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Objective quantification of trochlear dysp lasia: Assessment of the difference in morphology between control and chronic patellofemoral instability patients

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ABSTRACT

Background: Trochlear dysplasia is an important risk factor associated with patellofemoral instability, but it remains difficult to classify with consistency. Currently there is no objective way to quantify the dysplasia. The purpose of this study is to define and quantify objectively the trochlear morphology by volume and length via computed tomography (CT).
Methods: One-hundred control patients (136 knees) were retrospectively reviewed and compared to 36 consecutive patients (72 knees) who were treated surgically for recurrent patellar instability and known trochlear dysplasia based on a lateral radiograph. Trochlear morphology was analyzed from a pre-operative CT and data presented as trochlear sulcus volume trochlear length. To determine where along the trochlear length dysplasia is most variable, the trochlear length was radiographically divided into thirds, volume was quantified along that section and compared to control trochlear.
Results: A significant difference in trochlear morphology exists between cohorts, volume (1.98 vs 3.77 cm^3) and length (31.97 vs 34.66 mm) ($p < 0.05$). However, there appears to be a gender based difference in trochlea morphology. The trochlea volumetric analysis between the female cohorts (L: 2.02 cm^3 vs. 2.94 cm^3, R: 1.95 cm^3 vs. 2.93 cm^3) demonstrated significantly less volume in instability patients ($p < 0.001$). The proximal third of the trochlear contributed the majority of dysplasia difference determined by comparing mean trochlear volume, 95% of the difference. This difference decreased in distal sections, 53% and 32% respectively.
Conclusion: This reproducible technique can be used to quantify the trochlea morphology, in order to describe the severity of a dysplasia.

1. Introduction

Symptomatic patellofemoral instability is poorly understood due to its complexity. Patellofemoral stability is provided by a combination of osseous and soft tissue structures [14]. Instability may result from limb malalignment, ligamentous deficiency,

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patellar height, trochlear dysplasia or more commonly multifactorial. Moreover, persistent patellofemoral instability has been implicated in articular cartilage damage, if left untreated [12].

With renewed enthusiasm, medial patellofemoral ligament (MPFL) reconstruction has been widely described to improve the patient's stability and improved patient function in some studies [2,3,6]. However, recurrent instability has been reported in up to 32% of the patients who underwent isolated MPFL reconstruction [16]. Recurrent instability after MPFL reconstruction may be caused by other unrecognised risk factors, such as osseous architecture and malalignment. It has been reported that trochlear dysplasia can be found in 85% of patients with symptomatic patellar instability [4]. Owing to its complexity, trochlear dysplasia has been poorly defined and described. The normal trochlear groove has a three-dimensional shape that varies from proximal to distal. The groove deepens as the height of the lateral wall decreases from proximal to distal. There have been multiple studies to define this complex three-dimensional architecture with a variety of imaging modalities; however all of such efforts have been met with significant limitations. Dejour et al. described trochlear morphology based on a lateral radiograph and characterized it into four types [4]. Nevertheless, radiographic assessment can misrepresent the extent of dysplasia due to its inherent limitations by trying to image a three-dimensional structure in a two-dimensional plane and because of poor reproducibility of the radiographic scan. There has been an effort to correlate radiographic to magnetic resonance imaging with mixed results [9].

The purpose of this study is to report a technique to objectively define and quantify trochlear volume and length via computed tomography, and to apply this technique to evaluate the difference in trochlear morphology between controls and patients with known chronic patellofemoral instability. The hypothesis is that there is a significant difference in volume and length in a symptomatic instability group compared to a healthy control group.

2. Material and methods

This study was a retrospective review of patient charts, radiographs and computed tomography (CT) from the Boston Medical Center between 2007 and 2012. The control cohort consisted of 100 consecutive patients between the ages of 15 to 35, who received a CT scan of the lower extremities that included the knee joint and femoral condyles. Indications for the study included lower extremity blunt or penetrating trauma, vascular injury, or generalized leg pain. Any scans with fractures of the distal femur and/or patella, open physis or obvious patellofemoral arthritis were excluded. By a retrospective chart review, any patients scanned for the evaluation of patellofemoral complaints were also excluded. One hundred patients were included in the normal control cohort.

Between 2012 and 2013, 36 consecutive patients were evaluated and required surgical treatment for recurrent patellofemoral instability by either of the two of the senior authors (C.E. and A.A.S.). Patient charts, radiographs and CT scans were prospectively collected and reviewed.

2.1. Trochlea morphology and volumetric assessment by computed tomography

A 64 multi-detector computed tomography (MDCT) scanner (Lightspeed VCT, GE Medical Systems, Milwaukee, WI) was used. All CT images were acquired with a standard musculoskeletal imaging protocol utilizing 1.25 mm collimated images with a reconstruction interval of 0.625 mm. The control patient images were acquired in a more varied fashion, as different protocols were used depending on the initial indication. These included images acquired at 0.625 or 1.25 mm collimation, with reconstruction intervals of 0.625 or 1.25 mm, respectively, imagine not collected with a minimum of 1.25 mm slices were not used.

Trochlear morphology was assessed on the post-processed images using GE Healthcare Volume Viewer 2, AW Suite 2.0 6.5.1z (GE Medical Systems, Milwaukee, WI). This imaging processing tool is standard with our GE Image processing system and to our knowledge available with most systems [15]. To determine reproducibility of this technique, measurements were taken by four independent observers (an attending orthopedic surgeon, an attending musculoskeletal radiologist, a PGY3 (postgraduate year; 3rd year of residency) orthopedic resident, and a PGY2 (postgraduate year; 2nd year of residency) radiology resident). They were given a list of all patients (control and instability groups were mixed), not knowing which patient belonged to the instability group and which one belonged to the control group. Measurements were performed on the radiological software platform with no information about participant characteristics. The trochlear volume was measured of the sulcus morphology on the axial images. Trochlear anatomy was defined as the following based on accepted anatomic landmarks: the superior limit was defined to be the first axial cut distal to the physeal scar, while the inferior limit defined as the final axial image in which the sulcus could be visualized at the level of the intercondylar notch. This definition was further confirmed by the use of three dimensional (3D) volume rendered imaging to confirm these landmarks would contain the entire length of the trochlea. The bony contours were defined off the subchondral surface by manually being traced on consecutive serial axial images with the assistance of the "edge attraction" feature on the volume viewer from apex or crest of lateral wall across the sulcus and to the apex of the medial wall. To quantify this anatomical morphology the authors presented this as a "volume" by using the subchondral bone as the floor and a straight line between medial and lateral wall peaks as the ceiling of the anatomic structure and correlated with the articular surface. The 3D rendering program was then applied to the "defined" anatomic volume which provides a quantitated volume measurement directly dependent and related the surface morphology the trochlea measured (Figure 1).

To estimate the "length" of articular contact of the patella or sulcus, the length in the sagittal plane was measured from a midline sagittal reformatted image that was created in a plane 90 degrees to the posterior margin of the femoral condyles (Figure 2). This was measured at the time of volume measurements and used the same proximal and distal points on the axial cuts to define the starting and ending point to determine length. Figures 3 and 4 illustrate the method applied to a dysplastic and control knee.

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