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The effect of screw taper on interference fit during load to failure at the soft tissue/bone interface

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Abstract

The effect of screw geometry on the pullout strength of an anterior cruciate ligament reconstruction is well documented. The effect of a truly tapered screw has not been previously investigated.

Thirty bovine knees in right and left knee pairs were collected. Superficial digital flexors from the hind legs of sheep were harvested to form a quadruple tendon graft. For each knee pair, one tendon graft was fixed using a tapered screw (n=15) and the other with a non-tapered screw (n=15). Interference screws were manufactured from stainless steel, and apart from the tapered or non-tapered profile were identical. The screws were inserted into a tibial tunnel already containing the tendon graft. The interference fit was tested by extensile load to failure tests. The insertion torque of the screws and first sign of load to failure (by pullout) of the interference fit were recorded. Results were analysed using paired t-tests.

The results indicated that tapered screws have significantly higher resistance to interference failure (p=0.007) and insertion torque (p<0.001) than non-tapered screws.

The improved biomechanical performance of tapered screws demonstrated in this study may translate into superior clinical results, particularly at the tibial attachment of hamstring anterior cruciate ligament reconstruction, and also of hamstring fixation to the medial femoral condyle for patella instability.

Keywords: Cruciate reconstruction; Interference screw; Pullout strength; Insertion torque; Load to failure

1. Introduction

The long term results and relative merits of hamstring and patella tendon grafts for anterior cruciate ligament (ACL) reconstruction are well documented [1–10]. ACL reconstruction failures are typically due to interference failure rather than fixation failure or failure of the screw itself. Any design feature which improves the strength of the interference fit should reduce the number of clinical failures not only of ACL reconstruction, but also of patella stabilisation procedures where interference screws are used to anchor a semitendinosus graft in a bony tunnel in the medial femoral condyle.

It has been shown for hamstring grafts used for ACL reconstruction that fixation is weakest at the tibial tunnel [11]. There are many different types of screw available for hamstring and patella tendon graft fixation, with wide variations in core diameter, thread depth, pitch and taper. Differences in screw geometry, particularly length and diameter can have a significant effect on performance, as has been shown in several studies [12–14]. Tapered screws are associated with higher insertion torque than non-tapered screws, and higher insertion torque has been shown to be predictive of higher ACL graft load to failure resistance [15,16].

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A truly tapered screw has a constant taper along its entire length. However, it is rare for an interference screw to have a true taper as the "tapered" interference screws currently used in clinical practice are only tapered at the tip to facilitate insertion. If tapered screws were associated with increased pullout strength, this may support the use of these screws for ACL reconstruction in humans.

Therefore, the aim of this study was to determine whether screw taper is an important factor affecting both load to failure and insertion torque of interference screws.

2. Materials and methods

2.1. Screw design and manufacture

Tapered and non-tapered screws (Fig. 1) were designed based on commercially available interference screws. The length (30 mm), pitch (2 mm) and thread depth (1 mm) were identical for both non-tapered and tapered screws. The non-tapered screw had an outer diameter of 8 mm. The tapered screw had a consistent taper along the entire length, starting from a diameter of 9 mm and reducing to 7 mm. This gradient along the tapered screw is equivalent to a taper angle of 3.8° along both sides of the screw ($\tan^{-1}2/30$). Screws were manufactured by Austofix (Australian Orthopaedic Fixations Pty, Adelaide, Australia) from 316L surgical grade stainless steel. They were polished in a vibratory machine with ceramic media to round-off sharp edges on the thread profile and produce a standardised surface finish.

2.2. Specimen collection

All bovine specimens were collected from an abattoir. Thirty knees (in pairs) were dissected from bovine carcasses within 30 min of sacrifice. Animals were at least 18 months old. The distal femur and proximal tibia, including the knee joint, were stripped of soft tissue at harvest, wrapped in saline soaked gauze and frozen at −20 °C.

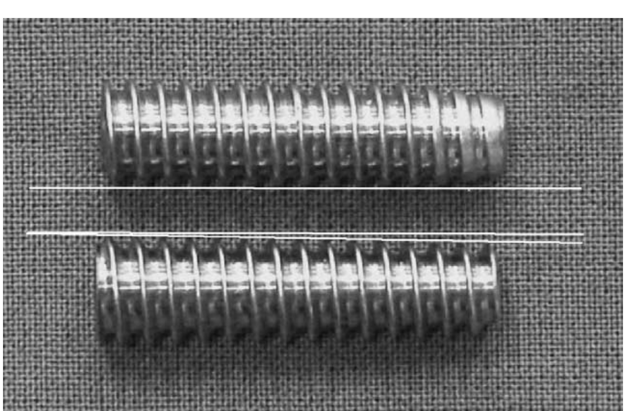

Fig. 1. Photo of the non-tapered (top) and tapered (bottom) screws.

One hundred superficial digital flexor tendons were harvested from the hind limbs of freshly killed sheep using a tendon stripper and stored as above. Only tendons of at least 12 cm in length were accepted.

Before testing, knee pairs and tendons were defrosted overnight. All soft tissue surrounding the knees was removed, leaving the femur–ACL–tibia complex intact. Knees and tendons were then placed and subsequently tested in a 0.9% saline bath at 37 °C.

All 15 knee pairs underwent distraction testing of the intact bovine ACL followed by load to failure tests of the ovine tendons fixed by a tapered or non-tapered screw in a bovine tibial tunnel. Knees were randomised in pairs to receive either the non-tapered or tapered screw to anchor the ovine tendon graft in the bovine tibial tunnel. The knees were harvested in pairs so that each sided knee would act as a control for the other side to reduce any effect of differences in bone density between non-paired knees.

2.3. Intact ACL failure strength

All biomechanical testing was conducted in an Instron model 8511 servo-hydraulic materials testing machine (Instron, High Wycombe, UK). To measure the failure strength of the intact ACL an apparatus was manufactured from stainless steel to allow rigid fixation of the distal femur and proximal tibia. A ball joint was fixed distally between the load cell and the tibial mounting cup and a horizontal x–y bearing table was placed proximally between the femoral cup and actuator to remove all shear forces and allow the ligament to self align along its long axis (Fig. 2). Each bone was fixed to the apparatus using transfixing pins and set screws. The construct was preconditioned with loads of 10–110 N applied sinusoidally at 0.1 Hz over 20 cycles. The intact bovine knee was then tested to failure at a distraction rate of 20 mm/min. Load and displacement data were recorded on a personal computer and the mode of failure determined by visual inspection. The distraction of the intact bovine ACL would provide additional confirmation that there was no difference between the right and left knee pairs.

2.4. Preparation of ACL reconstruction and measurement of screw insertion torque

After the intact ACL failure tests, tendon reconstructions were performed on the proximal tibia. Tendons were combined in pairs to give a graft diameter of 7 mm, measured using an Arthrex graft sizer (Arthrex, Naples, FL, USA), and whip-stitched using 0/vicryl (Ethicon, Piscataway, NJ, USA).

The entry point for the tibial tunnel was stripped of periosteum to allow graft and screw insertion. A natural depression adjacent to the tibial tubercle in bovine knees was used for the entry point. An Arthrex tibial tunnel jig was set to allow the exit point to be on the intercondylar