Biomechanical Comparison of Olecranon Sled Versus Intramedullary Screw Tension Banding for Olecranon Osteotomies

Cameron Kia,*† MD, Alex G. Dukas,† MD, MA, Silas T. Marshall,‡ MD, Andreas Voss,† MD, Elifho Obopilwe,† MS, Bruce D. Browner,§ MD, MHCM, and Augustus D. Mazzocca,† MD, MS

Investigation performed at the UConn Health Center, Farmington, Connecticut, USA

Background: Olecranon osteotomies are frequently performed to gain access to the distal humeral articular surface. Repair of the osteotomy or fixation of a simple 2-part olecranon fracture with traditional tension band construct is often plagued by complication. Proximal migration and irritation attributed to hardware are common complications of the standard construct of an intramedullary screw with tension band and are causes for reoperation.

Purpose: To compare the biomechanical performance, time of implant, and prominence of an intramedullary screw and tension band construct with that of a newer low-profile continuous loop tension band (Olecranon Sled) construct in an olecranon osteotomy model.

Study Design: Controlled laboratory study.

Methods: Chevron osteotomies were created in 6 matched pairs of fresh-frozen human elbows (mean age, 66 ± 16 years). Each matched pair was then randomly divided into 1 of 2 groups: fixation with a screw and tension band construct or the Olecranon Sled. Bone mineral density, implant prominence, and time for implantation were recorded. Following olecranon fixation, each specimen underwent cyclic loading of 0 to 10 N for 100 cycles (to simulate unresisted active range of motion) and then 0 to 500 N for 500 cycles (to simulate pushing up from a chair) to measure for any displacement at the osteotomy site. The constructs were then loaded to failure and compared.

Results: No differences were found in bone mineral density between the 2 groups ($P = .290$). When measured from the tip of the olecranon, the continuous loop tension band had a medial prominence of only 3.57 ± 0.4 mm, as opposed to the intramedullary screw fixation of 7.288 ± 0.762 mm ($P = .027$). Total time of implantation, including osteotomy preparation, was a mean 155 seconds shorter with the Olecranon Sled versus the traditional tension band ($P < .05$). Because of the fracture of 1 specimen during cyclic loading, it and its matched counterpart were excluded, and only 5 matched pairs were analyzed for displacement and load to failure. There were no significant differences between groups in load to failure or displacement during cyclic loading ($P > .05$).

Conclusion: The Olecranon Sled device was found to have no difference in biomechanical strength from that of the standard intramedullary screw with tension band construct. The Olecranon Sled was also found to be significantly less prominent while being faster to implant than the intramedullary screw.

Clinical Relevance: Evaluating an alternative option to the standard tension band construct is important for patients with olecranon fractures or osteotomies, as standard techniques have been fraught with hardware issues and need for revision surgery.

Keywords: olecranon; fracture; osteotomy; tension band; trauma; Olecranon Sled

Challenging intra-articular distal humeral fractures often necessitate an olecranon osteotomy for exposure.[22] Many techniques for olecranon osteotomy or simple 2-part fracture fixation have been described, including Kirschner wires (K-wires) combined with a figure-of-8 metal wire tension band (AOTrauma technique), intramedullary screw with or without a tension band, and plating.[7] Biomechanically, intramedullary screw with tension band constructs were demonstrated to be superior to traditional K-wire and tension banding with regard to fracture site displacement[8] and translation of the osteotomy site.[20]

However, traditional techniques of tension band fixation are fraught with complications, such as nonunion, proximal hardware migration, and irritation attributed to symptomatic hardware.[14] The occurrence of symptomatic hardware necessitating removal was reported in 10% to 82% of cases.[1,3,4,10,14,17-19,21] Romero et al,[17] Karlsson et al,[12] and Murphy et al[15] reported removal rates of 71.7%, 81%, and

The Orthopaedic Journal of Sports Medicine, 6(12), 2325967118816075
DOI: 10.1177/2325967118816075

80%, respectively. The intramedullary screw and tension band technique had a lower symptomatic hardware removal at 30%, although this was still clinically significant.[15]

