Original Article

Transforaminal lumbar interbody fusion with expandable cages: Radiological and clinical results of banana-shaped and straight implants

ABSTRACT

Purpose: Expandable titanium transforaminal lumbar interbody fusion (TLIF) devices are a relatively new group of implants allowing restoration of lumbar lordosis (LL) and thus improvement of sagittal alignment. The purpose of our study is to compare clinical and radiological results of two different expandable TLIF devices.

Materials and Methods: In a retrospective study, patients who underwent TLIF surgery with a banana-shaped or straight TLIF cage in our spine center were analyzed. Primary outcome was change of disc height (DH), segmental lordosis angle (SLA), and lumbar lordotic angle (LLA). Moreover, basic patients parameters and cage subsidence were evaluated.

Results: Sixty-one patients were studied (33 banana-shaped and 28 straight cages). DH changed in the banana group from 4.8 mm (standard deviation SD 2.5) to 10.4 (SD 2.4) and in the straight cage group from 6.2 mm (SD 2.5) to 9.6 mm (SD 1.7). The difference was statistically significant ($P = 0.03$). In addition, SLA correction was higher in the banana group with 5.8 (SD 5.0)–3.7 (SD 3.6), but not significant. LLA improved in the straight group with 5.2 (SD 6.4) compared to 3.7 (SD 5.8) in the banana group. We found subsidence in four patients (6.6%) in the banana-shaped group and nine cases (14.8%) in the other group.

Conclusions: Expandable titanium implants show similar improvements in restoring segmental and global lordosis. Banana-shaped expandable cages offer higher potency restoring the intervertebral DH and show less rates of subsidence compared to straight expandable cages.

Keywords: Banana-shaped, disc height, expandable transforaminal lumbar interbody fusion, global lordosis, segmental lordosis, straight, subsidence

INTRODUCTION

Transforaminal lumbar interbody fusion (TLIF) is an effective, well known, and often used procedure in degenerative disc disease.[1] The aim of surgery is pain reduction and segmental fusion. In recent years, the importance of the sagittal alignment in spinal arthrodesis has been well demonstrated. Here, the correlation of a restored LL and improvement of the quality of life was shown by many authors.[1,2] Most orthopedic- and neurosurgeons are familiar with a posterior approach to the spine and the advantage of TLIF to other posterior approaches like posterior lumbar interbody fusion (PLIF) is a reduced neural tissue retraction and a reduced trauma to bony structures.[3] Restoring lordosis is possible through shortening the posterior column or lengthening the anterior column of the spine. The first TLIF implants were static and limited in balancing the sagittal lumbar alignment. Therefore, many studies were published which show satisfactory results with anterior LIF (ALIF)[4] or lateral (oblique lateral interbody fusion,[5] lateral lumbar

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interbody fusion,[6] and extreme lateral lumbar interbody fusion[7]) applied implants in the lumbar spine. Expandable TLIF cages are a relatively new group of implants, which offer surgeons the possibility to affect greater lordosis than static devices by lengthening the anterior column and using a well-known posterior approach without the support of an access surgeon.[8] Expandable TLIF implants give surgeons the opportunity to maximize the potential for restoring lordosis while minimizing the challenge of insertion through a parallel distraction in the intervertebral disc space and an optimized endplate to endplate fit.[9] Common designs for expandable and static TLIF cages are a banana-shaped or straight design.[10] While straight cages are inserted in an oblique position of the intervertebral disc space, banana-shaped implants are usually placed into a more anterior position. However, there are no published data which compare these two TLIF implant designs of expandable cages and their effect on the intervertebral disc space, the segmental and LL. In this study, we evaluated the clinical and radiological data to elucidate the influence of the two different implants on lordotic parameters in single- or two-level degenerated disc diseases. We hypothesized that banana-shaped expandable TLIF implants would result in greater lordosis correction than straight expandable implants due to a higher potential of lengthening the anterior column.

MATERIALS AND METHODS

In a retrospective cohort study, patients who underwent TLIF surgery due to a degenerative disc disease of lumbar spine at a single institution between 2015 and 2017 were analyzed.

