Original Article

Fusion assessment in standalone lateral lumbar interbody fusion: 3D-printed titanium versus polyetheretherketone (PEEK) cages

Dominik Adl Amini[1,2]^, Manuel Moser[1,3]^, Lisa Oezel[1,4], Jennifer Shue[1], Matthias Pumberger[2], Andrew A. Sama[1], Frank P. Cammisa[1], Federico P. Girardi[1], Alexander P. Hughes[1]^

[1]Spine Care Institute, Hospital for Special Surgery, New York, NY, USA; [2]Department of Orthopedic Surgery and Traumatology, Charité University Hospital Berlin, Berlin, Germany; [3]Department of Spine Surgery, Lucerne Cantonal Hospital, Lucerne, Switzerland; [4]Department of Orthopedic Surgery and Traumatology, University Hospital Duesseldorf, Duesseldorf, Germany

Contributions: (I) Conception and design: D Adl Amini, M Moser, L Oezel, M Pumberger, AA Sama, FP Cammisa, FP Girardi, AP Hughes; (II) Administrative support: J Shue; (III) Provision of study materials or patients: All authors; (IV) Collection and assembly of data: D Adl Amini, M Moser, L Oezel; (V) Data analysis and interpretation: All authors; (VI) Manuscript writing: All authors; (VII) Final approval of manuscript: All authors.

Correspondence to: Alexander P. Hughes, MD. Spine Care Institute, Hospital for Special Surgery, 535 East 70th Street, New York, NY 10021, USA. Email: hughesa@hss.edu.

Background: Compare fusion at two independent timepoints (early and late) between 3D-printed titanium (Ti) and polyetheretherketone (PEEK) cages in patients undergoing standalone lateral lumbar interbody fusion (SA-LLIF). We hypothesized that 3D-printed Ti cages show higher fusion rates at an early timepoint compared to PEEK.

Methods: A retrospective study of patients undergoing SA-LLIF with 3D-printed Ti cages and PEEK cages between 11/2016 and 01/2020 at a single academic institution was done. Fusion was assessed for each treated level using multiplanar reconstructed computed tomography (CT) scans. Presence of fully bridged interbody trabecular bone or continuous bone centered in the cage was considered as fusion.

Results: In total, 91 patients (136 levels) were included in the final analysis, 49 patients (72 levels) in the early group and 42 patients (64 levels) in the late group. CT scans were performed on average 8.2±1.8 months postoperatively for the early group and 18.9±7.7 months for the late group. In the early group, fusion was significantly higher for 3D-printed Ti cages compared to PEEK cages (95.8% versus 62.5%; P=0.002), whereas in the late group no significant difference was seen (94.7% versus 80.0%; P=0.258).

Conclusions: In SA-LLIF, porous 3D-printed Ti cages showed significantly higher fusion rates at an early timepoint compared to PEEK. However, the difference in fusion rates between 3D-printed Ti cages and PEEK cages was found not to be significantly different at a later timepoint in another patient group. This might support the assumption that 3D-printed Ti cages with a porous architecture are more osteoconductive compared to PEEK and tend to fuse earlier.

Keywords: Lateral lumbar interbody fusion (LLIF); standalone; fusion; lumbar fusion; titanium (Ti)

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^ ORCID: Dominik Adl Amini, 0000-0002-8555-7304; Manuel Moser, 0000-0003-4517-359X; Alexander P. Hughes, 0000-0001-7293-9672.

Introduction

Lateral lumbar interbody fusion (LLIF) has become increasingly popular in the recent decade due to its safety and effectiveness for the treatment of degenerative spinal diseases (1-4). In past years, there is growing attention on standalone LLIF (SA-LLIF) in particular due to the ability of the procedure to maintain segmental stability through preservation of the anterior and posterior longitudinal ligaments and insertion of large cages that span the apophyseal ring bilaterally (5-9). Irrespective of the technique used, solid bony fusion of the treated level remains the final goal of any lumbar interbody fusion.