More recently, a continuous wire loop construct (Olecranon Sled; TriMed Inc) was designed as an alternative to the traditional tension band technique in the repair of olecranon osteotomies or simple fractures. This construct functions as a 1-piece tension band, eliminating the bulkiness and irritation of a standard tension band. To our knowledge, only 1 previous biomechanical study has compared the continuous loop construct with the traditional K-wire and tension band technique, finding no difference in osteotomy displacement.[5] However, the study did not compare intramedullary screw with tension band fixation or comment on hardware prominence.[5] Limited clinical data are available on the use of the Olecranon Sled.[9,13] Iorio et al[9] reported on 14 patients, with 1 requiring hardware removal. In a larger case series, Lovy et al[13] found no instances of nonunion, malunion, or hardware removal.

The purpose of this study was to compare the degree of displacement of olecranon osteotomies repaired with the Olecranon Sled versus an intramedullary screw and tension band construct. We hypothesized that the constructs would provide equivalent resistance to displacement but with less implant prominence with the Olecranon Sled. Displacement under cyclic loading, load to failure, and time required for implantation were also compared for both constructs.

METHODS

Six matched pairs of fresh-frozen cadaveric elbows were obtained (n = 12). None of the specimens had undergone any prior procedures, and all were free of any metabolic diseases. Bone mineral density for each specimen was recorded (Lunar DXE;) in a 1-cm^2 region of interest overlying the site allotted for the osteotomy. Measurements were performed by a bone densitometry technologist employed by our institution.

With removal of all skin and subcutaneous tissue, specimens were prepared with the joint capsule, medial and lateral collateral ligaments, annular ligament, and triceps tendon preserved. From the matched pairs, 3 left and 3 right elbows were chosen at random and allocated to the Olecranon Sled group; the remaining elbow in the matched pair was allocated to the tension band with intramedullary screw group. As described by Ring et al,[16] an apex distal chevron osteotomy was made in all specimens. Implants were provided by TriMed. Cadaveric specimens were funded by Arthrex and the Greater Hartford Orthopedic Research and Education Fund, and specimens were purchased from Science Care for the purpose of this study. Institutional review board approval was not needed for this cadaveric study.

Time of Implantation

The time of implantation was recorded for each specimen by a separate study member not performing the osteotomy or repair. For both groups, 3 time intervals were recorded: (1) time for marking and performing the osteotomy, (2) time for repair of the osteotomy, and (3) total time. Additional time for intramedullary guide wire placement, measurement, and predrilling was recorded for the intramedullary screw fixation group. Osteotomies as well as repair with either the Olecranon Sled or the intramedullary screw were performed by a single surgeon (S.T.M.) proficient with both constructs.

Olecranon Sled Technique

Briefly, a chevron osteotomy was performed and then manually reduced with a Weber clamp. Two vertical slits were made in the triceps to place the drill guide over the center of the olecranon. With the drill guide, 2 parallel 2-mm holes were drilled from the tip of the olecranon into the ulnar medullary canal. The guide was removed, and the 2 free legs of the sled were inserted into the predrilled holes. The implant was then advanced and well seated into the olecranon. The drill guide for the dorsal screws was used to place 3 unicortical 2.3-mm drill holes. The retaining washer was positioned, and three 3.2-mm cortical screws (length, 18 mm) were placed. The distal compression screw was then tightened to compress the osteotomy, and the remaining 2 screws were tightened to maintain fixation (Figure 1A).

Intramedullary Screw and Tension Band Technique

For all specimens allocated to the intramedullary screw group, a 4.5-mm drill was used to predrill for a 6.5-mm cannulated screw. The osteotomy was performed and reduced with a Weber clamp. The appropriate-length screw with a washer was then advanced over the wire through a vertical split in the triceps. A 2-mm hole was made 2 cm distal to the osteotomy apex, and 18-gauge surgical wire was passed. The tension band looped around the head and

*Address correspondence to Cameron Kia, MD, Department of Orthopaedic Surgery, UConn Health Center, 263 Farmington Ave, Farmington, CT 06032, USA (email: ckia@uchc.edu).

†Department of Orthopaedic Surgery, UConn Health Center, Farmington, Connecticut, USA.

