ORIGINAL RESEARCH

Dual Femoral and Tibial Osteotomies for Large Varus and Valgus Deformities

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Abstract

Aim and background: The aim of this study is to evaluate the outcomes of acute correction of large varus and valgus deformities with simultaneous distal femoral and tibial osteotomies. Acute correction of large coronal plane deformities is complex and if done incorrectly, can lead to problems like non-union, soft tissue problems, and joint line obliquity.

Materials and methods: Radiographic, clinical, and patient-reported outcomes are analysed through a retrospective series of 21 extremities in 18 consecutive patients with coexisting femoral and tibial deformities who underwent concurrent distal femoral and proximal tibial osteotomies with acute coronal plane correction and internal fixation.

Results: The mean mechanical axis deviation (MAD) correction was 56 mm for varus deformities ($n = 13$) and 45 mm for valgus deformities ($n = 8$) with an overall mean correction of the femoral tibial angle of 15° per extremity. The accuracy of correction was 92.9% compared to the goal MAD. Two patients had peri-incisional cellulitis that resolved with antibiotics. There was no incidence of non-union, deep vein thrombosis, compartment syndrome, deep infection, or peripheral nerve palsy. Patient-reported outcome scores had clinically meaningful improvements in pain, function, and mental health.

Conclusion: Acute correction of large coronal plane deformities can be accurately and safely performed with simultaneous distal femoral and proximal tibial osteotomies with internal fixation.

Clinical significance: This study highlights a safe method to accurately correct large coronal plane deformities in the lower extremity.

Keywords: Bowlegs, Corrective osteotomy, Deformity correction, Genu valgum, Genu varum, Joint preservation, Knock knees.

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Introduction

Lower extremity malalignment produces abnormal mechanical forces that lead to accelerated articular wear and early osteoarthritis. Realignment via osteotomy redirects these aberrant forces to prevent degeneration and prolong the lifespan of the native joint.[1–6] Most cases of moderate coronal plane malalignment (<10°) require only a single osteotomy, often in the form of a wedge, to correct the mechanical axis. A multitude of studies have shown that a single open wedge osteotomy of the femur or tibia heal reliably.[7–9] Correction of larger deformities can also be attempted with one osteotomy, however, significant acute corrections in one bone can lead to post-operative complications such as nerve palsies, joint contractures, and wound breakdown. The wide bone defects generated are at increased risk of delayed union, non-union and hinge fractures.[10] Gradual correction with external fixation can mitigate some of these risks by allowing accommodation of soft tissue tension and gradual bone formation via distraction osteogenesis. However, there are specific disadvantages including pin tract infections, the burden of manual adjustments, frequent physician follow-up, longer treatment times, and overall physical and psychological inconvenience.[2,11,12]

Depending on the deformity location, single-level corrections can also adversely affect the knee joint's obliquity. For example, in a patient with a large genu varum deformity with both femoral and tibial contributions, a single osteotomy in the distal femur can produce a mechanical axis within the normal range, but at the cost of excessive distal femur valgus and proximal tibia varus. Thus, the knee joint axis will have abnormal shear forces and stress distribution that negates one of the fundamental purposes of the intended treatment.[7]

Given these limitations, large frontal plane malalignment should be evaluated for osteotomies of both the femur and the tibia. In the applicable setting, osteotomy of the femur and the tibia will reduce the magnitude of each correction as well as achieve a normal knee joint line obliquity. Although the separate osteotomies could be staged, dual level correction under one

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anaesthesia allows concurrent osteotomy healing and shortened treatment time.

The present study analyses the degree of correction and outcomes associated with acute correction of large coronal plane deformities in the lower extremity via two level osteotomies. The hypothesis is that dual osteotomies in the femur and tibia can accurately correct large lower extremity deformities. The secondary aims of this study are to assess the related complications as well as document patient-reported outcomes.

Materials and Methods

Patient Selection

This study is a single-centre, retrospective case series of 21 extremities in 18 consecutive patients who underwent concurrent distal femoral and proximal tibial osteotomies with acute coronal plane correction and internal fixation between April 2016 and February 2020. Institutional Review Board approval was obtained prior to data collection, and patients were identified using the department's Research Electronic Data Capture (REDCap) database.