Interbody cages are manufactured from different materials such as polyetheretherketone (PEEK) and titanium (Ti), with PEEK representing the most commonly used material in the past because of its good mechanical and chemical properties (10-13). However, one main disadvantage of PEEK is the relatively low osseointegration, radiologically known as the 'PEEK-Halo effect', a biofilm layer around the surface of the implant (12,14,15). Therefore, bone tends to grow around the cage in order to bind to the host bone and create a solid fusion mass (13). With advancing technology and manufacturing capabilities, interbody cages are designed with complex features (16). The most advanced cages to date are 3D-printed Ti cages with a porous architecture that mimic trabecular bone. These cages have more compressive shear strength under physical force, maximize bone-to-implant contact and show less early subsidence in a SA-LLIF setting compared to traditionally used PEEK cages (14,17-21). With regards to fusion, 3D-printed Ti cages are reported to be more osteoconductive in laboratory settings compared to PEEK cages (18,22). Furthermore, due to increased friction created by the porous surface, these 3D-printed Ti cages have reduced micromotion that leads to bony on- and in-growth (18,23). The possibility of increased osteoblastic activity is of special interest when it comes to assessing fusion (24).

In this study, we defined two independent groups, an early and a late group based on the availability of postoperative computed tomography (CT) scans. Within those groups, we compared evidence of fusion between 3D-printed Ti cages and PEEK cages. We hypothesized that 3D-printed Ti cages show higher fusion rates at an early timepoint compared to PEEK cages. We present the following article in accordance with the STROBE reporting checklist (available at https://jss.amegroups.com/article/view/10.21037/jss-22-17/rc).

Methods

Study population and design

The study was conducted in accordance with the Declaration of Helsinki (as revised in 2013). This study was approved by the Hospital for Special Surgery Institutional Review Board (IRB# 2014-097) and informed consent was waived due to the retrospective nature of this study. Between November 2016 and January 2020, data of consecutive patients undergoing SA-LLIF at a single academic institution were reviewed. The inclusion criteria were as follows: (I) patients aged 18 years and older, (II) patients undergoing SA-LLIF from L1/2 to L4/5, (III) radiological follow-up with CT scans between 6–12 months (early group) and >12 months (late group), and (IV) pre-operative CT scans for the assessment of bone mineral density (BMD). The surgical indications for SA-LLIF were also reviewed.

Data collection

As potential contributing factors for fusion, demographic and surgical variables were collected including age, body mass index (BMI), gender, race, history of smoking, diabetes mellitus, surgical diagnosis, use of recombinant human bone morphogenetic protein-2 (rh-BMP2), level(s) of fusion and cage dimensions. Additionally, volumetric bone mineral density (vBMD) was retrospectively assessed using quantitative computed tomography (QCT; Mindways Software, Inc., Austin, TX, USA) on preoperative CT scans within 6 months prior to surgery as described in a previous study of ours (21). Bone status was assessed according to the "American College of Radiology guidelines for the Performance of Musculoskeletal Quantitative Computed Tomography (Qct)" (25).

Surgical technique and implants

At a single high volume spine center, all patients underwent SA-LLIF performed by one of four fellowship-trained orthopedic spine surgeons with at least 10 years of experience with the LLIF procedure. The appropriate cage size was determined based on preoperative imaging in combination with intraoperative cage templating. All cages in both groups were lordotic. Moreover, all cages were packed with rh-BMP2. The implants were positioned to span the apophyseal ring bilaterally. During the surgical procedure, intraoperative neuromonitoring was performed.

