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FIXATION OF PELVIC FRACTURES AND DISLOCATIONS

An Experimental Study on the Loading of Pelvic Fractures and Sacro-Iliac Dislocations after External Compression Fixation

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A trapezoid external compression fixation frame, assembled with the Hoffmann instruments, was used for stabilizing experimental injuries to the pelvic skeleton of ten cadaver specimens. The resistance to loading in a position corresponding to upright standing was tested in 17 experiments and related to the calculated load *in vivo*. The results indicated that ipsilateral injuries, either presenting as dislocations of the sacro-iliac joint and symphysis or as unilateral fractures of the sacrum or ilium in combination with fractures of the pubic rami could be stabilized by the external compression frame well enough to permit weight-bearing in the upright standing position. Bilateral injuries to the pelvic skeleton, vertical or oblique, could not, however, be stabilized enough to resist more than a fraction of the normal load in the upright standing position.

Key words: dislocation; fracture fixation; loading; pelvic bones; sacro-iliac joint; stability.

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The pelvis owes its stability to the circular arrangement of the individual bones forming the pelvic ring, to the strong interosseous ligaments between the sacrum and the ilium and to the pubic symphysis. The vertical load on standing is taken up by the sacrum which moves and rotates downwards and forwards. Due to its wedge-shape it becomes compressed between the iliac bones. Simultaneously the sacro-iliac ligaments tighten and add to the stability (Weisl 1954, Kopsch 1955, Solonen 1957, Hollinshead 1969).

The uneven articular surfaces of the sacro-iliac joint make possible an interlocking which is supposed to reinforce the stability of the pelvic ring particularly when this is loaded on standing (Weisl 1954).

In rupture, dislocation and/or fracture of the pelvic structures the stability of the pelvic ring becomes disturbed and the ultimate aim in treatment is to restore the stability by as accurate a consolidation of the dislocation and/or fracture as possible. This is particularly important in fractures of the posterior, weight-bearing areas as injuries in this region more often lead to persistent disability than is the case for fractures in the anterior region.

Conservative measures such as bed-rest, slings and plaster have for a long time been the accepted mode of treatment in these fractures but recently external fixation with the use of Hoffmann instruments has been advocated (Carabalona et al. 1973, Connes 1973, Slätis & Karaharju 1975).

In an experimental study Slätis & Karaharju (1975) demonstrated that compression osteosynthesis of posterior pelvic fractures was best obtained by a trapezoid frame and bar mounted with an inclination of 70° to the long axis of the body. The frame is attached to three pins inserted into each iliac wing. The trapezoid compression frame offers an acceptable fixation of dislocations and fractures of the posterior parts of the pelvic ring, but whether this fixation gives sufficient stability to allow weight-bearing in the standing position is not known. We consider this to be an important aspect as early mobilization could then be instituted with the compression frame in place. We have therefore carried out an experimental study to analyse the amount of load different posterior fractures and dislocations can take after being fixed by the trapezoid compression frame.

MATERIAL

Ten cadaver pelves were used (Table 1). They consisted of the pelvic ring with the fifth lumbar vertebra and had been cleaned of soft tissues excluding the ligaments. The specimens originated from patients who had died of diseases that did not involve the skeleton. In three cases, the medical records could not be obtained. On naked eye examination the pelvic specimens did not disclose any signs of disease. A total of 17 loading experiments were performed on the ten specimens, in which dislocations and fractures had been produced prior to loading. To obtain sacro-iliac dislocations all the sacro-iliac ligaments and the symphysis were cut. Fractures were produced by chiselling through the sacrum or the ilium and through the pubic rami in the desired direction (see Table 2).

Unilateral injuries

Ten loading experiments were performed; in five there was a dislocation of one sacro-iliac joint and the symphysis; in the other five there were fractures of the sacrum or ilium combined with fractures of the pubic rami (Table 2).

Bilateral injuries

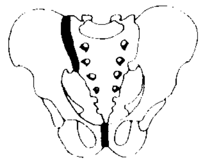
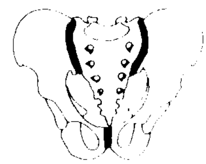
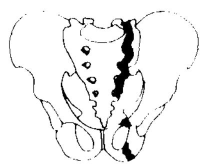
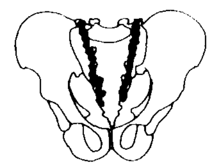
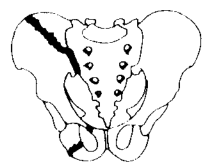
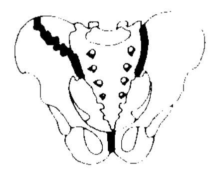
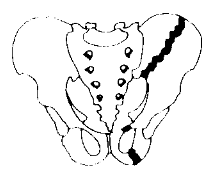
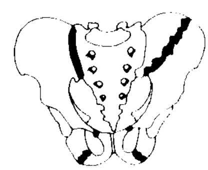
Seven loading experiments were performed; in two there were bilateral dislocations of the sacro-iliac joints and the symphysis, in three there were

Table 1. Specimens used for experimental injuries to the pelvic skeleton and subsequent external compression fixation.

