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Stability of Talar Neck Fracture Fixation: A Biomechanical Comparison of 4.0 Cannulated Headed Screws and Conical Headless Screws

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Stability of Talar Neck Fracture Fixation: A Biomechanical Comparison of 4.0 Cannulated Headed Screws and Conical Headless Screws

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Abstract

Objective: The purpose of this study was to compare the mechanical stability of cannulated conical variable pitch headless (CH) screws to partially threaded 4.0 cannulated (4.0 C) screws for fixation of talar neck fractures.

Methods: A controlled talar neck fracture was produced in 24 sawbone tali. The fractures were stabilized with CH screws in 12 tali and with 4.0 C screws in 12 tali. A Mechanical Testing System machine was used to apply a dorsally-directed shear force to the talar head with the talus body fixed to simulate walking and the clinical mode of failure of talar neck fracture fixation. Stiffness of the fixation devices was calculated for each specimen and the groups statistically compared. The results were confirmed in 10 cadaveric bone specimen.

Results: The fixation of talar neck fractures by the CH screws was significantly stiffer than the 4-0 C screw (mean 635 N and 335 N, respectively, $P < 0.05$).

Conclusions: The results of this study support the clinical use of the cannulated conical headless variable pitch screw for talar neck fracture fixation. The improved fixation of this device is likely to decrease the incidence of fixation failure and poor clinical results due to malunion, nonunion, and stiffness. The CH can be placed using the same surgical exposure and ease of a 4.0 C screw, while eliminating the problem of screw head prominence.

Key Words: talar neck fracture, fixation strength

INTRODUCTION

Fractures of the talus are the second most common injury of the tarsal bones and neck fractures account for approximately 50% of all talar fractures[3]. Fixation of the fracture with screws is the typical treatment and results are generally reported to be favorable. However, there are a variety of problems with screw fixation, and failure of fixation compromises the expected clinical outcome.

The 4.0 cannulated (4.0 C), partially threaded screw is the most commonly used device for fixation of these fractures. This device is implanted using an anterior-to-posterior (retrograde from the dorsum of the talar head across the fractured neck into the talar body) approach which allows adequate visualization of the fracture site and control of the distal fragment for reduction[6]. Screw placement through the distal fragment dorsal cortex is usually possible and compression with stable fixation can be achieved. However, the obliquity of this screw can cause cortical comminution rather than fracture compression when the screw is tightened[7]. Fixation and clinical outcome are compromised if comminution occurs intraoperatively or fixation is lost.

A variety of alternatives have been suggested to overcome this anatomic problem. The point of entrance from the dorsal cortex of the talar head to the articular surface of the talar head may be altered so the screw is collinear to the longitudinal axis of the talar neck. This requires exposure of the joint surface of the talar head by dislocation or forced subluxation of the talo-navicular joint as well as countersinking of the screw head beneath the articular surface to the talar head. Fixation is typically secure but there is considerable damage to the talo-navicular joint by this approach with concern for stiffness and degenerative changes.

Alternatively, the screw may be inserted using a posterior-to-anterior approach. This technique has associated benefits and drawbacks. A posterior-to-anterior approach through the talus provides stronger fixation compared to an anterior-to-posterior approach[10]. However, this approach is technically more difficult due to neurovascular structures, including the sural nerve and unfamiliarity to most surgeons. There is a limited surface of posterior cortex available for screw insertion and the screw head can impinge upon the ankle or subtalar joint. Further, there is no direct exposure of the fracture site for reduction.

