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Spinopelvic fixation using iliac screws for adult spinal deformity: Radiographic and clinical analysis of 100 patients

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Abstract

Objective: Iliac screws are a biomechanically sound method for deformity correction and stabilization of a long multi-segment lumbar constructs, which are instrumented down to S1. There is disagreement about complications and the effect on the fusion rate. The aim of the study is to analyse the safety and outcome of iliac screws.

Materials and methods: All patients with fusion of more than 4 segments and bilateral S1 and iliac screws were included in this retrospective study. The additional inclusion criteria were postoperative radiographic follow-up with x-ray after 6 months and one year. Screw loosening was determined by the appearance of radiographic halo zone sign around the screw. Bony fusion was investigated by CT scans. Exclusion criteria were spinopelvic fixation for diseases other than deformity

Results: The data of our 100 patients show a low revision rate of 4% for pseudarthrosis and 2% for prominences of the iliac screw heads. there was no lumbar loss of correction. The incidence of iliac screw loosening was 0.5% and the incidence of S1 screw loosening was 2%. Compared to the literature, our data showed similarly good results with regard to revision rates, frequency of non-union and correction losses due to the implantation of ilium screws using the free-hand implantation technique. The radiological analysis showed no influence of the screw length on the results.

Conclusion: Iliac screws for adult patients with spinal deformities were shown to be an effective method of spinopelvic fixation with high lumbosacral fusion rates and low complication rates.

Keywords: Bilateral iliac screw • Spinopelvic fixation • Correction of adult spinal deformity

Introduction

Background

Previous studies on spinopelvic fixation with iliac screws had high complication rates and revision rates. Some publications provided evidence that bilateral iliac screws in combination with bilateral S1 screws could offer a promising alternative fixation technique for long dorsal fusion. However, especially for deformity corrections in adults with long lumbar fusion to the sacrum in conjunction with spinopelvic fixation by iliac screws, there was a lack of evidence on the mechanical failure pattern of iliac screws in their bony store and on the effect of spinopelvic fixation on the fusion rate of the L5/S1 segment included in an instrumentation. To date, no clinical radiological studies have been published to assess spinopelvic fixation using iliac screws in adult spinal deformity in relation to this topic

Objective

The aim of this study was generally to investigate the effects of spinopelvic fixation with iliac screws on the fusion rate, correction result and loosening rates of implanted pedicle screw rod systems. In addition specifically, it should be investigated whether the freehand implantation technique is effective over a follow-up period of at least one year postoperatively on the rate of iliac screw loosening, the rate of S1 screw loosening, pseudarthrosis in the L5/S1 segment, pseudarthrosis above L5, implant fractures, loss of correction and the incidence of sacral fractures, degenerative changes of the sacroiliac joint and the incidence of revision due to a local prominent screw head should be investigated. Radiological evaluation should clarify whether screw length has an influence on outcomes.

Material and Methods

The study was designed as a purely retrospective study with assessment of x-rays and computed tomography scans and was performed between 2019 and 2022. All records of patients who had undergone surgery for spinal deformity between 2015 and 2020 and had received lumbar fusion of more than 4 segments with simultaneous instrumentation by bilateral S1 and bilateral iliac screws and the iliac screws had been inserted using a freehand technique and whose surgery at the start of this study was at least one year ago were included. Other inclusion criteria were the presence of postoperative radiographs 6 months and one year postoperatively. Exclusion criteria were spinopelvic fixation for tumors and pelvic fractures

Radiological assessment

For radiological assessment in the follow-up, adequate pre- and postoperative imaging in the form of X-rays and CT scans was available for all patients. All imaging data had been collected and reviewed by experienced spine surgeons and radiologists.

