3D Curvature Analysis as a Visualization Tool for Trochlea Dysplasia

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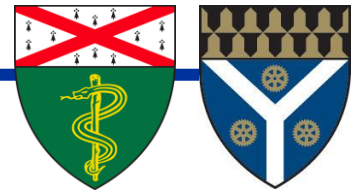
Financial Disclosures

I have nothing to disclose.



Introduction

In the following you will see a quick overview of published open-access work in Arthroscopy, Sports Medicine, and Rehabilitation titled:

Visualization of Trochlear Dysplasia Using 3-Dimensional Curvature Analysis in Patients With Patellar Instability […] by Sieberer et. al. 2025 [1]

Link to the article

Trochlea dysplasia

- Understanding and classification of trochlea dysplasia is important for clinical decision making in patellofemoral instability (PFI) [1]
- Current classification methods have low interrater reliability and fail to capture the full 3D morphology of the femoral trochlea. [3]
- 3D Curvature Analysis can highlight features such as Trochlea Morphology [1]

Figure 1: In PFI the patellar tracks laterally [2]

Curvature Analysis

- 3D Curvature analysis allows us to describe the local shape of a surface by assigning magnitude values to the local curvature.
- These values can be used to visualize the local curvature via colors (see Figure 2)

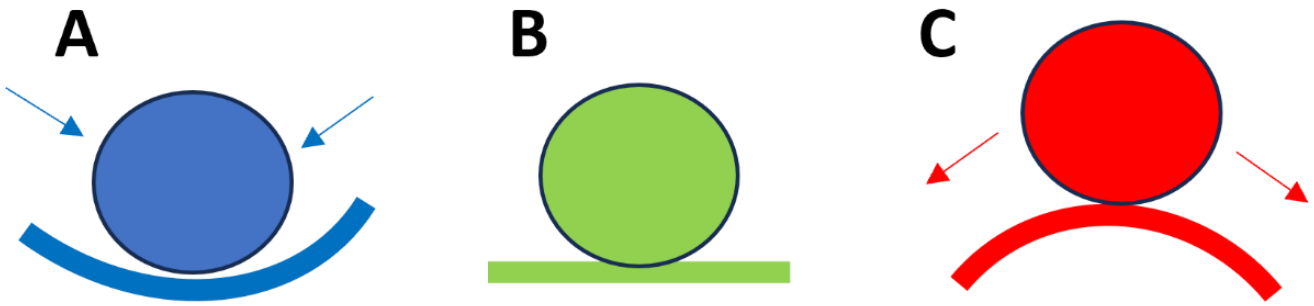


Figure 2: In this simple 2D example, three different curvature types are displayed (A-concave, B-flat, C-convex). Curvature analysis allows us to assign values to the specific curvature. [1]

Visualization of Trochlea Dysplasia

- The method highlighted in Figure 2D was applied to the distal femur of PFI patients with recurrent dislocations and healthy controls (See Figure 3).

- Two different method configurations were used to highlight trochlea ridges and the groove. Red symbolizes strong convex curvature (ridges), blue strong concave curvature (groove).

