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ORIGINAL ARTICLE • PELVIS - FRACTURES

A new minimally invasive U-shaped lumbopelvic stabilization technique

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Abstract
Lumbopelvic stabilization is a surgical technique used frequently to treat lumbosacral fractures; however, it can also be used in revision cases, infections, or during deformity correction. However, the related soft tissue complication rates associated with open lumbopelvic stabilization are high. Different authors have recently reported minimally invasive surgical techniques. We developed a rigid minimally invasive technique for lumbopelvic stabilization. We present our technique and also present preliminary results from 10 cases. We did not observe soft tissue-related complications in any patient. Implant removal was performed twice, to release healthy disks and because of implant prominence. One patient required revision surgery because of implant loosening due to osteoporosis, and one patient required revision surgery due to screw cap loosening. Postsurgical mobilization was good in all patients without further injuries; however, polytraumatized patients were limited by additional injuries. Thus, minimally invasive U-shaped lumbopelvic stabilization is a useful technique combining the soft tissue-related advantages of minimally invasive surgical techniques as well as a theoretically very rigid construct caused by strong implants.

Keywords Lumbopelvic stabilization · Trauma · Sacral fracture · Wound healing · Infection · Surgical technique

Introduction

Lumbopelvic stabilization (LPS) is a surgical technique to reconstruct posterior pelvic ring fractures. Several modifications have been published [1–7]. The traditional technique is based on an open approach with pertinent soft tissue dissection. However, related complication rates are relatively high. Wound healing disorders and infections occur in up to 26% of cases. Moreover, postoperative pain and resulting delayed mobility remain challenging and can be observed frequently [5]. With minimally invasive surgical (MIS) techniques becoming more and more popular in all fields of surgery, there have also been reports of minimally invasive LPS [8–11].

The authors think that three important aspects have to be kept in mind to understand soft tissue complications following LPS: (1) the surgical approach is close to the intergluteal cleft with its special hygienic demands; (2) the soft tissue layer above L5 is thick, but lean above the sacrum and especially over the posterior superior iliac spine; (3) open LPS requires intensive soft tissue dissection above the sacrum for implantation of the iliac screws and for connecting them to the lumbar spine with a rod.

Minimally invasive LPS techniques address these three aspects in a better manner than open techniques. They prevent soft tissue complications, as soft tissue dissection is smaller, and the incision does not have to be located in the midline near the intergluteal cleft.

LPS in general represents a very stable implant construct, for instance, when compared to iliosacral screws for the treatment of unstable sacral fractures [2]. It is commonly accepted that instability of implant constructs can cause pain and extend postoperative mobilization. Therefore, biomechanical demands at the lumbopelvic junction must be considered when operating on this anatomic area.

At the lumbopelvic junction, rigidity meets flexibility. While the sacroiliac joint only allows for less than 2 mm of translation, making this connection very rigid, the sacrum connects the pelvis with the flexible lumbar spine [12, 13]. Moreover, at this area, vertical loads are transferred into shear loads due to sacral tilt and pelvic anatomy [13].

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Considering soft tissue and biomechanical demands, we observed several wound complications and prolonged immobilization after open LPS, especially following sacral and posterior pelvic ring fractures, in our own patient population. We therefore strived to develop a minimally invasive technique that provides good stability for immediate weight-bearing after surgery as well as addresses the soft tissue aspects depicted above.

Here, we present a percutaneous minimally invasive technique for LPS as well as our first clinical results. The presented technique has been developed from already published techniques and is used routinely in eligible patients [9, 10, 14].

Methods

Surgical technique

The surgical technique described hereafter was essentially developed by the senior author (CWM) of this manuscript.

