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Safe corridor for iliosacral and trans-sacral screw placement in Indian population: A preliminary CT based anatomical study

Vivek Trikha*, Sahil Gaba, Arvind Kumar, Samarth Mittal, Atin Kumar

JPN Apex Trauma Centre, All India Institute of Medical Sciences, New Delhi, India

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ABSTRACT

Objectives: Nonsurgical management of unstable pelvic ring injuries is associated with poor outcomes. Posterior pelvic ring injuries include sacroiliac joint disruption and sacral fractures or a combination of the two. Morbidity is high in non-operatively managed patients. Screw fixation is being increasingly used to manage unstable posterior pelvic injuries. Limitations include a steep learning curve and potential for neurovascular injury. This is the first study in Indian population to describe the safe corridor for screw placement and check the feasibility of screw in both upper and lower sacral segments.
Methods: This study involved retrospective analysis of 105 pelvic CT scans of patients admitted to the emergency department of a Level 1 trauma centre. Vertical height at the level of constriction (vestibule) of S1 and S2 was measured in coronal sections and anteroposterior width of constrictions was measured in axial sections. We created a trajectory for 7.3 mm cylinder keeping additional 2 mm free bony corridor around it and confirmed that bony limits were not breached in axial, coronal and sagittal sections. Whenever there was breach in bony limit we checked applicability of 6.5 mm screw.
Results: The vertical height and anteroposterior width of vestibule/constriction of S1 was significantly higher in males, whereas S2 vestibule height and width were similar in males and females. Both male and female pelves were amenable to S1 Trans-sacral and S1 Iliosacral screw fixation with a 7.3 mm screw when a safe corridor of 2 mm was kept on all sides. However, when S2 segment was analysed, only 42.9% of male pelves and 25.7% of female pelves were amenable to insertion of trans-sacral 7.3 mm screw.
Conclusion: An individualized approach is necessary and each patient's CT must be carefully studied before embarking on sacroiliac screw fixation in Indian population.

1. Introduction

Nonsurgical management of unstable pelvic ring injuries is associated with poor outcomes.[1] Apart from high initial mortality (4.8–50%),[2] the morbidity in those who survive the acute phase can be substantial due to chronic pain, deformity, sexual dysfunction, etc.[3] Posterior pelvic ring injuries include sacroiliac joint disruption and sacral fractures or a combination of the two. Options of posterior fixation like sacral plating and lumbopelvic fixation have been known to cause complications such as implant prominence and skin necrosis.[1] Hence, with better understanding of radiological sacral anatomy and wide availability of intra-operative fluoroscopy, screw fixation is being increasingly used to manage unstable posterior pelvic injuries. Although their use is increasing, there are limitations such as a steep learning curve and potential for neurovascular injury.

The bony corridors available for safe screw placement in sacrum are narrow and as such there is risk of the screw threads breaching the cortex and damaging the surrounding structures.[4,5,6,7] Dysmorphic sacrum makes insertion of sacroiliac screws difficult or even impossible in some cases.[1,8] Hence, pre-operative identification of the corridors of the sacrum shall be helpful in avoiding complications.

The pre-requisites for safe placement of iliosacral screws are accurate reduction of sacroiliac joint or sacral fractures (open or closed reduction), pre-operative identification of abnormal sacral anatomy, and adequate recognition of bony landmarks on intra-operative fluoroscopic images.[3] The standard fluoroscopic views used to insert screws are inlet view, outlet view and true lateral view of the pelvis. Only after this has been ensured, the significance and releance of adequate and safe corridors for inserting the Iliosacral or Transilaic screws comes in to reckoning.

* Corresponding author at: Room number 318, First floor, JPNATC, All India Institute of Medical Sciences, Ansari Nagar, New Delhi, 110029, India.
E-mail addresses: vivektrikha@gmail.com (V. Trikha), drsahilgaba@gmail.com (S. Gaba), arvindmamc@gmail.com (A. Kumar), samarthmittal@gmail.com (S. Mittal), dratinkumar@gmail.com (A. Kumar).

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Although CT quantification of sacral "safe-corridor" has been done in previous studies, such a study is lacking in Indian population.

