often hypermobile, and when it is not, this can be indicative of incongruity of the joint.[1] In the hindfoot, observation from behind the patient can help determine if there is pes planovalgus with contracture of the Achilles, which could lead to persistent medial overloading.

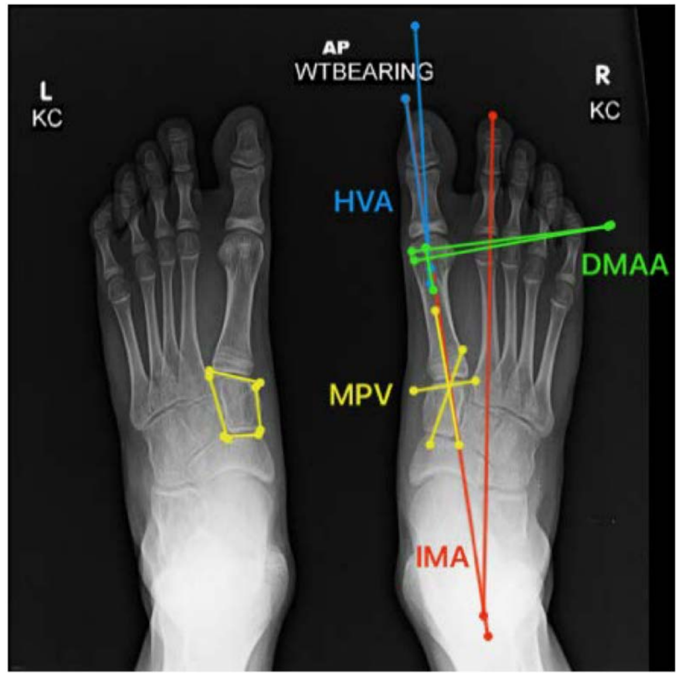

***Figure 1**. Radiological assessment of hallux valgus (hallux valgus angle [HVA], normal <15 degrees; intermetatarsal angle [IMA], normal <10 degrees; distal metatarsal articular angle [DMAA], normal <10 degrees). Metatarsus primus varus (MPV) is due to medial deviation of the first metatarsal-medial cuneiform. The cuneiform is often trapezoidal.[2]*

Weight-bearing radiographs are used to evaluate the severity of the bunion as well as for surgical planning (Figure 1). The intermetatarsal angle (IMA), which identifies the MTP deformity, is measured between the long axis of the first and second metatarsals. Normal IMA is <10 degrees. The hallux valgus angle, which is measured on the long axis of the first metatarsal and the proximal phalanx, should be <15 degrees in the normal foot. The DMAA is measured between the first metatarsal long axis and a line through the base of the distal articular cap and should be <10 degrees.[6] The metatarsal index demonstrates the relative lengths of the distal metatarsals. This is important when planning surgical correction to ensure that the metatarsal parabola is corrected or maintained, as this contributes to appropriate weigh distribution across the forefoot. The appearance of the metatarsal can, however, be affected by the radiographic technique and position of the foot.[3] Lateral displacement of the sesamoids may also be appreciated on the radiographs, although this is generally more severe in the adult hallux valgus deformity. This lateralization may contribute to the increased pressure on the medial aspect of the first metatarsal head, causing pain.[4,6] Metatarsus primus adductus may also be found in the juvenile bunion. The metatarsus adductus angle is the line bisecting the second metatarsal and the lesser tarsal bones on weight-bearing film.[3]

Management Options in Juvenile Hallux Valgus

Conservative Treatment

Patients with juvenile bunions often present with concerns about the cosmetic appearance of the foot as well as difficulty with shoe wear and pain. As the foot grows, the distance between the metatarsal heads increases, widening the foot. Patients may complain of overlapping toes, especially the second over or under great toe and ingrown toenails[2] (Figure 2).

Compared with the adult population, these patients less commonly complain of pain as the main reason for consultation. Nonsurgical interventions include Achilles stretching, taping, toe spacers, larger toe box shoes, low-heeled shoes, or orthotics. Taping the toes or using toe spacers has a limited role in preventing progression of the deformity in the pediatric population.[7] If a flexible flat foot is present, an orthotic to offload the first ray as well as stretching of the Achilles tendon in a subtalar neutral position may be beneficial.

Figure 2. *This child with Stickler syndrome has hallux valgus with second toe overlap and some clawing of the lesser toes.*

Although improperly fitting footwear is not the cause of juvenile bunions, it may contribute to worsening deformities or increase in pain. Shoes with a narrow toe box and high-heel shoes can increase the pressure along the MTP area. Pain can develop as the deformity worsens, causing rubbing in the shoes. Pressure from tight shoes on the apex of deformity can lead to irritation of the dorsal cutaneous nerve. Recommending boys' athletic shoes to girls with a wider toe box may be helpful.[2] Choosing shoes in the pediatric patient to allow enough space in the toe box is a temporary treatment until the foot is skeletally mature.

