Chapter Six

Sacroiliac Screw Fixation for Tile B Fractures

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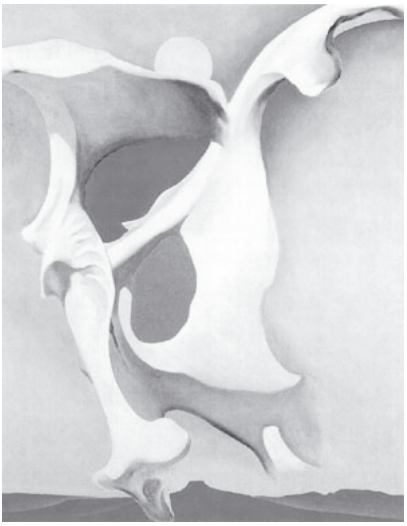

SUMMARY

Objective.

To investigate whether the stability of partially unstable pelvic fractures can be improved by combining plate fixation of the symphysis with a posterior sacro-iliac screw.

Design.

Comparative cadaveric study.

Materials and Methods.

In 6 specimens a Tile B1 (open book) pelvic fracture was created. We compared the intact situation to isolated anterior plate fixation and plate with sacro-iliac screw fixation. Using a 3-dimensional video system we measured the translation and rotation stiffness of the fixations and the load to failure.

Results.

Neither absolute displacements at the pubic bones or at the sacroiliac joint or stiffness of the ilium in respect to the sacrum were significantly different for the techniques with or without sacroiliac screw or the intact situation. Load to failure was only reached in one of the six cases. In all other cases the fixation of the pelvis to the frame failed before failure of the fixation itself. In these cases a load of about 1000N or more could be applied.

Conclusions.

The addition of a sacroiliac screw in a Tile B1 fracture does not give significant additional stability. Although cyclic loading was not tested, in these experiments forces could be applied similar to full body weight. Clinical experiments into direct postoperative weight bearing are recommended to examine the clinical situation.

Introduction

In Tile B1 pelvic injury, also known as open book fracture, the pelvic ring is only rotationally unstable without vertical instability. Although the anterior pelvic ring is disrupted completely, the posterior sacroiliac ligaments remain intact. Most studies have investigated the stability of various techniques in Tile C fractures[1-9], while only a few reported about the optimal fixation for Tile-B fractures[10-13]. In a Tile B1 injury (disrupted symphysis in combination with disrupted sacroiliac joint) various combinations of fixation techniques were described. These included one or two anterior plates[10,12,14] in combination with external fixation[14] or posterior plate fixation and sacroiliac screw fixation[10,15]. Some studies indicate that only anterior fixation of the pelvis is sufficient to stabilize Tile B injuries[12,14]. Because there is no agreement in literature about the optimal fixation technique for partially unstable pelvic fractures we investigated whether additional stability of the pelvis can be obtained by combining plate fixation of the symphysis with a posterior sacroiliac screw in partially unstable pelvic fractures using a 3D measurement system.

Materials and methods

We used 6 embalmed cadaveric pelves, which were dissected, leaving the ligamentous structures intact, including the sacrospinous and sacrotuberous ligaments. The femora, all lumbar vertebrae and all muscles were removed. The average age of the specimens was 78.9 years. One pelvis showed signs of arthrosis of the sacroiliac joint, the other pelves showed no abnormalities during dissection. A Tile B1 fracture was created by disruption of the pubic symphysis while dissecting the anterior sacroiliac ligaments[10,12]. In order to ensure sufficient horizontal instability a diastasis of at least 2.5 cm at the symphysis was applied.

All pelves were stabilized anteriorly with a 4-hole self compression plate (3.5 mm x 50 mm) of the symphysis (Biomet®, Warsaw, In., U.S.A.), posteriorly one 70 mm canulated partially threaded, cancellous lag screw (Biomet®) with washer was inserted over a K-wire. We inserted the screw through the posterior ilium and into the first sacral vertebral body across the sacroiliac joint, according to the technique of Matta and Saucedo[16]. The quality of the fixation was scored based on the grip of the screws and we made a clinical estimation of the bone quality during dissection on a three point scale.

