Press-fit strength of osteochondral mosaicplasty.

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INTRODUCTION
Mosaicplasty (MP) is a popular surgical procedure for the repair of focal osteochondral lesions. In this procedure, one or more cylindrical osteochondral autografts are press-fit into pre-drilled holes in the articular surface in order to achieve primary graft fixation. This technique has also been used successfully to reattach loose osteochondritis dissecans fragments and may be a suitable method of providing primary fixation and initial load bearing capacity for bio-engineered cartilage tissue. In these applications, the short-term load bearing capacity of single osteochondral grafts may be critical to success of the procedure.

Successful MP exhibits long-term graft fixation capable of full weight bearing as cancellous bone of the donor graft integrates with that of the recipient site\textsuperscript{1}. Short-term fixation strength has not been quantified. Based on the healing response of compressed cancellous bone fractures\textsuperscript{2}, minimum load bearing capacity is expected to occur approximately one week post-surgery. The purpose of this study was to develop a protocol to quantify the graft’s press-fit strength, and to apply this experimental model to examine the change in graft load bearing capacity immediately after and one week following the procedure.

METHODS
The hind legs of five female six-month old pigs, each weighing 90-115 kg, were obtained from a local abattoir. Femoral condyles were exposed and the MP technique performed within one-and-a-half hours of animal sacrifice using the Soft Delivery System™ (Sulzer Orthopedics Ltd., Ch-6341 Barr, Switzerland). Femoral condyles from one leg were separated into four specimens, each containing an osteochondral autograft, and incubated in culture media (DMEM Ham’s F12, pH 7.4, 10% newborn calf serum, 0.02% penicillin/streptomycin) for one week prior to mechanical testing. Specimens matched for location in the contralateral leg underwent immediate mechanical testing. Due to the direct relationship between elastic modulus and press-fit pressure, modulus was selected to assess changes in biomechanical tissue properties over the seven-day incubation period in culture media. All mechanical tests were performed on an electromechanical materials tester (model 1122, Instron, Canton, MA, USA) at a crosshead speed of 2 mm/min, low enough to avoid hydraulic stiffening due to marrow entrainment (Nakabayashi et al., 1994). Press-fit strength and cancellous bone modulus were analyzed using a 2-way repeated measures ANOVA. All factors were balanced for left versus right leg and matched for spatial location within the knee.

Specimens assigned to pull-out tests had a φ2.2 mm core drilled along the long axis of the graft for insertion of a threaded Steinmann pin (minor φ=2.2 mm, major φ=2.6 mm). The Steinmann pin was aligned with a reference axis consisting of a plumb line and a line level on a horizontal wire, and tension exerted on the pin to apply the pull-out load. Specimens assigned to push-in tests were aligned with the reference axis using a Kirchener wire inserted into the guide hole in the graft. Following removal of the Kirchener wire, a φ5.6 mm oval-tipped cylindrical indentor was lowered onto the graft’s cartilage surface to apply the push-in load. Press-fit strength for both pull-out and push-in tests was determined to be the load at which the graft failed as indicated by a sudden drop in the load-displacement curve. Visual inspection of depth markers on each Steinmann pin and of graft movement within the recipient site confirmed that failure occurred at the press-fit interface.

RESULTS

Average press-fit strength, as determined by both push-in and pull-out tests, decreased 44% (F1=37.22, p=0.004) from 135.7 N to 75.5 N over the seven day period following MP (Fig. 1-a). Pull-out strength was generally less than push-in strength (F1=9.52, p=0.037); however, the relative decrease in strength over the seven day period was not statistically different for the pull-out and push-in tests (F1=1.34, p=0.311). No statistical difference in cancellous bone modulus over the seven-day incubation period (F1=2.409, p=0.196) indicated that biomechanical tissue properties remained essentially constant (Fig. 1-b).
**DISCUSSION**

A methodology has been developed to quantify the press-fit strength of osteochondral grafts implanted using the MP technique. Since extremely low frictional forces exist between the articular surfaces of a synovial joint, in-vivo compressive loading creates a principal stress normal to the articular surface. The push-in tests within the current protocol applied a normal load directly to the cartilage surface of the graft using an oval-tipped indentor aligned and centered on the graft’s long axis. It is believed that these loading conditions reasonably approximate in-vivo loading. Pull-out strength was measured to assess the required force needed to remove a graft during the surgical procedure using a threaded pin. Changes in pull-out strength also provide an indication of the graft’s resistance to outward movement relative to initial fixation strength. In-vivo, negative pressures within the joint capsule and a difference in boundary conditions at the superficial and deep ends of a graft may contribute to outward loads on the graft; however, these are likely insignificant relative to compressive loads that occur during contact with the opposing articular surface.

When MP is performed to repair a focal defect, insertion of adjacent grafts and the resulting recipient site dilation adds to graft stability. The current protocol more closely mimics use of the MP technique for primary fixation of osteochondral fragments or cultured cartilage tissue where graft proximity is not a factor. A relatively larger distance between grafts, thus a lower press-fit pressure, may significantly reduce short-term load bearing capacity and increase the risk of graft movement relative to the receptor site resulting in disruption of the healing response and graft-receptor surface congruency.

The current study evaluated the change in single graft press-fit strength using an in-vitro porcine model. MP graft press-fit strength declined 44% over seven days from the post-operative state. The suspected cause of press-fit strength degradation is a change in the mechanical properties of cancellous bone at the graft-receptor interface due to local cell necrosis likely caused by acute surgical trauma and possibly, press-fit pressure. Modulus measures of cancellous bone reported in this study reflected the macroscopic tissue properties and therefore were not sensitive to microscopic changes occurring local to the graft-receptor interface. Further research is needed to quantify the short-term press-fit strength over the entire recovery period before these results can be applied to the development or evaluation of recovery procedures.

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