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Original Article

Sacroiliac secure corridor: analysis for safe insertion of iliosacral screws★

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ABSTRACT

Objective: Posterior pelvic lesions, especially of the sacral-iliac joint, have high mortality and morbidity risks. Definitive fixation is necessary for the joint stabilization, and one option is the sacral percutaneous pinning with screws. Proximity to important structures to this region brings risks to the fixation procedure; therefore, it is important to know the tridimensional anatomy of the pelvis posterior region. Deviations of the surgeon's hand of four degrees may target the screws to those structures; dimorphisms of the upper sacrum and a poor lesion reduction may redound in a screw malpositioning. This study is aimed to evaluate the dimensions of a safe surgical corridor for safe sacroiliac screw insertion and relations with age and sex of the patients. *Method:* One hundred randomly selected pelvis CTs of patients with no pelvic diseases, seen at a tertiary care teaching Hospital. Measurements were made by computer and the safest area for screw insertion was calculated by two methods. The results were expressed in mm (not in degrees), in order to be a further surgical reference. *Results:* There was a significant size difference in the analyzed sacral vertebra, differing on a wider size in men than in women. There was no significant statistical difference between vertebral size and age. By both methods, a safe area for screw insertion could be defined. *Conclusion:* Age does not influence the width of the surgical corridor. The surgeon has a safe corridor considered narrower when inserting screws in a female pelvis than when in a male one. However, as the smallest vertebra found (feminine) was considered for statics, it was concluded that this corridor is 20 mm wide in any direction, taking as a reference the centrum of the vertebra.

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Corredor de segurança sacro-ilíaco: análise para inserção segura de parafusos íliossacrais

R E S U M O

Objetivo: Lesões pélvicas posteriores, especialmente da articulação sacro-ilíaca, têm alta mortalidade e morbidade. Fixação definitiva é necessária para estabilização, parafusos percutâneos são uma opção no sacro. Estruturas nobres próximas à região trazem riscos à fixação. Assim, é importante conhecer a anatomia tridimensional da região posterior da pelve. Desvios da mão do cirurgião da ordem de 4º podem direcionar os parafusos àquelas estruturas; dismorfismos do sacro superior e redução ruim da lesão podem contribuir para mau posicionamento dos parafusos. Este estudo objetiva avaliar as dimensões do corredor de segurança para inserção segura de parafuso iliossacral e relações com sexo e idade dos pacientes. *Métodos:* Selecionadas randomicamente 100 tomografias computadorizadas de pelve de pacientes sem doenças pélvicas, atendidos em hospital terciário de ensino. Feitas medições por computador, calculada por dois métodos a área mais segura para inserção de parafusos, resultado expresso em mm (não em graus), para ser mais uma referência cirúrgica. *Resultados:* Houve diferença significativa no tamanho da vértebra sacral analisada, que tem volume maior em homens do que em mulheres. Não houve significância estatística entre tamanho vertebral e idade. Encontrou-se pelos dois métodos área segura para inserção de parafusos. *Conclusões:* A idade não influencia o tamanho do corredor. O cirurgião tem um corredor de segurança considerado menor ao inserir parafusos em uma pelve feminina do que masculina. Porém, como foi considerada para estatística a menor vértebra encontrada (feminina), concluiu-se que esse corredor é de 20 mm em qualquer direção, a tomar-se como referência o centro vertebral.

Palavras-chave:
Fixação de fratura
Fixação interna de fraturas
Ílio
Ossos pélvicos
Parafusos ósseos
Sacro

Introduction

Fracturing of the pelvis with rupturing of posterior osteoligamentous structures and the sacroiliac joint is associated with high morbidity and mortality, due to lesions that cause hemodynamic instability and hypovolemic shock.[1,2] Despite the advances of modern medicine, such as external fixation, angiography and cardiopulmonary resuscitation, the mortality rate due to pelvic fractures may still reach up to 20% of the cases. Posterior lesions of the pelvis imply complications that are even more serious than those of the anterior region.[3-6]

Since these are common causes of severe hemodynamic instability,[7] external fixation becomes imperative for stabilizing the situation. The definitive treatment, which may be conservative (when it is decided to keep the external fixator in place) or may be surgical, can be done as a second procedure, after performing appropriate imaging examinations and surgical planning.[6]

The surgical treatment for these lesions consisted of external fixation until 1985, when the technique of posterior stabilization of the pelvis using spongy screws was introduced. The current techniques recommend use of cannulated screws and this is the most accepted method for stabilizing sacral fractures with disjunction of the sacroiliac joint.[6] This technique achieves fixation of the sacrum to the iliac through directing the screws from the surface of the posterior wing of the iliac to the body of the first sacral vertebra. Compression between the fragments is thus achieved (Figs. 1 to 5).[8]

