Coronal fractures of the distal femoral condyle: A biomechanical evaluation of four internal fixation constructs

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Summary This study evaluated different fixation methods in posterior femoral condyle coronal fractures. A standardised osteotomy was created in synthetic composite femurs and fixed with one of four methods (one 3.5 mm diameter screw, two 3.5 mm screws, one 6.5 mm screw, two 6.5 mm screws). The stiffness and mean loads to specified displacements were measured. The stiffness of two 6.5 mm screws was significantly greater than both single 3.5 mm screw (3567 versus 2584 N/mm; $p = 0.0075$) and double 3.5 mm screws (3567 versus 2080 N/mm; $p = 0.003$). There was no statistical difference in the stiffness of one 6.5 mm screw compared to either the single or double 3.5 mm screws. Increasing the screw diameter and using two screws increased the load at 1, 2 and 3 mm of displacement. In the fixation of posterior femoral condyle fractures, two 6.5 mm screws are more rigid than either single or double 3.5 mm screws. The use of a second screw marginally increases the rigidity of fixation. If 3.5 mm screws are used in the fixation of posterior femoral condyle fractures, at least two screws should be used to approximate the biomechanical stability of a single 6.5 mm screw.

Introduction

Coronal fractures of the posterior femoral condyle are rare fractures and are eponymously referred to as Hoffa fractures.[5] In one clinical review, only seven cases were reported, and the largest series in the literature appears to consist of twenty fractures.[7,8] There are relatively few recommendations in the literature for fixation of coronal fractures of the posterior femoral condyles. Liebergall et al recommended use of 6.5 mm cancellous screws.[9] Mize suggested that K-wires and absorbable pins are usually not strong enough and recommended use of 4.0 mm cancellous or similar screws.[11] Benirschke and Swiontkowski suggested the use of 3.5 mm cortical lag screws.[2]

The goal in the treatment of articular fractures is to achieve anatomical reduction of the joint surface with stable internal fixation that permits early range of motion in order to restore function. The current trend in the treatment of periarticular fractures is the use of small fragment implants that are lower profile and necessitate less periosteal and soft tissue disruption.[1]

The purpose of this biomechanical study was to evaluate the use of one or two 6.5 mm screws compared to one or two 3.5 mm screws in the fixation of coronal fractures of the posterior femoral condyles.

Materials and methods

Twenty synthetic composite femurs (Pacific Research Laboratories, Vashon Island, WA) designed to simulate the mechanical stiffness of young human femora were used. The synthetic bones were selected to eliminate the broad variability that exists in cadaveric specimens and to better model the stronger bone found in young patients as opposed to the osteoporotic bone of most cadaveric specimens. The specimens were cut in half at the midshaft and the distal femur was potted in a metal mounting fixture using methacrylate with the knee joint positioned horizontal to the mounting jig. A custom fixture was used to create a standardised osteotomy of the posterior aspect of the lateral femoral condyle using a bandsaw.

The fractures were anatomically reduced and held provisionally with a tenaculum. The fractures were secured in lag fashion from anterior to posterior using one of the following four techniques: (1) one 6.5 mm diameter partially threaded cancellous screw, (2) two 6.5 mm diameter partially threaded cancellous screws, (3) one 3.5 mm diameter cortical screw, and (4) two 3.5 mm diameter cortical screws. (Fig. 1) The screw insertion sites and angles were standardised using a custom drill guide. Screws were tightened with a torque wrench to 19 Nm. When a single screw was used its length was 65 mm, when two screws were used the proximal screw was 65 mm in length and the distal screw was 60 mm in length.

The test specimens were mounted in an Instron 1122 materials testing machine, (Instron Corporation, Canton, MA). A compressive force was applied directly to the fracture fragment utilising a stainless steel rod (2.54 cm diameter) at a rate of 20 mm/min. (Fig. 2) Load and displacement data were recorded at 100 Hz. Reported here are load values at 1, 2 and 3 mm of displacement. The slope of the linear region of the load-displacement curve was used to determine the stiffness of each test specimen.

