Fixing Midshaft Clavicle Fractures; a Biomechanical Study

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Introduction

Operative plate fixation of displaced mid-shaft clavicle fractures has been shown to improve the functional outcomes and decrease the likelihood of non-union over non-surgical techniques. The purpose of the study was to biomechanically compare the pull-out strength of two locking bicortical screws versus three non-locking bicortical screws used in plate fixation of midshaft clavicle fractures. We hypothesized there would be no significant difference in pull-out strength between the experimental groups and the load to failure of the two fixation methods would both exceed the reported load to failure in other more physiologic cantilever bending midshaft clavicle fracture-plate biomechanical models.

Methods

Midshaft clavicle fractures were created in ten paired embalmed cadaveric specimen. The specimen of a pair were randomly assigned to fixation with either three non-locking screws or two locking screws, each group having an equal number of right and left clavicles. For the non-locking group, three holes were drilled into the superior surface of lateral half of the clavicle using a drill. The plate was fixed to the clavicle fragment and attached using three, 3.5mm bicortical non-locking screws. The screws were placed one in each of the three most lateral holes. Two nylon straps, with three holes corresponding to the location of the three screws, were placed between the bone and the plate.

Midshaft clavicle fracture

For the locking group, a similar technique was used. Two holes were drilled into the superior surface of lateral halves of the locking group using the same diameter drill. The same plate was then held to the clavicle fragment and fixed using two, bicortical locking screws. The screws were placed in the first and third hole position on the plate. Two nylon straps with three holes corresponding to the location of the three potential screws, also were placed between the bone and the plate.

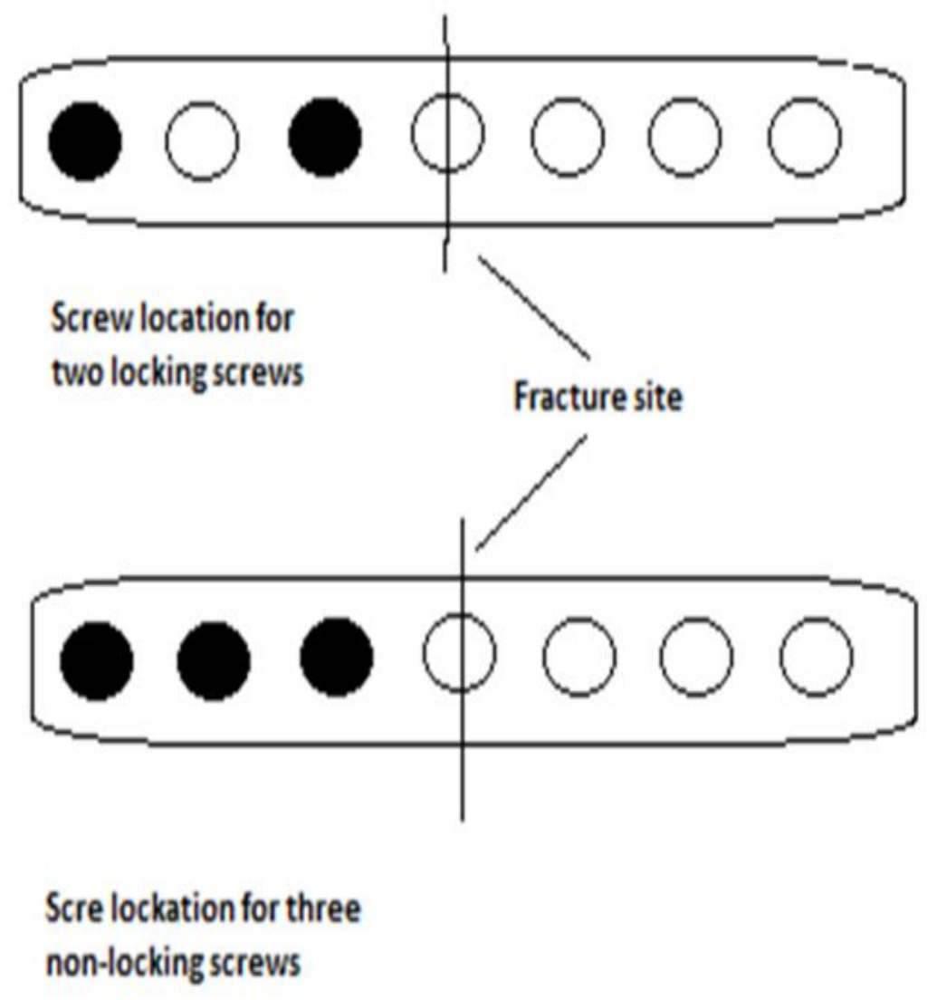
The specimens were preloaded at 75 N of tension oriented along the long axis of the clavicle for five minutes to remove the initial viscoelastic effect. The cyclic tensile load along the long axis of the clavicle cycled from 10 N to 75 N in a sinusoidal pattern at a rate of 1 Hz. The samples were then re-oriented for the pull-out-failure, which was performed at 0.5mm/sec, parallel to the long axis of the screws. The force was applied by pulling the two nylon straps in opposite directions until failure.

