European Spine Journal (2019) 28:2053–2059
https://doi.org/10.1007/s00586-019-06065-3

REVIEW ARTICLE

Dual iliac screws in spinopelvic fixation: a systematic review

Anouar Bourghli[1] · **Louis Boissiere**[2] · **Ibrahim Obeid**[2]

Received: 15 April 2019 / Revised: 14 June 2019 / Accepted: 8 July 2019 / Published online: 12 July 2019

Abstract

Purpose The classical spinopelvic fixation includes 1 iliac screw on each side. The purpose of this study is to specify the indications of the "dual iliac screw" (DIS) construct, i.e., when to put 2 iliac screws on each side, to describe its biomechanical advantages, and to define its related technical aspects.

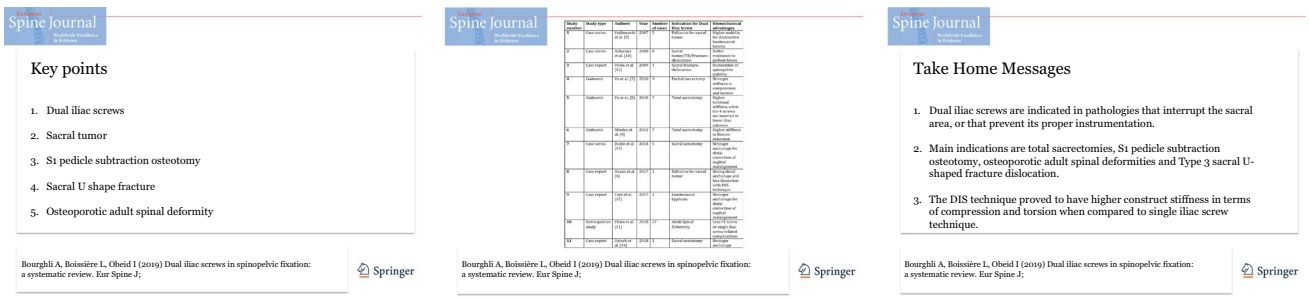
Methods A primary search on Medline through PubMed distribution was performed, with the use of the terms "pelvic fixation" or "spinopelvic" or "lumbo-iliac" and the terms "dual iliac screw" or "double iliac screw." English papers corresponding to the inclusion criteria were analyzed regarding the specific indications of the DIS construct and its surgical technique and advantages.

Results Eleven papers were identified according to the research criteria and included in this review. Three main indications were identified for the DIS technique according to three types of pathologies: in adult deformities when a long construct is needed in an osteoporotic patient or when correction requires three-column osteotomy of the sacrum; in trauma when a U-shaped fracture–dislocation of the sacrum is involved; in sacral tumors when a sacrectomy is performed or when destructive metastatic lesions of the sacrum require palliative surgical treatment. Biomechanically, the DIS technique proved to have higher construct stiffness in terms of compression and torsion.

Conclusion In specific cases, affecting different areas of spinal diseases, the DIS technique is more advantageous, when compared to the "single iliac screw" version, as it would provide a stronger and safer fixation at the base of the spinopelvic construct.

Graphic abstract

These slides can be retrieved under Electronic Supplementary Material.



Keywords Dual iliac screws · Sacral U-shaped fracture · S1 pedicle subtraction osteotomy · Sacral tumor · Osteoporotic adult spinal deformity

Introduction

Since the early 2000s, spinopelvic fixation with the use of iliac screws [1] became a standard technique in the management of various spinal pathologies, where the bottom of

Electronic supplementary material The online version of this article (https://doi.org/10.1007/s00586-019-06065-3) contains supplementary material, which is available to authorized users.

