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by Mohammad Zaim Chilmi

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Choosing between the Conventional Plates, Locking Plates, or Iliosacral Screws for Sacroiliac Joint Dislocation: A Biomechanic Comparative Study

Trixie Brevi Putri¹, Erwin Ramawan¹, Mohammad Zaim Chilmi¹,

Kukuh Dwiputra Hernugrahanto¹, Jifaldi Afrian Maharaja Dinda Sedar¹,

Fundhy Sinar Ikrar Prihatanto²

¹Department of Orthopedic & Traumatology, Dr. Soetomo General Hospital/Universitas Airlangga, Surabaya, Indonesia

²Department of Anatomy & Histology, Faculty of Medicine, Universitas Airlangga, Surabaya, Indonesia

ABSTRACT

Background: This study examines the comparison of biomechanical strengths of three kinds of the most familiar implants available in Indonesia: conventional and locking sacroiliac plates and screws, also iliosacral screws. Despite the common thought that iliosacral screws are preferred compared to conventional plates and screws due to its biomechanic superiority, this study tested whether the locking plates and screws could offer an alternative.

Materials and Methods: This study was an in vitro experimental study with a Randomized Post Test - Only Control Group Design using pelvic bones from male cadavers aged 20-50 y.o. Twelve samples were divided into three treatment groups and one control group. Group CPS was fixed with two conventional plates, LPS was fixed with two locking plates, IS was fixed with two iliosacral screws, and control group with sacroiliac joint was left intact. Each group was given an increasing load until a vertical shift of the sacroiliac joint ≥ 2.0 mm was obtained.

Results: The average force load for 2 mm displacement among the fixation systems being tested shows a statistically significant difference ($p < 0.05$). Load failure force for 2 mm displacement in the group LPS has the highest average (591.33 ± 56.08 N) compared to the group IS (583.67 ± 73.56 N) and group CPS (574 ± 106.05 N).

Conclusion: Biomechanically, the fixation system using two locking anterior sacroiliac plates and screws is more stable than the iliosacral screws and conventional sacroiliac plates and screws.

Keywords: *biomechanics; sacroiliac joint dislocation; anterior plating sacroiliac; locking; iliosacral screwing*

Level of Evidence: II



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Corresponding Author:

Erwin Ramawan, M.D.,
Dr. Soetomo General Hospital/Universitas Airlangga,
Surabaya, Indonesia.
Email: erwin-ramawan@fk.unair.ac.id

Introduction

The pelvic ring is an essential part of the human skeletal system. It has two important functions of protecting the pelvic organs and providing stability to support body weight. Pelvic stability is obtained through the osteo-ligamentous structure's ability to withstand physiological stress without abnormal deformation.^{1,2} Fractures and injuries to the pelvic ring, whether related or not with severe trauma, usually occur in the range of 2-8% of all musculoskeletal fractures.³⁻⁵ In the United States, it is estimated that pelvic fracture occurs in 37 of 100,000 people per year.⁶

The pelvic ring's stability depends primarily on the sacroiliac complex's integrity, which holds the posterior load.⁷⁻⁹ The implant of choice for sacroiliac joint dislocation is one of the never-ending debatable topics among orthopedic surgeons.¹⁰ Many implant choices are available in the market. This study is a biomechanical study that aims to compare the biomechanical stability of three kinds of the most familiar implants available in Indonesia: conventional and locking sacroiliac plates and screws, also iliosacral screws. This study tested the locking plates and screws that were not commonly explored in Indonesia's daily practice to treat pelvic ring injury. We hypothesize that sacroiliac joint dislocation fixed with locking plates and screws will offer an alternative.

Material and Methods

Study Design

This research is an in vitro experimental study with a Randomized Post Test - Only Control Group Design. The study was conducted in the Anatomic laboratory in our institution and the Special Testing Laboratory of the Faculty of Civil, Environmental, and Earth Engineering. This study had already approved by the IRB of the authors' affiliated medical faculty.