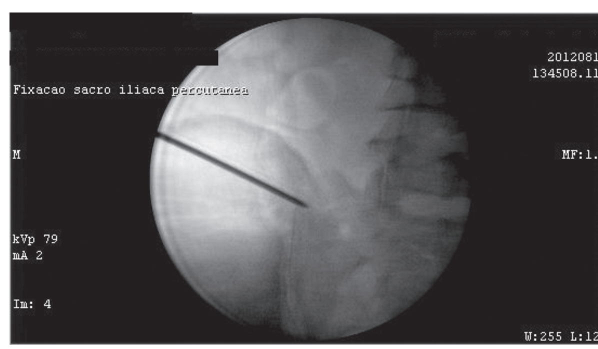

Figure 1 - Percutaneous fixation technique; positioning of the guidewire with the aid of fluoroscopy in the operating theater, anteroposterior image.

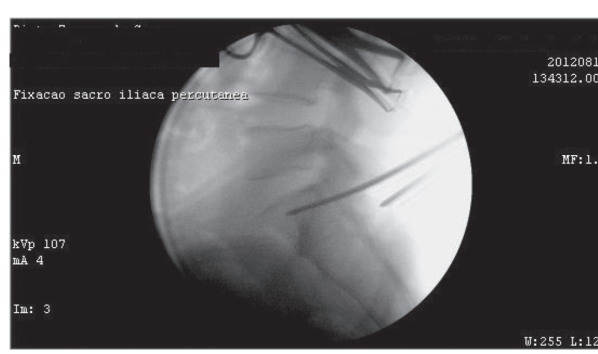

Figure 2 - Percutaneous fixation technique; positioning of the guidewire with the aid of fluoroscopy in the operating theater, lateral image.

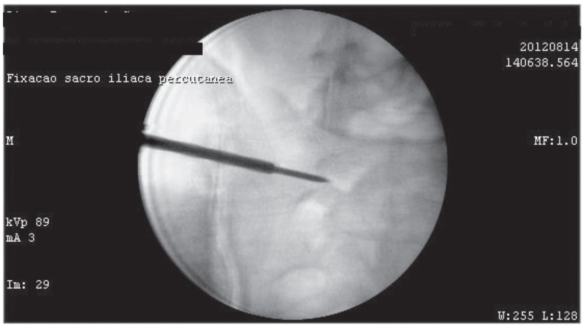

Figure 3 - Percutaneous fixation technique; passage of bit by means of the guidewire with the aid of fluoroscopy in the operating theater, anteroposterior image.

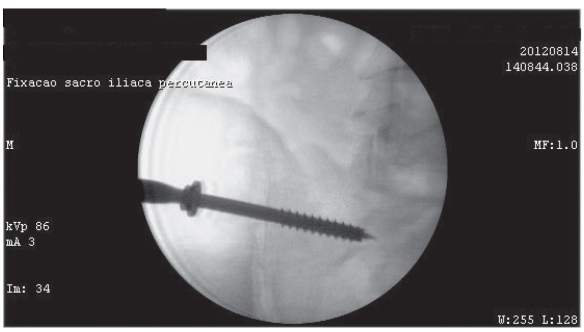

Figure 4 - Percutaneous fixation technique; placement of cannulated screw with the aid of fluoroscopy in the operating theater, anteroposterior image.

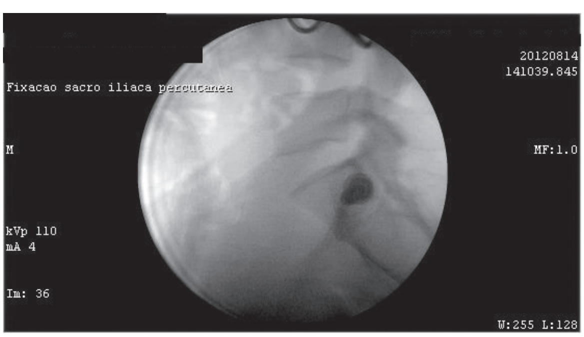

Figure 5 - Percutaneous fixation technique; cannulated screw and washer correctly positioned in the vertebra S1, lateral image with the aid of fluoroscopy in the operating theater.

After a computed tomography scan has been produced, the screws can be placed both by means of an open posterior route and percutaneously, with the aid of fluoroscopy. Choosing the best surgical access method for each case is at the surgeon's discretion.[9] The open method has the disadvantage that it imposes greater morbidity on the patient, while the percutaneous method increases the chances of injuring prime structures (vessels and nerves) and viscera.[10]

The proximity of the internal iliac vein and the lumbosacral plexus present risks in relation to internal pelvic fixation, and for this reason it is extremely important to have knowledge of the three-dimensional anatomy of the posterior region of the pelvis, for correct insertion of the iliosacral screw.[9] In the literature, it is shown that deviations of the surgeon's hand by as little as four degrees may direct the screws towards the foramen of S1 or through the anterior wall of the sacrum.[9]

Objectives

This study aimed to evaluate the sacral morphological differences among patients from the region covered by a tertiary referral and teaching hospital, who had undergone computed tomography scans of the pelvic region at this regional hospital because of non-orthopedic problems, and to correlate differences that might be encountered with the patients' age and gender, such that this could be a further reference for orthopedic surgeons in cases requiring fixation of open pelvic ring complexes.

