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Percutaneous screw fixation of the pubic symphysis versus plate osteosynthesis: a biomechanical study

David E. O'Neill, MD[a,*], Hallie R. Bradley, MD[a], Brandon Hull, MD[b], William Pierce, BS Eng[c], Ishvinder S. Grewal, FRCS[a], Adam J. Starr, MD[a], Ashoke Sathy, MD[a]

Abstract

Objectives: To compare the stability of screw fixation with that of plate fixation for symphyseal injuries in a vertically unstable pelvic injury (AO/Tile 61-C1) associated with complete disruption of the sacroiliac joint and the pubic symphysis.

Methods: Eight fourth-generation composite pelvis models with sacroiliac and pubic symphyseal disruption (Sawbones, Vashon Island, WA) underwent biomechanical testing simulating static single-leg stance. Four were fixed anteriorly with a symphyseal screw, and 4 with a symphyseal plate. All had single transsacral screw fixation posteriorly. Displacement and rotation were monitored at both sacroiliac joint and pubic symphysis.

Results: There was no significant difference between the 2 groups for mean maximum force generated. There was no significant difference in net displacement at both sacroiliac joint and pubic symphysis. There was significantly less rotation but more displacement in the screw group in the *Z*-axis. The screw group showed increased stiffness compared with the plate group.

Conclusions: This is the first biomechanical study to compare screw versus plate symphyseal fixation in a Tile C model. Our biomechanical model using anterior and posterior fixation demonstrates that symphyseal screws may be a viable alternative to classically described symphyseal plating.

Keywords: biomechanical, pelvis, fixation, pubic symphysis, percutaneous, Tile C, symphyseal fixation, pelvic ring

1. Background

Percutaneous reduction and fixation of pelvic ring fractures are accepted as safe and effective methods of treatment.[1] The fixation of posterior ring injuries with iliosacral and transsacral screws is widely described, and the percutaneous repair of iliac wing and superior ramus fractures is now in common use.[2–4]

Currently, most surgeons repair unstable symphyseal injuries using open reduction and plate fixation using a Pfannenstiel approach. This technique is effective but not without complications. There is a significant risk of infection in obese patients.[5,6] Percutaneous fixation of the pubic symphysis has been described by researchers in China and Spain.[7–13] In 2009, Mu et al[8] reported a series of patients with symphyseal injuries treated with percutaneous screw fixation inserted using navigation. Cano-Luis et al[12] and Lazaro Gonzalvez et al[9] conducted biomechanical studies evaluating symphyseal screw fixation in Tile type B1 injuries. Clinical results of percutaneous symphyseal screw fixation from China are promising, showing less blood loss, better functional outcomes, shorter operative times, and equivalent rates of implant failure.[10,11,13]

The purpose of our biomechanical study was to compare the 3-dimensional displacement of screw fixation with that of plate fixation for symphyseal injuries in a vertically unstable pelvic injury (AO/Tile 61-C1) associated with complete disruption of the sacroiliac joint and the pubic symphysis. To the best of our knowledge, this is the first biomechanical study to perform this comparison in the setting of a complete posterior ring injury stabilized with a transsacral screw. Our hypothesis was that symphyseal screw fixation would have comparable strength of fixation and stability of fixation to symphyseal plate fixation.

2. Materials and Methods

Eight fourth-generation composite pelvis models (Sawbones, Vashon Island, WA) were used to create a vertically unstable pelvic injury. These came prefabricated with an incompetent unilateral SI joint and disrupted pubic symphysis to replicate an unstable unilateral type C1 fracture (AO/Tile 61-C1). Sawbones were chosen for analysis in this study because they have more uniformity/less variability than the cadaver bone, which makes it easier to demonstrate a significant difference in fixation strengths between the 2 methods of fixation. Their use in biomechanical studies of the pelvis is well described in the literature.[14–18] The material properties of cadaveric specimens can differ based on disease, diet, age, sex, and a host of other factors.

All specimens were anatomically reduced under direct visualization with clamps and stabilized posteriorly with a single

[a] Department of Orthopaedic Surgery, University of Texas Southwestern Medical Center, Dallas, TX, [b] OU Health, Oklahoma City, OK; and [c] Department of Orthopaedic Surgery, Texas Scottish Rite Hospital for Children, Dallas, TX.

