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A biomechanical study of headless compression screws versus a locking plate in radial head fracture fixation

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Hypothesis: Fixation of a 3-part radial head fracture with cannulated compression screws will show equivalent stiffness to a locking plate under axial load. Debate exists regarding the management of Mason type III fractures, with many believing that open reduction and internal fixation provides advantages over other options. By virtue of their subarticular placement, screw fixation is less likely to cause impingement compared with plate fixation, which can result in loss of rotation and requirement for hardware removal. Insufficient fixation stability can lead to nonunions, necrosis of the radial head, pain, and instability. We tested the mechanical stability of fixation of simulated radial head fractures using headless compression screws compared with standard plate construct.

Methods: Standardized test constructs were created with repeatable osteotomy cuts and hardware placement on each Synbone model (Synbone AG, Malans, Switzerland). We presectioned 22 proximal radius Synbone models to simulate a 3-part radial head fracture. The models were fixed using a radial head locking plate or headless compression screws in a tripod construct. The constructs were potted into a compression test jig using 2-part epoxy resin. Compression testing was performed using a 30-kN Instron Universal machine (Instron, Norwood, MA, USA). The compression tool was spherical, representing the surface of the capitellum.

Results: There was no significant difference between the stiffness of the Synbone constructs under axial load.

Conclusion: There was no significant difference between fixation stiffness of a 3-part radial head fracture with headless compression screws in a tripod structure vs. a locking plate in Synbone. Further study is required to allow clinical application.

Level of evidence: Basic Science Study; Biomechanics

Keywords: Biomechanical; stability; radial head; fracture; fixation; stiffness

Radial head fractures comprise 3% to 4% of fractures about the elbow.[10,18,22,29] Previously classified by Mason in 1954, type I and II fractures with full pronosupination can be managed conservatively.[18,19,23,27] Mason II fractures with a block to rotation and type III fractures warrant operative intervention,

This study did not require ethical approval.

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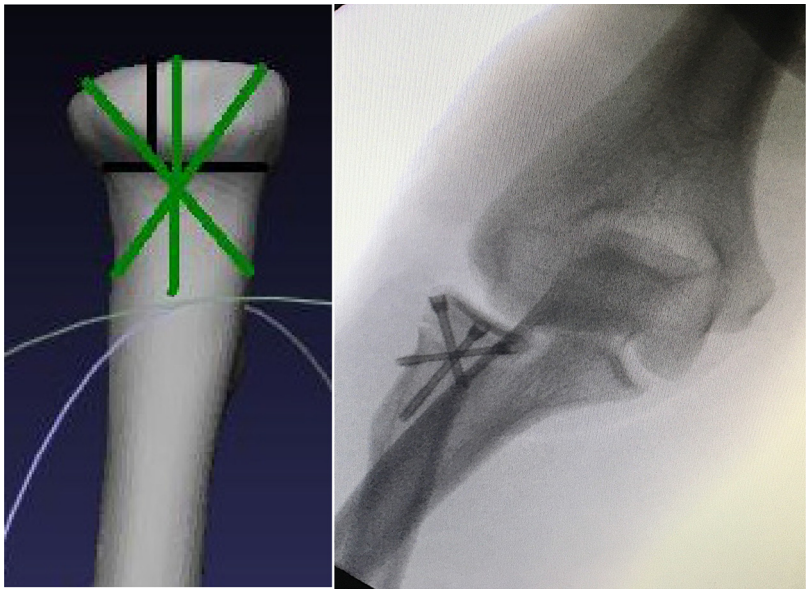

Figure 1 (**Left**) Position of the osteotomy and tripod construct a schematic drawing. (**Right**) X-ray image of the construct. Note that the 60% fragment contains 2 screws, with a single screw in the 40% fragment.

which has led to debate regarding optimal surgical management.[9,11,12,15,16,20,21]

Oblique screw fixation of comminuted radial head fractures was described by Smith et al[28] in 2007. They described a technique that was less invasive, decreased hardware impingement, and advocated its use in axially stable fracture patterns. There is also concern about loss of rotation with plate fixation and a higher potential for hardware removal compared with screw fixation.[28] Insufficient fixation stability can lead to nonunions, necrosis of the radial head, pain, and instability.[4,27]

Our study evaluated the mechanical stability of a simulated Mason type III radial head fracture using headless compression screws in a tripod construct (Fig. 1) and a locking radial head plate construct in a Synbone model (Synbone AG, Malans, Switzerland).

