Comparison and Validation of Preoperative Planning Techniques for Distal Femoral Osteotomies and Proximal Tibial Osteotomies

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Abstract

Preoperative planning is important for accurate intraoperative execution in many surgical fields. Planning for distal femoral osteotomies (DFOs) and proximal tibial osteotomies (PTOs) consists of choosing the level of the osteotomy, measuring the angle of the osteotomy based on hip-knee-ankle alignment, and choosing a proper osteotomy wedge size. Medical imaging IT solutions company Sectra has implemented a new osteotomy tool in their radiographic system that is simpler than the accepted standard of modified center of rotation of angulation (mCORA) technique, yet unvalidated. In this study, we aim to compare the Sectra osteotomy tool versus the mCORA technique to measure the osteotomy angles as well as wedge sizes in both DFOs and PTOs to validate this new tool. We enrolled $n = 30$ consecutive patients with DFOs and $n = 30$ PTOs from the last year. The Pearson correlation coefficient (PCC) along with descriptive statistics was used to evaluate for similarity between the two techniques. We also compared interobserver and intraobserver reliability using intraclass correlation coefficients (ICC).
The PCC for osteotomy angles in DFOs and PTOs were both 0.998 ($p < 0.001$ for both). For wedge sizes, the PCC in DFOs was 0.993 and 0.980 in PTOs ($p < 0.001$ for both). ICCs were high for both interobserver measurements in osteotomy angles and wedge sizes (range: 0.989–0.999) as well as intraobserver measurements (0.994–0.999).
The Sectra osteotomy tool is a validated tool for preoperative measurements of DFOs and PTOs. It is reliable and simpler than the current practice of the mCORA technique. We suggest future studies to analyze this Sectra osteotomy tool in other settings as to incorporate it into widespread clinical use.

Keywords
- preoperative planning
- distal femoral osteotomy
- proximal femoral osteotomy

Picture archiving and communication system (PACS) has been the gold standard for hosting, accessing, and analyzing medical imaging in recent times. For many different surgical specialties, PACS serves as the vehicle not only for hosting radiographic images but also for pre-operative planning. Preoperative planning is important for accurate intraoperative execution in many surgical fields, including general surgery, otolaryngology, neurosurgery, plastic surgery, and orthopaedic surgery.[1–5] Specifically in orthopaedics, preoperative planning can be used to achieve proper alignment in lower extremity osteotomies to help patients improve and regain functionality whether for daily living, work, or sport.[6–11] Results of knee joint realignment and preservation have been excellent. Success of treatment is influenced by accuracy of realignment.[6] A precise preoperative plan of the magnitude of correction and the height of the opening or closing wedge helps the surgeon perform the realignment with precision during surgery.[7]

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Preoperative planning for distal femoral osteotomies (DFOs) and proximal tibial osteotomies (PTOs) consists of choosing the level of the osteotomy, measuring the angle of the osteotomy based on hip-knee-ankle alignment, and choosing a proper osteotomy wedge size. Traditionally, the senior authors (ATF, SRR) have used a modified center of rotation of angulation (mCORA) to create such an osteotomy in their presurgical planning.[12] This is a modification of CORA planning that avoids any translation at the osteotomy.[13] This is useful for DFO and PTO opening and closing wedge osteotomies that require an intact hinge cortex at a defined level. However, recently, medical imaging IT solutions company Sectra (Linköping, Sweden) has implemented a new osteotomy tool within their PACS that is simpler yet unvalidated.

Currently, this tool has yet to be validated despite its implementation already into clinical use. A commonly accepted measurement technique, especially in our practice, is the mCORA technique.[12–14] In this study, we aim to compare the Sectra osteotomy tool versus the mCORA technique to measure the osteotomy angles as well as wedge sizes in both DFOs and PTOs.