‡Proliance Orthopaedic & Sports Medicine, Bellevue, Washington, USA.

§Department of Orthopaedic Surgery, Duke University Health System, Durham, North Carolina, USA.

One or more of the authors has declared the following potential conflict of interest or source of funding: This study received funding from the Greater Hartford Orthopedic Research and Education Fund and from Arthrex. The implants were provided by TriMed and Synthes USA. No funding providers had any influence on the study design, data collection, or final manuscript. A.D.M. is a consultant for Arthrex, Arthrosurface, and Orthofix and receives research support from Arthrex. AOSSM checks author disclosures against the Open Payments Database (OPD). AOSSM has not conducted an independent investigation on the OPD and disclaims any liability or responsibility relating thereto.

Ethical approval was not sought for the present study.

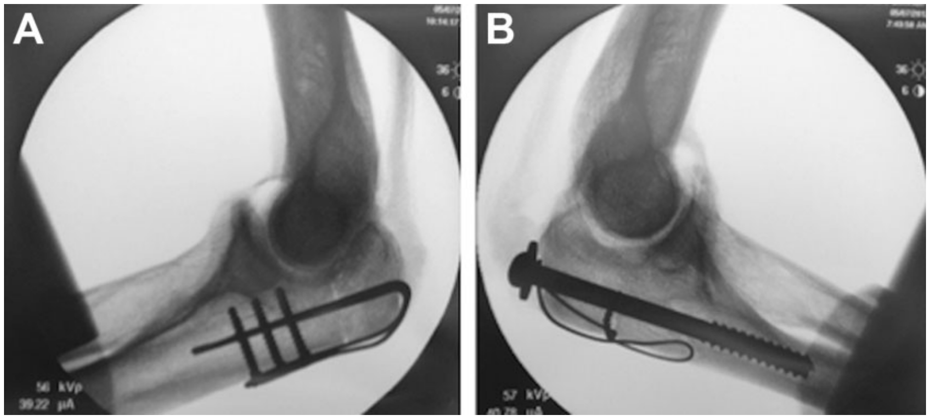

Figure 1. Radiographs showing (A) Olecranon Sled position and (B) intramedullary screw with tension band construct after repaired osteotomy.

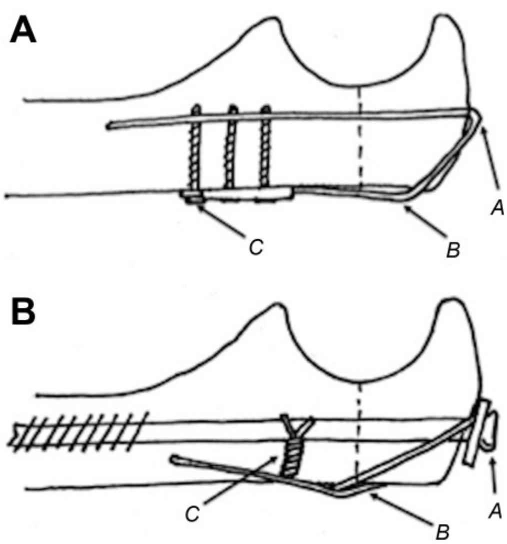

Figure 2. Measured points of prominence in the (A) Olecranon Sled and (B) intramedullary tension band. The following sites were recorded: *A*, the prominence of the implant at the tip of the olecranon; *B*, the dorsal prominence; and *C*, the most distal screw or tension band knot.

Figure 3. Biomechanical setup of cadaveric specimens in the materials testing system. The proximal end of the humerus was potted in polymethyl methacrylate and flexed to 90°.

washer of the screw. The screw was then advanced and seated down to bone. The tension band was tensioned with a standard 1-knot technique (Figure 1B).

Implant Prominence Measurement

Implant prominence was measured with a MicroScribe G2 Digitizer (Immersion Corp) with an accuracy of ±0.2 mm. In the Olecranon Sled group, the prominence of the implant at the tip of the olecranon and dorsal bend was recorded for the medial and lateral limbs (Figure 2A). In addition, the prominence of the most distal screw was measured. For the intramedullary screw group, the prominence of the screw at the tip of the olecranon, the most prominent medial and lateral portions of the tension band wire dorsally, and the tension band knot were recorded (Figure 2B). Each measurement was performed twice by 2 study members not involved with osteotomy or implant insertion. Neither was blinded to the nature of the study, and both values were used to determine the mean prominence at each point.

