An Original Study

Locking and Nonlocking Plate Fixation Pubic Symphysis Diastasis Management

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Abstract

We evaluated the stability of locking and nonlocking plate fixation of the pubic symphysis in a cadaveric model of an unstable pelvic injury. Five fresh cadaver pelves—intact and with an unfixed simulated Tile B injury—were tested under compressive load simulating a 2-legged stance. On each pelvis, 3 pubic symphysis fixation constructs were tested: a 4-hole unicortical locking plate, a 4-hole bicortical locking plate, and a 4-hole bicortical compression plate.

There were no significant differences in displacement among the 3 fixation methods tested on Tile B pelvic simulations. Symphysis pubis fixation alone reduced the anterior superior pubic symphysis mean gap displacement by 95% and the anterior inferior pubic symphysis by 78%, compared with the noninstrumented Tile B injury.

There is no evidence that anteriorly placed locking constructs confer an advantage, in terms of pubic symphysis stability, over standard anterior compression plates for Tile B injuries.

Traumatic injuries to the pelvic ring are reported in 3% to 8% of trauma patients,[1-3] and 46% of these pelvic injuries are biomechanically unstable, Tile classification types B and C (Tile B, Tile C).[4] Associated trauma to the head and chest, as well as intrapelvic bleeding and prolonged bed rest, has led to a mortality rate of 10% to 20% in unstable pelvic injuries.[5-9] Progress in the form of aggressive resuscitation combined with techniques developed for stable internal fixation of pelvic ring injuries has led to a decrease in the morbidity and mortality associated with these injuries.[10-14] Although these outcome studies have shown improvement in the management of unstable pelvic ring injuries, many patients have chronic pain and functional limitations after radiographic healing.

The stability of the pelvic injury is directly related to the structures involved. Rotationally unstable (Tile B) injuries have intact posterior sacroiliac structures, which lend vertical stability to the pelvis. Anterior stabilization alone has been shown to be clinically effective in the management of Tile B injuries.[10,12,15-20] Several biomechanical studies have been conducted on use of different anterior fixation methods with simulated unstable pelvic injuries in a simulated 2-legged stance, and their results have shown that anterior plate fixation alone provides stability to the disrupted pubic symphysis but has little effect on sacroiliac motion when this joint is compromised.[21-26] Locking plate designs allow for use of a fixed-angle construct, which may provide increased anterior and posterior biomechanical stability to unstable pelvic ring injuries. To our knowledge, investigators have not compared the biomechanical properties of locking plates and standard plates for pubic symphysis diastasis in unstable pelvic cadaver models.

We conducted a study to compare the biomechanical stability of an anteriorly placed locking plate construct and a nonlocking plate construct, and the stability of unicortical and bicortical locking screw fixation, in a cadaveric model of unstable pelvic ring injuries.

Materials and Methods

Five (1 woman, 4 men) fresh-frozen nonpreserved cadaveric pelves (L4 to femoral midshaft) were used in this study. Mean age was 70.6 years (range, 55-81 years). Mean femoral-neck bone mineral density, measured with dual-energy x-ray absorptiometry (DXA), was 1000 mg/cm^2 (range, 641-1316 mg/cm^2). After being thawed to room temperature, each specimen was dissected free of soft tissues. Care was taken to protect the hip capsules, symphysis pubis, sacroiliac joints, sacrotuberous and sacrospinous ligaments, and iliolumbar ligaments. Throughout testing, saline was applied to keep the pelves moist. Anteroposterior radiographs of each pelvis—which were reviewed for skeletal abnormalities—showed no signs of osseous lesions or significant arthrosis at time of procurement.

The biomechanically simulated 2-legged stance used in this study (Figure 1) has been used by other

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Am J Orthop. 2012;41(12):540-545.

investigators[22,23,26,27] to compare internal fixation devices in the management of unstable pelvic ring injuries. The L4 vertebrae were potted with bone cement in a container so that the servohydraulic materials testing system (MTS Bionix Model 858; MTS Systems Corporation, Eden Prairie, Minnesota) could apply an axial compressive load. The femora were mounted in aluminum cylinders with bone cement in 5º valgus for a male pelvis and 7º valgus for a female pelvis to simulate the normal femoral alignment in the 2-legged stance. The pelves were kept upright with the superior endplate of L4 vertebrae parallel to the floor and the anterior superior iliac spine and pubic tubercles parallel to the coronal plane. In this configuration, the load axis was in line with the femoral heads and the potted ends of the femora.