Methods

Study Design

We analyzed the last 30 consecutive DFOs and PTOs treated at our institution in the last year. Inclusion criterion was any patient in the last year that received a DFO or PTO. After obtaining institution review board approval, a retrospective review of the standing bilateral hip-to-ankle radiographs of these 60 patients was conducted. All of these digital radiographs were analyzed separately by the two junior authors (DTZ, PSP), trained by the two senior authors (ATF, SRR) whom are both fellowship-trained and board-certified orthopaedic surgeons.

All of our measurements were done in Sectra PACS (Sectra IDS7), where the angle of the osteotomy to a tenth of a degree and the wedge height to a tenth of a millimeter were recorded. The two reviewers' responses were used to compare interobserver reliability. After 1 week, the measurements for the 60 patients were repeated by the primary observer to assess intraobserver reliability.

Measurement Technique

Preoperative planning using the mCORA technique aligned three points: the center of the femoral head, the center of the knee—specifically the midpoint between the two tibial spines, and the center of the tibial plafond.[12] For both femurs and tibias, in general, there were four steps when planning the osteotomies using the mCORA technique: (1) draw the planned new mechanical axis of the lower extremity from the bone not having the osteotomy, (2) label the site of the osteotomy, (3) draw the mechanical axis of the single bone operated on, and (4) measure the angle between the hip-to-ankle's mechanical axis and the bone's mechanical axis. Specifically, for each bone, the following was done for the mCORA technique. All planning was done to neutral mechanical axis deviation.

As seen in ►Fig. 1, for DFOs, a straight line was drawn from the center of the tibial plafond through the bisection of the medial and lateral tibial spines to the level of the center of the femoral head, with this end-point representing the new femoral head after correction (blue in ►Fig. 1). The osteotomy site was drawn from 1 cm distal to the medial flare of the femur

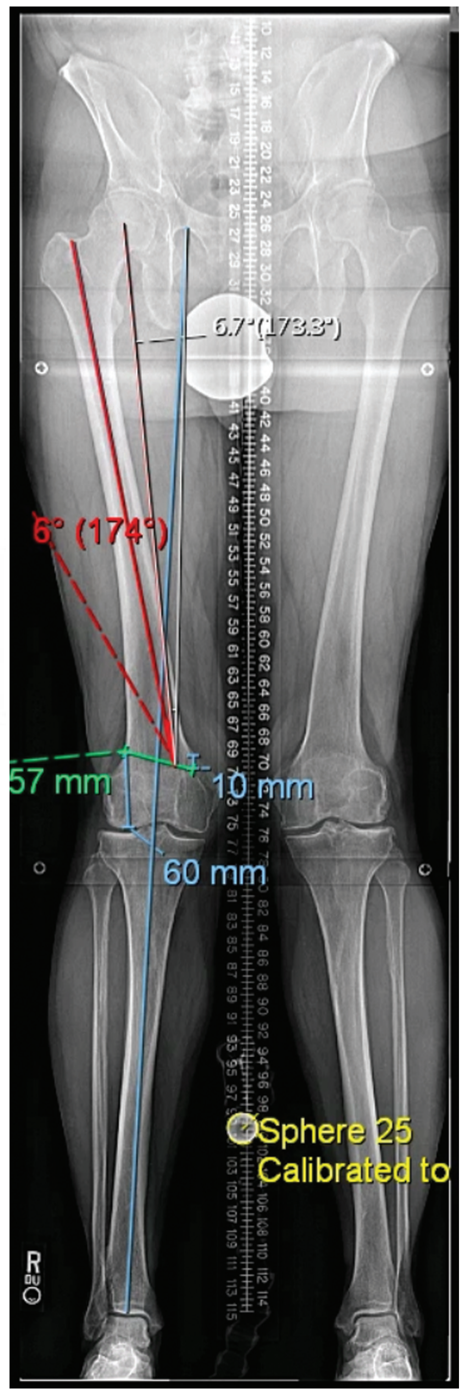

Fig. 1 Measuring distal femoral osteotomy wedge angle of 6.7 degrees using the modified center of rotation of angulation (mCORA) technique. The longest blue line indicates the planned, new mechanical axis of the lower extremity. The green line is the osteotomy site, with the two smaller blue lines aiding its placement. The red lines indicate the natural angle between the hip-to-ankle's mechanical axis and the femur's mechanical axis. The white lines measure the distal femoral osteotomy wedge angle.

