Patient specific instrumentation allow precise derotational correction of femoral and tibial torsional deformities

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A R T I C L E I N F O

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Patellofemoral instability
Patient-specific cutting guide
Accuracy
Clinical outcomes
Torsional malalignment syndrome

A B S T R A C T

Background: Rotational malalignment deformities of the lower limb in adults mostly arise from excessive femoral anteversion and/or excessive external tibial torsion. The aim of this study was to assess the correction accuracy of a patient specific cutting guides (PSCG) used in tibial and femoral correction for lower-limb torsional deformities.
Methods: Forty knees (32 patients) were included prospectively. All patients had patellofemoral pain or instability with torsional malalignment for which a proximal tibial (HTO) or distal femoral (DFO) or a double-level osteotomy (DLO) had been performed. Accuracy of the correction between the planned and the postoperative angular values including femoral anteversion, tibial torsion, coronal and sagittal alignment were assessed after tibial and/or femoral osteotomy.
Results: Forty knees were included in this study. In cases of HTO, the correction accuracy obtained with PSCG was 1.3 ± 1.1° for tibial torsion (axial plane), 0.8 ± 0.7° for MPTA (coronal plane) and 0.8 ± 0.6° for PPTA (sagittal plane). In cases of DFO, the correction accuracy obtained with PSCG was 1.5 ± 1.4° for femoral anteversion (axial plane), 0.9 ± 0.9° for LDFA (coronal plane) and 0.9 ± 0.9° for PDFA (sagittal plane). The IKSG was improved from 58.0 ± 13.2° to 71.4 ± 10.9 (p = 0.04) and the IKSF from 50.2 ± 14.3 to 87.0 ± 6.9 (p < 0.001).
Conclusions: Using the PSCG for derotational osteotomy allows excellent correction accuracy in all the three planes for femoral and tibial torsional deformities associated with patellofemoral instability.
Level of clinical evidence II, prospective cohort study.

1. Introduction

Torsional malalignment syndrome of the lower limb can be caused by excessive femoral anteversion, excessive external tibial torsion or both which may be accompanied by patellar malalignment, with an increased Q angle [1]. Excessive femoral anteversion can lead to many clinical presentations including anterior knee pain, patellofemoral instability and internally rotated gait [2,3]. Some surgeons suggest to perform derotational osteotomy torsional malalignment symptoms [3,4]. At long term, the clinical impact of these torsional disorders on developing osteoarthritic changes is still debated. Weinberg et al. concluded from 1158 cadaveric tibiae and femora, that neither tibial torsion nor femoral anteversion had a significant influence on the development of knee osteoarthritis [5].

The aim of derotational osteotomy is to normalize the lower limb axial alignment to a physiological femoral anteversion of 10–15° or reproduce the contralateral value when the malrotation concerns only one side [6]. Inadvertant changes in the coronal plane may occur after a derotational osteotomy and Nelitz et al. demonstrated in their three dimensional virtual analysis, that lateral distal femoral angle (LDFA) may decrease by as much as 6.9° in case of distal femoral derotational osteotomy of 30° [7,8]. Several procedures have been proposed in order to reduce this side effect, including the use of a biplanar osteotomy as described by Hinterwimmer et al. [9] or a diaphyseal osteotomy fixed by an intramedullary nail to reduce the osteotomy's influence on the coronal axis [3,10,11]. Use of three-dimensional planning, utilizing custom made cutting guides, have shown an improvement to achieve accurate and reliable outcomes after osteotomy. Their superiority in the coronal and sagittal plane corrections after high tibial and distal femoral osteotomies have been demonstrated but the accuracy of correction in the axial plane remains of academic and clinical interest [12].

The aim of this study was to assess the correction accuracy of a patient specific cutting guides (PSCG) used in tibial and femoral correction for lower-limb torsional deformities.

The secondary aim was to assess the patients postoperative clinical scores after a derotational osteotomy.

The hypothesis was that performing a derotational osteotomy using PSCGs results in accurate correction and achieves satisfactory functional outcomes at two years follow-up.

2. Methods

2.1. Patient selection

Following local ethical committee approval, a cross-sectional analysis of a prospectively collected database was performed. Any patient undergoing a distal femoral osteotomy (DFO) or high tibial osteotomy (HTO) or a double level osteotomy (DLO) to correct an abnormal lower limb torsion between February 2014 and February 2018 were identified. The inclusion criteria consisted of patients under sixty years of age with torsional deformity (excess of femoral anteversion and/or excess of external tibial torsion) and symptoms including anterior knee pain or patellar instability. Surgical criteria included femoral anteversion greater than 25° or external tibial torsion greater than 35° [13] with patellofemoral pain or instability. Patients were provided with a consent form to participate in the study. The exclusion criteria included osteotomy during prior surgery, severe knee arthritis (Ahlbäck 3 or 4), artefacts that would interfere with preoperative templating or refusal to participate in the study. In five patients, a concomitant medial patellofemoral ligament reconstruction was performed, no tibial tubercle transfers or trochleoplastys were performed. Fifteen patients had prior surgery in other centres, including six with tibial tubercle transfers, four partial meniscectomy and five patients who had a history of femoral nailing resulting in a malrotation deformity (Figure 1).

