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Anterolateral proximal tibial opening wedge osteotomy for biplanar correction in genu valgum recurvatum using patient specific instrumentation (PSI). A technical note

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ABSTRACT

Background: Biplanar anterolateral proximal tibial opening wedge osteotomy has been described as successful for patients with combined recurvatum and valgus alignment. As it is a correction in two planes, it is a technically demanding procedure. We report the use of a novel technique with patient specific instrumentation (PSI) guides for different steps, aiming to reduce the complexity of this procedure.
Methods: One patient was treated for genu valgum recurvatum. A virtual surgical plan was made. A two-step PSI approach was used, consisting of an osteotomy guide and a repositioning guide and a custom trial wedges.
Results: Follow-up showed full function and improved VAS and KOOS scores. A neutral alignment was achieved. There was 2.76 degrees less varus compared to pre-operative planning, 1.24 degrees of excess slope and a rotational difference of 0.10 degrees. Saw plane accuracy was within 1 mm.
Conclusions: PSI is a recent technical addition to HTOs as a modality to improve accuracy and reduce surgical complexity. Pre-planning and PSI use in an anterolateral opening wedge PTO allowed for an accurate and reproducible biplanar correction in genu valgum recurvatum. Accuracy was comparable to PSI use in lateral open wedge high tibial osteotomies.

1. Introduction

Genu recurvatum is a condition defined by more than 5 degrees of hyperextension in the knee [1]. Patients often report knee pain with a feeling of instability and poor proprioceptive control, affecting gait. Genu recurvatum can be congenital or it can occur secondary to trauma, physeal plate arrest, polio, neurological conditions (congenital or acquired), Osgood-Schlatter disease or prolonged casting [2–4].

Abbreviations: PSI, Patient specific instrumentation; HTO, High tibial osteotomy; KOOS, Knee Injury and Osteoarthritis Outcome Score; VSP, Virtual surgery planning.

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In symptomatic genu recurvatum due to a negative tibial slope, an anterior opening wedge high tibia osteotomy (HTO) can be performed. This procedure was first described by Lecuire et al [5]. Dean et al in a recent review describe that the anterior opening wedge HTO currently is the most common surgical technique used [2]. In patients with a combined recurvatum and valgus alignment a combined correction can be chosen. A biplanar anterolateral proximal tibial opening wedge osteotomy has been described as successful for these patients [6,7]. However as it is a correction in two planes, this is a more technically demanding procedure.

In this case report, we present our surgical technique using PSI (Patient Specific Instrumentation) for a patient with symptomatic unilateral genu valgum recurvatum. The process of three-dimensional planning, PSI design, the surgical technique used and an evaluation of the post-operative result are described.

2. Materials and methods

A 23 year old male patient presented with persistent left lateral knee pain. There was no history of trauma. Physiotherapy and activity modulation had no effect on symptoms. He reported a mean VAS score of 5. KOOS scores were as follows: Pain 72.22, Symptoms 60.71, ADL 89.7, Sport/Rec 85.00, QOL = 43.75. The patient's past medical history revealed an arthroscopic subtotal lateral meniscectomy at age 19 due to a chronic bucket-handle meniscal tear as an amateur football player. Furthermore, he was diagnosed with bilateral pes cavus and metatarsus adductus of unknown etiology.

Physical examination showed a left-sided genu valgum recurvatum. Knee function F/E 140/0/10. Supine examination with extended knees revealed 12 cm heel height on the left side, compared to a heel height of 6 cm on the right. Collateral and cruciate ligament tests were normal with no signs of hypermobility.

Radiographic imaging showed a valgus knee with a patella bipartita, with minimal degenerative changes of the lateral compartment and an anterior tibial slope of 12 degrees (Fig. 1). A standing leg radiograph showed a mechanical valgus alignment of 8 degrees (Fig. 2). MRI revealed grade 1–2 chondropathy of the lateral compartment without any signs of ligamentous injury and a status after subtotal lateral meniscectomy. To prevent further progression of lateral compartment osteoarthritis surgical treatment was advised in order to correct valgus alignment and tibial slope by an anterolateral opening wedge HTO using PSI.

2.1. Virtual surgical planning (VSP)

A CT scan was performed of the deformed left tibia as well as the contralateral 'healthy' side. The raw DICOM image data were imported into Mimics version 23 (Materialise, Brussels, Belgium) for 3D bone reconstruction. All relevant bone structures were segmented as separate masks using threshold-based segmentation techniques and split-mask features. The seg-

Fig. 1. Radiographic AP and lateral views of the left knee.