just proximal to the medial epicondyle to 6 cm superior to a tangent to the lateral condyle (green in ►**Fig. 1**). Then, a 6-degree angle was drawn to the level of the osteotomy between the mechanical axis of the femoral head and the anatomical axis of the femur in the proximal third of the diaphyseal femur from the piriformis fossa (red in ►**Fig. 1**). Finally, the angle was measured from the new, planned femoral head to the current femoral head, yielding the angle of correction planned at the DFO (white in ►**Fig. 1**). Using simple trigonometry, the length of the osteotomy was multiplied by the tangent of this angle to yield the planned height of the wedge size. The angle and wedge size were recorded.

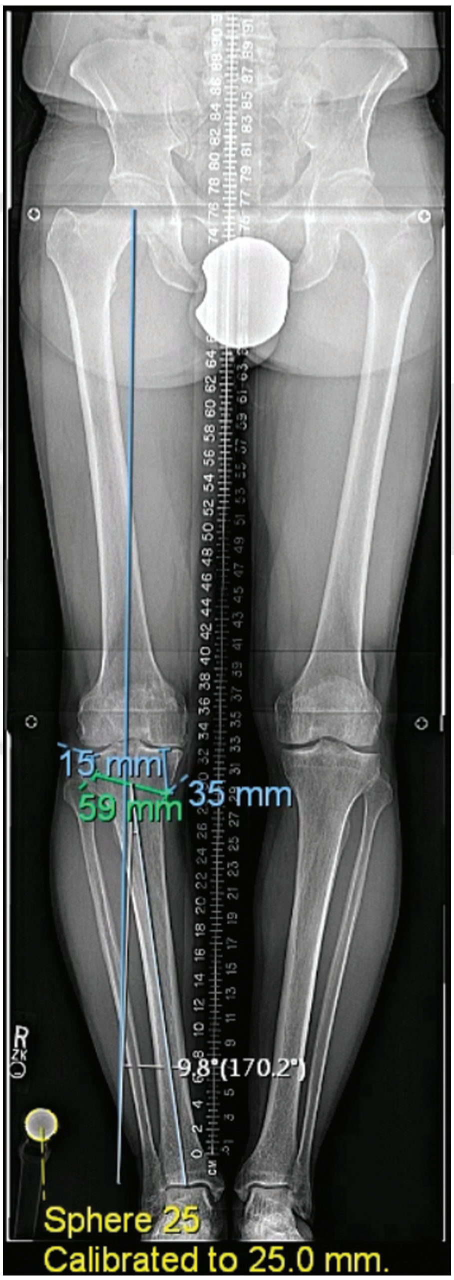

Fig. 2 Measuring proximal tibial osteotomy wedge angle of 9.8 degrees using the modified center of rotation of angulation (mCORA) technique. The longest blue line indicates the planned, new mechanical axis of the lower extremity. The green line is the osteotomy site, with the two smaller blue lines aiding its placement. The white lines measure the proximal tibial osteotomy wedge angle.

►**Figure 2** demonstrates the mCORA technique in PTOs. A straight line was drawn from the center of the femoral head bisecting the tibial spines to the level of the new tibial plafond (blue in ►**Fig. 2**). The osteotomy was drawn to be from 3.5 cm inferior to a tangent to the medial plateau of the tibia to 1.5 cm inferior to a tangent to the lateral plateau (green in ►**Fig. 2**). Because the mechanical axis and anatomic axis in the tibia are the same, a line simultaneously representing both axes was drawn from the center of the tibial plafond to the level of the osteotomy. Finally, the osteotomy angle was measured from the new tibial plafond to the old one (white in ►**Fig. 2**). Similarly, the osteotomy wedge size was calculated from the product of the length of the osteotomy and the tangent of the angle.