Patients were included if they were skeletally mature, had follow-up lasting until clinical and radiographic healing, and were treated with internal fixation only (plate or intramedullary nail). Often, patients had multi-planar deformity that involved sagittal and/or axial plane malalignment or asymmetry (leg length discrepancy) in addition to the coronal plane deformity. These patients were included as long as the coronal plane was affected by each femoral and tibial osteotomy correction. Patients who had gradual correction with an external fixator or were treated for pure leg length discrepancy, sagittal deformity, or rotational malalignment were excluded.

Pre-operative and post-operative physical examinations were performed by the treating surgeon. Weight-bearing 51-inch hip-to-ankle radiographs and lateral 30° flexion knee radiographs were taken to evaluate coronal plane alignment and patellar height using a 25 mm metallic marker. Measurements were extracted from prior chart documentation or the institution's picture archive and communication system (PACS). Radiographic measurements were validated by the primary author using Sectra IDS7 (Sectra, Linköping, Sweden). Mechanical axis deviation (MAD) is defined as the distance between the centre of the knee (centre of the tibial eminences) and a line drawn from the centre of the femoral head to the centre of the tibial plafond. Definitions and normal values for standard deformity measurements such as the mechanical lateral distal femoral angle (mLDFA) and the mechanical medial proximal tibial angle (mMPTA) were referenced from principles of deformity correction.[4] The Caton-Deschamps Index (CDI) was used to evaluate patellar height, with an index <0.6 defined as patella baja.[13]

The target correction goal was designated pre-operatively by the operating surgeon and determined based on degree of deformity, patient age, and pre-existing joint degeneration. Correction targets were categorised by a distance range of the MAD relative to the midpoint between the medial and lateral tibial eminences, with a tolerance of ±5 mm. A neutral correction goal was defined as a median MAD of 0 mm with an acceptable range between 5 mm medial and 5 mm lateral to the mid-point, regardless of varus or valgus deformity. An overcorrection goal had a median MAD of 10mm with an acceptable range between 5 and 15 mm (positive if overcorrecting a varus deformity, and negative if overcorrecting a valgus deformity). An under-correction goal had a median MAD of 10 mm with an acceptable range between 5 and 15 mm (negative if under correcting a varus deformity, and positive if under correcting a valgus deformity).

Surgical Technique

Both the distal femur and proximal tibial osteotomies were performed in one anaesthesia setting by one of two surgeons fellowship trained in deformity correction. Construct (plate or intramedullary nail) and osteotomy type (opening or closing wedge; transverse) were patient specific and based on surgeon preference and rigorous pre-operative planning. When concurrent closing wedge and opening wedge osteotomies were performed, the bone resection from the closing wedge was often used as autograft for the opening wedge. Blocking screws, temporary fixator assisted nailing, selective prophylactic anterior compartment fasciotomies, prophylactic peroneal nerve decompression, and soft tissue releases (e.g. iliotibial band tenotomy) were performed at the discretion of the surgeon. For example, a peroneal nerve release was commonly performed for large valgus deformities due to the increased tension expected on the lateral leg with deformity correction, however, no discrete values were used to make these decisions. The decision to perform either an opening wedge or closing wedge osteotomy was typically based on if that limb or limb segment was relatively shorter or longer than the contralateral limb, respectively. Based on the patient's symptoms and magnetic resonance imaging, adjunctive procedures such as knee arthroscopy, micro-fracture, or meniscectomy were performed at the same time as corrective osteotomy.

Immediately post-operatively, patients were allowed 50 lbs partial weight-bearing with a continuous passive motion (CPM) machine during their inpatient recovery. Patients were started on chemoprophylaxis (typically aspirin 325mg twice daily or apixaban) for venous thrombosis post-operative day 1. Patients were evaluated 2–3 weeks post-operatively to assess the incisions, then at regular intervals until clinical and radiographic healing were determined. Home exercises were provided, and outpatient physical therapy was instituted as needed to improve knee range of motion. Progression of weight-bearing typically occurred at 6 weeks post-operatively but was occasionally delayed based on surgeon assessment of radiographic healing. Bone healing was defined as three or more bridging cortices on orthogonal radiographs.