Conception

The aim is not only to perform minimally invasive surgery but also to use a rigid and stable construct for better postoperative pain relief. As a level-one trauma center, the main intention is to use the technique for severe pelvic and/or sacral fractures (Fig. 1); however, it can also be used for patients suffering from tumor, infection, or deformity or in revision cases. We want to stabilize all relevant directional movements including extension/flexion, rotation, and translation at the lumbopelvic junction. The invented implant construct therefore is as follows: LPS from L3/4 to the ilium with a strong crossing rod/cross-connector in between the iliac screws. The idea is that a long construct provides higher stability during bending, whereas a thick cross-connector between the iliac screws provides greater rotational stability. An ex situ array of the implants can be seen in Fig. 2. We connect both iliac screws with a 5.5-mm transversal rod. Afterward, the latter is connected to the pedicle screws using 5.5-mm lateral connectors. For connection of the transversal rod and the lateral connectors, the incision for implantation of the iliac screws is sufficient and soft tissue can be mobilized enough for fixation. According to the percutaneous approach, neither spinal nor sacroiliac fusion is performed. Concerning the formation of the rods, we call this technique minimally invasive U-shaped LPS. As to our philosophy, the screw diameter should always be as large as possible, with the screw length of the iliac screws not being shorter

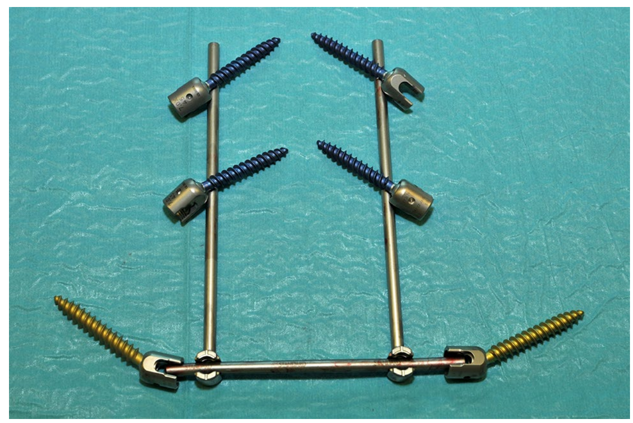

Fig. 2 Schematic array of implants for minimally invasive U-shaped lumbopelvic stabilization. Four pedicle screws are implanted. Moreover, two iliac screws are implanted and connected by a crossing rod. Afterward, pedicle screws are connected with the crossing rod using lateral connectors

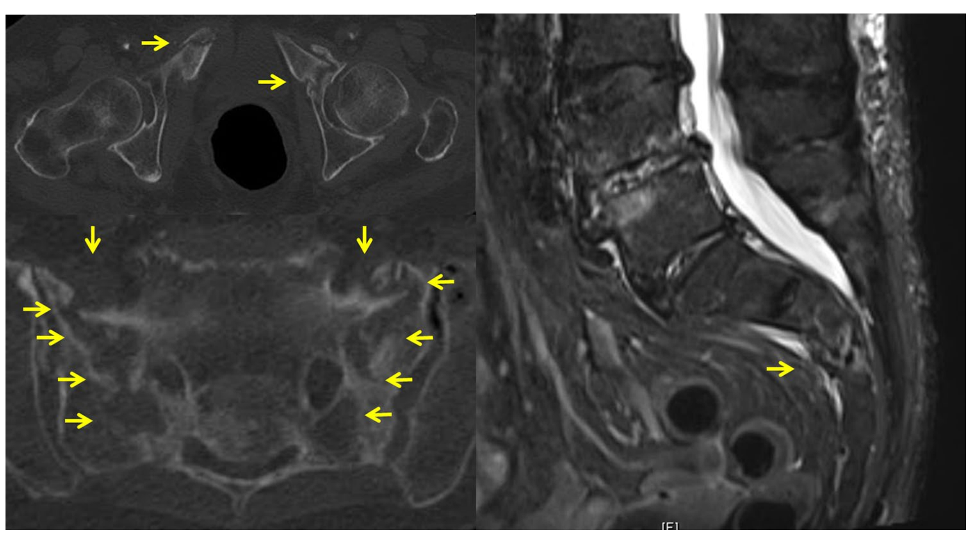

Fig. 1 Spinopelvic dissociation. A 74-year-old female patient suffered from a U-shaped sacral fracture as well as bilateral anterior pelvic ring fracture. Yellow arrows indicate the fracture lines. Degeneration is present in the lower lumbar spine (color figure online)

than 80 mm. We use Viper II and Expedium instrumentation (DepuySynthes, Johnson and Johnson, USA).