Specimen no.	Age	Sex	Weight, kg	Diagnosis
1	65	M	--	------
2	66	M	74	Liver cirrhosis and acute pyelonephritis
3	67	M	69.5	Nephropathia with uraemia
4	69	M	74	Myocardial infarction
5	71	M	81	Cancer of the thyroid with metastasis of the liver and lymph nodes
6	72	F	--	Cerebral thrombosis
7	73	F	69	------
8	77	F	74	------
9	77	F	67	Pulmonary embolism, cancer of the uterus
10	82	M	47	Pulmonary embolism, myocardial infarction, acute pancreatitis

------ information not available

Table 2. Experimental injuries of pelvic specimens

Unilateral injuries		Bilateral injuries	
Injury	Nos.	Injury	Nos.
	5		2
	3		3
	1		1
	1		1

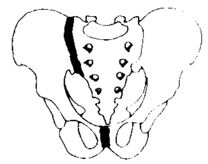
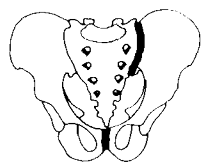
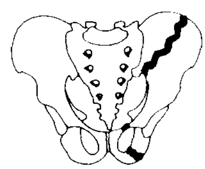
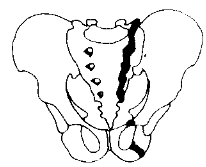
bilateral fractures of the sacrum and pubic rami and in two unilateral iliac fracture and contralateral dislocation of the sacro-iliac joint combined with fractures of the pubic rami or sectioned symphysis (Table 2).

METHODS

To achieve stability of the pelvic girdle an external compression frame assembled with the Hoffmann instruments was employed (Connes 1973). The mountings were anchored to the pelvic girdle with three pins inserted into each iliac crest. The parts of the pelvic girdle were re-adapted and compression exerted by a compression bar as part of a trapezoid compression frame with the connector bars inclined to the long axis of the body at 70° as described by Slätis & Karaharju (1975).

As a preamble to the loading tests the compressive force exerted by the Hoffmann instruments at the site of injury was measured in two cases with unilateral dislocation of the sacro-iliac joint and symphysis and in two cases with unilateral fracture of the sacrum or ilium and pubic rami (Table 3). Small mercury-filled rubber balloons were inserted between the dislocated or fractured surfaces. The balloons were connected to a horizontal cylinder each containing an indicator piston. Compression of the pelvis squeezed mercury into the cylinder and caused movement of the piston; counterpressure was then exerted with a movable vertical tube, filled with mercury, until the indicator mark on the piston returned to its initial position (cf. Slätis & Karaharju 1975). The compression was registered near maximum obtainable compression when the individual components of the frame started bending.

Table 3. Compression obtained with external compression fixation of injuries to the pelvic skeleton

Specimen no.	Injury	Compression of the posterior arch, kPa	Compression of the anterior arch, kPa
7		146	116
8		145	117
9		4•	86
10		177	35

•Fixation with dislocation of iliac fracture, in contact only at its lower part.

The loading experiments on the specimens, stabilized by the external compression fixation, were performed in a standard material testing machine (Alwetron Model T-2000) with a deformation speed of 5 mm per minute (cf. Gunterberg et al. 1976). The ischial tuberosities and the inferior pubic rami of the specimens were fixed in two separate blocks of epoxy resin (Plastic Padding®), one for each side, in a position corresponding to upright standing (Figure 1). The load and time were registered on an x-y-recorder. The hypothetical load in upright standing was calculated according to Nachemson & Elfström (1970).

RESULTS

The compressive forces obtained at the site of injury in the posterior and anterior arches of the pelvic girdle are presented in Table 3. In specimen No. 9 the fracture of the ilium was not totally reduced and thus compression was only exerted on its caudal part, whence the mercury-filled balloon was twisted and not compressed.

The results of the load tests are shown in Tables 4a and 4b. Graphic recordings of load tests are shown in Figure 2.