*Corresponding author. Address: Department of Orthopaedic Surgery, University of Texas Southwestern Medical Center, 5200 Harry Hines Blvd, Dallas, TX 75235. E-mail: david.oneill@phhs.org.

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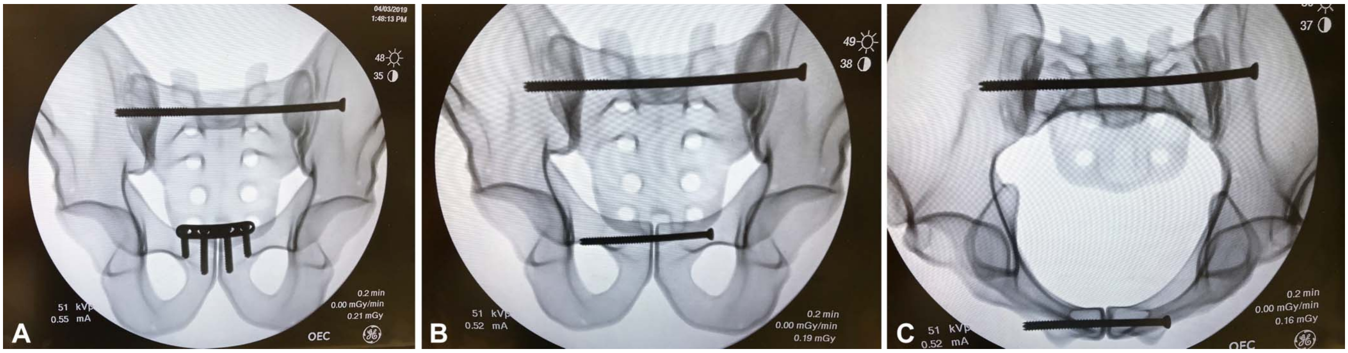

Figure 1. A, AP projection of pelvis model with symphyseal plate and sacroiliac screw. B, AP projection of pelvis model with symphyseal screw and sacroiliac screw. C, Inlet projection of pelvis model with symphyseal screw and sacroiliac screw.

cannulated partially threaded stainless steel 6.5 mm × 150 mm (46-mm thread) S1 transsacral screw (Smith & Nephew, Memphis, TN). In 4 specimens, the anterior ring was stabilized with a 4-hole pubic symphysis plate (Smith & Nephew, Memphis, TN) with 4 solid 6.5-mm fully threaded cancellous screws. The pubic symphysis in the other 4 specimens was stabilized with a single partially threaded stainless steel 6.5 mm × 90 mm (46-mm thread) cannulated screw inserted in a transverse manner (Figs. 1A–C) (Smith & Nephew, Memphis, TN). This provided bicortical fixation. All specimens underwent fluoroscopy to verify reduction and implant placement. As shown in Figs. 1B and C, the pubic symphyseal screw was advanced through the far cortex to ensure maximum purchase despite the small risk of screw prominence.

We created a single-leg stance model similar to previously described models,[14,19–22] with elements used from other biomechanical models.[19,20,23,24] Each pelvis was securely attached to the material testing system (Bionix 858, MTS, Eden Prairie, MN). Hip abductor muscle function was represented by maintaining a level pelvis by adjusting the tension on the ilium using a turnbuckle. A 44-mm Delrin plastic sphere was used to simulate the femoral head (Fig. 2). This model was chosen to simulate maximum forces seen by the pelvis during ambulation.

Each specimen was loaded in stroke control by applying a vertical compressive displacement of 7 mm through the sacrum at a rate of 0.2 mm/s. This was repeated 5 times for each specimen while the tension on the ilium was adjusted between each cycle to preserve alignment and keep the hemipelvis level. Stiffness was measured at maximum stroke distance. Our particular material testing system was unable to load in load control, so we chose a stroke control model.

