In Vitro Study of Biomechanical Analysis of Modified Lateral Lumbar Interbody Fusion—crenel Lumbar Interbody Fusion

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Abstract

Background To analyze the biomechanical stability of the modified LLIF, crenel lateral interbody fusion (CLIF), and compare various methods of instrumentation of CLIF in vitro.

Methods Three fresh-frozen cadaveric lumbar spines (L1-S1) were used in our study. The modified CLIF interbody cage was inserted into the L3/4 level in each specimen. Every specimen was tested under 5 conditions: intact group; stand-alone CLIF group; CLIF with lateral plate group (CLIF + LP); CLIF with lateral plate and unilateral pedicle screw group (CLIF + LP + UPS); CLIF with bilateral pedicle screw group (CLIF + BPS).

Results The ROM of each CLIF group was significantly reduced when compared with intact group in all directions of loading ($p < 0.05$). The CLIF + LP + BPS group was the most stable in all directions of loading. CLIF + LP group has less ROM when compared with stand-alone group except for the extension condition. CLIF + BPS group has less ROM than CLIF + LP group in every condition.

Conclusions CLIF combine with lateral plate and bilateral pedicle screw is the most stable supplemental fixation, and lateral plate could reduce the ROM under rotation and lateral bending conditions. For patients with good bone quality, stand-alone with or without is a alternative method to achieve a good clinical result.

Background

The lateral lumbar interbody fusion (LLIF) is a minimal invasive technique to treat degenerative spinal diseases, which is firstly introduced by Ozgur [1]. LLIF can preserve posterior structures, minimize soft tissue dissection and decrease blood loss when compare to traditional posterior approach. However, LLIF still has the risk of neurologic, vascular and visceral injury, including the lumbar plexus, genitofemoral nerve, aorta injury [2].

In order to reduce the approach-related complications of LLIF, a new modified technique named as crenel lateral interbody fusion (CLIF) was firstly introduced by Li et al[3]. CLIF reached the lateral space of the spine through anterior 1/3 of the psoas muscle. The purpose of this study is to analyze the biomechanical stability of the CLIF technique by in vitro.

Methods

Specimen preparation

Three adult lumbar specimens were obtained from the department of anatomy of Zhejiang University. The test was approved by the medical ethics procedure. The mean donor's age was 57.67 years (range from 52 to 63 years). In all specimens, anterior-posterior and lateral X rays were taken to rule out spinal deformity, tumor or fracture. Dural-energy X ray was also performed to quantify the bone mineral density

(BMD) of each specimen. Nonstructural soft tissue was removed for each specimen, and the discs, facet joint capsules, and all ligaments were preserved. All specimens were wrapped and sealed with saline-infiltrated gauze and frozen at -20°C for further test. Before the biomechanical testing, all specimens were thawed at room temperature. Half of the cranial and half of the caudal vertebral body were embedded in polymethylmethacrylate cement (PMMA).

Instrumentation and surgical procedures

The modified CLIF interbody cage was inserted into the L3/4 level in each specimen by the standard CLIF procedure that was introduced by Li [3]. The entire nucleus, lateral annulus and cartilaginous endplates were removed. The pedicle screws, rods and modified lateral plate were provided by Shanghai Sanyou Company (Fig. 1). The experimental groups were divided into as follows: Intact; Stand-alone CLIF group; CLIF with lateral plate (CLIF + LP); CLIF with lateral plate and unilateral pedicle screw (CLIF + LP + UPS); CLIF with bilateral pedicle screw (CLIF + BPS) (Fig. 2).

Biomechanical testing

In all conditions, specimens were studied using standard pure moment flexibility tests. For all tests, an apparatus was used in which a system of cables and pulleys imparted nondestructive, nonconstraining torque in conjunction with a standard servohydraulic test system (Shanghai Sanyou Medical Co., China) [4]. Loads of 5 N m maximum were applied in the appropriate anatomical axes to induce 6 different types of motion: flexion, extension, left and right lateral bending, left and right rotation. In each loading condition, 5 N m were applied for three cycles, and the last cycle used for data analysis. Three-dimensional vertebral kinematic response was measured by an optical infrared camera system. All collected data were recorded with data acquisition software.

