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# Biomechanical Analysis of a Novel Buried Fixation Technique Using Headless Compression Screws for the Treatment of Patella Fractures

Publish date: July 10, 2018

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Author Affiliation | **Disclosures**

**Authors' Disclosure Statement:** Dr. Alayan and Dr. Metzger report that they receive research support from Acumed; and Dr. Moon reports that he serves as a consultant for and receives research funding from Acumed. Funding for the study was provided by Acumed. The other authors report no actual or potential conflict of interest in relation to this article.

**Acknowledgments:** The authors would like to thank Lea Kanim, MS, for her work on the statistical analysis, and Mina Sadeghi for performing the dual-energy X-ray absorptiometry scans.

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## Take-Home Points

- Symptomatic implant removal rates are high after patella fixation with standard techniques.
- Novel buried technique may address the issue of symptomatic implants and is an attractive alternative.
- Both techniques withstand physiologic loads, but the buried technique had overall increased gapping and lower load to failure.
- The significance of these inferior results in clinical and functional settings has not been established.
- Long-term functional outcome studies will delineate the utility of the proposed new construct.

Patella fractures are common injuries that can cause considerable disability to the knee extensor apparatus.<sup>1-3</sup> Transverse patella fractures are the most common fracture pattern associated with patella fractures. {Harrell, 2003 #3}<sup>2</sup> Given that the patella plays a crucial role in knee extensor biomechanics, its proper integrity is vital for physiological knee motion and ambulation.<sup>4</sup> Traditionally, patella fractures with >2 mm of displacement have been managed with cannulated screws or Kirschner wires (K-wires) and a stainless-steel wire tension band.<sup>5-9</sup> The goal in the treatment of patellar fractures is to reduce fracture fragments accurately and to minimize additional insults to the articular cartilage.<sup>10</sup>

Despite advances in surgical protocols and acceptable radiographic outcomes, functional impairment remains common after the treatment of patella fractures. Functional impairment includes knee pain, screw head pain, implant removal, wire breakage, and patella baja.<sup>1</sup> The need for implant removal is one of the most common complications following the open reduction internal fixation of patella fractures.<sup>2,11</sup> The subcutaneous and exposed nature of the patella in conjunction with soft tissue irritation resulting from standard fixation (SF) predisposes the patient toward prominence and discomfort with the retained implant. Although nonunion rates are low, the rate of implant removal can reach as high as 52%.<sup>2,10-12</sup> To overcome some of these complications, we designed a novel buried fixation (BF) method for the treatment of transverse fractures. Our method minimizes the amount of exposed implant to improve patient comfort and potentially reduce the need for future implant removal. These effects are achieved by using headless compression screws and nonabsorbable sutures to attenuate the soft tissue irritation associated with traditional fixation.<sup>13</sup> While our novel technique has demonstrated improved clinical results, it has not been tested biomechanically against a traditional fixation technique. Therefore, this study aims to evaluate and compare the structural integrity of our novel BF technique with that of the standard technique that uses cannulated screws and wire tension band. We hypothesized that the stability provided by our technique would be similar to that provided by SF for transverse patella fractures.

## Materials and Methods

### Specimen Preparation

Thirteen matched pairs of fresh-frozen human cadaveric knees were obtained from a Cedars-Sinai approved tissue bank. Specimens were cut midfemur and were intact to the foot. Legs with major structural bony or ligamentous abnormalities, extensor mechanism disruption, or septic knees were excluded from testing. To assess the bone quality of each specimen prior to testing, dual-energy X-ray absorptiometry was performed using a GE Lunar iDXA scanner (GE Healthcare). Specimens were stored at  $-30^{\circ}\text{C}$  and thawed at room temperature for 24 hours prior to biomechanical testing.

A midline anterior approach to the patella was performed, and the extensor retinaculum, quadriceps tendon, and patellar tendon were exposed. A digital caliper was used to measure the craniocaudal and mediolateral dimensions of the patella, and a transverse osteotomy (Arbeitsgemeinschaft für Osteosynthesefragen/Orthopaedic Trauma Association [AO/OTA] type 34-C1) was created at the midway point between superior and inferior poles by using an oscillating saw. The retinaculum was then incised to the level of the midaxial line of the femur. One leg from each matched pair was allocated to the SF group, and the other was allocated to the BF group. Left and right legs were alternately assigned to each group to ensure that laterality was balanced between the 2 groups.

