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Retrospective Case Series of Porous Titanium Cages in Oblique Lumbar Interbody Fusion Surgery Assessing Subsidence, Fusion and Functional Outcomes

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Abstract

Purpose: Implant subsidence is a possible complication of spinal interbody fusion. We aim to evaluate porous titanium cages subsidence, fusion and functional outcomes in patients subjected to oblique lumbar interbody fusion (OLIF) with these novel devices. **Methods:** Our institutional review board approved a single-center experience which included 60 patients who underwent OLIF from June 2018 to June 2020 utilizing the porous titanium implants. Data was collected in accordance with the Declaration of Helsinki, and written informed consent was obtained. Imaging studies including radiographs 1, 3, 6 and 12 months and computed tomography (CT) scan at 6 months obtained during routine postoperative follow-up visits, were studied for signs of implant subsidence, fusion and clinical parameters to determine the effectiveness of surgery such as Oswestry disability index (ODI). **Results:** Radiographic subsidence occurred in 1 out of 89 porous titanium interbody cages (1.1%). No subsidence was observed in the posterior screws and rods fixation group (N = 57). However, one case of subsidence occurred in the lateral plate fixation group (N = 3). The subsidence occurred in an osteoporotic elderly patient operated for adjacent segment disease, and she was later revised with posterior instrumentation using cemented screws and rods. She had an uneventful recovery. Fusion rates were evaluated under CT scan at 6 months with a rate of 88%. In terms of clinical outcomes, ODI decreased significantly from 20.3 preop to 10.7 postop with a P-value < 0.05. **Conclusions:** In our study, the subsidence rate was lower than previously reported in the literature. Also, we had good fusion rates at 6 months likely due to the porous titanium cages use. We had no subsidence in the posterior instrumented group and one case in the lateral fixation group with improved clinical outcomes.

Keywords

Degenerative Diseases, Osteoarthritis, Lumbar Spine, Anterior-to-Psoas, Oblique Lumbar Interbody Fusion

1. Introduction

Patients with low back pain or instability refractory to conservative care are treated with interbody fusion of the lumbosacral spine. It necessitates the removal of disc material with preparation of the vertebral endplates, and placement of the interbody cages filled with bone graft. The aim of this surgery is to restore physiological spinal alignment and disc height as well as to encourage bone growth between the two vertebral segments, thus eliminating any motion. Interbody fusion surgery can be done through multiple approaches including anterior, posterior, lateral and oblique [1] [2] [3] [4].

Atraumatic tissue dilators and expandable retractor systems are used in oblique lumbar interbody fusion (OLIF) to make sure dissection is safe anterior to the psoas to access the disc space. The advantage of this technique is that it avoids potential disturbances to the lumbar plexus within the psoas and by insertion of large rectangular interbody cages, it restores the disc height. This helps with indirect decompression of the neural elements through the restoration of foraminal height and distraction of the facet joints leading to spinal canal restoration [5] [6] [7]. One of the possible complications with OLIF is cage subsidence which can cause reversal of indirect decompression through the loss of disc height. Moreover, subsidence of intervertebral cages can occur in situations 1) without supplementary posterior transpedicular instrumentation 2) excessive distraction of the disc space leading to endplate damage or 3) osteoporosis of the vertebral bodies or, 4) overly aggressive endplate preparation leading to damage [8] [9] [10].

Young's modulus (E) measures material stiffness defined as the extent a specific material will deform under a given stress. The stiffness of commonly used materials for intervertebral cages like solid titanium alloys and polyetheretherketone (PEEK), is much higher than the stiffness of cancellous bone [11]. Laboratory studies demonstrated that porous intervertebral cages resulted in a substantial decrease of stress at the bone-hardware interface [11]. Thus, a porous titanium cage was created with bone-like biomechanical properties to decrease stress shielding and subsidence. The subsidence and fusion rates in patients have not been studied thoroughly yet. The aim of this study was to report radiographic subsidence, fusion as well as Oswestry Disability Index (ODI) of patients undergoing OLIF with porous titanium interbody cages.

2. Material and Methods

Our institutional review board (Ramsay Health Care Vic/NSW Human research ethics committee, 2021-LNR-006) approved a single-center experience which included 60 patients who underwent OLIF at Peninsula private hospital, Frankston, from June 2018 to June 2020 utilizing the porous titanium implants. Data were collected in accordance with the Declaration of Helsinki, and written informed consent was obtained. Sixty consecutive patients undergoing OLIF using porous porous titanium cage (Modulus; NuVasive, San Diego, CA) were included in this study. The surgeries were performed by our principal author, JC using a previously described oblique anterior to psoas (ATP) dissection between June 2018-July 2020. Fifty seven patients had supplementary fixation with posterior pedicle screws and rods, and three patients had an oblique plate for fixation. All patients had at least one year of post-operative follow-up. Exclusion criteria encompassed patients with tumors, infection, no scans during followup, less than one year of follow-up. Following these criteria, 60 patients were included in this study. Degenerative disc disease, spinal stenosis, spondylolisthesis, adult spinal deformity and adjacent segment disease were the indications for our study group.

