Can an external frame fixation reduce the movements in the sacroiliac joint?

A radiostereometric analysis of 10 patients

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To evaluate whether a Hoffmann-Slätis frame can reduce movements in the sacroiliac joints, 10 patients (7 women) with severe posterior pelvic pain of long duration were externally stabilized. The movements were analyzed with radiostereometric analysis (RSA) in supine and standing positions, preoperatively and postoperatively with the frame applied. In 2 patients, there was no reduction in the movements with the frame, perhaps because it was not properly tightened. In the remaining 8 patients, the median reduction in rotation was 55% on the left side and 63% on the right side around the helical axes, and 74% around the x-axes on the left side and 66% on the right side.

Our data suggest that external fixation using the Hoffmann-Slätis frame, substantially reduces sacroiliac joint mobility in some patients, which must be considered when using the frame as a diagnostic tool. Pre-stressing the frame by tightening the vertical bars before the compression bar is applied is recommended to reduce the risk of this shortcoming.

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Many women suffer from posterior pelvic pain during pregnancy (Östgaard et al. 1991). It usually disappears within 6 months after delivery (Östgaard and Andersson 1992). However, in some patients it persists for years. Similar pain patterns are seen in other patients (Sturesson et al. 1989). Although one can distinguish between back pain and posterior pelvic pain, there is no evidence that posterior pelvic pain is caused by a specific anatomical structure (Östgaard et al. 1994) or related to increased movements of the sacroiliac joints (Sturesson et al. 1989).

Slätis (1989) suggested that patients with a positive external fixation test of the pelvis will have a good outcome after a sacroiliac fusion. However, Wahlheim (1984) found no stabilizing effect on symphyseal mobility with an external frame.

In this study, we have investigated the influence of an external trapezoid pelvic fixator on movements of the SI joints.

Patients and methods

Between 1989 and 1996, 7 women and 3 men with posterior pelvic pain were accepted for a trial of an external Hoffmann-Slätis frame (The Original Hoffmann® Fixation System). The study was approved by our ethics committee.

The duration of pain was between 1 and 10 years (Table 1). In 6 cases, the pain had started during pregnancy, in 1 case a fall trauma was implicated, in 1 case a reactive clamydial arthritis was the probable cause of pain, whereas no reasonable cause could be found in the remaining 2 patients. 8 patients had bilateral symptoms. 8 of the patients were unable to work, 1 was a student and 1 was still able to perform light work. All patients used analgesics and had severe pain walking, standing and sitting. They had all attended several physical exercise programs, without any positive effects.

Table 1. Clinical data of the patients

	Sex	Age	Duration years	Cause	Occupation	Days between external fixation and RSA
1	M	26	3	A	SL	2
2	F	36	10	P	SL	21
3	F	38	8	P	SL	21
4	F	39	8	P	W	21
5	F	27	4	U	SL	10
6	M	27	5	U	S	14
7	F	27	3	P	SL	21
8	F	33	5	P	SL	21
9	M	45	1	T	SL	21
10	F	40	5	P	SL	21

A arthritis, P postpartum, T trauma, U unknown.
SL sick leave, W working, S studying.

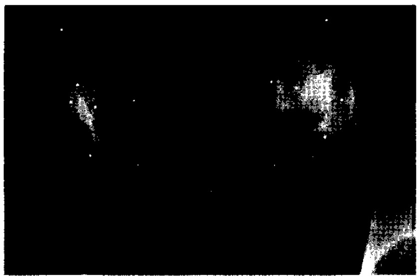


Figure 1. Radiogram of the plastic bony model, with tantalum balls in the usual pattern.

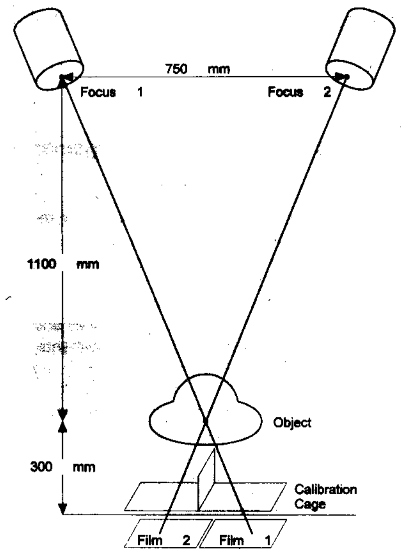


Figure 2. The positions of roentgen tubes (focus 1 and 2), object and roentgen films.