Patient-reported Outcomes

Pre-operative and post-operative patient-reported outcome scores were collected by online survey or telephone using both the patient-reported outcomes measurement information system (PROMIS) scores and limb deformity-scoliosis research society (LD-SRS) scores. Post-operative scores were collected a minimum of 6 months after surgery. Specific PROMIS measures were PROMIS CAT v1.0 – Pain Intensity, v2.0–physical function; global health, and v1.1–Pain Interference. Clinical significance was set as a difference of >0.5 points deviation or otherwise referenced by the PROMIS group.[14–16]

Statistical Analysis

Statistical analysis was performed using Microsoft Excel 2021 (Microsoft Corp, Redmond, WA). Continuous variables were compared using two-tailed Student's *t*-test with an alpha <0.05 set for statistical significance. The accuracy of correction was based on MAD and calculated using the formula in Figure 1.[17,18] Accuracy is

$$Accuracy = 1 - Error = 1 - \frac{(Post\text{-}operative\ MAD\ -\ Goal\ MAD)}{Pre\text{-}operative\ MAD}$$

Fig. 1: Equation to calculate the accuracy of the correction. Error is dependent on the difference between what MAD was achieved and the goal MAD (numerator) normalised to the magnitude of the initial deformity (denominator). The goal MAD was pre-operatively determined to be neutral, overcorrected, or under corrected based on patient specific factors

MAD, mechanical axis deviation

Table 1: Patient demographics and pre-operative deformity characteristics

Extremities/patients	21/18			
Age (years)	37 (21–65)			
Female/male	10/11			
BMI	32 (19–53)			
Unilateral/bilateral	15/3			
Varus/valgus	13/8			
Pre-operative deformity	*Varus*	*(n = 13)*	*Valgus*	*(n = 8)*
MAD (mm)	65	(24–99)	45	(24–73)
mTFA (°)	17	(7–25)	15	(9–20)
mLDFA (°)	95	(90–102)	82	(78–86)
mMPTA (°)	81	(75–88)	93	(88–96)
Knee ROM arc (°)	128	(115–140)	129	(90–150)
CD index	0.9	(0.7–1.1)	1.1	(0.7–1.4)

*Values listed as average (Range); BMI, body mass index; CD, Caton-Deschamps Index; MAD, mechanical axis deviation; mTFA, mechanical tibio-femoral angle; mLDFA, mechanical lateral distal femoral angle; mMPTA, mechanical medial proximal tibial angle; ROM, range of motion

Table 2: Surgical characteristics outlining femur and tibia implant type as well as additional procedures performed at the time of surgery

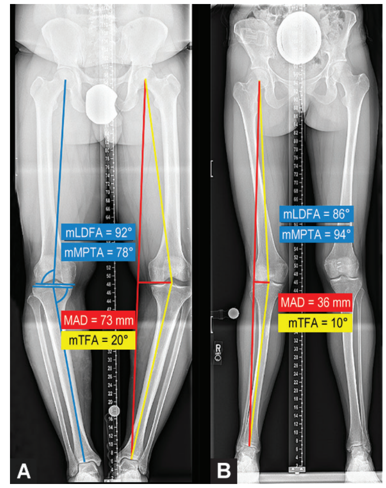
Characteristic	*Varus (n = 13)*	*Valgus (n = 8)*
Femur implant	12 plate/1 nail	8 plate/0 nail
Tibia implant	13 plate/0 nail	2 plate/6 nail
Prophylactic fasciotomy	1	5
Prophylactic nerve release	1	8
Adjunctive procedures	3	3

defined as 1–Error. Error is defined as the ratio of how close the post-operative MAD was to the target range (average post-operative MAD minus the nearest target goal) divided by the magnitude of correction intended (average pre-operative MAD minus the median of the target goal) (Fig. 1). This equation encompasses the correction magnitude as well as the patient specific correction goal (neutral, over-correction, under-correction).