Surgical Treatment

When conservative treatment fails, patients often seek out surgical management. It is important that the patient understands the goals of surgical correction. Treating bunions for purely cosmetic reasons may leave the patients disappointed. It is difficult to make asymptomatic patients better. Cosmetic improvement often occurs with surgical correction,[1] but surgical treatment is recommended if patients experience pain that is not well controlled with conservative measures or shoe wear becomes increasingly difficult. An additional consideration for earlier treatment is the progression of the lesser toe deformities which can contribute significantly to pain and create long-term issues for patients, despite bunion correction.[8] It is possible to correct the deformity prior to skeletal maturity with growth plate modulation, growth plate sparing osteotomies, or with distal metatarsal osteotomies, as these do not involve a growth plate.

Figure 3. *Lateral hemiepiphysiodesis with a cannulated drill bit for a juvenile bunion.*

Multiple surgical procedures (>130) have been described in the literature. There is no gold standard procedure as not all juvenile hallux valgus deformities are the same. Therefore, when assessing the foot, it is important to abide by principles of deformity correction, including assessment of the hindfoot, midfoot, and forefoot. The objectives of surgical correction are to reduce pain, correct the deformity and rotation of the first ray, maintain range of motion of the first MTP joint, and diminish the risk of recurrence. Increasingly, minimally invasive procedures are becoming common practice since they are believed to have faster recovery/less rehabilitation time due to less soft-tissue dissection, thus decreasing pain and increasing patient satisfaction. One downside of many minimally invasive procedures is the need for increased use of intraoperative fluoroscopy compared with open procedures.[4] Surgical procedures for bunion correction are based on the severity of the deformity, origin of the deformity, and most strongly, surgeon preference.[4,6]

Figure 4. *A) Preoperative anteroposterior radiograph of a right hallux valgus. B) Postoperative anteroposterior radiograph following a scarf and Akin osteotomy (used with permission from Jacob Zide, MD).*

Surgical treatment of bunions in the pediatric population continues to be controversial as there is up to a 50% recurrence rate if performed prior to skeletal maturity.[4] Treatment of the adolescent bunion is often recommended after skeletal maturity because of this concern. Few studies in the literature of juvenile bunions comparing the various techniques have been performed. Harb et al. performed a systematic review of outcomes following surgery for adolescent hallux valgus. Nine studies reporting on 201 osteotomies in 142 patients were reviewed.[6] Although the studies were heterogenous and retrospective, they found excellent clinical and radiographic outcomes with a lower recurrence rate compared with historic numbers. The cohort demonstrated the diversity of treatment options for pediatric hallux valgus. Osteotomies performed included the scarf first metatarsal osteotomy, proximal metatarsal osteotomy, chevron distal metatarsal osteotomy, double metatarsal osteotomy, modified Simmonds-Menelaus procedure, percutaneous technique with distal osteotomy, and bunionectomy with lateral soft-tissue release and dorsal wedge osteotomy. An Akin proximal phalanx closing wedge osteotomy was performed in 9.5% of the patients, most in conjunction with a scarf osteotomy.[6] Overall, the American Orthopedic Foot and Ankle Society (AOFAS) scores improved from preoperative assessment to between 80 and 94.6. Radiologic parameters also improved, but not necessarily to normal range. Recurrence rates were 8% in this contemporary study, which is much lower than historic numbers. Dividing the studies into younger (10-14 years of age) and older (14-17 years of age) groups, recurrence rates were three of 22 (14%) and four of 17 (24%), respectively.[6] These results suggest that in select cases, pediatric patients may benefit from surgical treatment of painful bunions.

Review of Selected Surgical Procedures

Surgical treatment should address the etiology of the deformity. For example, bunionectomy to address the medial prominence in adolescent bunions is not usually indicated, as there are no osteophytes.[9]

Lateral Hemiepiphysiodesis

The presence of the open physis in the growing child makes juvenile hallux valgus more challenging to correct. In a younger child, under the age of 10 years, a lateral hemiepiphysiodesis of the proximal first metatarsal, with or without a hemiepiphysiodesis of the medial proximal phalanx, could be considered. There are multiple studies demonstrating a stabilization or improvement of the IMA and hallux valgus angle using this technique if there is enough remaining growth. Often, this intervention does not improve the IMA as much as an osteotomy but can relieve symptoms and is safe in the younger child. Techniques for lateral hemiepiphysiodesis of the first metatarsal can be done with a temporary screw or with percutaneous drilling of the lateral growth plate (Figure 3).

