Biomechanical Study of 4-hole Pubic Symphyseal Plating: Locked Versus Unlocked Constructs

MARK L. PRASARN, MD; GREG ZYCH, DO; GREG GASKI, MD; DINAH BARIA, MS; DAVID KAIMRAJH, MS; TED MILNE, BS; LOREN L. LATTA, PHD

abstract

Full article available online at Healio.com/Orthopedics. Search: 20120621-15

To the authors’ knowledge, no published studies have examined the use of locking plates on injuries of the anterior pelvic ring. The purpose of this study was to determine whether locked plates provide enhanced stability in the treatment of pubic symphyseal disruptions.

Completely unstable pelvic injuries were simulated in pelvic Sawbones (model 1301; Pacific Research Laboratories, Vashon, Washington) and 2 different fixation constructs used for anterior fixation (4-hole, 3.5-mm pubic symphysis plate with all locked or all unlocked screws). Adjunctive sacroiliac screw fixation with a single 7.3-mm screw placed into S1 was used in all specimens. Specimens were analyzed for motion at the pubic symphysis and sacroiliac joints using a Material Testing System (MTS Systems Corporation, Eden Prairie, Minnesota). Each specimen was subjected to compressive loading in a single-limb stance. Side loading was also examined. The main outcome measurement was motion at the pubic symphysis and sacroiliac joints and overall construct stiffness. No significant difference existed in overall construct stiffness between the 2 methods of pubic symphysis fixation. The motions at the pubic symphysis or injured sacroiliac joints were not significantly different. In addition, motion at the pubic symphysis joint with lateral load was not improved with a locking construct.

No significant difference existed between 4-hole locked or unlocked constructs used for fixation of the pubic symphysis. No apparent advantage of locking screws exists for disruptions of the pubic symphysis, and recent reports have questioned the possibility of catastrophic failure.

---

Dr Prasarn is from the Department of Orthopaedics and Rehabilitation, University of Texas, Houston, Texas; Drs Zych and Gaski are from the Department of Orthopaedics and Rehabilitation, University of Miami, and Ms Baria, Messrs Kaimrajh and Milne, and Dr Latta are from Max Biedermann Institute of Biomechanics, Miami Beach, Florida.

Drs Prasarn, Zych, Gaski, and Latta, Ms Baria, and Messrs Kaimrajh and Milne have no relevant financial relationships to disclose.

Correspondence should be addressed to: Mark L. Prasarn, MD, Department of Orthopaedics and Rehabilitation, University of Texas, 6400 Fannin, Ste 1700, Houston, TX 77030 (markprasarn@yahoo.com).

doi: 10.3928/01477447-20120621-15
Controversy exists regarding the optimal fixation construct in the treatment of disruptions of the pubic symphysis. Many authors have advocated external fixation, whereas others have promoted various internal fixation techniques. In addition, an internal anterior fixator (InFix) has recently been proposed. Those in favor of open reduction and internal fixation state that by avoiding external fixation, patients are more comfortable, and pin-tract complications are avoided. Regardless of the modality used, it has been demonstrated that adjunctive anterior fixation enhances overall pelvic ring stability and improves healing and the maintenance of reduction.

Various types of internal fixation have been advocated, including cerclage wiring, suture fixation, single or double plate and screw constructs, and box plate constructs. Although some authors have promoted 2-hole plate and screw constructs, Sagi and Papp reported improved clinical outcomes for patients treated with multiple-hole plates with additional screws on both sides of the pubic symphysis. In their retrospective review of 109 patients, the 2-hole plate constructs had a higher fixation failure rate (33% vs 12%, respectively) and more malunions (57% vs 12%, respectively) than patients fixed with multiple-hole plate constructs.

The use of locked vs unlocked plating constructs for pubic symphysis has not been previously compared biomechanically. The purpose of the current biomechanical study in pelvic Sawbones (model 1301; Pacific Research Laboratories, Vashon, Washington) was to determine the effect of using of a 4-hole plate construct with locking technology for disruptions of the pubic symphysis. The null hypothesis was that no biomechanical advantage conferred by the use of locking screws for injuries of the pubic symphysis exists.