We included patients undergoing a one-level or two-level TLIF surgery with an expandable device. A single surgeon performed surgery and patients were categorized according to cage type (banana-shaped vs. straight). Surgical technique was a standard TLIF approach with unilateral removing of the facet joint, direct decompression, endplate preparation, and oblique or anterior interbody cage insertion. Parallel and lordotic expandable cages were used, one cage design was straight with a position in the middle or the posterior third of the vertebral body [Figure 1], while the other cage was banana-shaped and placed as anterior as possible in the intervertebral disc space, preferably on the apophyseal ring [Figure 2].

Radiological evaluation was performed on pre- and post-operative plain radiographs of the lumbar spine. The segmental lordotic angle (SLA) was measured as the Cobb angle between lines parallel to the upper endplate of the cranial vertebra and the lower endplate of the caudal vertebra of the index level [Figure 3a]. The lumbar lordotic angle (LLA) was found as the Cobb angle between the lines parallel to superior endplate of L1 and the upper endplate of the sacrum [Figure 3b]. Disc height (DH) was defined as the distance between the center of the superior and inferior endplates of the index level [Figure 3c]. Cage subsidence was defined as >2 mm migration of the interbody cage into the adjacent vertebral bodies.

In addition, patient's demographics including sex and age at time of surgery were collected. Furthermore, duration of intermediate care and hospitalization were recorded and compared as well as major complications.

Statistical analysis was performed using Students *t*-test. The test was used to compare the perioperative and radiological parameters between the two groups of expandable cages. Statistical significance was defined as $P < 0.5$. All analysis were conducted using IBM SPSS version 23 (IBM Corporation, Armon, NY, USA).

RESULTS

We identified 61 patients who underwent expandable TLIF surgery with cage placement in our hospital. In 33 cases,

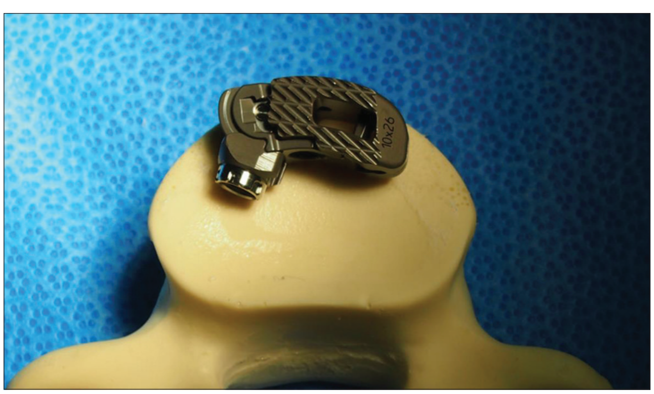

Figure 1: Banana-shaped expandable transforaminal lumbar interbody fusion cage, placed anterior of the vertebral body on the apophyseal ring

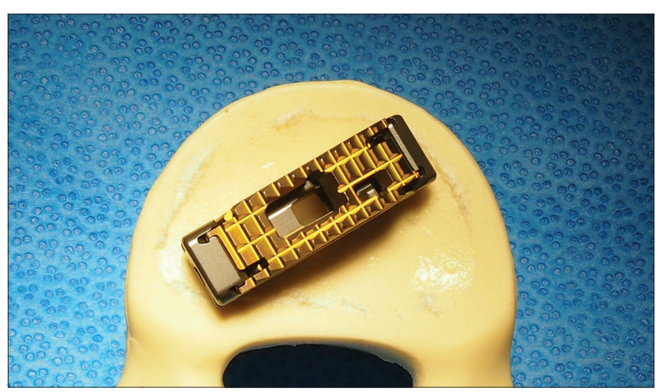

Figure 2: Straight expandable transforaminal lumbar interbody fusion cage placed in the middle of the intervertebral disc space

a banana-shaped implant and in 28 cases a straight TLIF cage was applied. Baseline characteristics were similar in the groups [Table 1]. In the banana-shaped group, the mean Operative time (OR) was shorter than in the straight group with (134.1 [standard deviation [SD] 39.0]–142.5 [SD 40.0] min). However, the difference was not statistically significant ($P = 0.49$). There was also no significant difference between the hospital stay (9.1 [SD 6.5] days in the banana vs. 11.6 [SD 6.6] days in the straight group) corresponding to $P = 0.15$. On average, the intervertebral DH in the straight group was 6.2 mm (SD 2.5) before cage implantation and increased up to 9.6 mm (SD 1.7) postoperative.

