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Salvaging the Pullout Strength of Stripped Screws in Osteoporotic Bone

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Abstract

Our goal was to determine whether the pullout strength of stripped screw holes in osteoporotic bone could be increased with readily available materials from the operating room. We inserted 3.5-mm stainless steel nonlocking self-tapping cortical screws bicortically into 5 osteoporotic humeri. Each screw was first stripped by rotating it 1 full turn past maximum torque. In the control group, the screw was pulled out using an MTS machine (858; MTS Inc, Eden Prairie, Minnesota). In the treatment groups, the screw was removed, the hole was augmented with 1 of the 3 materials (stainless steel wire, polysorb suture, or polyethylene terephthalate glycol plastic sheet), and the screws were replaced and then pulled out. The effect of material on pullout strength was checked for significance ($P < .05$) using a general linearized latent and mixed model (Stata10; StataCorp, College Station, Texas). The mean (95% confidence interval) pullout strength for the unaugmented hole was 138 N (range 88-189), whereas the holes augmented with plastic, suture, or wire had mean pullout strengths of 255 N (range 177-333), 228 N (range 149-308), and 396 N (range 244-548), respectively. Although wire augmentation resulted in pullout strength that was significantly greater than that of the unaugmented screw, it was still below that of the intact construct.

Keywords

screw stripping, osteoporosis, bone density, inadvertent stripping, ankle fracture, humerus fracture

Introduction

Screw stripping is likely more common than realized,[1-3] especially in osteoporotic bone, and may place fracture fixations at risk of premature failure. Even when a screw is recognized as having been stripped, there are few choices for remedying the situation; the surgeon can leave the screw in place, exchange the screw for a larger diameter one, drill a new hole elsewhere, or augment the hole. However, in 1 study, exchanging a stripped 3.5-mm screw for a 4-mm screw had little effect on pullout strength,[2] and another study found that the use of bone graft material to "pack" the stripped hole did not restore pullout strength in a synthetic bone model,[4] although acrylic bone cement has been found to increase pullout strength in augmented pedicle screw fixation in the osteoporotic spine.[5]

Placing a strip of material in a stripped hole is a technique used in other fields, such as woodworking, where it is referred to as a "dutchman." We propose that there is some appropriate material that may be inserted intraoperatively into a stripped hole to augment the purchase of the screw. The purpose of our study was to determine whether common materials found in the operating room could be inserted into stripped screw holes to increase the screw's purchase. Specifically, we hypothesized that augmenting the screw hole would significantly increase screw pullout strength.

Materials and Methods

Five upper limbs were obtained from the Maryland State Anatomy Board, and the distal radius was scanned with dual-energy X-ray absorptiometry (Hologic QDR 4500, Hologic Inc, Bedford, Massachusetts) to determine the bone mineral density. The limbs were stored frozen ($-20°C$) and then thawed at room temperature just before use. The humeri were removed, denuded of soft tissue, and kept moist with 0.9% saline-soaked gauze. Two humeri were from a 103-year-old caucasian woman (t scores, -4.0 and -4.1), 2 humeri were from a 74-year-old caucasian woman (t scores, -3.2 for each side), and 1 humerus was from an 82-year-old caucasian woman (t score, -4.5).

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Three regions of the diaphysis were designated as proximal, middle, and distal. Within each of the 3 regions, 4 screws were inserted: 2 from lateral to medial and 2 from posterior to anterior directions. Screws were inserted one at a time; the first and second screws were perpendicular to each other at the same lengthwise position in the diaphysis, as were the third and fourth, and so on. This technique permitted each screw to be inserted into a region of bone that was not damaged by the testing of the previous screw, and the arrangement minimized the effects of local variations in the bone by placing screws as closely together as possible without causing interference. Each hole was at least 25 mm apart from another. We used 3.5-mm stainless steel nonlocking self-tapping cortical screws (Veterinary Implants Direct, Huntington Beach, California) of appropriate lengths to ensure that the 2 cortices were completely engaged by the thread.

The humeri were clamped horizontally in a custom-made fixture.[6] A 2.5-mm pilot hole was drilled through the diaphysis using a drill press so that the hole passed through the centerline of the humerus and was perpendicular to the base plate of the fixture. The fixture was mounted to a translation table on a materials testing machine (MTS 858 Bionix Test System; MTS, Eden Prairie, Minnesota) that allowed motion in the horizontal plane. The fixture also ensured that the pilot hole was coaxial with the actuator of the materials testing machine. Each subsequent hole was prepared after the completion of the test on the previous hole.