Hemiepiphysiodesis of the proximal phalanx is often performed via percutaneous drilling of the medial side of the growth plate. Sabah et al. reviewed their results of lateral hemiepiphysiodesis of the first metatarsal for hallux valgus and showed the AOFAS/hallux metatarsophalangeal-interphalangeal scale for forefoot pathologies

Figure 5. *This 15-year-old with painful right hallux valgus has an increased intermetatarsal angle of 16 degrees and a hallux valgus angle of 40 degrees. She underwent double level metatarsal osteotomy.*

Figure 6. *Clinical photograph demonstrating placement of entry point of 2mm wire and incision placement and size for percutaneous technique.*

was improved significantly. Radiographic alignment slightly improved without statistical significance.[10] The radiological measurements did not worsen with growth.[10] Likely, the reason the radiological measurements were not improved is related to lack of growth remaining. Most patients with juvenile bunions do not present for surgical treatment before age 10 years, in which case there is probably not enough remaining growth to correct the deformity. Although the IMA and MTP angle did not improve as much as reported with the distal chevron osteotomy and scarf osteotomy, at the time of publication, no patient needed additional procedures for hallux valgus correction or had significant bony or soft-tissue complications.[10]

Proximal Osteotomies

The Lapidus procedure was described in 1934 to stabilize the hypermobile tarsometatarsal joint. Hypermobility and gastrocnemius tightness are thought to be atavistic traits.[11] The Lapidus procedure was originally described to address metatarsus primus adductus associated with hallux valgus. Hansen utilized the Lapidus procedure as a forefoot reconstruction that could be performed after skeletal maturity.[11] The modified Lapidus arthrodesis eliminates motion at the hypermobile first metatarsocuneiform joint and historically was commonly used to treat juvenile bunions. However, arthrodesis surgery in the younger population is generally discouraged due to risks of avascular necrosis, growth arrest, and arthritis in adjacent joints.[3]

Proximal osteotomies are powerful tools to correct more severe deformities but can be technically more challenging.[12] These include a proximal chevron osteotomy, abduction-supination osteotomy, and proximal crescentic osteotomy with soft-tissue procedures. Okuda et al. described a proximal abduction-supination osteotomy of the first metatarsal to reduce some risk factors for recurrence, including under correction of pronation and incomplete reduction of the sesamoids. In this procedure, the medial eminence is excised, the medial capsule is plicated, and a crescentic osteotomy of the proximal metatarsal is performed. They reported no recurrence of hallux valgus in 11 patients (12 feet) with average follow-up of 22 months.[13]

The medial cuneiform osteotomy may be considered in more severe hallux valgus with metatarsus primus adductus. The oblique take-off of the medial cuneiform can contribute to recurrence of deformity and/or under correction. A distal metatarsal osteotomy can be performed safely in conjunction with a medial cuneiform opening wedge osteotomy. This avoids any growth plate violation. For more severe bunions, the authors recommend performing a distal percutaneous metatarsal osteotomy as the first-line surgical treatment and using the medial cuneiform osteotomy to correct any residual deformity at a secondary time if needed. This sequence of surgical intervention avoids too much lengthening of the medial column as well as unnecessarily fusing the metatarsocuneiform joint.[13]

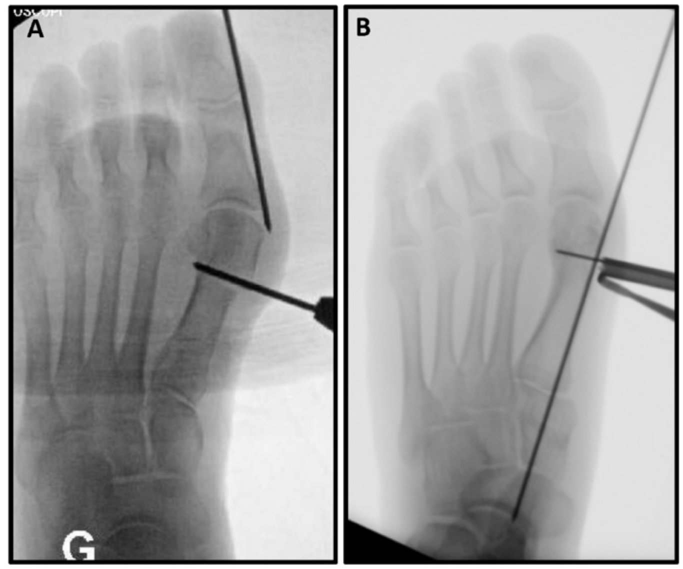

Figure 7. *A) Intraoperative radiograph demonstrating initiation of the osteotomy using an irrigation burr at 90 degrees to the metatarsal shaft. If the cut is not perpendicular, the distal fragment will either shorten or be displaced distally with translation. B) Intraoperative radiograph demonstrating alternative method of using multiple drill holes with a 1.6- to 2-mm multiple wire hole osteotomy. Note a wire is placed on top of the foot to demonstrate osteotomy position of 90 degrees to the metatarsal.*