Paley's method [14] was used to measure the angular values in the coronal plane with the Hip–knee–ankle angle (HKA), medial proximal tibial angle (MPTA) and lateral distal femoral angle (LDFA). In the sagittal plane, the posterior plateau tibial

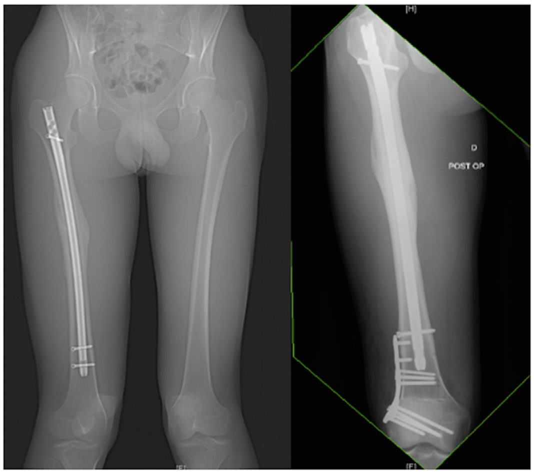

Figure 1. Patient with a post-traumatic etiology of malrotation after a history of femoral nailing, a distal femoral derotation was performed.

angle (PPTA) and posterior distal femoral angle (PDFA) were measured. In the transverse plane, angles for the femoral neck version (AF) and the tibial torsion (TT) were obtained.

The proximal tibial plane was created by fitting 35 points on the medial and lateral tibial compartments. The intersection of the proximal tibial plane and the tibial axis between the tibial knee centre and the tibial ankle centre was then determined as the PPTA. The posterior angle between the sagittal femoral axis connecting the anterior and posterior points of the femoral condyles and the femoral mechanical axis in the sagittal plane was defined as the PDFA [15].

2.2. Planning

Preoperatively, all patients had standard X-ray views (weight bearing long-leg radiographs, A/P and lateral views) and underwent a CT scan. Correction planning was performed by the surgeon assisted by a trained engineer (Figure 2). The CT scan protocol consisted of acquiring selective images centered on the femoral head, the knee (allowing the distal femur and 15 cm of the proximal tibia to be captured), and finally centered over the ankle joint. The slice thickness was 0.625 mm for the knee and 2 mm for the hip and ankle (GE Light Speed VCT64, General Electric Healthcare, Milwaukee, WI). The AF was defined by the projected angle onto the transverse plane between the femoral neck axis and the most posterior points on the medial and lateral condyle which define the posterior condylar axis, the tibial torsion was defined the projected angle onto the transverse plane of the line connecting the two more posterior points of the medial and lateral plateau and the ankle axis (defined as the line connecting the medial and lateral malleoli) [13]. In some cases an intentional change of the coronal or sagittal plane was performed for MPTA (66.7%, n = 12/18), LDFA (45.5%, n = 10/22), PPTA (50%, n = 9/18) and PDFA (18.2%, n = 4/22). This correction was low in most cases and allows to "lock" the initial coronal of sagittal deformity as it is known that derotation osteotomies inadvertantly modify the angular values in the other planes [7,8].

2.3. Surgical technique

Based on the surgeon's intended correction, a high tibial osteotomy (HTO), a distal femoral osteotomy (DFO) or a double level osteotomy (DLO) model was used to virtually perform the desired correction. In this model, an Activmotion HTO and/or DFO plate (Newclip Technics®, Haute-Goulaine, France) was positioned on the tibia and /or the femur as per the manufacturer's recommendations for ideal positioning. The PSI design takes into account the resection plane and the position of the screw tunnels relative to the virtual positioning of the distal femoral and/ or high tibial plate. The objective behind the PSI was to define the optimal plate position after distal femur, (and/or) high tibial osteotomy correction and then to transpose this anatomical position to the pre-osteotomy guide position (Figure 3). The PSI allows to define the optimal plate position, only one jig was used for the drill and the positioning of the plate screws after the correction. The PSI was secured to the bone with two pins, then the holes needed for the plate were pre-drilled prior to performing the osteotomy. The saw blade was guided by the specific slots of the PSI for the biplanar cut. The cutting guide was removed to finish the osteotomy in a single/ two planes and the osteotomy was then gradually opened/closed or derotated until the pre-drilled screw holes were aligned with the plate holes which was finally secured with screws.

The surgical technique followed a previously described step-by-step process for both femoral [16] and tibial osteotomies [14]. For femoral derotation, a default lateral approach was performed except in cases of associated medial patellofemoral ligament reconstruction for which a medial approach was performed or if previous medial scar was found.