**Materials and Methods**

Completely unstable pelvic injuries were simulated in pelvic Sawbones by disrupting the pubic symphysis and left sacroiliac joints. This model of Sawbones has a cancellous core and a hard cortical shell that simulates real human pelvis. The pubic symphyses were fixed with a precontoured 3.5-mm SP plate (Synthes, Paoli, Pennsylvania) placed superiorly using 4 locked (3.5-mm locking cortical) or 4 unlocked (nonlocking 3.5-mm cortical) screws using the standard AO technique (Figure 1).

In the locked and unlocked groups, drill guides were threaded into the plate, and holes drilled bicortically as dictated by the trajectory provided by the guides. Screw lengths for the lateral and medial holes were 40 mm and 45 mm, respectively. The appropriate length screws, all locking or all regular 3.5-mm screws, were then placed bicortically and tightened with a torque driver to 3 Nm. The sacroiliac joint was fixed with a 7.3-mm cannulated lag screw (Synthes) into the sacroiliac body, which was also tightened with a torque driver. The starting point of the screw was standardized on the specimens by measurements from the sciatic notch and posterosuperior iliac spine. An anterior cruciate ligament guide was used for consistent placement of the guide wire into S1. Screws were 85 mm in length.

Ten constructs were prepared and tested (5 pelves with locking screws and 5 pelves with nonlocking screws) on a Materal Test Systems machine (MTS 858 Mini Bionix II; MTS Systems Corporation, Eden Prairie, Minnesota). Sawbones femurs were cut in the distal diaphysis and placed in an adjustable angle vise at 8° of varus with the hip joint in full extension. A tension band was applied from the greater trochanter to the iliac wing with a turnbuckle for length adjustment to simulate the pull of the abductors. A universal joint was cemented to the sacrum and aligned to the center of rotation of the hip joint in the sagittal plane to align the vertical compression load to the gravity load line of the lumbar spine. The load mechanism of the MTS ram was mounted on X-Y linear bearings (Parker Hannifin Corporation, Cleveland, Ohio) so that the load would always be vertical and follow the movements of the pelvis. A bracket with an array of 3 light-emitting diodes (InnoVision Systems, Columbusville, Michigan) was attached to each of the bone parts near the pubic symphysis and sacroiliac joints (Figure 2).

A cyclic compression load of 15 N to 150 N was applied through the sacrum...
with the femur held fixed, simulating the single-leg stance. The level of load was large enough to establish a clear load-displacement curve in the elastic range to measure the stiffness of each construct, yet small enough to assure that no plastic deformation took place. A Selspot camera system (Innovision Systems) tracked the motion of each bracket to an accuracy of approximately 0.05 mm. From the MTS load-displacement curves, a slope was identified in the linear range and defined as the stiffness of the construct. The movements measured in the Selspot computer were translated into a custom software program, which calculated the 6° of freedom of motion across each joint during loading. Statistical comparisons were made with Student’s t test.

After loading, the femur was held at the greater trochanter, and the pelvis was subjected to a side load of 100 N measured by a dynamometer (Chatillon, Largo, Florida) to simulate forces that may occur from a fall. Movements of the pubic symphysis joint and angular changes of the screws were measured from a video recorded by the fluoroscope with image measurements in the Image Pro software (Media Cybernetics, Inc, Bethesda, Maryland).

RESULTS
In the current model, no significant difference existed in overall construct stiffness between the 2 methods of pubic symphysis fixation (Figure 3), in translation or rotation at the pubic symphysis joint during single-leg stance loading (Figures 4, 5), in sacroiliac joint translations or rotations (Figures 6, 7), or in motion at the pubic symphysis joint with lateral load (Figure 8). No catastrophic failure or screw pullout was observed during testing. Data are presented in the Table.