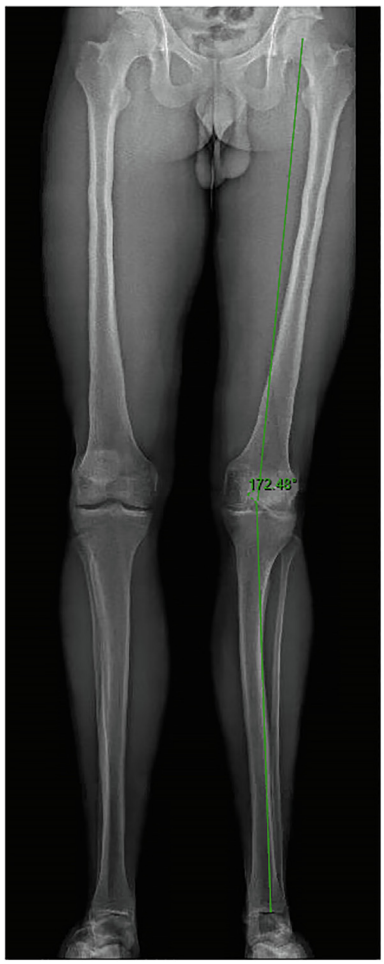

Fig. 2. Pre-operatieve full leg standing radiograph (EOS Imaging, Paris, France) demonstrating a valgus mechanical axis (172 degrees, 8 degrees of valgus).

mented structures were reconstructed as 3D surface models and exported to 3-matic version 15 (Materialise, Leuven, Belgium) for Virtual Surgical Planning (VSP).

In the first VSP step the contralateral tibia was mirrored and best fit aligned to the distal deformed tibia using the registration algorithm (Supplement 1). The overlaid contralateral side functioned as a template to which reshaping of the pathological tibia could be done. First the required correction was calculated by digitally cutting the affected tibia at the most prominent point of deformation. The proximal part was subsequently aligned to the goal template, providing the correction angles by its relative translation, which was 8 degrees of valgus and 17 degrees of slope.

A desired posteromedial hinge point and osteotomy plane (as per a standard HTO) was then chosen and the same biplanar rotation was then applied to the original tibia. An option for slight slope under-correction (12 degrees correction) was included since exact mimicking of contralateral might result in extension deficit and/or too much stress on ligaments and tendons during wedge opening. Hinging in the VSP occurred at a single point (biplanar correction) and as a result the wedge opens anteriorly as well as laterally. The tuberositas osteotomy was not preplanned.

PSIs were designed to transfer the VSP to the surgical field. A two-step PSI approach was used, consisting of an osteotomy guide (fitting the affected tibia) and a repositioning guide (fitting the desired tibial correction) (Supplement 2). By using this methodology the reposition guide can be slided over the K–wires, thus forcing the K-wires into parallel positions and consequently steering the tibial parts towards their planned positions. Parallel K-wire trajectories were chosen in the final outcome position for use in the reposition guide. By using reverse-engineering the relative K-wire positions were found in the malunited position for use in the design of the osteotomy guide. In addition to both guides, trial wedges were designed (by taking the dimension of the planned gap and a reduced gap for 12 degrees correction) that could be placed into the open wedge.

2.2. Surgery

The patient was placed in supine position, using a pneumatic compression device around the upper leg. An anterior midline incision was used, extending from the patella to just distal of the tibial tuberosity. After exposing the patellar tendon and tuberosity, the first PSI guide was positioned and fixed with 2 mm K-wires (Fig. 3). The guide was removed, leaving the K-wires in place, and an osteotomy of the tuberosity was performed which was consequently flipped upwards and covered with a wet gauze. A posteromedial release, including release of the pes anserinus and sMCL, was done and the cutting guide was placed over the K-wires. The oblique cut was performed using a 1.27 mm saw blade, leaving the posteromedial cortex intact and careful finishing the posterolateral cut with an osteotome. The cut was gradually opened with osteotomes, a printed trial wedge was inserted and a positioning guide was placed over the previously placed K-wires, first using the 12 degrees slope correction option. Heel height in full extension was comparable with the contralateral side, confirming an adequate correction of the tibial slope. The coronal correction was double checked with fluoroscopy by estimating the mechanical axis with a long metal rod. A 7-hole high tibial osteotomy (HTO) plate (FlexitSystem, Neosteo, Nantes, France) was positioned over the anteromedial aspect of the proximal tibia and fixed with angular stable screws. After removing the positioning guide and trial wedge, the osteotomy gap was filled with a femoral head allograft which was shaped according to the trial wedge. The tuberosity was flipped back and fixed with 3 bicortical small fragment screws distal and 1 screw proximal to the osteotomy. By referencing the level of fixation to the proximal tibia, patella infera was prevented. After closing the wound in layers, a pressure bandage and a removable extension splint were applied.