Figure 8. *Intraoperative radiograph demonstrating completion of the osteotomy using an osteotome.*

Diaphyseal Osteotomies

Coughlin described soft-tissue release with a single- or double-level osteotomy.[14] Coughlin performed a soft-tissue realignment and then planned the osteotomy level based on the severity of the hallux valgus deformity. He reported a 10% recurrence rate and 13% complication rate.[14] No recurrences occurred in the double osteotomy group as compared with four in the chevron group and two in the McBride group.[14] The scarf osteotomy, demonstrating versatility and longevity of the correction achieved by performing the single osteotomy with an average follow-up of 57 months, has been reviewed by Shine et al.[15] (Figure 4). The authors showed a low complication rate, ability to perform bilateral procedures, stability, early weight bearing, and return to full activity at 5.3 weeks.[15] Farrar et al. also described good results with scarf osteotomy with high patient satisfaction and an 18% recurrence rate (seven of 30 feet).[15] Zide reported in the 2020 AAOS Instructional Course Lecture that approximately 86% of adolescent bunions have a valgus orientation of the DMAA.[1] The metatarsal joint is congruent but dysplastic in a valgus orientation.[1] Zide described his ideal osteotomy for correction of an adolescent bunion with increased DMAA as one that can decrease the IMA and reorient the metatarsal head, correcting hallux valgus.[1] Zide recommends a scarf osteotomy with "paradoxical" internal rotation of the distal metatarsal segment placing the metatarsal head in neutral. With more severe deformity, DMMA >40 degrees, he recommends combining a Lapidus with distal biplanar chevron osteotomy. No lateral soft-tissue release is performed because the joint surface is congruent[1] (Figure 4). The scarf osteotomy can be a challenging osteotomy to perform in smaller bones, and many surgeons have experienced difficulty in achieving reproducible results.[14]

Distal Metatarsal Osteotomies

The Austin chevron osteotomy is a horizontally directed, 60-degree "V" osteotomy of the metatarsal head, apex distal, with a medial capsulorrhaphy.[17] This was described to correct mild to moderate bunions without

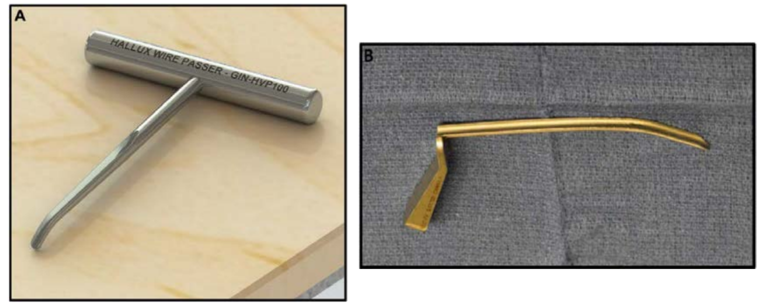

Figure 9. *A) Image of the Hallux Wire Passer, B) Alternate solutions include a Kelly clamp or this fast-fix slotted cannula*

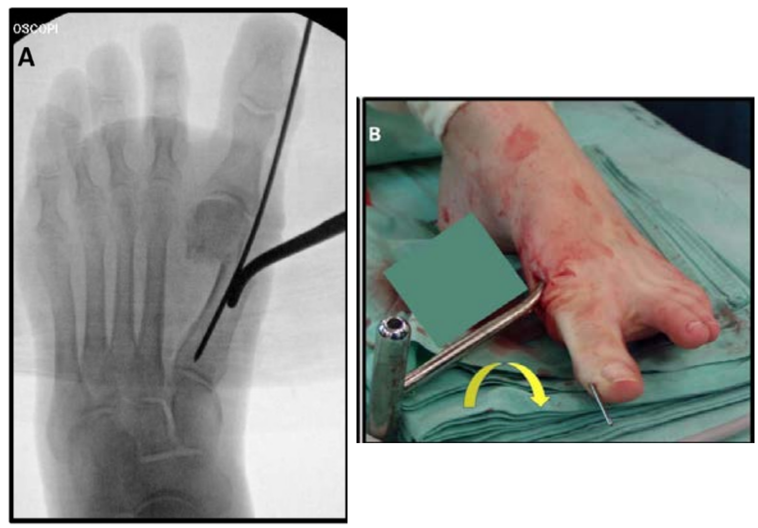

Figure 10. *A) Intraoperative radiograph demonstrating the use of the Bosch instrument to help guide the wire into the proximal portion of the first metatarsal. B) Intraoperative image demonstrating correction of pronation deformity (yellow arrow) while inserting the wire.*