Hence, the objectives of this study include the description of the safe corridor and trajectory for Iliosacral and Transiliac screw placement in normal Indian pelves and to compare the measurements and applicability of screws between male and female pelves. This is the first study which attempts to describe the dimensions of the sacral anatomy and assess the feasibility of sacroiliac or transilliac screw insertion in Indian population.

2. Materials and methods

This study involved retrospective analysis of 105 pelvic CT scans of patients admitted to the emergency department of a Level 1 trauma centre. These CT scans were performed as a screening procedure in polytrauma patients or for evaluation of acetabular fractures. Exclusion criteria were age <18 years, dysmorphic upper sacral segment[1,8] and CT showing gross disruption of posterior pelvic ring where exact CT measurements were not possible. The acquired CT scans were analysed using Iplan(®) CMF 3.0 (Brainlab AG, Feldkirchen, Germany). Ethics committee approval was obtained prior to the commencement of the study.

Measurements were performed for both the upper and second sacral segments (Figs. 1 and 2). In the coronal sections, vertical height was measured at the level of constriction (vestibule) of S1 and S2. In axial cuts, anteroposterior width of constrictions of S1 and S2 transverse processes were measured.

After aligning L5- S1 disc space horizontally in sagittal and coronal planes, the axial and coronal cuts were studied to measure the dimensions in the path of the osseous corridor for screw placement. Antero-posterior constriction (in axial cut) of S1 was measured as the maximum distance from the antero-lateral corner of sacral canal to the anterior cortex and perpendicular to it. Vertical constriction (in coronal cut) of S1 was measured as the vertical distance from superior most extent of first neural foramen to the deepest part of superior cortex of S1 segment and perpendicular to it.

S2 antero-posterior constriction (in axial cut) was measured as the maximum distance from anterior most point of sacral canal to the deepest part of anterior cortex of S2 segment, in a direction perpendicular to a horizontal line passing through the deepest part of anterior cortex of S2 segment. S2 vertical constriction (in coronal cut) was measured as the maximum vertical distance from superior most extent of second neural foramen to the inferior most part of first sacral neural foramen.

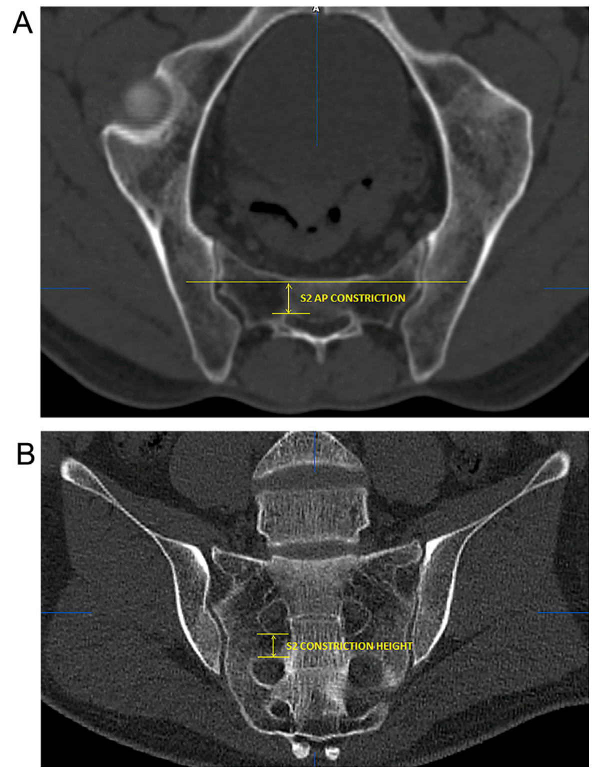

Fig. 2. a. Axial cut of S2 showing measurement of anteroposterior width of constriction. b. Coronal cut of sacrum showing measurement of vertical height of constriction of S2.