Materials and methods

The present study was submitted to the research ethics committee of the tertiary referral hospital where the study was conducted, and was granted prior approval by the committee.

Tomographic examinations on 100 patients, who were randomly selected from among the general patients of this tertiary referral and teaching hospital between April and August 2012, were used. Initially, 50 men and 50 women (all adults) were evaluated retrospectively in relation to anatomical variations of the sacral vertebrae. Patients with evidence of disease relating to the sacroiliac joint, trauma or pelvic or spinal surgery were excluded from the study. Thus, one female patient was excluded because she presented a pathological condition of the pelvic bone, which resulted in N = 99. Physical data such as weight, height and ethnicity were not taken into consideration for the present study.

In this study, the area of the S1 vertebra of the sacrum, which represents a secure bone corridor for inserting screws, was measured.[11,12] For this, the images were analyzed and a consensus was reached between a radiologist and an orthopedist who was a hip specialist.

All of the tomographic scans were produced at the tertiary referral hospital, in the same (and only) tomographic scanner (General Electric®), with eight-channel multidetectors (Multislice). Volumetric data were acquired in the axial plane from the upper abdomen and pelvis, with the patient in the supine position, with a slice thickness of 3.75 mm and the possibility of restructuring in several planes. During the tomographic examinations, the position of the pelvis was established individually, such that the anatomical structures remained symmetrical in the slices, thus enabling proper assessment. The standard settings for the examinations were 120 kV and 81 mA, and reformatting in the sagittal plane was performed.

The images were reformatted in a window for bone, in the axial and sagittal planes for the sacrum, at intervals of 3.75 mm, in parallel with the sacroiliac joint, in order to facilitate measurement of the dimensions of the sacral wall.

To create sagittal images parallel to the sacroiliac joint, multiplanar reconstructions were performed.

To analyze and reformat the images obtained as above, the e-film® software was used, which converted the data to files in DICOM format.

Axial tomographic images converted into DICOM format were selected such that they would take into account anatomical reference points of the interapophyseal joint, between the fifth lumbar vertebra (L5) and the first sacral vertebra (S1), and the vertebral foramen immediately adjacent, i.e. the L5-S1 segment. The cursor of the image analysis software was positioned at this level, and a paramedian line was traced out to define the plane and the sagittal reformatting of the tomographic images (Fig. 6).

To measure the secure corridor in the sagittal plane, images were produced starting from the sacroiliac joint and extending medially to the sacral vertebral body. From the sequence of sagittal images, the one with the smallest slice area was enlarged. The cortical margin of the narrowest region of the sacral wall was highlighted on the computer and was measured (height, width and angles) through the geometrical center (Fig. 7).

After the image in the sagittal plane had been obtained, four reference points were marked out on the first sacral vertebra: anterosuperior, anteroinferior, posterosuperior and posteroinferior borders. These points, when jointed together, delimited an irregular quadrilateral with dimensions that were known through the software tool used, which made measurements of the distances between points that had previously been established. These connecting lines for analysis were classified as line "A", which joined the posteroinferior and posterosuperior points; line "B", which joined the posterosuperior and anterosuperior points; line "C", which joined the anterosuperior and anteroinferior points; and line "D", which joined the anteroinferior and posteroinferior points (Fig. 7).

To statistically analyze the data, parametric tests were used, since the results presented normal distribution. Student's t test was applied with the aim of comparing the data obtained between the patients.

Two types of area measurement were used: one that took the entire quadrilateral and the other that used a circumferential area inscribed within this quadrilateral. In the first measurement, the area of the quadrilateral formed by the abovementioned four lines was calculated for each of the imaging examinations on the patients. The area calculation on the quadrilateral that resulted from joining the lines was done by dividing it into two triangles. The calculation was done by means of a computer (Fig. 8). In the second type, a circumference was inscribed tangentially to the sides of the quadrilateral. This circumference, which was centered in the middle of the vertebra, thus marked out the radius along which the screw should be located, plus a margin of error that would be tolerated at the time when the screw was inserted (Fig. 9).

At the time of the examination, all the patients agreed to participate in the research project, through acceptance of a free and informed consent statement. At that time, proper explanations of the purpose of the present study were provided. The patients were free to choose whether to participate or not, without any advantage and without any identification of patients at the time of their acceptance of the statement.