✉ Anouar Bourghli
anouar.bourghli@gmail.com

Extended author information available on the last page of the article

the construct needs to be strong. These pathologies include adult deformities with coronal or sagittal malalignment, neuromuscular scoliosis with pelvic obliquity, high-grade spondylolisthesis, and lumbosacral tumors (primary or secondary). The objective of the pelvic fixation is either to consolidate S1 pedicle screws by achieving a solid construct with distally sacral or pelvic additional grips, or to palliate the impossibility of putting screws in S1 by bypassing the sacral area. In the past, several techniques were used to reinforce the instrumentation below S1, such as S2 screws, Harrington iliac bars, iliosacral screws, Luque–Galveston technique, sacroiliac plate, and Chopin block [2]. These techniques revealed different types of complications like screws pullout or non-union [2, 3]. Therefore, the concept of iliac internal fixator system was developed, with entire iliac column instrumentation on both sides (iliac screws). This was followed during the past decades by the development of the S2-alar-iliac (S2AI) screw [4]; one main advantage of the latter over the former is that there is no need for an offset connector as the screw is in line with the pedicle screws above, which facilitates the rod insertion. The 2 aforementioned techniques became the 2 main techniques used in adult or pediatric deformities with long instrumentation to the pelvis, insertion of either screw may be performed with the freehand technique, and the choice depends on the surgeon habits and self-opinion about the method used. Nevertheless, single iliac screw or S2AI screw may show some limits in certain cases when the instrumentation of the whole sacrum becomes very difficult or impossible, and therefore, the grip inside the pelvis needs to be even stronger. In such cases, the S2AI screw is no longer an option, and the best choice becomes the dual iliac screw (DIS) technique, i.e., to put 2 iliac screws on each side (Fig. 1a, b). The DIS technique is not very common in the spine surgeon practice, even when deformities are encountered, and its indications and advantages may not be very obvious.

The purpose of this study is to review the literature to identify the indications of the DIS technique, to describe its biomechanical advantages, and to define its related technical aspects.

Materials and methods

A primary search on Medline through PubMed distribution was performed, with the use of the terms “pelvic fixation” or “spinopelvic” or “lumbo-iliac” and the terms “dual iliac screw” or “double iliac screw.” Additional papers were extracted from the references of the papers found in the literature search. Only the papers where the pelvic fixation mentioned 2 screws in each iliac wing were included. Only English papers were included, and the studies were analyzed regarding the specific indications of the DIS construct and its surgical technique and advantages. Two reviewers extracted data and evaluated the abstracts independently for potential eligibility and subsequently full-text articles for eligibility. A third author (arbiter) resolved any relevant discrepancies.

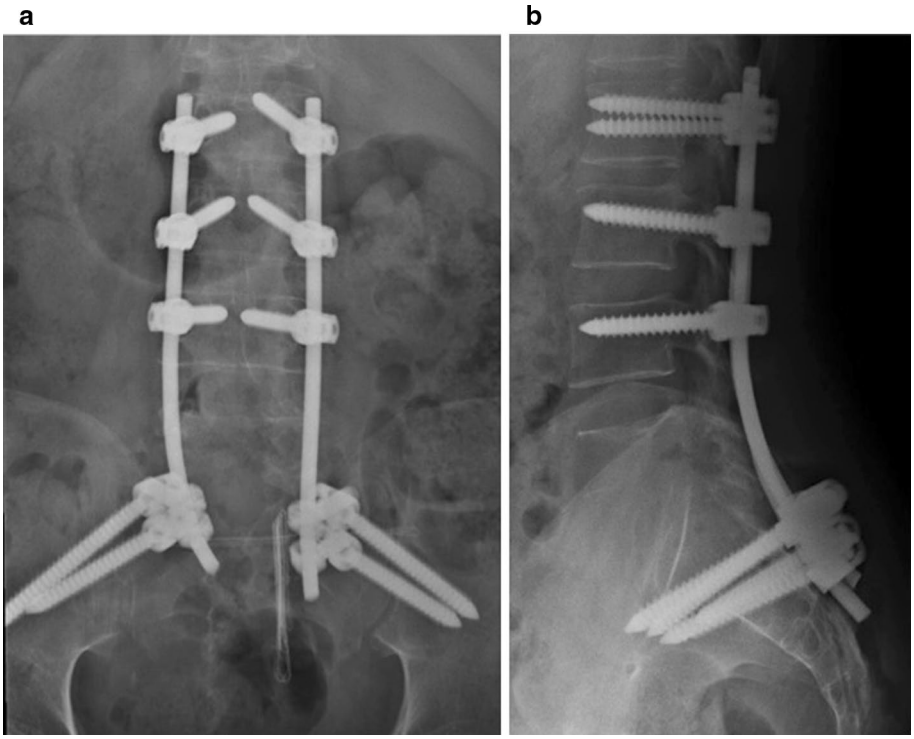


Fig. 1 Example of a spinopelvic construct bypassing the lumbosacral junction with the use of dual iliac screws. AP and lateral X-rays (**a**, **b**)