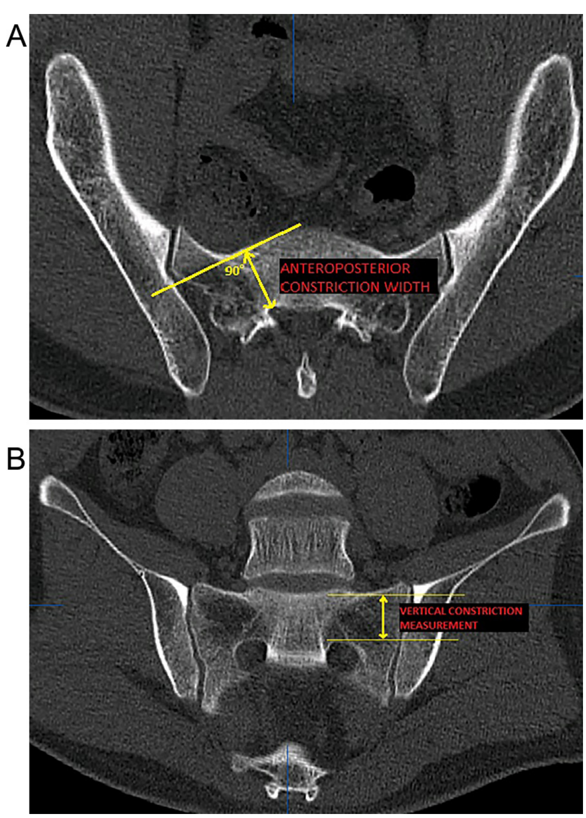

Fig. 1. a. Axial cut of S1 showing measurement of anteroposterior width of constriction. b. Coronal cut of sacrum showing measurement of vertical height of constriction of S1.

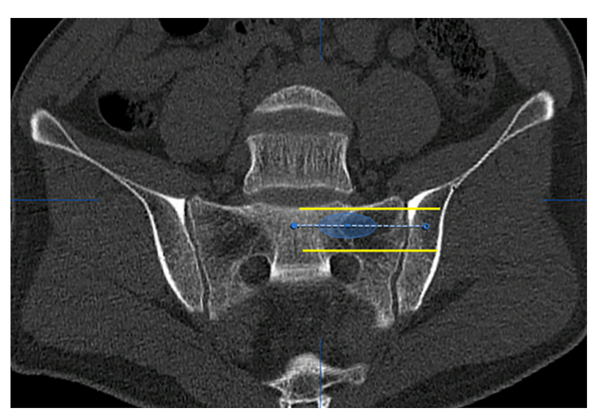

Fig. 3. Showing a cylinder of 11.3 mm diameter (7.3 mm for screw and 2 mm safe zone on either side) representing the trajectory of a Iliosacral screw in coronal section.

Iliosacral screw trajectories were created on the 3D CT model (Figs. 3 and 4) in S1 starting from a point on iliac bone and ending in mid line just posterior to anterior surface of the sacral promontory in such a way that the direction of screw trajectory was perpendicular to a line measuring the constriction, in both axial and coronal planes. In other words, the trajectory was kept parallel to superior cortex in coronal plane and to the anterior cortex in axial plane at the level of vestibular constriction of S1 segment. We created a trajectory for 7.3 mm cylinder keeping additional 2 mm free bony corridor around it and confirmed that bony limits were not breached in axial, coronal and sagittal sections. Whenever there was breach in bony limit we checked applicability of 6.5 mm screw. Larger screw size that could be passed without breaching bony limits was noted. No other screw size was tested when none of the above screw trajectories were found appropriate. Similarly, trajectories were created for trans-sacral screws in both S1 and S2 (Figs. 5–8) spanning both sacroiliac joints and passing through S1 and S2 transverse processes without breaching the bony limits. 2 mm of additional safety corridor was kept in trajectories for both 7.3 mm and 6.5 mm screws.

To minimize error in measurement, all measurements were made by two observers and the mean was calculated.

3. Results

A total of 105 3D CT scans were analysed. 35 were females and 70 were males.

The vertical height and anteroposterior width of vestibule/constriction of S1 was significantly higher in males, whereas S2 vestibule height and width were similar in males and females. The dimensions and applicability of screws in summarized in Table 1. Statistical analysis was done using SPSS version 22.