Statistical analysis was done using the StatView statistics package (SAS Institute Inc., Cary NC). An Analysis of Variance (ANOVA) was performed to determine if a significant difference ($p < 0.05$ significant) existed between the four fixation treat-

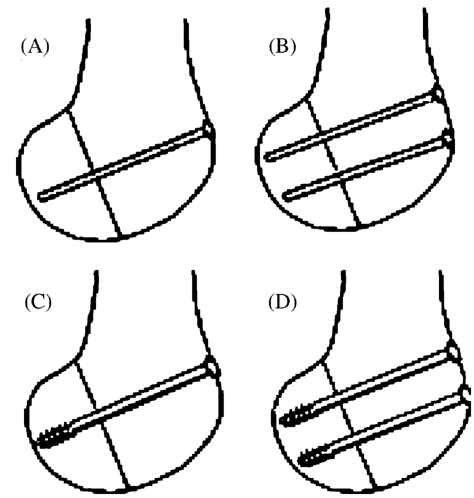

Figure 1 Four fixation constructs studied. (A): Single 3.5 mm diameter cortical screw. (B): Double 3.5 mm diameter screws. (C): Single 6.5 mm diameter partially threaded cancellous screw. (D): Double 6.5 mm diameter partially threaded cancellous screws.

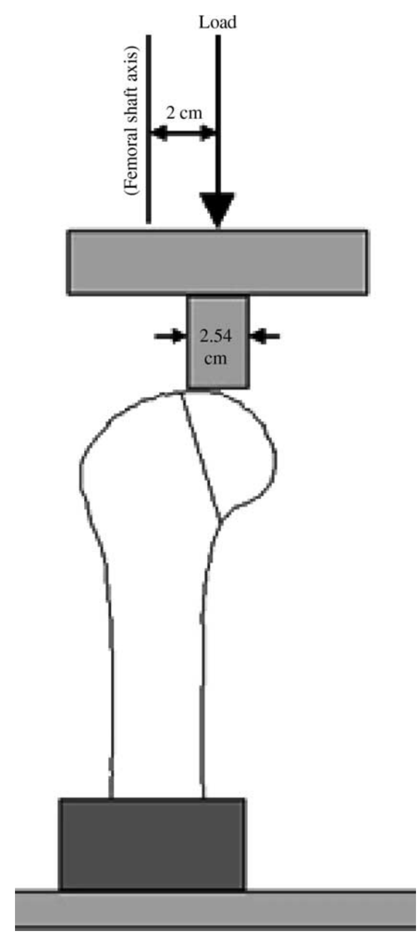

Figure 2 Test set-up.

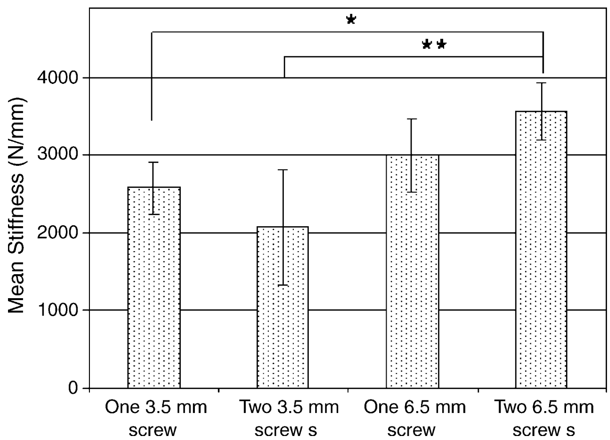

Figure 3 Mean stiffness (N/mm) and standard deviation of four fixation constructs. Significant differences were found between the double 6.5 mm screws and the 3.5 mm screw constructs. (* p = 0.0075, ** p = 0.003).

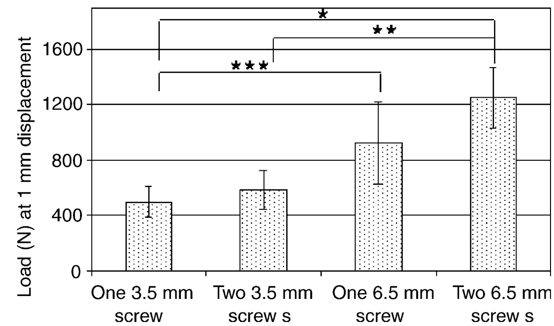

Figure 4 Load (N) and standard deviation at 1 mm of displacement. Significant differences were found between the double 6.5 mm screws and the single and double 3.5 mm screw constructs. Significant difference was also found between the single 6.5 mm screw and the single 3.5 mm screw construct. (* p = <0.001, ** $p < 0.001$, *** p = 0.0045).

ment groups in the load at displacements of 1, 2 and 3 mm. An ANOVA was also used to determine if there was a significant difference ($p < 0.05$ significant) between the mean stiffness of the treatment groups. In both cases, when significant, a Bonferroni-Dunn follow up test was performed to determine which fixation methods were different.