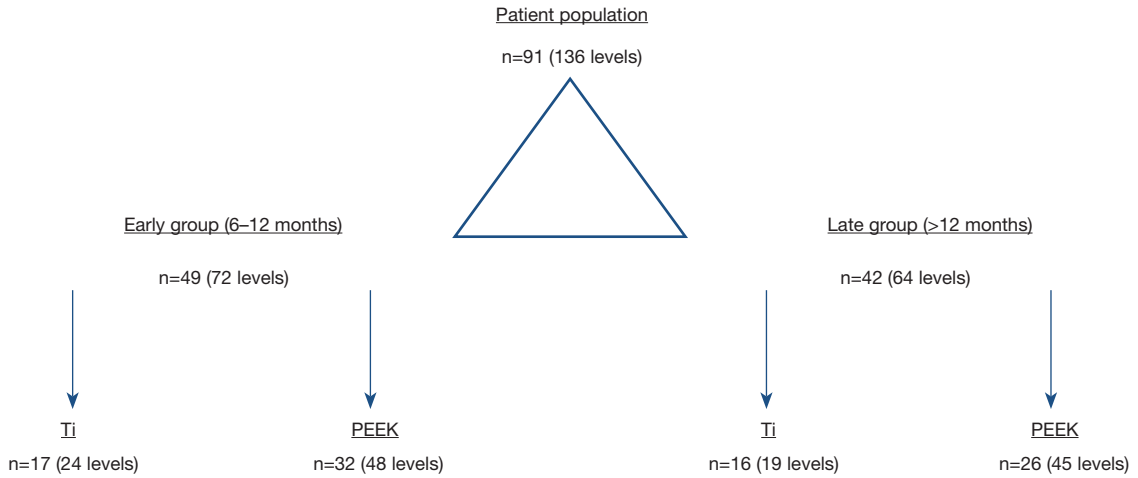

Figure 1 Patient population. n, number of patients (levels treated). Ti, titanium; PEEK, polyetheretherketone.

Two PEEK cage systems [XLIF (NuVasive, Inc., San Diego, CA, USA)] & the COUGAR system (DePuy Spine Inc., Raynham, MA, USA) or two 3D-printed Ti cages systems [Modulus XLIF (NuVasive, Inc.) & Lateral Spine Truss System (4WEB Medical, Inc., Frisco, TX, USA)] were utilized during the study period.

Fusion assessment

Evidence of fusion was assessed on multiplanar reconstructed CT scans using the hospital's Picture Archiving and Communication System (PACS) software Sectra IDS7 Version 22.7 (Sectra AB, Linköping, Sweden). Assessment of fusion was independently performed by two researcher-physicians not involved in any of the procedures. Additionally, all findings were compared to the radiological report and the latter used for further evaluation in cases of disagreement. Presence of fully bridged interbody trabecular bone or continuous bone through the cage in any plain was considered as evidence of fusion.

Postoperative follow-up CT imaging was not standardized among surgeons, possibly to reduce preventable radiation exposure. Routine radiological follow-up was carried out using standing plain X-rays at 6 months as a standard of care. In patients fulfilling inclusion criteria for one of the two timepoints, the indication for CT was recorded as "standard of care", "discomfort/pain" or "fall".

Statistical analysis

Proportions were used for categorial variables to summarize their distribution.

Comparisons between categorical variables were performed utilizing Fisher's exact test and the χ^2 test. The Shapiro-Wilk test was used to assess for normal distribution of continuous variables. Comparisons between normally distributed continuous variables were performed using the Student *t*-test, and the Mann-Whitney U test was used for the comparisons between non-normally distributed continuous variables. Statistical analysis was performed with SPSS Statistics version 23.0 (IBM Corp., Armonk, NY, USA). The statistical significance was set as P≤0.05.

Results

Study population

We retrospectively reviewed the data of 157 consecutive patients undergoing SA-LLIF with a minimum of 6-month radiological follow-up. Of these, 91 patients (136 levels) fulfilled our inclusion criteria: 49 patients (72 levels) had a CT scan between 6–12 months postoperatively and formed the early group and 42 patients (64 levels) had a CT scan after a minimum of 12 months postoperatively and formed the late group for fusion assessment (*Figure 1*). Both the early and late group were independent groups and included different patients based on the availability of CT scans during follow-up. For the early group, CT scans were performed on average 8.2±1.8 months (Ti: 8.4±1.8; PEEK: 8.0±1.8, P=0.376) postoperatively, and for the late group on average 18.9±7.7 months (Ti: 18.8±6.9; PEEK: 18.9±8.4, P=0.756) after surgery.