Toe-touch weight bearing on crutches was allowed for the first 6 weeks. Knee flexion started after 2 weeks building up to 90 degrees at 6 weeks.

A low dose CT scan was performed after surgery as a means of follow-up. The images were imported into Mimics Medical, segmented and then the STL was compared to the pre-operative plan to assess procedural precision.

3. Results

Patient was pain-free and satisfied, 6 weeks postoperatively. X-rays showed adequate implant positioning with evidence of bone-healing (Fig. 4) and a neutral alignment (Fig. 5). Weight bearing was increased to 50% bodyweight. At three months he was ambulatory without crutches, reporting a VAS score of 0. KOOS scores were as follows: Pain 97.22, Symptoms 82.14, ADL 100.00, Sport/Rec 75.00, QOL 62.50. Knee range of motion was symmetric with contralateral (F/E 140/0/5). Radiographs demonstrated progressing consolidation. Post-op CT fusion showed 2.76 degrees less varus compared to the pre-operative planning, 1.24 degrees of excess slope and a rotational difference of 0.10 degrees (Supplement 3). Saw plane accuracies were within 1 mm. Maximum gap distance was 12 mm.

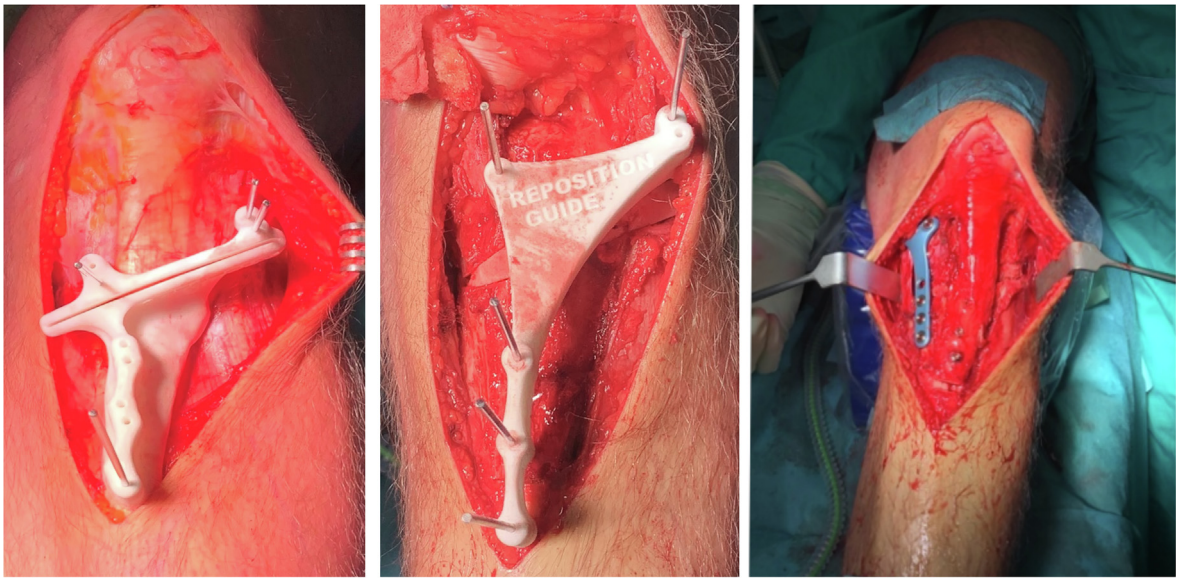

Fig. 3. A: the PSI cut guide, B: the reposition guide in place, with the osteotomized tibial tuberosity (TT) reflected, note the inserted trial wedge, C: final result after plate fixation, filling of the gap and refixation of the TT.

Fig. 4. Post-operative AP and lateral radiographs at six weeks demonstrating progressive consolidation.