The lateral aspect of the distal femur was exposed by incising through the fascia latae and the performing a sub-vastus lateralis muscle approach. This was elevated and dissected from the intermuscular septum. Following fluoroscopic confirmation for the correct guide pin placement and PSI drill holes, the osteotomy was performed using an oscillating saw. Two Schanz screws, proximal and distal to the planned osteotomy, were used to facilitate the derotation by rotating the proximal and distal fragments to the desired correction. A distal femoral Activmotion DFO Plate was applied (Newclip Technics®, Haute-Goulaine, France) with eight locking screws (four metaphyseal proximal and four diaphyseal distal to the osteotomy) to secure the femoral osteotomies. An Activmotion Size two (Newclip Technics®, Haute-Goulaine, France) plate was applied for tibial osteotomies. If needed, bone defects were filled using femoral head allografts. In cases of femoral derotation, an additional blount staple was added allowing a more stable fixation. For tibial derotation, an ascending or descending cut was performed behind the tibial tuberosity to rotate it or not with the distal tibial fragment. If the plan was to correct the tibial-tuberosity to trochlear groove distance (TT-TG) during the internal tibial rotation, an ascending cut behind the tibial tuberosity was perfomed, the internal tibial rotation allowed an associated medialization of the tibial tuberosity. If no TT-TG correction was intended, a descending cut extending to the diaphysis was performed leaving the tibial tuberosity on the proximal part of the tibia (Figure 4). A proximal osteotomy of the fibula was added when the derotation was over 20° to avoid neurological compromise and facilitate correction.

For all patients, postoperative management included toe touch weight bearing for 6 weeks, aided with the use of crutches. Full weight-bearing was allowed at 6 weeks and patients were allowed to resume recreational activities at 6 months.

2.4. Outcomes

All patients were reviewed at 1 month postoperatively to evaluate potential early complications and then every 3 months for regular follow-up with radiographs (long-leg standing, A/P and lateral). The accuracy of the correction was estimated

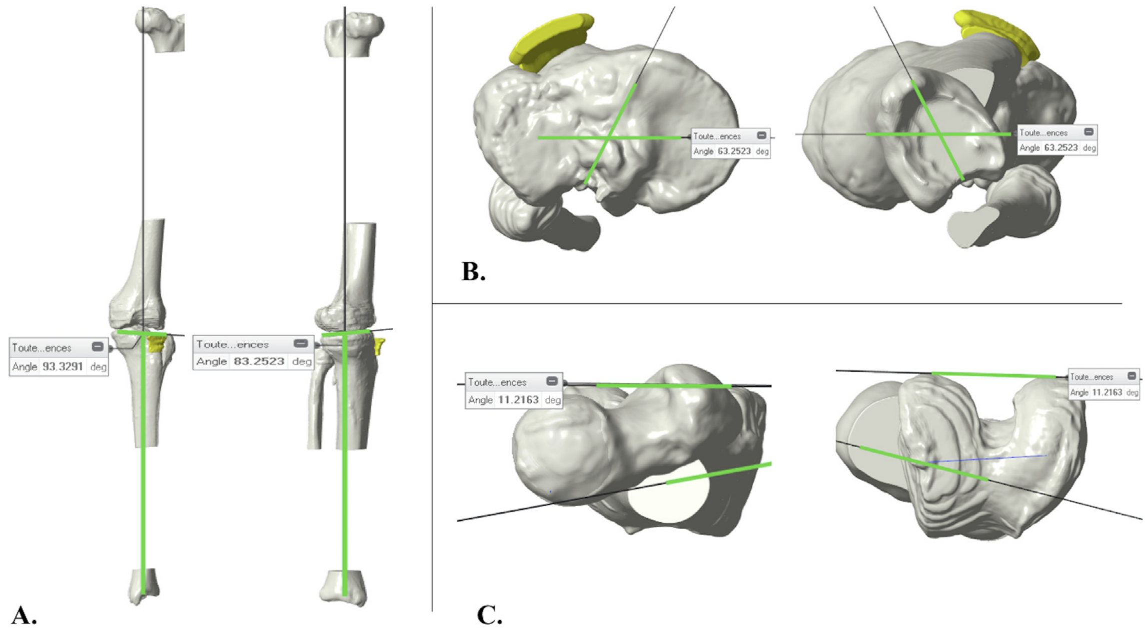

Figure 2. The angular values and torsional deformities are modelised on this 3D reconstruction representing a patient with excessive external tibial torsion. A. Frontal and sagittal tibial axis, B. Pathological tibial external rotation at 63 °C. Normal femoral anteversion at 11°.