A third option is a new fixation screw that is a conical threaded headless variable pitch screw (CH). This screw is placed in the same manner as the standard 4.0 cannulated but does not depend upon cortical contact for fixation in the distal fragment. Fixation is achieved in the cancellous bone of the talar head and body by the conical cross section of the screw. There are aspects of the CH screw that may provide optimal strength for reduction and fixation of talar neck fractures. The CH screw has a headless, tapered, fully threaded variable pitch design and is fabricated from a titanium alloy. The CH screw has a shaft that is threaded along its entire length and thread pitch that continuously becomes coarser toward the distal aspect of the screw to achieve compression at the fracture site during insertion[12]. The headless feature decreases the problem of cortical cracking and eliminates head prominence as a problem. The screw can be inserted through the surgically accessible dorsal cortex but is not dependent upon this oblique cortex for fixation in contrast to the 4.0 cannulated screw. Headless screws may be effectively placed extra-articularly, avoiding the problems of surgical injury to the talo-navicular joint.

In previous research comparing compression strength and fixation of various fixation screws it has been reported that CH screws outperformed other models[12]. The CH and 4.0 C screws produced comparable fragment compression in both types of specimens while CH and 4.0 C screw compression were significantly greater than that of the Herbert screw. However, CH screws maintained compression after cyclic loading (500 cycles) significantly better than 4.0 C and Herbert screws. The push-out force of CH and 4.0 C screws were significantly greater than that of the Herbert screw in both types of specimens. The torque required to break fragment contact was significantly higher for the CH than for the 4.0C screws or Herbert screws[12]. These experimental results raised the question as to whether the CH screw could be used in talar neck fracture fixation, allowing an anterior-to-posterior surgical approach and provide compression and fixation sufficient to withstand normal, anticipated stress loads of everyday activities like walking. In the experiment conducted by Wheeler et al, a series of mechanical tests on cancellous bone and cancellous bonelike foam specimens were conducted to evaluate and compare a CH compression screw with a 4-mm cancellous screw and a Herbert screw.

The purpose of this study to examine the relative stability of CH screws and 4.0 C screws for the fixation of talar neck fractures. We hypothesized that CH screws used in fixation of talar neck fractures would provide improved stability compared to 4.0 C screws. Our second hypothesis is that less cortical fragmentation would occur on insertion of the CH screws compared to the 4.0 screws.

MATERILS AND METHODS

Specimens

Sawbone tali (Synthes®, Davos, Switzerland) were used to ensure that each specimen had consistent density and composition. This model has been shown to provide consistent clinically relevant results. Power analysis of preliminary data indicated that 20 sawbone specimens would be required to demonstrate a 20% difference in mechanical stability with sawbones. In contrast, 250 cadaveric specimens would be required to show the same difference due to the inconsistency of cadaveric bone quality between specimens. Twenty-four sawbone specimens were tested; 12 served as controls to measure the fixation strength of the 4.0 C screws and 12 comprised the experimental group to determine the fixation strength of the CH screws. Results were then confirmed in 10 (5 specimens each) cadaveric bones.

Preparation of Specimens

Guide wires (0.062 mm K-wire) were directed into the talar head in an anterior-to-posterior direction (Figure 1). Each guide wire entered and transversed the talar head, travelled through the talar neck, and entered into the body of the talus. An X-ray of the model with the guide pin in place was obtained to ensure the accuracy of screw placement. A fracture through the talar neck was created by cutting the cortex circumferentially with an oscillating saw with a thin, sharp blade and then manually breaking the cancellous bone (Figure 2). The guide pins were sequentially overdrilled. Screws were then placed over the guide pins in the synthetic talar bone model in the anterior-to-posterior direction. Each screw entered and traversed the talar head, traveled through the talar neck, and entered and traversed cancellous portion of the body of the talus (Figure 3). The amount of torque during screw tightening was controlled. Each specimen was cemented in an acrylic cylindrical molding, oriented so that the talar head and neck were exposed.

Testing of Specimens

A Mechanical Testing System (MTS) machine was used to apply a dorsally-directed shear force to the talar head to simulate clinical loads to the talus seen in walking (Figure 4). The displacement mode of MTS was used at the rate of 3.3-mm/second, as described in the literature. The end deflection was 5 mm. The yield point for each specimen was set to be the point on the load-deformation curve at which load and deformation lose their linear relationship. From these results, the stiffness (slope of the load-deformation curve) and energy absorbed (area under the deformation curve) were calculated for each specimen. The results were statistically compared using a student's t-test. In addition, the results were confirmed in 5 pair (10 specimens) of cadaveric bone.