In the banana-shaped group [Figure 4], different results were found. Here, the intervertebral DH changed from 4.8 mm (SD 2.5) preoperative to 10.4 mm (SD 2.4) postoperative. The change was 5.6 mm (SD 2.9) in the banana-shaped group and 3.4 mm (SD 2.6) in the straight group. A *t*-test showed a statistic relevant difference with a $P = 0.03$ between the groups [Table 1 and Figure 5]. There was also a change in the segmental lordosis (SL). In the banana-shaped group, the Cobb angle changed from 19.6° (SD 8.9) to 25.9° (SD 9.2) postoperative. In the straight group, the angle increased from 18.5° (SD 7.7) to 22.9° (SD 8.6). We found no significant differences in SLA changes ($P = 0.69$) but a higher correction in the banana group [Figure 5].

Subsidence was found overall in 13 cases (21.3%). 9 cases (14.8%) were in the straight group and only 4 cases of subsidence (6.6%) occurred in the banana-shaped group. We found no statistic difference between the two groups ($P = 0.58$) [Table 1]. At least, we evaluated the LL between the endplates of L1 and S1. We found a better correction in the straight group. Before surgery, the LLA was 38.0° (SD 9.0)

Table 1: Basic characteristics, clinical, and radiological results of patients treated with expandable transforaminal lumbar interbody fusion with comparison by cage type

	Banana shaped	Straight	*P*
n (%)	33 (54.1)	28 (45.9)	-
Age (years) (SD)	65.8 (10.5)	68.6 (11.6)	0.31
OR time (min) (SD)	134.1 (39.0)	142.5 (40.0)	0.49
Hospitalization (days) (SD)	9.1 (6.5)	11.6 (6.6)	0.15
DH preoperative (mm) (SD)	4.8 (2.5)	6.2 (2.5)	0.35
DH postoperative (mm) (SD)	10.4 (2.4)	9.6 (1.7)	0.13
DH change (mm) (SD)	5.6 (2.9)	3.4 (2.6)	0.03
SLA preoperative (°) (SD)	19.6 (8.9)	18.5 (7.7)	0.61
SLA postoperative (°) (SD)	25.9 (9.2)	22.9 (8.6)	0.25
SLA change (°) (SD)	5.8 (5.0)	3.7 (3.6)	0.69
LLA preoperative (°) (SD)	40.7 (15.9)	38.0 (9.0)	0.42
LLA postoperative (°) (SD)	44.4 (13.7)	44.1 (9.1)	0.93
LLA change (°) (SD)	3.7 (5.8)	5.2 (6.4)	0.32
Subsidence (%)	4 (6.6)	9 (14.8)	0.58

OR - Operative time; DH - Disc height; SLA - Segmental lordosis angle; LLA - Lumbar lordotic angle; SD - Standard deviation. *P* values are calculated using *t*-tests

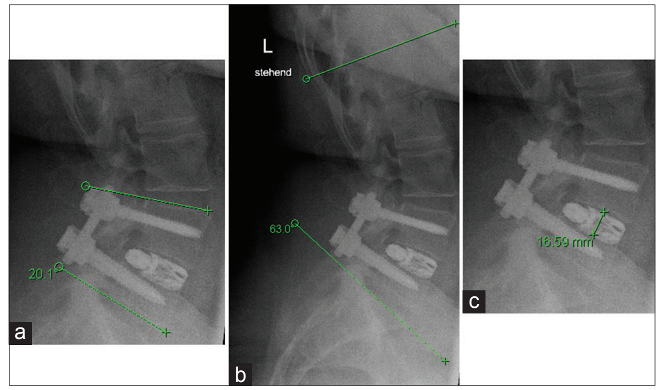

Figure 3: (a-c) Radiological findings after implantation of an expandable transforaminal lumbar interbody fusion banana-shaped cages. (a) segmental lordosis angle, (b) lumbar lordotic angle between L1 and S1 and (c) Disc height

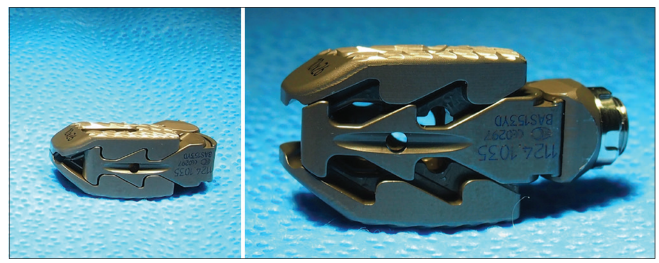

Figure 4: Banana-shaped transforaminal lumbar interbody fusion nonexpanded on the left picture and expanded on the right picture