Relative 3-dimensional (3D) (Rx, Ry, Rz, dX, dY, dZ) motion was monitored at the sacroiliac (SI) joint and pubic symphysis by using a pair of infrared rigid body markers placed on either side of the disrupted symphysis and SI joint, respectively.[9] The motion

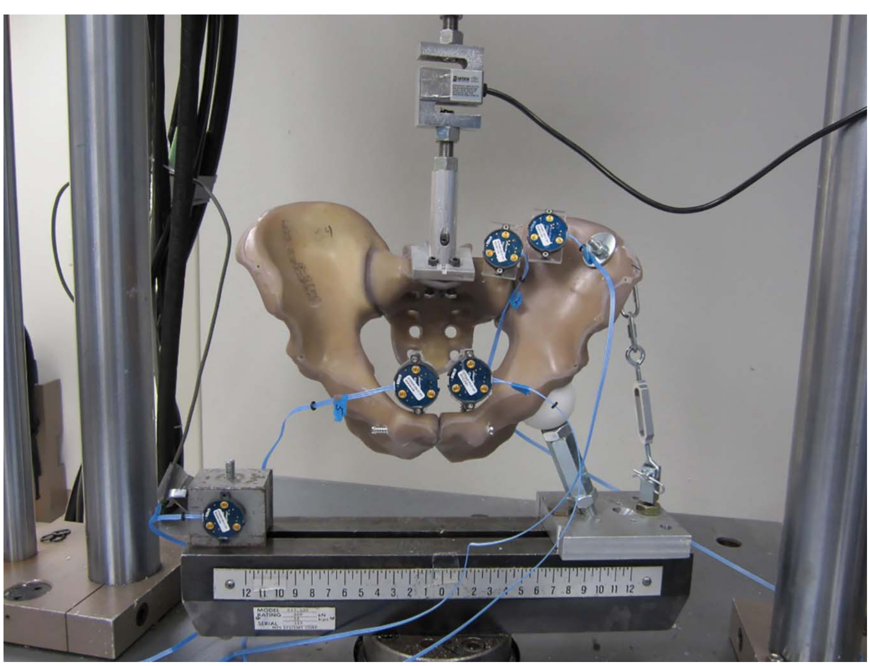

Figure 2. Pelvis model testing apparatus with Delrin sphere femoral head and turnbuckle used for abductor tensioning.

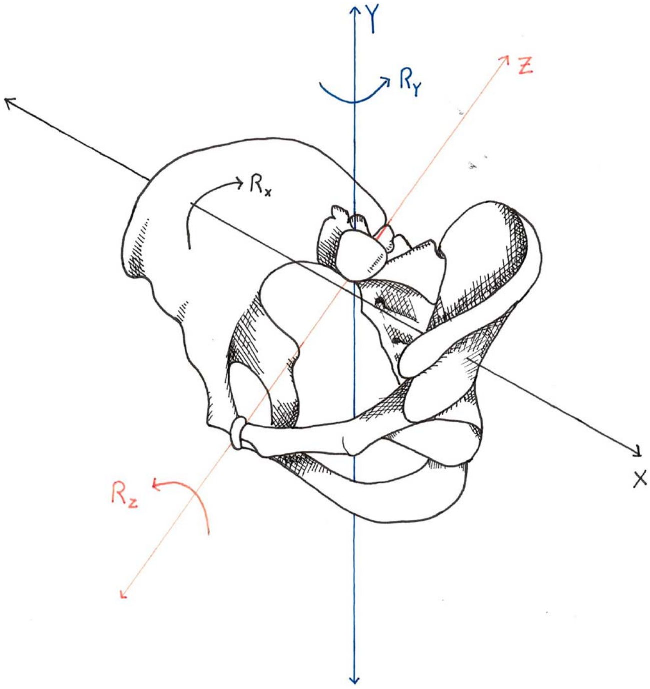

Figure 3. Schematic of axes of rotation and motion as measured.

was tracked and recorded with the Optotrak 3D motion capture system (Northern Digital Inc., Waterloo, ON, Canada). The Optotrak system has an accuracy of 0.1 mm and contains 3 motion sensors in the array. Using the Optotrak software, we were able to analyze displacement and rotation in 3 dimensions. x-Axis displacement is medial-lateral, y-axis displacement is vertical, and z-axis displacement is anteroposterior. x-Axis rotation represents flexion/extension in the sagittal plane, y-axis rotation represents internal/external rotation in the axial plane, and z-axis rotation represents abduction/adduction in the coronal plane (Fig. 3).

3. Results

The mean maximum force generated with 7 mm of stroke control testing was 1213 N in the screw fixation group versus 1196 N in the plate fixation group. This difference was not statistically significant ($P = 0.8$). Paired Student t tests were used to determine statistical significance between samples.

