ORIGINAL STUDY

The Risk of Subsidence in Standalone Oblique Lumbar Interbody Fusion: A 12-Month Follow-Up Prospective Study

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Abstract

Background data: The incidence of interbody cage subsidence in oblique lumbar interbody fusion (OLIF) is 8—9.5%. It occurs mainly secondary to osteoporosis or end-plate damage during disk space clearance. An anatomical study correlated the surface area contact and position between the cage and the disk space to the incidence of subsidence. Studies have concentrated on the optimal place in the disk space to place the cage to obtain less incidence of subsidence, as it was reported that the central part of the disk space, called the epiphyseal ring, is the toughest part. Subsidence is usually noted in the superior vertebral end plate. Until now, there has been a lack of data regarding the main cause of subsidence.

Study design: This is a prospective, clinical case study.

Objective: This study aims to assess the subsidence rate in patients undergoing standalone (SA)-OLIF for degenerative lumbar diseases.

Patients and methods: Patients with adult degenerative scoliosis following specific inclusion criteria underwent SA-OLIF. The following data were all analyzed and compared statistically: preoperative and postoperative clinical data; back and leg pain visual analog score (VAS) and Oswestry disability index; radiological data; spinopelvic parameters, segmental Cobb’s angle and anterior disk height, and intraoperative data; operative time; the amount of blood loss; complications (intraoperative or postoperative); and hospital stay.

Results: A total of 28 patients and 30 levels were operated on by SA-OLIF, with a mean age of 50.54 ± 6.05, including 14 males and 14 females. The mean operative time/min, blood loss, and hospital stay/day was 91.29 ± 14.23, 195.54 ± 42.29, and 2.78 ± 0.875, respectively. The mean of back pain VAS, the mean of leg pain VAS, and Oswestry disability index changed from preoperatively 7.36 ± 0.98, 6.36 ± 0.911, and 53.71 ± 18.9 to 4.07 ± 1.01, 2.07 ± 0.9, and 45.25 ± 18.76 in 1 year, respectively. Fusion rates were assessed at 6 and 12 months by multislice computed tomography. During the 6-month follow-up period, 83.3% (25 levels) of grade I and grade II fusion was interpreted as solid fusion and 6.6% as cage subsidence (two levels), and during the 12-month follow-up, 89.9% (27 levels) as grade I and grade II fusion and 6.6% cage subsidence (two levels).

Conclusion: Subsidence in SA-OLIF highly contributed to end-plate injury during the surgery and osteoporosis; consequently, posterior instrumentation is advised in these patients along with OLIF to decrease the subsidence rate.

Keywords: Cobb’s angle, Deformity, Degenerative lumbar diseases, Oblique lumbar interbody fusion, Scoliosis, Subsidence
Introduction

Lumbar spine degenerative disk disease (DDD) is considered an aging-related process. In 1983, the theory that was considered the mainstay of DDD was postulated by Kirkaldy-Willis [1], which is called the three-joint complex. It stated that aging is responsible for DDD. Kirkaldy-Willis divided the degeneration process into three processes: first, the degeneration of the intervertebral disk, followed by the instability phase, and finally, the stability phase associated with osteophytes formation and stenosis of the spinal canal [1].

The term adult degenerative scoliosis (ADS) is defined when the Cobb angle is more than 10° in the coronal plane in a previously normal person [2,3]. The specific etiology and pathophysiology of ADS are not defined yet, but Kirkaldy-Willis three-model theory shares the major portion of the etiology of ADS [1]. In ADS, there is a combination of DDD, facet arthropathies, spinal canal stenosis, ligament hypertrophy, and muscle weakness.

The utilization of lumbar interbody fusion was an advancement in spine surgeries in the management of DDD [4]. Since its first introduction by Ralph Cloward in the 1940s [5], it has been improved significantly to form various approaches and techniques. Standalone-oblique lumbar interbody fusion (SA-OLIF) was introduced to overcome the cons of the other fusion types and to obtain indirect neural decompression, maintain spine stability, and achieve a safe surgical approach [6].