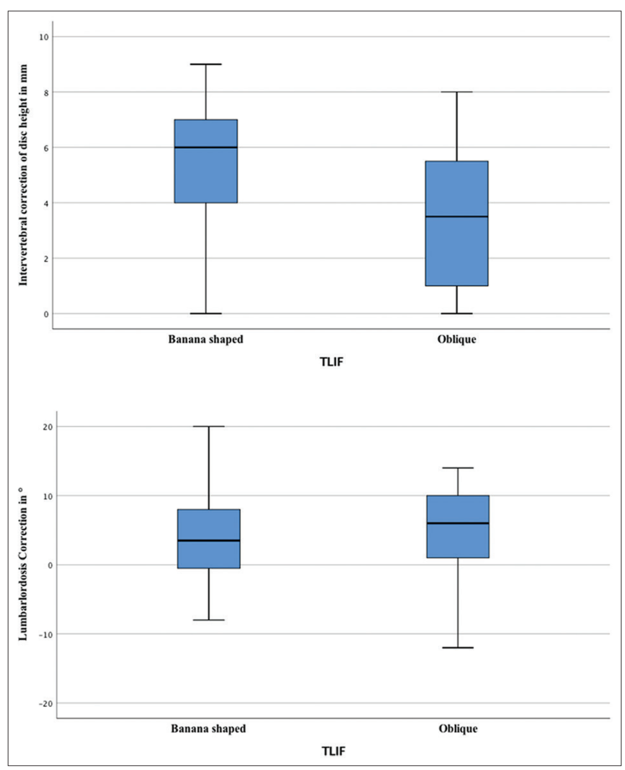

Figure 5: Intervertebral correction of disc heights and lumbar lordosis between the different transforaminal lumbar interbody fusion cages

and increased 5.2° (SD 6.4) to 44.1° (SD 6.4). In the banana group, the change was 3.7° (SD 5.8). Here, the angle changed from 40.7° (SD 15.9) to 44.4° (SD 13.7). A statistical analysis showed no significance ($P = 0.32$).

DISCUSSION

To the best of our knowledge, this is the first study to compare two different expandable TLIF devices. The DH in the group of the banana-shaped cages improved from 4.8 mm preoperative to 10.4 mm postoperative. In the other group, it increased from 6.2 mm (SD 2.5) to 9.6 mm (SD 1.7). This improvement was statistically significant. Rice *et al*. compared static TLIF cages in a kidney (banana) and a straight-shaped design. The authors found a better lordosis correction in the group for the kidney-shaped implant in concordance to our results.[11] We hypothesize that the reason for this phenomenon is the higher potency of a more anterior position of the implant compared to the oblique technique. The mean correction of the DH in the study of Rice *et al*. was also significant better in the kidney group than in the straight group. This is similar to our results, although the authors did not compare expandable devices. In another study, Recnik *et al*. found an increase of DH after application of a static TLIF implant, but the authors did not notice any significant changes of the SL.[12] Kwon *et al*. made a radiological analysis of TLIF in the treatment of isthmic spondylolisthesis and found in 35 patients an increase of DH and a higher restoration of lordosis when the static implant was placed as anterior as possible in the intervertebral disc space and concluded that the improvement in sagittal alignment is dependent on anterior placement of the interbody device.[13] In contrast to our study, the authors did not compare different TLIF implants.

Gödde *et al*. published another clinical study about the influence of cage geometry on sagittal alignment. They included 42 patients who underwent short-segment posterior fusion and found out that wedge-shaped cages show better radiological results than rectangular cages.[14] However, in this study, no expandable devices were used. Kim *et al*. published first results of minimally invasive (MIS) TLIF implants with the possibility to expand the device in the intervertebral space in 2016. They included 50 patients and used an expandable TLIF spacer. They found a preoperative DH of 8.3 mm, which increased postoperative to 12.4 mm. The cage design was straight. This is comparable to our results, especially the change of the DH when using straight expandable cages. We detected an improvement of 3.4 mm but a higher correction in the more anterior placed banana-shaped TLIF.[15] Another interesting fact is that they found no cage migration or subsidence in a 2-year follow-up.