Routine conventional two-plane, antero-posterior and lateral spine x-rays were generally obtained 6 weeks postoperatively and then at 3-month, 6-month or 12-month intervals. If there were any suspicions of pseudarthrosis based on radiological imaging and/or pain symptoms, typically in the form of new or worsening back or sciatic pain, additional CT spine images (including the pelvis and iliac screws) were obtained to assess bony fusion. Here, CT scans were performed in 22 patients out of 100 patients during the postoperative course.

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The following spinopelvic parameters were measured using standard techniques: sagittal vertical axis (SVA), thoracic kyphosis (Stagnara angle between the superior endplate of T4 and the inferior endplate of T12), lumbar lordosis (Stagnara angle defined as the angle between the superior endplate of L1 and the superior endplate of S1), the pelvic incidence (PI) and the pelvic tilt (PT). Complications related to the iliac screws (screw loosening and screw fracture), screw head protrusion, rod fracture and pseudarthrosis were identified at follow-up and/or confirmed intraoperatively during revision. Radiologically documented iliac screw loosening was defined as a loosening margin around the screw thread ≥ 2 mm (periscrew translucency) on subsequent radiographs or CT scans. Complications related to the lumbosacral junction were defined as L5-S1 pseudarthrosis and S1 screw loosening or fracture.

Analysis parameters

Pseudarthrosis was defined as in a computer tomography detectable lack of fusion in one segment or over several segments from dorsal and ventral (Albert *et al.* 2000). Successful fusion was defined as the simultaneous presence of several criteria, namely evidence of continuous bone structure between the fused segments, regular seating of the implants, no signs of loosening around the pedicle screws, no cage loosening, no material failure, no rod fractures (Kuklo *et al.* 2001, Larosa *et al.* 2003, Lamberg *et al.* 2005). Local buttock pain reported during clinical follow-up was taken as evidence of a prominent iliac screw head under the skin.

The achieved postoperative correction is the result of subtracting the PI-LL difference preoperatively minus the PI-LL difference postoperatively. The spinopelvic parameters were analysed on the basis of radiographs in the postoperative course after 6 weeks, 3 months, 6 months and after one year. A change in the achieved postoperative correction was carefully observed to verify whether spinopelvic fixation had an influence on the maintenance of correction in the postoperative course. The extent of any degeneration of the sacroiliac joints was determined using antero-posterior radiographs of the lumbar spine. The underlying radiological criteria for joint osteoarthritis were joint space narrowing, sclerosis, hypertrophy and osteophytes (Gellhorn *et al.* 2013).

Table 1: Patient demographics and surgical data.

Age of patient on day of surgery	Number of patients
42 – 58 years	4
59 – 69 years	42
70 – 85 years	54
Patient gender	
Women	73
Men	27
Surgical indication	
Adulte Scoliosis	7
Degenerative Scoliosis	19
Sagittal imbalance	39
Hyperkyphosis und Kyphoscoliosis	15
Spondylolisthesis und lumbar instability	7
Extension in pseudarthrosis	3
Extension in adjacent segments complication	10

Table 1: Patient demographics and surgical data for the study cohort (n=100 patients)

Description of the implants

The length of the iliac screws used for the spinopelvic fixations varied between 70 mm and 100 mm and had a diameter of 8.5 mm. The length of the S1 screws varied between 40 mm and 50 mm; the diameter was 6.5 mm in all cases. Intervertebral cages (L5/S1) were used in 95 patients. The connections between S1 and iliac screws were established by a lateral connector

Incidence of revisions

The incidence of revisions due to pseudarthrosis was 4%. The pseudarthrosis was either localised in the L5/S1 segment (2%) or also combined with pseudarthrosis above L5 (2%). The incidence of revision due to local pain in the area of the iliac screw head, which is often prominent under the skin, was 2%. One patient had the iliac screw removed on one side and another patient on both sides at 1.5 years postoperatively due to prominence. Two further revisions were performed due to proximal junction fractures