It was found that the incidence of interbody cage subsidence is 8–9.5%. It occurs mostly secondary to osteoporosis or end-plate damage during disk space clearance [7–9]. An anatomical study correlated the surface area contact and position between the cage and the disk space to the incidence of subsidence [10]. Studies have concentrated on the optimal place in the disk space to place the cage for less incidence of subsidence, as it was reported that the central part of the disk space, called the epiphyseal ring, is the toughest part [11,12]. Subsidence is usually noted in the superior vertebral end plate [13].

Until now, there has been a lack of data regarding the leading cause of subsidence, and this study aims to assess the subsidence rate in patients undergoing SA-OLIF for the treatment of DDD.

Patients and methods

This prospective study was performed between January 2019 and January 2021 jointly between the Neurosurgery Department at Suez Canal University Hospitals, Ismailia, Egypt, and the Center for Spinal Studies at Nottingham University Hospitals, Nottingham, UK. The inclusion criteria included the following: patients with DDD with deformity in sagittal or coronal planes with either fresh or recurrent pathology; patients aged between 30 and 70 years of any sex; and those who have failed adequate conservative therapy. The exclusion criteria included the following: patients with osteoporosis (T < -2.5), other pathologies (trauma, tumor, and metabolic diseases), and contraindications to general anesthesia.

In this study, we followed the World Medical Association Declaration of Helsinki — Ethical Principles for Medical Research involving human patients. All patients consented to the surgical intervention and research consent for publishing the medical data. The study was approved by our IRB.

Clinical and radiological evaluation

Complete demographic data of the patients were collected, including age and sex. Patients’ comorbidities were also collected. Preoperative clinical assessment of the patients included full general and neurological evaluation, visual analog score (VAS) for back and leg pain, and Oswestry disability index (ODI) for disability assessment. Preoperative radiological evaluation included radiographic anteroposterior, lateral, and dynamic (flexion and extension) views of the lumbosacral spine, and MRI and multislice computed tomography (MSCT) of the lumbosacral spine. Patients with coronal Cobb’s angle of more than 10° on the anteroposterior spine are considered scoliotic. Fusion was evaluated on MSCT [14]. Radiographic subsidence was objectively defined by a breach in any of the end plates [15].

Operative technique

Under general anesthesia, on a radiolucent operating table, the procedures were done in the left lateral decubitus position with flexion of the ipsilateral hip. Adhesive tape and an operating table belt were used to stabilize the patient. Then, the operating table was jackknifed to increase the subcostal space and surgical field space. Leveling was done by the C-arm in anteroposterior and lateral positions as the center of the disk space was marked and hence the surgical incision was marked. Standard surgical sterilization and draping were done. Incision length is 4–10 cm according to the intended number of operating...
levels. Blunt dissection is performed on the oblique abdominal muscles. After accessing the retroperitoneal space noted by the fat appearance below the internal oblique muscle, Kelly clamps are used to dissect the space until reaching the retroperitoneal paravertebral muscles, quadratus lumborum, and the psoas muscles. Self-retaining SynFrame is used as the frame blades are inserted as follows: two blades in the craniocaudal position and two blades in the lateromedial position. The surgical plane lies between the abdominal aorta and the psoas major, a naturally located plane. Annulectomy and discectomy were performed using long-armed curettes and intervertebral disk rongeurs. It was crucial to obtain a wide surface area of the disk space without breaching the end plates as the cage used in SA-OLIF is bigger than standard cages used in OLIF, Spineway Kili cages; the height used in OLIF, Spineway Kili cages; the height used in SA-OLIF is bigger than standard cages.

Cage trials are inserted until the desired size is palpated and confirmed to be reached by the C-arm. Cage trials are inserted until the desired size is obtained. Finally, hemostasis is followed by layer-by-layer closure with a suction drain inserted retroperitoneally.