Surgery

After general anesthesia and standard prone positioning, skin sterilization, and draping, fracture reduction is performed if required. For this, traction and compression can be applied. Moreover, reduction can be achieved using the implants after insertion. We percutaneously inserted polyaxial pedicle screws in L3 and L4 using a standard technique, as described previously with the use of an image intensifier [9]. Longitudinal skin incisions usually measure not more than 1.5–2 cm per pedicle screw. Afterward, approximately 4 cm skin incisions slightly medial to the posterior superior iliac spine are performed. This simplifies iliac screw insertion because of its trajectory from medial to lateral [9]. Sharp dissection down to the bone with intermittent hemostasis is done, and the posterior superior iliac spine is visualized using retractors. Afterward, the cortical bone is opened using a luer. We always strive to set up the entry point slightly caudal to the posterior superior iliac spine in order to prevent implant prominence. Moreover, we make sure to reduce postoperative screw prominence as much as possible by resection of sufficient cortical bone to slightly countersink the screw head. The iliac bone is probed. After confirmation of the correct trajectory (digital and by the use of the image intensifier as previously reported [9]), iliac screws are inserted. We favor polyaxial (sometimes dual innie) iliac screws; the dimensions are always being adapted to individual anatomy but with a length not less than 80 mm. Iliac screws are directed close to the sciatic notch, aiming toward the anterior inferior iliac spine. Afterward, iliac screws are connected by a crossing 5.5-mm rod. We use this to provide more rotatory biomechanical stability and thus ease postoperative mobilization and reduce pain. Precise bending is needed to avoid implant prominence after surgery. From a surgical point of view, bending the transversal rod as well as rod passage can be challenging, because it is hard to get over the sacral spinous processes and the positioning should be as close to the bone as possible. To achieve this, sometimes several attempts are required with repeated modification of the bending. Preoperative detailed analysis of posterior sacral anatomy helps to anticipate individual anatomy. If planned presurgically, the dual innie mechanism at this point allows for blocking of the polyaxial mechanism, with the screw head being fixed while still being able to apply distraction/compression if needed. Screwdrivers can be used as handles, which might help reduce a fracture. Afterward, 5.5-mm lateral connectors are used to connect the pedicle screws in L3 and L4 to the crossing rod. They are inserted from distal to proximal. Prebending, especially in obese patients, can be demanding because of the length of the construct and the lordotic alignment that must be achieved. Appropriate restoration of lumbar lordosis, however, is crucial. Preoperative planning of spinopelvic parameters (pelvic incidence, pelvic tilt, sacral tilt, and lumbar lordosis) and correct anticipation of patient positioning (lordosis) help to correctly bend the implants. However, this technique is not for sagittal plane correction but for primarily fracture treatment with restoration of the prefracture status. Importance should therefore be ascribed to prevent implant prominence. After locking the rods, irrigation is performed, and the wounds are closed in layers. The procedure is visualized in Fig. 3.

Postsurgical care

Patients are allowed immediate full weight-bearing after surgery. Physiotherapeutic-assisted mobilization is executed at the first day. After mobilization, (standing) X-rays are performed (Fig. 4). Computed tomography is not performed routinely.

Patient population

The study was approved by the local ethics committee (No. 2479-2014). We retrospectively searched the records of our level 1 trauma center for all LPS techniques performed using the minimally invasive U-shaped LPS as described above. Included patients were all aged ≥ 18 years. Informed consent was obtained preoperatively in every case. We included nine patients who underwent surgery as described above. Additionally, one patient was only stabilized from L4 to the ilium (Fig. 5).

We searched patients' files for diagnosis, demographic data, additional injuries, intraoperative complications, and postoperative complications and mobilization.

Radiographic assessment

All available radiographic examinations were analyzed briefly. Underlying sacral fractures were classified as U-shaped, H-shaped, or Denis 1–3 injuries to best describe their anatomic fracture pattern, if possible [15, 16]. Concomitant pelvic fractures were also described.

Results

Patient details are summarized in Table 1

No soft tissue complications, such as wound healing disorders, were observed in our patient cohort. We did not perform computed tomography routinely during follow-up; however, clinically, there were no signs of nonunion.

