SHEAR STRENGTH OF ALLOGRAFT BONE SCREW FIXATION IN SLIPPED CAPITAL FEMORAL EPIPHYSIS

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Introduction: Slipped capital femoral epiphysis (SCFE) is the most common hip disorder affecting adolescent children [1]. The etiology is thought to be multifactorial, related to both biological and biomechanical factors [2]. SCFE occurs when the epiphysis of the proximal femur slips in relation to the metaphysis through the growth plate, causing pain, disability and potential long-term sequelae from joint incongruity. The current standard treatment for SCFE is percutaneous fixation using a single steel screw with the goal of preventing further slipping and obtaining early physeal closure. Bone allograft epiphysiodesis is an alternative treatment method in which a single threaded freeze–dried cortical allograft is placed percutaneously into a drill hole through the cortex, up the femoral neck and into the femoral head [3]. Allograft epiphysiodesis avoids the need for a second surgery to remove the hardware, but has the disadvantage that it cannot achieve stability until the allograft is incorporated into the surrounding bone. We hypothesized that a threaded cortical bone allograft could provide sufficient initial stability to serve as a viable alternative to the steel implant.

The objective of this study was to compare the fixation strength of a single threaded bone allograft versus a single steel screw in an in vitro pig model of SCFE.

Methods: Twelve matched pairs of fresh frozen, immature porcine femurs (age ~ 52 weeks) were stripped of all soft tissue except for the perichondrial ring and kept frozen, related to both biological and surgical towels in sealed packages. At the time of testing each pair was allowed to thaw in a warm water bath for 90 minutes. The femur was placed onto a custom jig for MTS testing and secured with worm drive compression clamps. The undersurface of the proximal femur, lesser trochanter and femoral neck were potted using Bondo-Glass™ fibreglass reinforced polyester to distribute the load evenly across the posterior aspect of the proximal femur, assisting in preventing deformation in a specimen and prevent deformation of the femoral neck during testing. During curing of the potting material the femoral head, perichondrium and exposed proximal femur were wrapped in saline–moistened gauze. The bondo was allowed to harden for 30 minutes, for a total thawing time of ~120 minutes. We used a selection of 25-mm thick double-arched shearing rams, with major arch diameters of 38, 41 or 44 mm. The rig holding the potted femur was mounted onto the base of a Materials Testing System. The shearing ram was placed with its leading surface as close to the physis as possible. An anterior to posterior force was applied parallel to the physis at a rate of 0.03 mm/sec, until failure was achieved. Failure was defined to occur at a 30% decline from maximum load or a total displacement of one-third the physeal diameter. Forces were monitored with a 20,000 N load cell (sensitivity: 2–12 N) and displacement with an optical encoder (sensitivity: 0.1 micrometer). Data were sampled at a rate of 30 Hz.

The mechanically created slips were allowed to spontaneously reduce upon removal of the load. The femurs were randomly assigned to either a steel screw or bone allograft fixation group. The bone screw implant was constructed from bovine cortical bone and specially prepared for us by Regeneration Technologies Inc. (Alachua, Florida). The distal 4-mm of the 9-mm diameter and 35-mm long Cortis™ cortical bone interference HT allograft screws were removed to reduce the taper at the tip. The HT screw has an external square head, buttress-shaped threads and is cannulated for insertion of a 1.5-mm guide wire. The bone screws were obtained frozen in sealed plastic bags and thawed in saline for about 30 minutes before use. A 9-mm diameter Cortis™ ST tap was used to tap the hole under C-arm intensification. The 9-mm ST tap is designed to be used with the 9-mm ST allograft, which has V-shaped threads, but it was a better fit for our less tapered HT screw than the 9-mm HT tap. The reasons for this were that the tapered tip was removed from the screws and the pitch and diameter of the 9-mm ST tap is approximately the same as that of the 9-mm diameter HT screw.

We calculated the differences (changed scores) between the intact pre-slip peak load (maximum load sustained prior to failure) and the post-slip peak load for metal screw fixation and for allograft fixation. A paired Student T-test was used to compare the changed scores.

Results: The means (SD) of the peak loads for 12 intact pairs of femurs were 1,984 N (SD 338) for the left and 1,961 N (SD 310) for the right femurs. There was no difference between left and right sides (p = 0.52, paired Student T-test). The overall mean was 1,973 N (SD 317, range 1,497–2,596). The mean epiphyseal plate area was 12.9 mm² (SD 1, range 11–14.3). The mean antero-posterior epiphyseal plate diameter was 37 mm (SD 1, range 34–39).

After slip, the peak load for the metal screw group was 2,108 N (SD 323) compared with 1,579 N (SD 257) for the allograft screw. Allograft fixation provided 81% of the initial loading at a small Student T-test (p = 0.005) and metal 106% (p = 0.3, power = 0.4). Failure of the allograft group occurred by fracture of the posterior femoral neck and not by screw failure or loosening. Failure in the metal group resulted in deformation of the screw, cutout from the head and posterior femoral neck fracture. The changed score for the metal-fixed peak load was greater (by 480 N) than that for the allograft-fixed peak load (p = 0.003, paired Student T-test).

Discussion: Although the peak load of the allograft screw fixation (1,579 N) was less than that of the standard steel screw, it compares favorably with the peak load sustained by the human capital femoral plate (mean 1,450 N, age 9 to 13 years, [4]). The epiphyseal plate area and strengths of our 1 year old pig specimens were within the range of values reported for human adolescents [4]. Both a bovine and canine model have been used in testing SCFE fixation techniques. However, the proximal femoral physis in the bovine model [5] is considerably stronger in shear (mean 4,500–4,950 N) than that of the human physis. On the other hand, the canine model [6] is smaller and considerably weaker (mean 394 N) than the human physis at the age when SCFE occurs.

Our study has several inherent limitations that need to be considered: Our results are for monotonic loading to failure and do not indicate how the fixation will behave under cyclic loading and single loads. Our failure criterion for the initial creation of slip resulted in complete destruction of the growth plate cartilage while leaving the perichondrium intact, which may not be representative of severe slip. This was an in vitro model so the effects of growth plate closure and eventual screw incorporation by the host bone could not be examined.

Allograft bone fixation of slipped capital femoral epiphysis has several potential advantages over metal screw fixation: The avoidance of another surgery to remove the hardware, the presumed eventual incorporation of the allograft bone into the host bone, the ability to use MRI, the potential for earlier physeal closure and postulated lower risk of avascular necrosis [3]. Our study suggests that allograft bone screw fixation could combine the benefits of the immediate stability achieved with metal screw fixation and the avoidance of additional surgery achieved with bone graft epiphysiodysis.

References:

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