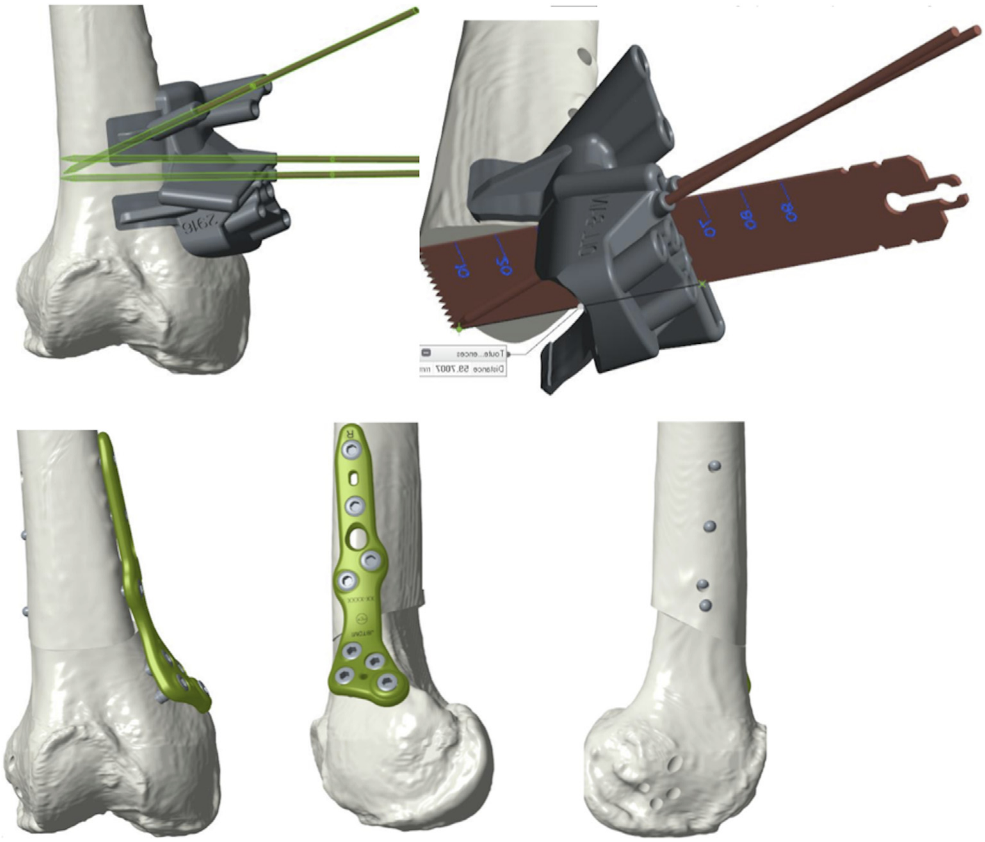

Figure 3. PSI used for osteotomy, after femoral derotation the staggered holes of the PSI are coincident with the holes plate. The PSI is positioned in the femoral edge, the holes needed for the plate were pre-drilled. The osteotomy is then performed with the saw advancing on the specific slot. After closed osteotomy, the pre-drilled screw holes (two above and four below the osteotomy site) were aligned with the plate holes after the derotation and two additional screws were positioned at the proximal part.

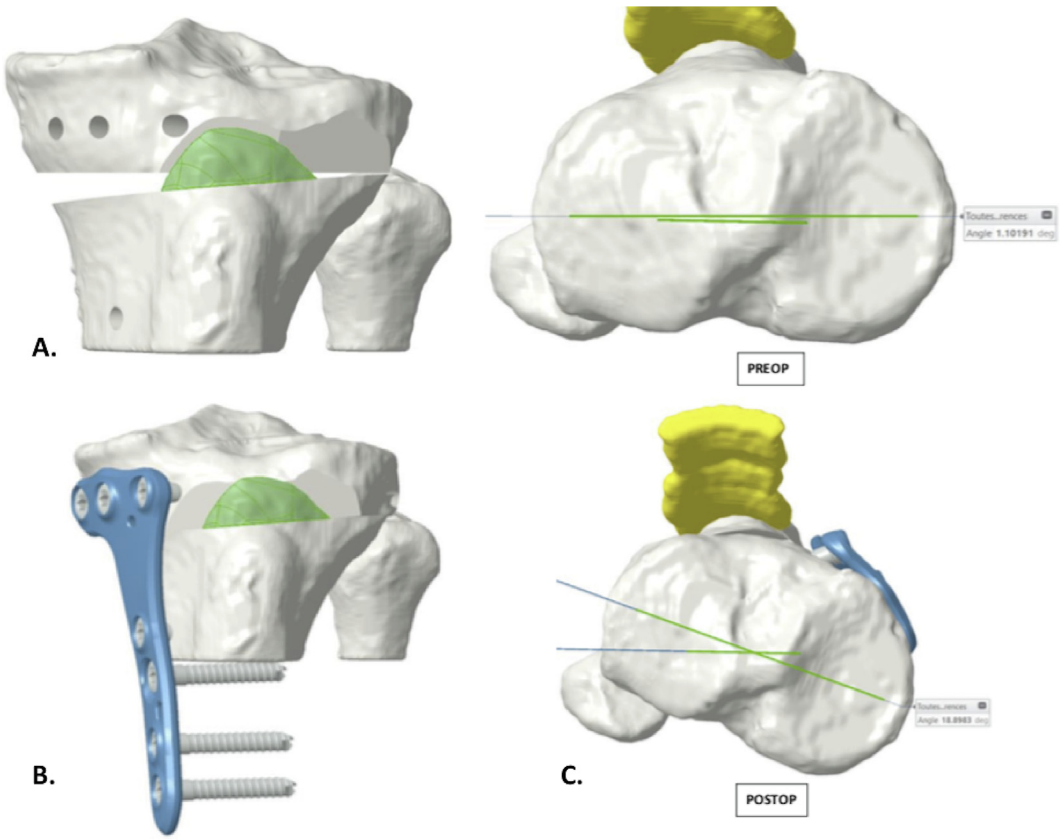

Figure 4. Tibial derotational osteotomy with biplane ascending cut. A. A tibial biplane ascending osteotomy is performed with an associated valgus correction of 5°, B. Leaving the tibial tuberosity distal to the osteotomy allow to medialize it during tibial internal derotation, C. In this case a derotation of 20° was realised.

using a CT-scan performed at 1 month postoperatively, including 3D reconstruction according to the department standards. Postoperative range of motion and functional scores were recorded at final follow-up. To ensure the reproducibility and accuracy of the measured angles, the analysis was repeated by two independent observers to obtain the inter-observer intraclass correlation coefficient (ICC).