## Surgical Technique

The repair of the specimens in the SF group involved the use of 2 parallel 4.0-mm partially threaded cannulated screws (Acumed) and an 18-gauge monofilament steel wire (Ethicon) in a figure-eight tension band (**Figure 1A**). The repair of the specimens in the BF group involved the use of 2 parallel standard Acutrak headless compression screws (Acumed), a No. 2 FiberWire (Arthrex) in a figure-eight tension band, and a No. 5 FiberWire (Arthrex) was applied as cerclage around the patella (**Figure 1B**).

## Mechanical Testing

Mechanical testing was performed on a biaxial 370.02 Bionix Testing System (MTS Systems Corp.). The femur was rigidly and horizontally secured to a custom-built test frame, and the lower leg was left free to move. The quadriceps tendon was secured in a freeze clamp and was attached to the MTS actuator for loading via a pulley system such that raising the actuator was translated into a simulated quadriceps extensor force.

A differential variable reluctance transducer (DVRT) (Lord MicroStrain) was placed across the osteotomy site to measure the distraction, or gap, across the fracture line. The minimum load to full extension for each specimen was then determined under a slow, controlled increase in load until the leg was in a fully extended position. Any distraction across the fracture line during the initial loading phase was determined by using digital calipers. The specimen was then subjected to a preconditioning phase with 10 cycles from 0 N to full extension under the previously determined load, which was applied at the rate of 5 N/s. Meanwhile, displacement across the fracture site was recorded via the DVRT. Following the preconditioning phase, each specimen was then tested to failure in displacement control at the rate of 1.5 mm/s. Failure was defined as implant failure (screw pullout) or DVRT gapping across the osteotomy site >3 mm.<sup>10,14</sup>

Outcome measures included stiffness (N/mm), which was calculated as the slope of the linear change in load from full extension to failure vs DVRT displacement during the final loading phase; failure load (N); gapping (mm) across the osteotomy site at each cycle during the preconditioning phase; and failure mode (pullout vs >3.0 mm gap).

## Statistical Analysis

An a priori power analysis revealed that 13 knees per group would be required to obtain an  $\alpha$  of 0.05 and a power of 0.80. This calculation was based on a 20% difference in fracture displacement calculated by using the standard deviation and mean previously reported for cannulated screws with nonabsorbable sutures.<sup>14</sup>

Means and standard deviations for all dependent outcome measures were computed and compared across the independent measure of fixation type (BF vs SF) through repeated measures Analysis of variance (ANOVA-GLM, SAS 9.3, SAS Institute, Inc.) after controlling for bone mineral density (BMD), gender, and age. Multivariate repeated-measures ANOVA with Tukey's studentized range was applied to cyclic gap data. The mode of failure was compared across fixation type (BF vs SF) for matched data using McNemar's test. Intracorrelations were computed and examined over all data and separately on the basis of screw fixation type (BF vs SF). All tests were considered statistically significant when  $P < .05$ .

## Results

Specimen donors were 46% (6/13) male with an average age of 78.5 years ( $\pm 13.77$ ; range, 56-91 years) and 54% (7/13) female with an average age of 76.57 years ( $\pm 14.37$ ; range, 59-102 years). Average BMD was significantly lower in female ( $0.71 \pm 0.18$ ) than in male specimens ( $1.15 \pm 0.33$ ) ( $P < .05$ ).

The average load to full extension across all specimens was 272 N ( $\pm 54$ ; range, 160-360 N) and was well balanced across matched pairs ( $270 \pm 56$  N for BF and  $273 \pm 54$  N for SF). Of the 13 BF specimens, 4 experienced distraction across the fracture line during the determination of the minimum load to full extension. This initial pretest gap was measured with digital calipers (average, 1.5 mm; range, 0.90-1.85 mm) and added as an offset to the respective DVRT displacement data recorded during testing.