Biomechanical Testing

The surgically repaired elbows were tested on a materials testing system (MTS Systems). The protocol was based on the work of Carofino et al[2] and Hutchinson et al.[8] The proximal end of the humerus and the distal end of the ulna were potted in polymethyl methacrylate molds and rigidly fixed at 90° of flexion. By using a connecting segment of Kevlar strap and a pulley, the triceps tendons were attached to a 1-kN Instron load cell that was fixed to the materials testing

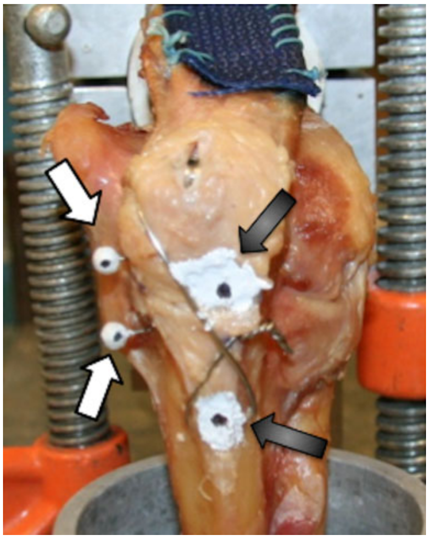

Figure 4. Location of sensors for dorsal displacement (black arrows) and periarticular displacement (white arrows).

system activator (Figure 3). The joints were isometrically loaded via the triceps tendon under 2 conditions: 0 to 10 N for 100 cycles at a frequency of 1 Hz, simulating the approximate forces generated during normal active range of motion without resistance, and 0 to 500 N for 500 cycles at a frequency of 1 Hz, simulating the forces generated while pushing up from a chair.[8] Fracture site displacement during loading was recorded with paired sensors (MTS Systems): the first pair placed directly across the dorsal aspect of the osteotomy and the second pair depicting the articular surface, inserted in bone just off the medial articular surface (Figure 4). Sensor displacement was recorded with a high-definition camcorder (HDR-FX1000; Sony Inc) and analyzed with 2-dimensional analysis software (MaxTRAQ; Innovision Systems Inc). This system has a sensitivity of 0.1 mm within the viewing window (75 mm × 75 mm). The maximum displacement was then compared for each method. Finally, each elbow was loaded to failure and the failure curves recorded.

Statistical Analysis

A power analysis was performed to determine sample size, with 6 elbows per group chosen to detect a 1-mm difference of displacement, given a standard deviation of 0.6 mm with a confidence of 90%. This standard deviation was chosen after a review of previous literature on this topic.[2,8,14] The Wilcoxon signed-rank test was used to evaluate differences in the cyclic loading, ultimate load to failure, slope, age, bone mineral density, time, and hardware prominences between the Olecranon Sled and the intramedullary screw with tension band construct. The alpha level was 0.05 for all statistical tests. Two-way random intraclass correlation coefficient (ICC) was used to assess the reliability of the hardware prominence measurements. $ICC_{2,1}$ values were calculated for absolute agreement and consistency of agreement and graded as follows: <0.4 poor reliability, 0.4-0.75 moderate reliability, and >0.75 excellent reliability. The statistical analysis was conducted with SPSS (v 22.0; IBM).