Screw fractures, sacral fractures and lumbar corrective losses

There were no cases of iliac screw or sacral screw fractures. There were also no cases of sacral insufficiency fractures. Lumbar correction loss did not occur in any of the patients in the postoperative course. The postoperative PI-LL difference was constant in all patients on radiographic control at 3 months, 6 months and one year

Case study

77-year-old female patient with degenerative lumbar kyphoscoliosis (Figures 1-3)

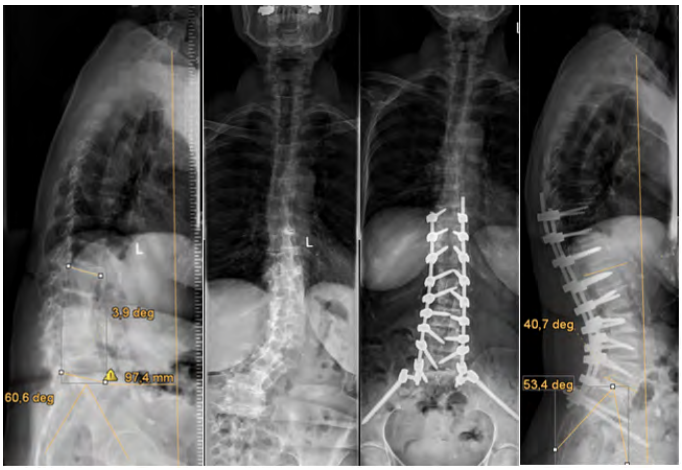


Figure 1: Preoperative and 6 weeks postoperative whole spine x-ray a.p and lateral in standing position

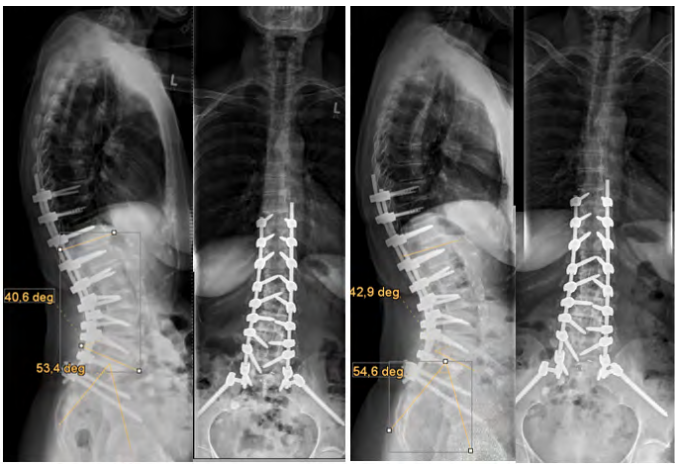


Figure 2: X-ray of the whole spine a.p and laterally in standing position after 3 months and 6 months postoperatively shows no loss of correction and no material failure

Figure 3: X-ray of the whole spine a.p and laterally in standing position and CT scan of lumbar spine after one year postoperatively show no loss of correction, no material failure and a good fusion

Loosening of iliac screws and S1 screws

A patient experienced unilateral loosening of an iliac screw. The patient was multimorbid and had several predisposing factors indicating poor bone stock and therefore developed pseudarthrosis. In addition to the iliac screw loosening, he showed S1 screw loosening bilaterally, L5/S1 pseudarthrosis and diffuse pseudarthrosis of the entire fusion line. After a ventrodorsal revision of the spondylodesis he became delayed fusion. S1 screw loosening occurred in 3 patients, bilaterally in one patient and unilaterally in two patients (Figure 4).