Table 1 Demographic characteristics for the early group versus late group

Variables	Early group				Late group			
	Total (n=49)	Ti (n=17)	PEEK (n=32)	P value	Total (n=42)	Ti (n=16)	PEEK (n=26)	P value
Gender, n (%)								
Male	27 (55.1)	10 (58.8)	17 (53.1)	0.769§	23 (54.8)	10 (62.5)	13 (50.0)	0.530§
Female	22 (44.9)	7 (41.2)	15 (46.9)	0.769§	19 (45.2)	6 (37.5)	13 (50.0)	0.530§
Race, n (%)								
Caucasian/White	46 (93.9)	17 (100.0)	29 (90.6)	0.428**	40 (95.2)	15 (93.8)	25 (96.2)	0.325**
African-American	2 (4.1)	0	2 (6.3)	0.428**	1 (2.4)	0	1 (3.8)	0.325**
Other	1 (2.0)	0	1 (3.1)	0.428**	1 (2.4)	1 (6.3)	0	0.325**
Age at surgery, years, mean ± SD (range)	60.6±13.2 (22–83)	56.8±13.5 (22–81)	62.6±12.8 (36–83)	0.143*	63.5±12.3 (24–82)	58.1±12.9 (24–77)	66.9±10.9 (39–82)	0.023*
BMI (kg/m^2), mean ± SD (range)	28.0±4.8 (19.2–41.1)	27.4±5.0 (19.2–41.1)	28.3±4.7 (19.6–39.6)	0.559*	27.5±4.6 (19.6–42.6)	27.7±5.6 (23.6–42.6)	27.4±4.0 (19.6–33.7)	0.891*
Smoking status, n (%)								
Never	27 (55.1)	11 (64.7)	16 (50.0)	0.479**	22 (52.4)	10 (62.5)	12 (46.2)	0.197**
Former	20 (40.8)	5 (29.4)	15 (46.9)	0.479**	19 (45.2)	5 (31.3)	14 (53.8)	0.197**
Current	2 (4.1)	1 (5.9)	1 (3.1)	0.479**	1 (2.4)	1 (6.2)	0	0.197**
Diabetes mellitus, n (%)	5 (10.2)	1 (5.9)	4 (12.5)	0.646§	1 (2.4)	0	1 (3.8)	1.000§
QCT vBMD (mg/cm^3), mean ± SD (range)	130.0±40.1 (47.1–265.0)	142.3±44.6 (63.1–265.0)	123.4±36.6 (47.1–213.6)	0.119*	130.2±37.2 (47.1–197.5)	137.8±26.5 (88.6–183.0)	125.5±42.3 (47.1–197.5)	0.252*
QCT normal, n (%)	29 (59.2)	13 (76.5)	16 (50.0)	0.126§	26 (61.9)	12 (75.0)	14 (53.9)	0.206§
QCT osteopenia, n (%)	15 (30.6)	3 (17.6)	12 (37.5)	0.202§	13 (31.0)	4 (25.0)	9 (34.6)	0.733§
QCT osteoporosis, n (%)	5 (10.2)	1 (5.9)	4 (12.5)	0.646§	3 (7.1)	0	3 (11.5)	0.275§

§, Fisher's exact test; *, Student *t*-test; **, Chi-squared test. Ti, titanium; PEEK, polyetheretherketone; BMI, body mass index; QCT vBMD, quantitative computed tomography volumetric bone mineral density.

Our predominantly White/Caucasian population (94.5%) consisted of 50 male and 41 females with an average age at surgery of 61.9±12.7 years. vBMD analysis revealed 8 osteoporotic patients. In the early group, no statistically significant difference was found in demographic characteristics between Ti and PEEK cages, whereas in the late group, patients treated with PEEK cages were significantly older compared to those receiving Ti cages (P=0.023). Demographic characteristics and surgical diagnoses stratified for each group and both cage materials are summarized in *Tables 1*,*2*.