Samples Criteria

In this study, the experimental unit was pelvic bones from 5 male cadavers aged between 20-50 years preserved less than three years before the experiment. Any pelvic with gross anatomical deformity and damages due to injuries, any congenital abnormalities, joint inflammatory or infection disorders, bone tumors were excluded.

Study Stages

This study's implementation was divided into three stages—first, cadaveric pelvic bone preparation and internal fixation assembly. Second, a biomechanical test to determine the stability of all groups and data recording. The third is the data collecting and analysis of research data.

Preservation, Preparation, and Sacroiliac Joint Disruption Modeling in Specimens

Preservation had been done with 10% formalin, and the samples were cleaned from all soft tissues that adhered to it. The samples were from the L5 vertebral body, sacrum, and two innominate. Pelvic ring ligaments and pubic symphysis were separated for the treatment groups. These were the dissected ligaments of pelvic ring: Posterior Sacroiliac (both long and short), Interosseus Sacroiliac, Anterior Sacroiliac, Sacrotuberous, Sacrospinous, and Iliolumbar. While in the control group, only pubic symphysis was separated.

Fixation of Specimens

The treatment sample was then divided randomly (simple random) into three treatment groups, namely group CPS (fixation with conventional plates and screws), group LPS (fixation with locking plates and screws), group IS (fixation with iliosacral screws), and one control group. Each pubic symphysis was fixated by first author using a conventional 3.5 mm 316 L stainless steel five holes-small DCP plate and screws. The method of fixation is illustrated in figure 1.

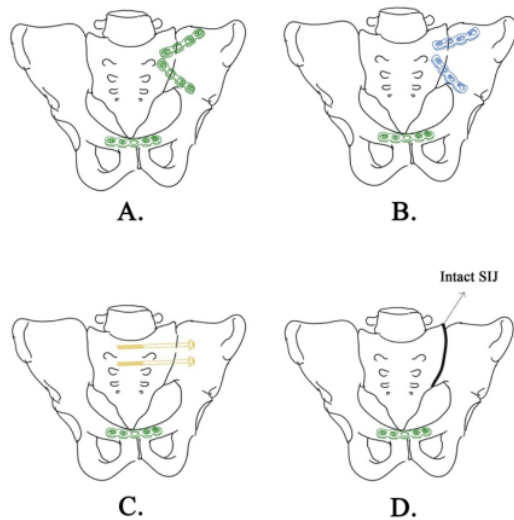


Figure 1. Method of Fixation. A. Group CPS (Conventional Plate and Screws), B. Group LPS (Locking Plate and Screws), C. Group IS (Iliosacral Screws), and D. Control.

Group CPS used two conventional 3.5 mm pre-contoured 316 L stainless steel four holes-reconstruction plate (ORMED®). Drilling was done with a 2.7 drill bit. The hole was tapered with a cancellous taper. Later on, 3.5 mm cancellous screws were put on (one screw on the side of the sacrum and two screws on the side of the ilium). In group CPS, two plates were arranged at an angle of 60° to each other.

Group LPS used two locking 3.5 mm pre-contoured 316 L stainless steel four holes-reconstruction plate (ORMED®). Drilling was done with a locking 2.8 drill bit. Then 3.5 mm self-tapered self-locking screws were put on (one screw on the side of the sacrum and two screws on the side of the ilium). In group LPS, two plates were arranged at an angle of 60° to each other.

Group IS used K-wire threaded installation for guidance. Drilling was done with the cannulated drill bit. Then two 316 L stainless steel 6.5 mm cannulated (long threaded-32 mm) screws (ORMED®) were installed from the posterior iliac fossa toward S1 and S2 bodies.

Control group was left without fixation since the sacroiliac joint remained intact.

