The double-transforaminal lumbar interbody fusion: an innovative one-stage surgical technique for posterior kyphosis correction

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Abstract

Posttraumatic deformities after vertebral fractures are challenging for orthopedic surgeons in the non-operative and operative field. Especially osteoporotic fractures may cause a hyperkyphosis resulting in segmental or global sagittal imbalance and chronic back pain. Different vertebral osteotomies are potent to restore sagittal profile but show a very high perioperative risk including neurological and soft tissue complications. In addition, some of these extensive operations require a two-step procedure including posterior and anterior approaches. Therefore, these established techniques may be contraindicated in elderly or multimorbide patients suffering from concomitant diseases. The authors describe the double transforaminal lumbar interbody fusion (TLIF) osteotomy (DTO) as an innovative one-stage and low-invasive surgical technique to correct a fixed posttraumatic kyphosis in the thoracolumbar junction. The procedure includes posterior release (laminectomy, facettectomy, nucleotomy) combined with two expandable TLIF implants (sandwich technique) and posterior instrumentation and is illustrated by a case of a multimorbide 78-year old female.

Introduction

Structural fixed spinal deformities in the adult patient are frequently leading to imbalance in the sagittal profile. Especially kyphosis is not only psychologically debilitating but also may result in poor function and chronic back pain. Moreover, following biomechanical principles lumbar or thoracic kyphosis increases the risk of vertrebral fractures significantly.

One major cause of hyperkyphosis in the elderly patient is osteoporotic fracture of vertebrae, predominantly found in females. If non-operative treatment is performed and the fracture is neither reduced nor fixed by instrumentation a structural fixed deformity may result.

Although pain release can be archieved by three-point or dynamic orthosis the global mid- and longterm outcome of these patients is poor including increased mortality.[1-4]

However, surgical kyphosis correction of the thoracic or lumbar spine is technical demanding and requires an elaborated surgical planning preoperatively. Different techniques such as subtractive or additive osteotomies have been described in the literature[5-8]

Here, the degree of correction in these established techniques is very limited, the procedures are demanding for both – the surgeon and the patient. Concerning this, previous investigators reported high complication rates.[9,10,11]

Two typical representatives are the Smith-Petersen osteotomy (SPO) and the pedicle subtraction osteotomy (PSO). The SPO is recommended for patients with a degenerative sagittal dysbalance. Here, approximately 10° of correction can be achieved per segment.[5,6] In contrast, the PSO shows a higher correction potential of about 30 – 40° but is associated with high complication rates, especially in ankylosing spondylitis.[7,8]

Even some modifications of SPO or PSO were described in the literature, transient or permanent neurologic problems are commonly encountered after these

osteotomies. Also implant failure based on poor bone quality in the osteoporotic vertebra may result. Especially the pullout strength of pedicle screws is reduced in these patients. In this context, the reduction of kyphosis by instrumented solid chromium cobalt (CrCo) rods is risky based on poor bone quality. Even if a sufficient initial correction can be achieved, the pullout of pedicle screws is a common complication in short- or midterm. Here, cemented screws may lower this risk but prevent from osteointegration and reduce implant survival in long-term. Moreover, there is limited room for surgical options if cement augmented screws were applied and implant loosening occur. Therfore, the reduction of kyphosis by instrumented solid chromium cobalt (CrCo) rods is risky in poor bone quality. Even if a sufficient initial correction can be achieved, the pullout of pedicle screws is a common complication in short- or midterm.

In addition, it is evident that the elderly and fragile patient is not appropriate for extensive salvage procedures such as vertebral column resection.[12] Here, the mortality rate is high and the risk-benefit profile is poor for the multimorbid patient.[13] In case of a destroyed or collapsed vertebra usually a combined retroperitoneal or transthoracic approach is required beside posterior instrumentation.

In exceptional cases also the Three-Column Reconstruction Through Single Posterior Approach (TRSP) is described in the literature, where the anterior and middle column is reconstructed by cages after a subtotal corpectomy of the vertebral body.[14-16]

However, this extensive procedure seems limited for the multimobid patient since surgical trauma is high. Figure 1 compares the osteotomy levels between different techniques. Based on a case study we describe an innovative and low invasive surgical technique for hyperkyphosis correction in the elderly patient.