4. Discussion

Although first used in spine surgeries,[1] use of iliosacral screws for posterior pelvic stabilization has gained popularity. With increasing incidence of pelvic ring injuries due to a rise in high velocity road traffic accidents, more and more patients will need iliosacral screw fixation to stabilize the posterior pelvic ring in order to hasten the mobilization of such patients, allow early weight bearing, and avoid complications related to prolonged immobilization (bed sores, pneumonia, deep vein thrombosis). Hence a thorough understanding of the sacral anatomy and 'safe corridor' is essential to safely carry out these procedures. The advantages of iliosacral screws include ability to insert via percutaneous approach if sacroiliac dislocation or sacral fracture can be reduced by closed means, completely intra-osseous course which eliminates implant prominence related complications and also reduces the risk of infection, and that they can be placed in any position (supine, prone) even in the presence of soft tissue injury.[3]

The study of sacral morphology and the applicability of iliosacral and trans-sacral screws is extremely germane to the trauma surgeon, if complications are to be avoided. As previous studies mainly focus on Caucasian subjects, their results cannot be extrapolated to the Indian (or Asian) patients. A study done by Hasenboehler et al.[8] in western population found significant difference in all CT measurements between males and females. Whereas in our study, only height and width at the level of vestibule of S1 was significantly higher in males. S2 vestibule height and width were more in males, but the difference was

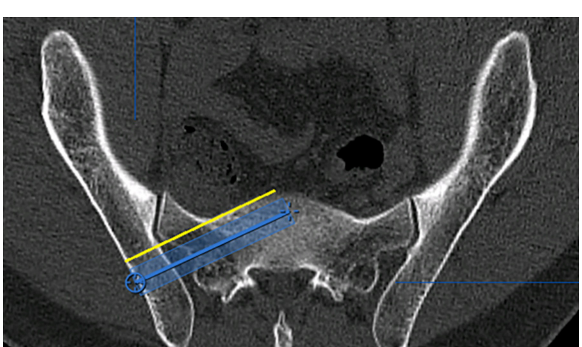

Fig. 4. Showing a cylinder of 11.3 mm diameter (7.3 mm for screw and 2 mm safe zone on either side) representing the trajectory of a Iliosacral screw in axial section.

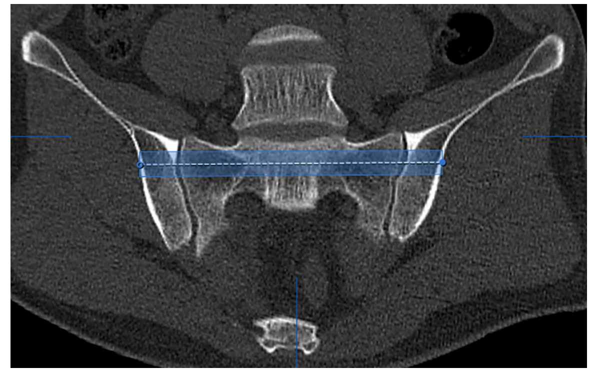

Fig. 5. Showing a cylinder of 11.3 mm diameter (7.3 mm for screw and 2 mm safe zone on either side) representing the trajectory of a trans-sacral S1 screw in coronal section.

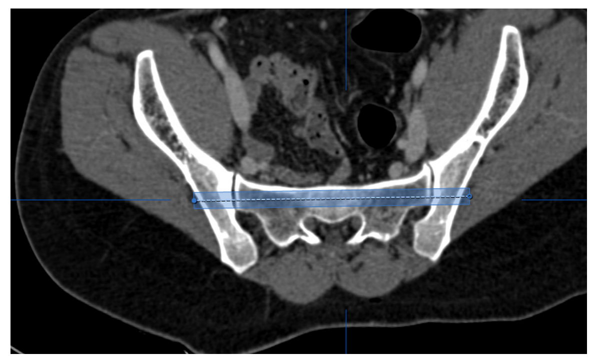

Fig. 6. Showing a cylinder of 11.3 mm diameter (7.3 mm for screw and 2 mm safe zone on either side) representing the trajectory of a trans-sacral S1 screw in axial section.

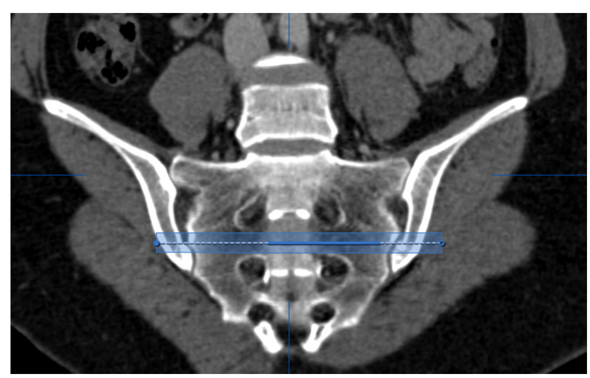

Fig. 7. Showing a cylinder of 11.3 mm diameter (7.3 mm for screw and 2 mm safe zone on either side) representing the trajectory of a trans-sacral S2 screw in coronal section.