The technology of OLIF with porous titanium interbody cages:

Young's modulus (E) measures material stiffness defined as the extent a specific material will deform under a given stress. The stiffness of used materials for porous titanium intervertebral cages is close to the stiffness of cancellous bone [11]. Laboratory studies demonstrated that porous intervertebral cages resulted in a substantial decrease of stress at the bone-hardware interface [11]. Thus, a porous titanium cage was created with bone-like biomechanical properties to decrease stress shielding and subsidence.

Surgical technique:

After induction of general anesthesia, the patient was positioned in a true lateral position, which was verified by fluoroscopy. Then, the disc spaces were outlined as well as the tentative incision lines. This was followed by prepping and draping of the patient in the usual sterile fashion. A skin incision was made either horizontally or vertically depending on the number of levels involved, followed by blunt dissection through the subcutaneous tissue, the external oblique, the internal oblique, and the transversus abdominis muscles, thus arriving at the retroperitoneal cavity. Under fluoroscopic guidance, a small dilator was introduced anterior to the psoas muscle at the anterior third of the disc space, then a K-wire is passed through the dilator, followed by sequential dilation of the space. After which, a self-retaining retractor (MaXcess; NuVasive, San Diego, CA) is positioned onto the disc space in the correct orientation. Then, an annulotomy knife is used on the lateral side of the disc space, followed by Cobb periosteal elevator advancement under fluoroscopy to rupture the contralateral annulus. Furthermore, the disc material was removed using pituitary rongeurs, and disc shavers; then the endplates were prepared using ring curettes. The final cage size was assessed with the insertion of cage templates. Finally, the porous titanium cage was filled with ceramic bone graft substitute (Attrax; NuVasive, San Diego, CA), which is non-inferior to autograft [12], and then advanced in the disc space under fluoroscopy.

Data collection included patient demographics, operative characteristics (number of implants, type of supplemental fixation) from the patient files. The main outcomes of this study are radiographic cage subsidence, fusion and ODI score changes which were collected during postoperative follow-up. Subsidence was determined on the sagittal cut of CT scans and the lateral view of spine x-rays (**Figure 1(A)** and **Figure 1(B)**). Subsidence was considered significant if the cage buried into the neighboring vertebra more than 2 mm. Radiographic imaging in the form of x-ray was obtained immediately postop, and during follow-up visits at 1 month, 3 months, 6 months, and 12 months. CT scan was obtained only at 6 months postop to assess for fusion as well (**Figure 2**).

Statistical Analysis:

All statistical analyses were performed using SPSS (IBM Corp.). Parametric data are provided as means ± standard deviations. Student t-test was used to compare ODI values.

3. Results

60 patients (28 males vs 32 females) underwent OLIF, with 3 patients undergoing fixation with a lateral plate and 57 patients received posterior pedicle screws and rods. The average age was 70 with an average BMI of 30.2 (**Table 1**). Most of the patients were non-smoker or have stopped smoking for over a year, with only two smokers whom we asked to stop smoking prior to surgery. ODI decreased significantly from 20.3 preop to 10.72 one year postop with a P value

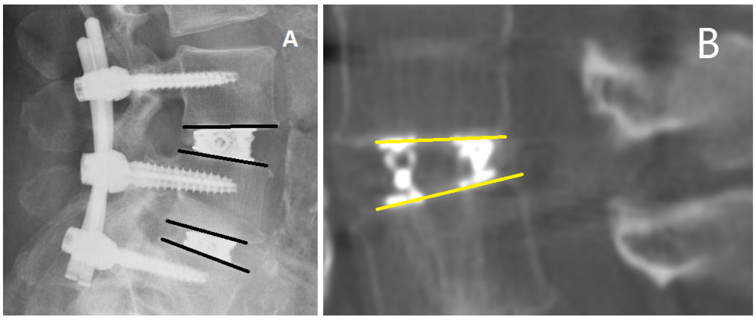

Figure 1. (A) Lateral view of spine x-ray, lines trace endplates showing no subsidence. (B) Sagittal cut of CT scan, lines trace endplates showing no subsidence.

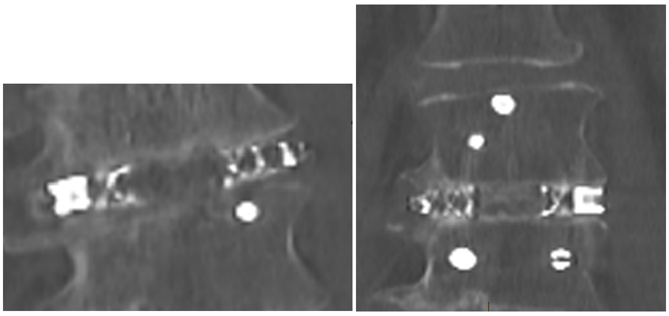

Figure 2. Cages with bone graft on coronal CT scan showing fusion.