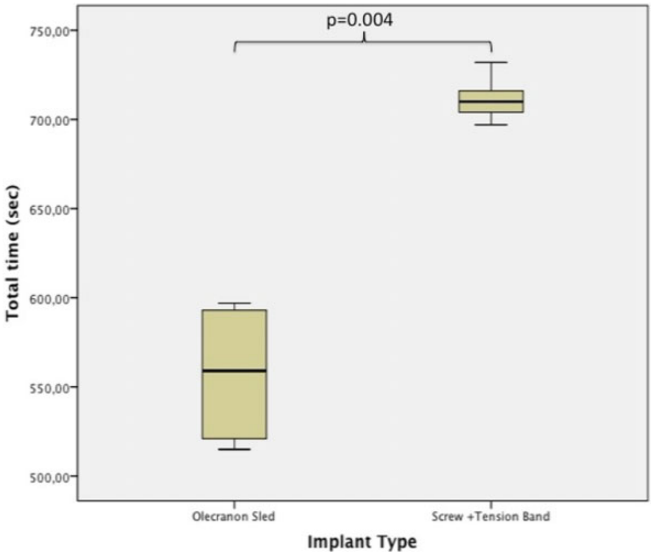

Figure 5. Box plot of time of fixation between the Olecranon Sled and intramedullary screw tension band fixation. Values are presented as median (line), interquartile range (box), and 95% CI (error bars).

RESULTS

The mean ± SD age of the specimens obtained (N = 12) was 66 ± 16 years. The mean bone mineral density was 0.503 ± 0.120 g/cm^2 for the Olecranon Sled group and 0.468 ± 0.177 g/cm^2 for the screw group, with no statistical significance between the groups (P = .290). One matched pair was excluded from final analysis in displacement and load to failure owing to fracture of the proximal osteotomy fragment after 20 cycles. Measurement of hardware prominence was performed prior to cyclic loading.

Time of Implantation

Time for creation of the osteotomy for the Olecranon Sled and intramedullary screw groups was 218 ± 24 seconds and 192 ± 10 seconds, respectively (P > .05). Implant placement was 339 ± 9 seconds for the Olecranon Sled and 344 ± 18 seconds for the intramedullary screw group (P > .05). For the intramedullary screw group, time for placement, measurement, and predrilling of the guide wire was 174 ± 24 seconds. Total procedural time was 712 ± 11 seconds for the intramedullary screw fixation with tension band, versus 557 ± 32 seconds for the Olecranon Sled group (Figure 5). While there was no significant difference in osteotomy time or time for implant placement between the groups, the total time for the procedure was significantly less for the Olecranon Sled group (P = .004). The 155-second mean difference between the groups can be attributed to the additional steps of guide wire placement, measurement, and

TABLE 1
Mean Prominence of Olecranon Sled vs Intramedullary Tension Band Construct[a]

	Tip, mm		Dorsum, mm		
Implant Type	Medial	Lateral	Medial	Lateral	Third Screw / Knot
Olecranon Sled (n = 6)	3.57 ± 0.403	3.20 ± 0.573	2.268 ± 0.499	2.874 ± 0.888	3.131 ± 0.711
Screw (n = 6)	7.288 ± 0.762	7.288 ± 0.764	2.149 ± 0.347	2.064 ± 0.654	4.476 ± 0.680
P value	.027[b]	.027[b]	.600	.116	.027[b]

[a]Values are presented as mean ± SD.
[b]Significant difference between groups following 500 N for 500 cycles to simulate pushing out of a chair.

predrilling required for the intramedullary screw tension band construct.

Implant Prominence

Measured from the tip of the olecranon, the prominence of the continuous loop tension band was 3.57 ± 0.4 mm medially and 3.2 ± 0.57 mm laterally. The intramedullary screw was significantly more prominent at 7.29 ± 0.76 mm (P = .027) when compared with both limbs of the Olecranon Sled (Table 1).

The medial dorsal prominence of the Olecranon Sled (see Figure 2B) was 2.27 ± 0.5 mm, and the lateral prominence was 2.87 ± 0.89 mm. The medial prominence of the tension band and intramedullary screw construct was 2.15 ± 0.35 mm and 2.06 ± 0.65 mm laterally. There was no significant difference between groups medially (P = .60) or laterally (P = .116) (Table 1). The mean prominence of the distal-most screw in the Olecranon Sled was 3.13 ± 0.71 mm, while the tension band knot was significantly larger at 4.48 ± 0.68 mm (P = .027). ICCs ranged from 0.884 to 0.954 for all measurements between observers.

Cyclic Loading

Active range of motion was simulated with cyclic loading of 0 to 10 N for 100 cycles. In all specimens, displacement was negligible at the dorsal ulna as well as the articular margin. All displacement was less than the threshold for the analytic software (0.1 mm) and therefore undetectable.

