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Percutaneous iliosacral fixation in external rotational pelvic fractures. A biomechanical analysis

Miguel A. Giráldez-Sánchez [a], Ángel Lázaro-Gonzálvez [a], Javier Martínez-Reina [b], David Serrano-Toledano [a,*], Alfredo Navarro-Robles [b], Pedro Cano-Luis [a], Evangelos M. Fragkakis [c], Peter V. Giannoudis [c]

[a] Clinical Orthopaedics, Trauma Surgery and Rheumatology Management Unit, Hospital Universitario Virgen del Rocío, Seville, Spain
[b] Department of Mechanical Engineering, University of Seville, Escuela Superior de Ingenieros, Seville, Spain
[c] Academic Department of Trauma and Orthopaedics, Clarendon Wing, Level A, Leeds General Infirmary Great George Street, LS1 3EX Leeds, UK

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ABSTRACT

Introduction: Although the gold standard in open book pelvic fractures remains the pubic symphysis (PS) plate fixation, the clinical outcomes are not satisfactory, despite the excellent anatomical reduction assessed radiologically. Some authors suggest that residual instability of the posterior pelvic elements may be responsible for the chronic pain and the early osteoarthritic changes in the sacroiliac joint (SIJ).
Objective: To evaluate whether the isolated posterior fixation with one or two iliosacral screws (ISSs) is sufficient to provide adequate stability for the treatment of Burgess Young APC-II (YB APC-II) type of pelvic ring injuries.
Methods: Biomechanical experimental study using 7 fresh human pelvises, where an YB APC-II pelvic injury was previously implemented. The isolated posterior fixation of the pelvic ring with 1 or 2 ISSs directed in the S1 vertebra body was analysed in each specimen following an axial load of 300 N. The different displacement of the SIJ and of the PS were analysed in all three spatial axes, using the validated optical measurement system 3D PONTOS 5 M. A multivariate version of Friedman test (non-parametric ANOVA for repeated measures) was performed.
Results: The isolated fixation of the SIJ with 1 ISS did not show any differences with respect to the intact pelvis ($p = 0.851$). Regarding the PS, both type of fixations (with 1 or 2 ISSs) confirmed an acceptable correction and adequate control of the PS even though with some differences compared to the intact pelvis ($p = 0.01$). The presence of the second ISS found not to offer any significant additional benefit. The three-dimensional analysis of the behaviour of the pelvic elements, in these two different types of fixation, did not show any statistical significant differences ($p = 0.645$).
Conclusion: The posterior fixation with ISS can represent an alternative option for treatment of pelvic injuries associated with rotational instability. Further prospective clinical studies are necessary to determine, the influence of the residual pubic symphysis mobility in the every day life, when the above-mentioned technique is applied.

Introduction

Pubic symphysis (PS) plating is considered nowadays the gold standard of treatment of open book pelvic lesions with partial preservation of the posterior anatomical structures (Young Burgess APC-II (YB APC-II) [1] or AO/Tile B1 [2,3]) [2,4,5]. In spite of a high rate of radiologically confirmed anatomic reduction of the symphysis joint, clinical outcomes reveal that 32.2% of patients report persistent pelvic back pain in the long-term [6]. These clinical results are analogous to those pelvic lesions characterised by complete disruption of the posterior pelvic ring elements [7,8].

Residual pain and secondary arthritis of the sacroiliac joint (SIJ) [4,9] have been reported in patients who sustained antero-posterior compression pelvic injuries with partial lesion of the SIJ treated solely by plating of the PS. Not surprisingly, several authors questioned whether this strategy of stabilization of these pelvic ring lesions is sufficient [10–15] to adequately control the SIJ. It

* Corresponding author at: Clinical Orthopaedics, Trauma Surgery and Rheumatology Management Unit, HU Virgen del Rocío, Avda. Manuel Siurot s/n, E-41013 Seville, Spain. Tel.: +34 649514163.
E-mail address: serranotoledano@gmail.com (D. Serrano-Toledano).

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was argued that the potential micro-instability component in SIJ [10,15,16] following the injury may represent the cause of the contradictory results between optimal post-operative radiological findings of the anatomical reduction, with respect to the less satisfactory functional outcome during the long term follow up. Osterhoff et al. [17] have recently concluded that "percutaneous sacroiliac screw fixation alone is a sufficient technique for the stabilization of rotationally unstable pelvic fractures". The authors of the study underlined the importance of restoring the integrity of the posterior pelvic arch.

Considering that pain is mainly located in the posterior region of the pelvic ring, precisely at the SIJ, is one incorrect to postulate whether anterior fixation of the PS is insufficient to guarantee stability of the posterior elements of the pelvic ring? Moreover, is it possible to restore the pelvic ring anatomy and prevent the micro-movements of the SIJ by solely posterior fixation? The literature regarding this clinical situation remains obscure. The aim of this study therefore is to determine the degree of pelvic stability after isolated posterior fixation using one or two iliosacral screws (ISSs) as definitive treatment in pelvic external rotation injuries (Young Burgess APC-II (YB APC-II) or AO/Tile B1).