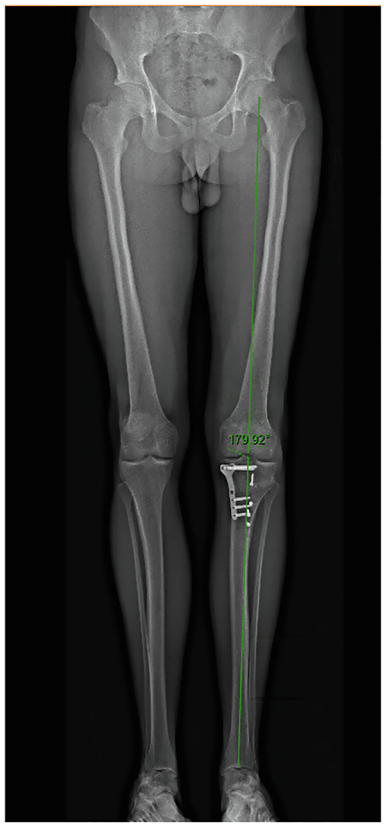

Fig. 5. A full leg standing radiograph (EOS Imaging, Paris, France) demonstrating a neutral mechanical axis (180 degrees).

4. Discussion

An anterolateral proximal tibial open wedge osteotomy for correcting both frontal as well as sagittal alignment is a technically demanding procedure as it is hard to control movement in two planes at once. Gaskill et al placed plane marking pins using fluoroscopy and then used a spreading device inserted into the anterolateral plane, opening the wedge till heel height measurements were symmetrical [6]. Dean et al used an adjustable guide, set to an oblique angle, and performed a similar correction [7]. Satisfactory results are reported however no comparison was made between planned and achieved reduction.

Observations in uniplanar HTO corrections, usually for unicompartmental osteoarthritis, showed the need for meticulous gap measurements and intraoperative checks [8]. A review from van den Bempt et al demonstrated that medial open wedge osteotomies had a poor accuracy and that there was a tendency to under correct [9]. This while especially accurate sagittal plane correction is essential to prevent inferior clinical outcome [10,11].

PSI is a recent technical addition to HTOs as a technique to improve accuracy and reduce surgical complexity. Donnez et al demonstrated a high accuracy of correction in both frontal and sagittal planes within 1 degrees in standard open wedge high tibial osteotomy in a cadaver study [12]. Chaouche et al reported a cohort of 100 patients, with plane accuracy less than 1 degree and good functional outcomes at a mean of 2 years [13]. Fucentese et al described 23 patients treated with PSI with less than 1 degree of error in coronal and transverse planes and 1.3 degrees in the sagittal plane (tibial slope) [14]. The achieved results in this case are comparable. An important factor to note is the difference in measurement between weight bearing full leg radiographs versus CT scans in a supine position to analyse planar malalignment. This may explain the slight planar error in the post-op CT comparison versus the post-op standing radiograph.

This is the first report on the use of PSI for a multi-planar correction in a symptomatic genu valgum recurvatum. The 3D printed trial-wedge piece and the repositioning guide both prevented correction loss, reducing the complexity of the procedure. A potential future addition can be the use of an intersecting k-wire to prevent medial hinge fracture as described by Gulaguci et al. [15] Furthermore, if required, the plate and screws can be preplanned and placed using a drill guide placed in the reposition guide. The technique described can also be used for a medial closing wedge or other types of multiplanar osteotomy in multiplanar deformities.

In case of unilateral genu recurvatum, mirrored contralateral CT imaging can be useful as a template [16]. However, care should be taken not to mimic the contralateral slope without checking the heel height, as this potentially can lead to clinical overcorrection and loss of extension. A rule of thumb, based on a clinical study of Sachs et al, is 1 cm of difference in heel height for 1.06 degree of slope correction [17]. A tibial tuberosity osteotomy was performed to prevent a patella infera and to act as a biological plate [18].

5. Conclusion

Pre-planning and PSI use in an anterolateral opening wedge HTO allowed for an accurate and reproducible biplanar correction in genu valgum recurvatum. Informed consent has been obtained from the patient for publication of the case. No METC approval was obtained as the presented surgical procedure was performed as normal clinical procedure. Declaration of interest: no interest to declare for all authors.

Ethical statement

Informed consent has been obtained from the patient for publication of the case. No METC approval was obtained as the presented surgical procedure was performed as normal clinical procedure.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix A. Supplementary material

Supplementary data to this article can be found online at https://doi.org/10.1016/j.knee.2021.08.030.

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