Satisfactory clinical and radiological results when using expandable TLIF devices were published by Boktor *et al.* But as a difference to our data, the authors of that study included all types of cage design and different material properties and focused on clinical outcomes.[8] Massie *et al*. looked at the results of an expandable banana-shaped implant in spondylolisthesis and found an increased DH of 3.1-mm postoperative, while we found 5.6 mm in our data with the same implant designs and material.[9] Hawasli *et al*. found better restoration of DH with expandable MIS TLIF devices in comparison to static TLIF implants especially in patients with a collapsed disc.[16]

But what is the effect of different TLIF designs on the sagittal alignment and the SL? Kim *et al*. found only small changes and increasing segmental Cobb angle from 9.1° to 10.3°. As mentioned before, in this study, a straight cage was used. In our data, the segmental Cobb angle was preoperative 18.5° (SD 7.7) and increased to 22.9° (SD 8.8) postoperative. We measured an improvement of 3.7°, whereas Kim *et al*. only 1.2° with the same implant design.[15] A difference can be found in the surgical approach, because we included open and MIS approaches, while in the cited study only MIS was used. Choi *et al*. published a prospective randomized clinical trial. They applied banana-shaped and straight cages in MIS TIF and enrolled 40 patients. The authors found a significant greater change of DH and SL in the banana-shaped group.[17] Moreover, they found more subsidence rates in the banana-shaped group. In our data, we measured preoperatively a SLA of 19.6° (SD 8.9) in the banana group. This angle increased postoperative to 25.9° (SD 9.2). The change was 5.8° (SD 5.0) and therefore higher than in the published studies as a result of the cage design and the implant distraction. Yee *et al*. published different results. The investigators compared segmental and lumbar sagittal angles of expandable and static cages in TLIF and found no significant differences between the groups and lower correction values than we did. Therefore, the authors concluded that an expandable device alone do not consistently achieve greater increases in lumbar and SL.[18] Studies evaluating the effect of expandable cages on lordosis in TLIF are rare. A cadaveric study was published by Qandah *et al.*; they performed Smith–Peterson osteotomies on human cadaveric spines and documented the effect of expandable TLIF on sagittal balance. The authors found that each additional millimeter in height expansion resulted in a 1° correction of LL. Subsidence was found in 9 of 21 interbody levels because of poor bone quality.[19] Alimi *et al*. studied 49 patients with polyetheretherketone implants who underwent TLIF surgery and found no significant changes in SL and LL.[20] Our data showed improvement of LL for both groups. In the banana-shaped group, we saw preoperative a Cobb angle of 40.7° (SD 15.9°) which changed to 44.4° (SD 13.7) postoperative. Even higher changes with 5.2° (SD 6.4) were measured in the group of the straight cages. Here, the lordosis between L1 and S1 increased from 38.0° (SD 9.0) to 44.1 (SD 9.1). Our data show better results than in comparable literature.[17,18] Ahlquist *et al*. compared different approaches and found that ALIF and LLIF produced greater improvement in radiographic measurements in comparison to TLIF and PLIF. The authors examined expandable and static devices in their data. This was different to our study design.[21] Jäger and Tassemeier used expandable devices to restore the sagittal alignment in osteoporotic bone in a TLIF technique and showed in a case report the opportunity to lengthen the anterior column of the spine with a posterior placed device.[22] Cage subsidence is well known in the history of interbody devices and can lead to a loss of DH and lordosis.[23-25] Choi *et al*. found subsidence rates of 33.3% after TLIF surgery at L5-S1.[26] We saw subsidence of cages in 4 cases (6.6%) of the banana-shaped group and in 9 patients (14.8%) of the straight group. There was no need to perform revision surgery. On the other hand, Kim *et al*. found no subsidence in fifty patients.[15] Reasons for that could be a different technique of disc preparation. Excessive and overzealous curettage can lead to endplate damage and cage subsidence and surgeons have different standards for sufficient endplate curettage.[27] Other factors that may affect subsidence rates are patient-related like osteoporosis and obesity.[28]

CONCLUSIONS

In this clinical trial, we compared the radiological and clinical outcomes of expandable titanium TLIF performed using banana-shaped and straight cages. To the best of our knowledge, there are no published data comparing different cage designs of the expandable technique. The banana cage was significantly superior to the straight cage in terms of restoring DH and showed less rates of subsidence and a better SL correction. The straight cage was superior in restoring the LL but without statistical significance.

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Conflicts of interest

There are no conflicts of interest.

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