Each specimen was first tested with intact pubic symphysis, sacroiliac ligaments, sacrotuberous, and sacrospinous ligaments. As no injuries were involved, no fixation was used. This test was taken as the baseline for comparison with subsequent tests. Then, a rotationally unstable (Tile B) pelvis injury was created by sectioning the pubic symphysis, the right-sided anterior sacroiliac ligaments, and the ipsilateral sacrotuberous and sacrospinous ligaments. Figure 2 shows the plates used to fix the disrupted pubic symphysis. This Tile B injury specimen was tested as follows:

- Without fixation.
- With 4-hole 3.5-mm pubic symphysis locking plate (PSLP) (Synthes, Paoli, Pennsylvania) and unicortical (28-mm length) 3.5-mm self-tapping screws after drilling with 2.8-mm bit and drill guide.
- With 4-hole 3.5-mm PSLP and bicortical (85-mm length) 3.5-mm self-tapping screws after drilling with 2.8-mm bit and drill guide.
- With 4-hole 4.5-mm Burgess dynamic compression plate (BDCP) (Synthes) and bicortical 4.5-mm fully threaded cortical screws placed after drilling with 3.2-mm bit.

Each specimen was loaded through the lumbar spine fixture, simulating axial compression. For each test sequence, each specimen was cyclically loaded from 40 N to 400 N at 1 Hz, and the maximum 400 N load was selected to represent the approximate weight of the normal body (100 lb) above the pelvis in the 2-legged stance. This physiologic loading procedure was used by others[22,23,26,27] to characterize overall mechanical properties. There were 5 preconditioning load cycles, not included in the analysis, and then 5 data collection load cycles. This procedure was repeated 6 times for each testing construct.

Two linear variable differential transformers (LVDTs) (M-DVRT-6; MicroStrain, Williston, Vermont) were used to measure the displacement produced by the applied loads in real time. LVDT-1 was placed on the anterior superior surface of the pubic symphysis joint, and LVDT-2 was placed on the anterior inferior surface of the joint (Figure 3). These LVDTs measured the opening of the gap created by sectioning the pubic symphysis. Figure 4 shows the symphysis pubis with the 3 plate fixation methods used for stabilization. Measurements of MTS load and LVDT displacement were recorded for analysis.

Figure 1. Experimental setup.

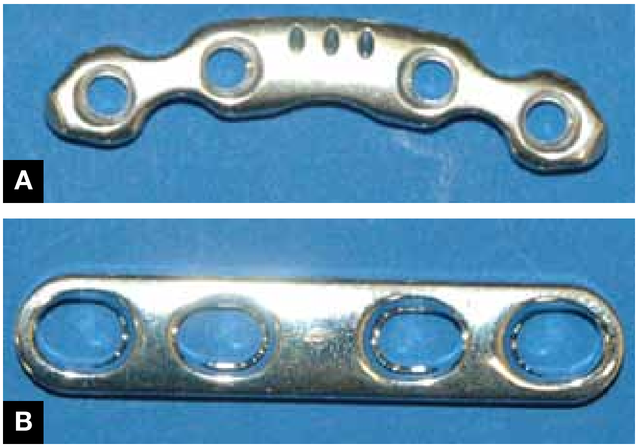

Figure 2. Plates used to fix disrupted symphysis from top: (A) 4-hole 4.5-mm Burgess dynamic compression plate (Synthes, Paoli, Pennsylvania) and (B) 4-hole 3.5-mm locking plate (Synthes).