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Case Report

Case and surgical technique

A 78-year-old female patient with multiple secondary diseases (ASA IV) suffered an osteoporotic fracture of the 12th thoracic vertebra (Figure 2A).

The treatment was non-operative for at least 8 weeks. At the first presentation the patient was nearly complete immobile and painful. X-rays of lumbar and thoracic spine were performed and showed a failure of segmental compensation and a local and global hyperkyphosis. At this time, the segmental kyphosis angle of the collapsed T12 vertebra was 41°. As a result of segmental decompensation the local kyphosis angle was 51° (T11/L1). MRI presented muscular fatty degeneration and no signs of instability corresponding to clinical weakness and fixed hyperkyphosis.

The initial procedure was the attempt of a posterior correction using a rigid system (CoCr rods) in a percutaneous technique. Based on poor bone quality the pedicle screws were cemented. The x-ray control after 14 days shows an insufficient correction of the fixed kyphosis (Figure 2B). At this time, the multimorbide patient was suffering from severe low back pain radiating both lower legs and was completely bedridden. The pain did not improve significantly even after application of NSAD, metamizole and morphine. Consequently, the indication for operative revision was confirmed. Due to the fragile general condition of the patient, we decided to perform a one-step posterior approach aiming for immediate mobilization after surgery.

Surgical procedure

The patient was placed in a prone position at the operation table. Here, the kyphosis was located upon the adjustible electro-hinges of the table allowing different positions in the sagittal plane during surgery. A mid-incision upon the processi spinosi was performed and the paravertebral muscles were detached from the periosteum using a Cobb elevator. Based to previous surgery the rigid CoCr rods were removed and the subtotal laminectomy and facettectomy was completed to allow sufficient decompression of the dura and never roots. A microsurgical nucleotomy followed proximal and distal to the fractured vertebra (T11/12 and T12/L1). The procedure also included a refreshment of the base and cover plates by a cuerette and a modest anterior release of the front longitudinal ligament under fluoroscopic control. Especially, this procedure is technical demanding and should be done under stand-by by of a vascular surgeon. When the posterior and anterior release was completed, the operation table was placed in a lordotoic position to support reposition of the hyperkyphosis. At next two expandable titanium TLIF implants (RISE™, Fa. Globus Medical Audubon, PA, USA) were applied (Figure 3).

The exact size and shape of the implants were adopted to the pre-operative planning on x-rays and confirmed intraoperatively by templates. The major advantage of this system is that the expandable lumbar fusion device allows minimizes insertion force, provides controlled distraction and optimizes endplate-to-endplate fit. Both TLIF cages were placed directly on top of each other only separated by a thin layer of compressed spongious bone of the collapsed vertebra. After final fluoroscopic control of the correct location of the corresponding implants, the TLIFs were expanded gently and stepwise. Using this technique a reposition of the kyphosis was achieved. The double-TLIF osteotomy (DTO) allows not only a sufficient correction of the kyphosis and an improvement of sagittal balance but also a restoration of the vertebral high and an enlargement of the intervertebral foramina as well as a decompression of overloaded

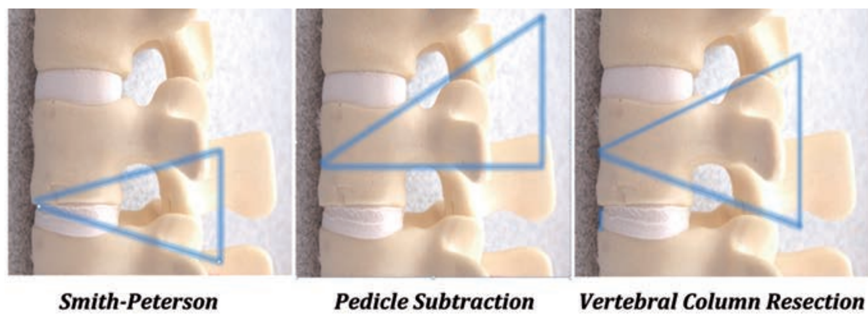

Figure 1. Resection lines of Smith-Peterson osteotomy, pedicle substraction osteotomy and vertebral column resection.