Results

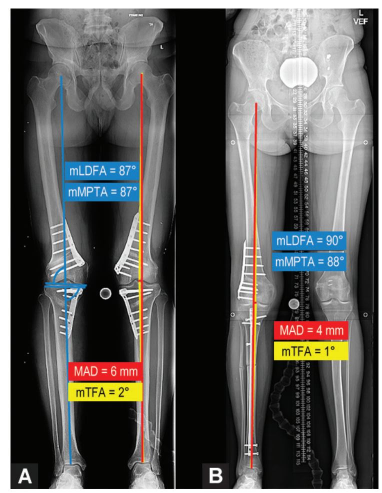
Radiographic Measures

Twenty-one extremities in 18 patients had acute, simultaneous femoral and tibial coronal plate correction with internal fixation. Patient demographics and pre-operative characteristics are represented in Tables 1 and 2. Average patient age was 37.4 years (range, 20.9–65 years) with average follow-up of 14.5 months (range, 12–40.2 months). There were 13 primary varus deformities



Figs 2A and B: Two case examples of coronal plane deformity. (A) A patient with genu varum deformity who underwent bilateral femoral and tibia acute correction (staged) and (B) A patient with genu valgum deformity who underwent unilateral deformity correction

MAD, mechanical axis deviation; mTFA, mechanical tibio-femoral angle; mLDFA, mechanical lateral distal femoral angle; mMPTA, mechanical medial proximal tibial angle



Figs 3A and B: Hip-to-ankle standing radiographs after correction and healing of the two case examples from Figure 1. (A) Staged bilateral genu varum deformity correction with dual femoral and tibial opening wedge osteotomies and plate fixation; (B) Acute correction of a genu valgum deformity with plate fixation for a distal femoral osteotomy and tibial intramedullary nail fixation after correction. Note the tibial blocking screw used to obtain and maintain coronal plate correction

MAD, mechanical axis deviation; mTFA, mechanical tibio-femoral angle; mLDFA, mechanical lateral distal femoral angle; mMPTA, mechanical medial proximal tibial angle

with an average MAD of 64.5 mm medial (range, 24–99 mm) and average mechanical tibio-femoral angle (mTFA) of 17.3° (range, 7–25°). There were eight primary valgus deformities with an average MAD of 44.6 mm lateral (range, 24–73 mm) and average mTFA of 14.8° (range, 9–20°). Figures 2 and 3 represent two case examples.

For the varus deformity group, 12 out of 13 femoral osteotomies were acutely fixed with a plate (5 medial opening wedge

Table 3: Post-operative characteristics of patients after deformity correction along width accuracy of the procedure

Characteristic	*Varus (n = 13)*	*Valgus (n = 8)*	*Total (n = 21)*
Delta MAD (mm)	56 (24–84)	45 (17–75)	52 (17–84)
Delta mTFA (°)	16 (10–24)	13 (8–20)	15 (8–24)
mLDFA (°)	88 (84–95)	90 (87–93)	
mMPTA (°)	90 (85–98)	89 (85–92)	
Knee ROM arc (°)	127 (120–130)	123 (95–140)	125 (95–140)
CD index	0.8 (0.39–1.07)	1.1 (0.91–1.26)	0.9 (0.39–1.26)
Accuracy	91.8%	95.2%	92.9%

osteotomies and 7 lateral closing wedge osteotomies). One patient had a transverse mid-shaft osteotomy fixed with an ante grade femoral nail. All 13 tibias were corrected with a medial opening wedge osteotomy with plate fixation.

For valgus deformities, all eight femurs were fixed with a plate - seven with lateral opening wedge osteotomies and one with a medial closing wedge osteotomy. Six tibias had percutaneous transverse osteotomies fixed with intramedullary nails. The two remaining patients had medial closing wedge osteotomies stabilised with plate osteosynthesis.

Concomitant Procedures

One of 13 varus extremities underwent both a prophylactic anterior compartment fasciotomy and peroneal nerve release, while all 8 valgus extremities had a peroneal nerve release and five underwent prophylactic selective fasciotomy.

Overall, 6 patients had concomitant articular or patellofemoral procedures that were related but separate from the deformity correction. Three patients with a varus deformity had a concurrent intra-articular procedure including arthroscopic chondroplasty and meniscectomy-one of which also had a lateral collateral ligament reconstruction. In the valgus deformity group, one patient had a micro fracture, one an open lateral release of the patella, and one had a medial patellofemoral ligament reconstruction in addition to an open lateral release.