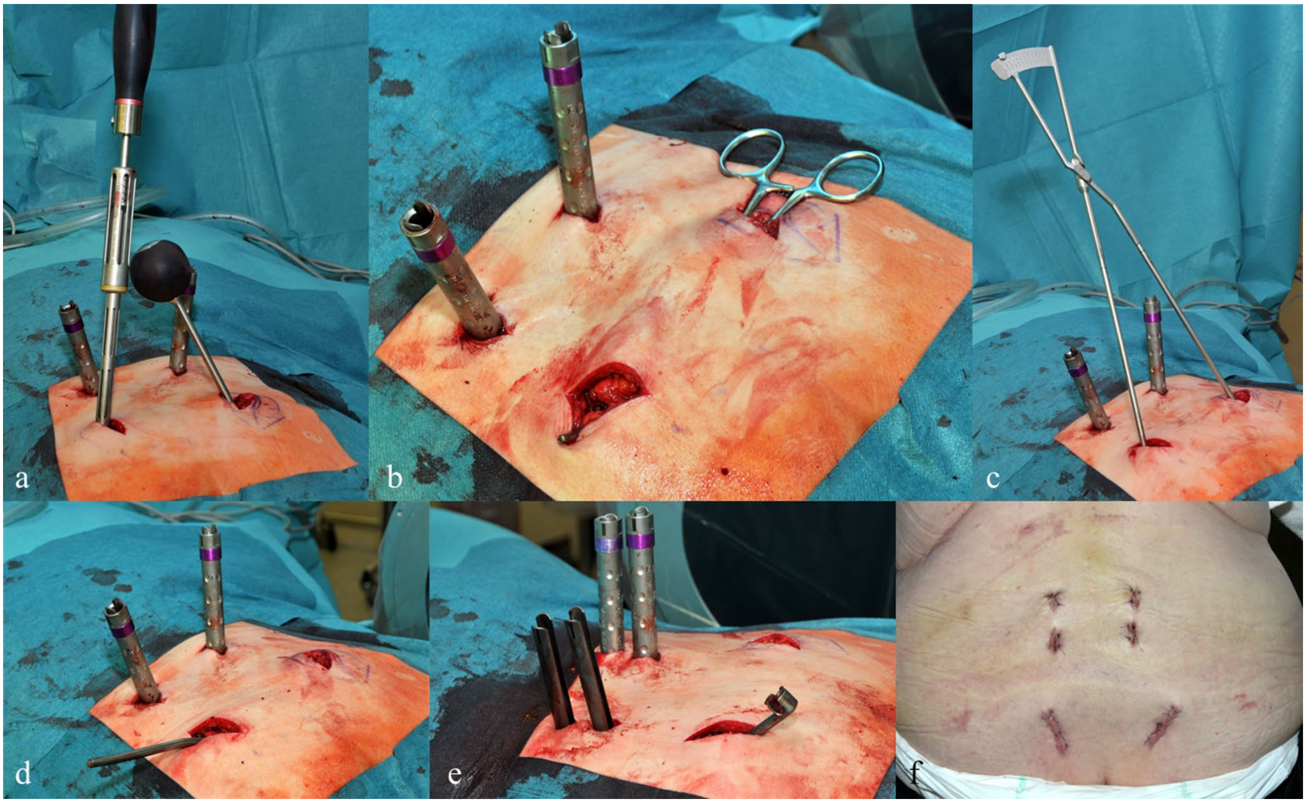

Fig. 3 Surgical procedure for minimally invasive U-shaped lumbopelvic stabilization in the patient presented in Fig. 1. **a** Pedicle screws are already implanted in L3. Incisions medial to the posterior superior iliac spines have been performed obliquely. The left iliac screw is already implanted; the right one is still being tapped, with the instrument in situ. **b** Afterward, the canal for the crossing rod between the iliac screws is prepared. It should be as close to the sacral bone as possible. **c** The distance between the iliac screws has to be measured. **d** The crossing rod is prepared, with bending being challenging in some cases, with multiple insertions and removals until a perfect fit is achieved. **e** After implantation of pedicle screws in L4 (which can also be done directly when preparing L3), the lateral connectors are also present and then inserted to connect the pedicle screws with the crossing rod. **f** Postoperative wounds

Mean operative time was 140 ± 11 min for patients without additional procedures performed at the same time. Patient 4 suffered from severe polytrauma. During the same surgery, the anterior pelvic ring was reconstructed, including repositioning from the supine-to-prone position. Patient 6 also underwent removal of a supraacetabular external fixation and received an iliosacral percutaneous screw. Patient 8 also underwent reduction and internal fixation of a forearm fracture as well as debridement of severe soft tissue wounds and needed to be repositioned during surgery. Patient 10 suffered from severe polytrauma, including a comminuted fracture of his left ilium. This was reconstructed using a Kocher–Langenbeck approach during the same surgery.

