LABORATORY COMPARISON OF THE CANNULATED HERBERT BONE SCREW WITH ASIF CANCELLOUS LAG SCREWS

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The compression produced by and the resistance to pullout of the 6.5 mm cannulated Herbert screw were compared with those of ASIF headed screws. The latter were tested with and without washers and in the following sizes: 4.5 mm cortical, 6.5 mm cancellous with a 16 mm threaded segment, and 6.5 mm cancellous with a 32 mm threaded segment. Polyurethane foam was used as a substitute for cancellous bone and ASIF artificial bone for corticocancellous bone.

The compression produced by a cancellous lag screw with a washer was significantly greater than that produced by a Herbert screw of equivalent size ($p < 0.05$). When the screws were tested using the corticocancellous composite the ASIF cancellous screw without a washer produced significantly greater compression ($p < 0.05$); when used with a washer the difference was highly significant ($p < 0.001$).

The dual pitch Herbert screw is not appropriate for the management of fractures in which compression is of greater importance than the need to avoid prominence of the screw head.

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The Herbert scaphoid screw (Zimmer Ltd, Swindon, UK) has an established place in the management of scaphoid and osteochondral fractures. The difference in pitch between the leading and trailing threaded portions has the effect of drawing the two bone fragments together, and the absence of a conventional screw head allows the implant to be buried below the articular surface of the bone. Although biomechanical tests have shown that the Herbert scaphoid screw produces less compression than a headed 4.0 mm ASIF cancellous screw (Shaw 1987; Lange et al 1990), there is usually sufficient compression to maintain stable fixation of a scaphoid fracture.

Two larger cannulated versions of the Herbert screw have been developed and marketed by Zimmer (Zimmer Ltd, Swindon, UK) for the management of fractures through cancellous bone. These screws have leading thread diameters of 4.5 mm and 6.5 mm respectively, compared with that of 3 mm of the original, non-cannulated Herbert scaphoid screw. Our aim was to compare the compression produced by the 6.5 mm Herbert screw with that produced by the 6.5 mm ASIF cancellous screws (Synthes; Strauman Ltd, Welwyn Garden City, UK) and the 4.5 mm ASIF cortical screw. The ASIF screws were tested both with and without washers. The resistance to pullout of the different screws was also assessed. In the tests we used polyurethane foam with mechanical properties similar to those of cancellous bone. We then repeated them using segments cut from the tibial plateau region of ASIF artificial bones to simulate the corticocancellous bone in femoral and tibial condylar fractures.

MATERIALS AND METHODS

In this study we used the 6.5 mm cannulated Herbert screw and three different ASIF screws: the 4.5 mm cortical screw, the 6.5 mm cancellous screw with a 16 mm threaded segment, and the 6.5 mm cancellous screw with a 32 mm threaded segment (Fig. 1). All the ASIF screws were tested with and without washers.

Rigid polyurethane foam was used as a bone substitute as this has been shown to have consistent mechanical properties similar to those of human bone (DeCoste et al 1990). It was cut into 40 mm blocks.
The screws used in the study. Left to right: the 6.5 mm cannulated Herbert screw, the ASIF 4.5 mm cortical screw; the ASIF 6.5 mm cancellous screw with a 16 mm threaded segment; and the ASIF 6.5 mm cancellous screw with a 32 mm threaded segment.

which were positioned in two steel brackets, one of which was attached to the load cell and the other to the base of an Instron machine. The screw under test was passed between the two blocks of foam through holes of 13 mm diameter in the centre of the opposite faces of the steel brackets (Fig. 2). The cannulated Herbert screws were introduced into the two blocks as recommended by the manufacturer. After passing a guide wire, the cannulated proximal and distal drill bits and the distal tap were used in sequence. The screw was then inserted over the guide wire, using a torque-limiting screwdriver which gave a maximum torque of 0.5 Nm, approximately equivalent to that generated by using only one finger and thumb on a screwdriver handle. The screw was advanced through the foam blocks at a rate of one revolution every five seconds, and the compression produced was measured using a load cell attached to the Instron apparatus (Fig. 3). For the ASIF screws, holes were drilled and tapped with the appropriate ASIF equipment. Again, the compression produced was measured as the screw was advanced into the foam blocks at a rate of one revolution through the foam blocks at a rate of one revolution every five seconds.

Instron machine and load cell. Blocks of foam were positioned within two steel brackets one of which was attached to the load cell, the other to the base of an Instron machine. The screw is advanced through the foam blocks.

Typical compression curve as a cannulated Herbert screw is advanced through the foam blocks at a rate of one revolution every five seconds.

Diagram to illustrate the placement of the substitute corticocancellous block in the testing apparatus.
every five seconds. The compression achieved by the screws increased to a maximum, after which the threads cut out, with a corresponding reduction in the compression recorded (Fig. 4).