Post-operative Characteristics

Post-operative characteristics are represented in Table 3. The overall magnitude of MAD and mechanical tibio-femoral angle correction was 52 mm and 15°, respectively. For varus deformities, MAD was corrected 56.3 mm (range, 24–84 mm), mTFA 16.5° (range, 10–24°) with a final mLDFA of 88° (range, 84–95°) and final mMPTA 90° (range, 85–98°). For valgus deformities, the magnitude of MAD correction was 44.6 mm (range, 17–75 mm) and mTFA 13.3° (range 8–20°) with a final mLDFA of 90° (range, 87–93°) and final mMPTA 90° (range, 85–92°).

There was no significant difference in knee range of motion pre- and post-operatively ($p = 0.255$). There was a 0.1 average (range 0.49 decrease to 0.3 increase) decrease in CDI. One patient developed radiographic patellar baja (CDI < 0.6).

Overall, there was a 92.9% accuracy. In three cases, the final MAD matched the goal MAD exactly. The final MAD was within 1–5 mm in 9 cases, within 6–10 mm in 5 cases, 11–20 mm in 2 cases, and more than 20 mm from the goal MAD in 2 cases.

Complications

There were no incidences of non-union, deep vein thrombosis, compartment syndrome, deep infection, or peripheral nerve palsies.

Table 4: Patient-reported outcomes before and after deformity correction surgery

Outcome	*Pre-operative*	*Post-operative*	*Change*
PROMIS			
Pain intensity	51.7	43.0	–8.7*
Physical function	39.9	45.3	5.4*
Pain interference	60.1	53.3	–6.8*
Global mental health	52.3	55.0	2.7
Global physical health	45.4	47.3	1.9
LD-SRS			
Function	3.3	4.1	0.8*
Mental health	4.0	4.3	0.3*
Pain	3.4	4.1	0.7*
Self-image	3.2	4.2	1.0*
Total	3.5	4.2	0.7*

*Post-operative difference above meaningful clinical threshold minimums; LD-SRS, limb deformity-Scoliosis Research Society; PROMIS, patient-reported outcomes measurement information system

Two patients had peri-incisional cellulitis that resolved with antibiotics. No patients returned to the operating room for unplanned surgeries in the early or late phases of healing.

Patient-reported Outcomes

Patient-reported outcome scores are represented in Table 4. Average PROMIS scores had meaningful changes in pain intensity, physical function, and pain interference domains. On average, pain intensity and pain interference decreased by 8.7 and 6.8 points, respectively. Physical function increased by 5.4 points. Global Mental Health increased by 2.7 points and Global Physical Health increased by 1.9 points.

Limb deformity-scoliosis research society scores had clinically important differences in all domains. Function scores increased by 0.8. Mental Health scores increased by 0.3. Pain scores improved by 0.7 and self-image by 1.0 points. Total scores increased by 0.7 from 3.5 to 4.2 on average. Overall, post-operative satisfaction with management was scored at 4.6 out of a maximum of 5 points.

Discussion

The results of this study demonstrate that simultaneous acute osteotomies of the femur and tibia are an accurate and safe method to correct lower limb malalignment with meaningful improvements in patient-reported pain and physical function.

Large deformities in the femur and tibia can be treated through acute or gradual correction. When performed acutely, single level opening wedge osteotomies are at greater risk of cortical hinge fracture that may require additional fixation.[19] Gradual corrections can lead to prolonged treatment periods as well as associated obstacles related to external fixation such as pin site irritation, pin tract infection, patient discomfort, and patient inconvenience. In addition, correction through a single osteotomy can cause excessive joint line obliquity. Studies have shown that shear stresses are dramatically increased with a joint line obliquity more than 5°, which is detrimental to articular cartilage.[10,20] Utilizing femur and tibia osteotomies allows the joint line to be corrected along with the mechanical axis. In the present study, normal joint line orientation angles were restored. The average post-operative mLDFA and mMPTA were 88° and 90° in the varus group and 90° and 89° in the valgus group.

Accuracy was assessed with a simple mathematical equation based on previously published methods.[21] The overall accuracy in this series was 92.9%. Three cases had a final MAD that exactly corresponded with the target goal. Overall, 17 of 21 (80.9%) cases were within 10 mm of the goal MAD. Three of the four cases that were over the goal MAD by 11 mm or more had a pre-operative MAD greater than 75 mm.