inducing a growth arrest. The translation of the distal metatarsal should be limited to 50% of the width of the distal metatarsal. No instrumentation is required secondary to the inherent stability of the osteotomy. The long-term results show maintenance of correction at an average of 7.3 years of follow-up.[17] The Mitchell osteotomy[15] is a distal step cut osteotomy that displaces the metatarsal head laterally. Because it may shorten the metatarsal, there is an increased[17] incidence of metatarsalgia. This procedure can be used in more severe hallux valgus deformities than the chevron but may result in rotational instability, avascular necrosis, or malunion.[18] It should be noted that adjuvant soft-tissue procedures are often recommended (sesamoid-phalangeal and sesamoid-metatarsal ligaments, adductor tendon releases, transverse metatarsal ligament release, and capsular shortening or capsulorrhaphy) with these techniques. In Harb et al., multiple soft-tissue techniques were described in six of nine papers reviewed, and there is significant heterogeneity between techniques to manage soft tissues.[6]

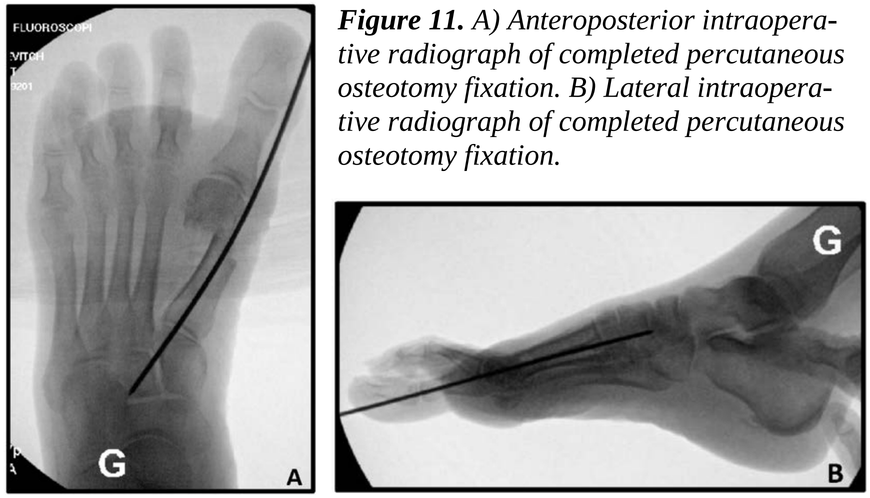

Figure 11. *A) Anteroposterior intraoperative radiograph of completed percutaneous osteotomy fixation. B) Lateral intraoperative radiograph of completed percutaneous osteotomy fixation.*

Double Level Metatarsal Osteotomy

Double level metatarsal osteotomies involve combining a proximal base of the first metatarsal osteotomy with a distal osteotomy (such as a chevron). These combined osteotomies can be used to achieve a greater radiographic correction but can be accompanied by more complications (Figure 5). Edmonds et al. reviewed radiographic outcomes of surgical correction in juvenile hallux valgus. When comparing single proximal, single distal, and double osteotomies, the single distal osteotomy had the most consistent outcomes with a low risk of complications and improved radiographic measurements.[19] At final follow-up, the IMA demonstrated no statistical difference between the three groups. The DMAA was improved significantly in the double osteotomy. The revision rate between osteotomy types was significant, with the proximal osteotomy having a higher revision rate than the double osteotomy, 21% and 8%, respectively.[19]

Percutaneous Distal Metatarsal Osteotomy

The second purpose of this paper is to document our technique of percutaneous osteotomy for adolescent bunion. The percutaneous hallux valgus technique was initially described by Bösch et al. in 1990 and re-popularized by the Italian group Magnan et al. in 2005.[20,21] Their indications for performing the percutaneous distal metatarsal osteotomy were the same as for the open technique and can be performed with an IMA as high as 20 degrees.[20] This procedure consists of four basic steps:

Figure 12. *Intraoperative radiograph demonstrating removal of bony prominences on the proximal medial portion of the first metatarsal with a bone rongeur.*

1. Extra-osseous medial placement of K-wire for later stabilization
2. Percutaneous osteotomy at the meta-diaphyseal junction
3. Lateral translation of the distal segment and fixation with the wire
4. Removal of medial diaphyseal spike