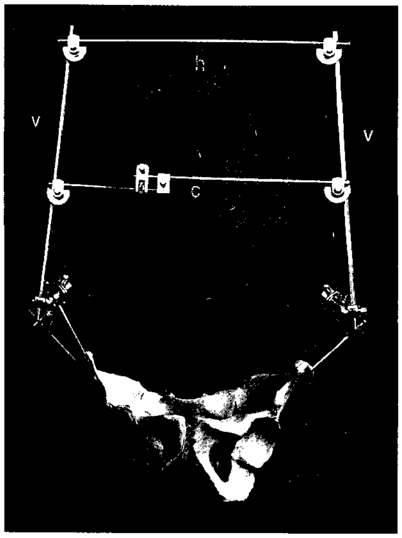
All patients had a positive "posterior pelvic pain provocation test," and a pain distribution as seen in posterior pelvic pain (Roos-Hansson and Zetherström 1991, Östgaard et al. 1994).

Under fluoroscopy and local anesthesia, 0.8 mm tantalum balls were implanted from a posterior approach into the pelvic bones (Figure 1). Using a cannula with a spring-piston-release mechanism-striker system that presses the ball into position, 4–6 tantalum balls were placed geometrically well spread into the iliac bones and the sacrum (Sturesson et al. 1989). The RSA examination was made in the roentgen department. Two ceiling-suspended telescopic units with exposure synchronization were used. With our set-up, it was possible to make horizontal and vertical exposures and the subject could move freely in front of the films so long as it was positioned at the intersection of the roentgen beams (Figure 2). The roentgen films were positioned parallel under a calibration cage of plexiglas with known positions of the tantalum markers. The cage provided a three-dimensional coordinate system in which the positions of the markers in the patient as well as the roentgen foci could be calculated. The films were digitized on a measurement table, having a videocamera with 16 times magnification (coefficient of variation 0.0015). The two-dimensional coordinates thus obtained were the input data for the photogrammetric calculations, whereby the coordinates for the markers in the patient were calculated for each exposure. Thus, the relative movements between the skeletal segments could be calculated between different exposures, irrespective of the patient's position in relation to the cage. Rigid body conditions were assumed for each skeletal segment. An internal check in the computer program could reveal and exclude unstable tantalum markers. The calculations were performed as described by Selvik (Selvik et al. 1983, Selvik 1989, 1990), using the computer programs Kinlab, Kinerr and X-RAY 90.

The patients were examined in supine and standing positions (Kärrholm 1989, Selvik 1989, 1990). In a second procedure, an external HoffmannSlätis frame was applied and the frame was adjusted into compression during surgery (Figure 3). After 2–21 days (Table 1), a second RSA-examination was performed in the supine and standing positions, with the pelvis externally fixed.

The sacrum was defined as the fixed segment, and the movements were described as a rotation around the three axes in a body-oriented coordinate system (Figure 4), as well as a helical axis rotation (screw axis rotation), i.e., the axis around which the rotation really occurs.

The error in measurements was assessed using a plastic pelvic model, with tantalum markers implanted in the same number and same configuration as in the patients. The relative movements of the SI-joints were analyzed 20 times, as in the patients, i.e., between the supine and the standing position. In this model, the relative movements were assumed to be zero, since its joints were fixed. The precision was assessed as a 99% confidence limit for each degree of freedom, based on the standard deviations from zero and the two-sided Student distribution ($2p = 0.01$ and $v = 20$) (Table 2). An internal check in the computer program for instability of the markers revealed that the markers in the patients were more stable than in the plastic model.



