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Screw oversizing for anterior cruciate ligament graft fixation in primary and enlarged tibial tunnels: A biomechanical study in a porcine model☆

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ABSTRACT

Background: Ideal diameter for tibial interference screw fixation of the anterior cruciate ligament (ACL) graft remains controversial. Tibial graft fixation with screws matching the tunnel diameter vs. one-millimetre oversized screws were compared.
Methods: In 32 cadaveric porcine tibiae, bovine extensor tendons with a diameter of eight millimetres were fixed in (I) a primary ACL reconstruction scenario with eight-millimetre tibial tunnels (pACL), with eight-millimetre (pACL-8) vs. nine-millimetre (pACL-9) screws, and (II) a revision ACL reconstruction scenario with enlarged tunnels of 10 mm (rACL), with 10-mm (rACL-10) vs. 11-mm (rACL-11) screws. Specimens underwent cyclic loading with low and high load magnitudes followed by a load-to-failure test. Graft slippage and ultimate failure load were recorded.
Results: In comparison with matched-sized screws (pACL-8), fixation with oversized screws (pACL-9) showed with significantly increased graft slippage during cyclic loading at higher load magnitudes (1.19 ± 0.23 vs. 1.98 ± 0.67 mm; $P = 0.007$). There were no significant differences between the two screw sizes in the revision scenario (rACL-10 vs. rACL-11; $P = 0.38$). Graft fixation in the revision scenario resulted in significantly increased graft slippage in comparison with fixation in primary tunnels at higher loads (pACL vs. rACL; $P = 0.004$). Pull-out strengths were comparable for both scenarios and all screw sizes ($P > 0.316$).
Conclusions: Matched-sized interference screws provided better ACL graft fixation in comparison with an oversized screw diameter. In revision cases, the fixation strength of interference screws in enlarged tunnels was inferior to the fixation strength in primary tunnels.

1. Introduction

Secure graft fixation is essential in the early period of rehabilitation after anterior cruciate ligament (ACL) reconstruction. The tibial fixation site represents the mechanically weakest point, due to the reduced bone mineral density (BMD) at the tibial metaphysis [1]. Interference screw fixation is one of the most common fixation techniques for soft-tissue grafts.

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Initial graft fixation with interference screws is influenced by several factors, such as BMD at the proximal tibia, the ratio of the graft and tunnel diameters, and screw-related factors such as screw length, insertion angle, and diameter [1–7]. There is clear evidence that a higher BMD, a longer screw, and screw insertion parallel to the axis of the tibial tunnel improve fixation strength [2, 4–9]. However, the ideal screw diameter for ACL graft fixation at the tibial tunnel still continues to be a matter of controversy.

Graft slippage at the tibial screw fixation site represents one of the major risks for graft laxity and reconstruction failure during the early postoperative phase [10–13] and it may therefore be a clinically more relevant parameter than pull-out forces alone. The results of the few previous studies investigating graft slippage during cyclic loading for oversized screw diameters remain controversial [12, 13].

Enlarged tibial tunnels are often present in revision ACL reconstructions, and a single-stage reconstruction using soft-tissue grafts has been described, with a tibial tunnel diameter of up to 10 mm [14]. Concerns were raised about the initial fixation strength using interference screws in enlarged tibial tunnels. Many surgeons therefore regard this as an indication for using oversized screw diameters [14].

The aim of the present study was to investigate the effect of one-millimetre screw oversizing on graft slippage during cyclic loading and pull-out strength in a primary ACL reconstruction scenario and also in a revision scenario. It was hypothesised that larger screw diameters reduce the amount of graft slippage and result in higher ultimate failure loads. It was further hypothesised that screw fixation strength would be higher in primary tunnels in comparison with enlarged tibial tunnels in a revision reconstruction scenario.

2. Materials and methods

2.1. Specimen preparation

The study used 32 fresh-frozen porcine tibiae (16 pairs from skeletally mature animals aged six to nine months) and tendon grafts from bovine digital extensor tendons obtained from a local slaughterhouse. Eight matched pairs of tibiae and tendons were used for each of the primary ACL (pACL) and revision ACL (rACL) scenarios. The porcine model was used because it has been reported to approximate the BMD and biomechanical properties of young human bone [4, 7, 15–17], and bovine extensor digitorum communis tendons are reported to have structural and viscoelastic properties similar to those of human hamstring tendons [18, 19].

The specimens were stored at −20 °C and thawed at room temperature for two hours (tendon grafts) and 12 h (tibiae), respectively, before preparation. All specimens underwent one freeze–thaw cycle prior to experimental testing. The tibiae were isolated, and the skin and soft tissues were removed. For graft preparation, the tendons were trimmed in line with the fibre orientation to achieve a doubled graft, adjusted to a diameter of eight millimetres with a graft-sizing block. The tendons were cut to a single-stranded length of 170 mm in order to achieve a folded graft length of approximately 85 mm. At each end, 35 mm was split in order to create an intratunnel four-stranded graft, and 30 mm of the four strands were whip-stitched using high-strength suture material (Ethibond Excel No. 2; Ethicon/Johnson & Johnson International, Vienna, Austria). Grafts with diameters larger or smaller than eight millimetres were excluded. The tendons were kept moist with physiological saline solution during the entire preparation and testing process.

2.2. Tibial tunnel preparation

The tibial tunnel was created at the ACL footprint using a tibial drill guide, set at an angle of 55°. The drill guide was positioned at the anteromedial aspect of the tibia, measuring 40 mm of intraosseous length on the drill sleeve. A full eight-millimetre (pACL) or 10-mm tunnel (rACL) was drilled using a cannulated drill. The graft was pulled through the tibial tunnel from distal to proximal, leaving a graft length of 35 mm in the tunnel. Graft rotation was kept constant in order to have one anterior and one posterior free graft strand outside the tibial tunnel.

2.3. Interference screw insertion

Tibial graft fixation was performed with biodegradable interference screws 30 mm in length and with variable diameters (Milagro; DePuy Synthes, Raynham, Massachusetts) according to the allocated study group (pACL-8, pACL-9, rACL-10, rACL-11).

For screw insertion, the femoral graft end was provisionally fixed while the graft was distally tensioned in line with the tunnel at 70 N using a force gauge. A nitinol guide wire was inserted eccentrically into the tibial tunnel posterior to the graft. The biodegradable interference screw was inserted over the guide wire until the screw tip was flush with the articular tunnel aperture [7]. The screw position was controlled by visual inspection.

2.4. Biomechanical testing

Graft slippage and ultimate failure load were studied in eight-millimetre (pACL) and 10-mm (rACL) tunnel apertures with matched and one-millimetre oversized interference screws, using a cyclic loading protocol followed by a load-to-failure test. The ultimate failure load may be crucial in a catastrophic postoperative event such as a fall, whereas cyclic loading occurs during everyday early postoperative rehabilitation and mobilisation of the patient [20]. Graft slippage during cyclic loading was therefore considered to be the parameter of greater clinical relevance and was defined as the main outcome parameter in this study.

The tibiae were fixed into a customised jig, and the graft was fixed to the actuator of a servohydraulic material testing machine (MTS Mini-Bionix 858; MTS, Eden Prairie, Minnesota) looped over a five-millimetre stainless-steel rod. The tensile force applied to

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