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Individual Lordotic Cages Implantation and Radiographic Evaluation of Segmental and Lumbar Lordosis Correction for Patients with Adult Degenerative Scoliosis

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Abstract

Background. The development of minimally invasive surgery has led to the development of new methods for surgical treatment of the spine. Conventional surgical technique, such as vertebrotomy is accompanied by a several number of disadvantages (high blood loss, prolonged hospital stay, long intraoperative time, postoperative neurological deficit). An alternative to improve sagittal balance in the spine is to use custom-made hyperlordotic cages, which can also be used for indirect decompression of neural structures. ***The purpose*** is to compare the degree of segmental and total lumbar lordosis using hyperlordotic cages through ALIF and TLIF with posterior instrumentation. ***Materials and Methods.*** A single-center retrospective cohort study using 96 patients treated from 2018 to 2019 about degenerative spinal deformities. Comparison of two groups: group 1 (A) consisted of 30 patients who were held anterior spinal fusion with individual lordotic cages from minimally invasive anterior approach (MISS ALIF) without posterior fixation. Group 2 (B) consisted of 33 patients whom were performed spinal fusion from the posterior approach (TLIF) with Smith-Peterson Osteotomy (SPO) and transpedicular fixation. Measuring segmental and lumbar lordosis, teleradiographs were used in a standing position. For an accurate assessment, the non-commercial available Surgimap software, © Nemaris, was used. ***Results.*** Segmental lordosis were superior to preoperative ones. In the intergroup comparison, the ALIF group showed an excellent increase in the enlarged lordosis segment (L3-L4 in 8 degrees; p = 0.0005, L4-L5 in 7 degrees; p = 0.0002, L5-S1 in 7 degrees; p = 0.0001). When conducting an intergroup comparison of total lumbar lordosis in the preoperative period, there was a statistically significant difference between them (p = 0.0043). At the same time, a greater degree of correction of lordosis is shown in ALIF compared to TLIF group (29,1 in comparison with 22,5; p = 0.00005). ***Conclusion.*** The results of this study confirm that the using of custom-made lordotic cages can significantly increase segmental and total lumbar lordosis for patients with degenerative scoliosis in adults.

Keywords: degenerative scoliosis, individual implant, lumbar lordosis, ALIF, TLIF.

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Introduction

The development of minimally invasive (MI) surgery has led to the elaboration of new methods for surgical treatment of spinal diseases. This is especially true for spondylodesis (spinal fusion), which is considered less traumatic [1, 2]. E.g., the use of vertebrotomy for degenerative scoliosis (DS) in adults is accompanied by a number of disadvantages: high blood loss, prolonged hospital stay, long duration of surgery, and postoperative neurological deficit [3, 4, 5, 6]. An alternative to vertebrotomy for the correction of the sagittal and frontal spine balance is the use of individual lordotic cages (ILC) made by 3D printing [7]. Their advantage is the ability to provide the indirect decompression of neural structures [2, 8, 9]. MI access can increase both the segmental and total lumbar lordosis and makes it possible to carry out the same volume of intervention as with posterior open techniques employed vertebrotomy and instrumental fixation of the spine [10].

The purpose of the study was to compare the degree of segmental and total lumbar lordosis correction employing ILC in anterior lumbar interbody fusion (ALIF) or using the traditional techniques from the posterior approach, transforaminal lumbar interbody fusion (TLIF), Smith-Peterson osteotomy (SPO) and transpedicular fixation (TF).

Materials and Methods

The study design

A single-center retrospective cohort study was conducted from 2018 to 2019, 63 patients with degenerative spinal deformities participated in it.

Patients

Inclusion Criteria:

– disturbance of the sagittal balance;

– L and N types of frontal arc according to Schwab classification, which do not require correction of the frontal profile [11];

– body mass index <35 kg/m^2;

– age from 45 to 75 years.