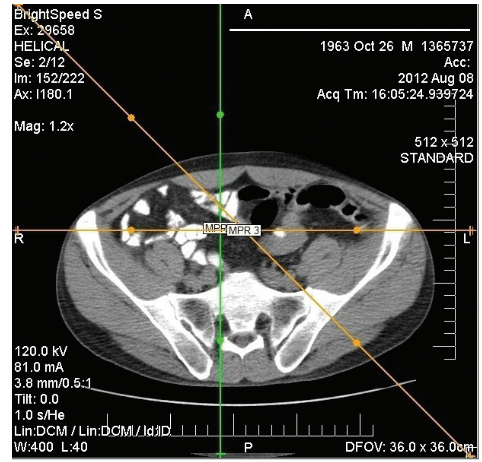

Figure 6 - Axial slice of the pelvis, using the e-film® software; tracings of lines for reformatting the image in a sagittal slice , with emphasis on the vertebra S1.

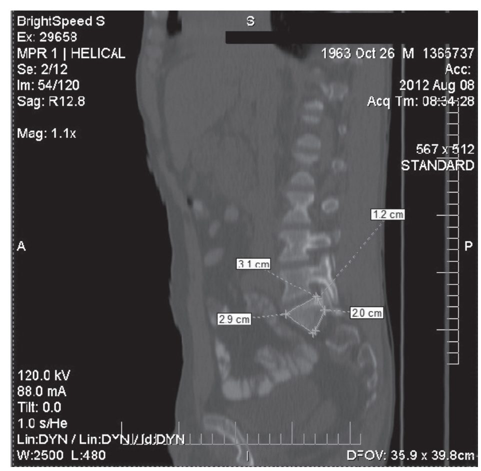

Figure 7 - Computed tomography image, sagittal slice; marking of reference points and measurements on the vertebra, using the e-film® software.

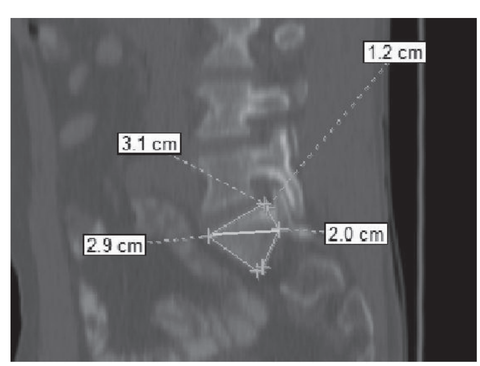

Figure 8 - Division of the irregular quadrilateral into two triangles, in order to measure the area.

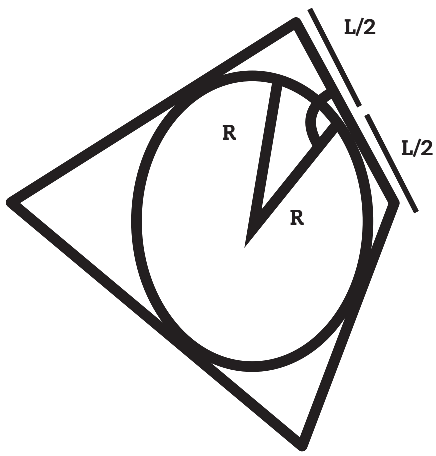

Figure 9 - Irregular quadrilateral with inscribed circumference.

Results

Two types of mathematical-statistical analysis were used on the tomographic images. In the first type, the measurements A, B, C and D on the tomographic slices were analyzed for each patient and comparisons were made between them. The general standard deviation (sd), mean among the patients, mean among the male patients, mean among the female patients, male sd, female sd, largest measurement, smallest measurement, largest male and female measurements and smallest male and female measurements were obtained (Table 1).

Student's t test for independent samples was performed, with the aim of comparing the abovementioned measurements (A, B, C and D) in relation to the patients' gender. It was found, with a minimum significance level of 5% ($p < 0.05$), that the measurements differed between the sexes, with the exception of measurement C (Table 2).

Table 1 - Statistical comparison of the measurements A, B, C and D.

	A	B	C	D
SD	0.24	0.33	0.31	0.26
Mean	1.40	2.69	2.79	2.16
Male mean	1.46	2.78	2.83	2.23
Female mean	1.33	2.60	2.75	2.09
Male deviation	0.26	0.32	0.33	0.28
Female deviation	0.17	0.33	0.29	0.23
Max	2.3	3.7	3.7	3.2
Min	1.1	1.6	1.8	1.7
Male max	2.3	3.7	3.7	3.2
Male min	1.1	2	1.8	1.8
Female max	1.9	3.2	3.5	2.7
Female min	1.1	1.6	1.8	1.7

Table 2 - Values for the measurements A, B, C and D, in relation to the patient's sex.