**Postoperative protocol**

Patients were ambulated the day after surgery and discharged from the hospital on day 3. All patients were submitted for plain radiographs before discharge. All patients were scheduled for routine outpatient clinic visits after 1, 3, and 6 months and then at 6-month intervals. Primary outcome parameters were cage subsidence and interbody fusion rate based on MSCT findings, while secondary outcome parameters were leg and back pain VAS and ODI.

**Statistical analysis**

The SPSS (Statistical Package for the Social Sciences, SPSS company IBM, Chicago, USA) 18.0 software package was used to statistically analyze the data. χ² statistics was used in the comparison of categorical measurements between groups, and independent t tests were used for the comparison of numerical measurements between groups. The statistical significance level was taken as 0.05 in all tests.

**Results**

In total, 28 patients were recruited for this study and completed a minimum of a 12-month follow-up. They were 14 females and 14 males with a mean age of 50.54 ± 6.05 years (38–60 years). The reported demographic data, clinical data, and comorbidities are presented in Tables 1–3. All patients suffered from single-level disk disease except for two patients with a two-level pathology. The 30 operated disk levels were as follows: L4/L5 in 22 patients, L3/L4 in seven patients, and L2/L3 in one patient. The reported operative data were as follows: the mean operative time was 91.29 ± 14.23 min (77–110 min), and the mean blood loss was 195.54 ± 42.49 ml (153–237 ml).

The clinical data were collected, and it was found that the mean back pain VAS improved from 7.36 ± 0.99 preoperatively to 5.64 ± 0.87 and 4.07 ± 1.02 at 6-month and 12-month follow-up, respectively. The mean leg pain VAS improved from 7.36 ± 0.99 preoperatively to 4.01 ± 0.9 and 2.07 ± 0.9 at 6-month and 12-month follow-up,

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**Table 1. Demography, clinical presentation, and comorbidities or reported patients (N = 28).**

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td>50.54 ± 6.05 (38–60)</td>
</tr>
<tr>
<td>Sex</td>
<td>Male 50%, Female 50%</td>
</tr>
<tr>
<td>Symptom's duration (months)</td>
<td>34.44 ± 16.68 (12–84)</td>
</tr>
<tr>
<td>Presentation [n (%)]</td>
<td></td>
</tr>
<tr>
<td>Back pain</td>
<td>19 (67.85)</td>
</tr>
<tr>
<td>Leg pain</td>
<td>16 (57.14)</td>
</tr>
<tr>
<td>Sensory deficit</td>
<td>5 (17.8)</td>
</tr>
<tr>
<td>Reflexes deficit</td>
<td>3 (10.7)</td>
</tr>
<tr>
<td>Motor deficit</td>
<td>1 (3.5)</td>
</tr>
<tr>
<td>Sphinctor's deficit</td>
<td>1 (3.5)</td>
</tr>
<tr>
<td>Comorbidities [n (%)]</td>
<td></td>
</tr>
<tr>
<td>HTN</td>
<td>11 (42.8)</td>
</tr>
<tr>
<td>DM</td>
<td>6 (21.4)</td>
</tr>
<tr>
<td>IHD</td>
<td>9 (32.1)</td>
</tr>
<tr>
<td>Obese</td>
<td>10 (35.7)</td>
</tr>
<tr>
<td>Smoking</td>
<td>8 (28.5)</td>
</tr>
</tbody>
</table>

DM, diabetes mellitus; HTN, hypertension.

**Table 2. Clinical data between preoperatively and at 6-month follow-up.**

<table>
<thead>
<tr>
<th>Items</th>
<th>Preoperatively</th>
<th>6-month follow-up</th>
<th>t</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>VAS (back)</td>
<td>7.36 ± 0.98 (6–9)</td>
<td>5.64 ± 0.870 (1–5)</td>
<td>10.115</td>
<td>&lt;0.05a</td>
</tr>
<tr>
<td>VAS (leg)</td>
<td>6.36 ± 0.911 (4–8)</td>
<td>4 ± 0.903 (0–4)</td>
<td>17.06</td>
<td>&lt;0.05a</td>
</tr>
<tr>
<td>ODI%</td>
<td>68.615 ± 8.72 (10–80)</td>
<td>28.38 ± 8.5 (10–55)</td>
<td>12.24</td>
<td>&lt;0.001a</td>
</tr>
</tbody>
</table>

Data are in mean ± SD.