The accuracy of the postoperative alignment was defined by the difference between the desired correction defined preoperatively and the correction obtained postoperatively. In order to evaluate the functional outcome, we used the International Knee Society Score with a Global evaluation (IKSG) including seven items on objective knee score (maximum value at 100 points) and Function evaluation (IKSF) including 19 items (maximum value at 100 points) [17]. Postoperative flexion and the presence of fixed flexion deformity or a recurvatum were recorded at a minimum follow-up of 2 years. The study was approved by the local ethics research committee.

2.5. Statistics

Based on previous research, investigating PSCG's precision [17], we designed our study to be able to detect difference between planned and obtained correction < 2° regarding frontal, sagittal and transversal morphological measurement with a statistical power of 80%, thus, 32 patients were required. Both calculations are for a two-sided test with alpha of 0.05 and 1-Beta of 0.8. Statistical comparison of pre- and postoperative variables was made using a two-tailed paired t test and $p < 0.05$ was taken to be statistically significant.

3. Results

3.1. Correction accuracy

The Table 1 shows inter-observer reproducibility. The precision was excellent for MPTA, LDFA and femoral anteversion, good for PDFA and moderate for PPTA and tibial torsion.

Table 1
Reproducibility analysis of angular values measurements.

Criterion	Inter-observer ICC	$CI_{95\%}$
MPTA	0.90	0.83–0.95
LDFA	0.95	0.91–0.97
PPTA	0.69	0.45–0.87
PDFA	0.79	0.63–0.88
Femoral Anteversion	0.95	0.90–0.97
Tibial Torsion	0.67	0.46–0.81

MPTA medial proximal tibial angle, *LDFA* lateral distal femoral angle, *PPTA* posterior plateau tibial angle, *PDFA* posterior distal femoral angle, *ICC* Intraclass correlation coefficient, *CI* confidence interval.

Forty knees (32 patients) were included in the study. The demographic data are set out in Table 2 and preoperative measures in Table 3. Thirty HTOs, seven DFOs and three DLOs were performed.

In cases of tibial osteotomy, the correction accuracy obtained with PSCG was 1.3 ± 1.1° for tibial torsion (axial plane), 0.8 ± 0.7° for MPTA (coronal plane) and 0.8 ± 0.6° for PPTA (sagittal plane). In cases of femoral osteotomy, the correction accuracy obtained with PSCG was 1.5 ± 1.4° for femoral anteversion (axial plane), 0.9 ± 0.9° for LDFA (coronal plane) and 0.9 ± 0.9° for PDFA (sagittal plane) (Table 3).

The correlation between the planned and the postoperative angular values involving:

- Tibial osteotomy: 0.8 (0.7–0.9) for tibial torsion, 0.9 (0.8–1.0) for MPTA and 0.8 (0.6–0.9) for PPTA.
- Femoral osteotomy: 0.8 (0.4–0.9) for femoral anteversion, 1.0 (0.9–1.0) for LDFA and 0.7 (0.5–0.8) for PDFA.

On multiple linear regression models (Table 4), a significant relationship was found between the planned and the postoperative angular values for all tibial parameters (R^2 = 0.80 for tibial torsion, R^2 = 0.88 for MPTA and R^2 = 0.76 for PPTA; $p < 0.01$) and femoral parameters except for the PDFA (R^2 = 0.62 for femoral anteversion, R^2 = 0.78 for LDFA; $p < 0.01$).

Table 2
Demographic parameters.

Characteristics	Values
Patients, n	32
Osteotomies, n	40
Female, n(%)	21 (65.6%)
follow-up, n ± sd	3.2 ± 1.1 years
Age, n(min – max)	20.4 (17–27)
BMI, n(min – max)	19.8 (15.3–26.1)
Left side n(%)	18 (45%)
Location of initial deformity:	22
– Excessive femoral anteversion, n(%)	(55.0%)18
– Excessive external tibial torsion, n(%)	(45.0%)13
– Combined femoral and tibial deformities, n(%)	(32.5%)
Etiology:	35
– Congenital, n(%)	(87.5%)5
– Posttraumatic, n(%)	(12.5%)

Table 3
Pre-, postoperative CT scan angular values and obtain accuracy after derotational osteotomy.

	Preoperative Measures	Correction Targets	Postoperative Measures	Differences with Target Corrections	Paired Correlation (IC95%) Target-Postop. Measures
HKA (°)	181.3 ± 5.0	–	–	–	
MPTA (°)	86.6 ± 2.9	88.3 ± 2.0	87.6 ± 2.0	0.8 ± 0.7	0.90 (0.83–0.95)
LDFA (°)	85.3 ± 3.4	87.3 ± 2.5	88.1 ± 2.3	0.9 ± 0.9	0.95 (0.91–0.97)
Femoral Anteversion (°)	25.7 ± 9.4	18.5 ± 3.7	17.1 ± 3.4	1.5 ± 1.4	0.78 (0.43–0.92)
Tibial Torsion (°)	36.4 ± 6.6	27.8 ± 1.1	26.3 ± 1.8	1.3 ± 1.1	0.84 (0.68–0.93)
PPTA (°)	84.7 ± 2.2	84.1 ± 1.2	83.4 ± 1.7	0.8 ± 0.6	0.76 (0.59–0.87)
PDFA (°)	82.7 ± 2.3	82.7 ± 2.3	81.8 ± 1.8	0.9 ± 0.9	0.67 (0.45–0.81)

HKA hip–knee–ankle angle, *MPTA* medial proximal tibial angle, *LDFA* lateral distal femoral angle, *PPTA* posterior plateau tibial angle, *PDFA* posterior distal femoral angle.