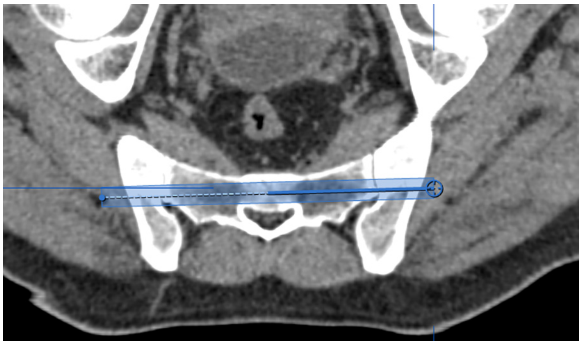

Fig. 8. Showing a cylinder of 11.3 mm diameter (7.3 mm for screw and 2 mm safe zone on either side) representing the trajectory of a trans-sacral S2 screw in axial section.

statistically insignificant. The possibility of this observation being a result of low sample size cannot be ruled out.

The results of this study show that both male and female pelves were amenable to S1 Trans-sacral and S1 Iliosacral screw fixation with a 7.3 mm screw when a safe corridor of 2 mm was kept on all sides. However, when S2 segment was analysed, only 42.9% of male pelves and 25.7% of female pelves were amenable to insertion of trans-sacral 7.3 mm screw (Table 1). When feasibility of 6.5 mm screw was studied, 64.3% of male pelves and 68.6% of female pelves were amenable to its insertion. Hence, 35.7% of male pelves and 31.4% of female pelves did not allow even 6.5 mm screw to be inserted safely, and this difference in applicability of screw in male and female pelves was statistically insignificant. This finding is in contrast to the findings in the study by Gras et al.,[9] which concluded that the male pelvis is more amenable to screw insertion as compared to the female pelvis. For cases not amenable to 6.5 mm screw insertion, other methods of fixation (eg. Trans-iliac plating, spinopelvic fixation) may be more appropriate.

As a 1 mm safe corridor seems very difficult to achieve, and unrealistic during the actual surgical procedure, the applicability of all the screws was checked keeping a 2 mm safe margin.

Previous studies have found sacral dysmorphism in 14.5–54% cases.[1,8,10–12] The incidence varies with race and gender. The difficulty in inserting screws in dysmorphic sacrum has been clearly described.[13] However, as our study shows that even in non-dysmorphic pelves 35.7% of male pelves and 31.4% of female pelves did not allow safe insertion of a 6.5 mm S2 trans-sacral screw. Hence, a CT scan should be routinely ordered in all patients planned for a posterior pelvic ring percutaneous screw fixation and carefully studied. This is the only method which can potentially eliminate the neurovascular complications seen with insertion of these screws.

Using standard intra-operative fluoroscopic landmarks, the rate of incorrect screw placement is nearly 10–15% even after appropriate placement according to fluoroscopy.[6,8,14,15] This misplacement can cause nerve root impingement, and is reported to be more common in cases with sacral dysmorphism or fracture mal-reduction.[5,13,16] As little as 5 mm fracture mal-reduction in a Denis Zone II fracture results in a 36% decrease in the S1 screw corridor.[16] To eliminate these outliers, various authors have used intra-operative CT and navigation to insert sacroiliac screws.[17–19] Although this technique has the potential for eliminating cortical breach in all cases, this has not yet gained widespread popularity because of limited availability and increased radiation exposure.[20] Hence, fluoroscopy guided iliosacral screw still remains the gold standard.

Our study is not without a few limitations. First of all, our sample size is low. Moreover, this is retrospective data from a level one trauma centre with its inherent shortcomings. Consequently, this data might not be representative of a cohort of patients with posterior pelvic ring disruption. Also the cases of sacral dysmorphism were not included in this study which could have altered the results presented. Though every effort was made to avoid human error in the various CT based measurements, some error could still have crept in. Lastly, although the present study is carried out in uninjured pelves, the safe corridor reduces drastically in mal-reduced fractures,[16] which must be taken into account.