Specimens were then loaded to 500 N for 500 cycles to simulate the forces generated while pushing up from a chair. Both fixation techniques experienced more displacement dorsally than at the articular margin. The matching elbow repaired with the Olecranon Sled completed the protocol with 3.59-mm displacement dorsally and 0.80-mm displacement at the articular margin; however, this was not included in the final analysis (Table 2).

The Olecranon Sled allowed a mean dorsal displacement of 1.12 ± 0.58 mm and a mean displacement at the articular margin of 0.816 ± 0.30 mm (Table 2). The intramedullary screw and tension band construct allowed a larger mean dorsal displacement of 2.26 ± 1.72 mm and mean displacement at the articular margin of 1.67 ± 1.62 mm. However, these differences did not reach significance between the implants either dorsally (P = .225) or at the articular margin (P = .502) (Figure 6).

TABLE 2
Mean Load to Failure and Osteotomy Displacement[a]

	Olecranon Sled (n = 5)	Screw and Tension Band (n = 5)	*P*
Peak load to failure, N	1201.9 ± 432.2	1571.94 ± 383.67	.225
Displacement, mm			
Dorsal	1.12 ± 0.584	2.260 ± 1.722	.225
Periarticular	0.816 ± 0.302	1.666 ± 1.616	.502

[a]Values are presented as mean ± SD.

Load to Failure

There were no significant differences in load to failure between the groups (Table 2). Mean peak load to failure was 1201.9 ± 432.2 N for the Olecranon Sled group and 1571.94 ± 383.67 N for the intramedullary screw group (P = .225). With the Olecranon Sled, 5 of the 6 specimens failed because of implant cutout, while 1 was secondary to tendon failure. For the intramedullary screw with tension band group, 4 specimens failed owing to implant cutout, while the remaining 2 failed with either tension band or tendon failure. As mentioned previously, 1 specimen with intramedullary screw fixation failed during cyclic loading, as opposed to none of the Olecranon Sled specimens.

DISCUSSION

In this study, the Olecranon Sled device was compared with the traditional intramedullary screw and tension band construct. We found that the Olecranon Sled was equally as strong yet significantly less prominent when compared with the traditional fixation method.

Review of the fracture literature indicates that the traditional K-wire and tension band technique has had high rates of symptomatic hardware removal.[12,17] Its use in osteotomies has demonstrated lower rates of removal.[4,16] Coles et al[4] found an 8% incidence of symptomatic hardware requiring removal; however, another 21% of patients had their olecranon hardware removed in conjunction with another procedure. Ring et al[16] demonstrated that 24% of

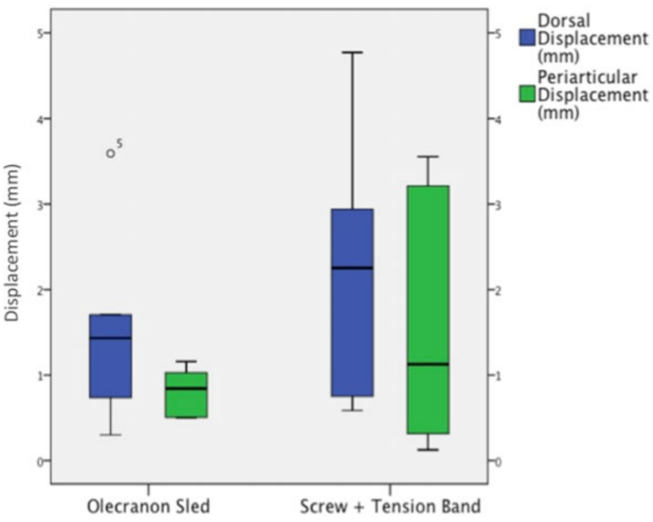

Figure 6. Box plot of dorsal and periarticular displacement measured during 500-N cyclic loading. Values are presented as median (line), interquartile range (box), and 95% CI (error bars).