ODI, Oswestry disability index; VAS, visual analog score.

a Statistically significant P value less than 0.05 at 95% confidence interval.
respectively. The mean ODI also decreased from 68.615 ± 8.72 preoperatively to 28.38 ± 8.5 and 20.23 ± 4.7 at 6-month and 12-month follow-up, respectively (Tables 2 and 3).

Fusion rates were assessed at 6 and 12 months by MSCT. At the 6-month follow-up period, 25 (83.3%) levels of grade I and grade II fusion were interpreted as solid fusion. Meanwhile, there were two levels (6.6%) of cage subsidence. At the 12-month follow-up, there were 27 (89.9%) levels of grade I and grade II fusion. Meanwhile, the were still two (6.6%) levels of cage subsidence (Fig. 1, Table 4).

Operative complications were reported in four cases. Three cases had vascular injuries to radicular ‘segmental’ arteries during blunt dissection over the vertebral bodies and were managed by monopolar electrocautery without clinical complications. One patient suffered from anterior dislodgement of one cage postoperatively and this cage was removed, and the patient underwent posterior instrumentation in the same setting. Two patients had cage subsidence at a 12-month follow-up that was discovered radiologically, but they had no clinical symptoms and refused to have further surgery.

Discussion

In this study, radiologically, OLIF proved to obtain 83.3% fusion rates and 6.6% cage subsidence, while clinically, OLIF managed to influence both back and leg pain as the VAS back and leg pain decreased from 7.36 ± 0.98 and 6.36 ± 0.911 preoperatively to 4.07 ± 1.01 and 3.01 ± 0.9 after a 12-month duration, respectively.

After being discovered by Silvestre et al. [6], OLIF was proven to be a safe and effective method for managing DDD. OLIF can avoid iatrogenic injuries commonly occurring with the traditional posterior approach in posterior lumbar interbody fusion.

### Table 3. Clinical data between 6-month and 12-month follow-up.

<table>
<thead>
<tr>
<th>Items</th>
<th>6-month follow-up</th>
<th>1-year follow-up</th>
<th>t</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>VAS (back)</td>
<td>5.64 ± 0.870 (1–5)</td>
<td>4.07 ± 1.01 (0–5)</td>
<td>12.563</td>
<td>&lt;0.05*</td>
</tr>
<tr>
<td>VAS (leg)</td>
<td>4 ± 0.903 (0–4)</td>
<td>2.07 ± 0.9 (0–3)</td>
<td>11.9</td>
<td>&lt;0.05*</td>
</tr>
<tr>
<td>ODI%</td>
<td>20.38 ± 8.5 (10–55)</td>
<td>20.23 ± 4.7 (10–21)</td>
<td>11.9</td>
<td>&lt;0.001*</td>
</tr>
</tbody>
</table>

Data are in mean ± SD.

ODI, Oswestry disability index; VAS, visual analog score.

* Statistically significant P value less than 0.05 at 95% confidence interval.

![Image](https://via.placeholder.com/150)

**Fig. 1.** (a) MRI preoperative T2W sagittal cuts showing canal stenosis at L3/L4 and decreased disk height. (b) Preoperative anteroposterior (AP) lumbar radiograph shows advanced L3–L4 disk degeneration with degenerative scoliosis with Cobb’s angle of 28. (c, d) AP and lateral lumbar radiographs at 12-month follow-up with corrected Cobb’s angle to 7.3° after standalone OLIF L3/L4 with increased disk height, while the upper end plate of the lower vertebrae show signs of subsidence. (e, f) Postoperative MSCT after 12 months; sagittal and coronal reformats showing the subsidence of the OLIF cage in the upper end plate of the caudal vertebrae. MSCT, multislice computed tomography; OLIF, oblique lumbar interbody fusion.