Biomechanical Test

The displacement (vertical shift) between the sacrum and the ilium for each group was measured after the loading. Displacement was measured by comparing the distance between the two points before and after being given continuous loading. The tools and materials used were Shimadzu AG-x5kN autograft, pliers, and digital calipers. Biomechanical tests were carried out by the constant loading on the upper part of the L5 sacral body using an autograft. Pelvic bones were placed in a fixation device on the autograft machine. On both sides of the pelvic bone (i.e., on the side of the ilium and the side of the sacrum), each point was marked by a dot to perform the measurement.

In this study we only evaluate for one specific force – vertical shear – to avoid bias that came from another force types (anteroposterior or lateral compression) that will damage the bone microarchitecture and could affect another observation to be done. The vertical shear loading force of the autograft machine was given starting at 0 N, then rising at a 1 mm / second speed until a shift (translation) is obtained at the sacroiliac joints of 2.5 mm and 10 mm. The force applied was noted when reaching these three shifts. The initial load was given at 100 N in the vertical direction; the load was increased until a shift (translational) was obtained from the sacroiliac joint ≥ 2.0 mm. A picture when performing the biomechanical test is shown in Figure 2. To ensure that each sacroiliac joint being tested will not affect the contralateral side, a holder device was made to create a model of unilateral stance for each test. Moreover, every sacroiliac joint with implanted devices that are already being tested were not being used for testing another implant system to maintain the microstructure of the bone.



Figure 2. Biomechanical Testing of Cadaveric Pelvic Bone Using Autograf. A particular holder device was made to fix the pelvic during the experiment.

Statistical Analysis

The analysis was performed statistically using SPSS software version 23.0 (SPSS Inc., Chicago, IL, USA). The determination of α value was 0.05. The data normality test used the Shapiro Wilk test, and the data homogeneity test used the Levene test. Data intervals or ratios, normal distribution, and variations between the same groups were done using one-way ANOVA test with Friedman test as Post hoc analysis.

Results

This is an experimental analytic study comparing the biomechanical strength of fixation in the dislocation of sacroiliac joints between CPS, LPS, and IS. In Figure 3, the comparison of the load to failure upon axial forces among fixation groups is shown.

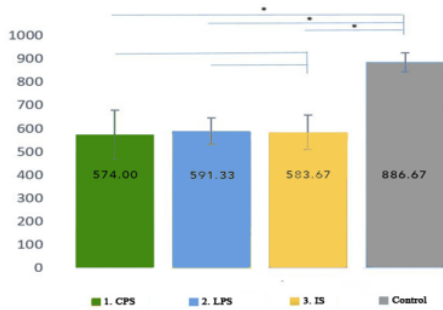


Figure 3. Comparison of the load to failure upon axial forces among fixation groups : 1. Group CPS (Conventional Plate and Screws), 2. Group LPS (Locking Plate and Screws), 3. Group IS (Iliosacral Screws), and Control. Data are presented as mean \pm SD. n=3/ group, *, $p < 0.05$

The statistical analysis using the One-way ANOVA test in Table 1 shows a significant difference between the average load forces that cause a 2 mm load failure based on a fixation system ($p = 0.002$). This result indicates that the load failure force of 2 mm in group LPS has the highest average (591.33 ± 56.08 N) compared to other groups. There is no significant difference between the mean force loads that cause either 5 mm or 10 mm load failure based on a fixation system ($p = 0.147$ and $p = 0.066$, respectively). The Post hoc Tukey HSD analysis shows a significant difference between the mean force loads that caused a two mm shifting failure between the control group and group IS ($p = 0.004$), the control group and group CPS ($p = 0.004$), the control group and group LPS ($p = 0.005$).