The total number of specimens included in the displacement data calculations decreased from 13 to 11 per group because DVRT data were not recorded during cyclic loading for 1 specimen and were considered unreliable in another. The maximum displacement measured across the fracture site during cyclic loading was significantly higher in the BF ( $0.94 \pm 1.21$ ) group than in the SF group ( $0.19 \pm 0.26$ ) as shown in the **Table**. The average slope of the gap per cycle for each specimen was calculated and compared between the BF and SF groups. The BF group demonstrated a significantly greater increase in gap per cycle than the SF group (**Figure 2**). Stiffness during load to failure was calculated for all but 1 specimen that did not display any measurable displacement during the final loading cycle. The average final stiffness and failure load between the BF and SF groups were not significantly different (Table). An equal number of specimens in both groups failed through gapping (6/13) and pullout (7/13).

Failure load was significantly positively correlated with BMD ( $R = 0.62$ ,  $P < .001$ ) when all specimens were grouped together. When analyzed separately, the SF group was significantly correlated with BMD ( $P < .01$ ), whereas the BF group had a marginally significant correlation ( $P = .06$ ) with BMD (**Figure 3**). In both groups, BMD was positively correlated with stiffness and negatively correlated with gapping. Neither of these trends, however, was significant.

## Discussion

We proposed a novel BF technique for the treatment of noncomminuted transverse patella fractures. Our technique utilizes headless cannulated compression screws and nonabsorbable suture tension bands. We then biomechanically compared our proposed technique with an established fixation technique that uses partially threaded cannulated screws and stainless steel wire tension bands. We hypothesized that the mechanical response of the BF technique to cyclic and failure loading would be similar to that of the SF technique. Our results demonstrate a significant increase in gap formation across the fracture site among knees and an overall reduced load to failure in the BF group (Figure 2). Whether these inferior results manifest clinically is not yet established. Both constructs could withstand forces that are typically experienced during the postoperative period. Given the high rate of symptomatic implant removal associated with the traditional technique, the low-profile buried technique might be an attractive alternative that provides increased patient comfort but may require an extended period of postoperative protection against bony ingrowths.

Patellar fixation constructs that use a combination of cannulated screws and a wire tension band provide the best resistance to patella fracture displacement when compared with screws or wires alone.<sup>4,15</sup> Although this combination is biomechanically favorable, the steel wire often causes the painful irritation of the surrounding soft tissues and can break or migrate, thus increasing the rates of implant removal surgery to as high as 52%.<sup>4,10,12,15</sup>

We developed our novel BF technique, which uses headless compression screws and a No. 2 FiberWire tension band, to address the high rates of reoperation and patient dissatisfaction associated with the SF technique.

Headless compression screws have been successfully used in the reduction and fixation of scaphoid fractures and sesamoid fractures.<sup>16,17</sup> The pull-out strengths of these screws are comparable with those of other commonly used screws, such as Twinfix and Herbert-Whipple screws.<sup>16</sup> Similarly, the strength of a No. 5 FiberWire is comparable with that of an 18-gauge stainless-steel wire.<sup>14,18</sup> Several studies have also obtained good outcomes with nonmetallic constructs that use nonabsorbable sutures alone.<sup>19,20</sup> In this study, we utilized a No. 2 FiberWire as the tension band. The use of the No. 2 FiberWire facilitated threading through headless cannulated screws and created a low-profile knot. However, the use of thin FiberWire, despite a No. 5 FiberWire cerclage, likely contributed to the increase in distraction across the fracture.

The highest patellofemoral joint reaction force during level walking is approximately 35 kg (half body weight), which is equivalent to 350 N.<sup>15,21,22</sup> This force is similar to the average cyclic load used in this experiment ( $272 \pm 54$  N). Gapping increased in the BF group but did not reach the defined failure value of 3 mm, and the ultimate load to failure was relatively high across both groups (SF, 1123 N; BF, 973 N). These results suggest that both fixation methods can withstand the typical patellofemoral joint forces that are experienced during the postoperative period.<sup>4</sup> In addition, in a clinical setting, patients are placed in hinged knee braces for at least 2 weeks to limit their flexion angle and to allow for healing and bony ingrowth. Postoperative knee-brace protection presumably increases the overall strength of the fixation.

