Trochlear Contact Pressures After Straight Anteriorization of the Tibial Tuberosity

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Background: Anteromedialization of the tibial tuberosity has been shown to decrease mean total contact pressures of the lateral trochlea and to shift contact pressures to the medial trochlea.

Hypothesis: Modifying the anteromedialization osteotomy to a straight anteriorization osteotomy of the tibial tuberosity can decrease trochlear contact pressures without a resultant medial shift of forces to the medial trochlear contact area.

Study Design: Controlled laboratory study.

Methods: Ten cadavers were tested before and after straight anteriorization tibial tuberosity osteotomy by loading the extensor mechanism with 89.1 and 178.2 N at 0°, 30°, 60°, and 90° of flexion following a validated patellofemoral joint loading protocol. Contact pressures were measured with electroresistive pressure sensors placed directly on the trochlea.

Results: The mean trochlear contact pressures after osteotomy decreased significantly ($P < .05$) for loads of 89.1 and 178.2 N at both 30° (23% and 20%, respectively) and 60° (18.7% and 31.9%, respectively) of knee flexion. The peak contact pressures decreased significantly ($P < .05$) for loads of 89.1 and 178.2 N at 30° (24.3% and 27.0%, respectively) and 60° (31.9% and 24.5%, respectively) and for loads of 89.1 N at 90° (13.4%) of knee flexion.

Conclusion: The authors demonstrated significantly decreased trochlear contact forces after straight anteriorization osteotomy of the tibial tuberosity, without a significant resultant medial shift of the center of force.

Clinical Relevance: Straight anteriorization of the tibial tuberosity may be a useful adjunct for patients with medial articular defects of the patellar or trochlea in whom anteromedialization would be otherwise contraindicated.

Keywords: trochlea; contact pressures; tibial tuberosity; tubercle; osteotomy; anteriorization

Anteromedialization (AMZ) of the tibial tubercle (TT), as described by Fulkerson et al,[13,17] has been shown to decrease total trochlear contact pressures, albeit with a resultant shift of forces to the medial trochlea.[2] Cartilage repair procedures such as autologous chondrocyte implantation have been shown by Peterson et al[29] to have improved results when combined with AMZ of the TT, presumably owing to unloading and protecting the repair.[10,19]

Despite this, there is still a subset of patients with medial patellofemoral cartilage lesions for whom AMZ is not a viable option in isolation or combined with a cartilage repair procedure because of the resultant medial shift of contact forces. Pidoriano et al[30] reported that patients with distal or lateral patellar chondral lesions had significantly better results than did those with medial or proximal lesions. Previous tibial tuberosity anteriorization osteotomies have been described (most well known is the Maquet); however, there have been significant complications such as fracture, nonunion, and skin necrosis, and their use has largely been abandoned.[35] Fulkerson et al

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(unpublished data, 2007) described a straight anteriorization (SA) osteotomy of the TT that is different from the traditional Maquet procedure in that, similar to the AMZ, it does not require bone graft. The benefits of SA osteotomy are yet to be fully elucidated, but potential advantages over the Maquet anteriorization osteotomy are secure bone-to-bone fixation with bicortical screws, no requirement for bone grafting, and less chance of skin complications due to less prominence and more gradual anterior sloping of the osteotomy.

We hypothesized that SA osteotomy of the TT would result in decreased total trochlear contact pressures without the concomitant medial shift of forces as seen in AMZ. Such an osteotomy may have a role in a specific subset of patients with cartilage lesions of the medial trochlea or patella at the time of cartilage repair procedures, to offload and protect the repair, or in patients with global patellofemoral disease. In addition, there are patients without apparent malalignment of the patellofemoral compartment who have central trochlear isolated defects. These patients may benefit in a like manner during cartilage repair techniques if the absolute stress of the patellofemoral compartment is decreased with SA. This study investigates the effects of SA osteotomy on trochlear pressures.