Table 4
Multiple linear regression model determining the relation between planned and postoperative angular values after tibial and femoral axial correction.

Measures Accuracy	Tibial osteotomy	Femoral osteotomy
MPTA	R^2 = 0.88	–
LDFA	–	R^2 = 0.78
PPTA	R^2 = 0.76	–
PDFA	–	*n.s*
Femoral Anteversion	–	R^2 = 0.62
Tibial Torsion	R^2 = 0.80	–

R^2 correlation coefficient, *n.s* not significant ($p < 0.05$ is considered as a significant difference), *MPTA* medial proximal tibial angle, *LDFA* lateral distal femoral angle, *PPTA* posterior plateau tibial angle, *PDFA* posterior distal femoral angle.

Table 5
Clinical results after tibial and femoral rotational osteotomy.

	Preoperative Measures	Postoperative Measures	*p* value
IKSF	50.2 ± 14.3	87.0 ± 6.9	<0.001
IKSG	58.0 ± 13.2	71.4 ± 10.9	0.04
Active Flexion (°)	123.6 ± 4.2	127.0 ± 5.5	0.001

IKSF International Knee Society Score with Function evaluation, *IKSG* International Knee Society Score with Global evaluation.

3.2. Clinical results

At last follow-up, a significant improvement in the clinical outcomes after the surgery was observed. The IKSG improved from 58.0 ± 13.2° to 71.4 ± 10.9 ($p = 0.04$) and the IKSF from 50.2 ± 14.3 to 87.0 ± 6.9 ($p < 0.001$). The active flexion improved from 123.6 ± 4.2° to 127.0 ± 5.5° postoperatively ($p = 0.001$) and no genu recurvatum was observed postoperatively (Table 5).

4. Discussion

The main result of this study is the high accuracy correction in all the three planes after derotational osteotomy performed using PSCGs. The target was achieved with an accuracy within 1.5° with the use of custom cutting guides based on pre-operative CT scans.

As a result, it is now possible to achieve accurate osteotomies for rotational malalignment utilizing this technology. Previous studies have proved the superiority of these guides in the frontal and sagittal planes after open-wedge high tibial osteotomy with an excellent correlation between the planned and the achieved correction [14]. This high accuracy compared to conventional methods has also been demonstrated after distal femoral osteotomy [17]. In the rotational-transverse plane, the literature remains poor with regards to accuracy after derotational correction. Jud et al. reported on 12 patients and 19 derotational osteotomies using a custom cutting guide with an accuracy error of 4.8° ± 3.1° for femoral derotational osteotomies. There was a significantly lower precision for tibial corrections at 7.9° ± 3.7°, the tibial undercorrection was explained by the authors probably due to the lack of fibula osteotomy which acts like a locking mechanism during internal tibial derotation [18]. Dobbe et al. evaluated the accuracy of tibial rotational osteotomy using PSI and showed an accuracy of $\leq$ 1.1° in their plastic bone model [19]. These results are similar to those seen in this study, with a mean correction accuracy of 1.3° for the tibia. The correlation between the planned preoperative values and the achieved target correction was slightly better for tibial derotation osteotomy compared to femoral derotation osteotomy. However, no study has demonstrated the ideal correction needed after derotation osteotomy.

An increased internal femoral torsion results in a lateralizing force vector by the quadriceps, which can result patella maltracking/instability in the absence of insufficient medial restraint [20,21]. Femoral derotational osteotomy may reduce this pathological force vector, decreasing the risk of patellofemoral instability. Several authors reported good to excellent clinical results after derotational femoral osteotomy [22,23] but this procedure is not common in part because the indications are not yet clearly defined. In our experience, the ideal indication is a type 3e in Frosch's classification of patellar instability corresponding to a patellar maltracking with pain or patellar instability and torsional deformity [24]. The choice of the surgical approach, the bone cuts, associated deformity correction and other procedures remain challenging. In our practice, we perform an oblique single osteotomy cut at the femoral side in case of associated coronal deformity and a horizontal cut if the femoral deformity is only present in the axial plane. We didnot perform any tibial tuberosity medialization but the value of the TT-TG influences our choice of cut. An ascending biplanar tibial cut will medialize the TT-TG with internal derotation while a descending cut will not modify the position of the tibial tuberosity related to the trochlear groove (Figure 5).