To enable the application of load to the pelvic ring, the sacrum was fixed between two plates with screws and methylmethacrylate-polymere resin (Demotec®, Demotec Siegfried Demel, Nidderau, Germany). The pelvis was oriented with anterior superior iliac spines and the symphysis in the frontal plane which is approximately comparable to the physiological position during standing[1,12]. A pelvis fixated in the frame can be seen in figure 1.

The load was applied by introducing a force to a plate attached to the ilium. Through an extension device the pelvis was loaded along a vertical line of action passing through the sacroiliac joint. This approximates force during weight bearing.

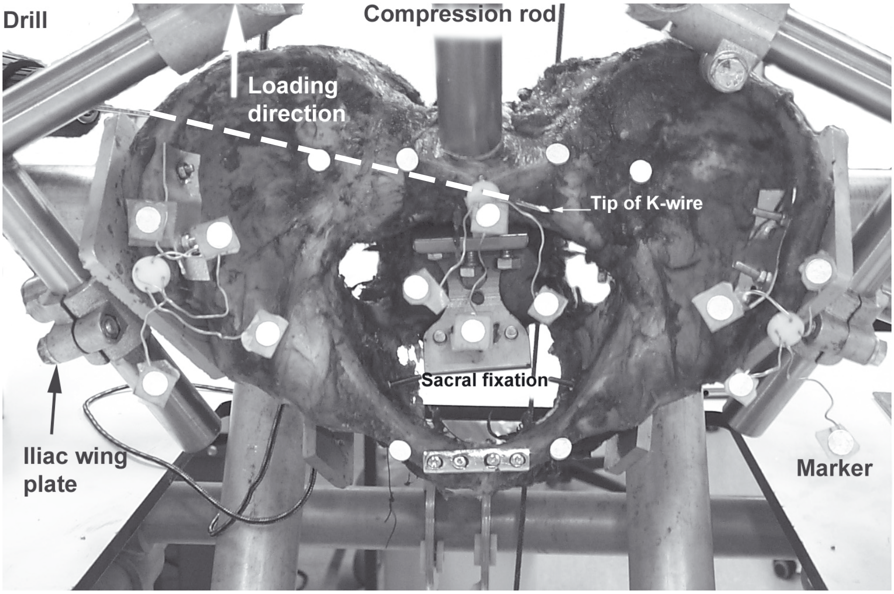

Figure 1. Pelvis with markers while fixated in the loading frame. Positioning of the K-wire is shown.

With a 3D video system displacements were measured in all 6 degrees of freedom (3 dislocations and 3 rotations). To enable the computerized video registration of bone displacements, clusters of four infrared light reflecting markers were attached to the cranioventral edge of the first sacral vertebral body and to both superior anterior iliac spines. Two markers were placed bilaterally, about 2 cm from the sacroiliac joint and two markers were positioned on both superior rami of the pubic bone, close to lateral edges of the plate. For reference of the markers see figure 1. The markers were illuminated by an infrared light source mounted on the cameras. The image coordinates from the two cameras were combined to three-dimensional spatial coordinates using Direct Linear Transformation[17,18]. From previous tests the resolution of the system proved to be about 0.1 mm.

For baseline measurements the intact pelvis was loaded on the left and right side. After a unilateral Tile B1 fracture was created and the pelvis was fixated with anterior plate fixation, it was loaded on both sides. Subsequently a sacroiliac screw was added to the fixation. During three consecutive cycles a maximum load of 300N was used, similar to forces used by Macavoy and Dujardin[12,15]. In a pilot study this has proven to be safe, avoiding failure levels and permanent displacement. After this the load to failure was measured (loaded to a maximum of 700N) of the combined anterior and posterior fixation. If failure levels could not be reached when loaded up to 700 N, the sacroiliac screw was removed and load to failure measured of the isolated anterior fixation. In one pelvis the iliac plate, to which the load was applied, loosened from the pelvis at 600N. In this case final measurements were made while loading the contralateral side. We investigated the stiffness of the fixation and the load to failure. We defined the translation stiffness (in N/mm) of the fixation as the slope of the load displacement curves of the ilium with respect to the sacrum up to 300 N. The rotation stiffness was defined as the applied load divided by the observed rotation in N/degree because the exact moment was not known. In a linear model the slope of the load displacement curves from the three cycles was calculated with the least squares method. The load to failure was defined as the force required to produce 5 mm displacement of the fracture parts. For the statistical calculations we used S.A.S. version 6.12 of the SAS institute inc, Cary, NC, USA.. In order to compare the translation stiffness, the rotation stiffness and the load to failure of the two fixation methods we performed a MANOVA with the translation/rotation stiffness of the fixated pelvis as depending variable. As baseline we examined the translation/rotation stiffness of the intact pelvis. As co-variables we used the fixation technique, bone quality, fixation quality. Because the distribution was skewed we applied a log transformation to the data and provided median and range instead of mean and standard deviation.