Siddiqui and LaPorta performed a multicenter study at four centers in North America utilizing this minimally invasive technique in 180 adult patients (217 feet).[22] They demonstrated the advantages of the percutaneous bunion technique including immediate weight bearing, which facilitates bilateral surgery; extra-articular surgery, which helps preserve range of motion; no additional soft-tissue procedures, as well as a very cosmetic incision; no retained hardware; and consistently reproducible results.[1,18]

The full description of the surgical technique can be found in the Siddiqui and LaPorta article and by viewing the accompanying technical pearls video. [22,23]

Recent publications reported reliable results for this technique in juvenile bunions with excellent radiographic and clinical corrections.[4] The AOFAS scores improved from an average of 66 to 96. All radiographic measurements, including the hallux valgus angle, IMA, and DMAA, significantly improved after surgery.[4] Improved hallux valgus angles did decrease an average of 6 degrees 2 weeks after K-wire removal.[4]

Complications noted with the use of the percutaneous technique in juvenile bunions were minor and included sagittal plane displacement (asymptomatic malunion) of the metatarsal head as well as bony prominence of the proximal medial side of the osteotomy. Both of these complications can be avoided by correct surgical technique, including central placement of the K-wire in the sagittal plane at the time of surgery and removal of the medial prominence with a rongeur.[4] Other reported complications of the percutaneous technique in the adult population include superficial pin site infections (19%-21%), nerve-related numbness (4%), delayed union (1.7%-3%), and hardware failure prior to removal of the K-wire (3.3%).[22]

The percutaneous technique has a learning curve that is fairly rapid. Paying special attention to the following pearls will yield the best surgical results.

Technical Pearls for the Percutaneous Bunion Technique

1. Entry of the 2mm stainless steel wire should be at the intersection of the base of the nail bed and the midline portion of distal toe (in the sagittal plane) (Figure 6).
2. The wire should go down to bone and then glide onto the bone until it captures a portion of the capsule of the distal metatarsal head but before it reaches the prominent metatarsal head. It is imperative to put the wire down to bone when placing

Figure 13. *A) Anteroposterior radiograph at 4 weeks postoperatively (prior to wire removal). Note that there is very little radiographic callous formation. B) Anteroposterior radiograph at 3 months postoperatively with a healed osteotomy. C) Standing anteroposterior radiograph of both feet one year postoperatively showing excellent bony remodeling.*