Table 1. Demographic characteristics.

Demographic characteristics	Frequency or mean (+SD)	Percentage or range
Age (years)	70.2 ± 9.09	45 - 88
Gender	32 F 28 M	53.33% 46.67%
BMI (kg/m^2)	30.2 ± 5.65	19.6 - 45.2
Smoking history	2	3.3%
ODI preop	20.3 ± 7.29	4-33
ODI postop (at 1 year)	10.72 ± 6.52	1 - 28

P value < 0.05.

less than 0.05 (**Table 1**). 88% fusion rate was noted at 6 months under CT scan. Subsidence was classified using the following scale described by Marchi *et al.*, Grade 0, 0% - 24% postoperative disc height loss; Grade I, 25% - 49%; Grade II, 50% - 74%; and Grade III, 75% - 100% [13]. The most treated level was L4/5 followed by L3/4 then L2/3 and L1/2 levels. Also, most of our patients (95%) were supplemented with posterior pedicle screws. We had one grade 2 subsidence per implant level, and 88 grade 0 (**Table 2**). The grade 2 subsidence occurred in an osteoporotic patient with a DEXA scan spine score of −3.3 and a BMI of 19.8. She had a prior fusion surgery and was suffering from adjacent segment failure; however, she refused posterior fixation and so we opted for plate fixation. During her one-month postop visit, failure of the construct with subsidence of the cage was noted. Then, she was revised using posterior cemented pedicle screw and rods supplementation (**Figure 3** and **Figure 4**).

4. Discussion

Minimally invasive anterior to psoas, oblique lateral interbody fusion, can be used to treat a variety of different pathologies by using indirect decompression via disc height restoration and ligamentotaxis [6] [7] [10]. These pathologies include degenerative disc disease up to a moderate level of central stenosis and foraminal stenosis, symptomatic spondylolisthesis, degenerative scoliosis, and adjacent segment disease [2] [5]. A possible complication is cage subsidence which can reverse the benefits of indirect decompression, by increasing deformity, decreasing fusion rates, and reoperation in some cases [14] [15] [16]. It is potentially due to multiple factors like bone quality, operative technique, stand-alone implants, size, and material of the cage [9] [11] [17]. Studies have shown that maximizing the surface area of contact between bone and hardware, and using implants with similar architecture could reduce stress shielding and subsidence [11] [18]. Thus, the porous titanium cage was created to fit those qualities.

According to the published literature, the superior endplates of the lumbar spine are usually weaker than the inferior endplates [19]. However, in our study the one incidence of subsidence and endplate violation 1 month postop occurred

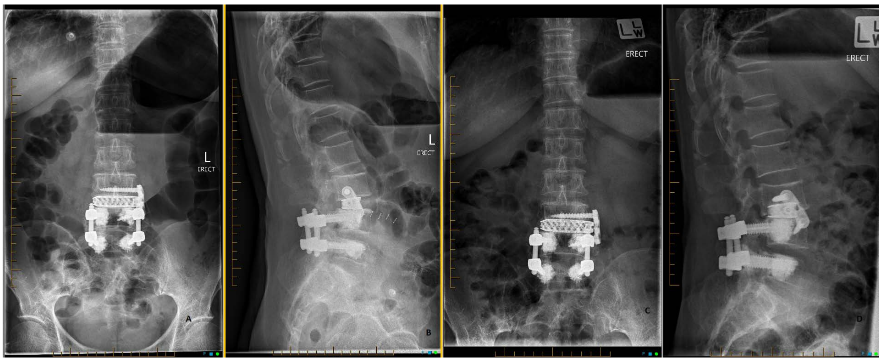

Figure 3. (A) AP view x-ray of lumbosacral spine immediately postop. (B) Lateral view x-ray of lumbosacral spine immediately postop. (C) AP view x-ray of lumbosacral spine 1 month postop. (D) lateral view x-ray of lumbosacral spine.