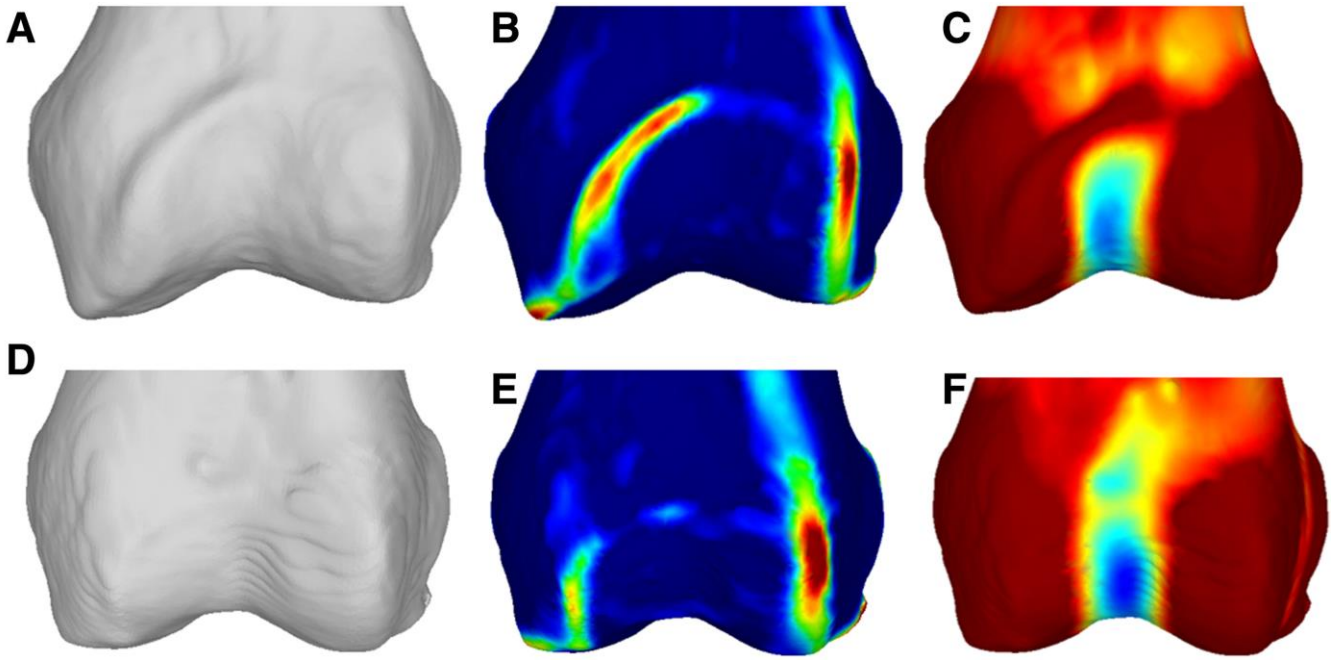


Figure 3: Trochlea of a PFI patient (A-C) and a control (D-F) were visualized with curvature analysis. The patient's medial ridge extends further lateral (B) and the trochlea groove terminates before end of the trochlea (C)

Methods

- We used the technique on 30 PFI and 30 control knees and evaluated them qualitatively and quantitatively by measuring the entry point to transition groove angle (EP-TG).

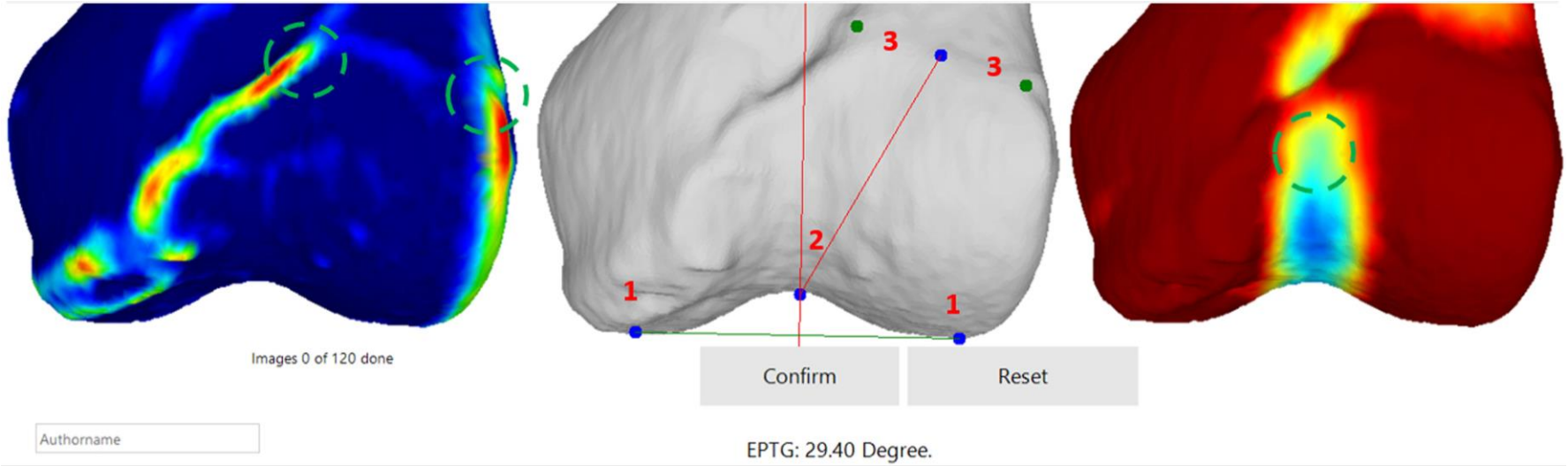


Figure 4: A custom tool was used to measure EP-TG. The entry point (EP) is the mid point between the proximal trochlea ridges. EP-TG is the angle between a perpendicular line through the Trochlea Groove (TG) and a line through EP and TG. It is a measure of laterality of the EP.

Qualitative findings

- We found that the curvature analysis helps visualize common features routinely found in PFI patients, namely flat trochlea grooves, and laterally extended medial ridge.