A screw, of appropriate length, was inserted by hand through a piece of one-third tubular dynamic compression plate (Synthes, Inc, West Chester, Pennsylvania) placed in a custom-made pullout fixture.[2] Screws were assigned to 1 of the 4 groups: 1 control and 3 treatments. Each screw was initially stripped by fully inserting it then tightening it 1 full turn past maximum torque. Maximum torque was recorded with a torque cell mounted to the screwdriver (Imada Digital Torque Screwdriver, Imada Inc, Northbrook, Illinois). The screws in the control group were subjected to a pullout test immediately after stripping. Screws in the 3 treatment groups were carefully removed after stripping, then 1 of the 3 treatment materials was inserted into the hole according to a predetermined schedule that permutated treatment assignment on hole location. The 3 treatments consisted of metal, plastic, or suture material readily available in the operating room. For the metal treatment, we chose 0.9-mm diameter surgical steel monofilament suture (ETHI-PACK, Ethicon, Somerville, New Jersey). For the plastic insert, we used polyethylene terephthalate glycol plastic (McMaster-Carr, Robbinsville, New Jersey), because it had material properties similar to those of absorbable polymers such as 85:15 poly (L-lactide-co-glycolide) previously used in fracture fixation applications.[1] Strips 0.5-mm thick and 3.5-mm wide were bent in half lengthwise and inserted into the hole. The material dimensions were chosen during pilot tests because thicker strips were severed by the screw threads and thinner strips buckled during insertion. For the suture treatment, we used 4 strands of polysorb no. 1 suture (Covidien, Norwalk, Connecticut). During pilot tests, we determined that more than 4 strands made screw insertion difficult.

A power analysis was performed based on the pilot data, and we determined that a sample size of 15 screws in each intervention group was expected to exhibit significant differences ($P < .05$) at 80% power.

Table 1. Effects of Different Types of Interventions on Screw Pullout Strength.

	Pullout strength, N	
Group	Mean (n)[a]	95% confidence intervals
Control	138	88-189
Plastic	255	177-333
Suture	228	149-308
Wire	396	244-548

[a] 15 measures per treatment group.

Once the material was inserted, the screw was reinserted with the treatment material inserted between the screw and bone until the screw head made contact with the tubular plate. All pullout tests were performed at 1-mm displacement per second (MTS 858; MTS) recording force, displacement, and time.

Preliminary data analysis indicated that there was no significant effect of side (right vs left), screw orientation, or screw site (region) on pullout strength, so these factors were dropped from the analysis. The effect of treatment on pullout force was evaluated for significance using a generalized linear latent and mixed model[7] with a random effects term to account for the pairing of some specimens (Stata10; Statacorp, College Station, Texas). Stripping torque was included as a cofactor.

Results

None of the humeri fractured during testing, and all screws were successfully pulled out with no disruption of adjacent screw hole sites (Table 1). The wire intervention resulted in pullout strength that was significantly greater than that of the controls but not significantly different than that of the plastic or suture intervention (Table 1). The pullout strengths of the plastic and suture interventions were not significantly different than that of the controls.

Discussion

All 3 intervention groups show greater pullout loads than the control, supporting our hypothesis that partially filling a stripped hole will result in improved screw pullout strength. The best improvement in pullout strength was achieved with a wire insert. We postulate that wire was the best because it was not deformed or destroyed by the reinsertion of the screw. Our observations were that the plastic and suture material inserts were often damaged by the cutting head of the self-tapping screw tip during screw reinsertion.

Although the wire augmentation in the greatest pullout strength was significantly greater than that of the stripped hole (control), it was still well below the intact pullout strength (>1000 N) of 3.5-mm screws inserted into osteoporotic bone.[6] The pullout strengths of the various interventions tested in the current study were similar to that of another salvage method

(334 N), the so-called rescue screw.[2] It remains unknown how much purchase is needed to maintain plate-to-bone contact, thereby stabilizing the fracture fixation until healing occurs.

Limitations of the study include the usual ones associated with using cadaveric tissue. We could not investigate the effect of screw augmentation on healing. It is unknown whether the augmentation would affect the healing process or whether cyclic loading during rehabilitation would cause the augmentation to become dislodged and migrate. We chose to investigate 3 commonly available materials in the operating room. Perhaps there are other augmentation materials more suited for the current application.

In conclusion, stripped screw hole augmentation using suture wire resulted in significantly increased pullout strength, but it remains unknown whether the increase is clinically sufficient.

Declaration of Conflicting Interests

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