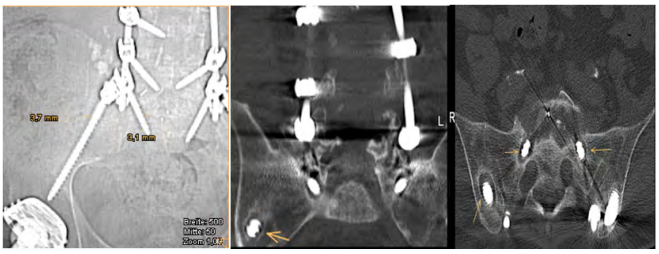
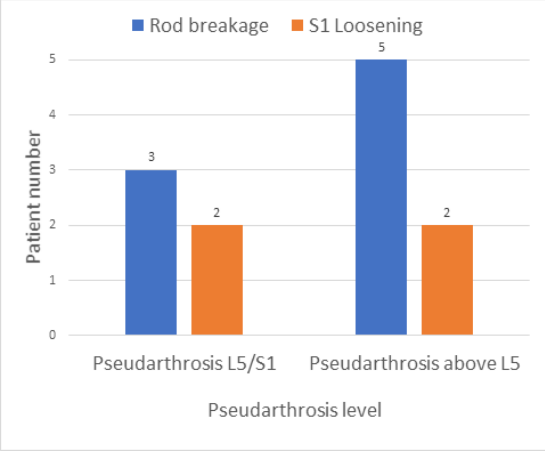


Figure 4: The X-ray under the magnifying glass at 9 months postoperatively showed a loosening margin around the screw thread of more than 3 mm (lysis margin) CT images 9 months postoperatively confirmed the suspicion and showed screw loosening S1 bilaterally and of the iliac screw on the right side.

Pseudarthrosis rate

Pseudarthrosis in the L5/S1 segment occurred in 5 patients, three of whom had combined pseudarthrosis above L5. In total, three of the 5 patients with pseudarthrosis in the L5/S1 segment suffered a rod fracture above S1. Overall, 6 of the 100 patients in our sample developed pseudarthrosis above L5. A rod fracture above S1 occurred in 9 of the 100 patients in our sample. It was interpreted as an indirect sign of a possible pseudarthrosis, which was then detected or ruled out on the basis of a CT scan (Figure 5 and 6).



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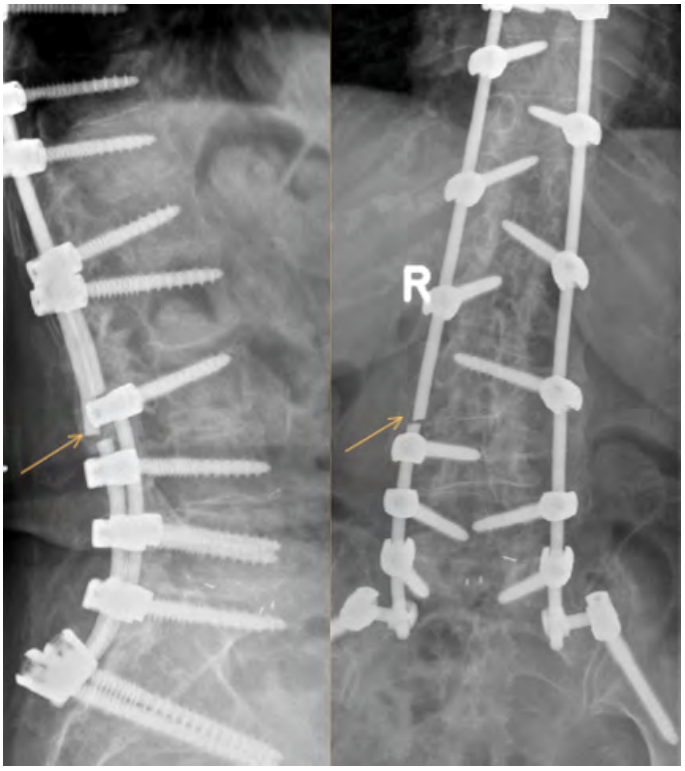

Figure 6: X-ray a.p and laterally in standing position shows a rod fracture as an indirect sign of pseudarthrosis

Degenerative changes of the sacroiliac joint

No additional degenerative changes of the sacroiliac joint were found in the radiological follow-up. Patients with ready signs of sacroiliac joint osteoarthritis in preoperative x-rays did not show any increase in pre-existing degenerative changes in the postoperative radiological follow-up.