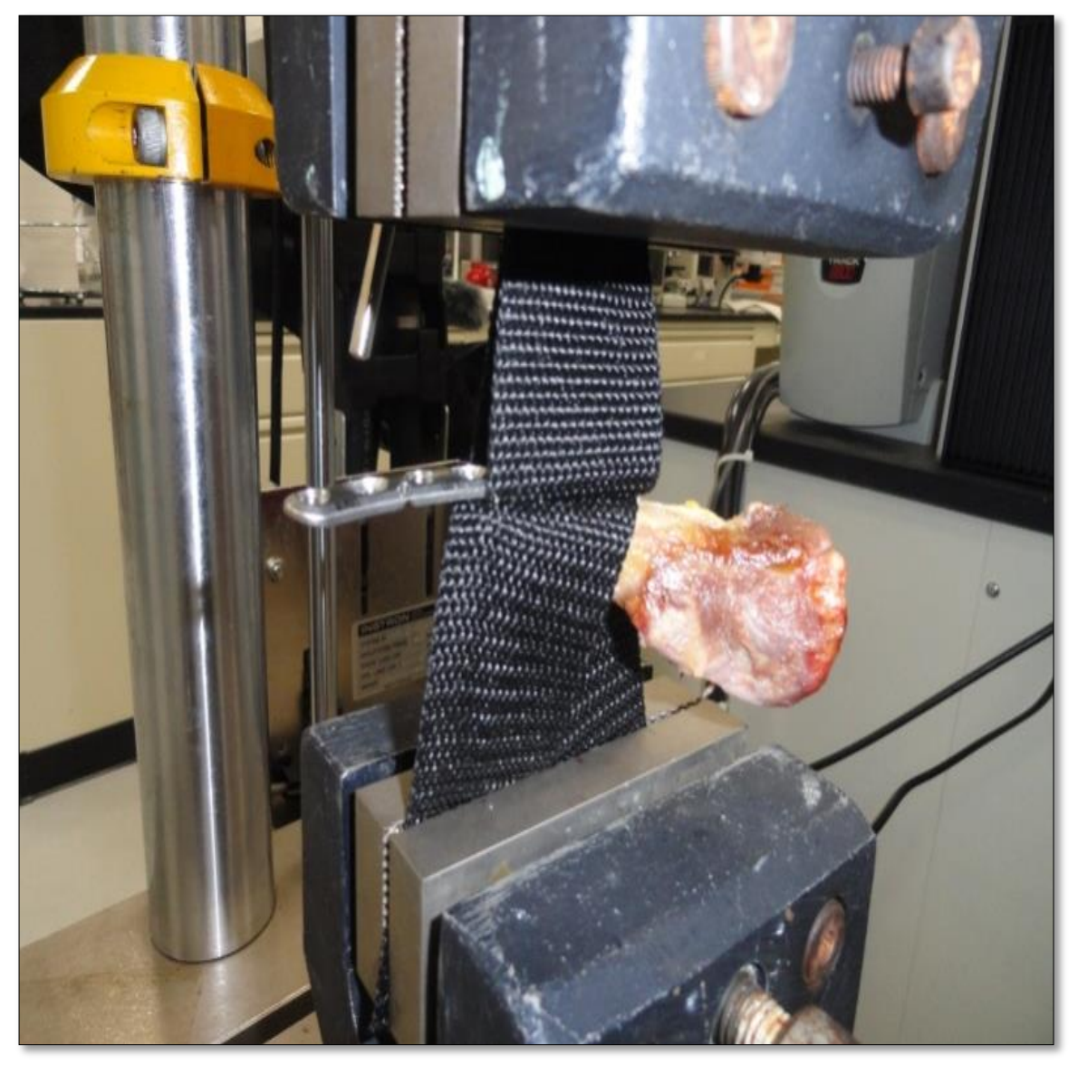
Cyclic displacement, yield load, ultimate load, and stiffness were measured using an INSTRON 8871 with a 5kN load cell secured to the cross-head. Statistical analysis of the samples was performed using a paired t-test (α = 0.05). SigmaPlot 11.0 (Systat Software, Inc.) was used to perform the calculations.