Translational stiffness (N/mm)			
	Loaded on ipsilateral side		
	intact	with isolated plate	additional SI screw
Median	268	187	184
Range	160 - 4861	57 - 326	79 - 2499
	Loaded contralateral		
Median	540	679	666
Range	196 - 42102	139 - 2105	227 - 8479

Table 1. Movements of the ilium versus the sacrum: translational stiffness

RESULTS

Initially the maximum load for all pelves was restricted to 300 N, thus avoiding permanent damage of the pelvic bone, ligaments and fixation. Both displacement between the pubic bones and the between the sacrum and the ilium at the sacroiliac joint were measured. The maximum displacement measured between the pubic bones was 0.5 mm median (range 0.2 - 0.9 mm). Most displacement after fixation was seen in the anteroposterior and craniocaudal direction, diastase of the pubic symphysis was less than 0.1 mm. When fixated the median displacements were median 0.8 mm (0.4 - 1.7 mm) with isolated plate and median 0.7 mm (0.4 - 1.9 mm) with sacroiliac screw and plate. The displacements measured at the sacroiliac joint were in the direction of the applied force, i.e. the ilium moved upward. For the intact pelvis the median displacement was 0.7 mm (0.3 - 1.3 mm), with isolated plate 1.1 mm (0.5 - 1.8 mm) and after addition of the sacroiliac screw the displacement was 0.9 mm (0.5 - 1.2 mm) (no significant differences). Some gapping of the sacroiliac joint was seen (all <1.5 mm, no significant differences).

Additional to the measurements between the pubic bones or at the sacroiliac joint, the displacement of the entire ilium in respect to the sacrum was observed. The medians of the maximum displacements were 1.4 mm (0.5 - 2.5 mm) intact, 2.1 mm (1.0 - 5.0 mm) with isolated plate and 2.0 mm (0.6 - 3.9 mm) when loaded up to 300 N ipsilateral. Loaded contralateral to 300 N, the medians were 1.2 mm (0.7 - 1.7 mm), 0.6 mm (0.6 - 2.0 mm) and 1.0 mm (0.6 - 1.6 mm) respectively (no significant differences). The median rotation of the iliac wing was 0.9 degree (0.5 – 1.5 degree) in the intact situation, 1.0 degree (0.5 – 1.9 degree) with isolated plate fixation and 1.0 degree (0.4 – 1.3 degree) for plate with sacroiliac screw. In all three situations the rotation axis of the loaded ilium was directed mainly along

Rotational stiffness (N/deg)			
	Loaded on ipsilateral side		
	intact	with isolated plate	additional SI screw
Median	902	487	461
Range	398 - 9563	171 - 2824	261 - 11714
	Loaded contralateral		
Median	2339	2719	2556
Range	622 - 7647	382 - 6778	616 - 6095

Table 2. Movements of the ilium versus the sacrum: rotational stiffness

the transversal axis. When loading the ipsilateral side, both in the intact and in the fixated pelves the ilium rotated upwards with respect to the sacrum in all cases. At the pubic symphysis this rotation showed as movement of the loaded pubic bone upwards and forwards.

Besides the absolute displacements and rotations, the stiffness of the ilium in respect to the sacrum, when loaded up to 300 N, was measured. These values were summarized in table 1 and 2. No significant differences were observed between intact, fixated with isolated plate or with plate and sacroiliac screw ($p>0.1$). The effect of the other co-variables (bone quality, fixation quality and fracture side) was not significant ($p>0.12$). The overall effect of technique on the stiffness was not significant either ($p = 0.41$).