their patient cohort required removal for symptomatic hardware. Other than a tension band construct, plate fixation may be used as well. Duckworth et al[6] compared outcomes between plate fixation and tension band wire fixation and found a significantly higher rate of symptomatic hardware in the latter (63% vs 38%, respectively). Jones et al[11] examined the use of two 4.0-mm cancellous screws in a biomechanical study and found no difference in cyclic loading or load to failure when compared with a K-wire tension band construct. Although this may provide a less prominent hardware alternative, the use of isolated 2 transcortical screws has not been demonstrated in clinical studies.[11]

The dorsal olecranon has a thin subcutaneous layer and is presumably the area of concern for most patients when it comes to palpable or symptomatic hardware. Dorsally, the most prominent aspect for the Olecranon Sled and intramedullary screw construct was the third screw and tension band knot, respectively. However, the Olecranon Sled was significantly less prominent than the intramedullary screw construct. No statistically significant difference was found in dorsal prominences between constructs. However, it is unknown whether the 0.8-mm difference in lateral dorsal prominence is clinically significant.

We found no significant difference in osteotomy displacement during either the active range of motion test or the "push up from a chair" test. It should be noted, however, that 1 specimen in the intramedullary screw group did fail with higher cyclic loading, as opposed to its matched pair in the Olecranon Sled group, which did not. There were also no significant differences in peak load to failure between groups.

Our findings of decreased hardware prominence in the Olecranon Sled may play an important clinical role in reducing symptomatic hardware removal. Clinically, there are limited reports on the use of the Olecranon Sled in the literature.[9,13] Iorio et al[9] reported their use of olecranon osteotomies repaired with the Olecranon Sled. Of 14 patients, 1 (7.1%) had symptomatic hardware requiring removal; this is far below tension band construct rates.[12,17] More recently, Lovy et al[13] retrospectively examined displaced olecranon fractures treated with the Olecranon Sled in 22 patients, with a minimum 1-year follow-up. They found that patients had a mean Disabilities of the Arm, Shoulder and Hand (DASH) score of 3.1 and there were no hardware-related complications at follow-up.[13]

There are several weaknesses to this study. The biomechanical nature of the study did not allow us to determine whether the differences found are clinically meaningful. For instance, although timing of implantation was significantly less for the Olecranon Sled, the 155-second difference is unlikely to account for any clinically significant difference. Also, since only 1 surgeon performed all procedures, extrapolating true time from this is difficult, as multiple measurements across surgeons would be needed to truly validate whether one procedure is more time-consuming than another. Another limitation was that 1 matched pair of elbows was excluded from the displacement and load-to-failure analysis owing to failure of the intramedullary screw during cyclic loading. Although this may have underpowered our analysis for displacement and load to failure, no differences were found in the remaining matched-pair groups. In addition, the standard deviation in displacement of the intramedullary screw and tension band group was higher than that seen in the literature.[2,8] These differences could be attributed to the sensitivity of the transducers or the variability in cadaveric specimens. However, even when these outliers were excluded, no difference in displacement persisted between groups. This leads us to believe that there is truly no difference between the implants.

Our study showed that fixation with the Olecranon Sled is equal to that of the traditional intramedullary screw and tension band construct. There was no difference in displacement during either cyclic loading or load to failure. In addition, the Olecranon Sled was significantly less prominent at the olecranon tip. With all of these aspects taken into consideration, the Olecranon Sled is an appealing alternative to the intramedullary screw and tension band construct. Further comparative clinical studies will be needed to determine if the difference in prominence results in a clinically significant difference in hardware irritation and need for reoperation.

REFERENCES

1. Baecher N, Edwards S. Olecranon fractures. *J Hand Surg Am*. 2013;38(3):593-604.
2. Carofino BC, Santangelo SA, Kabadi M, Mazzocca AD, Browner BD. Olecranon fractures repaired with FiberWire or metal wire tension banding: a biomechanical comparison. *Arthroscopy*. 2007;23:964-970.
3. Chalidis BE, Sachinis NC, Samoladas EP, Dimitriou CG, Pournaras JD. Is tension band wiring technique the "gold standard" for the treatment of olecranon fractures? A long term functional outcome study. *J Orthop Surg Res*. 2008;3:9.
4. Coles CP, Barei DP, Nork SE, Taitsman LA, Hanel DP, Bradford Henley M. The olecranon osteotomy: a six-year experience in the

treatment of intraarticular fractures of the distal humerus. *J Orthop Trauma*. 2006;20(3):164-171.