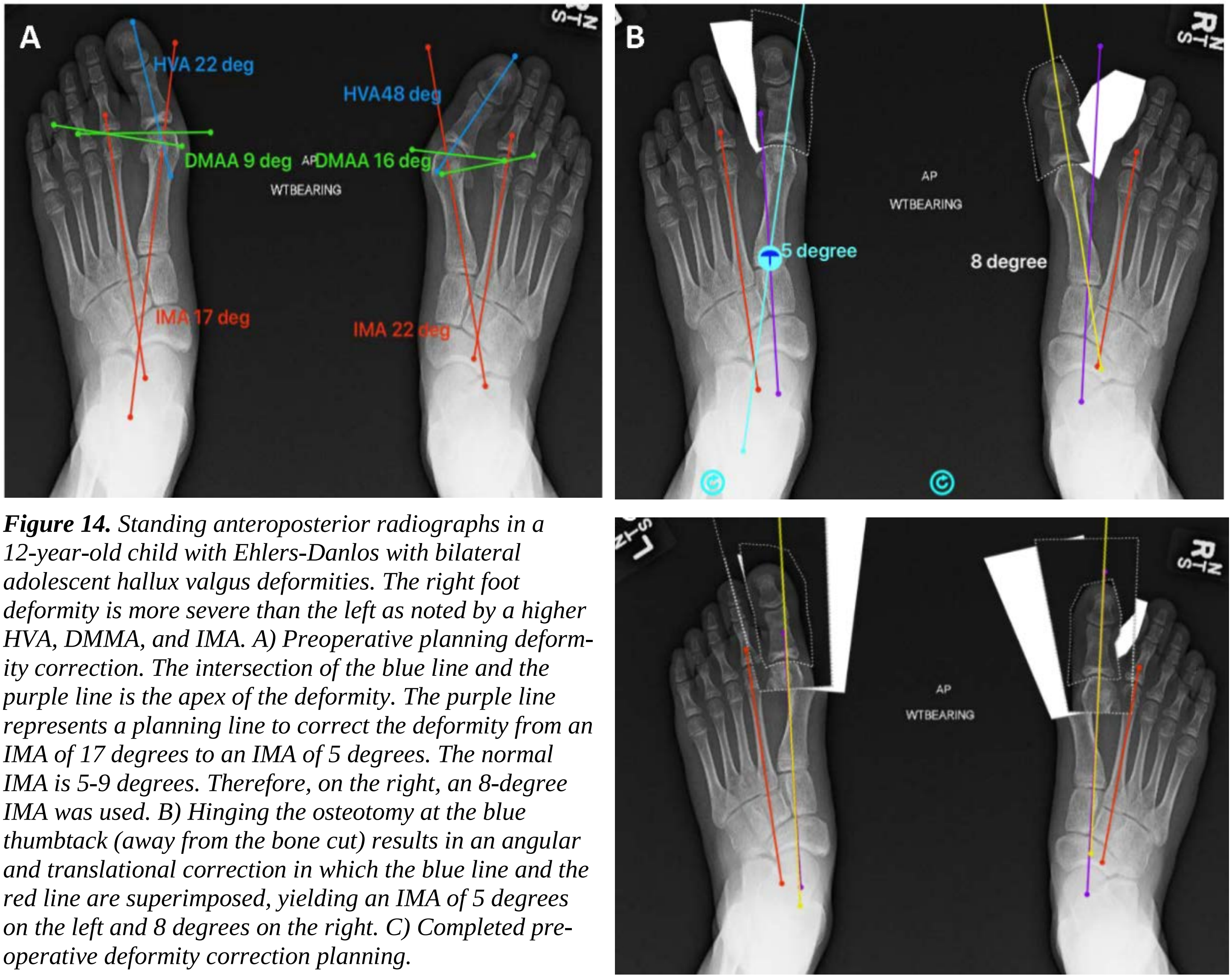

Figure 14. Standing anteroposterior radiographs in a 12-year-old child with Ehlers-Danlos with bilateral adolescent hallux valgus deformities. The right foot deformity is more severe than the left as noted by a higher HVA, DMMA, and IMA. A) Preoperative planning deformity correction. The intersection of the blue line and the purple line is the apex of the deformity. The purple line represents a planning line to correct the deformity from an IMA of 17 degrees to an IMA of 5 degrees. The normal IMA is 5-9 degrees. Therefore, on the right, an 8-degree IMA was used. B) Hinging the osteotomy at the blue thumbtack (away from the bone cut) results in an angular and translational correction in which the blue line and the red line are superimposed, yielding an IMA of 5 degrees on the left and 8 degrees on the right. C) Completed preoperative deformity correction planning.

alongside the distal phalanges, otherwise, skin necrosis can occur.

3. A small percutaneous incision for the skin at the metaphyseal-diaphyseal junction is made under fluoroscopic guidance (Figure 6).
4. An irrigation burr at low velocity is used to initiate the osteotomy cut. Alternatively, a K-wire (1.6mm or 2mm) can be used to place multiple drill holes prior to osteotomy (Figure 7A and 7B).
5. The angle of the osteotomy to the metatarsal bone should be at 90 degrees in both the sagittal and coronal planes when possible.
    a. The preferred coronal plane angle is at 90 degrees which often results in slight lengthening of the shaft secondary to the translation and compensates for the 2-mm burr cut. In the coronal plane, if the angle slopes distally, the oblique cut will result in lengthening of the metatarsal (which is rarely required) and higher risk of the osteotomy slipping. If the angle slopes proximally, then the oblique cut will result in shortening of the metatarsal (which often causes secondary metatarsalgia).
    b. In the sagittal plane, it is recommended to try and stay perpendicular to avoid causing oblique

cuts that would result in translation in dorsiflexion or plantarflexion.

6. The osteotomy should be completed with an osteotome (as opposed to a saw) to prevent heat necrosis and to ensure the best biology for healing (Figure 8). Soft tissues are protected during the osteotomy.

7. Once the osteotomy is complete, a Kelly hemostat or the modified Bosch instrument (Hallux Wire Passer, Pega Medical, Montreal, QC) is then inserted into the osteotomy site to create the translation (Figure 9A). An arthroscopy fast-fix slotted cannula (Smith and Nephew, Memphis, TN) can also be used to guide the K-wire (Figure 9B).