After the loading cycles up to 300 N, the pelves were loaded up to 700 N. In none of the pelves signs of failure of the fixation were observed and in all cases the sacroiliac screw was removed. Neither the stiffness, nor the displacements at the pubic symphysis or at the sacroiliac joint showed any significant differences between the techniques with or without sacroiliac screw. The maximum loading force and the reason of termination of the experiment are shown in table 3. Only in one pelvis the predefined criterion of load to failure (5 mm displacement at the sacroiliac joint) was reached after removal of the sacroiliac screw. In all other cases a sacral fracture at the edge of the fixation to the frame or a failure of the plate at the ilium limited further measurements. In these cases a load of 960 to 1481 N could be reached.

Specimen	Maximum force applied	Reason for failure
1	1100N	transforaminal sacral fracture at edge of sacral fixation plate
2	1481N	transverse sacral fracture through foramina S2 at edge of plate
3	617N	side plate at ilium failed, other iliac wing loaded to 900N
4	1200N	transforaminal sacral fracture at edge of sacral fixation plate
5	960N	true sacroiliac joint dislocation (only failure of fixation)
6	960N	fixation of pelvis to frame failed

Table 3. Reason of failure: maximum loading force with isolated plate fixation and reason of termination of the experiment.

Discussion

To investigate whether the combination of sacroiliac screw fixation with anterior plate fixation gives additional stability compared to isolated anterior plate fixation in Tile-B fractures we loaded six embalmed pelves and measured the displacements of the fracture parts using a 3D video system. In the literature several authors have used sacroiliac screws[6,7,16,19], but little is known about their additional value in Tile-B fractures. Simonian examined the stability of various combinations of fixation techniques[10]. He concluded that combined anterior and posterior fixation was optimal for Tile B fractures. He did not find any difference between sacroiliac plate fixation and screw fixation, neither did Dujardin[15]. Limitations in his study design were the use of multiple chains to stabilize the pelvis which may have restrained motions in the fracture planes.

Dujardin reported decreased micromotion at the sacroiliac joint when combining anterior plate fixation with sacroiliac fixation compared to isolated anterior plate fixation[15]. Combined anterior and posterior fixation gave similar results as in the intact situation. However the design with repeated measurements, which differed between specimens, made removal and refixation of the pubic plates necessary. This may have resulted in suboptimal plate fixation, which made the quality of pubic plate fixation difficult to judge.

We chose to fixate the anterior pelvic ring with one plate, which, according to MacAvoy et al, has similar biomechanical properties as two plates[12]. They reported decreased stability compared to the intact pelvis, but no difference between single and double plate fixation. For posterior fixation we used one sacroiliac screw. The addition of one sacroiliac screw is a small procedure, which can be carried out in supine position and percutaneously, although it carries some risk of neurological injury. If the addition of a sacroiliac screw to the anterior plate fixation would give a similar biomechanical situation as the intact pelvis, patients could be mobilized directly postoperatively.

Our results showed no significant difference in the translation and rotation stiffness between isolated plate fixation and plate and sacroiliac screw fixation when loaded up to 300N. This applied to both ipsilateral and contralateral loaded pelves. When determining the load to failure the fixation did not prove to be the limiting factor. In all but one pelvis a load of over 900 N could be applied. Generally this is well above the force exerted by the upper body under physiological conditions. In most cases the experiment was ended by a sacral fracture at the edge of the sacral fixation plate. This suggests that isolated plate fixation can withstand even higher forces. In addition, the translation and rotation stiffness of the fixated pelves were similar to the intact situation when loaded up to 300 N.

The extrapolation of our results to the physiological situation is limited by the fact that we used aged embalmed pelves, lacking muscle activity, loaded in an experimental setting. Although the injury created by surgical transsection of the ligaments is reproducible, it is not entirely equal to open book fracture.

In contrast to the findings of Dujardin[15], we did not find a significant additional stability of a sacroiliac screw in Tile B1 fractures and recommend isolated plate fixation in Tile B1 fractures. Although we did not examine the fatigue of the fixation, the observed biomechanical stability seems sufficient to examine direct postoperative weight bearing in Tile B fractures in a clinical study.

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