Of 136 treated levels, 54 (39.7%) were single level SA-LLIFs. L4/5 (41.9%) was the level most often treated followed by L3/4 (33.8%). While the early group did not show a significant difference between 3D-printed Ti cages and PEEK cages for the number of levels treaded, the late group had significantly more multilevel procedures with PEEK compared to the 3D-printed Ti cages (P=0.006). Surgical characteristics are shown in *Table 3*.

Fusion assessment

The indication for CT scans during the follow-up periods did not differ between early and late groups (*Table 4*). After an average follow-up of 8.2±1.8 months in the early group, 23/24 (95.8%) of levels treated with 3D-printed Ti cages compared to 30/48 (62.5%) of levels treated with PEEK cages showed evidence of fusion (P=0.002). In the late group, after an average follow-up of 18.9±7.7 months, 18/19 (94.7%) of levels treated with 3D-printed Ti cages and

Table 2 The surgical diagnosis of patients included in this study divided into the early and late group

Variables, n (%)	Early group				Late group			
	Total (n=49)	Ti (n=17)	PEEK (n=32)	P value	Total (n=42)	Ti (n=16)	PEEK (n=26)	P value
Degenerative disc disease	20 (40.8)	9 (52.9)	11 (34.4)	0.237[§]	15 (35.7)	9 (56.3)	6 (23.1)	0.047[§]
Spinal stenosis	34 (69.4)	12 (70.6)	22 (68.8)	1.000[§]	31 (73.8)	11 (68.8)	20 (76.9)	0.720[§]
Foraminal stenosis	24 (49.0)	6 (35.3)	18 (56.3)	0.232[§]	19 (45.2)	7 (43.8)	12 (46.2)	1.000[§]
Spondylolisthesis	35 (71.4)	14 (82.4)	21 (65.6)	0.323[§]	32 (76.2)	13 (81.3)	19 (73.1)	0.715[§]
Herniated disc	4 (8.2)	1 (5.9)	3 (9.4)	1.000[§]	1 (2.4)	1 (6.3)	0	0.381[§]
Neurogenic claudication	2 (4.1)	2 (11.8)	0	0.116[§]	6 (14.3)	4 (25.0)	2 (7.7)	0.180[§]
Scoliosis	13 (26.5)	4 (23.5)	9 (28.1)	1.000[§]	12 (28.6)	2 (12.5)	10 (38.5)	0.090[§]

It must be mentioned that some patients had multiple diagnoses. [§], Fisher's exact test. Ti, titanium; PEEK, polyetheretherketone.

36/45 (80.0%) of levels treated with PEEK cages showed evidence of fusion (P=0.756) (*Figure 2*). When comparing multilevel procedures, the early group displayed evidence of fusion in 90.9% of levels treated with 3D-printed Ti cages compared to 58.1% of levels treated with PEEK cages. For the late group, 100.0% of patients treated with 3D-printed Ti cages versus 80.0% with PEEK cages showed evidence of fusion.

Discussion

To the authors knowledge, this is the first study comparing evidence of fusion between 3D-printed Ti cages and PEEK cages at two different timepoints in the setting of SA-LLIF. Our results demonstrated that after an average of 8.2±1.8 months, Ti cages achieved significantly higher fusion rates compared to PEEK cages. However, in the independent late group, no significant difference in fusion rates was found between the two cage materials after an average of 18.9±7.7 months. These findings support the assumption that 3D-printed Ti cages with a porous architecture are more osteoconductive and therefore tend to fuse earlier than PEEK cages.