While additional procedures and type of injury did affect postoperative mobilization, Table 1 demonstrates that all patients without multiple injuries could be mobilized without problems, including patients also suffering from L5 fractures. Limitation of mobilization always resulted from other injuries and procedures independent from minimally invasive U-shaped LPS.

Implant-related complications (loosening of screw cap, screw loosening) were observed in two patients. Although screw loosening was due to poor bone quality, the reason for loosening of a screw cap remains unclear.

As described by other authors, we tend to release healthy disks after fracture healing, especially in young patients and in patients with implant prominence [9]. Implant removal due to implant prominence only was performed in one case (Table 1).

Discussion

We present a minimally invasive U-shaped LPS technique. We did not observe soft tissue-related complications in any patient. Postsurgical mobilization was good in all patients without further injuries; however, polytraumatized patients were limited by additional injuries. The construct is very rigid and, in our experience, very effective for the treatment of severe fractures of the lumbopelvic junction, especially

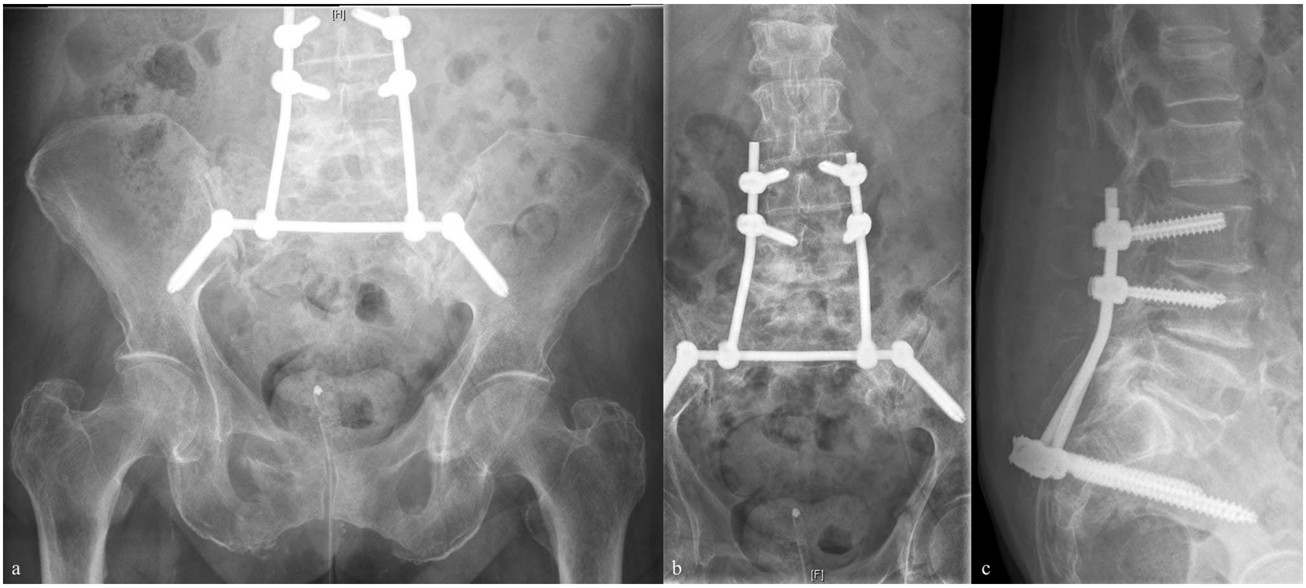

Fig. 4 Postoperative X-rays of the patient from Figs. 1 and 3. We tend to perform an anterior–posterior (AP) X-ray view of the pelvis (**a**) and lumbar spine (**b**) as well as a lateral view of the lumbar spine (**c**). Without the AP pelvic view (**a**), iliac screw tips are often cut off (**b**). Like seen on the X-rays, it is important that implants are close to the bone to avoid implant prominence