Results

The initial search yielded 181 results. Eighteen duplicates were removed, leaving 163 studies. Ten additional eligible studies were identified through source bibliographies. After screening, 27 full-text articles were obtained, of which 16 did not the meet the inclusion criteria. Eleven papers were finally identified and included in this review [5–15]. Figure 2 summarizes the search process. In total, 8 papers were clinical studies including 49 patients and 3 papers were cadaveric biomechanical studies including 23 specimens.

No studies fulfilling criteria for level I, II, or III evidence were found in the literature. A summary of the included studies is given in Table 1.

Three main indications were identified for spinopelvic fixation with dual iliac screws in the current literature.

First one was the most frequently cited, as the most obvious, where the DIS technique is widely used: resection of primary sacral tumors. Spinopelvic reconstruction with DIS should be done when:

- Total sacrectomy in which the whole sacroiliac joint is removed on both sides [9].
- Partial sacrectomy involving more than 50% of sacroiliac joint on each side, or partial sacrectomy involving less than one half of the sacrum but with one-side sacroiliac joint resection [7].

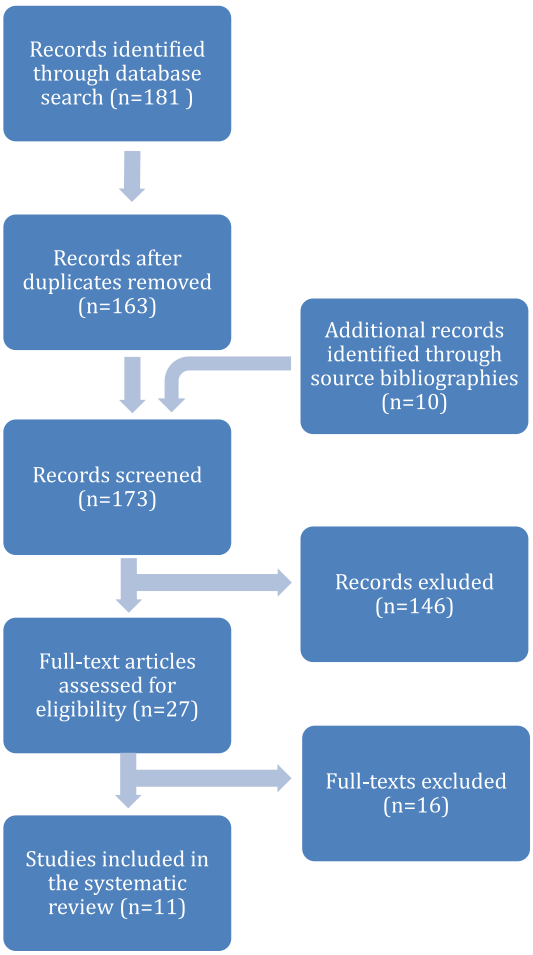


Fig. 2 Flowchart describing the literature search process

Another indication involving neoplasms is palliative fixation for unstable destructive lumbosacral metastatic lesions where pedicle screws anchorage in the sacrum is extremely poor [8].

Second indication involves spinal deformities. It can be done in osteoporotic adult spinal deformity patients when a long construct is required with a strong spinopelvic fixation [11]. It is also performed when sagittal malalignment requires a sacral (S1) pedicle subtraction osteotomy (PSO) [13, 14]; frequently, history includes multiple prior surgeries for L5S1 spondylolisthesis with a very high pelvic incidence and a fusion mass at the lumbosacral junction where apex of the deformity is located. The classical PSO technique is performed but at S1 level with some specificities related to the location. Within this deformity category, another technique requiring the DIS was recently described in the literature, which is the bilateral longitudinal sacral osteotomy [15]: This novel technique was developed in order to correct malalignment by reducing the high pelvic incidence.

