Injury, Int. J. Care Injured 45 (2014) 2055–2059

Contents lists available at ScienceDirect

Injury

journal homepage: www.elsevier.com/locate/injury

Biomechanical study of four kinds of percutaneous screw fixation in two types of unilateral sacroiliac joint dislocation: A finite element analysis

Lihai Zhang [a,1], Ye Peng [a,1], Chengfei Du [b,1], Peifu Tang [a,*]

[a] Department of Orthopaedic Surgery, General Hospital of Chinese People's Liberation Army, 28 Fu-Xing Road, 100853 Beijing, People's Republic of China
[b] Key Laboratory for Biomechanics and Mechanobiology of Ministry of Education, School of Biological Science and Medical Engineering, Beihang University, Beijing, People's Republic of China

ARTICLE INFO

Article history:
Accepted 14 October 2014

Keywords:
Biomechanics
Percutaneous screw
Sacroiliac joint
Pelvis
Finite element analysis

ABSTRACT

Objective: To compare the biomechanical stability of four different kinds of percutaneous screw fixation in two types of unilateral sacroiliac joint dislocation.
Methods: Finite element models of unstable Tile type B and type C pelvic ring injuries were created in this study. Modelling was based on fixation with a single S1 screw (S1-1), single S2 screw (S2-1), two S1 screws (S1-2) and a combination of a single S1 and a single S2 screw (S1–S2). The biomechanical test of two types of pelvic instability (rotational or vertical) with four types of percutaneous fixation were compared. Displacement, flexion and lateral bend (in bilateral stance) were recorded and analyzed.
Results: Maximal inferior translation (displacement) was found in the S2-1 group in type B and C dislocations which were 1.58 mm and 1.90 mm, respectively. Maximal flexion was found in the S2-1 group in type B and C dislocations which were 1.55° and 1.95°, respectively. The results show that the flexion from most significant angulation to least is S2-1, S1-1, S1-2, and S1–S2 in type B and C dislocations. All the fixations have minimal lateral bend.
Conclusion: Our findings suggest single screw S1 fixation should be adequate fixation for a type B dislocation. For type C dislocations, one might consider a two screw construct (S1–S2) to give added biomechanical stability if clinically indicated.

Introduction

Sacroiliac (SI) joint disruption is a common injury associated with unstable pelvic ring injuries [1–3]. According to the Tile classification, reduction and internal fixation of the sacroiliac joint is routinely performed in type B and C SI dislocations [4]. Sacroiliac screws are the most common type of fixation of posterior ring injuries as they provide stability with a minimally invasive technique [5–9].

There are numerous kinds of percutaneous SI screw fixation techniques. Many anatomic and biomechanical studies of SI screws were done in previous studies [10–13]. However, percutaneous sacroiliac screws fixation is still technique demanding owing to the adjacent neurovascular structures [14–16]. A single SI screw will decrease the biomechanical stability of fixation, and more screws will increase the risk and complications of surgery and patients' cost [17].

The most common types of SI screw fixation are a single S1 SI screw, a single S2 SI screw, or a combination of both. However, there is sparse biomechanical research to help the surgeon decide which kind of fixation is better to treat different kinds of posterior ring injuries.

This study was performed to analyze four kinds of SI screw fixation (screw in S1 or S2 separately and combined) in two types of SI joint dislocations through three-dimensional finite element analysis. This study compares the biomechanical stability for each to potentially aid the clinician in decision making for fixation technique of SI dislocations (if clinically indicated).

* Corresponding author at: Department of Orthopaedic Surgery, General Hospital of Chinese People's Liberation Army, 28 Fu-Xing Road, 100853 Beijing, People's Republic of China. Tel.: +86 010 68212342; fax: +86 010 68212342.
E-mail addresses: zhanglihai74@yahoo.com.cn (L. Zhang), dr_pengye@163.com (Y. Peng), duchengfei163@163.com (C. Du), pftang301@126.com (P. Tang).
[1] The first three authors contributed equally to this work.

http://dx.doi.org/10.1016/j.injury.2014.10.052
0020–1383/

Materials and methods

Model construction

Finite element models were constructed from computed tomography (GE Medical Systems/light speed 16) images from a normal female (165 cm, 55 kg, 35-years old). The slices were 1 mm thick. The virtual 3D model of the pelvis was created from the CT data under the image-processing software (Mimics, Materialise's Inter-active Medical Image Control System, Materialize, Belgian) with DICOM format. The bones, cartilages, and ligaments of FE model were developed based on the geometrical model in Hypermesh 11.0 (Altair Engineering Corp., Michigan, USA). The cortical bone of the sacrum and ilium were simulated as a 0.45 and 1.0 mm thick shell, respectively. Bony element properties were made according to previous studies [18–20]. The cartilage in the SI joint was developed with a uniform thickness and the ratio of thickness of the sacral and iliac parts of the cartilage were 1:2. Sacral cartilage was 1.8 mm thick and iliac cartilage 0.8 mm. The gap between two cartilages was 0.3 mm [21]. Eight kinds of ligaments were constructed as 3D tension truss element: ASL (anterior sacroiliac ligament), ISL (interspinous ligaments), LPSL (long posterior sacroiliac ligament), SPSL (short posterior sacroiliac ligament), SS (sacrospinous ligament), ST (sacrotuberous ligament), SP (superior pubic) and AP (arcuate pubic). Attachment regions were done according to a previous study [22]. The entire model has 285,170 elements and 58,948 nodes (Tables 1 and 2, Fig. 1).