Data Analysis

Statistical analyses were performed using SPSS 22.0 software. Data were normalized such that each specimen served as its own control. Comparisons between multiple sets of sample means were performed by one-way analysis of variance (ANOVA). $P < 0.05$ was considered statistically significant.

Results

The L3-L4 ROM in different groups was showed in table 1 and Fig. 3. In all fixation conditions, the ROM was significantly reduced relative to the intact condition in all directions of loading ($p < 0.05$). For stand-alone group, the ROM was reduced to 93% of the intact ROM during flexion condition ($p = 0.069$), 84% during extension, 68% during left bending, 94% during right bending, 91% during left rotation, 89% during right rotation ($p < 0.05$). For CLIF + LP group, the ROM was reduced to 79% of the intact ROM during flexion condition, 83% during extension, 63% during left bending, 65% during right bending, 86% during

left rotation, 80% during right rotation ($p < 0.05$). For CLIF + LP + BPS group, the ROM was reduced to 73% of the intact ROM during flexion condition, 64% during extension, 31% during left bending, 50% during right bending, 69% during left rotation, 70% during right rotation ($p < 0.05$). For CLIF + BPS group, the ROM was reduced to 75% of the intact ROM during flexion condition, 81% during extension, 50% during left bending, 60% during right bending, 73% during left rotation, 73% during right rotation ($p < 0.05$).

Of all the constructs tested, the CLIF + LP + BPS group was the most stable in all directions of loading. CLIF + LP group has less ROM when compared with stand-alone group except the extension condition. CLIF + BPS group has less ROM than CLIF + LP group.

Our study showed the lateral plate could reduce the ROM under rotation and lateral bending conditions. Bilateral pedicle screws group demonstrated the greatest reduction in ROM.

Table 1
The L3-L4 ROM in different groups.

Groups	AF	PE	LB	RB	LR	RR
Intact	4.53±0.12	3.08±0.04	3.31±0.05	3.50±0.03	5.16±0.04	5.07±0.06
Stand-alone	4.23±0.03	2.58±0.02	2.24±0.01	3.30±0.02	4.69±0.02	4.53±0.04
CLIF+LP	3.57±0.03	2.55±0.01	2.08±0.02	2.29±0.01	4.46±0.02	4.07±0.04
CLIF+BPS+LP	3.28±0.07	1.96±0.02	1.03±0.01	1.74±0.02	3.57±0.02	3.54±0.02
CLIF+BPS	3.39±0.01	2.51±0.02	1.67±0.03	2.11±0.02	3.78±0.01	3.71±0.01
CLIF, crenel lumbar interbody fusion; LP, lateral plate; BPS, bilateral pedicle screw; AF, anterior flexion; PE, posterior extension; LB, left bending; RB, right bending; LR, left rotation; RR, right rotation.						

Discussion

LLIF provides a larger interbody cage with preserving posterior elements when compared to TLIF or PLIF by posterior approach. Several studies showed the biomechanical stability with LLIF much better than other interbody fusion approaches [5, 6]. However, LLIF still has the risk of neurologic, vascular and visceral injuries. In order to reduce the approach-related complications of LLIF, Li introduced a modified LLF technique, and his study showed CLIF has the less complications when compared to standard LLIF [3]. This is the first study to evaluate the biomechanical stability of CLIF.

Our study showed the CLIF + LP + BPS group was the most stable in all directions of loading. CLIF + LP group has less ROM when compared with stand-alone group except the extension condition. CLIF + BPS group has less ROM than CLIF + LP group. Lateral plate could reduce the ROM under rotation and lateral bending conditions.

With regard to LP fixation, Nayak et al. showed the pedicle screw and rod fixation had less ROM when compared to lateral plate fixation under flexion-extension and lateral bending conditions in a 2-level LLIF

[7]. Some studies demonstrated a combination of lateral and spinous process plate fixation could achieve a similar biomechanical stability with BPS [8, 9]. In our study, BPS has less ROM than LP, but LP could limit the rotation and lateral bending when compare to intact group, which was similar with the Nayak's study. We do not perform the spinous process fixation because the advantage of lateral plate fixation could be fixed with CLIF in the same approach, while spinous process and pedicle screw need extra posterior approach.