Exclusion Criteria:

– other types of scoliotic deformities;

– rigidity of the scoliotic arch;

– a high degree of degeneration and lowering of the intervertebral disc height [12];

– body mass index > 35 kg/m2;

– age more than 75 years;

– metastatic disease of the spine.

According to the above criteria, 63 patients were included in the study: 35 (55%) women and 28 (45%) men. The average age of the patients was 53±5 years, the average body mass index was 32±3 kg/m^2. N type of the frontal deformation (less than 30°) prevailed in 53 patients, L type (only the lumbar region with a Cobb angle of 31 to 38°) — in 10 patients. Group A consisted of 30 patients undergone MI ALIF with ILC without posterior fixation. Group B consisted of 33 patients undergone ALIF with standard cages from the posterior approach, TLIF, with SPO and TF.

Preoperative planning

Before the surgery, all patients underwent teleradiography of the spine in a standing position. Then, they were measured the spinal-pelvic parameters (SVA, LL, PT, etc.) with non-profit Surgimap software (Nemaris, USA). Group A patients were subjected to CT scan with contrast, a pitch of 0.5 mm, for building a 3D high-resolution model of the operated spine. When the contrast was contraindicated (an allergic reaction to a contrast medium, etc.), an MRI scan was performed. The bones and adjacent great vessels segmentation was carried out with free software 3DSlicer (Harvard, USA) and Blender (Blender Foundation, the Netherlands). The location of the cages and the lordotic angles degree were identified using teleradiography. Then the cages placement was simulated with Surgimap. After that the appropriate sizes of the cages were designed according to the obtained values (Fig. 1).

Finally, the physical models of cages were produced of titanium powder by an industrial 3D printer (Fig. 2).

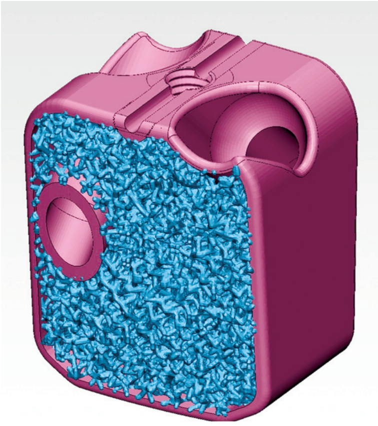

Fig. 1. Layout of an individual cage.

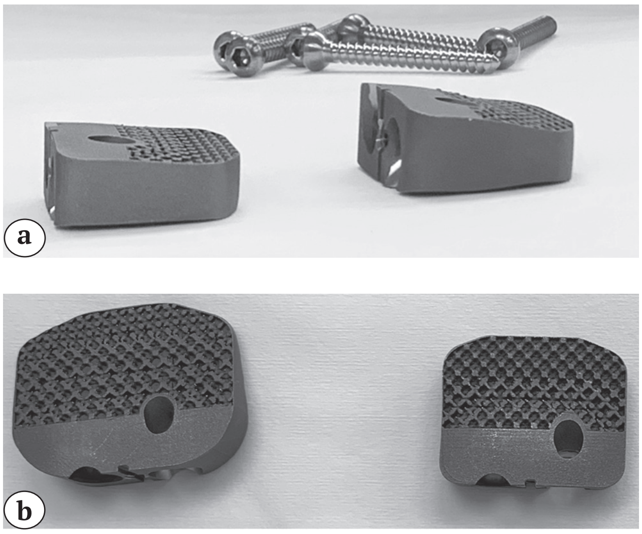

Fig. 2. Printed titanium cages for ALIF:
a — side view;
b — top view.