There was significantly less displacement at the symphysis in the y-axis (vertical) in the screw group ($P < 0.05$). No differences in displacement were seen in the x-axis (medial-lateral). There was significantly more displacement in the z-axis (anteroposterior) in the screw group at both joints ($P < 0.05$) (Fig. 4A). There was no significant difference in net displacement at either joint between the 2 groups.

There was no difference in rotation at either joint in the x-axis (flexion/extension) or y-axis (internal/external rotation). In the z-axis (abduction/adduction), however, there was significantly less rotation at both joints in the screw group ($P < 0.05$) (Fig. 4B).

The screw fixation group showed increased stiffness at the SI joint ($P < 0.05$) (Fig. 5A). The difference in stiffness at the pubic symphysis was not significant ($P = 0.14$) (Figs. 5B).

4. Discussion

To the best of our knowledge, our work is the first biomechanical study to compare screw fixation with plate fixation for symphyseal injuries in a vertically unstable Tile type C model with a complete posterior ring injury. A Tile C injury is described as a high-energy pelvic ring injury found to be both rotationally and vertically unstable. The biomechanical stability of the symphyseal screw construct was comparable with that of the plate construct (Fig. 5).

We found that 7 mm of stroke control testing generated a force of approximately 1200 N. This is similar to the model used by Yinger et al[22] which simulated single-leg stance with a 1000 N pelvic load, and that of Pohlemann et al,[20] which used loads up to 1181 N. We should mention that these forces in the laboratory are significantly higher than those seen in vivo if a patient was following foot-flat weight-bearing precautions with an assistive device.

Our study complements and adds on what has been shown by researchers in China and Spain.[7–13] Yu et al[13] and Yao et al[7] conducted biomechanical studies using finite element analysis. They found similar biomechanical properties between symphyseal screw and plate constructs. Only 2 cadaveric biomechanical studies have been performed to date.[9,12] In 2012, Cano-Luis et al[12] showed that anterior fixation with two 6.5-mm cannulated screws restored symphyseal biomechanics to that of an uninjured state in a B1 cadaveric model using 10 specimens simulating static double-limb stance. In their study, they axially loaded the cadaveric

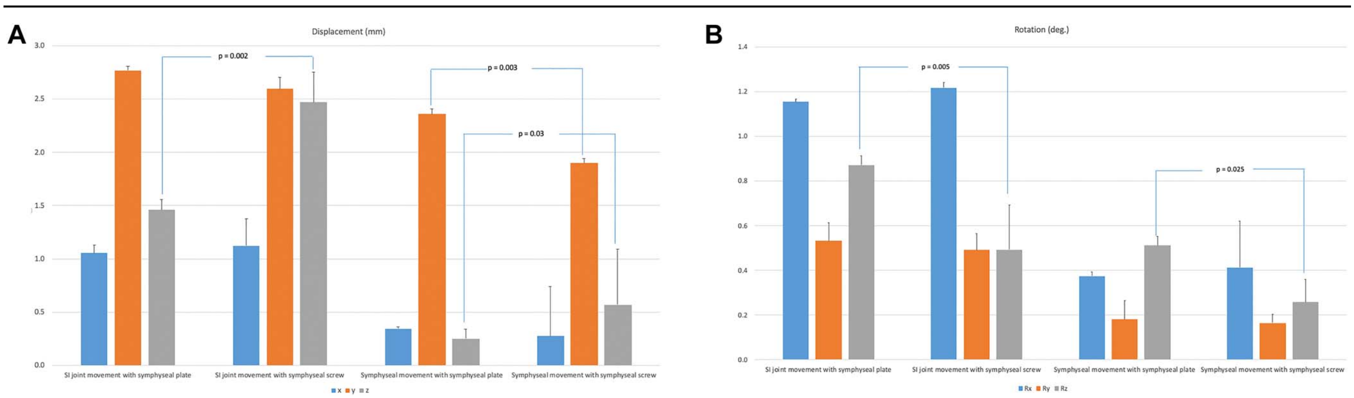

Figure 4. A, Displacement in millimeters as measured using the testing apparatus. B, Rotation in degrees as measured using the testing apparatus.