5. Dieterich J, Kummer FJ, Ceder L. The Olecranon Sled—a new device for fixation of fractures of the olecranon: a mechanical comparison of two fixation methods in cadaver elbows. *Acta Orthop*. 2006;77(3): 440-444.
6. Duckworth AD, Clement ND, White TO, Court-Brown CM, McQueen MM. Plate versus tension-band wire fixation for olecranon fractures: a prospective randomized trial. *J Bone Joint Surg Am*. 2017;99(15): 1261-1273.
7. Hak DJ, Golladay GJ. Olecranon fractures: treatment options. *J Am Acad Orthop Surg*. 2008;8(4):266-275.
8. Hutchinson DT, Horwitz DS, Ha G, Thomas CW, Bachus KN. Cyclic loading of olecranon fracture fixation constructs. *J Bone Joint Surg Am*. 2003;85:831-837.
9. Iorio T, Wong JC, Patterson JD, Rekant MS. Olecranon osteotomy fixation using a novel device: the Olecranon Sled. *Tech Hand Up Extrem Surg*. 2013;17:151-157.
10. Jensen CM, Olsen BB. Drawbacks of traction-absorbing wiring (TAW) in displaced fractures of the olecranon. *Injury*. 1986;17:174-175.
11. Jones TB, Karenz AR, Weignhold PS, Dahners LE. Transcortical screw fixation of the olecranon shows equivalent strength and improved stability compared with tension band fixation. *J Orthop Trauma*. 2014;28(3):137-142.
12. Karlsson MK, Hasserius R, Besjakov J, Karlsson C, Josefsson PO. Comparison of tension-band and figure-of-eight wiring techniques for treatment of olecranon fractures. *J Shoulder Elbow Surg*. 2002;11: 377-382.
13. Lovy A, Levy I, Keswani A, Rubin T, Hausman MR. Outcomes of displaced olecranon fractures treated with Olecranon Sled. *J Shoulder Elbow Surg*. 2018;27:393-397.
14. Macko D, Szabo RM. Complications of tension-band wiring of olecranon fractures. *J Bone Joint Surg Am*. 1985;67:1396-1401.
15. Murphy DF, Greene WB, Dameron TB. Displaced olecranon fractures in adults: clinical evaluation. *Clin Orthop Relat Res*. 1987;224: 215-223.
16. Ring D, Gulotta L, Chin K, Jupiter JB. Olecranon osteotomy for exposure of fractures and nonunions of the distal humerus. *J Orthop Trauma*. 2004;18:446-449.
17. Romero JM, Miran A, Jensen CH. Complications and re-operation rate after tension-band wiring of olecranon fractures. *J Orthop Sci*. 2000;5:318-320.
18. Saeed ZM, Trickett RW, Yewlett AD, Matthews TJW. Factors influencing K-wire migration in tension-band wiring of olecranon fractures. *J Shoulder Elbow Surg*. 2014;23:1181-1186.
19. Van der Linden SC, van Kampen A, Jaarsma RL. K-wire position in tension-band wiring technique affects stability of wires and long-term outcome in surgical treatment of olecranon fractures. *J Shoulder Elbow Surg*. 2012;21(3):405-411.
20. Wagener ML, Driesprong M, Heesterbeek PJ, Verdonschot N, Eygendaal D. Biomechanical evaluation of three different fixation methods of the chevron osteotomy of the olecranon: an analysis with roentgen stereophotogrammatic analysis. *Clin Biomech (Bristol, Avon)*. 2013;28(7):752-756.
21. Wilkinson JM, Stanley D. Posterior surgical approaches to the elbow: a comparative anatomic study. *J Shoulder Elbow Surg*. 2001;10: 380-382.
22. Woods BI, Rosario BL, Siska PA, Gruen GS, Tarkin IS, Evans AR. Determining the efficacy of screw and washer fixation as a method for securing olecranon osteotomies used in the surgical management of intraarticular distal humerus fractures. *J Orthop Trauma*. 2015; 29(1):44-49.