In spite of these shortcomings, we feel that this data being the first of its kind from Indian population shall provide a reference of information regarding the sacral morphology of Indian pelves in both males and females. This study, for the first time, proves that due to morphological differences between Caucasian and Indian pelves, Indian pelves are less amenable to safe insertion of sacral screws than their Caucasian counterparts.[8] We suspect that

Table 1
Summary of measurements and applicability of screws (safe corridor of 2 mm on all sides).

	Overall	Males	Females	Remarks
Total number	105	70	35	
Age (years)	Mean 42.21 (range 18–80) (SD 17.29, SEM 2.01)	Mean 41.02 (range 18–75) (SD 15.27, SEM 2.10)	Mean 44.60 (range 19–80) (SD 19.11, SEM 4.63)	P = 0.331 (not significant) (unpaired *t*-test)
Vertical vestibular height S1 (Coronal section)	21.06 mm (range 14.5–27.0) (SD 3.12, SEM 0.305)	22.23 (range) (SD 2.67, SEM 0.32)	18.73 (range) (SD 2.65, SEM 0.44)	$p < 0.005$ (significant) (unpaired *t*-test)
Anteroposterior vestibular width S1 (Axial section)	21.30 mm (range 16.10–27.40) (SD 2.73, SEM 21.30)	21.87 mm (range 16.7–27.4) (SD 2.57, SEM 0.30)	20.17 mm (range 16.10–26.10) (SD 2.72, SEM 0.46)	p = 0.002 (significant) (unpaired *t*-test)
Vertical vestibular height S2 (Coronal section)	12.00 mm (range 8.0–20.3) (SD 2.12, SEM 0.21)	12.01 mm (range 8.0–20.3) (SD 2.43, SEM 0.29)	11.98 mm (range 9.9–16.5) (SD 1.35, SEM 0.23)	p = 0.93 (not significant) (unpaired *t*-test)
Anteroposterior vestibular width S2 (Axial section)	12.18 mm (range 7.5–17.8) (SD 2.08, SEM 0.203)	12.29 mm (range 7.5–17.8) (SD 2.41, SEM 0.29)	11.9 mm (range 9.7–14.6) (SD 1.18, SEM 0.20)	p = 0.450 (not significant) (unpaired *t*-test)
Trans-sacral screw S1	7.3 mm applicable in all cases.	7.3 mm applicable in all cases.	7.3 mm applicable in all cases.	p = 1.0000 (Fisher's exact test)
Trans-sacral screw S2	7.3 mm applicable in 39 cases. 6.5 mm applicable in 69 cases. Not applicable in 36 case.	7.3 mm applicable in 30 cases. 6.5 mm applicable in 45 cases. Not applicable in 25 case.	7. 3 mm applicable in 9 cases. 6.5 mm applicable in 24 cases Not applicable in 11 cases.	p = 0.299 (not significant) (Fisher's exact test)
Iliosacral screw via S1	7.3 mm applicable in all cases.	7.3 mm applicable in all cases.	7.3 mm applicable in all cases.	p = 1.0000 (Fisher's exact test)

applicability of screws may be even less in Indian dysmorphic pelves, but their exclusion from this study does not allow us to definitively comment on this. This should lead to further large sample size multicentric studies based on age, height and weight related data on sacral morphology in Indian population. The knowledge of this fact will enable the trauma surgeon to be extra-cautious while operating on patients with an unstable posterior pelvic injury, and pre-operatively determine patients not suited to screw fixation.

5. Conclusion

Although dimensions of vestibule of S2 were similar in males and females, those of S1 were significantly greater in males. 7.3 mm iliosacral screw and S1 trans-sacral screw could be safely inserted in all cases, only 42.9% of male pelves and 25.7% of female pelves were amenable to insertion of S2 trans-sacral 7.3 mm screw. An individualized approach is necessary and each patient's CT must be carefully studied before embarking on sacroiliac screw fixation in Indian population.

Conflict of interest

None.

Source of funding

None.

Contributions

Study design: Vivek Trikha, Samarth Mittal, Atin Kumar.
Data collection: Vivek Trikha, Sahil Gaba, Atin Kumar.
Statistical analysis: Sahil Gaba, Arvind Kumar.
Literature review: Sahil Gaba, Samarth Mittal.
Manuscript writing: Vivek Trikha, Sahil Gaba, Samarth Mittal, Arvind Kumar.
Final editing and formatting of manuscript: Vivek Trikha, Samarth Mittal.