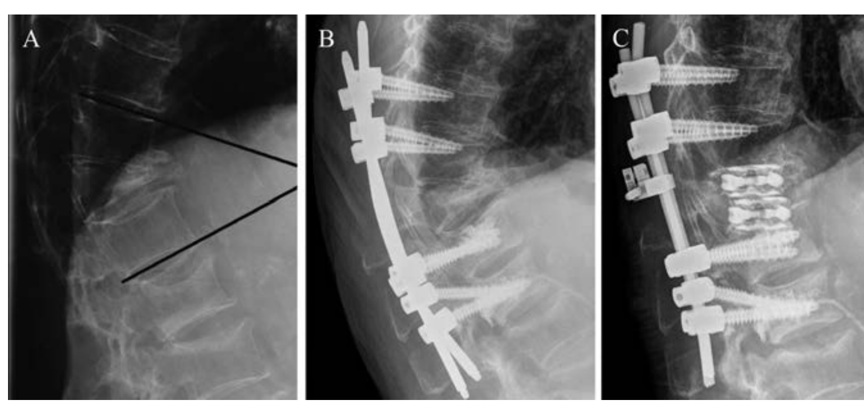

Figure 2. Radiographic follow-up: the lateral view of collapsed T12 with hyperkyphosis and the thoracolumbar junction (A), reposition of the hyperkyphosis failed. Cemented screws were applied (B), postoperative x-rays of the double transforaminal lumbar interbody fusion osteotomy 12 days after surgery (C).

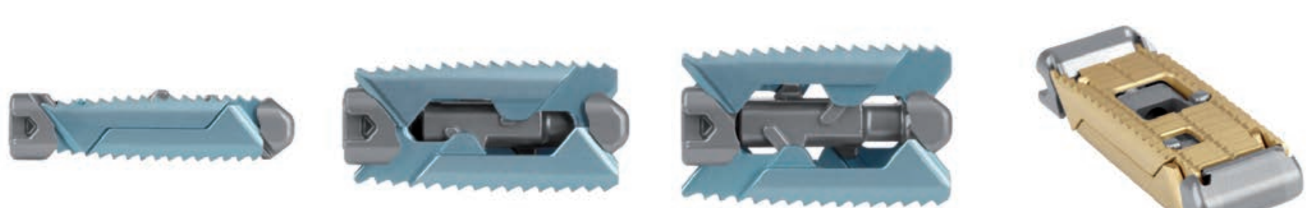

Figure 3. Expandable transforaminal lumbar interbody fusion cage in the collapsed and expanded condition. The parallel grooves of the titanium implant allow solid initial fixation between the bony endplates of the vertebra.

facet joints. Subsequently, the correction was fixed and secured by posterior instrumentation with titanium rods. Finally, a transverse connector was applied to strengthen the instrumentation. The total operation time was 243 minutes; the estimated blood loss was 500 mL (initial Hb 9.5 g/dL, postoperative Hb 11.3 g/dL, transfusion of 4 erythrocyte concentrates). By this technique described above a correction of the segmental kyphosis from 41° to 19° and a correction of the local kyphosis from 51° to 18° with high primary stability was obtained. Figure 2C showed the postoperative result, whereas Figure 4 summarizes the different surgical steps of the DTO.

Postoperative follow-up

The patient was immediate mobilized postoperatively supported by a physiotherapy program and analgetics. Here, the pain decreased significantly postoperative within of three days. At time of discharge, the patient was mobile and free of pain. To support soft tissue healing a semiflexible orthosis (T-Flex™, TIGGES-Zours GmbH, Hattingen, Germany) was provided for 6 weeks postoperatively. The further follow-up was uneventful. The subsequent X-ray control after 4 month confirmed solid fusion and the high stability of the procedure (Figure 5). The total correction angle (T10/L3) was 35° (preoperative angle 53° *vs* angle at last follow-up 18°). The correction of a structurally fixed hyperkyphosis by a single posterior pathway is an alternative to the established osteotomies in multimorbid patients. Moreover, the combination of two distractable TLIF implants can achieve an adequate height gain as well as a very good correction result without performing a ventral approach.

