

Three-Dimensional Tibial Tubercle Transfer Planning

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Background: Historically, decisions regarding tibial tubercle transfer have been made using 2-dimensional (2-D) criteria. This work is based on the belief that tibial tubercle transfer planning, aided by 3-D imaging, will be more accurate.

Indications: Understanding how the patella enters the trochlea and the path it follows to a deepening trochlea upon knee flexion, using objective metrics, will help in planning tibial tubercle transfer surgery.

Technique Description: Computerized tomography was used to create 3-D replications of patellar instability in patient knees at 0° and 20° of flexion. Studying these 3-D studies has yielded new metrics—the entry point-trochlear groove (EP-TG) angle and the entry point-transition point (EP-TP) angle—to objectify patellar tracking paths in patients with patellar instability. Tibial tubercle-trochlea groove (TT-TG) distance, Caton-Deschamps ratio (C-D ratio), and heat map contours were also determined using 3-D to maximize accuracy.

Results: Understanding EP-TG and EP-TP angles, TT-TG in 3-D, and heat map contours provides further insight when combined with traditional TT-TG and C-D ratios in planning tibial tubercle transfer for the surgical treatment of patellar instability. This has led to a *winter sports* approach, in which we plan tibial tubercle transfer to guide the patella safely along and past contours in its tracking path that might lead to displacement of the patella (also known as the skier or bobsled effect) out of its groove. Preoperative planning enables the precise determination of how to relocate the tibial tubercle optimally, and even the possibility of creating 3-D custom-printed surgical guides to achieve the desired osteotomy with precision.

Discussion/Conclusion: A 3-D understanding of trochlea shape, orientation, and contours improves knowledge of the femoral trochlea, particularly proximally, where the patella is most vulnerable to dislocation in the majority of patients with patellar instability, adding further objectivity to surgical planning regarding tibial tubercle transfer, visualizing the 3-D path as a skier or bobsledder might view a downhill course, and can enable surgical adjustment of the patellar position through tibial tubercle transfer to maximize safe and stable patella tracking.

Keywords: patella; 3-dimensional imaging; tibial tubercle transfer; tibial tubercle osteotomy; trochleaplasty

VIDEO TRANSCRIPT

BACKGROUND

Traditionally, planning for tibial transfer surgery has relied on 2-dimensional (2-D) criteria—including plain

radiographs and magnetic resonance imaging (MRI). Three-dimensional (3-D) imaging, however, provides a much better understanding and great potential for improved surgical planning.

INDICATIONS

We have adopted a *winter sports approach*, in which we consider the angles, curvatures, and slopes of the femoral trochlea in 3-D as part of the tibial tubercle transfer decision-making process. This additional information enhances the accuracy of surgical planning.

TECHNIQUE DESCRIPTION

Considering the patella as a ball that needs to be balanced in a stable way as it enters the femoral trochlea helps in establishing how far to move the tubercle and in what

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direction. Visualizing the patella as unstable at the top of the hill and then moving it to make sure it is stable on the downward slope of the hill, in a way that it cannot return to the top of the hill, makes intuitive and mechanical sense. An important goal of this approach is to balance articular loads to diminish the risk of arthritis, which is increased in patients with abnormally lateral patellar entry to the trochlea.³ Visualizing the patella as a bobsled entering a bobsled track makes accurate surgical planning tangible and realistic. The goal is to maintain the patella in its groove permanently, ensuring optimal load distribution.

The tibial tubercle–trochlear groove metric is helpful but quite variable, as it crosses the tibiofemoral joint and is prone to error based on the patient's position at the time of the MRI on which it is based.^{4,5}

Yu et al⁷ identified the entry point–transition point angle (EP-TP) as a strong indicator of the patella's lateral entrance to the trochlea. One might also refer to this as a structural J sign. Sieberer et al⁵ have shown that the EP-TP angle of patellar dislocators is very elevated compared with controls. Understanding this simple metric enables accurate surgical planning.

Questions a surgeon can answer better with 3-D include the relationship of the patellar entry point to the central trochlear groove (where the patella needs to go) and how far medial, distal, and anterior to move the tibial tubercle. We are still learning how best to utilize these metrics and understand contours.

Similar to the EP-TP metric, the entry point–trochlear groove (EP-TG) angle, introduced by Beitler et al,¹ further adds to the understanding of the lateral patellar entry angle in the trochlear groove.

Enhanced understanding of contours and slopes using 3-D imaging helps in understanding and surgical planning.⁶ The traditional concepts of shallow, flat, and convex trochlea contours remain helpful but may be appreciated throughout the trochlea in 3-D.

Using proximal transverse slice images of the trochlea provides a glimpse of the surface onto which the patella enters its trochlea. However, the contours of the trochlea are complex and require greater appreciation of the overall tracking path to optimize surgical planning for tibial tubercle transfer and patellar navigation around or past detrimental contours.

Understanding proximal ridges and spurs around the patellar entry zone helps in planning tubercle anteriorization to lift a distal patella past and over them. In some cases, 3-D images may help in planning a proximal trochlea spur recession combined with a tibial tubercle transfer bypass, thereby eliminating the need for trochlear deepening in most cases.

With knowledge gained from 3-D computerized tomography, one can design a tibial tubercle transfer guide to provide a precise cut for predetermined medialization, anteriorization, and distalization. The surgeon thereby navigates the patella to permanent stability and optimal load distribution, and hopefully long-term joint preservation as well as stability.

RESULTS

We are still learning how best to apply these powerful metrics and appreciate contours in 3-D. Essentially, when a patella is further lateral as determined using all available metrics and contour images, the need for medialization increases. Patella alta requires distalization, which also helps patellar engagement in the trochlea. Articular lesions, reducing load, and proximal spur bypass require anteriorization. Our best current advice is to consider proximal trochlear contours, ligamentous laxity, the J sign, patella alta, the TT-TG, EP-TG, and EP-TP metrics, femoral version, musculoskeletal deformities, and articular lesions when planning an anteromedial tibial tubercle transfer. Adding dynamic and motion analysis will provide further understanding when available.⁶

DISCUSSION/CONCLUSION

3-D analysis enhances decision-making options regarding tibial tubercle transfer surgery, likely leading to improved outcomes and fewer complications, as surgical planning is based on a greater understanding. Automation of 3-D metrics will make interpretation increasingly accessible.²

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