Materials and methods

Sample preparation

The study used 22 Synbone radii (model number 7220). These were made of solid bone foam without a cortical shell. The osteotomy pattern (Fig. 2) was selected to reflect an in vivo 3-part radial head fracture pattern. The horizontal cut was positioned 14 mm from the proximal end of the radius, and the vertical was offset from the center, creating a 40:60 split through the radial head. To improve homogeneity of cuts and screw placement among the samples, an all-in-one osteotomy and Kirschner (K) wire cutting block for both test groups were designed using Materialise software (Materialise, Leuven, Belgium; Fig. 3) The model was printed using a Replicator 2 3-dimensional printer (Makerbot, Brooklyn, NY, USA).

The Synbone models were inserted into the cutting blocks, clamped, and cut using a 0.3-mm oscillating saw blade mounted on a battery-powered Stryker CD4 driver (Stryker, Kalamazoo, MI, USA). K wires were then inserted through the cutting block K wire guides.

Figure 2 Osteotomy planned to depict the separate 40% and 60% fragments.

For samples undergoing screw fixation, 3 Medartis SpeedTip (Medartis, Basel, Switzerland) 3.0-mm short thread cannulated compression screws 24 mm in length were inserted over the guidewires

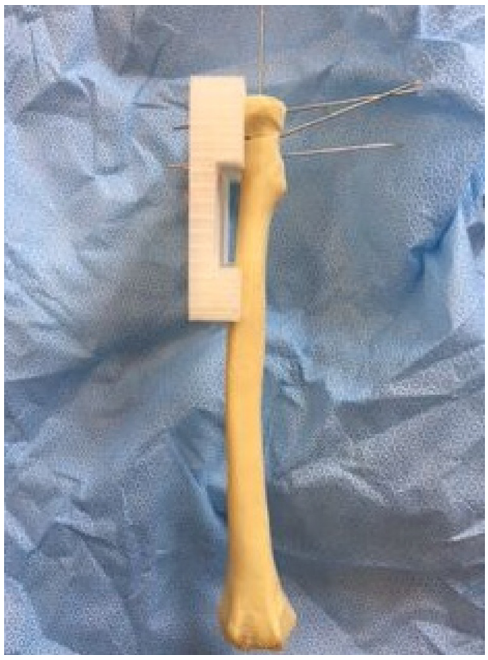

Figure 3 Osteotomy jig and Kirschner wires inserted to allow repeatable fracture simulation and plate position.

Figure 4 Tripod fixation with Medartis Cannulated compression screws (Medartis, Basel, Switzerland) in a Synbone model (Synbone AG, Malans, Switzerland).

simulating a 3-screw tripod fixation construct (Fig. 4). The larger fragment received 2 screws and the smaller fragment 1 screw.

For samples undergoing plate fixation, a Medartis radial head rim plate (A-4656.68) was placed in the radial head safe zone. Plate position was reproduced using K wires inserted through the osteotomy jig and fixed into position using 11 locking screws (Fig. 5) Interfragmentary compression was applied with a clamp while the

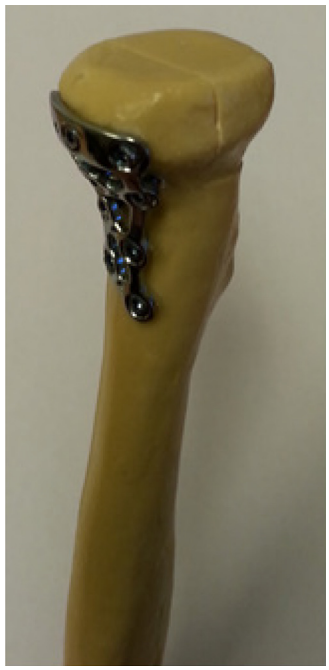

Figure 5 Medartis radial head rim plate (A-4656.68; Medartis, Basel, Switzerland) with locking screws in a Synbone model (Synbone AG, Malans, Switzerland).

screws were applied in a locking mode. No lag screws were used. The screws placed in the radial head were unicortical, and the nonarticular distal screws were bicortical, simulating what would be aimed for in a clinical application.

After fixation, the specimens were sectioned 80 mm from the proximal end to prevent midshaft flexion of the Synbone specimens during compression testing. The cut specimens were potted into a compression testing jig using 2-part epoxy resin.