	Male versus female (p-value)
A	0008273831*
B	0.007511125*
C	0.22263867
D	0.010008664*

An irregular quadrilateral joining the measurements ABCD was obtained, and the area of this quadrilateral was calculated for each of the patients. With the resultant measurements (Table 3), Student's t test for independent samples was also performed and the area of the quadrilateral formed was compared in relation to the patients' gender. The minimum significance level was obtained ($p < 0.05$). Thus, there was a difference between the sexes regarding the area of the vertebrae analyzed in these patients (for the women, the mean area was 4.48 cm^2 and for the men it was 5.08 cm^2) (Table 4).

Since the p value remained below 0.05, the null hypothesis of equality between the sexes was rejected and, at the minimum significance level of 5%, it was affirmed that the vertebral area found in male patients was greater than in female patients.

Lastly, the correlation between the patients' age and the area formed was calculated, and a value of -0.023 was obtained, which showed that there was no correlation between the variables of patient age and vertebral area, i.e. the area did not change with the patients' age.

In the second type, the measurements (ABCD) were used to form a quadrilateral, but a circumferential area inscribed in the quadrilateral formed by the abovementioned measurements (ABCD) was constructed because the screw acts as a penetrating circumference when seen in the patient's lateral view (the screw is seen axially in this manner), For this, we take the diameter to be the core plus the thread.

From the Figure, it can be seen that the circumference is tangential to the four sides of the polygon, such that the measurement of the radius of the internal circumference is greater than half of the smallest side (represented by L/2); for better comprehension, half of the smallest side (L/2) will be called L2 (Fig. 9).

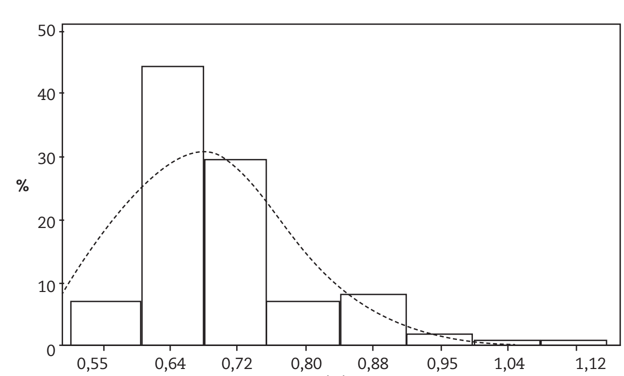

Figure 10 - Histogram of the frequency of the smallest side.

Table 3 - Measurements of the points B, C and D and the area of the vertebra S1 in each patient.

Patient	Sex	Age	A (cm)	B (cm)	C (cm)	D (cm)	Area
2	M	70	1.5	3.3	3.2	2.3	6.1061697
3	F	46	1.4	1.9	2.3	2.0	3.4335922
4	F	54	1.2f	2.4	2.5	2.4	4.188453
5	F	27	1.1	2.5	3.0	2.3	4.3728232
6	F	27	1.1	2.5	2.3	2.1	3.7241754
7	F	41	1.2	3.0	2.8	2.4	5.0658077
8	M	32	1,3	2,5	2,8	2.5	4.7692159
9	M	75	1.2	2.8	2.8	2.4	4.8616977
10	F	68	1.2	2.8	2.9	2.1	4.5935545
11	F	66	1.4	2.5	2.7	1.8	4.1097669
12	M	44	1.4	2.6	2.8	2.2	4.7365562
13	F	71	1.3	2.8	3.0	2.3	5.0582711
14	M	81	1.2	3.1	3.1	2.5	5.5436963
15	F	57	1.2	1.6	2.5	1.9	2.8293314
16	F	80	1.2	2.8	2.6	2.5	4.7933493
17	F	69	1.1	2.5	2.7	1.8	3.6806114
18	M	51	1.7	2.3	2.5	2.0	4.4008524
19	M	54	1.6	2.7	2.4	2.4	5.0095778
20	F	43	1.2	2.6	2.5	1.9	3.898461
21	M	65	1.3	2.8	2.8	2.5	5.1291389
22	M	59	1.7	2.0	2.0	1.8	3.497872
23	M	80	1.7	2.5	1.8	2.5	4.373298
24	M	58	1.3	2.9	2.6	2.1	4.6018629
25	M	39	1.5	3.2	3.0	2.1	5.541592
26	F	45	1.4	2.7	2.9	2.3	5.0339734
27	M	36	1.4	2.5	2.7	2.3	4.6564529
28	M	44	1.2	2.8	3.0	2.2	4.7768371
29	F	37	1.1	2.5	2.7	2.1	4.0043773
30	M	56	1.7	3.1	2.7	2.0	5.3180009
31	M	70	1.2	2.8	2.8	2.3	4.7527827
32	F	48	1.2	2.6	2.5	2.1	4.1119404
33	M	56	1.3	2.6	2.8	2.0	4.3586595
34	M	32	1.4	2.5	3.0	2.1	4.6192333
35	F	46	1.2	2.5	2.9	2.1	4.261742
36	F	55	1.2	2.7	2.8	2.2	4.5374036
37	F	47	1.4	2.8	2.8	1.8	4.4596
38	M	45	1.2	2.4	3.1	2.6	4.7544145
39	M	53	1.5	2.8	2.8	1.9	4.7381812
40	M	60	1.4	2.4	2.8	1.8	4.0558788
41	F	62	1.4	2.4	2.6	1.8	3.9495154
42	F	54	1.4	2.6	3.3	2.7	5.5954205
43	F	61	1.2	2.8	2.8	2.3	4.7527827
44	F	29	1.4	3.2	3.2	2.2	5.6855769
45	F	53	1.1	2.7	2.4	2.0	3.8642383
46	F	57	1.2	2.5	2.9	2.2	4.3712367
47	F	36	1..2	2.7	2.6	2.0	4.169989
48	F	41	1.2	2.7	3.0	2.3	4.777594
49	F	84	1.2	2.9	3.0	1.8	4.3730579
50	F	48	1.2	2.8	3.1	2.3	4.9564615