The surgical technique from the anterior approach

The retroperitoneal access to the lumbar spine was used. The lower epigastric vessels were visualized, preserved and retracted posteriorly and laterally. Iliopsoas muscle and the genitofemoral nerve were visualized. After identification of the vessels (left common iliac artery and vein), a low-profile narrow annular retractor system was introduced. The iliac arteries and veins were exposed and pulled laterally to visualize the intervertebral disc. The median sacral vessels were twice ligated and burned with a diathermocoagulator. Tissue dissection in the region of the L5–S1 disk was made with tupfers to avoid diathermic damage to the sympathetic nerves crossing the disk to reduce the risk of retrograde ejaculation in men. In the process of accessing the L3–L5 segments, the ascending iliolumbar vein should be ligated. Otherwise, the traction can cause significant bleeding. H-shaped annulotomy was made with a discotom. Then a total discectomy was performed by the Cobb elevator. The intervertebral disk space was expanded with the help of distractors, and then the interbody implant was placed (Fig. 3). The implant device was fixed with screws.

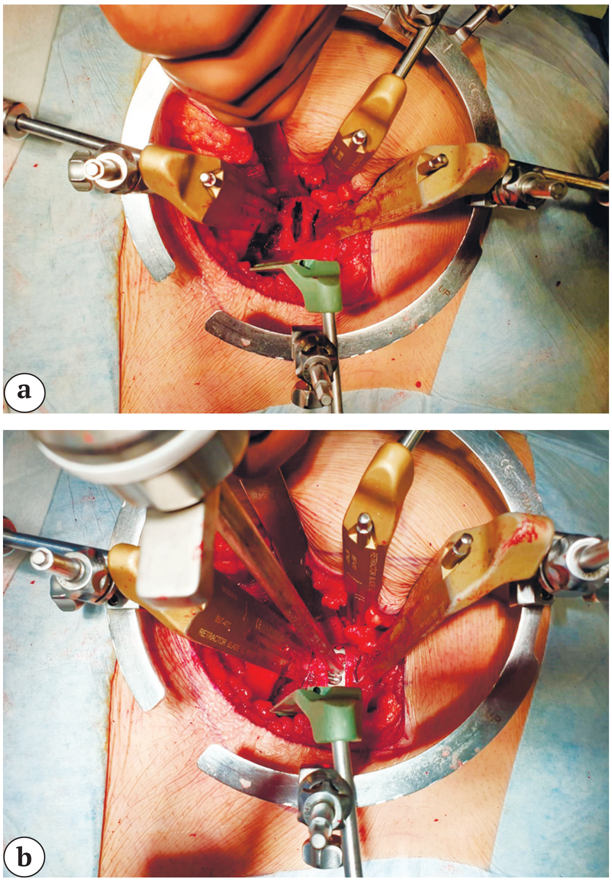

Fig. 3. Installation of a retractor system for L5-S1 (a) and individual lordotic cage implantation (b).

After hemostasis, the retractors were removed. The retroperitoneal drainage was placed. Wounds were sutured in layers according to the standard technique.

The surgical technique

After preliminary marking by electron optical converter, the vertebral bodies were accessed with the standard median approach. Subcutaneous fat and fascia were dissected, soft tissues were skeletonized. The access to the posterior spine structures was achieved. The resection of the intervertebral joints, yellow, interspinous, supraspinous ligaments was carried out along the spinal deformity to achieve spinal mobility. After the Kambin's triangle visualization, the standard cage was placed by TLIF in the frontal plane (in the anterior intervertebral space). Its position was checked by intraoperative fluoroscopy. After this, TF of the operated segment was conducted.

X-ray analysis

The segmental and lumbar lordosis measurement was performed by teleradiography in a standing position of the patient. To make it accurate the Surgimap software was used (Fig. 4).

Statistical analysis

The statistical processing was carried out with StatPlus: mac software (AnalystSoft Inc., USA) using descriptive statistics methods (box-plot, histograms, average value with standard deviation). For the intergroup comparison, the parametric two-tailed Student test for different variances after the control of the distribution normality was chosen. Statistical significance was taken at $p<0.001$.

Results

The analysis of radiographic parameters was carried out both within groups and between them. The intragroup comparison revealed that the postoperative values of the segmental lordosis exceeded the preoperative in both groups (Fig. 5, 6).