### Table 4. Fusion grading according to multislice computed tomography [14] of the lumbosacral spine (N = 30 levels).

<table>
<thead>
<tr>
<th>Grade of fusion</th>
<th>6 months postoperatively</th>
<th>1 year postoperatively</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grade I: bridging trabecular bone</td>
<td>N = 10</td>
<td>33.3%</td>
</tr>
<tr>
<td>Grade II: continuous bony density</td>
<td>N = 15</td>
<td>50.0%</td>
</tr>
<tr>
<td>Grade III: marginal radiolucency</td>
<td>N = 2</td>
<td>6.6%</td>
</tr>
<tr>
<td>Grade IV: secondary signs of motion</td>
<td>N = 0</td>
<td>0%</td>
</tr>
<tr>
<td>Grade V: hardware loosening and fatigue</td>
<td>N = 1</td>
<td>3.3%</td>
</tr>
<tr>
<td>Grade IV: subsidence</td>
<td>N = 2</td>
<td>6.6%</td>
</tr>
</tbody>
</table>
(PLIF) and transforaminal lumbar interbody fusion; also, SA-OLIF allows the avoidance of complications associated with posterior instrumentation, such as blood loss, early mobilization, and avoidance of adjacent segment diseases \[16,17,31–33\]. Until now, SA-OLIF outcomes are promising, although specific points need to be thoroughly studied, such as fusion rates, risk of subsidence, and long-term outcomes, as SA-OLIF is considered a novel approach that requires long-term and high population studies. In addition, many spine centers have not used SA-OLIF and accept the traditional interbody fusion techniques for various reasons, for example, the learning curve, surgeon preference, and the lack of feasible implants to be used in SA-OLIF.

In this series, the total number of patients with cage subsidence was two (6.6\%) after 12 months. They were radiologically diagnosed by MSCT, and they were clinically subtle. Cage subsidence in SA-OLIF is attributed to factors such as end-plate preparation violation and osteoporosis \[18\]. The current data published on SA-OLIF drawbacks reported that the average incidence of SA-OLIF complications ranges between 3.7 and 66.7\% \[19\]. Zeng et al. \[18\], in their study of 235 patients with OLIF (October 2014 to May 2017), reported that 22 cases with end-plate injury and a high prevalence of cage subsidence were found in SA-OLIF compared with the augmented group by posterior instrumentation. The etiology and the pathophysiology of endplate injury are still not formally evident, from either compressive forces on the SA-OLIF cage or injury during disk space preparation. Consequently, the avoidance of such complications requires studies to target biomechanical structures and finite elements of SA-OLIF. Fang et al. \[20\], in their study of a finite element between SA-OLIF and posterior augmented screws with OLIF in 2020, reported that SA-OLIF models had more range of motions than the posterior instrumented group. Moreover, they reported that posterior instrumentation with OLIF had less cage subsidence incidence, and SA-OLIF was at higher risk of end-plate injury and subsidence.