RESULTS

A paired t-test analysis indicated that the fixation of talar neck fractures by the CH screws was significantly stronger than the 4-0 C screw (671.67 +119.47 N versus 317.22+ 48.39 N; $p<0.001$) (Table 1 and Figure 5). Furthermore, inspection of the failure site indicated that in the 4.0 screw group, 83% of the specimens (10 out of 12 cases) showed widening of the osteotomy site; this widening was seen in 42% (5 out of 12 cases) in the CH group (Table 2 and Table 3). Further, on examination of specimens after failure, it was found that none of the CH screws were bent during failure while 7 out 12 screws in 4.0 groups were bent when the construct failed (Table 2 and 3). Comminution of the dorsal cortex occurred in 3 of the 4.0 specimens and none of the CH specimens. This was observed as cortical cracking in the bone dorsal to the screw on the distal talus. The screws were still tightened completely without breakout.

In the fresh cadaveric bone specimens, the fixation of talar neck fractures with the CH screws was stronger than the 4-0 C screw although not significant (480 N versus 238 N) which supports the data analysis of the synthetic bone study. Due to limited number of fresh cadaveric bone in the study, variability in the quality of the cadaveric bone and greater range of values obtained in this group, statistical analysis of data was not performed in this group.

DISCUSSION

Biomechanically, the CH screws placed in anterior to posterior direction in saw-bone talar neck fractures provide significantly greater strength of fixation than the 4.0 screws. This was our first conclusion drawn from the data. The results were reproducible and statistically significant. Another conclusion was that signs of dorsal comminution during 4.0 screw placement were evident in 3 specimens and not seen in the CH group. This is a subjective finding and did not result in loss of fixation or a change in the failure pattern compared to the other specimens in that group. Based on the findings of this study the primary method of fixation for talar neck fractures at our institution is now with CH screws.

Experience throughout this study and the conclusions can be tied back to the literature. Swanson *et al*. described an experimental model in which cadaveric talar bone specimens were cemented in an acrylic cylindrical mold oriented so that the talar head and neck were exposed[10]. Specimens were then loaded into an apparatus which stabilized the specimen in a MTS which was used to apply a dorsally directed shear force to the talar head which propagated the fracture. They then tested 4.0 cannulated screws placed anterior to posterior and posterior to anterior. This study was the basis for our biomechanical testing set up and prompted our goal of finding a stronger fixation method.

In our preliminary testing procedures, we were unable to consistently propagate a fracture through the saw-bone models using the method described by Swanson. We found that fractures were produced in areas of the talus other than the neck. The tendency of the talar neck to fracture more often as opposed to the other areas of the talus is thought to be due to the lower content of trabecular bone found in the talar neck and the fact that the orientation of the trabeculae in the talar neck is different from the orientation of the trabeculae in the talar body[4].

Another limitation in this study was that we used saw bones for the majority of the data. Optimally we would have preferred to use cadaveric tali for the testing, but this was not feasible based on our statistical calculations of needing 250 tali to have adequate power. The cadaveric tali that were tested showed a similar trend with the CH group being stronger, but the difference was not statistically significant.

Based on our results and a review of the literature we recommend using CH screws for the fixation of talar neck fractures over the use of 4.0 cannulated screws. The same approach and position of guide wires can be used. Both systems have a cannulated drill bit. The CH screw will provide greater strength of fixation and based on the study by Wheeler et al the amount of compression across the fracture site will also be greater. There will be no screw head prominence, likely no dorsal comminution and the far cortex does not need to be captured in order to have compression across the fracture site. Orthopaedic surgeons are cautioned when using variable pitch conical headless screws because they cannot be backed up or else compression across the fracture site is lost.