The number of specimens ( $n = 26$ ) evaluated in this study was greater than that used in other biomechanical patella fracture studies.<sup>14</sup> Furthermore, none of our specimens were reused. Our study design was further strengthened given that fellowship-trained trauma surgeons performed all surgical procedures. Finally, the data collection and analysis of numerous clinically relevant factors, such as BMD, age, and cyclical loading, contributed to the comprehensive description of each technique with respect to patient-specific criteria.

Similar to all cadaveric studies, our data only represent the immediate postoperative condition and does not represent any healing that would occur during postoperative rehabilitation. Postoperative knee-brace protection and bone healing across the fracture site would likely strengthen both constructs in a clinical setting. In addition, the average age of our specimens is 77.5 years, and therefore does not best represent the age range (20-50 years) of the typical adult population affected by patella fractures.<sup>3,23,24</sup> Finally, postsurgical reduction was confirmed through visual inspection and not through fluoroscopy as in a clinical setting. Radiographic images were obtained after each experiment only to confirm screw placement post facto (**Figures 4A, 4B**).

## Conclusion

This study demonstrates the utility of a novel BF technique. Nevertheless, the proposed technique exhibited increased gapping and a lower load to failure than the current gold standard. The significance of these inferior results in clinical and functional settings has not been established. The proposed BF technique may be an appealing alternative to the SF technique given its low profile and potential to reduce the rates of future implant removal. Further studies on the long-term outcomes of patients treated through the BF technique are currently under way and will ultimately determine the utility of the proposed construct.