Motion data for the anterior superior and anterior inferior surfaces of the pubic symphysis were analyzed, with 1-way analysis of variance and significance set at $P<.05$ (SPSS 16.0; SPSS, IBM, Chicago, Illinois), for any differences among the intact pelvis, the unfixed pelvis, and the 3 fixation methods. Data were also analyzed with a least significant difference multiple-comparison post hoc test with 5 measures per configuration. These analyses were used to determine the

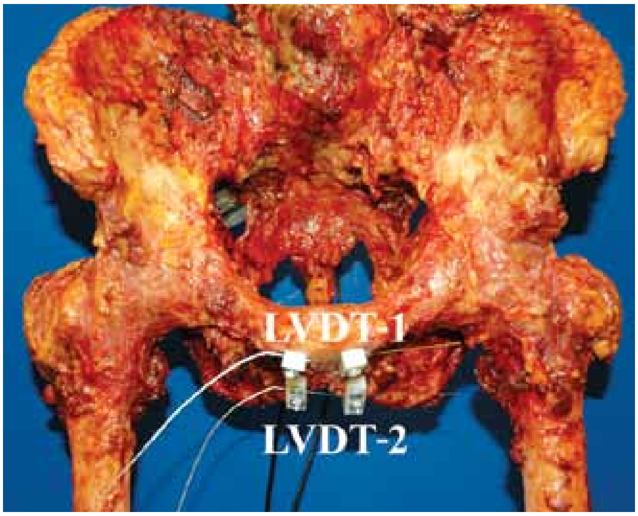

Figure 3. Linear variable differential transformers (LVDTs) in anterior region. LVDT-1 detects displacement at level of anterior superior pubic symphysis; LVDT-2 detects displacement at level of anterior inferior pubic symphysis.

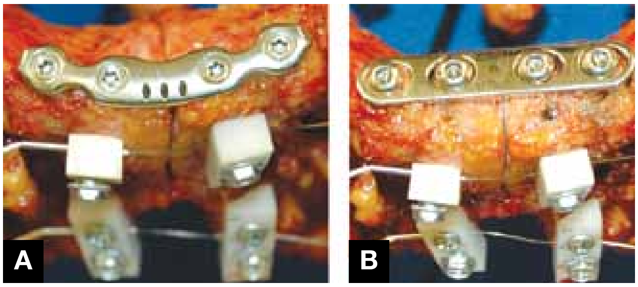

Figure 4. Anterior pubic symphysis fixation: (A) 4-hole 3.5-mm locking plate and (B) 4-hole 4.5-mm Burgess dynamic compression plate.

statistical relevance of the biomechanical stability of the pubic symphysis for each fixation construct. Mean and Standard Deviation (SD) were calculated for each testing sequence. The increased stability provided by internal fixation when compared with both the intact pelvis and the nonfixated Tile B injury constituted the final outcome for the study. The power analysis and sample size calculations used were Power and Sample Size Calculations 3.0.34.[28] We had planned to include 5 pairs of specimens in this study. Prior data indicated that the difference in the response of matched pairs is normally distributed with an SD of 0.2. If the true difference in the mean response of matched pairs is 0.4, we would be able to reject the null hypothesis that this response difference is 0 with probability (power) of 0.918. The type I error probability associated with this test of this null hypothesis is 0.05.

Results

Overall, the plate constructs reduced motion to approximately that of the intact pelves; either the anterior superior or the anterior inferior symphysis mean gap displacement was less than 0.4 mm with 400 N axial loading applied. In addition, results showed that plate fixation of the symphysis pubis alone reduced approximately 95% (range, 94.8%-96.5%) of the anterior superior gap displacement and approximately 78% (range, 76.7%-81.0%) of the anterior inferior gap displacement, compared with Tile B injury without fixation (Table I). This indicated that, with a Tile B injury, 4-hole plate fixation of the symphysis pubis alone restored most of the pubic symphysis stability.