Third indication for DIS technique is found in traumatology, when a high transverse sacral fracture [10, 12] is involved, with a dislocation of the proximal part (as both anterior and posterior cortices are ruptured) and the whole spine sliding forward. This lesion corresponds to the type 3 of sacral U-shaped fractures classification of Roy-Camille [16]. Spinopelvic instability is frequently associated with neurologic symptoms; therefore, in addition to lumbopelvic fixation, neurologic decompression is often necessary.

One last indication cited in a single paper [10] involved 2 cases of revision of a previously operated lumbosacral tuberculosis site complicated by pyogenic infection, where the lumbosacral area had to be completely bypassed.

Several biomechanical cadaveric studies evaluated the spinopelvic fixation techniques. In the setting of total sacrectomy, Mindea et al. [9] showed that the double-rod double iliac screw method provided the most rigid fixation, followed by the single-rod double iliac screw fixation, in comparison with single-rod single screw or modified Galveston technique. Yu et al. [5] demonstrated that dual iliac screws, when all inserted in the lower iliac column, exhibited higher compressive and torsional stiffness not only when compared to single iliac screws (short

Table 1 Summary of the studies included in the review

Study number	Study type	Authors	Year	Number of cases	Indication for dual iliac screw	Biomechanical advantages
1	Case series	Fujibayashi et al. [8]	2007	5	Palliative for sacral tumor	Higher stability for destructive lumbosacral lesions
2	Case series	Acharaya et al. [10]	2008	8	Sacral tumor/TB/fracture–dislocation	Better resistance to pullout forces
3	Case report	Vilela et al. [12]	2009	1	Sacral fracture–dislocation	Restoration of spinopelvic stability
4	*Cadaveric*	Yu et al. [7]	2010	9	Partial sacrectomy	Stronger stiffness in compression and torsion
5	*Cadaveric*	Yu et al. [5]	2010	7	Total sacrectomy	Higher torsional stiffness when the 4 screws are inserted in lower iliac columns
6	*Cadaveric*	Mindea et al. [9]	2012	7	Total sacrectomy	Higher stiffness in flexion–extension
7	Case series	Bodin et al. [13]	2014	5	Sacral osteotomy	Stronger anchorage for distal correction of sagittal malalignment
8	Case report	Hasan et al. [6]	2017	1	Palliative for sacral tumor	Strong distal anchorage and less dissection with MIS technique
9	Case report	Czyz et al. [15]	2017	1	Lumbosacral kyphosis	Stronger anchorage for distal correction of sagittal malalignment
10	Retrospective study	Ebata et al. [11]	2018	27	Adult spinal deformity	Less S1 screw or single iliac screw-related complications
11	Case report	Ozturk et al. [14]	2018	1	Sacral osteotomy	Stronger anchorage for distal correction of sagittal malalignment

and long) but also to dual iliac screws where 2 screws are inserted in the lower iliac column and 2 screws in the upper iliac column.

In regard to the surgical technique, it is globally similar to the single iliac screw insertion technique: The muscular attachments and soft tissues are carefully detached using electrocautery to expose the posterior superior iliac spine (PSIS); the entry point is typically placed slightly deep to the PSIS along the medial aspect of the inner table of the ilium in order to avoid prominent screw heads. We typically start with the inferior screw in the inferior portion of the PSIS. Starting point is obtained with a rongeur or a high-speed burr, and the pathway of the screw trajectory is identified using an iliac probe angled approximately 20–45 degrees caudal and 30–45 degrees lateral depending on the pelvic incidence and pelvic tilt. Gently advancing the probe should allow for the trajectory to stay between the inner and outer tables of the ilium, which is usually checked with a feeler, as a freehand technique, but intra-operative fluoroscopy may be used to confirm the correct screw position. A screw 7.5–8.5 mm in diameter and 65–80 mm in length should be used. Same steps are repeated for the superior screw approximately 2 cm above the inferior screw, and offset connectors are inserted (Fig. 3).