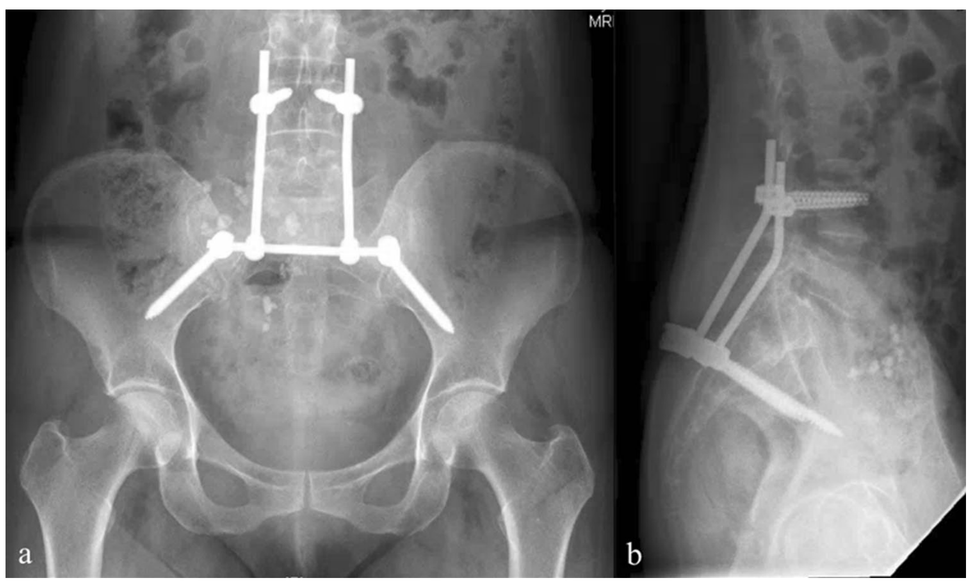

Fig. 5 Lumbopelvic stabilization L4 to ilium following a U-shaped sacral fracture. **a** Anterior–posterior pelvic view. **b** Lateral view of the lumbar spine

spinopelvic dissociation injuries or combined fractures of L5 and the sacrum. As the construct is very rigid, very unstable fractures, as presented in our case series, benefit significantly.

Percutaneous stabilization of the lumbosacral junction immobilizes healthy intervertebral disks. As long-term immobilization might cause degeneration of the motion segment, we recommend implant removal after 9 months in young patients, if fracture healing is confirmed by computed tomography. However, due to fatigue fractures in the elderly, we do not think that implant removal is required, as long as implants do not cause pain. Furthermore, studies proving our approach are missing so far. In our case series, implant removal due to implant prominence and to release healthy disks in a young patient was performed once each. Keel et al. published a case series of ten patients undergoing less invasive unilateral or bilateral lumbopelvic stabilization. They performed implant removal in five cases to release healthy disks and also prevent fusion of the sacroiliac joint. Comparability, however, is limited as patient age differs [8]. In contrast, Williams et al. always recommend implant removal [9]. Like our experience, they also described the rod passage

Table 1 Details of patients being treated with minimally invasive U-shaped lumbopelvic stabilization

Patient	Sex	Age (years)	BMI (kg/m^2)	ASA	Diagnosis (R = right, L = left)	Duration of surgery (min)	Complications during surgery	ICU after surgery	Mobility at discharge	Soft tissue complications	Revision of instrumentation
1	♂	61	20	3	Metastatic fracture L5 & S1 from hepatocellular carcinoma	144	No	No	Walking	No	No
2	♀	75	35	3	U-shaped sacral fracture, transverse process fracture L5 (R&L), anterior pelvic ring fracture L, atypical U-shape sacral fracture	153	No	Yes	Crutches	No	No
3	♀	74	28	3	Spondylodiscitis L5/S1	143	No	Yes	Walking	No	Correction of loosened screw cap
4	♂	55	26	3	Sacral fracture type Denis 1 R, transverse sacral fracture S1 and S5, pubic symphysis rupture, dislocated anterior pelvic ring fracture L	495	No	Yes	Wheelchair	No	No
5	♀	75	35	3	Nonunion of U-shaped sacral fracture	141	No	No	Walker	No	No
6	♀	71	24	3	Anterior pelvic ring fracture R&L, Denis type 2 sacral fracture L, Denis type 1 sacral fracture R, rupture of iliosakral joint L	252	No	No	Partial weight-bearing	No	No
7	♀	76	22	2	U-shaped sacral fracture, burst-fracture L5, ischial fracture R	142	No	No	Walking	No	Revision of screw loosening with loss of reduction, augmentation
8	♀	47	21	4	U-shaped sacral fracture, burst-fracture L5	299	Correction of initially misplaced iliac screw required	Yes	Walking	No	Implant removal because of implant prominence
9	♀	59	20	2	U-shaped sacral fracture	117	No	No	Walking	No	Implant removal to release healthy disks
10	♂	55	26	3	U-shaped sacral fracture, comminuted fracture ilium L	486	No	Yes	Ventilated, bed-ridden	No	No