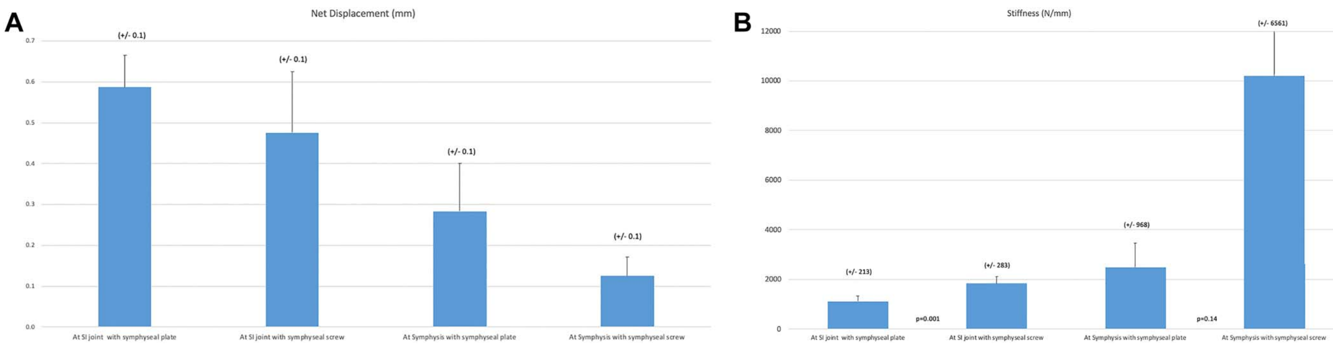

Figure 5. A, Net displacement of the tested hemipelvis. B, Stiffness N/mm of the testing construct.

specimen at 300 N and observed no differences in displacement or rotation between the intact cadaver specimen and those that were fixed with screw osteosynthesis. In 2016, Lazaro Gonzalvez et al[9] compared two 6.5-mm partially threaded titanium cannulated screws with 6-hole 3.5-mm plating in 9 cadavers with a B1 injury. Using a static double-limb stance model, they showed that the screw group restored physiologic stability to the pubic symphysis, whereas the plate group did not. They also showed that only the screw group restored rotational stability in the *y* and *z* axes.

Our study has notable differences from that of Lazaro Gonzalvez et al.[9] Our model replicates single-leg stance as opposed to double-limb stance. Single-leg stance results in compression across the pubic symphysis, whereas double-limb stance results in distraction. Our model has a complete posterior SI joint disruption that is stabilized with a transsacral cannulated screw. We believe this is more similar to standard fixation strategies used for unstable pelvic ring injuries. Posterior fixation is always recommended for an unstable posterior ring because posterior motion is best addressed with posterior fixation.[2,26] We used a Sawbones model (fourth-generation composite bone) rather than the cadaveric bone. This model has been identified as a suitable substitute for the cadaver bone because of its reproduction of the biomechanical properties of human bone.[18] Synthetic bone models have been used in numerous recent biomechanical studies of the pelvis.[14,15,19,22] They allow for consistent comparisons by eliminating the variability seen among cadaver specimens because of disease, diet, age, sex, and a host of other factors. Simonian et al[25–27] in their comparison of multiple plate fixation methods found significant reduction in motion with all plate constructs but supraphysiological motion in all but a “box plate” construct. Our model uses a 6.5-mm plate as opposed to a 3.5-mm plate and a single symphyseal screw versus dual screws. Accounting for these differences, we also found better rotational control in the *z*-axis in the screw group.

Our sample size of 8 is small, but comparable with many other previous studies that had total sample sizes ranging from 5 to 10 specimens.[9,12,20–24] Because Sawbones fourth-generation composite bone represents a strong healthy bone, one limitation is the inability to generalize our findings to osteopenic bone. In addition, because specimens were anatomically reduced under direct visualization, we are unable to generalize our findings to non-anatomic reductions. Early failure of anterior constructs is well described and may affect in vivo results.[28] As cyclic loading was not performed, whether there may be a potential difference in fatigue failure over time is unknown. It is also unclear how certain variables would affect the biomechanical strength of the construct: number of symphyseal screws, configuration of symphyseal screws, partially threaded versus fully threaded screws, etc. Future biomechanical studies could help answer these questions. Ultimately, more comparative clinical studies will help answer the question of optimal symphyseal reduction and fixation techniques.

5. Conclusion

This is the first biomechanical study to compare screw versus plate symphyseal fixation in a Tile C model. Our biomechanical model using anterior and posterior fixation demonstrates that symphyseal screws may be a viable alternative to classically described symphyseal plating. Our study confirms the need for further research on this topic.

Acknowledgments

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