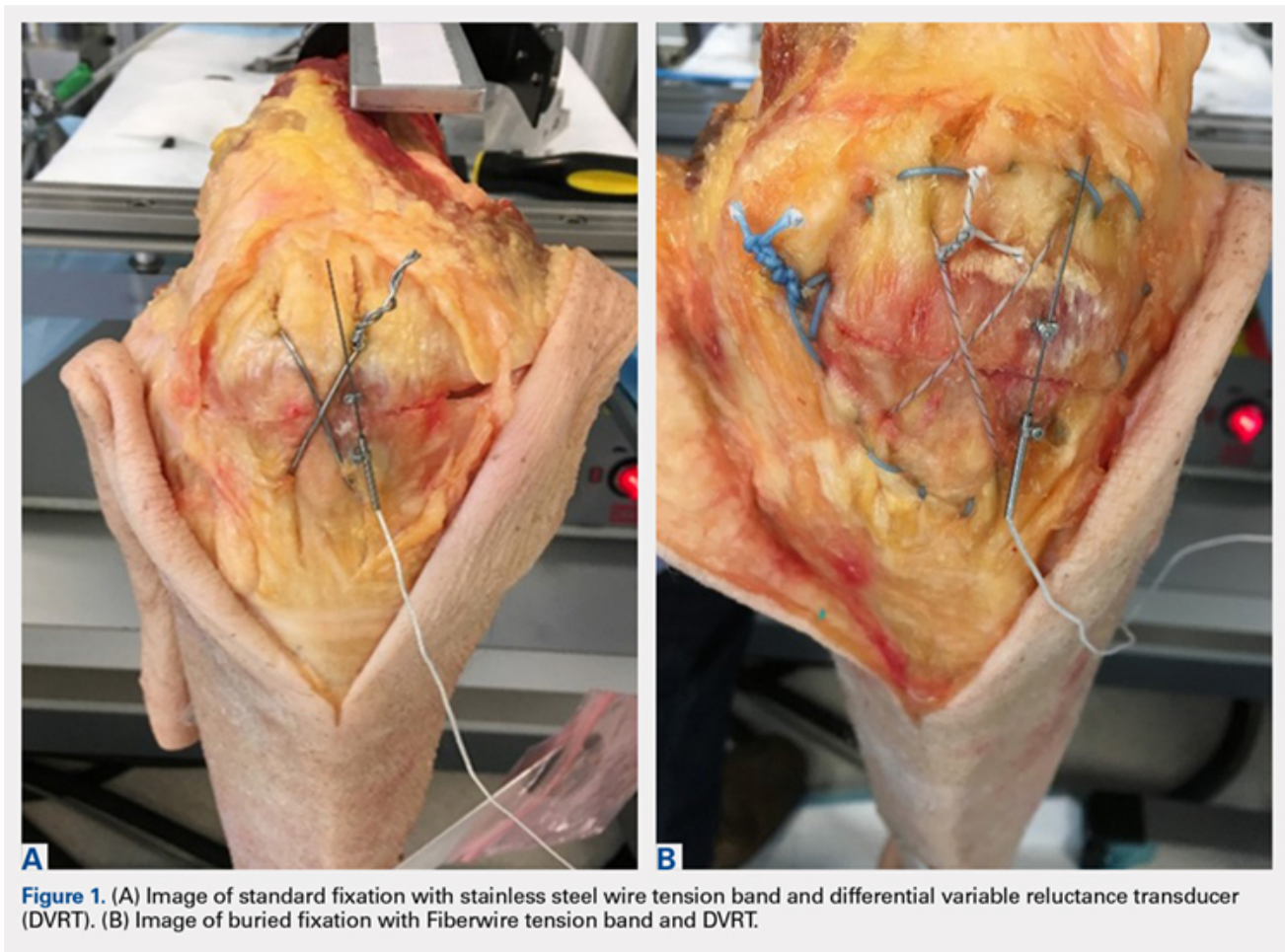
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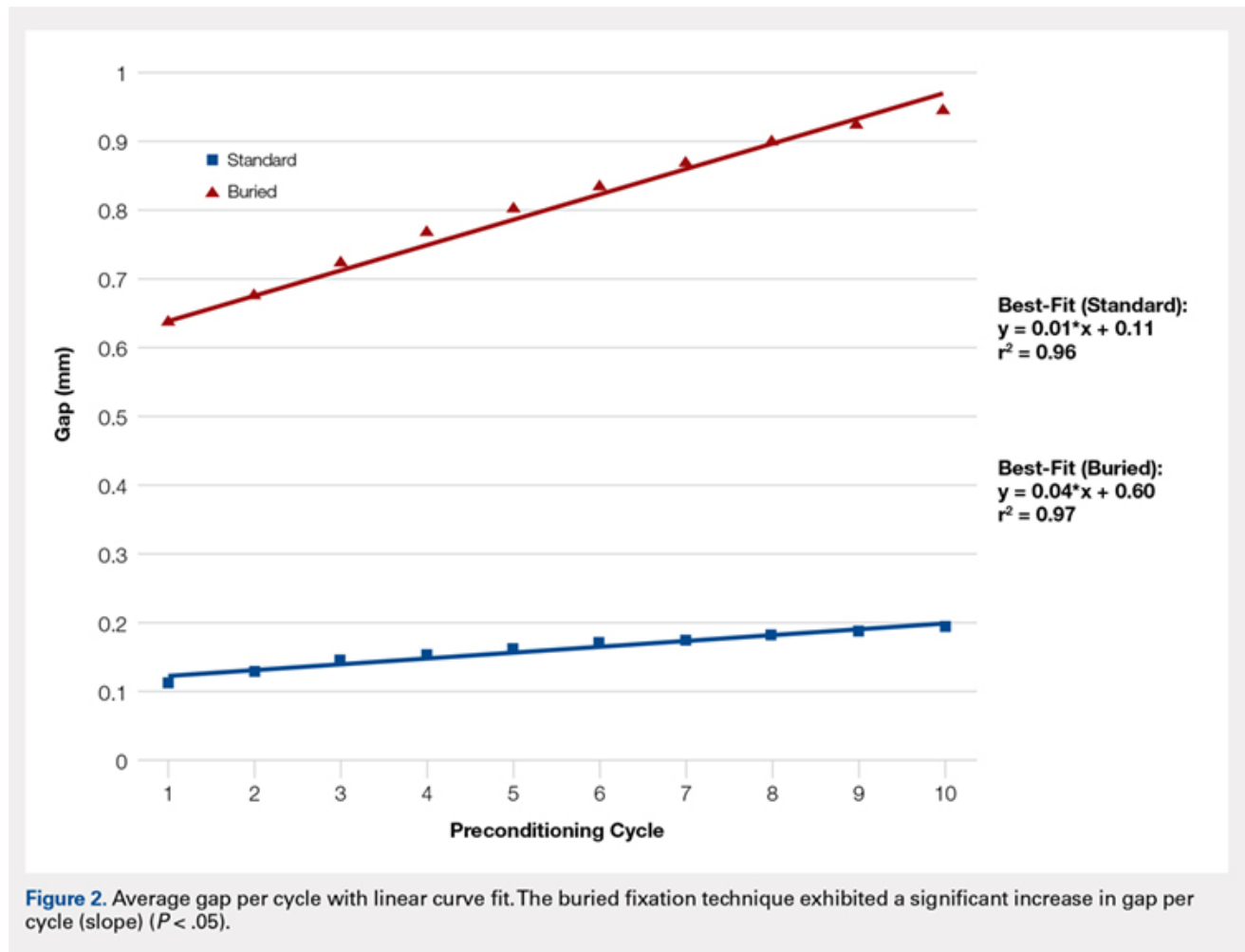
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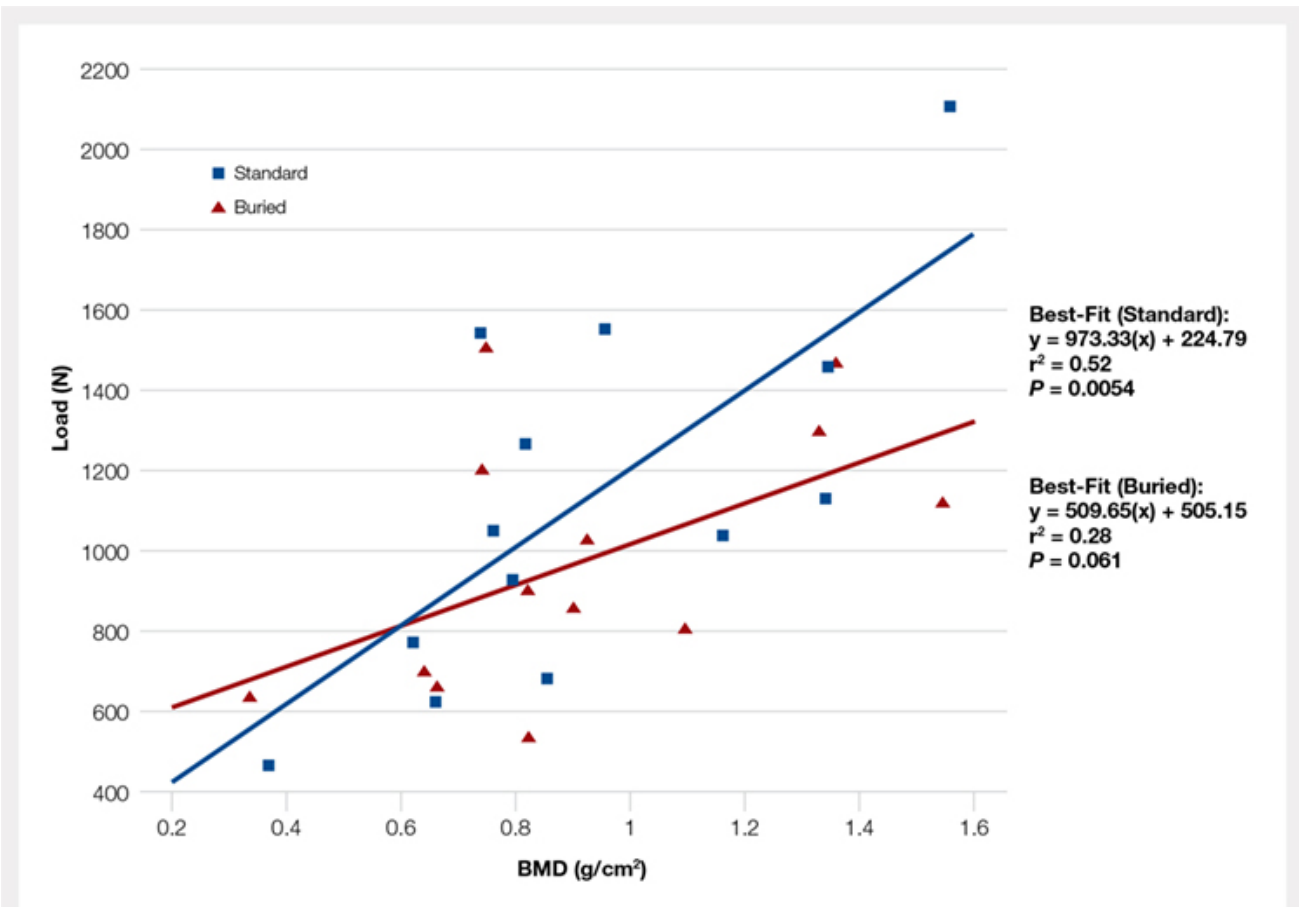
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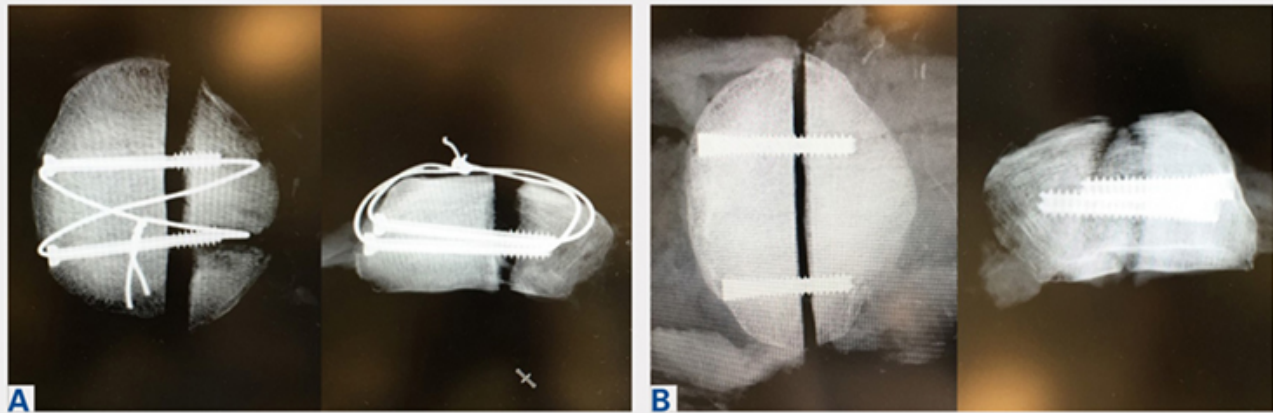
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**Figure 3.** Linear regression and associated correlation coefficients for bone mineral density (BMD) vs failure strength. BMD was significantly correlated with standard fixation ( $P < .01$ ) and was marginally ( $P = .06$ ) positively correlated with buried fixation.