References

1. Miller AN, Routt Jr. MLJr.. Variations in sacral morphology and implications for iliosacral screw fixation. *J Am Acad Orthop Surg*. 2012;20(Jan (1))8–16 [28].
2. Giannoudis PV, Pape HC. Damage control orthopaedics in unstable pelvic ring injuries. *Injury*. 2004;35:671–67710.1016/j.injury.2004.03.003.
3. Iorio JA, Jakoi AM, Rehman S. Percutaneous sacroiliac screw fixation of the posterior pelvic ring. *Orthop Clin North Am*. 2015;46(Oct (4)):511–52110.1016/j.ocl.2015.06.00.
4. Gardner MJ, Morshed S, Nork SE, Ricci WM, Chip Routt Jr. MLJr.. Quantification of the upper and second sacral segment safe zones in normal and dysmorphic sacra. *J Orthop Trauma*. 2010;24(10):622–629.
5. Routt Jr. MLJr., Simonian PT, Mills WJ. Iliosacral screw fixation: early complications of the percutaneous technique. *J Orthop Trauma*. 1997;11 (8):584–589.
6. Sagi HC, Lindvall EM. Inadvertent intraforaminal iliosacral screw placement despite apparent appropriate positioning on intraoperative fluoroscopy. *J Orthop Trauma*. 2005;19(2):130–133.
7. 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(May (4)):264–269.
8. Hasenboehler EA, Stahel PF, Williams A, et al. Prevalence of sacral dysmorphia in a prospective trauma population: implications for a safe surgical corridor for sacro-iliac screw placement. *Patient Saf Surg*. 2011;5:8.
9. Gras F, Gottschling H, Schröder M, Marintschev I, Hofmann GO, Burgkart R. Transsacral osseous corridor anatomy is more amenable to screw insertion in males: a biomorphometric analysis of 280 pelves. *Clin Orthop Relat Res*. 2016 Oct 1;474(10):2304–2311.
10. Kaiser Scott P, Gardner Michael J, Joseph Liu, Chip Routt Jr MLJr, Morshed Saam. Anatomic determinants of sacral dysmorphism and implications for safe iliosacral screw placement. *J Bone Joint Surg*. 2014;96(14):e120.
11. Kim J-J, Jung C-Y, Eastman JG, Oh H-K. Measurement of optimal insertion angle for iliosacral screw fixation using three-dimensional computed tomography scans. *Clin Orthop Surg*. 2016;8(2):133–13910.4055/cios.2016.8.2.133.
12. Conflitti JM, Graves ML, Chip Routt Jr. MLJr.. Radiographic quantification and analysis of dysmorphic upper sacral osseous anatomy and associated iliosacral screw insertions. *J Orthop Trauma*. 2010 Oct;24(10):630–636.
13. Routt Jr. MLJr., 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):171–177.
14. Wolinsky P, Lee M. The effect of C-arm malrotation on iliosacral screw placement. *J Orthop Trauma*. 2007;21:427–434.
15. Farcy JP, Rawlins BA, Glassman SD. Technique and results of fixation to the sacrum with iliosacral screws. *Spine*. 1992;17(Suppl. 6):S190–S195.
16. 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*. 2006;20(Suppl. 1):S37–S43.
17. Peng K-T, Li Y-Y, Hsu W-H, et al. Intraoperative computed tomography with integrated navigation in percutaneous iliosacral screwing. *Injury*. 2013;44:203–208.
18. Takao M, Nishii T, Sakai T, et al. Iliosacral screw insertion using CT-3D-fluoroscopy matching navigation. *Injury*. 2014;45:988–994.
19. Sciulli RL, Daffner RH, Altman DT, et al. CT-guided iliosacral screw placement: technique and clinical experience. *Am J Roentgenol*. 2007;188:W181–W192.
20. Goetzen M, Ortner K, Lindtner RA, Schmid R, Blauth M, Krappinger D. A simple approach for the preoperative assessment of sacral morphology for percutaneous SI screw fixation. *Arch Orthop Trauma Surg*. 2016;136:1251–125710.1007/s00402-016-2528-3.