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Tibial tubercle osteotomy: A biomechanical comparison of two techniques☆

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ABSTRACT

Purpose: The purpose of this study was to determine whether a modified step-cut tibial tubercle osteotomy (Maquet–Fulkerson hybrid) might produce comparable or better results than a standard oblique anteromedialization tibial tubercle osteotomy (Fulkerson type) and thus warrant the surgical need for additional cuts.
Methods: Six pairs of cadaveric knees were evaluated prior to and after tibial tubercle osteotomies. Simulation was done via a shallow knee bend simulator through 20 to 70° of knee flexion for the intact specimens and following the surgical procedures. The variables tested were trochlear contact forces and pressures and patellar motion.
Results: Testing showed a decreased force ($P = 0.027$), peak contact pressure ($P = 0.01$) and contact area ($P = 0.034$) on the lateral trochlea of the femur for both types of osteotomies. There was no significant difference in the lateral femoral peak pressure or in the medial femoral peak pressure between the oblique cut and the step-cut. Also, there was no difference in patellar motion after either procedure.
Conclusion: We conclude that both osteotomies decrease lateral patellofemoral trochlear pressure. The oblique osteotomy may decrease lateral pressure to a greater extent. Regarding biomechanical testing, there was no demonstrable advantage to performing a step-cut osteotomy.

1. Introduction

Patellofemoral joint disorders can be difficult problems to treat. These issues usually occur in adolescents or young adults. Complaints arise from a multitude of conditions including patellofemoral instability and malalignment, patellar and trochlear focal chondral lesions, or patellofemoral arthritis. History has shown that nonoperative measures are the mainstay of treatment with reasonably good clinical outcomes [1,2]. However, there are subsets of these patients that fail conservative means. For example, the recurrence rate of patellar instability after nonoperative treatment ranges from 15% to 44% [3]. Anteromedialization of the tibial tubercle has been shown to be an effective treatment for both patellofemoral instability and degenerative conditions [4]. A variety of osteotomies have been described to produce specific effects on the patellofemoral joint. For instance, a flat osteotomy described by Elmslie–Trillat produces pure medialization of the tibial tubercle to address isolated patellofemoral instability [5]. Maquet advocated a straight anteriorization osteotomy to unload the patellofemoral joint for alleviation of pain from degenerative disease [6]. An anteromedialization oblique osteotomy was later described by Fulkerson as a modification of both procedures to address instability and patellofemoral degenerative disease [4]. A combination of the osteotomies by Maquet and Fulkerson is a step-cut osteotomy

☆ IRB approval was not required for this cadaver biomechanical study. Our lower extremity lab has institutional biosafety approval for cadaver testing.
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that may allow for increased anteriorization and thus have more potential for greater overall correction. However, due to requiring multiple angular cuts, it can be technically more difficult.

Several studies have compared distinct osteotomy techniques with a variety of biomechanical outcomes [7,8]. To our knowledge, this modified step-cut osteotomy has not been compared in the literature to more standard procedures, like that described by Fulkerson.

The purpose of this study was to determine whether the modified step-cut osteotomy would produce comparable or better results than the oblique osteotomy and thus warrant the surgical need for additional cuts. We hypothesize that the modified step-cut osteotomy will yield better or equal results in regard to patellofemoral contact pressure and patellar translation when compared to the oblique osteotomy.

2. Materials and methods

2.1. Specimens and testing setup

Six pairs of fresh frozen cadaver knees (average age, 72 years; six males) were dissected and tested using a muscle activated knee simulator [9] based on an MTS load frame (MTS, Eden Prairie, MN). This test rig caused knee motion while allowing hip and ankle motion as forces were applied to the quadriceps and hamstring tendons. An intramedullary nail was cemented into the midshaft of each femur and attached to a set of bearings functioning as a mechanical hip joint (Figure 1). The attachment to the hip joint could be varied to position the femur so that the tibia was vertical when the knee was in full extension. The attachment unit supported a loading cage that contained the quadriceps and hamstring actuators and moved with the femur. The quadriceps tendon was split anterior/posteriorly to maximize contact with a clamp that was connected in series with a load cell and associated hydraulic actuator. The line of action of the quadriceps was adjusted so that it was parallel to the long axis of the midshaft of the femur. The biceps femoris, gracilis and semitendinosus tendons were each isolated and attached to their own clamps. Hamstring loading was distributed to have 50% of the hamstring force applied to the biceps femoris and 25% to each of the others. The location of the loading cage supporting the quadriceps and hamstrings actuators was selected relative to the femur to counterbalance its weight during knee flexion. The MTS vertical actuator supported the hip joint and was stabilized by a supplementary set of linear bearings to prevent shear forces acting on the MTS actuator and its corresponding load cell. Knee flexion/extension was caused by vertical motion of the MTS actuator while quadriceps and hamstring forces were applied.

The system design could allow or cause tibial rotation by a torsional actuator beneath the tibial pot. Tibial rotation was measured within the torsional actuator and tibial torque measured by a load cell. In this study, we chose to have free tibial rotation by using zero torque as a torque feedback to the torsional actuator. Beneath the torsional actuator was a simulated ankle joint that allowed ankle flexion/extension and ab/adduction.

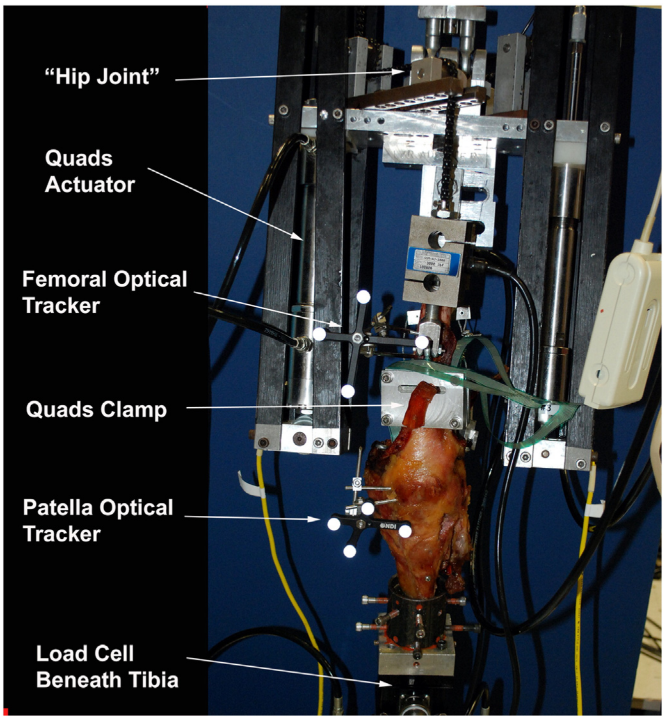

Figure 1. Muscle activated knee simulator.

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