8. The wire is then placed into the slot in the Bosch instrument or between the tips of the Kelly to help direct it into the metatarsal shaft in a retrograde manner (Figure 10A). It is very important to remember to slightly plantarflex the first MTP joint when inserting the wire as the natural slope of the first ray is slight plantarflexion; this ensures that the wire will be centered in the sagittal plane in the metatarsal head as well as the shaft. Correct central positioning of this K-wire in the sagittal plane will prevent loss of reduction in the postoperative period and allow for stability in weight bearing.

    a. The pronation deformity can also be corrected at this stage by supinating the distal segment ray and then crossing the metatarsal cuneiform joint with the wire to maintain this correction (Figure 10B).

    b. When possible, it is equally important to place the wire central in the metatarsal shaft and cross the metatarsal cuneiform joint as centrally as possible which implies the appropriate amount of translation is achieved and will be stable. This prevents the K-wire from having a bend to it. Another clue that the correction is well-achieved is a perfect reduction of the sesamoids under the metatarsal head. An obliquely placed K-wire often means that there is under correction (less translation than desired) of the metatarsal head and relies heavily on the medial bone of the metatarsal shaft to maintain the correction.

    c. The amount of translation can be up to 90% or more. In severe cases, if the translation surpasses 100%, this can result in metatarsal shortening but in the authors' experience, heals nonetheless.

9. Radiographic confirmation of correct placement on anteroposterior and lateral views of the foot should then be obtained (Figure 11A and 11B).

10. Once satisfactory positioning is achieved, the medial portion of the metatarsal bone on the proximal side of the osteotomy is removed to smooth the medial side of the foot and ensure no bony prominences remain. (A plastic surgery rongeur is recommended to get into the 5-mm incision [Figure 12].)

11. The skin is closed with a dissolvable stitch and a bunion dressing to support the correction. One author applies a kidney-bean shaped pad to unload the metatarsal head. The wire is bent and cut slightly proud of the skin and placed with the dressing/cast to avoid exposure and catching. Patients can be placed in a rigid sole-flat sandal or walking cast for full weight bearing. Follow up is either 1 or 2 weeks postoperatively for dressing/cast change. The wire is removed in the clinic 4 weeks postoperatively (Figure 13).

Discussion

Bunion deformities have historically been considered "cosmetic." However, there is growing evidence that the deformity of the first ray is responsible for changing the weight-bearing dynamics of the foot, thereby causing lesser toe deformities and metatarsalgia.[8] Deformities of the first ray with subluxation of the sesamoids may eventually lead to arthritis, pain, and gait alterations. Many surgical procedures have been described for addressing juvenile hallux valgus, including proximal tarsal, proximal metatarsal, distal metatarsal, and double

Figure 15. *A, B) Our 12-year-old EDS patient underwent a distal osteotomy of the distal 1st MT in both feet. Residual increased IMA on the right was treated with an additional 1st cuneiform osteotomy. C) At follow-up, both feet are healed, but the patient complained of pain at the right 1st MPTJ. D) Revision percutaneous hallux valgus correction was performed to shorten slightly overlengthening 1st MT with resolution of pain and excellent radiographic correction.*

osteotomies. None has been reported as the "gold standard." Most of these procedures use extensive soft-tissue dissection to expose the first MTP joint, which leads to stiffness, continued pain, and scarring.

The percutaneous hallux valgus osteotomy is able to correct the juvenile bunion because the osteotomy follows basic deformity correction principles. For instance, the apex of the bunion deformity is at the metatarsal cuneiform joint of the first ray, and because the osteotomy is far from the apex, translation and angular correction ensues. By correcting the underlying deformity following these principles, the alignment of the IMA, DMAA, and hallux valgus angles are restored to within normal values and the sesamoids are reduced (Figures 14 and 15).

Other advantages of the percutaneous hallux valgus osteotomy include: no adjuvant soft-tissue releases required to achieve correction or reduction of the sesamoids, the incision is minimal (5 mm), allows for full weight bearing postoperatively (facilitates bilateral procedures), and quick surgical time with reproducible results. Despite the simplicity of the technique, there remains a learning curve, and the pitfalls are described in the technical pearls. In addition, care must be taken not to over lengthen the metatarsal of the first ray by ensuring that the osteotomy is not oblique. A lengthening first ray creates increased joint reactive forces at the MTP articulation and pain. The procedure can also be combined with other bony procedures. If residual deformity exists after correction with distal osteotomy, an opening wedge medial cuneiform is an effective adjunct.[24] The percutaneous osteotomy can also be repeated if correction was not completed the first time (due to bunion severity) or as a revision procedure for previous bunion surgery.

Conclusion

Conservative treatment of juvenile hallux valgus should be exhausted before surgical treatment is recommended. Although the literature supports surgical intervention for persistent pain and failure to respond to conservative treatment, it is not recommended for "cosmetic" reasons. The risk for recurrence may be less with the current improved techniques than with those historically reported. Many techniques are described above. There are few comparative studies of the adolescent bunion to recommend the "gold standard." Proximal, diaphyseal, and distal osteotomies have been described with good outcomes.[19] The percutaneous distal osteotomy is one surgical tool for correcting juvenile/adolescent bunions and has the advantage of correcting the DMAA without requiring invasive proximal osteotomies or fusion procedures.

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