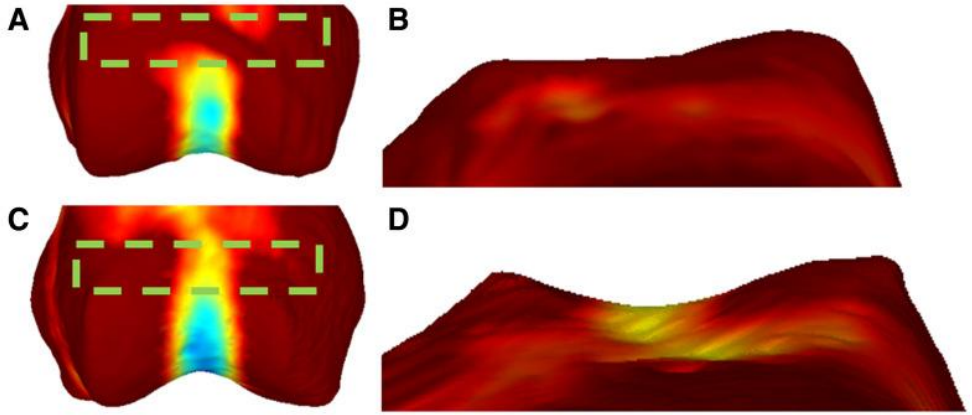


Figure 4: Raters found that curvature analysis helps to better understand a proximal flat groove (A-B) when comparing it to controls (C-D)

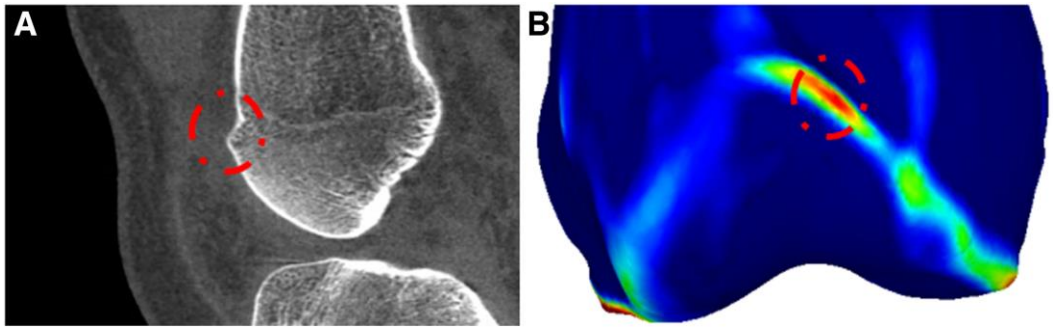


Figure 5: Raters found that curvature analysis(B) helps to better determine ridges compared to looking at high resolution CT-scans (A).

Quantitative Findings

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	Overall (n=60)	Patients (n=30)	Controls (n=30)	p-value
Age (years)	22.9±7.1	23.9±8.4	21.8±5.6	0.78
Sex (m/f)	46/14	24/6	22/8	0.76
EPTG	Mean±std			MWU p-value
With Aid	22.9±9.6	**28.3±6.7**	**17.4±9.0**	<0.001
Without Aid	23.7±9.1	**29.0±5.4**	**18.4±9.1**	<0.001
Female with Aid	23.1±9.5	**27.8±7.2**	**18.0±9.2**	n.a.
Male with Aid	22.0±10.3	**30.6±4.1**	**15.6±8.6**	
EPTG	ICC(A,1) [95% CI] – Three Raters once			Reliability
With Aid	0.87 [0.82-0.92]	0.78 [0.64-0.88]	0.85 [0.74-0.92]	Good to excellent
Without Aid	0.64 [0.51-0.75]	0.45 [0.21-0.67]	0.56 [0.35-0.74]	Moderate to good
EPTG	ICC(C,1) [95% CI] – Rater 1 thrice			Reliability
With Aid	0.89 [0.84-0.93]	0.88 [0.80-0.94]	0.81 [0.69-0.90]	Good to excellent
Without Aid	0.86 [0.80-0.91]	0.72 [0.56-0.85]	0.84 [0.74-0.92]	Good to excellent
EPTG	ICC(C,1) [95% CI] –Rater 2 thrice			Reliability
With Aid	0.91 [0.86-0.94]	0.93 [0.87-0.96]	0.83 [0.72-0.91]	Good to excellent
Without Aid	0.78 [0.68-0.85]	0.58 [0.36-0.76]	0.76 [0.61-0.87]	Moderate to good

Summary and Conclusion

- Summary

Using curvature-based visualization improved qualitative understanding of the trochlea groove and significantly improved the reliability of the curvature-based metrics EP-TG.

- Conclusion:

Curvature-based visualization aids overlayed on a 3D model have the power to increase the information gained from 3D imaging and corresponding 3D models, amplifying their potential value in clinical decision-making. Such visualizations facilitate both the identification of qualitative differences between patient and control morphology and improve the reliability of the Entry Point to Trochlear Groove angle (EPTG) trochlea dysplasia metric.

References

- [1] Sieberer J, Park N, Manafzadeh A, et al. Visualization of Trochlear Dysplasia using Three-Dimensional Curvature Analysis in Patients with Patellar Instability Facilitates Understanding and Improves the Reliability of the Entry-Point to Trochlea Groove Angle. *ASMAR.* 2024.
- [2] Foundation P. Patellofemoral Foundation Masters Course.
- [3] Martinez-Cano JP, Tuca M, Gallego A, et al. The Dejour classification for trochlear dysplasia shows slight interobserver and substantial intraobserver reliability. *Knee Surgery, Sports Traumatology, Arthroscopy.* 2024;32(6):1363-1369