Dynamization of the Taylor Spatial Frame with Modified Shoulder Bolts

INTRODUCTION:
Dynamization describes a concept in external fixation where the bone is trained to gradually accept an increasing load. This can be achieved by gradually destabilizing the frame construct or by allowing axial micromotion to occur with loading of the frame. The results of dynamization of uni-planar and circular fixators in the literature are mixed.

The Taylor Spatial Frame is circular fixator with rings connected by six angled struts via universal joints. There are no studies to date that have attempted to investigate dynamization of the Taylor Spatial Frame. A modified shoulder bolt with 2 mm of extra shank has been developed with the idea that it would allow controlled axial micromotion of the Taylor Spatial Frame. (Figure 1) Our hypothesis is the modified shoulder bolts will provide dynamization of the Taylor spatial frame by allowing axial micro-motion without creating excessive shear at the fracture/regenerate site.

METHODS:
Five identical two ring Taylor Spatial Frame constructs were mounted on Sawbones tibias. An osteotomy just below the level of the tibial tubercle was performed and then distracted 5 cm to create a visible gap between bone ends. (Figure 2) Using a MTS 858 MiniBionix Servohydraulic system a sinusoidal load from 20 to 200 N was applied at a rate of 0.25 Hz to the proximal end of the saw bone. The MTS was used to record the axial force and displacement. The six degrees of freedom for motion of the proximal and distal segments were recorded by the Selspot system via 2 brackets containing 3 IR LED’s each. (Figure 1)

Eight different constructs were tested: 1) All struts of the Taylor Spatial Frame intact, 2) Strut 1 loose, 3) Strut 1 and 3 loose, 4) Strut 1,3, and 5 loose, 5) All struts loose, 6) All struts intact with dynamization bolts on the proximal side, 7) All struts intact with dynamization bolts on alternating sides, 8) Threaded rods between the rings with two millimeters of dynamization.

Cyclic testing of the dynamization bolts was also performed. The same two ring Taylor Spatial Frame construct had the shoulder bolts on the proximal ring replaced with the dynamization bolts. Each bolt was tightened to 4 Nm, and then removed to see the relationship between the application and the removal torque. After 10,000 cycles of loading, we removed each screw and measured the removal torque for comparison.

RESULTS:
For the measurement of the MTS vertical displacement there was no statistically significant difference in vertical displacement between the Ilizarov rods and all struts locked. There was a statistically significant difference between the modified shoulder bolts and the Ilizarov rods (p < 0.01) and all struts locked (p < 0.05). This indicates that the modified bolts did allow axial motion to occur. (Figure 2)

From the Selspot cameras data, shear values were calculated. There was no statistically significant difference in shear values between all struts locked and the modified shoulder bolt struts. There was a statistically significant difference in shear values between one strut unlocked and all struts locked/dynamized struts (p < 0.05). (Fig. 2)

After 10,000 cycles, the screws were more resistant to removal (3.19 +/- 0.16 Nm) than before loading (2.88 Nm +/- 0.24). This was a statistically significant increase in removal torque by student’s t-test, P < 0.02.

The modified shoulder bolts did allow appropriate axial displacement to occur. Modified shoulder bolts allow more axial displacement than dynamized Ilizarov threaded rods and all struts locked constructs. There was no advantage to alternating the position of the modified shoulder bolts on both rings compared to leaving them all on the proximal ring. Unlocking any single or multiple struts allowed uncontrolled amounts of axial displacement.

The modified shoulder bolts did not allow inappropriate amounts of shear to occur. There was no difference noted when compared to the all struts locked construct. However, unlocking one, two or three struts creates a significant amount of shear at the regenerate/fracture site and should be considered unsafe. Unlocking all of the struts actually creates less shear than unlocking one, two, or three struts.

Cyclic testing of the modified shoulder bolts reveals that the bolts actually get tighter over time and should not have a risk of loosening in a clinical scenario.

SIGNIFICANCE:
The modified shoulder bolts may be a safe (and easy) way to dynamize the Taylor Spatial Frame. They allow appropriate axial motion without a significant increase in shear. One should not unlock a single (or multiple struts) as a way of dynamizing the Taylor Spatial Frame. This creates significant shear strains at the fracture/regenerate site.