Huo et al. \[21\] reported that 154 patients who had OLIF in 2019 had 2.4\% cage subsidence, and they analyzed the patients with subsidence and found that their \( t \) score on DEXA was less than \(-1.0\). Therefore, they reported that individuals with \( t \) score less than \(-1.0\) are at higher risk of subsidence; this is why they performed DEXA as a routine evaluation for all patients scheduled for SA-OLIF. Abbasi et al. \[22\] reported a 100\% fusion rate in their study. He et al. \[23\] demonstrated a 15.6\% subsidence rate in their study of SA-OLIF compared with 7.3\% in the OLIF group with posterior fixation by pedicle screws. Zhang et al. \[24\], in their series, discovered 36.3\% cage subsidence in SA-OLIF, and they hypothesized that the cause of subsidence is the end-plate injury caused during disk preparation. In their study, Lin et al. \[25\] reported an 81.9\% fusion rate at 1-year follow-up. Jin-Sung et al. \[26\] reported a 92.9\% fusion rate at 1-year follow-up, and Xi et al. \[27\], in their comparative study between ALIF and OLIF, used posterior instrumentation in both groups and the OLIF group had fusion rates of 76.3\%. In the work of Liu et al. \[28\], 78 patients underwent SA-OLIF and the effect of Modic changes on the rate of subsidence in SA-OLIF was studied, revealing that the group with sclerotic Modic changes had a lower incidence of subsidence compared with patients with no Modic changes (one patient to six patients). They hypothesized that end-plate sclerosis allows an interface to distribute the compressive force of the OLIF cage along the end plate, thus decreasing the incidence of subsidence \[28\]. Lee et al. \[29\], in their comparative study of the outcomes of ALIF, posterior lumbar interbody fusion, and transforaminal lumbar interbody fusion rates in single lumbar fusion, reported that transforaminal lumbar interbody fusion had the highest subsidence rates of 38\% at the 24-month follow-up; this was attributed to the cage design and placement site near the center concave portion in the intervertebral disk. Palepu et al. \[30\] reported in their biomechanical study of the risk of subsidence and its attributed risks that regardless of the cage type, the trabecular bone volume fraction is highly correlated with subsidence force on the cage.

The limitations of this study are the small sample size, which has a profound statistical correlation to our data. Applying this technique requires training in the retroperitoneal approach, which every spine surgeon should be familiar with.

**Conclusion**

Subsidence in OLIF is highly correlated to end-plate injury during surgery, so it is advised to preserve the end plates. OLIF has good fusion rates and can be utilized in degenerative scoliosis. More studies on OLIF with larger sample sizes are recommended to study the causing factors of subsidence in OLIF.

**Conflict of interest**

There are no conflicts of interest.
References


الملخص العربي
خطوة هبوط القفص الطلائي في جراحة الالتحام الأساسي المفصل البقاع يقلل الفرط الطلائي، دراسة مسبقة ومتاحة بعد 12 شهراً

البيانات الخفيفة
بلغ نسبة حدوث هبوط القفص بين الأجسام في جراحة الالتحام الأساسي البقاع يقلل الفرط الطلائي 9.5٪، وهي تحدث في الغالب نادرة للهشاشة.

الغرض
قياس نسبة هبوط الاقسام في الالتحام الأساسي البقاع يقلل الفرط الطلائي وتصميم الدراسة

المراجع

 globe 3-4 جموع البحث عدها 12 مريض بعد الدراسة الإحصائية وسوف يتم جراحه اصلاح الإعوجاج بالعظام البقاع باستخدام جراحة تثبيت الفرط من

المرضى والطريق

دراسة بحثية بمتناوبة بالعظام البقاع بين 26 مريض من المرضى الذين تمارسهم جراحة تثبيت الفرط من

النتائج

تم تقسيم محاولات الإعوجاج في 6 أشهر و 12 شهراً بواسطة الأشعة المتصلة بالعظام البقاع، خلال فترة المتابعة التي استمرت 6 أشهر، كان هناك 83.3٪ (25 مستوي من الإصابة الأولى) و 13.3٪ (27 مستوي من الإصابة الثانية) و 6.6٪ (12 مستوي من الإصابة الثالثة) من الإصابات في البقاع، و 6.6٪ (27 مستوي من الإصابة الأولى) و 3.3٪ (27 مستوي من الإصابة الثانية) و 6.6٪ (12 مستوي من الإصابة الثالثة) من الإصابات في البقاع.

الخلاصة

استخدام الأجهزة الخفيفة في جراحة الالتحام الأساسي المفصل البقاع يقلل الفرط الطلائي إصلاح الروج النحاسي أثناء الجراحة ووجود العظام المفصل في نفس المكان (الشكل 5). يُوصى باستخدام الأجهزة الخفيفة في هذه العمل، بناءً على جراحة الالتحام الأساسي المفصل البقاع يقلل الفرط الطلائي.