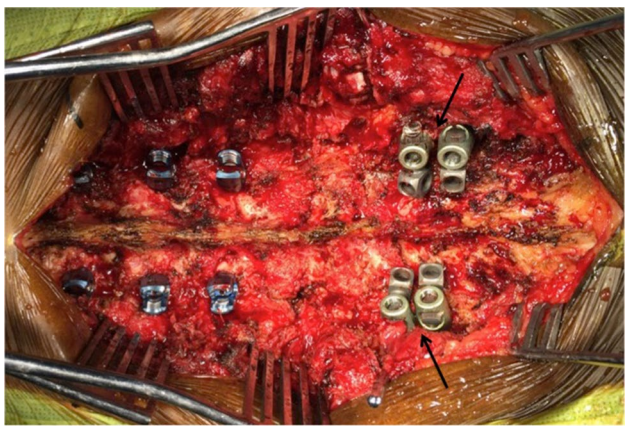


Fig. 3 Intra-operative image: black arrows are indicating the dual iliac screws with offset connectors

Discussion

Sacrum plays an important role in the posterior pelvic ring for the transfer of the body weight from the spine to the lower extremities. Thus, any pathology that may interrupt the sacral area, or prevent its proper instrumentation, will require a fixation below S1, with the need of a strong spinopelvic reconstruction, to support the load transmission from above to below the trunk. The dual iliac

screw or double iliac screw technique has been described as a good option in such cases, as the single iliac screw is not biomechanically strong enough, and the S2AI screw cannot either be an option as a single screw or be put in a dual version.

When sacral neoplasms are encountered, the need for partial or complete sacrectomy may be discussed depending on the malignancy or local aggressivity of the tumoral process [17, 18]. Such cases represent one of the main indications for the use of the DIS technique in order to have a solid basis at the bottom of the spinopelvic construct. In addition, within this sacral tumors group, DIS may be used in palliative fixation of metastatic lumbosacral lesions with extremely poor sacral bone quality; Fujibayashi et al. [8] reported this technique in 5 patients with an irregular follow-up between 3 months and 6 years (mean 28 months), with a good functional outcome but the occurrence of one iliac screw loosening and one rod breakage in long surviving patients. Screws may be inserted percutaneously as reported by Hasan et al. [6], as part of a minimally invasive spinopelvic stabilization in order to reduce soft tissue dissection and blood loss, and their case report described a unilateral DIS technique with a two screws, two rods construct, with a stable status at 1 year but no longer follow-up.

The importance of sagittal alignment and spinopelvic parameters is now well understood, and the negative consequences of sagittal malalignment and pelvic incidence–lumbar lordosis (PI–LL) mismatch on patient quality of life have been well established in the recent literature [19]. Pedicle subtraction osteotomy is a very efficient technique to correct sagittal malalignment when the spine is stiff, and it is mainly performed in the lumbar spine, but it may be done rarely in S1 in the case of severe dysplastic spondylolisthesis (with very high pelvic incidence) that has been operated before (or not) with an important kyphosis element inside the proximal part of the sacrum due to the dysplastic anatomy. The L5S1 disk should be included in the osteotomy to have a bone-on-bone contact after the closure of the osteotomy site. In a clinical and cadaveric study about the use of sacral and pelvic osteotomies, as an alternative to lumbar pedicle subtraction osteotomies, for the correction of lumbosacral kyphosis and to decrease the pelvic incidence [13], the authors advised the use of two iliac screws on each side to be able to close the osteotomy site between the lumbar pedicle screws and the iliac screws, but the DIS technique was not specifically studied from a clinical or biomechanical perspective. Navigation is advisable in such procedure to control the depth of the instruments in the surgical field to avoid any injury to the anterior vessels [20]. Nevertheless, sacral osteotomies are rare, and experience at most spinal centers is limited because of the low number of cases.

Adult spinal deformity patients may also benefit from the DIS technique in case of osteoporosis. In fact, and despite mechanical instability of adult deformity is not comparable to that of sacrectomy, in a series of 27 osteoporotic patients [11], the authors reported the use of dual iliac screws when a long construct is required with a strong spinopelvic fixation. Mechanical complications were reported, such as S1 screw or iliac screw loosening, displacement of the iliac screw, and internal or external perforation of the ilium by the iliac screw, but only one patient required revision. They concluded that the proposed option for osteoporotic ASD patients improved stability for long spinal and pelvic fusion, and it may allow superior correction over single iliac fixation to obtain ideal spinopelvic alignment.