The Sectra osteotomy tool (accessible via Ortho Toolbox → Knee → Osteotomy) requires five simples steps with a user-friendly guide that demonstrates each click: (1) center of femoral head, (2) center of tibial plafond, (3) first end-point of osteotomy, and (4) second end-point of osteotomy, (5) manipulate/pivot the image until the desired mechanical axis is achieved. The femoral and tibial osteotomies were drawn as described above. The final output yields an angle and wedge size as shown in ►**Fig. 3**.

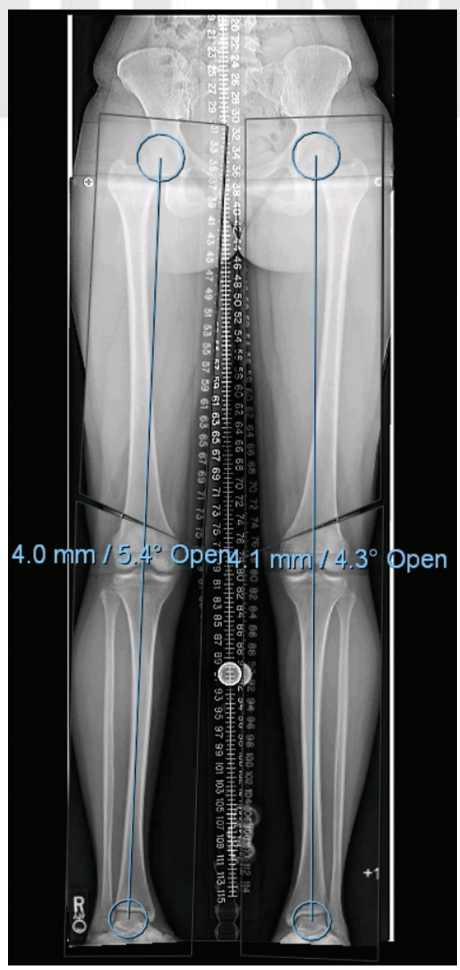

Fig. 3 Measuring osteotomies using the Sectra osteotomy tool.

Table 1 Demographics of patients receiving DFOs and PTOs[a]

	DFO ($n = 30$)	PTO ($n = 30$)
Age (years)	42.6 (17–64)	37.3 (15–62)
BMI (kg/m^2)	28.0 (19.4–41.9)	28.5 (18.9–69.2)
Female (%)	60%	33.3%
Laterality (% left/right)	43.3%/56.7%	46.7%/53.3%

Abbreviations: BMI, body mass index; DFO, distal femoral osteotomy; PTO, proximal tibial osteotomy.
[a]All values reported are in the form of "mean (range)."

Statistical Analyses

To compare the two different techniques, we use the Pearson correlation coefficient (PCC), r. A power analysis was done assuming $r > 0.9$ that resulted in a sample size of $n = 8$. The significance level was chosen to be 0.05, and any p-value less than that was deemed significant. We also included descriptive statistics to ensure that the distributions of the two samples of data were similar. All statistical analysis was done either in Microsoft Excel (Microsoft Excel for Mac 2019) or Stata (Stata/IC 15.1 for Mac). Intraclass correlation coefficient (ICC) was performed for interobserver and intraobserver reliability using the two-way mixed-effects model with absolute agreement, with 95% confidence intervals reported. Canonically, Cichetti's rating has been used to quantify the strength of ICCs.[15] We use a more strict classification by Koo and Li, where an ICC above 0.90 is excellent, 0.75 to 0.90 good, 0.50 to 0.75 moderate, and below 0.50 poor.[16] We hypothesize that all PCCs and ICCs will be excellent.

Results

We enrolled 30 patients in this study for each of the two types of procedures. ►**Table 1** shows their demographics.