One difficulty with planning large coronal plane corrections is assessing the contribution of the knee joint itself to the deformity. Malalignment through the knee can make weight-bearing alignment unpredictable due to asymmetric articular integrity and variable soft tissue laxity. To better predict the joint contribution during osteotomy correction, several authors have suggested trigonometric formulas that are based on knee stress views or contralateral knee radiographs.[8,9] At our institution, alignment testing is done intraoperatively with a rigid alignment rod and fluoroscopy before and after final fixation. Because this technique is non-weight-bearing, it can lead to discrepancies between intended alignment intraoperatively and post-operative weight-bearing radiographs. Intraoperative simulated weight-bearing or knee stress views can be performed while using the alignment rod, however this technique has not been validated.

Although a specific magnitude for simultaneous acute correction has not been explicitly defined in the literature, we believe that dual osteotomies should be considered when the mTFA is greater than 12° or when a single osteotomy correction would cause abnormal joint line orientation angles over 5° from normal (87°). The ideal patients for acute, simultaneous osteotomies of both the femur and tibia are those with equal or nearly equal contributions to the overall deformity from the femur and tibia. This allows for (1) explicit correction of each bone segment to restore normal anatomy (2) distribution of soft tissue tension over a larger area (3) avoidance of external fixation and (4) reduction in treatment time. Using dual osteotomies to target a goal MAD allows for individual normalisation of both the distal femur and proximal tibial joint line orientation angles based on patient specific pathology. For example, if a patient present with severe genu varum and pre-existing medial compartment arthritis, the goal may be to overcorrect the mechanical axis to distribute the load to the lateral compartment. In theory, this offloads the pathologic medial compartment, reduces pain, and may prolong the lifespan of the native joint.

There were no nerve palsies, joint contractures, or instances of wound dehiscence in this case series. Although a direct comparison to patients that underwent large acute correction with a single level osteotomy was not performed, the lack of soft tissue complications could be related to the wide distribution of tensile forces along the concave side of the knee, in additional to the prophylactic fasciotomy and nerve releases performed at the time of surgery. Opening wedge high tibial osteotomies have also been associated with patellar baja (decreased CDI).[22,23] In our study, there was an average decrease in CDI of 0.1. The single patient that developed radiographic patellar baja (CDI < 0.6) had full knee range of motion without patellofemoral instability or knee pain.

Patient-reported measures were taken pre-operatively and post-operatively to evaluate the functional effects of dual, acute correction using validated PROMIS and LD-SRS surveys. Notably in this series, there were clinically meaningful differences in specific subsets including pain, physical function, mental health, and self-image.

Our findings are similar to other publications. Abs et al. compared clinical and radiographic outcomes in 69 patients with genu varum treated with either an isolated opening wedge high tibial osteotomy (OWHTO) or a combination of an OWHTO and closing distal femur osteotomy.[1] They found that double-level osteotomy cohort had significantly more normalised joint line obliquity compared to the OWHTO only group (1.7° vs 5.6°). With a minimum 2-year follow-up, they also reported better patient satisfaction and University of California, Los Angeles (UCLA) activity scores.

Pioger et al. reported on 26 patients with valgus-only deformity treated with a double-level osteotomy using patient-specific cutting guides.[24] They showed that correction of a bifocal valgus knee deformity with the double-level osteotomy improved the hip-knee-ankle angle (HKA) to 0.9° ± 0.9° while normalising the mLDFA and mMPTA. Clinically, they report that KOOS and UCLA scores were significantly improved.

This study had some limitations to consider. It is a relatively small cohort of patients who were retrospectively reviewed. The patient-reported outcomes had short follow-up and may not be indicative of long-term results. Future studies to document longer term outcomes of dual level osteotomy for lower extremity alignment correction are warranted.

Conclusion

Acute femoral and tibial osteotomies to address lower extremity coronal deformity allows for large corrections without compromising a desirable joint obliquity. With careful planning and select adjunct procedures, these large corrections can be done accurately with minimal complications. This technique avoids external fixation and staged treatment that can prolong recovery time. Patient-reported outcome measures noted meaningful improvements in both physical and mental subsets.

Clinical Significance

This study highlights a safe method to accurately correct large coronal plane deformities in the lower extremity in the acute setting. Single level correction of the same deformity could lead to problems like non-union, nerve palsy, joint contractures, and abnormal joint line obliquity. This study provides considerations and techniques on how to successfully treat these large deformities.

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