McGilvray *et al.* (18) performed a comparative animal study that directly compared PEEK and 3D-printed Ti cages. They displayed significant differences for biochemical, micro-CT and histological performance of the Ti cages, with the porous Ti cages significantly reducing the range of motion (ROM) and increasing bone ingrowth compared to PEEK cages. Similar to equal results were reported in a recently published ovine model study by Van Horn *et al.* (16) In their micro-CT analysis, the bone volume (in-growth) in the 3D-printed Ti cage was significantly higher after 6 weeks postoperatively compared to the PEEK cage, but not after 12 weeks. Furthermore, in a histological analysis 3D-printed Ti cages showed significantly greater bony on-growth than PEEK cages at 6 and 12 weeks postoperatively. Of note, the bony on-growth was 2.7-times higher in the 3D-printed Ti cages than the PEEK cage at 6 weeks and 2.6-times higher at 12 weeks. However, even though it remains quantitatively unclear how bony in-/on-growth affects spinal fusion, Van Horn *et al.* (16) concluded that it is reasonable that more bony growth leads to greater stability of the treated segment and thus might prevent pseudarthrosis (16).

In general, non-union rates for lumbar fusion have been reported to be around 0–40%, with modern techniques such as interbody cages, pedicle screw fixation and bone graft substitutes lowering this number to 0–10% (26-29). Many studies have reported fusion rates for LLIF in the past, but only a few have explicitly focused on SA-LLIF (30-35). Investigating fusion rates of PEEK cages, Marchi *et al.* (35) evaluated 52 patients undergoing single-level SA-LLIF and reported a solid fusion of only 67.3% after 12 months and 86.5% after 24 months. They assessed fusion on X-rays and CT scans and defined fusion as bridging bone connecting the adjacent vertebral bodies through or around the implant (equal to our definition), less than 5° of angular motion, less than or equal to 3 mm of translation and an absence of radiolucent lines around more than 50% of either of the implant surfaces. In a prospective, randomized controlled study by Pimenta *et al.* (33) including 30 patients undergoing single-level SA-LLIF, a fusion rate of 100% after 36 months was reported that was independent of the

Table 3 The surgical characteristics of patients included in this study divided into the early and late group

Variables	Early group				Late group			
	Total	Ti	PEEK	P value	Total	Ti	PEEK	P value
No. of patients	49	17	32		42	16	26	
No. of levels	72	24	48		64	19	45	
Levels treated, n (%)								
1	30 (61.2)	13 (76.5)	17 (53.1)	0.087**	24 (57.2)	14 (87.4)	10 (38.5)	0.006**
2	16 (32.7)	2 (11.7)	14 (43.8)	0.087**	14 (33.3)	1 (6.3)	13 (50.0)	0.006**
3	2 (4.1)	1 (5.9)	1 (3.1)	0.087**	4 (9.5)	1 (6.3)	3 (11.5)	0.006**
4	1 (2.0)	1 (5.9)	0	0.087**	–	–	–	0.006**
Spinal levels, n (%)								
L1/2	3 (4.2)	2 (8.3)	1 (2.1)	0.273§	2 (3.1)	2 (10.5)	0	0.139§
L2/3	13 (18.1)	4 (16.7)	9 (18.8)	1.000§	15 (23.4)	5 (26.3)	10 (22.2)	0.746§
L3/4	23 (31.9)	7 (29.2)	16 (33.3)	0.764§	23 (35.9)	4 (21.1)	19 (42.2)	0.004§
L4/5	33 (45.8)	11 (45.8)	22 (45.8)	1.000§	24 (37.6)	8 (42.1)	16 (35.6)	0.531§
Cage height (mm), n (%)								
8	11 (15.3)	2 (8.3)	9 (18.8)	0.316§	15 (23.5)	3 (15.8)	12 (26.6)	0.521
10	49 (68.1)	21 (87.5)	28 (58.3)	0.016§	42 (65.6)	16 (84.2)	26 (57.8)	0.049§
12	12 (16.6)	1 (4.2)	11 (22.9)	0.051§	7 (10.9)	0	7 (15.6)	0.094§
Cage width (mm), n (%)								
18	3 (4.2)	0	3 (6.3)	0.546§	5 (7.8)	0	5 (11.1)	0.310§
22	49 (68.1)	24 (100.0)	25 (52.1)	<0.001§	47 (73.4)	19 (100.0)	28 (62.2)	0.001§
26	20 (27.7)	0	20 (41.6)	<0.001§	12 (18.8)	0	12 (26.7)	0.013§
Cage length (mm), n (%)								
40	1 (1.4)	0	1 (2.1)	1.000§	10 (15.6)	2 (10.5)	8 (17.8)	0.710§
45	9 (12.5)	3 (12.5)	6 (12.5)	1.000§	22 (34.4)	8 (42.1)	14 (31.1)	0.406§
50	19 (26.4)	9 (37.5)	10 (20.8)	0.161§	22 (34.4)	8 (42.1)	14 (31.1)	0.406§
55	30 (41.7)	10 (41.7)	20 (41.7)	1.000§	9 (14.1)	1 (5.3)	8 (17.8)	0.260§
60	12 (16.6)	2 (8.3)	10 (20.8)	0.314§	1 (1.5)	0	1 (2.2)	1.000§
65	1 (1.4)	0	1 (2.1)	1.000§	–	–	–	–
Cage lordosis, n (%)								
10°	70 (97.2)	22 (91.7)	48 (100.0)	0.108§	55 (85.9)	18 (94.7)	37 (82.2)	0.260§
15°	2 (2.8)	2 (8.3)	0	0.108§	9 (14.1)	1 (5.3)	8 (17.8)	0.260§