Tables II, III, and Figure 5 show the symphysis pubis gap displacement comparison of the intact specimens, the Tile B injury without fixation, and the 3 different fixation constructs. There was a statistically significant difference (*P*<.05, Table IV) in anterior superior and anterior inferior symphysis mean gap displacement between the intact specimens and the Tile B injury without fixation. Mean (SD) anterior superior displacement

Table I. Displacement of Noninstrumented Pelvic Rings Reduction, Tile B Injuries

Fixation Method	LVDT-1, %	LVDT-2, %
4-hole PSLP with unicortical screw	96.5	76.7
4-hole PSLP with bicortical screw	94.8	78.6
4-hole BDCP with bicortical screw	94.9	81.0
Mean	95.3	78.4

Abbreviations: LVDT, linear variable differential transformer; PSLP, pubic symphysis locking plate; BDCP, Burgess dynamic compression plate.

Table II. Pubic Symphysis Anterior Superior Surface Displacement (LVDT-1)

	Displacement, mm		
Specimen/Fixation Construct	Actual	Mean	SD
Intact pelvis	0.01	0.00	0.01
	0.01		
	0.00		
	0.00		
	0.03		
Unstable, unfixed pelvis	0.52	1.38	1.10
	0.59		
	1.44		
	1.13		
	3.23		
4-hole PSLP, unicortical screw	0.05	0.05	0.03
	0.02		
	0.06		
	0.10		
	0.02		
4-hole PSLP, bicortical screw	0.06	0.07	0.02
	0.07		
	0.06		
	0.10		
	0.07		
4-hole BDCP, bicortical screw	0.02	0.07	0.05
	0.08		
	0.06		
	0.04		
	0.14		

Abbreviations: LVDT, linear variable differential transformer; PSLP, pubic symphysis locking plate; BDCP, Burgess dynamic compression plate.

was 0.00 (0.01) mm (range, -0.03-0.01 mm) for the intact specimens and 1.38 (1.10) mm (range, 0.52-3.23 mm) for the Tile B injury without fixation. Mean (SD) anterior inferior displacement was 0.05 (0.08) mm (range, -0.19-0.00 mm) for the intact specimens and 1.56 (1.1) mm (range, 0.72-3.47 mm) for the Tile B injury without fixation.

There was no statistically significant difference (LVDT-1, $P = 1.0$; LVDT-2, $P = .91$; Table IV) in stability between the locking plate (4-hole PSLP bicortical screw) and nonlocking plate (4-hole BDCP bicortical screw) constructs. Mean (SD) anterior superior symphysis gap displacement was 0.07 in each case: 0.07 (0.02) mm (range, 0.05-0.10 mm) for the locking plate construct and 0.07 (0.05) mm (range, 0.02-0.14 mm) for the nonlocking plate construct. Mean (SD) anterior inferior symphysis gap displacement was 0.33 (0.12) mm (range, 0.14-0.48 mm) for the locking plate and 0.30 (0.17) mm (range, 0.09-0.51 mm) for the nonlocking plate.

In addition, there was no statistically significant difference (LVDT-1, $P = .94$; LVDT-2, $P = .93$; Table IV) in pelvic ring stability between the unicortical and bicortical locking screw fixation constructs. For the 4-hole PSLP unicortical screw construct, mean (SD) anterior superior symphysis gap displacement was 0.05 (0.03) mm (range, 0.02-0.10 mm), and mean (SD) anterior inferior symphysis gap displacement was 0.36 (0.16) mm (range, 0.09-0.49 mm).

Discussion

The results of this study provide an understanding of pelvic fixation biomechanics that can assist in choosing a surgical method to restore pelvic stability. We had 2 hypotheses for this study—first, that 4-hole 3.5-mm PSLP designs would provide at least as much pubic symphysis and sacroiliac joint stability as that provided by 4-hole 4.5-mm BDCP designs in a cadaver model with Tile B pelvic ring injuries in a simulated 2-legged stance and, second, that unicortical locking screw fixation would provide biomechanical stability equal to that provided by bicortical locking screw fixation in the simulated unstable pelvic ring injury. The data do not contradict these hypotheses. van den Bosch and colleagues[29] reported that use of isolated plate fixation in Tile B fractures provided stable fixation in terms of translation and rotation stiffness when loaded up to 300 N. Our data demonstrated that plate fixation of the pubic symphysis alone, using 4-hole 3.5-mm PSLP constructs, confers an advantage, in terms of pubic symphysis stability, over use of 4-hole 4.5-mm BDCP constructs in Tile B pelvic ring injuries for a 400 N loading. One possible advantage of a locked plating system over a conventional plating system is improved fixation in osteoporotic bone.[30-33]