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TABLE 1: Individual Specimen Force Requirements to Result		
CH		4.0 screw
861		345
755		399
778		323
487		500
520		318
594		360
612		320
673		258
518		284
734		248
653.2	Average	335.5
126.8795	+/-	73.63612
p value = 6.74273E-06		

Specimen #	Force (N)	Distance (mm)	Fracture	Screw bent	Osteotomy widening	Fx Propagation into talar body
7	500	4.9	Yes, medial screw	No	Widened	No
8	323	5.6	Yes, medial screw	No	No	No
10	345	4.4	Yes medial screw	Yes, lateral screw	Widened	Yes
11	399	6.0	Yes, medial screw	Yes, lateral screw	Widened	Yes
13	318	8.0	Yes, medial screw	No	No	No
20	320	6.0	Yes, lateral screw	Yes, lateral screw broke	Widened	No
21	248	7.5	Yes, medial screw	Yes, lateral screw	Widened	Yes
29	284	5.0	Yes, lateral screw	Yes, lateral screw	Widened	Yes
30	360	5.5	Yes, lateral screw	Yes, lateral screw	Widened	No
32	258	5.5	Yes, lateral complete and medial incomplete	No	No	No

Table 2: Individual Results of 4.0 Cannulated Screws With Mechanism and Characteristics of Failure

Specimen #	Force (N)	Distance (mm)	Fracture	Screw bent	Osteotomy widening	Fx Propagation into talar body
1	487	4.7	Yes, medial screw	No	No	No
2	755	6.2	Yes, lateral screw	No	No	No
3	594	5.1	Yes, medial screw	No	Widened	No
4	518	7.9	Yes, medial screw incomplete	No	No	No
6	861	5.6	Yes, medial screw	No	No	No
9	612	6.5	Yes, medial screw	No	Widened	No
12	520	7.7	No	No	Widened	No
14	778	4.2	Yes, medial screw	No	Widened	Yes
15	673	3.7	Yes, medial screw and lateral not through screw	No	No	Yes
16	734	4.5	Yes, medial screw incomplete	No	Yes	No

Table 3: Individual Results of Conical Headless Screws With Mechanism and Characteristics of Failure