Another indication of DIS construct in the deformities is the bilateral longitudinal sacral osteotomy [15]; this novel technique was described to palliate the limits of the S1 PSO when PI exceeds 90° with a completely vertical S1 endplate and the required correction exceeds 30°.

In traumatic lesions of the pelvis, U-shaped patterns of transverse sacral fractures may represent spinopelvic dissociation with significant instability, therefore requiring strong fixation distally. Iliosacral screw alone may not be successful in preventing a kyphotic deformity following such fractures [21], as the pelvis can flex in relation to the spine along the axis of the iliosacral screw; thus, DIS construct is advisable in such case, for eventual reduction and solid pelvic anchorage.

It should be reminded that sacral U-shaped fracture–dislocation and sacral osteotomy are both rather temporary instabilities that disappear when the fracture/osteotomy site is healed and that the real challenge is the treatment of cases with permanent instability like total sacrectomy where mechanical requirements persist and the implants are brought to the limit of fatigue.

One rare indication of the DIS construct found in the literature involved spinal infections. In fact, in a very heterogeneous series [10], the authors reported the use of the DIS technique in 4 sacral tumors, 2 fracture–dislocations, and 2 lumbosacral tuberculosis; the upper screws were inserted in the upper iliac column, and no implant failure or screw loosening occurred in a follow-up ranging from 3 to 54 months.

In pelvic fixation, utilizing the S2AI technique has dramatically increased during the past decades [22], as several advantages over the single iliac screw technique could be described such as no implant prominence and alignment with the other screws, therefore no need for offset connector, and no dissection of the iliac wings. But in case of a sacral pathology with the need of a strong instrumentation below S1, S2AI screw could not be an option because of the fragility of the sacral area, in addition to the need of at least 2 strong grips on each side; therefore, the best management would be done with the DIS technique.

In case of loosening of the classical pelvic fixation, with lucency (halo) seen around the pelvic screws on X-ray and

CT scan, or when the bilateral iliac screws are broken, revision may be required if alignment loss is noticed, distal nonunion is confirmed, and the patient is clearly symptomatic. In such case, replacing the single screws with the DIS technique is indicated [23].

Also when a distal junctional kyphosis occurs at the distal part of a construct below L5 with important displacement, the DIS technique would add an additional grip on each side for a stronger base in a revision case.

From the biomechanical studies, when spinopelvic reconstruction is needed for unstable conditions caused by total sacrectomy, the use of dual iliac screws is recommended compared with single iliac screw fixation techniques as reported by Mindea et al. [9]. In fact, they compared 4 methods of spinopelvic reconstruction technique; their tests were not mechanically demanding as a series of 3 load/unload cycles was performed for each motion with data analysis based on the final cycle, but they showed that the double-rod double iliac screw method provided the most rigid fixation, followed by the single-rod double iliac screw fixation, single-rod single screw, and the modified Galveston technique. In addition, insertion of all 4 screws of the DIS technique in the lower iliac columns exhibited higher compressive and torsional stiffness when compared to a construct where 2 screws are placed in the upper iliac column and the other 2 in the lower iliac column [5]. It should be reminded that "in vitro" studies may not account for all the factors contributing to stability "in vivo"; this is why several precautions were taken in the different studies [5, 9] to minimize as much as possible such drawback like comparing the different reconstruction techniques on the same specimen to minimize the interspecimen variation, normalizing the data to the intact conditions, and randomizing the test sequence to avoid bias to one particular reconstruction technique. Nevertheless, limitations of such studies were acknowledged by their authors [5, 7], where early stabilities of the instrumented constructs were only measured, but their long-term biomechanical effects have not been evaluated; therefore, care has to be taken when using these data as a guide for clinical practice.

Disadvantages of the dual iliac screw technique were not described in the papers of the literature, but logically the same drawbacks of the single iliac screw technique would apply [2] such as hardware prominence in thin patients, gait abnormalities (short step, waddle), and sacroiliac joint pain, but the latter symptom may be less as the insertion of a second screw on each side would prevent the classical remaining movement in the sacroiliac joint, acting as an antirotation screw, thus decreasing the related pain.