Discussion

Incidence of revisions: The low revision rates confirm our technique of placing iliac screws, which helps to avoid screw head prominence towards the skin surface by sinking the screw head deep into the SIPS. Our rate of screw head prominence is thus similarly low to the results of other studies using the same technique: for example, James *et al.* (2019) found 0% and Kuklo *et al.* (2001) found 1.2% revisions due to screw head prominence.

Kuklo *et al.* (2001) compared a group of patients with isthmic spondylolisthesis and a second group with other deformities in their 2-year follow-up of sacropelvic fixation and L5/S1 fusion using S1 and ilium screws. They found only 1.2% revisions due to screw head prominence. Nguyen *et al.* (2019) also found low complication rates after spinopelvic fixation using iliac screws in their 2-year follow-up study of 260 adult patients aged 23-84 years. Here, not a single screw head prominence was documented.

A higher incidence of iliac screw prominence was described by Kasten, who reported an incidence of 7.7%. In his study, both patient age and follow-up were comparable to the patient group studied here (Kasten *et al.* 2010). The discrepancy may be due to the large proportion of young patients with idiopathic scoliosis. Very likely, the screw system used plays a decisive role in a low complication rate.

Tsuchiya described a significantly higher incidence of iliac screw prominences at 34%. However, Tsuchiya used 3 different generations of

iliac screws with different implantation techniques (Tsuchiya *et al.* 2006).

Ishida *et al.* (2016) reported a retrospective series of 32 adult patients implanted with iliac screws and 68 patients implanted with S2AI screws. After a mean follow-up of 22 months, they found significantly higher rates of symptomatic screw prominences in the iliac screw group (11.1% versus 1.4%). However, the placement technique of the iliac screws was not accurately described.

Screw fractures, sacral fractures and lumbar correction losses: Screw fractures, sacral fractures and lumbar correction losses did not occur in our data. Screw fractures were also extremely rare in comparison with previous studies with the same implantation technique. Kuklo *et al.* (2001) reported 5.3% iliac screw fractures, Nguyen *et al.* (2019) found a proportion of 4.6% iliac screw fractures and 1.5% S1 screw fractures. Kasten *et al.* (2010) documented only one case with an iliac screw fracture in a total of 78 patients. In contrast, with different implantation techniques and different screw generations, as in the study by Tsuchiya *et al.* (2006), there were 7 iliac screw fractures in the follow-up of 67 patients. Sacral fractures or lumbar correction losses were not documented in our study or in other previous studies.

Loosening of iliac screws

The incidence of iliac screw loosening was 0.5% in our data. Compared with other studies in which screw loosening was described more frequently, this could be due to a well-functioning implantation technique. With identical implantation technique, Nguyen *et al.* (2019) found an incidence of iliac screw loosening of 3.5%. And in the earlier series with different implantation technique and different screw generations by Tsuchiya *et al.* (2006), iliac screw loosening was described in 29 of 67 patients, representing 43% of all interventions.

S1 screw loosening

The incidence of S1 screw loosening in our study was 2% and S1 screw loosening was combined with pseudarthrosis of the L5/S1 segment in all cases.

No S1 screw loosening was observed in the studies by Kuklo *et al.* (2001) and Tsuchiya *et al.* (2006). The low S1 screw complication rates may be due to the reduction of S1 screw loading by the iliac screws, which we interpret as an advantage of spinopelvic fixation.

Pseudarthrosis rate

In the data of our 100 patients with long corrective fusion for adult deformities, we found a rate of isolated pseudarthrosis of the segment L5/S1 at 2% and a rate of combined pseudarthrosis in the segment L5/S1 and above L5 (3%). Overall, pseudarthrosis in the L5-S1 segment was 5%.