Figure 1: Cadaveric Specimens with K-wires in Place

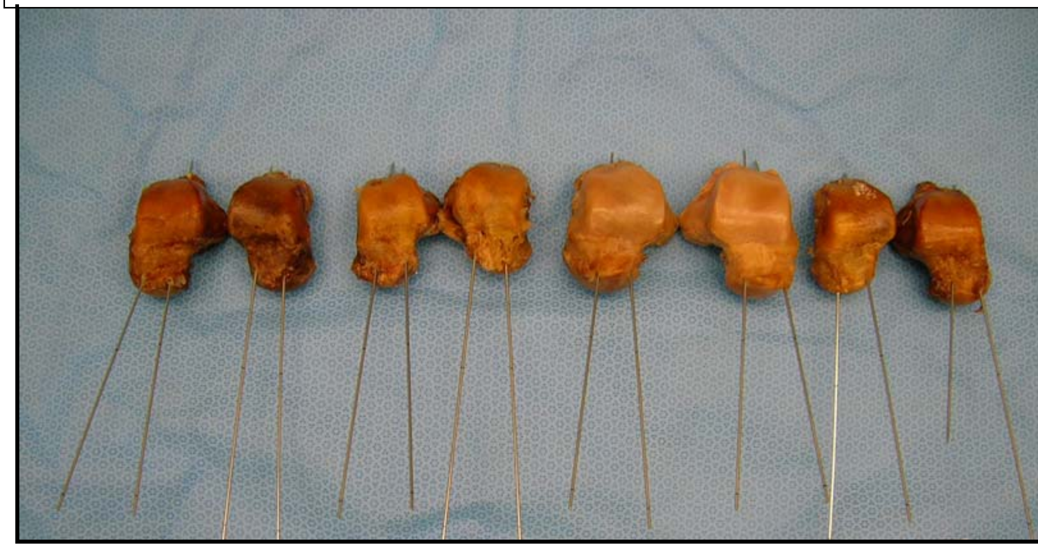

Figure 2: Fracture Through Talar Neck of Sawbone Specimen Fixed with CH Screw

Figure 3: Cadaveric Specimens Fixed with CH Screw (Left) and 4.0 C Screw (Right)

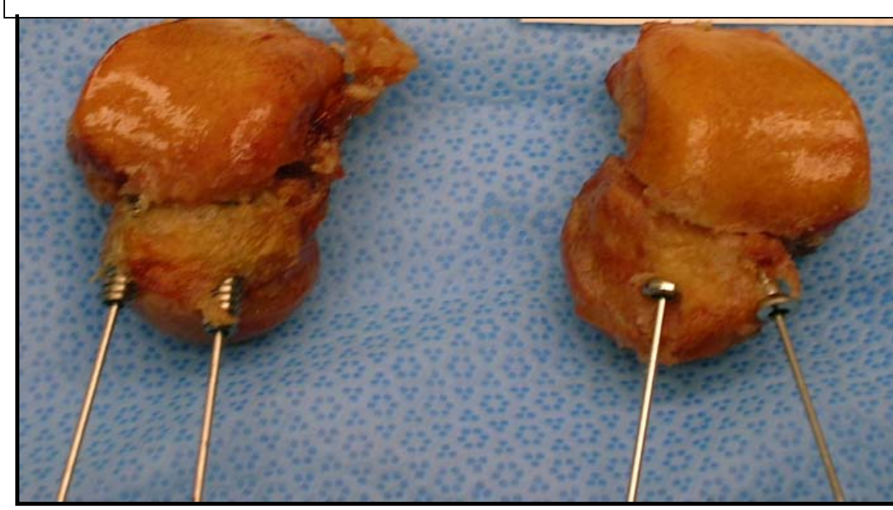

Figure 4: MTS System Prepared to Apply Dorsally Directed Force Across Talar Neck of Sawbone Specimen

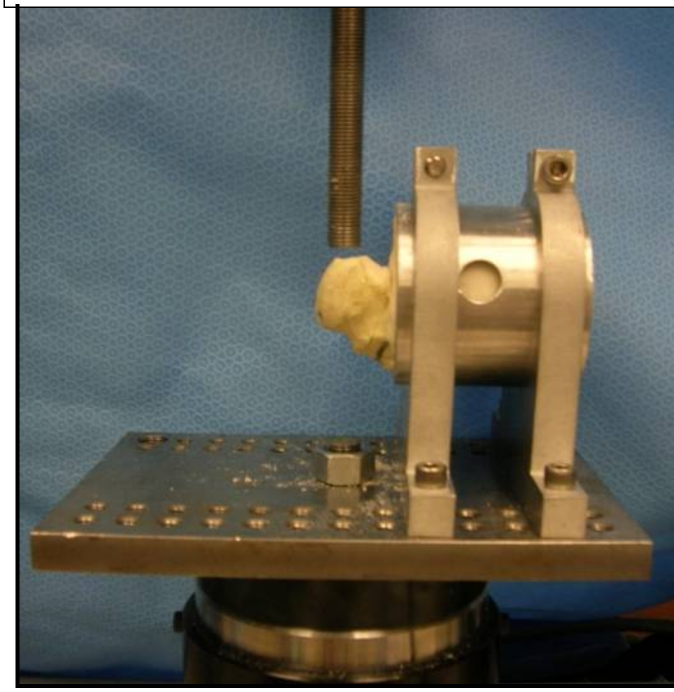

Figure 5: Average Force Required to Result in Construct Failure