When comparing the osteotomy angle and the size of the wedge between the two techniques, namely the mCORA technique and the Sectra osteotomy tool, we found the results were quite similar. As we can see in ►**Table 2**, the mean of the angles between the two techniques, for both DFOs and PTOs, were a few tenths to hundredths of each other with similar standard deviations. The PCCs were all excellent and statistically significant below the level of our intended 0.05 for both DFOs and PTOs. Similarly, for the wedge size in ►**Table 3**, the measurements were quite similar to each other with PCCs 0.980 to 0.993, also significant at the α level of 0.05. In general, all of these differences in measurement are well within the range of measurement error.

We also compared the ICC for interobserver and intraobserver reliability, shown in ►**Tables 4** and **5**, respectively. We can see that there was near-perfect reliability between the two observers and within the same observer on repeat measurement. The results aligned with our hypotheses.

Discussion

The goal of this study was to validate the Sectra osteotomy tool as compared with the gold standard of the mCORA technique. Our primary outcomes were the PCC r and a comparison of descriptive statistics of the two measurement techniques. We found very high correlations between the two techniques for angles and wedge sizes in both DFOs and PTOs. ICCs were excellent for interobserver and intraobserver reliability in all comparisons.

Our study examined ways to measure osteotomies when planning deformity corrections. These ideas were first established by Paley in several papers.[13,17] Since then, researchers have taken these principles and extended them to preoperative planning.[14] Barksfield and Monsell designed a model to predict the translation resulting from lower limb osteotomies.[18] Their results demonstrated a high level of predictability of the amount of translation based on the amount of angular correction and distance between the osteotomy site and the CORA.

Other studies have attempted to quantify interobserver and intraobserver reliability of various measurements. One study by Segev et al examined acetabular indices, center-edge angles, Reimer's indices, femur lengths, tibia lengths, mechanical lateral distal femoral angles, mechanical medial proximal tibial angles, and Cobb angles.[19] They found high intraobserver reproducibility and interobserver reliability across all these measurements. Other studies have even compared reliability between different forms of measurement, namely manual measurements on paper versus digital ones in PACS software.[20,21] Both Khakharia et al and Sailer et al found comparable reliability when transitioning to digital measurements, noting especially the reduction in evaluation time.[20,21]

Accuracy in preoperative planning for DFOs and PTOs is important to our group, which sees a high volume in these two operations and subsequently heavily studies both.[22–25] To our knowledge, no research has yet compared and evaluated two different techniques in measuring osteotomies.

Table 2 Comparison of mCORA technique versus Sectra osteotomy tool technique for the measurement of osteotomy angle[a]

DFO ($n = 30$)				PTO ($n = 30$)			
mCORA (degree)	Sectra osteotomy tool (degree)	PCC	p-Value	mCORA (degree)	Sectra osteotomy tool (degree)	PCC	p-Value
7.59 (4.46)	7.62 (4.41)	0.998	<0.001	11.15 (8.68)	10.85 (8.10)	0.998	<0.001

Abbreviations: DFO, distal femoral osteotomy; mCORA, modified center of rotation of angulation; PCC, Pearson r correlation coefficient; PTO, proximal tibial osteotomy.
[a]All values reported are in the form of "mean (standard deviation)."

Table 3 Comparison of mCORA technique versus Sectra osteotomy tool technique for the measurement of wedge size[a]

DFO ($n = 30$)				PTO ($n = 30$)			
mCORA (mm)	Sectra osteotomy tool (mm)	PCC	p-Value	mCORA (mm)	Sectra osteotomy tool (mm)	PCC	p-Value
6.97 (4.44)	6.88 (4.26)	0.993	<0.001	12.39 (12.88)	11.52 (9.47)	0.980	<0.001

Abbreviations: DFO, distal femoral osteotomy; mCORA, modified center of rotation of angulation; PCC, Pearson r correlation coefficient; PTO, proximal tibial osteotomy.
[a]All values reported are in the form of "mean (standard deviation)."