Table 1. Load Force for 2, 5, and 10 mm Shifting Failure Based on The Fixation System

Shifting	Conventional plates and screws (CPS) (Mean \pm SD) (N)	Locking plates and screws (LPS) (Mean \pm SD) (N)	Iliosacral screws (IS) (Mean \pm SD) (N)	Control (C) (Mean \pm SD) (N)	P-Value*	P Value*					
						C-IS	C-CPS	C-LPS	IS-CPS	IS-LPS	CPS-LPS
2 mm	574 \pm 106.05	591.33 \pm 56.08	583.67 \pm 75.36	886.67 \pm 40.41	0.002	0.004	0.004	0.005	0.998	0.999	0.991
5 mm	741 \pm 113.23	767.33 \pm 101.42	767.33 \pm 169.82	959 \pm 30.04	0.147	0.8	0.8	0.8	0.8	0.8	0.8
10 mm	793.67 \pm 104.97	821.33 \pm 150.46	976 \pm 325.81	1245.33 \pm 58.5	0.066	0.8	0.8	0.8	0.8	0.8	0.8

Note: *: One-way ANOVA Test
#: Post hoc Tukey HSD Analysis

Discussion

There are various methods for fixing sacroiliac joint dislocation, including iliosacral screws, anterior or posterior sacroiliac plates and screws, sacral bars, and triangular osteosynthesis.¹¹ Fixation of the sacroiliac joint allows for open and direct reduction with the drawbacks requiring a wider incision and approach to the sacroiliac joint to better view the surgery. In comparison, fixation with iliosacral screws requires adequate operator skills, good dimensional understanding, fluoroscopy support in surgery, and a greater risk of neurovascular injury due to reduction and implant placement.¹²⁻¹⁴ The displacement of fragments indicates the

stability of a fixation system in response to certain loads. Stiffness of fixation construction is the ratio of the load applied to the displacement between fragments.^{15,16} The stability of various internal fixation types of the sacroiliac joint has been investigated. Research on the biomechanical strength of plates using locking screw for sacroiliac joint fixation has not been done much in Indonesia.

This study aims to compare stability and shift in dislocation of sacroiliac joints fixed using CPS, LPS, and IS. In this study, the results obtained a significant impact that the greatest load force for 2 mm load failure was found in the LPS compared to another two fixation systems. This indicates that this system is the most stable than the other two methods, followed by IS and CPS. Alike with other studies, the intact pelvis has the greatest stability.^{17,18}

The stability of sacroiliac joints fixation using anterior sacroiliac plates and screws, which commonly uses conventional plates and screws in Indonesia, is more inferior than iliosacral screws. This study shows that the locking system obtained better stability compared to conventional systems and even iliosacral screws.¹⁹

We admit that our study has several limitations. Bias might come from the diversity of the cadaver pelvic bone mineral density, and conditions in cadaver bones may vary from the actual in vivo human pelvic bone. We were unable to control this bias due to the limited number of cadavers available and these were scarce and very valuable specimens to obtain. Another bias also from the small sample number due to the scarcity and availability of the cadaver samples. Whereas for the ideal statistic, the sample number equal to three times the current study. We also did not perform the post-fixation radiograph evaluation in this study. To equalize the scarcity of the sample number and ensure the bone quality to be tested will not be affected by another treatment, we made a holder device to create a model of unilateral stance. Every sacroiliac joints with implanted devices that are already being tested were not being used for testing another implant

system to maintain the microstructure of the bone.

Prospective clinical research is needed to assess the stability, function, and complications of the locking sacroiliac plates and screws in vivo. For future research, the finite element analysis model's usage should be explored more due to its practicality and ability to simulate the physical bone condition and test the microcosmic mechanical research to be a good complement for a biomechanical study. Many aspects could be studied, such as stress distribution, and the classical method using real cadavers is getting more difficult nowadays to be approached.

Conclusion

This study shows that the biomechanical fixation system using two locking sacroiliac plates and screws is more stable than the iliosacral screw system and conventional sacroiliac plates and screws with significant differences. The locking plates and screws offer two benefits: it is proven biomechanically stable compared to another two usual implants and its applicability when the fluoroscopy is not available. The direct reduction also hinders the complication from indirect reduction due to anatomical variances and technical difficulty identifying the "safe zone" during percutaneous iliosacral screwing.

Conflict of Interest

The authors affirm no conflict of interest in this study

Acknowledgement

None

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