Screws / Plates

Locking 3.5 mm bicortical screw (top left), Non-locking 3.5 bicortical screw (top right), 7-hole compression plate AR-2655CL (bottom)

Apparatus Set-Up





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Results

There was no significant difference in stiffness, cyclic displacement, yield or ultimate load between the constructs. Three non-locking screws demonstrated an average ultimate load of 2496 +/-1102 N, while the two locking screws had an ultimate load of 2715 +/-1150 N. This remained true when examining the data with the removal of outliers, as well as when examining only the desired method of failure (screw pullout).

Clavicle Plate Biomechanical Testing

Fixation With Two Locking Screws Vs. Three Non-Locking Screws

Sample #	Side	# of screws	Donor #	Age / Sex	Cyclic Disp.	Ultimate Load	Yield Load	Stiffness	Method of Failure
30	R	2	12-361	54 / M	0.13	2582	2582	257	screw pullout
30	L	3			0.04	2754	2754	197	screw pullout
2	L	2	11-380	63 /M	0.28	4205	4205	291	screw pullout
2	R	3			0.36	3632	3611	276	strap slipped in clamp
7	R	2	12-383	89 / F	0.06	1201	1201	135	screw pullout
7	L	3			0.11	4054	4054	345	screw pullout
5	R	2	11-310	70 / F	0.13	3028	3028	242	strap slipped in clamp
5	L	3			0.22	601	601	89	strapping material ripped
12	L	2	11-343	94 / F	0.43	876	876	147	screw pullout
12	R	3			0.12	1645	1645	183	screw pullout
4	R	2	11-368	94 / F	0.35	2955	2647	366	strapping material ripped
4	L	3			0.07	2504	2077	172	strapping material ripped
1	R	2	12-385	72 / M	0.19	4044	4044	228	screw pullout
1	L	3			0.18	4235	4235	262	screw pullout
8	L	2	12-374	56 / M	0.20	2036	2036	194	screw pullout
8	R	3			0.11	3284	3248	241	screw pullout
28	R	2	12-391	53 / F	0.08	1757	1757	146	screw pullout
28	L	3			0.02	1710	1710	180	screw pullout
11	L	2	11-398	77 / F	0.14	2278	2278	159	screw pullout
11	R	3			0.11	2764	2764	194	screw pullout

Statistical Analysis of Data

	Age	# of Screws	Cyclic Disp.	Ultimate Load	Yeild Load	Stiffness
Average with Standard Deviation	**72 ±**	**2**	**0.2 ± 0.12**	**2496 ± 1102**	**2465 ± 1092**	**217 ± 75**
		3	**0.13 ± 0.1**	**2715 ± 1150**	**2670 ± 1165**	**214 ± 70**
Stats Analysis (Paired T-test)	**n/a**	**n/a**	**p=0.196**	**p= 0.622**	**p=0.646**	**p=0.944**

Conclusion

Despite not demonstrating significant differences between our two experimental groups, the absolute values for pull-out strength of both groups exceed the reported load to failure in other more physiologic cantilever bending midshaft clavicle fracture-plate biomechanical models. This demonstrates that using either two locking bicortical, or three non-locking bicortical screws on both sides of the fracture site, is not the limiting factor in midclavicular fracture fixation strength and therefore, our study supports the use of two locking bicortical screws on each side of the fracture site rather than three screws for plating of midshaft clavicle fractures. The clinical implications include decreased cost, surgical time, incision length, periosteal exposure, plate length, number of screws and drill holes, and the ability to use shorter, simpler, and easier to apply standard straight plates along the straight segment of the mid-shaft clavicle.

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