The intergroup comparison before surgery revealed the statistically significant increase of the segmental lordosis in the ALIF group: L3–L4 by 8° (p = 0.0005); L4–L5 at7 ° (p = 0.0002); L5–S1 at 7° (p = 0.0001), while the total lordosis did not show any significant difference (p = 0.0043). After surgery, group A compared with group B demonstrated a greater degree of the total lordosis correction: 29.1° vs. 22.5°, respectively; p = 0.00005) (see the Table).

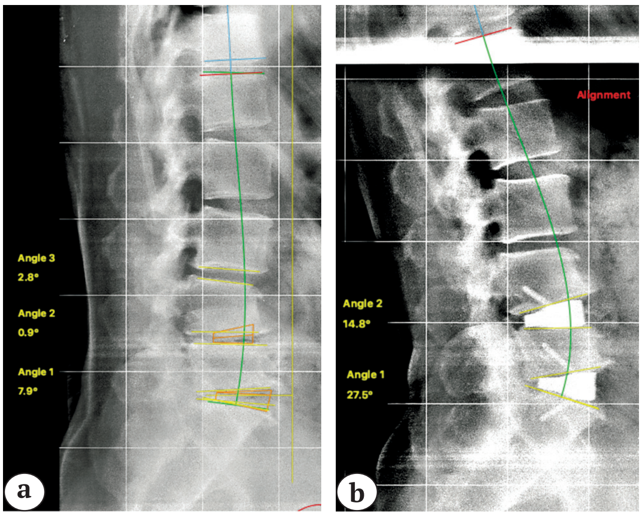

Fig. 4. Measurement of segmental and lumbar lordosis using the Surgimap program:
a — X-ray of the patient before the operation (on the left are the values of the angles L5-S1 = 7.9°, L4-L5 = 0.9°);
b — X-ray of the same patient after individual interbody cage implantation (values of the obtained angles of segmental lordosis L5-S1 = 27.5°, L4-L5 = 14.8°)

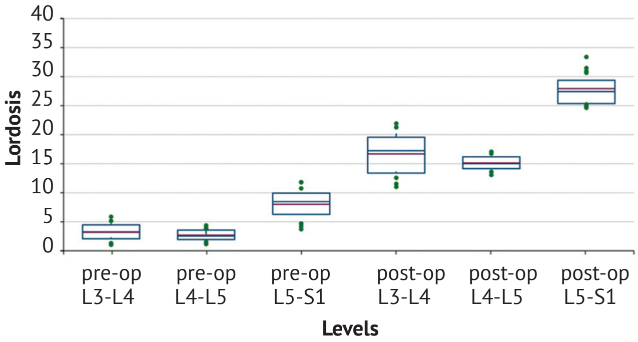

Fig. 5. Box-plot showing changes in segmental lordosis before and after surgery in group A (ALIF).

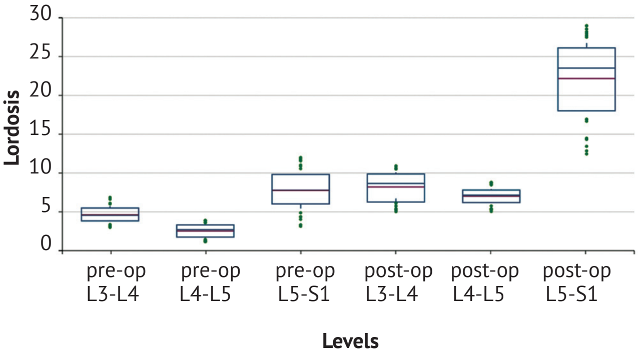

Fig. 6. Box-plot showing changes in segmental lordosis before and after surgery in group B (TLIF, SPO, transpedicular fixation).