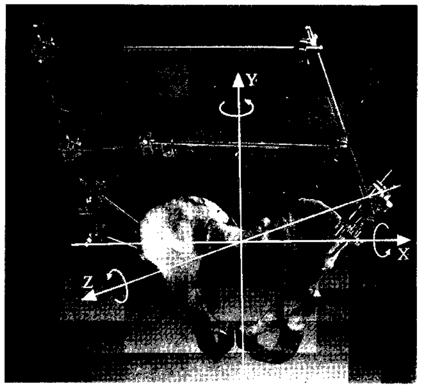


Figure 4. The pelvis with the rotational axes.

Figure 3. The external Hoffmann-Slätis frame is anchored to the iliac crests with two isolated-positioned screws, connected with a short bar on each side. The vertical bars (v) are connected with a horizontal upper bar (h) and a compression bar (c).

Table 2. 99% confidence intervals for the smallest significant movements

	Translation, mm	Rotation, degrees
Transverse (x) axis	0.2	0.3
Longitudinal (y) axis	0.2	0.4
Sagittal (z) axis	0.1	0.1
Helical axis	0.2	0.4

The statistical methods used for the patient comparisons were the Wilcoxon rank test and the One Sample Sign test.

Results

The movements of the sacroiliac joints had the same pattern as in a previous study (Sturesson et al. 1989) (Table 3). In 8 patients, the movements were analyzed

Table 3. Rotations in the sacroiliac joints when changing from supine to standing with or without the frame. In the statistical analysis patients 1 and 7 are excluded (Wilcoxon Sign Rank Test)

	Left SI joint				Right SI joint			
	Transverse axis		Helical axis		Transverse axis		Helical axis	
	without	with	without	with	without	with	without	with
1	−0.7	•	0.8	•	−0.8	−0.7	0.8	1.2
2	−1.3	−0.3	1.4	0.3	−1.5	−0.4	1.5	0.4
3	−1.5	−0.8	1.7	0.9	−1.7	−0.6	1.8	0.6
4	−2.3	−0.7	2.3	0.5	−2.4	•	2.5	•
5	−0.9	−0.7	0.9	0.7	−1.0	−0.7	1.1	0.8
6	−1.2	−0.2	1.2	1.2	−0.9	−0.3	1.4	0.4
7	−1.7	−1.7	1.7	1.9	−1.1	−1.5	1.2	1.6
8	−1.5	−1.6	1.6	1.7	−1.2	−0.7	1.3	1.9
9	−0.5	0.2	0.8	0.3	−0.4	−0.1	0.4	0.4
10	−1.0	0.2	1.1	0.4	−0.4	−0.3	0.8	0.3
Median	−1.2	−0.5	1.3	0.6	−1.1	−0.4	1.4	0.4
P	0.02		0.04		0.04		0.1	

Table 4. The effect of the Slätis–Hoffmann frame in the supine position. The values describe the change of position (in degrees) caused by the frame, that is the difference between the examinations with or without the Slätis–Hoffman frame applied. The rotations of the axis are illustrated in Figure 4. The negative values of the transverse axis imply that the iliac bones are forced by the frame to rotate backwards. In the statistical analysis patients 1 and 7 are excluded (One Sample Sign Test)

	Left SI–joint				Right SI–joint			
	Transverse	Longitudinal	Sagittal	Helical	Transverse	Longitudinal	Sagittal	Helical
1					0.6	–0.4	0.1	0.8
2	–0.2	–0.5	0.3	0.7	–0.4	0.2	–0.2	0.5
3	–1.8	–1.0	0.4	2.1	–1.2	0.6	–0.2	1.4
4	–1.4	–1.0	0.6	1.8	–1.8	1.8	–0.5	2.1
5	–0.1	–0.2	0.6	0.7	–0.5	0.2	0.0	0.6
6	–0.8	–0.4	0.5	1.0	–0.5	0.9	–0.1	1.0
7	0.3	0.4	–0.2	0.6	0.4	–0.2	0.2	0.5
8	–0.2	0.5	–0.7	0.9	–0.9	–1.0	–0.4	1.4
9	–0.5	0.6	–0.2	0.8	–0.1	–0.6	0.5	0.7
10	–0.5	0.9	–0.4	1.2	0.2	–1.5	0.9	1.7
Median	–0.5	–0.3	0.4	1.0	–0.5	0.2	–0.2	1.2
P	0.008	0.7	0.7	0.008	0.07	0.7	0.4	0.008

on both sides pre- and postoperatively and in 2 patients, on one side only, because the tantalum balls were obscured by the frame on the roentgen films.