DISCUSSION
Although it is well known that concomitant visceral and neurologic injuries often dictate the clinical outcome following significant pelvic trauma,16–19 it has been demonstrated that anatomic reduction and maintenance of fixation also have a significant effect.17,19–21 Although many modalities have been advocated for fixation of the pubic symphysis joint following injury, plate and screw constructs have proven to be the most effective biomechanically12 and clinically.19 In a large retrospective series, Sagi and Papp8 reported that patients treated with multihole plate and screw constructs had fewer fixation failures and malunions than the comparative 2-hole plate group. The 2-hole plate group also had a slightly higher reoperation rate, although this was not statistically significant.8

The current authors performed this investigation to determine which form of 4-hole anterior plating provides the most rigid construct for the maintenance of fixation of the pubic symphysis and sacroiliac joints. To the authors’ knowledge, the effectiveness of locking plate technology on disruptions of the pelvic ring has not been studied. Therefore, they examined the significance of using a locked vs unlocked 4-hole plate and screw construct on a globally unstable pelvic ring injury and its effects on stability. The results of the current study demonstrate no significant difference following testing in single-limb stance or side loading when comparing locked and unlocked constructs.
Since the introduction of locking plate technology, interest has increased in the application of these fixation devices in extremity fractures. In a recent systematic review, Anglen et al. examined all available peer-reviewed studies on the use of locking plates for extremity fractures and reported that insufficient evidence exists to support the use of locking plates over conventional plates in fracture care. The current consensus among experts is that locking plates are only indicated in periarticular fractures and osteoporotic bone.

By studying the 2 fixation constructs in pelvic Sawbones, the current authors were able to remove the variability in size and bone quality that would be observed in cadaveric specimens. This eliminated the interspecimen variability of cadaveric pelvises and allowed for the use of equivalent screw lengths between the different specimens. The consistent geometry is more important in the comparison of constructs than are the mechanical properties in measuring the relative differences. Sawbones pelvises were used because their geometry is more consistent than cadaver models.

The goal of the current study was to evaluate and compare the initial performance of the construct and screw-plate interface during physiological loading of the pelvis. This was accomplished, but further clinical investigation into the effect of such constructs on fixation of the pubic symphysis is warranted. The major limitations of the current study included the use of ex vivo testing with lack of soft tissue–stabilizing structures, no power analysis, limited specimen numbers, and the use of a single injury pattern. The authors chose such a model to simulate the most unstable injury pattern.

**CONCLUSION**

This study evaluated the use of similar locked vs unlocked multiple-hole plate and screw constructs on disruptions of the pubic symphysis. Based on the results of the study, locking plate and screw constructs have no advantage over non-locking plate and screw constructs for the fixation of the pubic symphysis. Further examination of such constructs for fixation of disruptions of the pubic symphysis in vitro may help determine when locking plates are necessary in pelvic injuries.

**REFERENCES**


11. Simonian, PT, Schwappach JR, Routt ML, Agnew SG, Harrington RM, Tencer FT. Evaluation of new plate designs for symphy-

**Table**

<table>
<thead>
<tr>
<th>Measure</th>
<th>Lateral Rotations, deg</th>
<th>Axial Rotations, deg</th>
<th>Sagittal Rotations, deg</th>
<th>Total Translation, mm</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Unlocked</td>
<td>Locked</td>
<td>Unlocked</td>
<td>Locked</td>
</tr>
<tr>
<td>Sacroiliac joint motions</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Average</td>
<td>0.87</td>
<td>0.97</td>
<td>0.22</td>
<td>0.57</td>
</tr>
<tr>
<td>SD</td>
<td>0.53</td>
<td>0.30</td>
<td>0.21</td>
<td>0.50</td>
</tr>
<tr>
<td>Pubic symphysis motions</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Average</td>
<td>0.61</td>
<td>0.52</td>
<td>1.14</td>
<td>1.47</td>
</tr>
<tr>
<td>SD</td>
<td>0.14</td>
<td>0.33</td>
<td>0.52</td>
<td>0.94</td>
</tr>
<tr>
<td>Structural stiffness measures, in N/mm</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Average</td>
<td>25.77</td>
<td>27.63</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SD</td>
<td>6.71</td>
<td>3.41</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Abbreviation: deg, degrees.