Results

Stiffness

The stiffness of the double 6.5 mm screw construct was significantly greater than both the single 3.5 mm screw (3567 versus 2584 N/mm; p = 0.0075) and the double 3.5 mm screw constructs (3567 N/mm versus 2080 N/mm; p = 0.003). (Fig. 3) There was no statistical difference between the double 6.5 mm screw and the single 6.5 mm screw constructs.

When comparing the single 6.5 mm screw construct to either the single 3.5 mm screw or the double 3.5 mm screw construct there was no significant difference in the mean stiffness. The mean stiffness of the double 3.5 mm screw construct was actually less than the single 3.5 mm screw construct, however the variation in stiffness of the double 3.5 mm screw construct was much greater, and the mean stiffness difference was not statistically significant.

The double 6.5 mm screws recorded significantly greater loads at 1, 2 or 3 mm of displacement compared to both the use of single and double 3.5 mm screws. (Fig. 4) When comparing the single 6.5 mm screw to the use of a single 3.5 mm screw, significantly greater load was recorded at 1, 2 or 3 mm of displacement. When comparing the single 6.5 mm screw to the double 3.5 mm screw construct there was no significant difference in the mean loads at 1 and 2 mm of displacement, and only at 3 mm of displacement was there a significant difference between the mean loads.

Discussion

The mechanism of injury in coronal posterior femoral condyle fractures is usually a high energy injury. Lewis et al postulated that an oblique or lateral force against the lateral condyle with the knee flexed results in the coronal fracture.[8] The importance of the flexed knee position at the time of impact was based on the fact that four of their seven patients reviewed sustained their injury in a motorcycle accident.

Traditional principles of internal fixation have dictated two points of fixation to prevent rotation of a fracture fragment. Recently, some investigators have suggested that fixation with a single compression screw may be sufficient since fracture site interdigitation and compression may be sufficient to prevent fracture fragment rotation.[6] The disadvantage to the use of multiple screws in fixation of Hoffa fractures is that their placement requires additional violation of the articular surface. The use of larger diameter screws also requires greater area violation of the articular surface. Because screws fixing posterior femoral condyle fractures usually have to be placed through an area of articular cartilage, the ideal fixation construct would use the smallest size and number of screws to minimise the damage to the articular cartilage.

Larger diameter screws, in principle, have a larger pullout strength because of their increased outer diameter/inner diameter ratio. Screw pitch also plays a role in pullout force with lower pitch screws, as seen in small diameter cortical screws, offering greater pullout force.[3] A potential advantage of smaller diameter screws is that more screws can be placed in a given fracture fragment. However, screw pullout strength is only one of many important variables relating to stable fixation of most fractures.

Construct rigidity is one of the most important mechanical factors following internal fixation. An internal fixation construct with low stiffness may produce large shear strain at the fracture site, disrupting osteogenesis and promoting nonunion.[4,10] While we examined the effect of a direct shear load, posterior condyle fractures may be exposed to various forces during early knee range of motion. The optimal stiffness required of an internal fixation construct for posterior femoral condyles is not known. One previous study has suggested that 3.5 mm screws may be sufficient to fix small periarticular fracture fragments without compromising their pullout strength.[12]

We did not test the strength of implant fixation to failure because it would not provide an accurate value of the fixation strength, rather it would reflect the strength of the cortical bone as the screws angulate and engage the posterior femoral cortex. Because of the importance of articular congruity, displacements in the range measured would be considered a clinical failure of fixation.

In the present study we examined both the fixation stiffness and the load at 1, 2 and 3 mm of displacement. Our biomechanical data indicates that double 6.5 mm screws are significantly more rigid than single or double 3.5 mm screw constructs. The double 6.5 mm screws recorded significantly greater loads at 1, 2 and 3 mm of displacement compared to both the use of single and double 3.5 mm screws. When comparing the single 6.5 mm screw to the use of a single 3.5 mm screw, significantly greater load was recorded at 1, 2 and 3 mm of displacement. However, when comparing the single 6.5 mm screw to the double 3.5 mm screw construct there was no significant difference in the mean loads at 1 and 2 mm of displacement, and only at 3 mm of displacement was there a significant difference between the mean loads. If 3.5 mm screws are used in the fixation of posterior femoral condyle fractures, at least two screws should be used to approximate the biomechanical stability of a single 6.5 mm screw.

Acknowledgement

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