Comments

Group 1: Specimens with unilateral dislocation of the sacro-iliac joint and symphysis.

In this series a gradual dislocation of the sacro-iliac joint started when approximately

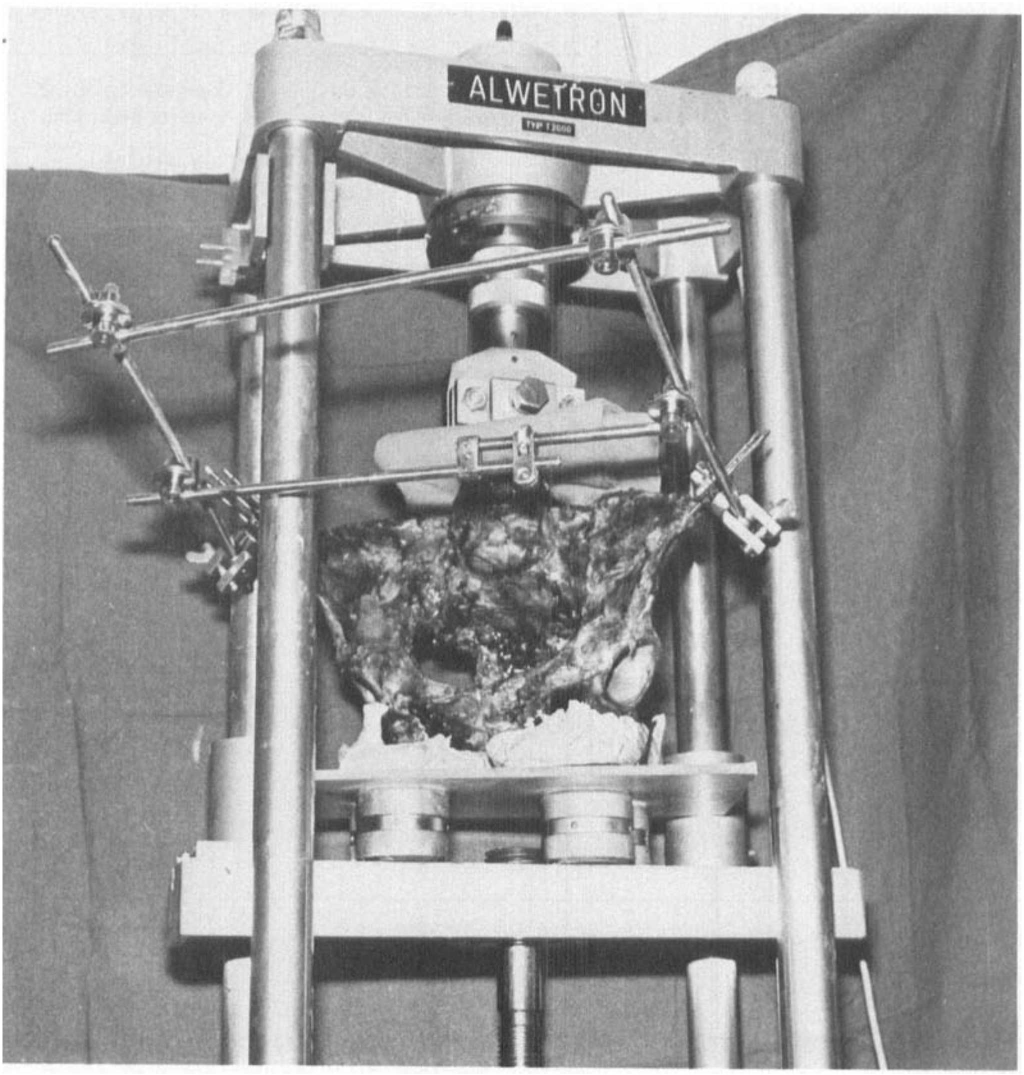


Figure 1. Specimen with the trapezoid external compression frame under load in material testing machine.

one third of the ultimate acceptance of load was reached.

Group 2: Specimens with unilateral fractures of the sacrum or ilium and the pubic rami.

In these cases a slight gradual dislocation took place when the posterior fracture was vertical but not when the fracture was oblique. In the latter case the pelvis was almost stable until the ultimate acceptance of load. At this time a fracture developed on the opposite side.

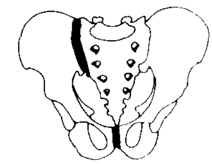
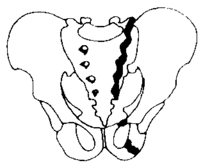
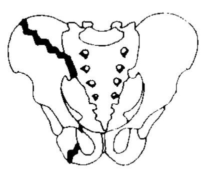
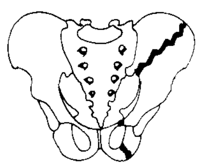
Group 3: Specimens with bilateral dislocation of the sacro-iliac joint and symphysis.