There are several limitations of our study. Firstly, it is an in vitro cadaveric study, did not consider the effect of soft tissues, in vivo study is required. Secondly, the small sample of the current study may affect the results and findings. Moreover, our study only evaluates the immediate postoperative result, which do not show the results of fusion rate, adjacent vertebral disease or subsidence rate. Further study is needed to confirm our findings.

Conclusion

Our study showed CLIF + LP + BPS group was the most stable in all directions of loading. BPS has less ROM than LP, but LP could limit the rotation and lateral bending when compare to intact group. For patients with good bone quality, stand-alone with or without is a alternative method to achieve a good clinical result.

Abbreviations

CLIF, crenel lateral interbody fusion

LP, lateral plate

UPS, unilateral pedicle screw

BPS, bilateral pedicle screw

ROM, range of motion

LLIF, lateral lumbar interbody fusion

BMD, bone mineral density

PMMA, polymerymethacrylate

Declarations

Ethics approval and consent to participate

The cadavers were donated to the department of Anatomy of Zhejiang University school of medicine for teaching and researching. Permission from the ethics committee of Zhejiang University was obtained before the study.

Consent for publication

Written informed consent from the donors or their next of kin was obtained before donation.

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Competing Interest

The authors declare that they have no competing interests.

Availability of data and material

The datasets supporting the conclusion of this article are included within the article.

Authors' contributions

CYL drafted the manuscript. LOJ and MWH collected data and manage the specimen; CYL, MYL, PJN performed the biomechanical tests. CYL and LOJ wrote discussion and introduction. MWH and CQX supervised the writing of the manuscript. All authors read and approved the manuscript.

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References

1. Ozgur BM, Aryan HE, Pimenta L, et al. Extreme Lateral Interbody Fusion (XLIF): a novel surgical technique for anterior lumbar interbody fusion. *Spine J* 2006;6:435-43.
2. Kwon, Brian, Kim, et al. Lateral Lumbar Interbody Fusion:, Indications, Outcomes, and Complications[J]. *J Am Acad Orthop Surg*, 2016, 24(2):96-105.
3. Li Fangcai, Chen Qixin, Chen Weishan. A modified surgical technique of lateral lumbar interbody fusion[J]. *Chin J Orthop*, 2018, 38(4): 212-219.

4. Crawford NR, Brantley AG, Dickman CA, Koeneman EJ. An apparatus for applying pure nonconstraining moments to spine segments in vitro. *Spine*. 1995;20:2097-2100.
5. Cappuccino A, Cornwall GB, Turner AW, Fogel GR, Duong HT, Kim KD, et al: Biomechanical analysis and review of lateral lumbar fusion constructs. *Spine (Phila Pa 1976)* 35 (26 Suppl):S361–S367, 2010 ☒
6. Kim SM, Lim TJ, Paterno J, Park J, Kim DH: Biomechanical comparison: stability of lateral-approach anterior lumbar interbody fusion and lateral xation compared with anterior- approach anterior lumbar interbody fusion and posterior fixation in the lower lumbar spine. *J Neurosurg Spine* 2:62–68, 2005
7. Nayak AN, Gutierrez S, Billys JB, Santoni BG, Castellvi AE: Biomechanics of lateral plate and pedicle screw constructs in lumbar spines instrumented at two levels with laterally placed interbody cages. *Spine J* 13:1331–1338, 2013
8. Fogel Guy R, Parikh Rachit D, Ryu Stephen I et al. Biomechanics of lateral lumbar interbody fusion constructs with lateral and posterior plate fixation: laboratory investigation.[J] .*J Neurosurg Spine*, 2014, 20: 291-7.
9. Zhang Zhenjun, Fogel Guy R, Liao Zhenhua et al. Biomechanical Analysis of Lateral Lumbar Interbody Fusion Constructs with Various Fixation Options: Based on a Validated Finite Element Model.[J] .*World Neurosurg*, 2018, 114: e1120-e1129.

Figures

Figure 1

Details of material used in the biomechanical test. a and b: lateral plate and screws; c: pedicle screws; d: modified CLIF interbody cages.

Figure 2

Different groups of CLIF model. a: intact group; b stand-alone group; c: CLIF + lateral plate and bilateral pedicle screws; d: CLIF + lateral plate.

Figure 3

The L3-L4 ROM in different groups.