MATERIALS AND METHODS

Ten cadaveric knees were tested before and after SA TT osteotomy by loading the extensor mechanism with 89.1 N and 178.2 N, following a validated model of nonweightbearing resisted knee extension described by Skyhar et al.[37] The mean age of the donors was 61.7 years (range, 46-72 years). All specimens were from donors without known skeletal diseases, and there were no significant signs of advanced articular cartilage degeneration, patellofemoral malalignment, or other bone or soft-tissue disease at the time of preparation.

The 10 frozen human cadaveric knee joints to be used were thawed overnight and regularly hydrated with normal saline throughout the procedure. An extended lateral parapatellar arthrotomy was performed on each specimen, and the electroresistive pressure sensor (Tekscan, South Boston, Mass) was secured in place on the trochlea using staples following the technique of Beck et al.[2] The arthrotomy was closed with suture. Each femur was clamped to the testing station. The quadriceps was loaded by 2 No. 5 Ethibond sutures (Ethicon, Somerville, NJ) through the tendon proximally and connected to a rope, which ran over a pulley in line with the shaft of the femur. Each knee was cycled through a full range of motion and then tested at varying degrees of flexion (0°, 30°, 60°, 90°, and 105°) at 89.1 N and 178.2 N, before and after SA TT osteotomy. The center of force, total contact pressure, and peak contact pressures on the trochlea were measured for each specimen. Statistical analysis was performed using a paired Student *t* test with significance set at $P < .05$. Error bars were calculated using the standard error of the mean.

OSTEOTOMY TECHNIQUE

Straight Anteriorization TT Osteotomy

The posterior cortex of the tibia and the margins of the TT were the reference points for the saw cuts. At the medial border of the patellar tendon insertion on the TT, a straight anterior-to-posterior saw cut was made in line with the long axis of the tibia. The cut was made to but not through the posterior cortex of the tibia and extended 10 cm distally (Figure 1). The lateral aspect of the proximal tibia was exposed, and the proximal transverse (lateral to medial) cut was made from the proximal aspect of the tuberosity, angling distally at approximately a 45° angle and perpendicular to the long axis of the tibia. A posterior longitudinal lateral-to-medial cut was made in the coronal plane, paralleling the posterior cortex and intersecting with the medial anterior-to-posterior cut. The osteotomy was completed by making the distal cut 10 cm below the proximal aspect of the tubercle. The tubercle was then rotated anteriorly 1 cm, measured at the proximal medial border of the tubercle, keeping the distal margin flush with the anterior surface of the tibia. The osteotomy was stabilized with two 4.5-mm standard cortical screws placed lateral to medial using a standard lag screw technique.

Technology

We used an electroresistive sensor with Mylar conductive paint for this study (K-Scan #4000, Tekscan). The sensor pads were each 28 × 33 mm in size, for a total of 56 × 33 mm of surface area coverage on the trochlea. The sensor pads are 0.1 mm thick with 63 sensels/cm^2 (the electroresistive sensing unit) and a resolution of 1.25 mm^2. The sensels calculate pressure by measuring the change in resistance, which is inversely proportional to the applied pressure. The software package used in this study records a virtual "movie" of the displayed pressure distributions on the trochlea over a 10-second duration. From this, total contact area and force can be averaged and displayed (Figure 2). The center of force was calculated as the weighted average, or centroid, of the entire pressure map. The mean forces and pressures were found by creating 2 boxes, 1 on each sensor where the main contact areas were found. The peak force and pressure were calculated for each box, and the highest value was reported for each specimen movie.

Before use, each pressure sensor was preconditioned and calibrated individually on a servo-hydraulic testing machine (Dartec 9690, Dartec Test Systems, Stourbridge, United Kingdom) according to the manufacturer's recommendations. Preconditioning consisted of loading each sensor 3 times to a pressure at least 20% higher than that expected. Subsequently, a 2-point calibration was performed by applying 2 loads within the maximum expected pressure values (20% and 80% of expected values). Calibration values corresponding to each sensor were calculated and loaded into the software before each test.