Table

Values of the total lordosis
The standard deviations are in brackets

The moment of the study	Group A, *n* = 30	Group B, *n* = 33	*p**
Before surgery	11.1 (2.1)	13.6 (1.63)	0.0043
After surgery	29.1 (2.4)	22.5 (3.0)	0.00005

* bilateral-t-Student test.

Discussion

The restoration of segmental lordosis is one of the main goals of the surgery for sagittal balance correction. Gradual improvements in surgical technique have resulted in the development of MI surgical access for segmental correction. E.g., lordotic cages in ALIF, LLIF, can correct the segmental lordosis up to 20° [13]. This type of correction is obviously creates a significant load on the interbody implant, and therefore on the locking plates, resisted to the axial load. The implant can weight down the end plates potentially resulting in the side effect, because decrease of the disk height may negatively affects not only the radiological results of the correction, but also the clinical outcomes. Despite some positive results [14], stand-alone cages for ALIF (without TF) did not prove their effectiveness [15, 16]. Although, their self-fixing version showed better clinical results compared to the placement of cages from the posterior approach with combined TF [17]. The results of our study confirmed that the use of lordotic cages with the angles from 20 to 30 ° significantly increased both the segmental and total lumbar lordosis. The results are clinically comparable to pedicle subtraction osteotomy (PSO) [18, 19, 20, 21]. In all our patients, the cages were placed with an individual, pre-planned angle of lordosis. The degree of segmental lordosis correction was almost identical to the predicted results for group A. This may be due to the implant placement technique, which in the case of ventral access requires the complete release of the anterior longitudinal ligament and the presence of the structural advantages of the implant used (wedge shape). There is no doubt that further studies are needed to determine the stability of the correction obtained and the functional outcomes of the treatment.

Our results demonstrate that in the patients with kyphotization of the lumbar spine, the use of lordotic cages provides almost complete correction of deformation, which is consistent with the results of other studies [22, 23, 24]. The average degree of correction of the lumbar lordosis was in the range from 27 to 43°, which indicated the recovery within the anatomical norm. And, as already mentioned, the reason for a successful result may be the release of the anterior longitudinal ligament, which gives a significant advantage in the restoration of the lumbar lordosis [25, 26].

The vast majority (77%) of ALIF were performed at the L5–S1 level, which helped to create a more natural distribution of lumbar lordosis than with PSO, which is usually performed at more proximal levels of the spine and with sharp angular correction [19, 27]. In our study, a significant number of patients underwent the complex correction of the spine. The degree of lordosis produced by each interbody device varied between groups. However, in the retrospective assessment, only pre- and postoperative X-ray images were analyzed, since most patients did not undergo any subsequent follow-up, which means that there was a possibility of losing the received correction.

In this study, the goal was not to study the clinical outcomes of ALIF, but only the degree of immediate correction of local deformity obtained. The limitation of the study, in our opinion, is the retrospective design of the work, the lack of evaluation of the spinal-pelvic parameters, as well as functional outcomes. To achieve these goals, it is necessary to conduct a prospective study and evaluate the results in 6 to 12 months after surgery, because in most cases postoperative complications are observed just at this time.

Conclusion

The results of the study confirmed that in the patients with adult DS the use of individual lordotic cages could significantly increase the segmental lordosis (L3–L4 by 8°; $p = 0.0005$, L4–L5, by 7°; $p = 0.0002$, L5–S1 by 7°; $p = 0.0001$) and the total lumbar lordosis (up to 29.1°, $p = 0.00005$).

Publication Ethics

All the patients gave voluntary informed consent to participate in the study and to publish the results.

Conflict of interest: The authors declare no conflict of interest.

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Authors' contributions

A.A. Denisov — research design, literature review, data statistical processing, text preparation and final editing.

D.A. Ptashnikov — research design, text editing.

D.A. Mikhaylov — text editing.

S.V. Masevnin — data statistical processing, text preparation.

O.A. Smekalenkov — literature review, text preparation.

N.S. Zaborovskii — data statistical processing.

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