The effect of the frame is described in Table 4, where the altered relations between the sacrum and the iliac bones with or without the frame in the supine position are calculated. The movements around the transverse axis (x-axis) showed that the sacrum rotated forward in 7 patients. Movements around the longitudinal axis (y-axis) measure anterior opening and closing of the pelvis. A negative value on the left side and a positive on the right side imply that the anterior part of the pelvis is closed. A closure of the anterior part of the pelvis was noted in 5 patients, with similar movements on both sides. In the remaining 4 patients, movements around the longitudinal axis were the opposite, but still symmetrical. Correspondingly, the movement pattern around the sagittal axis was symmetrical, but with rotation values close to the error of measurement (Table 2). Patients 1 and 7 differed from the others in rotation around the transverse, longitudinal and sagittal axes. Patient 10 differed from the others in transverse and longitudinal rotations of the right side.

Table 5. The difference in movement between supine and standing, with or without the external frame applied. The values around the transverse (x) and helical axes on the left and right sides are presented. Patients 1 and 7 are excluded (Wilcoxon Sign rank test)

	Median	Range	P-value
Without frame x left	-1.2	-0.5 to -2.3	0.02
With frame x left	-0.5	-0.2 to -1.6	
Without frame helical left	1.3		0.03
With frame helical left	0.6	0.3 to 1.7	
Without frame x right	-1.1	-0.4 to -2.4	0.02
With frame x right	-0.4	-0.1 to -0.7	
Without frame helical right	1.4	0.8 to 2.5	0.1
With frame helical right	0.4	0.3 to 1.9	

The median reduction of the rotation achieved by the frame was 69% on the left side (p= 0.02), and 42% on the right side (p = 0.04) around the transverse axes, and by 47% on the left side (p = 0.04) and 27% on the right side (n.s.) around the helical axes (Table 3). Patients 1 and 7 differed from the others with respect to the effect of the frame fixation; there was no reduction in the rotation around the transverse axis or in the helical axis rotation, when changing from supine to standing position. The median reduction of rotation in the remaining 8 patients was 74% on the left side (p = 0.02) and 66% on the right side (p = 0.02) around the transverse axes, and 55% on the left side (p = 0.03) and 63% on the right side (n.s.) around the helical axes (Table 5).

Discussion

When the Slätis frame was applied, the iliac bones were internally rotated in 5 of 9 patients. The movements were symmetrical around the longitudinal and sagittal axes, i.e., when the right joint had a positive rotation around the longitudinal axis, the left joint had a negative one (Table 4). This movement behavior is probably due to the shape of the joint. However, the movement that occurred in 15 of the 18 externally fixed joints was a posterior rotation around the transverse axis of the iliac bones. This indicates that, when the external frame was tightened, the sacrum was rotated anteriorly and in the same manner locked between the iliac bones. This corresponds well to the theory of the self-bracing model described by Snijders et al. (1993). Accordingly, forcing the sacrum in an anterior direction will reduce the range of movement in the sacroiliac joints. In 2 patients, the pattern of movement did not change with the external frame. This may be due to an insufficient compression induced by the external frame or to the anatomical shape of the SI joints in these particular patients (Solonen 1957). The latter explanation is more likely in patient no. 6, since there were differences related to the side in the rotations when comparing transverse axis and helical axis values, although the compression should be the same on both sides. In patients 1 and 7, the frame did not reduce the movements when the patients stood up from the supine position, indicating that the frame was not compressed enough to reduce mobility (Table 3). This lack of effect must be considered when using the frame as a diagnostic tool to assess pelvic pain. In the present study, we failed to reduce the movements in 2 patients (20%; 95% confidence interval 3–56%). In patient 10, the right sacroiliac joint showed no reduction in movement around the x-axis but an asymmetrical reduction around the y-axis, probably caused by variations in anatomy.