Table 4 - Student's t test for independent samples between the sexes, in relation to the area of the quadrilateral formed.[5]

Information	Value
T	-3.83537
Degrees of freedom	97
P-value	0.000223
Mean for group 1:	4.48788
Mean for group 2:	5.086834

Table 5 - Number of observations, mean for the smallest side, standard deviation, minimum and maximum.

Observations	Mean	Standard deviation	Min	Max
99	0.6924	0.1087	0.5500	1.1000

Table 6 - Number of observations, mean for the smallest side, standard deviation, minimum and maximum.

Sex	Observations	Mean	Standard deviation	Min	Max
Feminino	49	0.6602	0.0889	0.5500	0.9500
Masculino	50	0.7240	0.1176	0.5500	1.1000

Based on the patients' data, the minimum L2 was 0.55 cm and the maximum was 1.10 cm, which a mean of 0.6924 cm and a standard deviation of 0.1087 cm (Table 5). The frequency distribution for L2 is seen in Fig. 10. From this figure, it can be seen that for most patients, the smallest side was concentrated around the value of 0.64 cm, i.e. this was the modal value. Considering the sample size, according to the central limit theorem, it can be supposed that the distribution of the sample mean is normal. Thus, Student's t test was applied and it was assumed that there was a significant difference between the male and female genders (with a result of $p = 0.0034$) and that there was no significant difference between the different ages of the patients ($p = 0.6074$).

Table 6 shows the size of the variable L2 for men and women. It can be seen that for both genders, the minimum measurement for the smallest side was 0.55 cm (mean minimum for men = 0.7240 cm and for women = 0.6602 cm).

The mathematical-statistical analysis taken as type 2 in this study showed that the minimum radius that existed in the circumscribed polygon was 0.55 cm and that there was a significant difference between the genders, but without any correlation with the patients' age. Since the diameter of the screw was 0.70 cm (radius = 3.5 mm), it can be seen that the circumscribed circumference obtained in the vertebral area had a radius of at least 0.20 cm more than the radius of the screw.

Discussion

With the growth of the world's population, the greater distances that need to be traveled to the workplace and the advent of new transportation technologies with greater speed, occurrences of traffic accidents resulting in high-energy trauma have increased.[13]

Most pelvic ring injuries originate from high-energy trauma, and these injuries are associated with a mortality rate of 10% to 20%, particularly due to chest injuries and head-brain trauma.[3-5]

Modern strategies and philosophies relating to whether to perform surgical procedures have only recently evolved in order to determine the need for early reduction and fixation. Before the 1980s, there was little information regarding the biomechanics of bones and ligament structures, techniques for pelvic stabilization and long-term results from survivors of pelvic injuries.

Conservative treatment, even when properly indicated, is related to large numbers of complications that may lead to chronic losses within the personal and professional lives of patients thus treated.[14] The following have been cited in the literature as late complications: chronic lumbalgia, anisomelia, neurological lesions, paresthesia, bone nonunion and gait abnormalities. Thus, a large number of authors today are advocating surgical approaches as the definitive treatment for posterior pelvic injuries.[6]

The axiom at the time when treatments to open the pelvic ring started to be performed was that if patients survived pelvic fracturing, they would generally do so in a good condition.[15] With the passage of time and advances in studies, high incidence of poor results and long-term chronic pain among patients with a ruptured pelvis and nonsurgical treatment have been observed.[15] It has been noted that the functional results are related to the anatomy achieved through the reduction: the closer to anatomical that the reduction is, the better.[16]

Stabilization of the pelvic ring enables early mobilization and diminishes the mortality rate among these patients.[4]