Another advantage is a high resilience of the spine in postoperative mobilization. The authors recommend a consequent patient guidance within the first months postoperatively.

Discussion

As demonstrated by a case, we introduced an innovative and less invasive surgical procedure for kyphosis correction of the thoracolumbal apex compared to other established techniques.

In our hands, we see relevant advantages to use expandable cages since collapsed interbody cages facilitate insertion. This technique may also prevent from osseous damage of the endplates adjacent to the implant which is risky is patient with poor bone quality. Other authors showed the the safety and efficiency of these implants including intervertebral disc heigh resortation and high fusion rates.[17,18]

Following the high mechanical demands and to prevent from fatique fracture we used a titanium implant instead of polyether-ether-ketone (PEEK). Here, Stein *et al*. reported failure of the latter biomaterial following TLIF.[19]

However, the application of multilevel lumbar interbody fusion (LIF) in the spine for deformity correction is not new. Within a follup-up of 2 years the application of LIF in the lumbosacral (L5/S1) region showed promising results on sagittal and coronal balance of the spine when additional posterolateral fusion was applied.[20]

Other investigators confirmed these results.[21,22]

In 2014 Barrey *et al.*[23] suggested to combine PSO with additional fusion of the

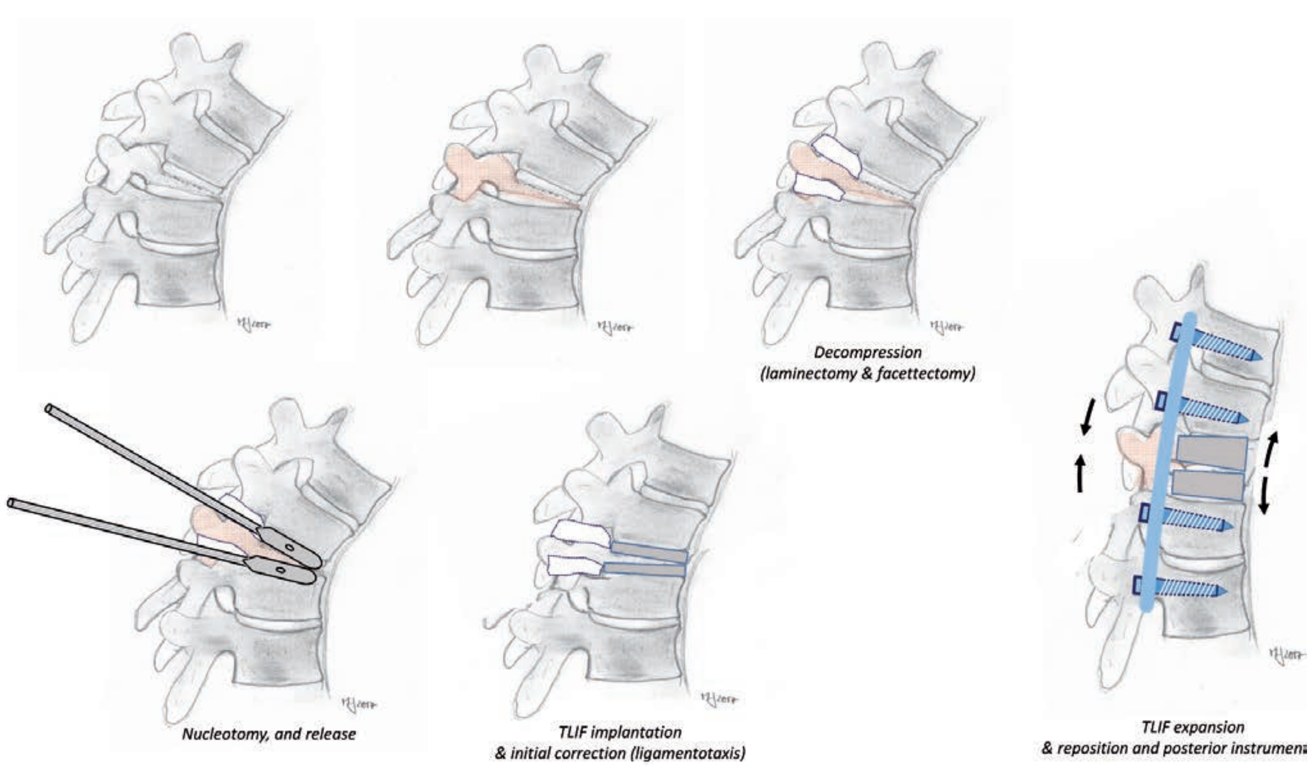

Figure 4. Different surgical steps of the double transforaminal lumbar interbody fusion osteotomy. As an innovative surgical technique, an anterior approach could be avoided by using this novel technique.

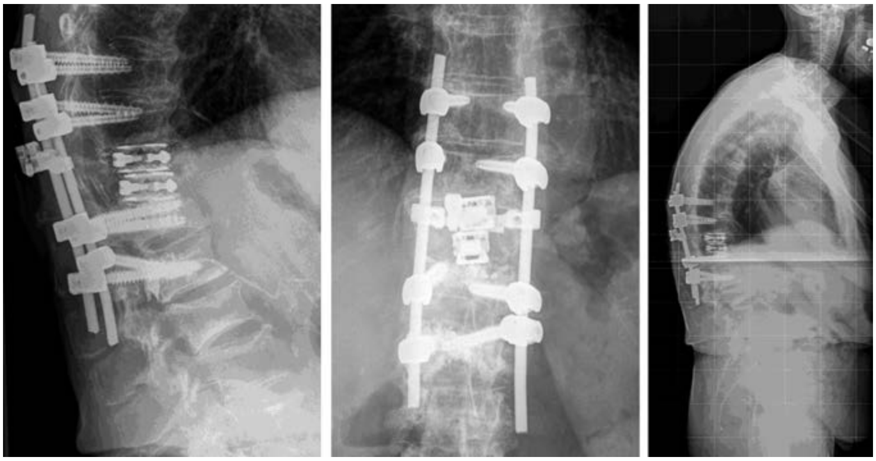

Figure 5. The radiographs of the spine in two planes show the result after 4 months postoperatively.

adjacent disks whatever the approach (PLIF/TLIF/XLIF) to limit the risk of mechanical complication. All these studies did not describe the DTO at the thoracolumbar level and its sandwich nature. The innovation of our procedure is to apply an expandable TLIF above L1 and to combine two cages to restore not only intervertebral disc but also replace a subtotal collapsed vertebra.