**, Chi-squared test; §, Fisher's exact test. Ti, titanium; PEEK, polyetheretherketone.

bone graft material (Silicate Calcium Phosphate or rh-BMP2) used within the cage. The authors also used X-rays and CT scans for the fusion assessment as described above. In another study including 74 patients with 98 treated levels, the same study group reported a fusion rate of 91% at 12 months (36). A recently published systematic review analyzing 22 SA-LLIF studies treated with PEEK cages for various surgical indications showed an overall

Table 4 The fusion assessment of patients included in this study divided into the early and late group

Variables	Early group				Late group			
	Total	Ti	PEEK	P value	Total	Ti	PEEK	P value
No. of patients	49	17	32	–	42	16	26	–
No. of levels	72	24	48	–	64	19	45	–
Reason for follow-up CT, n (%)								
Standard of care	18 (36.8)	6 (35.3)	12 (37.5)	0.383*	6 (14.3)	2 (12.5)	4 (15.4)	0.859*
Discomfort/pain	30 (61.2)	10 (58.8)	20 (62.5)	0.383*	32 (76.2)	12 (75.0)	20 (76.9)	0.859*
Fall	1 (2.0)	1 (5.9)	0	0.383*	4 (9.5)	2 (12.5)	2 (7.7)	0.859*
Evidence of fusion per level, n (%)								
No	19 (26.4)	1 (4.2)	18 (37.5)	0.002§	10 (15.6)	1 (5.3)	9 (20.0)	0.258§
Yes	53 (73.6)	23 (95.8)	30 (62.5)	0.002§	54 (84.4)	18 (94.7)	36 (80.0)	0.258§
Follow-up (months), mean ± SD (range)	8.2±1.8 (6.0–11.6)	8.4±1.8 (6.1–11.6)	8.0±1.8 (6.0–11.6)	0.376**	18.9±7.7 (12.0–38.8)	18.8±6.9 (12.3–34.3)	18.9±8.4 (12.0–38.8)	0.756**

§, Fisher's exact test; *, Chi-squared test; **, Mann-Whitney U test. Ti, titanium; PEEK, polyetheretherketone; CT, computed tomography.