Materials and methods

Seven female human freshly-frozen anatomical specimens were used (i.e. not embalmed cadavers) for this study. The mean age of the specimens was 73.9 (SD $\pm$ 13.85) years. None of the donors had any previous medical history of skeletal disorders. The cadaveric specimens were dissected in such way as to obtain a configuration including the L4–L5 vertebrae, the whole pelvis and also the lower third of both femurs. In all specimens the articular capsule and ligaments of the PS and SIJ were spared, including the sacrospinous and the sacrotuberous ligaments. The soft tissues of the lumbar spine and of the hip joints were spared as well.

After preparation, the anatomical specimens were frozen to below $-20\,^{\circ}$C [10,12,18,19]. Before running the tests, the specimens were defrosted and hydrated by immersion in room temperature water for 16–20 h. In this way the mechanical changes of the bone and the ligaments due to the freezing process and the dehydration were minimised. For the same reason the anatomic specimens were moistened with water before and during the experiments [12,19].

For the purposes of this study an electromechanical machine type Zwick/Roell Z100 (BT1-FB100TN), able to apply vertical loads, controlled by the test Xpert II software, was used. A patented and registered device [12,20] was attached to the electromechanical machine in order to appropriately anchor the pelvis specimens and simulate the standing position and alignment in the same sagittal plane of the anterior superior iliac spines and of the pubic tubercles [19]. Due to the properties of this specific device, it was possible to analyse the biomechanical behaviour of the fractured pelvis. The specimens were fixed proximally at an angle of 130° on a metallic plate attached on the vertebral bodies with 4 screws, 4 mm each, and 6 mm screw bolts for the sacrum. The remaining space between the metallic angled plate and the bone was filled with surgical cement polymethylmethacrylate (PMMA) Palacos LV®. Both femurs were distally fixed at 15° of anteversion and 10° of valgus, using a bi-component polyurethane resin type fast setting (Feropur®) (PR55-E55).

In all cadaveric specimens an YB APC-II pelvic injury was simulated (Table 1). Each specimen underwent a cyclic axial load of 300 N in 3 phases: (A) Intact pelvis, (B) injured pelvis with iliac-sacral synthesis by one screw at the lower portion of the S1 level (F1S), and (C) injured pelvis with iliac-sacral synthesis, adding a second screw to the previous fixation scheme, also in the S1 level (2FS), positioned superiorly with respect to the first screw. Following the YB APC-II type of injury pelvis reduction was achieved by manual manipulation until complete alignment was externally visualised around the anterior edge of the sacroiliac joint and the anterior-posterior pubic symphysis margins. X-rays were then used to both confirm reduction and perform osteosynthesis using Kirschner guide wires and titanium cannulated screws (Synthes®, Oberdof, Switzerland) of 7.3 mm diameter with washer as recommended by Kraemer [21]. Over each specimen, radiographic control was performed in inlet, outlet and lateral sacral views to ensure the proper position of the implant and reduction of injury (Fig. 1).

In order to study the three-dimensional directions of the different components of the pelvic ring, the PS and SIJ were marked with special adhesive markers. The movement and the characteristics of the pelvis under axial load in each phase of the study, were analysed, using a validated system for micro mobility biomechanical studies, PONTOS 5 M system [22] (GOM System, Optical Measuring Techniques). On the other hand, minor axial load cycles of 80 N were performed after every main axial load cycle of 300 N, with the final objective of verifying that the axial load of 300 N had not determined any bone fracture or that the repeated axial loads had not negatively influenced the overall mechanical behaviour of the specimens, which would have invalidated the study [12].

The displacements (measured in mm) were analysed and compared between the following structures: The superior and inferior level of the PS, the superior and inferior level of both sacroiliac injured joints, and the rotational movements (measured in°) of the whole injured hemipelvis with reference to the sacrum,

Table 1
Overview of the experimental phases of the study in chronological order.

Experimental phases	Description
Phase A	Cycle of axial load of 300 N applied on intact pelvis
Phase A′	Cycle of axial load of 80 N applied on intact pelvis
1st manipulation	*Anteriorly*: complete dissection of all ligaments of pubic symphysis *Posteriorly*: simulation of Young Burgess APC-II injury by dissection of ipsilateral sacrotuberous, sacrospinous, anterior sacroiliac and interosseous ligaments. The posterior sacroiliac ligaments were spared
2nd manipulation	Reduction and osteosynthesis with 1 ilio-sacral screw (F1S): the entry point of the first screw, was located 1.5 cm above the gluteal crest, at the midpoint between the iliac crest and the greater sciatic notch. The screw was positioned with an inclination of 30° in the coronal plane (cranial direction) and 15° in the axial plane, directed to the anterior portion of the S1 vertebral body
Phase B	Cycle of axial load of 300 N applied on pelvis with F1S
Phase B′	Cycle of axial load of 80 N applied on pelvis with F1S
3rd manipulation	Osteosynthesis with 2 ilio-sacral screws (F2S): the entry point of the second screw was located 1 cm above the first screw, with an inclination of 0° in the coronal plane and 15° in the axial plane, directed to the anterior portion of the S1 vertebral body
Phase C	Cycle of axial load of 300 N applied on pelvis with F2S
Phase C′	Cycle of axial load of 80 N applied on pelvis with F2S
4th Manipulation	Removal of ilio-sacral screws
Phase C″	Cycle of axial load of 80 N applied on injured pelvis