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Comparison of BMD in Distal Radius to Volar Plating Screw Mechanics.

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INTRODUCTION:

Fixation of fractures in osteoporotic bone has been a challenge for orthopaedic surgeons since the time fractures have been undergoing fixation. The problem in osteoporotic bones has traditionally been the interface between the implant and the bone. This interface is usually by use of screws that need to be anchored in bone that is either unable to hold the purchase or allow early loosening.[1] Several studies have looked at torque to failure in osteoporotic bone, but stripping also has been seen in regular bone due to the small pitch seen in distal radial screws. The amount of screw insertion torque required for construct stability has been estimated to be at least 3 Nm. In some situations, such as poor metaphyseal bone or osteoporotic bone, screw stripping can occur before the generation of sufficient torque, leaving the construct unstable.[2] For distal radius fractures, the overall rates were 30.2%, 16.8%, 32.3% and 25.9% for malunion, loss of reduction, loss of radial length and dorsal angulation.

METHODS:

Fifteen fresh frozen radii were dissected from forearms and bone mineral density (BMD) tests were determined using DXA. A volar plate was then placed on each radius and two 2.4 mm cortical screws, with 1.8 mm pilot holes, were driven into the radial shaft. Measurement of torque was recorded for every 180° of rotation as well as maximum torque until stripping of the thread/bone interface occurred. This was repeated for 30 cortical screws. Following this, two variable angle locking screws were driven into the distal radii. This was repeated for 30 screws and the average insertion torque was recorded before locking. After testing insertion torque, a third cancellous screw was inserted into the middle of the distal portion of the plate to a depth of 60% of the screw length (12 mm), allowing the screw head to be gripped and pulled at a rate of 5 mm/min until failure. A load/displacement curve was generated, from which the failure load was determined and compared to BMD.

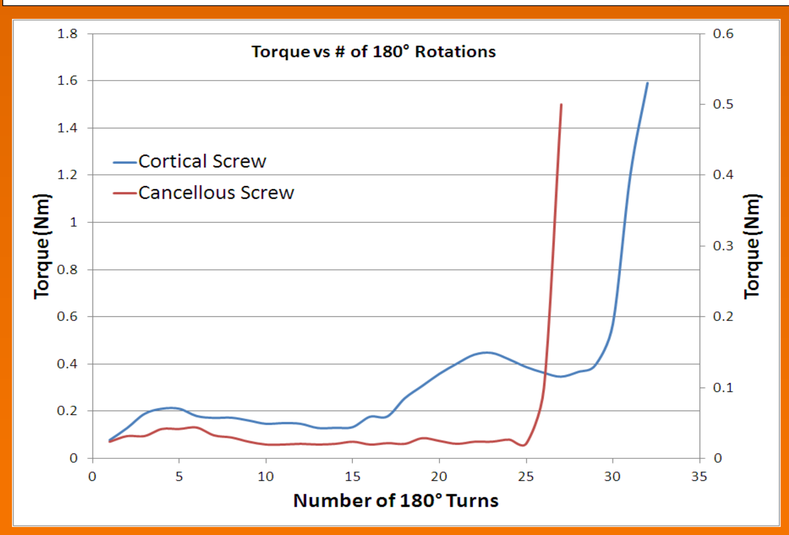

Figure 1 – Example of cortical and cancellous screw insertion torque w/ final x-ray

RESULTS:

For the cortical screw insertion into the shaft of the radius, there is an initial spike in insertion torque when entering the near cortex, followed by a decrease as the screw travels through the medullary canal and then a large spike as the screw penetrates the far cortex. After the screw exits the far cortex, the torque decreases until the screw head comes in contact with the plate and maximum torque is recorded when the screw strips or the head breaks (red values in table). For cancellous screw insertion, the tracking of insertion torque did not yield any obvious peaks until the locking head engaged into the plate. (Figure 1)

For the first cortical screw and second cortical screw, there were correlation coefficients of 0.79 and 0.90 for the peak torque before stripping respectively when comparing to the BMD, which suggests a high correlation between BMD and insertion torque.

For the first screw, the average maximum torque needed to penetrate the far cortex was 0.607 N·m. For the first and second screw, the average minimum torque needed to strip the far cortex was 0.641 N·m and the maximum average torque without breaking screw was 1.486 N·m The total cortical thickness in the area of the diaphyseal bone ranged from 3.7 mm to 7.1 mm, which can also be used as a method for quantifying bone quality as the thickness correlates to BMD as one would expect. During testing, several screw heads torqued off the shaft of the screw, ranging from 1.266 N·m to 2.218 N·m, and since those are not representative of the bone/screw interface failure, they were not included in the data analysis, although it is important to know mechanically. There was a high correlation between BMD and average cancellous insertion torque with correlation coefficients of 0.71 for the first cancellous screw and 0.60 for the second cancellous screw. However, the range of results in quite narrow with the minimum average torque being .021 N·m and the maximum insertion torque being 0.067 N·m, which is significantly smaller than the torque necessary to lock the screw into the plate. Also, there was a high correlation between BMD and pullout strength of the cancellous screw inserted 12 mm into the distal radius, with a correlation coefficient of 0.64.

DISCUSSION:

Based on the correlation coefficients comparing BMD and screw insertion torque for cortical screws, these values are highly correlated and when looking at the torque needed to lose purchase in osteoporotic bone and compare it to the maximum amount of torque needed to attain bicortical fixation, a torque limit between 0.6 N·m and .75 N·m would allow for the best balance between bicortical fixation and not overloading the screw heads as well as damaging the screw/bone interface. When looking at the cancellous screw insertion torques, the average torque also was highly correlated with BMD, but the torque values were well within the 0.02 N·m error of the measurement system combined with the small range (0.02-0.06 N·m) of insertion torques related to the plate/screw locking mechanism, that any stripping of the bone can occur before stripping of the plate/screw locking mechanism.

References:

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Table 1 - BMD, Torque, and Pullout Data

Bone	#1	#2	#3	#4	#5	#6	#7	#8	#9	#10	#11	#12	#13	#14	#15
Shaft BMD (g/cm²)	0.549	0.248	0.254	0.166	0.443	0.273	0.329	0.417	0.429	0.297	0.208	0.437	0.317	0.455	0.578
Distal BMD (g/cm²)	0.339	0.07	0.18	0.089	0.208	0.067	0.186	0.215	0.216	0.053	0.004	0.226	0.154	0.308	0.423
Avg. Cort. Peak Torq. (Nm)	0.607	0.337	0.342	0.190	0.454	0.329	0.425	0.435	0.607	0.399	0.245	0.486	0.377	0.544	0.504
Avg. Torq. Stripping (Nm)	1.600	1.153	0.907	0.641	1.337	1.385	1.467	1.586	1.636	0.862	0.714	1.424	1.236	1.486	1.455
Avg. Canc. Torq.(Nm)	0.035	0.033	0.024	0.024	0.047	0.028	0.033	0.029	0.032	0.025	0.026	0.030	0.037	0.040	0.065
Pullout Strength (N)	273.6	93.0	91.1	74.5	145.5	192.3	270.7	219.5	371.5	160.8	53.7	263.7	285.0	174.7	327.4

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