Several devices such as anterior external fixators, pelvic fixators (Ganz clamps) and pneumatic anti-shock trousers promote rapid stabilization in emergency situations, but these are not ideal definitive treatments because they do not control the mechanical instability of the posterior pelvic ring.[17,18]

Today, after studies in previous decades, use of external fixation for openings of the pelvic ring has increased greatly. Nonetheless, from analysis on better-defined patient groups, it has become clear that external fixation is not the most appropriate way of controlling unstable injuries involving opening of the posterior pelvic ring.[19]

The best technique for achieving surgical stabilization of pelvic ring injuries is a topic that still causes controversy. Several techniques exist, but most of them require extensive surgical exposure (which puts neurovascular structures at risk) and retroperitoneal tamponade. These procedures lead to a high possibility of infection.[20,21]

Percutaneous fixation using an iliosacral screw has been shown to be a safe and reproducible method. It is a rapid method, with minimal blood loss and only requiring small incisions, which diminishes problems such as bleeding with clinical repercussions, infections and soft-tissue complications.[22,23]

It is known that the pelvis presents great anatomical variability and thus, for correct insertion of the iliosacral screw, surgeons need to understand pelvic bone anatomy and to know that the pelvis is favorable for the procedure. Moreover, there needs to be a good correlation between the anatomy and the fluoroscopic images in the operating theater.[24,25]

Incorrect insertion of these screws puts prime structures at risk. For this reason, Carlson et al.[17] determined certain parameters for screw placement: the so-called "sacroiliac secure corridor". Ideally, the screw should be positioned at the center of the S1 and S2 vertebral bodies, in order to avoid penetration of the recess of the sacral wing, foramina of the nerve roots, spinal canal, L5/S1 disc space and anterior cortex of the sacrum.[26,27]

There are factors that contribute towards greater difficulty in achieving correct positioning of the screws. Prominent among these are poor quality of lesion reduction and dysmorphism of the upper part of the sacrum.[28-30]

The present study was justified because it brought to light measurements of the so-called secure corridor for insertion of iliosacral screws. It has provided an environment of greater security for orthopedic surgeons in fracture cases that require pelvic fixation.

Conclusion

There have been several reports in the literature regarding the deviations that are permissible in inserting iliosacral screws. It is known, for example, that deviations of the orthopedic surgeon's hand at the time of insertion that are as small as around four degrees may cause the screw to impinge on adjacent prime areas.

From the present study, the distance in millimeters at which the screw should be inserted can be deduced, along with the margin of error (and not in degrees, as in other, previous studies). Thus, it is safe to place the screw within a circumscribed area of 20 mm greater than the diameter of the screw, which is 7.00 mm (core + thread), or within the minimum area of the vertebra, of around 2.82 cm^2. We speak of minimum area of the vertebra because the measurement used the smallest vertebra found in the study. The two data treatment methods used reached similar conclusions: that the safe area from screw insertion, in the population studied and in relation to the smallest vertebra found, was around 20 mm from the center of the vertebra in any direction, provided that cannulated screws of 7 mm in diameter are used (the current standard) for fixation of the sacroiliac joint. The secure area may be larger in the case of larger vertebrae.

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Conflicts of interest

The authors declare no conflicts of interest.

REFERENCES

1. Gänsslen A, Hildebrand F, Pohlemann T. Management of hemodynamic unstable patients "in extremis" with pelvic ring fractures. Acta Chir Orthop Traumatol Cech. 2012;79(3):193-202.
2. Schulman JE, O'Toole RV, Castillo RC, Manson T, Sciadini MF, Whitney A, et al. Pelvic ring fractures are an independent risk factor for death after blunt trauma. J Trauma. 2010;68(4):930-4.
3. Routt ML Jr, Kregor PJ, Simonian PT, Mayo KA. Early results of percutaneous iliosacral screws placed with the patient in the supine position. J Orthop Trauma.1995;9(3):207-14.
4. Moed BR, Hartman MJ, Ahmad BK, Cody DD, Craig JG. Evaluation of intraoperative nervemonitoring during insertion of an iliosacral implant in an animal model. J Bone Joint Surg Am. 1999;81(11):1529-37.
5. Ziran BH, Smith WR, Towers J, Morgan SJ. Iliosacral screw fixation of posterior pelvic ring using local anaesthesia and computerised tomography. J Bone Joint Surg Br. 2003;85(3):411-8.
6. Nork SE, Jones CB, Harding SP, Mirza SK, Routt ML Jr. Percutaneous stabilization of u-shaped sacral fractures using iliosacral screws: technique and early results. J Orthop Trauma. 2001;15(4):238-46.
7. Burkhardt M, Nienaber U, Pizanis A, Maegele M, Culemann U, Bouillon B, et al. Acute management and outcome of multiple trauma patients with pelvic disruptions. Crit Care. 2012;16(4):R163.
8. Chen HW, Liu GD, Fei J, Yi XH, Pan J, Ou S, Zhou JH. Treatment of unstable posterior pelvic ring fracture with percutaneous reconstruction plate and percutaneous sacroiliac screws: a comparative study. J Orthop Sci. 2012;17(5):580-7.
9. Noojin FK, Malkani AL, Haikal L, Lundquist C, Voor MJ. Cross-sectional geometry of the sacral ala for safe insertion of iliosacral lag screws: a computed tomography model. J Orthop Trauma. 2000;14(1):31-5.
10. Ruatti S, Courvoisier A, Eid A, Griffet J. Ureteral injury after percutaneous iliosacral fixation: a case report and literature review. J Pediatr Surg. 2012;47(8):13-6.