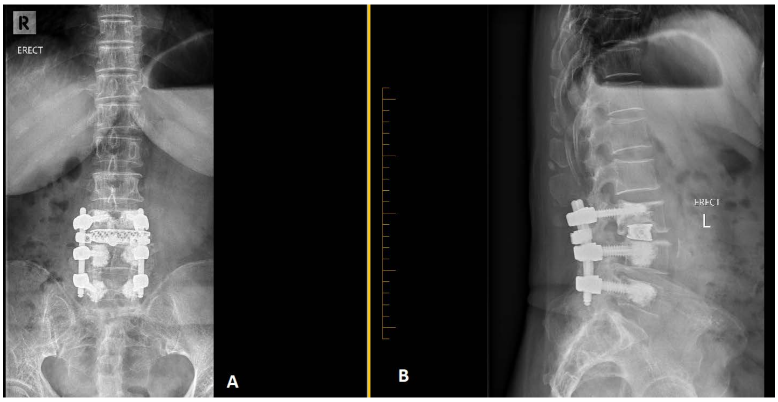

Figure 4. (A) AP view x-ray of lumbosacral spine 1 year after revision. (B) Lateral view x-ray of lumbosacral spine 1 year after revision.

Table 2. Operative characteristics.

Operative characteristics	Frequency	Percentage
Radiographic subsidence	1/60	1.7%
Subsidence per implant level	1/89	1.1%
Subsidence grade per implant level		
Grade 0	88	98.9%
Grade I	0	0%
Grade II	1	1.1%
Grade III	0	0%
Number of cages		
1	38	63.3%
2	17	28.3%
3	3	5%
4	2	3.3%
Spinal levels		
L1/L2	9	10.2%
L2/L3	13	14.6%
L3/L4	31	34.8%
L4/L5	36	40.4%

Continued

Supplemental fixation per patient		
Pedicle screws	57	95%
Lateral plate	3	5%

in the inferior end plate of the L3 lumbar vertebra. A study found an increasing rate of subsidence with stand-alone cages [8]. The cage in our study was fixed with a lateral plate initially which may have been insufficient in the patient's case. Another study using the (Modulus; NuVasive, San Diego, CA) cage showed on x-rays a subsidence rate per cage of 3.4% compared to our rate of 1.1% [20]. This may be due that most cages in our study had supplemental fixation in the form of either posterior pedicle screws and rods or a lateral plate. The subsidence rate is lower than previously reported rates in the literature when using PEEK (Polyetheretherketone) cages [15] [16] [17] [20]. It is known that subsidence can be caused by over distraction the disc space and endplate damage, as well as poor bone quality or increased implant stiffness [10]. Moreover, Young's modulus (E) of porous titanium cages is very close to that of cancellous bone [11]. In vitro studies demonstrated that porous intervertebral cages resulted in a substantial decrease of stress at the bone-implant interface [11]. Thus, a porous titanium cage was created with bone-like biomechanical properties to decrease stress shielding and subsidence rates.

There are numerous patient related outcomes scores available; one of the most used is the ODI. It is used in research often, but it does not reflect patient's satisfaction with the outcome reliably. Thus, a patient's acceptable symptom state for the lumbar spine degenerative disease was defined as ODI less than 22 to better reflect the success of the operation [21]. In our study, ODI decreased significantly between preop and postop results with $P < 0.05$ (**Table 1**). This is in accordance with the improved clinical outcomes expected after surgery.

Fusion is the end goal of any lumbar interbody fusion surgery, however, fusion in the recent porous titanium cages have not been documented enough. In a study, the bone graft substitute (Attrax; NuVasive, San Diego, CA), used was followed over a period of 2 years with CT scans to document fusion related changes and compare it to rhBMP-2 [22]. It concluded that there was no difference in fusion rates in instrumented constructs, but in standalone cages rhBMP-2 was faster in achieving fusion [22].

There are some limitations to this study. First, it was a retrospective single center study with no comparative groups. However, the subsidence rate is better than our own unpublished data using PEEK cages in OLIF. Second, the new porous titanium cage is still new and as such no established criteria for fusion evaluation are available. Third, this study has a small sample size.

In conclusion, the subsidence rate is lower compared to previously reported rates in the literature which may be in part due to posterior fixation in most patients as well as due to the type of cage used. Also, the clinical outcomes of the patients have improved significantly during their 1 year of follow-up. Further studies are needed to document the benefits of this new implant.

Declarations

Ethics Approval and Consent to Participate

Our institutional review board (Ramsay Health Care Vic/NSW Human research ethics committee, 2021-LNR-006) approved a single-center experience which included 60 patients who underwent OLIF from June 2018 to June 2020 utilizing the porous titanium implants. Data was collected in accordance with the Declaration of Helsinki, and written informed consent was obtained.

Availability of Data and Material

The datasets used and analysed during the current study are available from the corresponding author on reasonable request.

Authors' Contributions

JM: contributed to data collection, data analysis, writing and editing of the manuscript;

RB: contributed to data analysis, writing and editing of the manuscript;

JC: contributed to data collection, project conception and supervision, writing and editing of the manuscript.

Conflicts of Interest

The authors declare no competing interest.

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Abbreviations

Oblique lumbar interbody fusion (OLIF);
Computed tomography (CT);
Oswestry disability index (ODI);
Polyetheretherketone (PEEK);
Anterior to psoas (ATP).