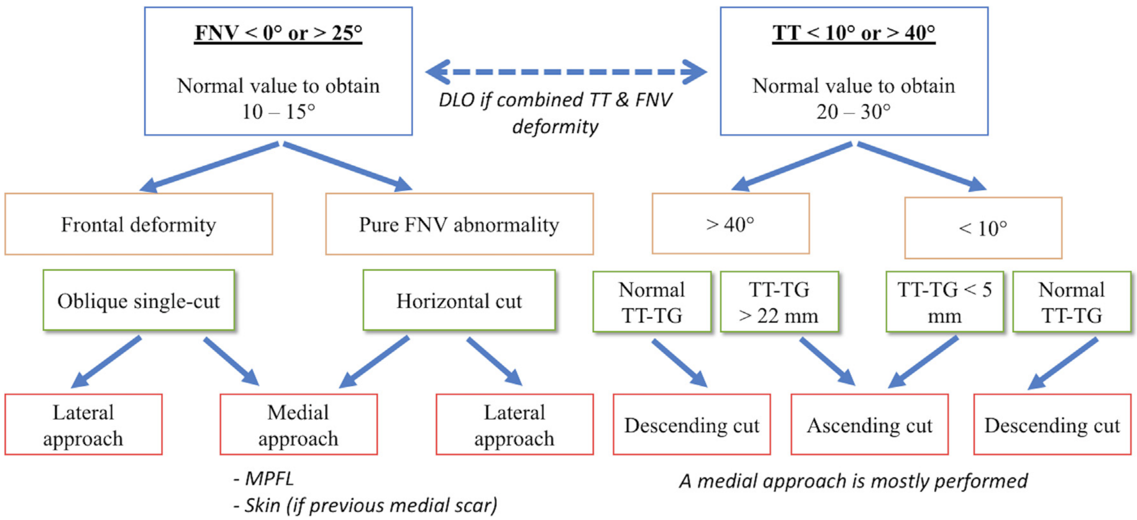

Figure 5. Lower limb torsional deformity algorithm. *FNV* femoral neck version, *TT* tibial torsion, *TT-TG* tibial-tuberosity to trochlear groove distance, *MPFL* medial patellofemoral ligament reconstruction.

Mutliplanar corrections are very difficult procedures as modification of the torsion of either femoral or tibial bone influence the global coronal morphology of them. Usually, external derotation of the distal femur and proximal tibial internal derotation creates varus [8]. As such, even when no frontal correction is required, the stability itself of coronal angular values implies morphological variation of the bone after derotation. This is one advantage of derotational correction using patient specific cutting guides to allow a perfect lower-limb alignment in all three planes (Figures 6 and 7). The current problems facing the conventional technique are the need of a great surgical experience and three-dimensional representation of the

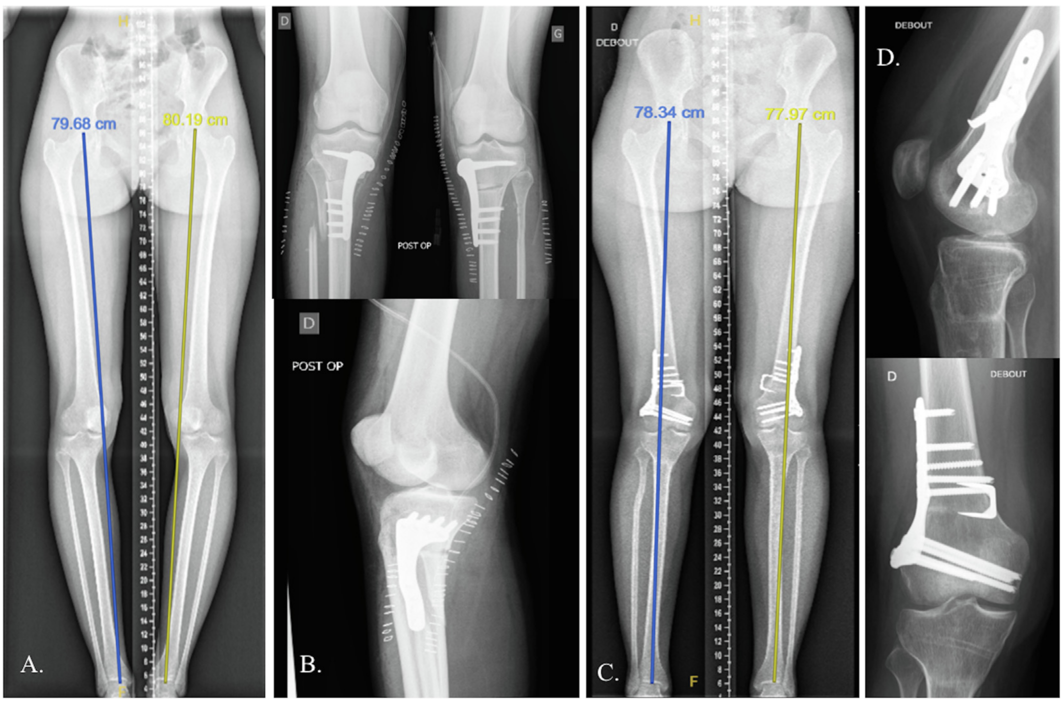

Figure 6. Bilateral tibial and femoral derotational osteotomy in two stage procedure for a patient with severe rotational malalignment deformity. A. Preoperative axial deformity with combined excessive tibial torsion (Right: 57°, left: 51°), excessive femoral anteversion (Right: 31°, left: 32°) and combined femoral and tibial varus B. The tibial osteotomies were operated first in one session, using a PSI with a planned target at 20°, a fibular osteotomy without osteosynthesis was also associated. C. The second surgery was performed with a target obtained at 15° for the femoral anteversion on both sides. D. No coronal or sagittal deformity has resulted after the bilateral femoral osteotomy using PSI.

