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Original article

Biomechanical assessment of an alternative method of staple fixation for anchoring the Bone Patellar Tendon Bone graft to the tibia

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ABSTRACT

Introduction: The Anterior cruciate ligament (ACL) is the most commonly injured ligament around the knee and is best reconstructed with a biological graft. For ideal graft fixation, there should be sufficient initial strength to avoid failure of fixation and sufficient stiffness to restore the stability of the knee and to avoid gradual loosening in the post-operative period.

When considering fixation of Bone Patellar Tendon Bone (BPTB) grafts to the tibia, the interference screw is considered to be the gold standard. As an alternative, we have used of staples and stainless steel (SS) wire to anchor the BPTB graft to the tibia and femur. The aim of this study was to assess the biomechanical efficacy of this fixation technique for anchoring the BPTB graft to the proximal tibia. We used a bovine model to compare three fixation techniques –interference screw, braided polyester sutures tied to a screw post and SS wire tied to a staple.

Materials and methods: Fifteen fresh bovine knees specimens were used for the study. The patella was fixed to a load cell and the construct was pre-tensioned to 40N to allow for creep of the tendon. The BPTB graft was fixed to the tibia using the three fixation techniques – the interference screw, polyester suture tied to a post, and SS wire anchored to a staple. After fixation, the graft was subjected to a single load to failure test, and the forces generated were recorded. The ultimate failure load (the pullout strength), stiffness, and mode of failure were noted.

Results: In the single load-to-failure biomechanical testing, *the ultimate failure load* and *stiffness* for Staple with SS wire were 726.40N and 61.9N/mm respectively. For the screw post and polyester suture, it was 733.20N and 53.22N/mm, and for Interference screw – 594.00N and 79.50 N/mm respectively. There was no statistically significant difference in the stiffness or ultimate failure load between the three fixation techniques. The graft fixation using interference screws failed at the bone- tunnel interface by slippage of the bone block from the tunnel in all 5 specimens. In all 5 of the specimens fixed with polyester suture and the screw post, the fixation failed when the polyester suture snapped. When the SS wire and staple construct was stressed, the graft failed as the SS wire cut through the graft in 4 specimens, and in the fifth construct, the knot over the staple unraveled as the load was applied.

Conclusion: The biomechanical properties of BPTB graft fixation with SS wire tied to a staple is similar to that of other fixation devices like the interference screw and suture post. This technique provides a simple, yet effective fixation for the graft – but needs further clinical assessment.

1. Introduction

Anterior cruciate ligament (ACL) injury is the most common ligament injury around the knee joint.[1] Reconstruction with a biological graft is the preferred treatment for rupture of the ACL. For an ideal graft fixation, there should be sufficient initial strength to avoid failure of fixation (i.e. high *pullout strength* or *ultimate failure load* of graft fixation), and sufficient *stiffness* to restore the stability of the knee to avoid gradual loosening in the early post-operative period.[2]

When considering fixation of Bone Patellar Tendon Bone (BPTB) grafts to the tibia, the interference screw is considered to be the gold standard for graft fixation.[3] Though, the interference screw provides good fixation strength, it has its own drawbacks like graft laceration and need for hardware removal.[4] It also has it's

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limitations in revision surgeries and in patients with poor proximal tibial bone stock.[5] As an alternative to the interference screw, we have used staples and stainless steel (SS) wire to anchor the BPTB graft to the tibia and femur. The graft is prepared by passing a 20G SS wire through the patellar and tibial bony ends of the graft. The BPTB graft is then passed through the bony tunnels made in the femur and the tibia and the SS wires at the two ends are tightened over staples placed perpendicular to the bony surface at the tunnel exit. In this technique, the staple is not used to fix the graft to the bone, but serves as a post for tensioning the graft. While similar to the suture post fixation technique, the SS wire has better stiffness and is biologically more inert than the suture material. This technique is simple, less expensive, technically less exacting, and posterior blow out of the femoral tunnel does not impede fixation. The aim of the study was to assess the biomechanical efficacy of this fixation technique in anchoring the BPTB graft.

2. Materials and methods

Fifteen fresh bovine knees were obtained from a local abattoir. The soft tissues and menisci were dissected off the tibia and the femur and discarded. The patella and the patellar tendon were left attached to the tibia. The bone mineral density of the proximal tibia was assessed using the DEXA scan. Only tibiae with trabecular bone density greater than 0.8gm/cm^3 were selected.[6] After the DEXA scan was performed, the ACL graft was harvested from the mid portion of the patellar tendon (10 mm in width), with a 30 mm x 10 mm quadrilateral bone plug from the bovine tibia. The patella was left intact and not fashioned into a bone plug. It served as a fixation point for the load cell.