One aim of this study extended beyond those of typical biomechanical studies. We compared unicortical locking screw constructs with bicortical locking screw constructs. Most authors have used standard DCP with bicortical screw construct as standard procedure.[10,12,15-26] Our study results suggest that, when a locking plate configuration is required for anterior pelvic fixation of an unstable pelvic ring injury, a unicortical locked plate construct can provide adequate stability. Possible advantages of unicortical screw placement include decreased surgical exposure, decreased exposure to ionizing radiation from fluoroscopy, decreased operative time, decreased blood loss, and less risk for morbidity from a malpositioned bicortical screw.

This study had several limitations. It was a cadaveric

Table III. Pubic Symphysis Anterior Inferior Surface Displacement (LVDT-2)

Specimen/Fixation Construct	Displacement, mm		
	Actual	Mean	SD
Intact pelvis	0.00	0.05	0.08
	0.00		
	0.02		
	0.04		
	0.19		
Unstable, unfixed pelvis	0.92	1.56	1.10
	0.72		
	1.22		
	1.45		
	3.47		
4-hole PSLP, unicortical screw	0.46	0.36	0.16
	0.38		
	0.09		
	0.48		
	0.40		
4-hole PSLP, bicortical screw	0.38	0.33	0.12
	0.34		
	0.14		
	0.48		
	0.33		
4-hole BDCP, bicortical screw	0.21	0.30	0.17
	0.41		
	0.09		
	0.26		
	0.51		

Abbreviations: LVDT, linear variable differential transformer; PSLP, pubic symphysis locking plate; BDCP, Burgess dynamic compression plate.

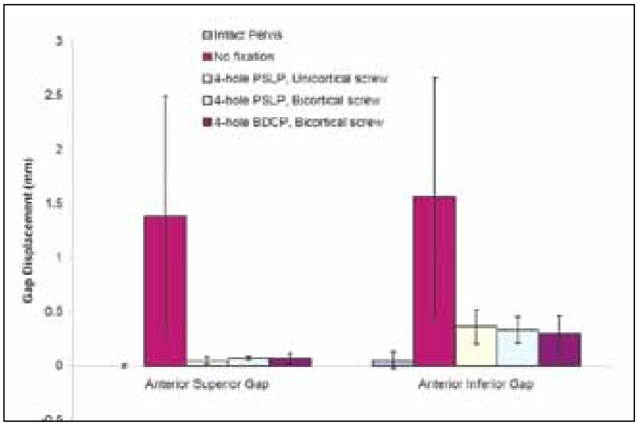

Figure 5. Mean (SD) symphysis pubis gap displacement as measured by anterior superior and anterior inferior surface motion as function of pelvic status (intact; disrupted and not fixed; or fixed with unicortical locking plate, bicortical locking plate, or bicortical Burgess dynamic compression plate).

Table IV. Differences in Pubic Symphysis Biomechanical Stability in Specimens/Fixation Constructs