being sometimes demanding. This definitely has to be kept in mind because surgery therefore can be challenging and is not for novice surgeons in minimally invasive surgery. Williams et al. instrumented L4/5 down to the ilium which is one segment less compared to our technique. Biomechanical data proving our approach are missing so far. In contrast, Keel et al. presented cases of whom some were also stabilized L3/4 down to the ilium [8].

Like in our series, no wound complications were observed by other authors using percutaneous techniques [8, 9]. This corresponds with almost all fields of orthopedic surgery with less invasive techniques being superior to big approaches when analyzing soft tissue complication rates.

Schildhauer et al. published a triangular osteosynthesis technique [1, 2]. They did prove high biomechanical stability. The crossing rod introduced in this manuscript further develops the biomechanical approach of high construct rigidity.

Concerning the crossing rod connecting the iliac screws and the long proximal extension up to L3, we think that this is a very rigid construct. This finding is supported by the clinical observation of easier postoperative mobilization than that with conventional techniques. However, biomechanical analysis is not yet complete and is needed to prove this theory.

Using our technique, L3 down to the ilium, with the exception of L5, is stabilized, whereas Williams and Quinnan reported a technique that only stabilized L4 and L5 down to the ilium [9]. In very painful sacral fractures, we believe that this helps to reduce extension/flexion of the lumbosacral junction and might contribute to pain relief and better mobilization after surgery. Moreover, our technique allows us to treat patients who suffer from L5 fractures in addition to sacral fractures. The crossing rod between the iliac screws, in contrast to that reported by Williams and Quinnan, is intended to cause increased rotatory stability [9].

Concerning the percutaneous approach, soft tissue dissection is reduced compared to that with open techniques. Wound healing disorders or infections were not observed in our case series. This corresponds with observations from other regions of the spine [17]. The benefits for the soft tissue are one of the major reasons to perform MIS techniques.

We already described that rod passage can be challenging, especially when implanting the crossing rod between the two iliac screws. Therefore, this technique is not for novice surgeons performing minimally invasive spine surgery but should be reserved for surgeons experienced in performing MIS techniques. Nevertheless, we think that connection of L3 and L4 with the ilia is slightly easier than that of L4 and L5, as L5 is deeper than L4.

However, there are also theoretical disadvantages of minimally invasive U-shaped LPS. As its name implies, we only stabilize but do not fuse. Nevertheless, passing the rods might cause violation of the facet joints, which itself can cause fusion due to degeneration [18]. This fact has to be discussed with patients prior to surgery. We did not encounter a patient with symptomatic spondylarthritis after implant removal; however, this development could require long-term fusion as a relevant sequela of percutaneous fusion. Moreover, reduction maneuvers as described above, if needed, are often more challenging than in open techniques, as the posterior pelvic ring is anatomically rigid and complex to reconstruct.

A relevant limitation of this technique is that neural decompression is impossible without an additional surgical approach; thus, surgeons should carefully evaluate patients prior to surgery and plan the operation appropriately to verify that patients are eligible for this technique.

Conclusion

Minimally invasive U-shaped LPS is a useful technique combining the soft tissue-related advantages of MIS techniques as well as a theoretically very rigid construct caused by strong implants. The latter still needs to be proven biomechanically. Surgery can be complex, and we would consider this technique to be technically advanced even though relevant complications were not observed in our patient cohort. Surgeons should be familiar with both spinopelvic anatomy and minimally invasive spine surgery when using this technique.

Compliance with ethical standards

Conflict of interest Authors declare that they do not have any conflict of interest.

Ethical statements This study complies with current law in Germany and was approved by the local ethics committee (No. 2479-2014).

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