In these cases a gradual dislocation of the sacro-iliac joint started from the onset of loading.

Group 4: Specimens with bilateral fractures of the sacrum or ilium and the pubic rami.

As in Group 2 a gradual dislocation took place during loading when the fractures were vertical. Oblique fractures combined with contralateral dislocation of the sacro-iliac

Table 4a. Results of external compression fixation of unilateral experimental injuries to the pelvic skeleton

Specimen no.	Injury	Ultimate acceptance of load, N	Calculated load in upright standing, N
1		1962	951
2		1530	1108
6		657	----
7		1207	961
8		1597	922
3		1540	1010
4		2452	1020
10		2695	624
5		2950	1020
•9		1177	824

• Compression only exerted on caudal part because of dislocation of the iliac fracture.

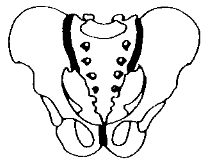
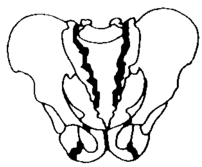
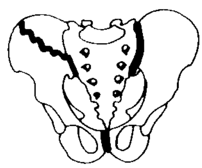
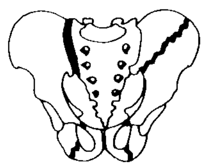
joint did not resist loading better than bilateral vertical fractures.

DISCUSSION

Fractures of the pelvis constitute some 3 per cent of all fractures. Traffic accidents and falls from heights are the causative factors and the severity of the impact is great. It has been found that 200 – 1000 kp (1962 – 9810N) are necessary to disrupt the pelvic girdle (Colachis et al. 1963). When the pelvic ring becomes fractured, the loss of stability is pronounced if the posterior, weight-bearing arch of the pelvic girdle is involved. The stability can at times be equalled to flailness. Conservative treatment by balanced traction or plaster fixation can to a certain extent reduce the fracture, but if the hemipelvis is grossly displaced, recurrent dislocation is apt to occur. Räf (1966) reported a high incidence of persistent pelvic asymmetry and low back pain at follow-up of patients with double vertical fractures.

Recent development of the armamentarium for external fixation of fractures has opened up new possibilities for the treatment of unstable pelvic fractures. Preliminary reports by Connes (1973) and Slätis & Karaharju (1975) indicate that external fixation of the pelvis not only stabilizes the fracture but also provides a great relief from pain in the

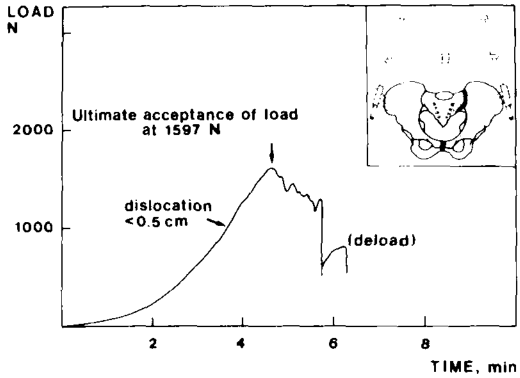
Table 4b. Results of external compression fixation of bilateral experimental injuries to the pelvic skeleton

Specimen no.	Injury	Ultimate acceptance of load, N	Calculated load in upright standing, N
6 7		50 102	— 961
3 4 10		118 353 471	1010 1020 624
8		422	922
9		216	824

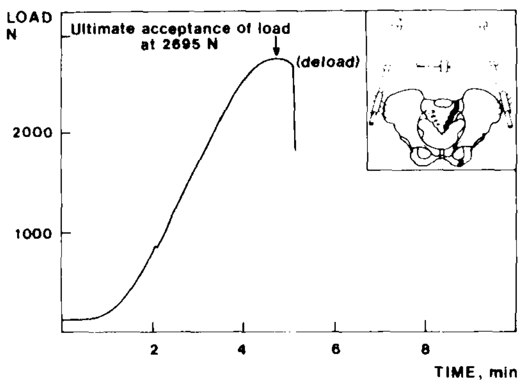
injured area. Based upon clinical experience, the time of recumbency advocated after external fixation of the fracture has been 3 weeks, but so far no firm evidence regarding the load acceptance of different pelvic injuries treated by external fixation has been available.