Model validation

The FE model was validated using in vitro data and other simulation study results [23–25]. To maintain consistency, the sacral spinous processes in the model were removed and all nodes on the iliac bones lateral to the ventral and dorsal ligament complexes. Point loads follow the in vitro study on the ventral surface and dorsal surface of the sacrum, all at the midsagittal plane of the inferior S1 and superior S2. The node on the superior sacral endplate was chosen as the displacement reference point. There are five translational loads (294 N) and three rotational moments (42 N m) (anterior, posterior, superior, inferior, mediolateral, flexion, extension, and axial rotation) were tested. The results were recorded and displayed in Fig. 2 and showed great consistency.

Biomechanical comparison of different percutaneous screws fixation in type B and C sacroiliac joint dislocation

There are two kinds of SI joint dislocation, type B and C [2]. The LPSL and SPSL were retained in the FE model of the type B dislocations, creating a rotationally unstable model. All the stabilizing ligaments of the hemipelvis were damaged to create a vertically and rotationally unstable model of type C dislocations. The model has a pubic ramus fracture and ligament disruption. Complete type C SI joint dislocations are characterized by disruptions of all the ligaments mentioned above in the posterior ring and represent a vertically unstable pelvic ring injury. Type B SI joint dislocations were modelled by ASL, SS, ST and the surface of articular capsular tissue disruption. Four kinds of percutaneous screws fixations were tested in this study. The FE models were constructed by implanting screws into injury models of the pelvis with unilateral dislocation of the SI joint along with a fracture of the pubic ramus. The four types of fixation are described as follows (Fig. 3):

S1-1: One SI screw fixation in a unilateral S1 segment.
S2-1: One SI screw fixation in a bilateral S2 segment.
S1–S2: One SI screw fixation in a unilateral S1 segment, the other SI screw fixation in a bilateral S2 segment.
S1-2: Two SI screws in a unilateral S1 segment.

The vertical shear was the main force across the posterior ring [26]. The inferior translation, flexion and lateral bend were recorded and analyzed.

Table 1
Model properties of materials.

	Young's modulus (MPa)	Poisson's ratio
Cortical bone	17,000	0.3
Trabecular bone	150	0.2
Interpubic disc	5	0.45
Screw	114,000	0.3

Table 2
Model properties of ligaments.

Ligament	*K* (N/mm)	Number of springs
Anterior sacroiliac	1500	30
Interspinous	3000	28
Long posterior sacroiliac	10,000	8
Short posterior sacroiliac	7500	26
Sacrospinous	8000	10
Sacrotuberous	9000	16
Superior pubic	250	12
Arcuate pubic	250	12

Results

The inferior translation, flexion and lateral bend are shown in Table 3. The inferior translation was defined as displacement of the

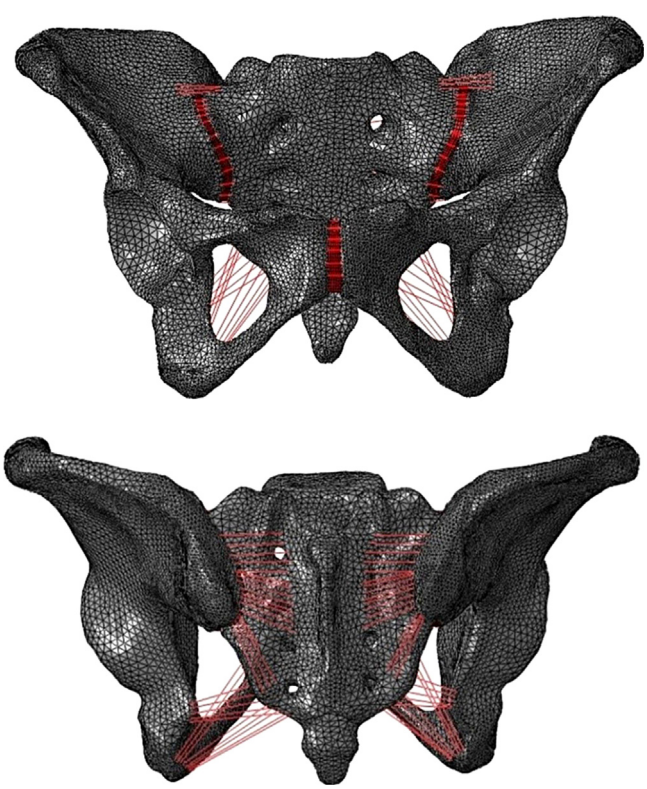

Fig. 1. FEA model of pelvis.