11. Templeman D, Schmidt A, Freese J, Weisman I. Proximity of iliosacral screws to neurovascular structures after internal fixation. Clin Orthop Relat Res. 1996;(329):194-8.
12. Prassopoulos PK, Faflia CP, Voloudaki AE, Gourtsoyiannis NC. Sacroiliac joints: anatomical variants on CT. J Comput Assist Tomogr. 1999;23(2):323-7.
13. Eastridge BJ, Burgess AR. Pedestrian pelvic fractures: 5-year experience of a major urban trauma center. J Trauma. 1997;42(4):695-700.
14. Wei R, Cao X, Tu D. Clinical treatment of open pelvic fractures associated with perineal injury. 2012;26(5):550-3.
15. Sagi HC. Pelvic ring fractures. In: Buchholz RW, Court-Brown CM, Heckman JD, Tornet P, editors. Rockwood and Green's fractures in adults. 7th. ed. Philadelphia: Lippincott Williams & Wilkins; 2010. p. 1415-62.
16. Holdsworth F. Dislocation and fracture dislocation of the pelvis. J Bone Joint Surg Br. 1948;30(3):461-6.
17. Carlson DA, Scheid DK, Maar DC, Baele JR, Kaehr DM. Safe placement of S1 and S2 iliosacral screws: the "vestibule" concept. J Orthop Trauma. 2000;14(4):264-9.
18. Prasarn ML, Horodyski M, Conrad B, Rubery PT, Dubose D, Small J, et al. Comparison of external fixation versus the trauma pelvic orthotic device on unstable pelvic injuries: a cadaveric study of stability. J Trauma Acute Care Surg. 2012;72(6):1671-5.
19. Kellam JF, McMurtry RY, Paley D, Tile M. The unstable pelvic fracture. Operative treatment. Orthop Clin North Am. 1987;18(1):25-41.
20. Reilly MC, Bono CM, Litkouhi B, Sirkin M, Behrens FF. The effect of sacral fracture malreduction on the safe placement of iliosacral screws. J Orthop Trauma. 2003;17(2):88-94.
21. Tile M. Acute pelvic fracture. I. Causation and classification. J Am Acad Orthop Surg. 1996;4(3):143-51.
22. McMurtry RY, Walton D, Dickinson D, Kellam J, Tile M. Pelvic disruption in the poly-traumatized patient: a management protocol. Clin Orthop 1980;(151):22-30.
23. Müller ME, Nazarian S, Koch P, Schatzker J. The comprehensive classification of fractures of long bones. Berlin: Springer-Verlag; 1990.
24. Tile M. Pelvic fractures. In: Schatzker J, Tile M. The rationale of operative fracture care. Berlin: Springer-Verlag; 2002. p. 221-70.
25. Routt ML Jr, Simonian PT, Agnew SG, Mann FA. Radiographic recognition of the sacral alar slope for optimal placement of iliosacral screws: a cadaveric and clinical study. J Orthop Trauma. 1996;10(3):171-7.
26. Routt ML Jr, Simonian PT. Posterior pelvic ring disruptions: iliosacral screws. In: Master techniques in orthopaedic surgery. Philadelphia: Lippincot-Raven; 1998. p. 595-612.
27. Ganz R, Krushell RJ, Jakob RP, Kuffer J. The antishock pelvic clamp. Clin Orthop Relat Res. 1991;(267):71-8.
28. Sanders R, DiPasquale T. External fixation of the pelvis: application of the resuscitation frame. Techn Orthop. 1990:4:60-4.
29. Routt ML Jr, Meier MC, Kregor PJ, Mayo KA. Percutaneous iliosacral screws with the patient supine technique. Oper Techn Orthop. 1993,3(1):35-45.
30. Simonian PT, Routt ML, Harrington RM, Mayo KA, Tencer AF. Biomechanical simulation of the anteroposterior compression injury of the pelvis. An understanding of instability and fixation. Clin Orthop Relat Res. 1994;(309):245-56.