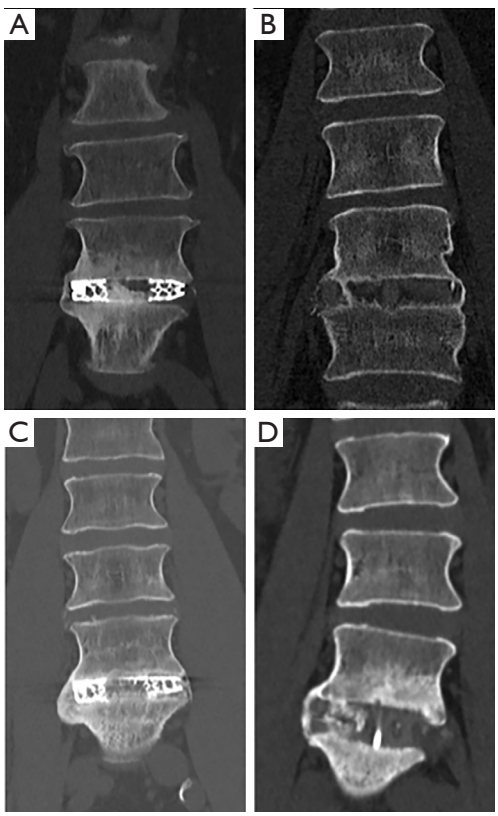

Figure 2 Analysis of fusion mass at the two different timepoints (early and late group) and for the different cage materials used (Ti and PEEK group). (A) Early group 3D-printed Ti cage. (B) Early group PEEK cage. (C) Late group 3D-printed Ti cage. (D) Late group PEEK cage. Ti, titanium; PEEK, polyetheretherketone.

fusion rate of 85.6% per person (37). The average follow-up for all included articles was 19.0 months, ranging from 6–62 months. Of note, fusion rates were not reported per treated level, but per person, and fusion assessment was done either on X-rays (11/22 articles) or on CT scans (11/22 articles). Interestingly, this review showed that fusion rates were higher in multilevel procedures (1 level: 89.2%, 2 levels: 90.5%, 3 levels: 96.9%) and fusion rates by each treated level were comparable throughout the lumbar spine (L1/2 96.6%, L2/3 95.8%, L3/4 96.0%, and L4/5 95.5%).

Currently, the literature about porous 3D-printed Ti cages in the setting of SA-LLIF is scarce. However, there are some studies investigating 3D-printed Ti cages with posterior pedicle screw fixation that also report fusion rates. Krafft *et al.* (38) published the first study evaluating 3D-printed Ti cages in 30 patients (59 levels). While their primary endpoint was cage subsidence, they also reported radiographic signs of fusion per level which was 62.7% after an average follow-up of 11.6 months (range, 3–23 months), which is considerably lower than our SA-LLIF fusion rate. X-rays were used for fusion assessment, however, so their results must be interpreted with caution. Mokawem *et al.* (11) assessed fusion rates with 3D-printed lamellar Ti cages using silicate-substituted calcium phosphate bone graft in 43 patients (87 levels). At 12 months postoperatively, they reported a fusion rate per level of 100% on CT scans.

There are several limitations to this study. First, both

the early and late group were independent groups and included different patients based on the availability of CT scans during follow-up. A longitudinal assessment of fusion was therefore not applicable, and no time course of fusion can be shown. Second, CT scans were not performed as a standard of care due to the involvement of different surgeons. Therefore, patients included in this study represent a subset of our patient population and consequently, there might have been unmeasured factors that led to selection bias. Third, the relatively small sample size of our groups and the single-center retrospective design limits the generalizability of our results further. Given these limitations, any conclusions must be interpreted with appropriate caution.

Conclusions

Our study demonstrated that in SA-LLIF 3D-printed Ti cages showed significantly higher fusion rates at an early timepoint compared to PEEK cages. However, the difference in fusion rates between Ti and PEEK cages was found not to be significantly different at a later timepoint in another patient group. In our cohort, this might support the assumption that 3D-printed Ti cages with a porous architecture are possible more osteoconductive compared to PEEK and possible tend to fuse earlier.

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Footnote

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Ethical Statement: The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. The study was conducted in accordance with the Declaration of Helsinki (as revised in 2013). This study was approved by the Hospital for Special Surgery Review Board (IRB# 2014-097) and informed consent was waived due to the retrospective nature of this study.

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