Patients with combined pseudarthrosis between L5/S1 and above L5 have a specific risk constellation in the development of pseudarthrosis; their pseudarthrosis is not limited to the weak point at L5/S1 alone. In contrast, in the studies in which instrumentation ends at S1 in long corrective fusion, pseudarthrosis rates are as high as 24% (Kim *et al.* 2006). In contrast, extending instrumentation to the pelvis showed lumbosacral fusion rates up to 95.1% and pseudarthrosis rates in the L5/S1 segment of 4.9% (Kuklo *et al.* 2001). Other studies also found low rates of pseudarthrosis in the L5/S1 segment when spinopelvic fixation was performed, with Tsuchiya *et al.* (2006) finding a rate of 7.5%, Kasten *et al.* (2010) of 15% and Nguyen *et al.* (2019) of 8.8%.

Spinopelvic anchorage appears to fuse the lumbosacral junction more securely and reduce S1 screw loading. Our results here are consistent with the literature, which also describes higher fusion rates and lower pseudarthrosis rates at the L5/S1 level in cases with spinopelvic instrumentation (Kuklo *et al.* 2001, Tsuchiya *et al.* 2006, Kasten *et al.*, 2010 and Nguyen *et al.* 2019).

Degenerative changes of the sacroiliac joint

The incidence of degenerative change of the sacroiliac joints in the radiological follow-up controls was 0% in our data. This is consistent with the findings of Kuklo *et al.* (2001), Tsuchiya *et al.* (2006), Kasten *et al.* (2010) and Nguyen *et al.* (2019).

It is possible that spinopelvic fixations in long lumbar fusions reduce the loads on the sacroiliac joint and may thus act as a protection against degenerative changes of the sacroiliac joint (Kasten *et al.* 2010, Nguyen *et al.* 2019).

Limitations

Patient data from clinical and radiological postoperative controls were only available up to one year postoperatively, so that the observation period was shorter than the observation period of other studies, which are therefore more meaningful with regard to long-term results. This also explains the comparatively low rates of pseudarthrosis with spinopelvic fixation in the present study group. The quality of the available radiographs was not uniformly good. This made assessment, measurements and comparison with other follow-up images sometimes difficult, so that some patients had to be completely excluded from the analyses. Buttock pain in the postoperative course was taken solely from the documentation of the outpatient follow-up visits; no specific (current) questioning of the patients was planned. The radiological assessment was primarily performed by the surgeon; in case of questionable pseudarthrosis or screw loosening, the radiological findings of the CT scan by the radiologist were additionally consulted. The fusion was not confirmed radiologically, as not all patients received CT examinations in the postoperative course. CT was only performed if pseudarthrosis or material failure was suspected. The comparison of the results of our study with other studies in the literature was only possible to a limited extent. For example, the few available studies that investigated spinopelvic fixation using iliac screws analyse the topic from different angles, making a direct comparison difficult.Moreover, because spinopelvic fixation has extensive indications, the different patient groups are particularly heterogeneous. The different methods and criteria of these studies also make it difficult to compare the results.

CONCLUSIONS

The clinical radiological analysis of our patient group demonstrates the advantages of spinopelvic fixation using iliac screws in the context of deformity correction by means of long-distance fusions with regard to pseudarthrosis rates and implant failure. Spinopelvic fixation obviously increases the biomechanical stability of fusion and leads to improved fusion rates in the lumbosacral junction. The observed low rate of complications associated with iliac screws was empirically proven for the first time in this study. This may help other surgeons in the future to decide on this safe and effective spinopelvic fixation.

Further comparative series or prospective clinical studies with homogeneous comparison groups as well as prospective studies comparing different implantation techniques are necessary in the future. The surgical learning curve and the technical skills of the surgeons in handling the spinopelvic instrumentation technique play a major role in the short- and medium-term outcome of spinopelvic fixation using iliac screws. This is also shown by the course of complication rates, which clearly decreased over 5 years in our data.

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