Slätis and Eskola (1989) found that the posterior pelvic pain decreased substantially when patients wore the external frame. It is suggested that a reduction in pain is caused by reduced movement, but this is not proven.

We chose to describe the movements as rotations rather than translations, since the latter depend on the spatial configuration of the markers and therefore have intra- and interindividual variations. Thus, an analysis of translations would not produce comparable results between patients, and not even between the sides of the same patient.

In this particular study, we did not assess the error in measurement due to the use of double examinations on patients (Mjöberg 1986). The reason for this is that the material is limited, and that double examinations would impose an additional dose of radiation to the patient and was not accepted by the Ethics Committee. We used a plastic pelvic model with the tantalum balls distributed as in our patients. The precision and quality of the RSA depends on the number of markers as well as the spatial configuration and stability of these markers (Kärrholm 1989). In our plastic model used for assessing the error of the RSA method in this particular application, the number of markers and their spatial configuration were similar to what was found in our patients. The stability of the markers in the patients showed in two out of three segments a higher precision than with the plastic model. The quality and accuracy of RSA is thoroughly discussed by Önsten (1994). Further, since our model is a pure paired situation, the measurement error can be assumed to be the same before and after the application of the frame.

Our results show that external fixation of the pelvis can, indeed, reduce sacroiliac joint mobility. In using the HoffmannSlätis frame, we recommend pre-stressing of the frame by tightening the vertical bars before the compression bar is applied. This suggestion is not based on our results but merely on clinical experience.

The movements of the SI joints are very small and close to the resolution of the method. However, the values show the same pattern as in a former study (Sturesson et al. 1989) and follow what we logically would expect.

Kärrholm J. Roentgen stereophotogrammetry: Review of orthopedic applications. Acta Orthop Scand 1989; 60; 491-503.

Mjöberg B. Loosening of the cemented hip prosthesis. Acta Orthop Scand (Suppl 221) 1986.

Roos-Hansson E, Zetherström G. Reliability of provocation test in posterior pelvic pain during pregnancy. Sjukgymnasten, Vetenskapligt 1991; 2: 23-4.

Selvik G. A roentgen stereophotogrammetric method for the study of the kinematics of the skeletal system. Acta Orthop Scand (Suppl 232) 1989; 60.

Selvik G. Roentgen stereophotogrammetric analysis. Acta Radiol 1990; 31:113-26.

Selvik G, Alberius P, Aronson S. A roentgen stereophotogrammetric system. Acta Radiol 1983; 24 (4): 343-52.

Slätis P, Eskola A. External fixation of the pelvic girdle as a test for assessing instability of the sacro-iliac joint. Ann Med 1989; 21: 369-72.

Snijders C J, Vleeming A, Stoeckart. Transfer of lumbosacral load to iliac bones and legs. Part 1: Biomechanics of self-bracing of the sacro-iliac joints and its significance for treatment and exercise. Clin Biomech 1993; 8: 285-94.

Solonen, K. The sacroiliac joint in the light of anatomical, roentgenological and clinical studies. Thesis, Acta Orthop Scand (Suppl 27) 1957.

Sturesson B, Selvik G, Udén A. Movements of the sacroiliac joints. A roentgen stereophotogrammetric analysis. Spine 1989; 14: 162-5.

Wahlheim G. Stabilization of the pelvis with the Hoffmann frame. Acta Orthop Scand 1984; 55: 319-24.

Önsten I. Fixation of the total hip components in rheumatoid arthritis and arthrosis. Thesis, University of Lund, Sweden 1994.

Östgaard H C, Andersson G B J. Low back pain postpartum. Spine 1992; 17: 53-5.

Östgaard H C, Andersson G B J, Karlsson K. Prevalence of back pain in pregnancy. Spine 1991; 16: 549-52.

Östgaard H C, Zetherström G, Roos-Hansson E, Svanberg B. Reduction of back and posterior pelvic pain in pregnancy. Spine 1994; 19: 894-900.