Variable	Specimen/ Construct, I	Specimen/ Construct, J	Mean Difference, I–J, mm	Mean Difference, (I–J)/I × 100, %	*P*
Anterior superior surface (LVDT-1)	Intact pelvis	Unstable, unfixed	1.38	—	.00[a]
		PSLP, unicortical	0.05	—	.88
		PSLP, bicortical	0.07	—	.82
		BDCP	0.07	—	.83
	Unstable, unfixed pelvis	Intact	–1.38	–100	.00[a]
		PSLP, unicortical	–1.33	–97	.00[a]
		PSLP, bicortical	–1.31	–95	.00[a]
		BDCP	–1.31	–95	.00[a]
	4-hole PSLP, unicortical screw	Intact	–0.05	–97	.88
		Unstable, unfixed	1.33	2665	.00[a]
		PSLP, bicortical	0.02	46	.94
		BDCP	0.02	43	.95
	4-hole PSLP, bicortical screw	Intact	–0.07	–102	.82
		Unstable, unfixed	1.31	1871	.00[a]
		PSLP, unicortical	–0.02	–33	.94
		BDCP	0.00	–2	1.00
	4-hole BDCP, bicortical screw	Intact	–0.07	–100	.83
		Unstable, unfixed	1.31	1873	.00[a]
		PSLP, unicortical	–0.02	–31	.95
		PSLP, bicortical	0.00	2	1.00
Anterior inferior surface (LVDT-2)	Intact pelvis	Unstable, unfixed	1.50	3009	.00[a]
		PSLP, unicortical	0.31	622	.34
		PSLP, bicortical	0.28	566	.39
		BDCP	0.25	490	.45
	Unstable, unfixed pelvis	Intact	–1.50	–96	.00[a]
		PSLP, unicortical	–1.19	–77	.00[a]
		PSLP, bicortical	–1.22	–78	.00[a]
		BDCP	–1.26	–81	.00[a]
	4-hole PSLP, unicortical screw	Intact	–0.31	–86	.34
		Unstable, unfixed	1.19	332	.00[a]
		PSLP, bicortical	–0.03	–8	.93
		BDCP	–0.07	–18	.84
	4-hole PSLP, bicortical screw	Intact	–0.28	–86	.39
		Unstable, unfixed	1.22	370	.00[a]
		PSLP, unicortical	0.03	9	.93
		BDCP	–0.04	–11	.91
	4-hole BDCP, bicortical screw	Intact	–0.25	–82	.45
		Unstable, unfixed	1.26	420	.00[a]
		PSLP, unicortical	0.07	22	.84
		PSLP, bicortical	0.04	13	.91

Abbreviations: LVDT, linear variable differential transformer; PSLP, pubic symphysis locking plate; BDCP, Burgess dynamic compression plate.
[a]Mean difference significant at *P* = .05.

study and provided no information about long-term outcomes. Cadaveric pelves lack some static restraints and dynamic muscle forces. Differences in quality of bone and soft tissue among specimens led to some uncertainty regarding use of cadaver pelves. As more male (4) than female (1) specimens were used, because of cadaveric specimen availability, the findings might apply more to male patients than female patients. Elderly specimens may have decreased flexibility at the pubic symphysis, sacroiliac, and interspinal disk joints because of increases in collagen cross-linking, despite the fact that no gross evidence of osteoarthritis or ankylosis was observed. We recognize that the 2-legged stance represents only a small portion of the stress and load distributions encountered by the pelvis and the fixation device during rehabilitation from a pelvic ring injury, and that other loading methods may place different mechanical demands on Tile B injuries. Therefore, testing with other loading methods is an appropriate next step. Finally, 1-legged stance testing of both sides would seem to be more clinically relevant and possibly stress the fixation constructs more. Sagi and colleagues,[34] who performed 1-legged stance testing with the side of the unstable hemipelvis potted in polyester resin, were unable to measure axial rotation in their model.

In addition, in our study an attempt was made to place the 4.5-mm cortical screw away from the locking holes for the PSLP, but it is possible that the bone eventually may have lost some of its integrity; however, our results showed that this was not a significant factor. We recognize that using the same screw hole for unicortical and bicortical screws could have degraded screw fixation in the bone and jeopardized fixation stability; again, though, our results showed that this was not a significant factor. This study is also limited in that we used linear displacement devices to measure true motion of the pubic symphysis. Use of instruments that can follow displacement in multiple planes, or use of a computer navigation system, might be a better means for determining motion during biomechanical testing of the pelvis. A follow-up clinical study is required to confirm our conclusions and to evaluate the nonbiomechanical advantages of unicortical locking plates.

Our overall conclusion is that there is no evidence that 4-hole PSLPs confer an advantage, in terms of pubic symphysis stability, over 4-hole BDCPs for Tile B pelvic ring injuries. A unicortical locking screws construct and a bicortical locking screws construct impart equal biomechanical stability in a cadaveric model of Tile B pelvic ring injuries.

Authors' Disclosure Statement

The authors report no actual or potential conflict of interest in relation to this article.

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This paper will be judged for the Resident Writer's Award.