Biomechanical testing

The compression testing was conducted using a 30-kN Instron Universal (Instron, Norwood, MA, USA) testing machine in displacement control at 1 mm/min. The specimens were loaded by a hemispherical metal loading device to simulate the capitellum of the humerus. The constructs were loaded to failure, with the degree of displacement (mm) of the platform vs. load (N) being recorded throughout the test (Fig. 6). Failure was deemed the point at which the recorded force transmitted through the specimen decreased for an increased displacement from the loading device. The mechanism of failure was observed and recorded for each specimen. The results were recorded allowing plotting of force and displacement, with the slope representing the macroscopic stiffness of the specimen. A very small nonlinear initial part of each curve was disregarded because it relates to initial consolidating of the entire test fixture.

Results were analyzed using SPSS 25 software (IBM, Armonk, NY, USA). Mean stiffness and load to failure was compared using the Mann-Whitney *U* test. A post hoc power analysis was performed using G*Power software (Heinrich-Heine-Universität, Düsseldorf, Germany). The Cohen *d* effect size estimation was calculated. This value, along with the sample size, means, and standard deviations, was used to calculate the power. The α value was set at 0.05, β error probability at 0.20, and power was $1 - \beta = 0.80$.

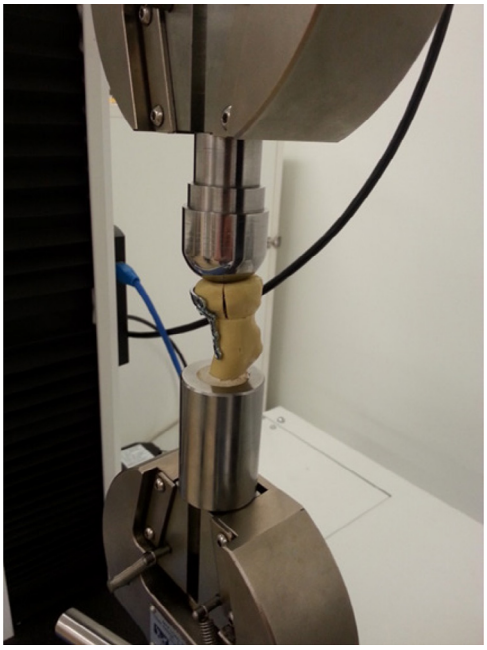

Figure 6 Compression testing. Force applied by hemispherical device to simulate the capitellum.

Results

There were 22 specimens prepared for testing, 10 in the tripod screw group and 12 in the plate group. The numbers within each group were dictated by the number of implants available to achieve the highest number of samples. Post hoc power analysis was calculated at 0.63. Values for the individual samples tested to failure are summarized in Table I. A mean stiffness (N/mm) values of 659.8 ± 29.4 N/mm and 678.4 ± 117.0 N/mm were recorded for the screw group and plate group, respectively. The plate group demonstrated greater stiffness by a mean difference of 18.6 ± 38.1. The difference between the mean stiffness of the screw group and the plate group was not statistically significant ($P = .843$). The

Table I Results for construct stiffness in the tripod screw group vs. the plate group

Tripod screw group	Stiffness	Plate group	Stiffness
1	655.022	1	833.333
2	652.174	2	535.714
3	689.655	3	675.676
4	631.579	4	689.655
5	660.793	5	497.512
6	675.676	6	622.407
7	626.305	7	678.733
8	614.754	8	714.286
9	694.444	9	852.273
10	697.674	10	578.035
		11	839.161
		12	625.00

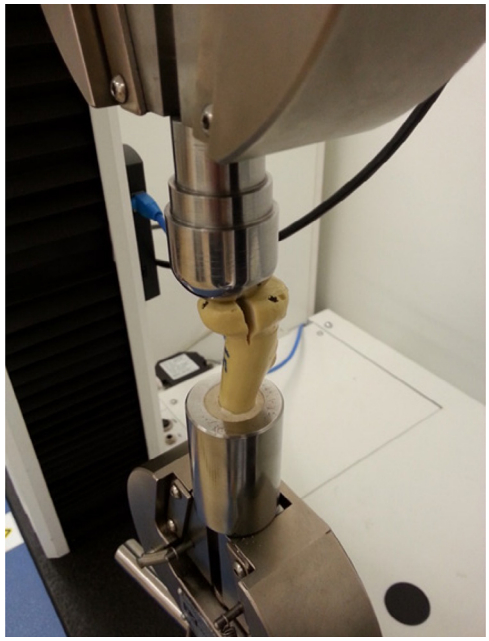

Figure 7 Failure mode of tripod fixation.