To assess the resistance to pullout, the screw was then inserted into a new foam block, and tightened only to 80% of the maximum compression achieved in the previous test, thus ensuring that the screw threads had not cut out. Tension was applied along the axis of the screw to produce displacement at a rate of 0.1 mm/s until failure occurred. Load-deformation curves were recorded using a chart recorder. The compression and pullout tests were repeated ten times for each screw variation used.

We then compared the Herbert screw with the ASIF screws in the corticocancellous model. Blocks were cut from the tibial plateau region of ASIF artificial bones (AO/ASIF Teaching and Research, Davos, Switzerland) and used as the first of the two blocks through which the screws were passed (Fig. 5). These substitute bones are manufactured to a uniform specification and provide a reasonable anatomical and mechanical model of human bone.

RESULTS

The 6.5 mm Herbert screw achieved significantly greater compression and resistance to pullout than did the 4.5 mm ASIF cortical screw, used with or without a washer, in both cancellous and corticocancellous substitutes (p < 0.05, for all comparisons). There was no significant difference in the force of compression or resistance to pullout between the Herbert screw and the 6.5 mm partially threaded ASIF cancellous screws in cancellous bone substitute when these screws were used without a washer (p > 0.05, for all comparisons). When the ASIF screws were used with a washer, however, both compression and pullout were significantly greater than for the Herbert screw (p < 0.05). In the tests using the corticocancellous substitute, significantly greater compression was produced by the ASIF cancellous screws used without washers than by the Herbert screw (p < 0.05). When a washer was used with the ASIF screws in these tests there was a highly significant difference in both the compression produced and the pullout force compared with the Herbert screw (p < 0.001).

Figure 6 shows the maximum compression and the maximum sustainable load during pullout for each of the screw/washer combinations tested, using both cancellous and corticocancellous substitutes. The ASIF cancellous screws with a 32 mm threaded segment achieved a greater maximum compressive force and a greater maximum load during pullout than the equivalent 16 mm threaded screw, but these differences were not found to be significant (standard error of differences between means, p > 0.05).

DISCUSSION

A polyurethane substitute for bone was chosen for this study because of the known variability in the mechanical properties of bone itself (Ansell and Scales 1968) which would present problems in the interpretation of results. DeCoste et al (1990) have shown that polyurethane foam, made by mixing 35 ml of urethane in a bone mould with a total volume of 85 ml, has similar mechanical characteristics to cancellous bone. Corticocancellous blocks cut from the tibial plateau of ASIF artificial bones were selected as being representative of the cortical thickness through which the screws would be introduced in vivo. In fact, the cortical hardness of such artificial bones is more like that of elderly human bones. This is important, as any increase in cortical hardness will tend to increase the compressive force generated by the headed screw, but will have relatively little effect on that generated by the Herbert screw. In younger, harder bones

![Image](https://via.placeholder.com/150)

The maximum compressive force and the maximum load (mean ± SEM) during pullout for each of the screw/washer combinations tested. Figure 6a – Proximal foam cancellous substitute, distal foam cancellous substitute. Figure 6b – Proximal foam corticocancellous substitute, distal foam cancellous substitute.
therefore the conventional headed screw should have even greater advantages over the Herbert screw.

The mode of failure of the different screw/washer systems in the two materials requires further comment. With the Herbert screw the leading threads cut out during every pullout test. With the headed screws, the threaded section of the screw cut out during pullout leaving the headed section in situ when they were used in the corticocancellous substitute and each time the screw was used in conjunction with a washer. In the case of the 32 mm partially threaded cancellous screw used without a washer in cancellous bone substitute, however, it was the head of the screw which cut out. This finding is compatible with the common observation in the operating theatre that in soft bone it is easy to sink the head of a cancellous screw into the bone without stripping the threads or experiencing a sense of compression. Conversely, if the screw is used in conjunction with a washer, then the screw head does not sink, and satisfactory compression is achieved.

The obvious advantage of the Herbert screw is that it does not have a head to protrude on the surface of the bone; this is especially of value in scaphoid fractures in which a prominent screw head might cause mechanical problems. The manufacturers of the larger cannulated Herbert screw, however, recommended its use in fractures of the tibial plateau, the femoral condyles, and the malleoli; these are prone to displacement because of the large shear forces which may occur at the fracture interface. Resistance to displacement depends on the degree of compression between the fragments and our study has shown that the compression produced by a cancellous lag screw, particularly if it is used with a washer, is significantly greater than that produced by a Herbert screw of equivalent size. Although the presence of a protruding screw head may cause minor problems at sites where there is limited soft-tissue coverage, there is not the same risk of mechanical interference as in scaphoid fractures. In our experience the prominence of a screw head seldom results in serious problems in these fractures and we believe that good compression at the fracture interface is of much greater importance.

Conclusions. In polyurethane foam bone substitute, the compression produced by a cancellous lag screw, particularly if used in conjunction with a washer, is significantly greater than that produced by a Herbert screw of equivalent size. The elegant mechanical principle of the dual pitch compressive screw is not appropriate for fractures in which compression is more important than the avoidance of a protruding screw head.

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REFERENCES