As with any systematic review, the strength of our conclusions relied heavily upon the quality of evidence available for analysis, which was studies only fulfilling criteria for level IV evidence, and mainly case series and case reports. Another limitation is the fact that 3 biomechanical cadaveric studies were added to the review in addition to the clinical studies; this was done for 2 reasons: the scarcity of the subject in the literature and in order to have a complete and global perspective of the DIS technique to demonstrate its true advantage from an experimental point of view in addition to the clinical standpoint.

In conclusion, the current study reviewed the literature in regard to the use of 2 screws in each iliac wing in spinopelvic constructs. The objective was to offer a better insight on this uncommon subject, that is the dual iliac screw technique, and to provide the spine surgeons community with clear indications and advantages of such a technique to avoid failure and decrease the rate of complications when spinopelvic junction constructs are needed. But given the level of the current available papers, it will need to be supported by future well-designed studies.

Compliance with ethical standards

Conflict of interest There are no conflicts of interest for this article.

References

1. Kuklo TR, Bridwell KH, Lewis SJ, Baldus C, Blanke K, Iffrig TM, Lenke LG (2001) Minimum 2-year analysis of sacropelvic fixation and L5-S1 fusion using S1 and iliac screws. Spine (Phila Pa 1976) 26:1976–1983
2. Moshirfar A, Rand FF, Sponseller PD, Parazin SJ, Khanna AJ, Kebaish KM, Stinson JT, Riley LH 3rd (2005) Pelvic fixation in spine surgery Historical overview, indications, biomechanical relevance, and current techniques. J Bone Joint Surg Am 87(Suppl 2):89–106. https://doi.org/10.2106/jbjs.e.00453
3. Emami A, Deviren V, Berven S, Smith JA, Hu SS, Bradford DS (2002) Outcome and complications of long fusions to the sacrum in adult spine deformity: Luque–Galveston, combined iliac and sacral screws, and sacral fixation. Spine (Phila Pa 1976) 27:776–786
4. Chang TL, Sponseller PD, Kebaish KM, Fishman EK (2009) Low profile pelvic fixation: anatomic parameters for sacral alar-iliac fixation versus traditional iliac fixation. Spine (Phila Pa 1976) 34:436–440. https://doi.org/10.1097/brs.0b013e318194128c
5. Yu BS, Zhuang XM, Zheng ZM, Li ZM, Wang TP, Lu WW (2010) Biomechanical advantages of dual over single iliac screws in lumbo-iliac fixation construct. Eur Spine J 19:1121–1128. https://doi.org/10.1007/s00586-010-1343-8
6. Hasan MY, Liu G (2017) Minimally invasive dual iliac screw, dual rod fixation in a rare case of pathological sacral fracture from a paraganglionoma: a technique description. J Neurosurg Spine 27:316–320. https://doi.org/10.3171/2017.3.SPINE161293
7. Yu BS, Zhuang XM, Li ZM, Zheng ZM, Zhou ZY, Zou XN, Lu WW (2010) Biomechanical effects of the extent of sacrectomy on the stability of lumbo-iliac reconstruction using iliac screw techniques: what level of sacrectomy requires the bilateral dual iliac screw technique? Clin Biomech (Bristol, Avon) 25:867–872. https://doi.org/10.1016/j.clinbiomech.2010.06.012