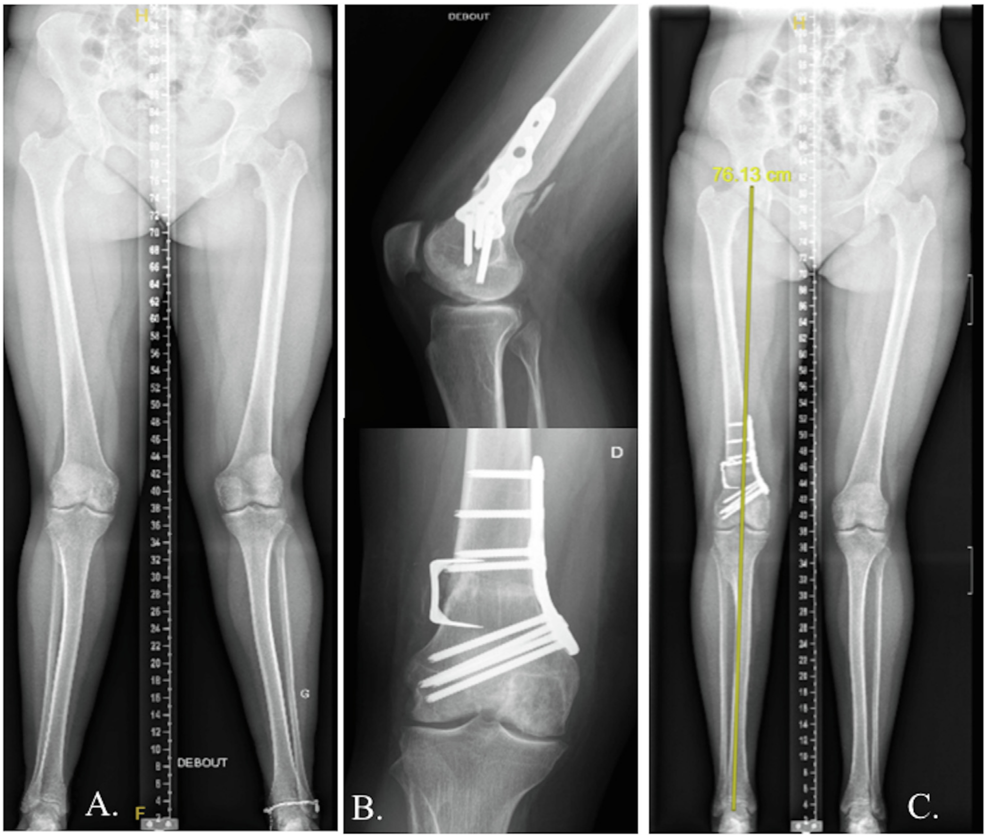

Figure 7. Plane-oblique distal femoral osteotomy for a young woman with patellofemoral instability. A. The preoperative deformity show an excessive femoral anteversion (31°) and a distal femoral deformity in valga (mLDFA = 83)°, B. A plane-oblique osteotomy was performed with PSI assistance to correct the lower-limb coronal alignment and is aligned and the torsonial malalignment, C. After the osteotomy with a coronal correction of 6° and axial correction of 15°, the weight-bearing line passes just at the center of the knee.

corrections to be made which may lead to a lack of accuracy and poor clinical outcomes. The use of PSI allows for improved accuracy, particularly for less experienced surgeons. A multiplanar correction is most easily achieved with PSI compared to free hand techniques. One of the major advantages of PSI is to limit the risk of unintentional associated correction in the coronal or sagittal plane. The proximal tibial osteotomy when performed with external tibial rotation is over 30° with patellofemoral symptoms has already demonstrated its safety [25]. Similar findings when looking at femoral and tibial osteotomies has also been demonstrated on patellar parameters like the patellar tilt, tibial tuberosity trochlear groove distance and axial patella engagement [26]. The clinical relevance of this axial plane correction requires further research to know exactly which degree of correction is required when a torsional deformity is associated with a coronal deformity. In our practice, a femoral anteversion greater than 25° or an external tibial torsion greater than 35° associated with patellar symptoms is corrected. These values are outside the "normal" range of a healthy population [13]. If there is a concomitant coronal deformity, the goal was to restore an anatomical MPTA and LDFA (at 87° ± 5°), in particular if the patient has lateral or more rarely medial compartment pain.

This study presents some limitations. Firstly, the limited sample size of the series. The number of included patients were sufficient to measure a difference since the indications are relatively rare and the standard deviation were not high which indicates the accuracy of the obtained values. Secondly, the lack of a control group, which would include the conventional method of correction. This procedure was always performed with PSCG assistance in our institution due to the previously discussed challenges encountered with conventional derotational osteotomy.

Further studies are needed to confirm the long-term clinical results including functional scores, osteoarthritic changes and gait analysis.

5. Conclusion

Using the PSCG for derotational osteotomy allows excellent correction accuracy in all the three planes for femoral and tibial torsional deformities associated with patellofemoral instability.

Funding

No funding was needed for this study.

Ethical approval

The local ethics committee approved our study protocol prior to investigation.

Declaration of Competing Interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: GM, BC, JNA, RK, CJ and PM have nothing to disclose. MO is educational consultant for Newclip.

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NA.

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