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**Figure 4.** Anteroposterior and lateral postfacto X-ray of (A) the standard fixation patella specimen illustrating the prominent wire that often requires removal given patient discomfort, and (B) the buried fixation patella specimen illustrating that buried screws lack implant prominence.

**Table.** Means and Standard Deviations of the Main Outcome Measures

	<b>Standard Fixation</b>	<b>Buried Fixation</b>	<b>N</b>	<b>P-value</b>
<b>Load at Failure (N)</b>	1112.78 ± 457.25	973.20 ± 321.38	13	0.265
<b>Final Stiffness (N/mm)</b>	358.42 ± 165.45	445.33 ± 310.09	11	0.175
<b>Max Cyclic Gap (mm)</b>	0.19 ± 0.26	0.94 ± 1.21	11	0.026 <sup>a</sup>
<b>Pullout: Gap Failure (ratio)</b>	7:6	7:6	13	NS

<sup>a</sup>Indicates statistical significance ( $P < .05$ ).

Abbreviation: NS, not significant.

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Alisa Alayan, MD Ruben Maldonado, BS Landon Polakof, MD Atul Saini, DO Melodie Metzger, PhD Carol Lin, MD, MA Charles Moon, MD . Biomechanical Analysis of a Novel Buried Fixation Technique Using Headless Compression Screws for the Treatment of Patella Fractures . *Am J Orthop*.  
Publish date: July 10, 2018

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