The experimental data obtained in the present investigation show that the external trapezoid compression frame stabilizes the pelvic girdle so that it can resist vertical load forces on the sacrum surprisingly well. The load tolerance is, however, closely related to the type of skeletal injury present. It is the unilateral injuries which can best resist vertical loading after compression fixation. A fracture through the sacrum or the ilium is more stable than a dislocation through the sacro-iliac joint. Furthermore an oblique fracture through the posterior arch is more stable than a vertical one. The reason for this can be found in the articular surfaces of the sacro-iliac joint, which are slippery and difficult to reduce into a locked position. The rugged surfaces of fractures appear to have better interlocking properties. Bilateral injuries, in which the hemipelvis is detached from the sacrum on both sides, remain – as may be expected – unstable for vertical load despite the compression device. The frame is here merely maintaining the position of the reduced parts of the pelvis.

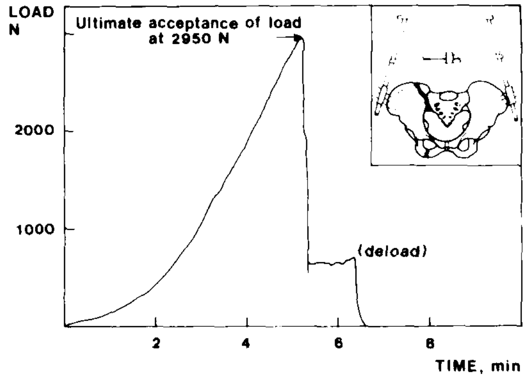
The body weight was known in eight of the ten cases for this investigation making it possible to calculate the normal load on the L V vertebra in the upright standing position



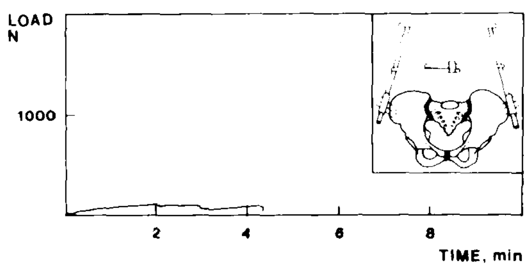
A: Specimen no. 8. The calculated normal load in the upright standing position was 922N.



B: Specimen no. 10. The calculated normal load in the upright standing position was 624N.



C: Specimen no. 5. The calculated normal load in the upright standing position was 1020N.



D: Specimen no. 6. The normal load could not be calculated but without doubt far exceeded this very low acceptance of load.

Figure 2. Load-time diagrams for pelvic specimens with different types of injury (see insets).

(Nachemson & Elfström 1970). It has been shown that the load varies depending on posture, movements, etc. On slow walking the load increased by about 15 per cent and on jumping by 40 per cent and finally on straining with erect posture by about 50 per cent.

Our method of supporting the loaded pelves by separate blocks of epoxy resin has for practical reasons not been quite physiological as the load is normally taken up by the hip joints. The results mainly give an indication of the resistance to loading when a compression frame has been applied to an experimentally injured pelvis.

In the present series, the ultimate load tolerances in unilateral lesions well surpassed the calculated values for vertical load on the pelvis during physiological conditions. In bilateral lesions, on the contrary, the resistance to vertical load was far below the calculated load in the erect position. These findings suggest that in unilateral lesions partial or full weight-bearing may be instituted immediately after application of the frame, whereas in bilateral lesions weight-bearing should be postponed for several weeks. In these experiments the stabilizing effect of muscular activity and the possibility of partly intact sacro-iliac ligaments in pelvic disruptions *in vivo* have not been given due consideration.

Hence, correlations with clinical conditions should be made with due caution. On the other hand, calculations regarding the physiological load in the upright position and the data obtained warrant certain conclusions which are applicable to clinical conditions. Thus, in lesions of the posterior and anterior arch of the pelvis, properly reduced and stabilized with the trapezoid compression frame, it may be suggested:

that in bilateral injuries no weight-bearing should be permitted before the already suggested 3 weeks of immobilization,

that the above recommendation also includes unilateral sacro-iliac dislocations and unilateral vertical fracture of the sacrum or iliac wing weight-bearing by crutches is possible,

that in unilateral injury involving oblique fracture of the sacrum or iliac wing early mobilization with full weight-bearing may be instituted.

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Nachemson, A. & Elfström, G. (1970) *Intravital dynamic pressure measurements in lumbar discs.* Almqvist & Wiksell, Stockholm.

Räf, L. (1966) Double vertical fractures of the pelvis. *Acta chir. scand.* **131,** 298–305.

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