8. Fujibayashi S, Neo M, Nakamura T (2007) Palliative dual iliac screw fixation for lumbosacral metastasis. Technical note. J Neurosurg Spine 7:99–102. https://doi.org/10.3171/SPI-07/07/099
9. Mindea SA, Chinthakunta S, Moldavsky M, Gudipally M, Khalil S (2012) Biomechanical comparison of spinopelvic reconstruction techniques in the setting of total sacrectomy. Spine (Phila Pa 1976) 37:E1622–E1627. https://doi.org/10.1097/brs.0b013e31827619d3
10. Acharya NK, Bijukachhe B, Kumar RJ, Menon VK (2008) Iliolumbar fixation—the Amrita technique. J Spinal Disord Tech 21:493–499. https://doi.org/10.1097/BSD.0b013e31815b5cc4
11. Ebata S, Ohba T, Oba H, Haro H (2018) Bilateral dual iliac screws in spinal deformity correction surgery. J Orthop Surg Res 13:260. https://doi.org/10.1186/s13018-018-0969-9
12. Vilela MD, Gelfenbeyn M, Bellabarba C (2009) U-shaped sacral fracture and lumbosacral dislocation as a result of a shotgun injury: case report. Neurosurgery 64:E193–E194. https://doi.org/10.1227/01.neu.0000336313.88450.5e **(Discussion E194)**
13. Bodin A, Roussouly P (2015) Sacral and pelvic osteotomies for correction of spinal deformities. Eur Spine J 24(Suppl 1):S72–S82. https://doi.org/10.1007/s00586-014-3651-x
14. Ozturk AK, Sullivan PZ, Arlet V (2018) Sacral pedicle subtraction osteotomy for an extreme case of positive sagittal balance: case report. J Neurosurg Spine 28:532–535. https://doi.org/10.3171/2017.8.SPINE17550
15. Czyz M, Forster S, Holton J, Shariati B, Clarkson DJ, Boszczyk BM (2017) New method for correction of lumbo-sacral kyphosis deformity in patient with high pelvic incidence. Eur Spine J 26:2204–2210. https://doi.org/10.1007/s00586-017-5205-5
16. Konig MA, Jehan S, Boszczyk AA, Boszczyk BM (2012) Surgical management of U-shaped sacral fractures: a systematic review of current treatment strategies. Eur Spine J 21:829–836. https://doi.org/10.1007/s00586-011-2125-7
17. Zhang HY, Thongtrangan I, Balabhadra RS, Murovic JA, Kim DH (2003) Surgical techniques for total sacrectomy and spinopelvic reconstruction. Neurosurg Focus 15:E5
18. Bederman SS, Shah KN, Hassan JM, Hoang BH, Kiester PD, Bhatia NN (2014) Surgical techniques for spinopelvic reconstruction following total sacrectomy: a systematic review. Eur Spine J 23:305–319. https://doi.org/10.1007/s00586-013-3075-z
19. Schwab FJ, Blondel B, Bess S, Hostin R, Shaffrey CI, Smith JS, Boachie-Adjei O, Burton DC, Akbarnia BA, Mundis GM, Ames CP, Kebaish K, Hart RA, Farcy JP, Lafage V, International Spine Study G (2013) Radiographical spinopelvic parameters and disability in the setting of adult spinal deformity: a prospective multicenter analysis. Spine (Phila Pa 1976) 38:E803–E812. https://doi.org/10.1097/brs.0b013e318292b7b9
20. Obeid I, Bourghli A, Boissiere L, Vital JM, Barrey C (2014) Complex osteotomies vertebral column resection and decancellation. Eur J Orthop Surg Traumatol 24(Suppl 1):S49–S57. https://doi.org/10.1007/s00590-014-1472-6
21. Hak DJ, Baran S, Stahel P (2009) Sacral fractures: current strategies in diagnosis and management. Orthopedics. https://doi.org/10.3928/01477447-20090818-18
22. O'Brien JR, Yu WD, Bhatnagar R, Sponseller P, Kebaish KM (2009) An anatomic study of the S2 iliac technique for lumbopelvic screw placement. Spine (Phila Pa 1976) 34:E439–E442. https://doi.org/10.1097/brs.0b013e3181a4e3e4
23. Shen FH, Mason JR, Shimer AL, Arlet VM (2013) Pelvic fixation for adult scoliosis. Eur Spine J 22(Suppl 2):S265–S275. https://doi.org/10.1007/s00586-012-2525-3

Affiliations

Anouar Bourghli[1] · Louis Boissiere[2] · Ibrahim Obeid[2]

[1] Orthopedic and Spinal Surgery Department, Kingdom Hospital, P.O. Box 84400, Riyadh 11671, Saudi Arabia

[2] Orthopedic Spinal Surgery Unit 1, Bordeaux Pellegrin Hospital, Bordeaux, France