Table 4 Comparing interobserver reliability using ICC and 95% confidence intervals[a]

	DFO ($n = 30$)		PTO ($n = 30$)	
	mCORA	Sectra osteotomy tool	mCORA	Sectra osteotomy tool
Angle	0.997 (0.994–0.999)	0.998 (0.996–0.999)	0.999 (0.999–1.000)	0.995 (0.989–0.997)
Wedge size	0.990 (0.979–0.995)	0.989 (0.977–0.995)	0.998 (0.996–0.999)	0.992 (0.977–0.997)

Abbreviations: DFO, distal femoral osteotomy; ICC, intraclass correlation coefficient; mCORA, modified center of rotation of angulation; PTO, proximal tibial osteotomy.
[a]All values reported are in the form of "ICC (95% confidence interval)." All ICCs were statistically significant with p-value < 0.001.

Table 5 Comparing intraobserver reliability using ICC and 95% confidence intervals[a]

	DFO ($n = 30$)		PTO ($n = 30$)	
	mCORA	Sectra osteotomy tool	mCORA	Sectra osteotomy tool
Angle	0.999 (0.997–0.999)	0.999 (0.998–1.000)	0.999 (0.999–1.000)	0.998 (0.996–0.999)
Wedge size	0.997 (0.993–0.995)	0.994 (0.988–0.997)	0.999 (0.998–1.000)	0.997 (0.994–0.999)

Abbreviations: DFO, distal femoral osteotomy; ICC, intraclass correlation coefficient; mCORA, modified center of rotation of angulation; PTO, proximal tibial osteotomy.
[a]All values reported are in the form of "ICC (95% confidence interval)." All ICCs were statistically significant with p-value < 0.001.

Sectra has created an osteotomy tool that simplifies the measurement of osteotomy angles and wedge sizes even more, further reducing planning time. Given that this tool has yet to be validated, we sought to compare it to the gold standard of the mCORA technique. What we found was that the two techniques were virtually equivalent, whether measuring the osteotomy angle or the wedge size, in both DFOs and PTOs.

The PCCs between the two techniques for all measurements were quite high (range: 0.980 to 0.998) and statistically significant (p-value < 0.001). Given that the two techniques' means and standard deviations were similar, we can be confident that we are comparing similar distributions of data. The ICCs showed highly reproducible measurements, independent of observer or time. It is important to note that the differences in angles and sizes were all either within or roughly equivalent to the amount of measurement error. Namely, as stated in the methodology, angles were measured to a tenth of a degree and wedge sizes to a tenth of a millimeter. Final differences between techniques, observer to observer, or an observer from time A to time B might be due to any of these parameters, confounding or not, or to the measurement error of the tool itself, which cannot be fully untangled.

Overall, the ease of the Sectra osteotomy tool as compared with the currently used mCORA technique cannot be understated. It is quicker—requiring fewer clicks—while also being more user-friendly. Given the results of our study, we recommend embracing this innovative technology to expedite preoperative planning in DFOs and PTOs.

Limitations

There are several limitations to this study. First, the patients enrolled in this study were all at a single institution, specifically a high-volume, academic center. It is possible that these results are not generalizable because this group of patients is biased in an unknown way, given the nature of a single institution. We recommend enrollment of more patients at other institutions to validate this work in a generalizable way.

Our technique was standardized so as to be able to compare across all patients and between the two techniques. However, it is possible and very likely that, for example, the osteotomy site may be at a different location than the one we have described above. For the purposes of our study, we do not believe that this changes our results, but we do wish to state this as a limitation.

Also, the differences in measurements between the two techniques, as noted before, are well within the range of the measurement error. Perhaps the tool can be refined even further, which along with future studies that reproduce our work with more data can allow us to even more confidently conclude the validity of this Sectra osteotomy tool.

Conclusions

The Sectra osteotomy tool is a validated tool for preoperative measurements of DFOs and PTOs. It is reliable and simpler than the current practice of the mCORA technique. We suggest future studies to analyze this Sectra osteotomy tool in other settings as to incorporate it into widespread clinical use.

Conflict of Interest
None declared.

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