2.1. Tibial specimen preparation

A 10 mm diameter bone tunnel was drilled from the tibial ACL insertion, directed inferiorly and antero-medially, in an inside out fashion. The tibia was mounted on the testing apparatus and fixed using a modified vice grip and further stabilized by two 3.5 mm cross pins that were passed through the vice grip into the tibial specimen.

2.2. Patellar tendon graft preparation

A 7 mm hole was made in the patella –to serve as a fixation point to the load cell. The 30 × 10 mm tibial bone plug was then prepared for fixation with the different techniques. Two 2 mm holes were drilled in the bone block. The proximal hole was placed 1 cm from the bone tendon junction and the second hole was 1 cm from the first. The distal hole was used to pass a stay suture (No.5 polyester) that served to pretension the graft at 40N. The proximal hole was used for fixation of the graft with either a 20 gauge SS wire or a 5′ethibond suture as explained below (Fig. 1).

2.3. Testing apparatus

The tibial portion of the graft was passed through the 10 mm tunnel in the tibia. A 7 mm thick 'S' shaped hook was passed through the patellar end of the graft, and attached to the load cell. The load cell – a standard cantilever load cell with a maximum sensing load of 1000N – was mounted on the mobile carriage of a lathe and could be moved at a constant rate of 1.6 mm/s (Fig. 2a). The load cell was connected to the bridge amplifier and the output recorded on a digital storage oscilloscope. The polyester stay suture attached to the distal tibial bone plug was fixed to a post and the graft was preloaded to 40N. This was done by moving the load cell mounted carriage mechanically, to stretch the tendon. After a period of 15 min to allow for "creep" of the graft, the specimen was reloaded to 40N before starting the experiment. A schematic of the experimental arrangement is shown in Fig. 2b.

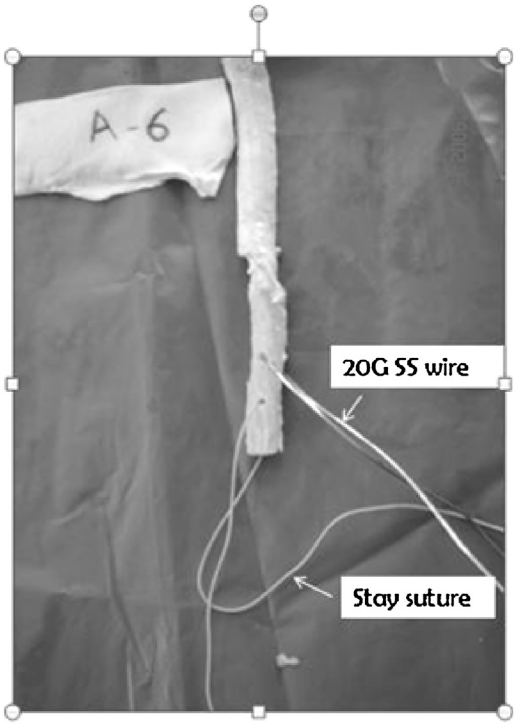

Fig. 1. Fixation technique-SS Wire to Staple: A 20G SS wire is passed through the bone plug 1 cm from tendon bone junction. The stay suture is used to pretension the graft at 40N.

2.4. Graft fixation

The tibial bone plug was then fixed to the tibia by means of three different fixation techniques i.e. interference screw, No.5 Ethibond tied to a screw fixation post and using SS wire fixed to a staple (Fig. 3).

- Interference screw fixation: A 9 × 30 mm softsilk titanium interference screw (Smith and nephew, London, UK), was inserted over a guide wire placed parallel to the graft in the tibial tunnel until the end of the screw was flush with the end of the bone block. While inserting the screw, the changes in the graft tension were recorded.
- Polyester suture (No.5′Ethibond) to screw fixation post: Two No.5′Ethibond sutures were passed through the tibial bone plug, and were used to secure the graft to a screw fixation post (55 × 6.5 mm AO cancellous screw with a 1.5 mm SS washer). The screw was inserted distal to the bone tunnel outlet at 65° to the bone surface, directed distally. The screw was tightened after the No.5′Ethibond was tied to the screw.
- SS Wire to Staple: The 20G SS wire placed in the tibial bone plug was tied to the 20 × 20 mm staple, which was placed distal to the bone tunnel. After knotting the SS wire on to the staple, it was tightened and tensioned using nose pliers.

2.5. Evaluation of pullout strength, stiffness and mode of failure-

After fixation of the graft to the tibia with the fixation device, the stay suture used to pretension the graft was cut, and the graft

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