To operate at this level the spinal cord is at risk. Therefore, an extensive decompression including bilateral laminectomy and facettectomy is crucial. The step-wise expansion of the TLIF avoids the excessive spinal cord and nerve root traction and therefore it reduces the risk of nerve damage. Further safety might be achieved by spinal monitoring which was not used in our case. In addition, percutaneous instrumentation as recommended by other authors[24] for PSO at levels below L2 seem to be obsolete in the Double TLIF Osteotomy. We do not see a disadvantage in the open technique not least because other investigators found similar clinical and radiological outomes between MIS TLIF and conventional TLIF.[25]

We recommend using the technique described only in qualified centers since the procedure is technical demanding and the application of TLIF above T12 is an off-label use.

During the last decade some studies documented good clinical outome for combining PLIF and posterolateral fusion for the treatment of Chance fractures (so called *Daniaux-Technique*).[26,27] In addition, Huang *et al.*[28] practiced TLIF on a female patient with an old T11/12 fracture and was able to correct kyphosis, but they do not apply a double TLIF. Moroever, our surgical technique described differs also from the *Three-Column Reconstruction Through Single Posterior Approach* (TRSP). This technically demanding procedure was initially described for the treatment of thoracolumbar burst fracture but later also for spinal tumor resection. In contrast to the DTO the TRSP represents a relatively large surgical trauma with relevant intraoperative and postoperative blood loss and more time of operation.[14,15,29,30]

Conclusions

In our hands, the DTO seems to be a low invasive and reliable surgical technique for kyphosis correction compared to the well-established extensive approaches. Especially the multimorbid patient with poor bone quality might benefit from this procedure.

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