Figure 8 Failure of plate group.

screw construct failed through displacement of the fragment with a single screw in situ, and the plate construct failed through distortion at the head-neck junction (Figs. 7 and 8).

Discussion

Optimal surgical treatment of radial head fractures is often debated. Open reduction and internal fixation with various implants, radial head replacement, and excision are common surgical options.[24,27,30] Operative excision of the radial head has become less popular due to the occurrence of elbow pain, limited range of motion, cubitus valgus, and elbow instability.[5,6,14,17,25,26] Proximal migration of the radius is prevented by radial head replacement; however, long-term results in young, high-demand patients are a concern. As a result,

reconstruction of the radial head is desirable in the young, high-demand patient.

By maintaining joint congruity and tensioning the lateral collateral ligament, the radial head contributes to elbow stability.[7] Lindenhovious et al[23] concluded radial head reconstruction reduced the risk of subsequent elbow dislocation and protected against long-term arthrosis. Due to the benefits of radial head reconstruction, a variety of fixation constructs have evolved to treat fractures of the radial head. Subarticular compression screws, interosseous headless screws, plates, and K wires all have been studied, all with strengths and weaknesses.[1,3,9,13,27] An optimal fixation method has not yet been established.

Our study showed that there was no difference in the stiffness of fixation with a tripod screw construct vs. a locking plate in a Synbone model. One of the major shortcomings associated with plate fixation is soft tissue irritation. Many different designs have been trialed and tested; however, there will always be some prominence, especially compared with headless compression screws.[5,17] Burkhart et al[5] studied the anatomic fit of various radial head plates and concluded that due to the radial head's complex anatomy, no one radial head plate perfectly fits all radial heads. The safe zone for plate fixation, to prevent mechanical impingement, can at times lead to confusion, evidenced by 2 previous cadaveric studies with contradictory zones.[8,28] The advantages of the fixation being entirely intraosseous in an area that contributes to forearm rotation cannot be understated.

This study has limitations. This is a biomechanical study, meaning clinical applications cannot be directly assumed. The Synbone models used in this study were made of solid homogenous foam and lacked a cortical shell. We recognize that the lack of a cortical shell is a shortcoming because it does not accurately reflect the structure of in vivo bone. However, advantages of this model include that the homogeneity and consistency of the Synbone models reduced the test variability between individual models, an issue when using cadaveric bone. Ali et al,[2] investigating a model for tibial plateau fracture biomechanical testing, demonstrated the variance between samples was larger in cadaveric bone compared with solid bone foam. Furthermore, using a 3-dimensional printed osteotomy and drill guide further decreased variability between each test construct, allowing good control of potential confounders.

The power of the study could be improved by increasing the number of samples tested. Economic constraints precluded this in our setting. More samples would have allowed more definitive results. Attention should be brought to the narrow confidence interval of the screw group stiffness value, reflecting construct consistency. A wider confidence interval featured in the plate group reflects greater variability between individual samples despite the above-mentioned steps taken to control for confounders.

We recognize that the radial head experiences torsional loads and that only axial loading was tested. The reasoning for this is that the radiocapitellar joint has been shown to absorb 58% of load transmitted during axial loading; thus, the radial head is most under strain when an axial load is applied.[16] The tripod samples had a common mode of failure (Fig. 7) in that the fragment that contained the single headless compression screw was a common point of yield and ultimately, failure, suggesting that the construct could be improved by a transverse interfragmentary screw.

One of the primary goals of radial head fixation is to allow early active range of movement (AROM). The results for both constructs showed a linear stress curve up to 1500 N, which equates to an applied load of 153 kg. One study published the force experienced by the elbow during a 1-handed push-up and found this to be 65% of body weight.[10] Forces across the elbow during an AROM protocol are not well described but considered less than those generated by a 1-arm push-up. This suggests it is likely both constructs would sustain an AROM program.

Conclusion

No significant difference was found between fixation stiffness of a 3-part radial head fracture with headless compression crews in a tripod structure and a locking plate in Synbones. Both constructs demonstrated sufficient stiffness to withstand physiologic loading expected in early AROM rehabilitation based on extrapolated elbow load data. Further studies are required to investigate the integrity of the constructs under cyclical loading and in the clinical setting.

Disclaimer

The implants for this study were donated by Medartis. The Synbones for the project were donated by Synthes.

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