3D-Printed Titanium Versus Ti-PEEK Cages in Degenerative Lumbar TLIF: Meta-Analysis of Clinical Outcomes

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INTRODUCTION: Transforaminal lumbar interbody fusion (TLIF) is a common surgical treatment for degenerative lumbar disorders when conservative management fails [1, 2]. The interbody cage is central to success, and material choice can affect fusion, subsidence, and symptom relief. While titanium-coated poly-ether-ether-ketone (Ti-PEEK) cages are popular for their radiolucency and bone-like modulus of elasticity, additively manufactured 3D-printed porous titanium (3D-Ti) cages may enhance osteointegration [3, 4]. However, direct comparisons between these two cage types are limited and inconclusive. We therefore conducted a systematic review and meta-analysis to evaluate radiographic and clinical outcomes between 3D-Ti and Ti-PEEK cages in patients undergoing degenerative lumbar TLIF.
METHODS: This review followed PRISMA guidelines [5]. A systematic search of PubMed, Embase, CENTRAL, and Google Scholar was conducted from inception to July 1, 2025. Eligible studies included randomized or observational investigations of degenerative lumbar TLIF comparing 3D-Ti and Ti-PEEK cages, with a minimum 12-month follow-up. Outcomes of interest were radiographic fusion, cage subsidence, re-operation rate, and visual-analogue scale (VAS) for back pain; VAS-leg and Oswestry Disability Index (ODI) scores were omitted due to insufficient data across the included studies. For each cage material, single-arm data were pooled using random-effects models. For dichotomous outcomes such as fusion or subsidence (event vs. no event), data were analyzed as logit-transformed proportions. For continuous outcomes like VAS pain scores, data were synthesized as raw means. Differences between cage materials were tested using a mixed-effects meta-regression. Risk of bias was assessed using the Cochrane RoB 2 tool for randomized trials and the ROBINS-I tool for non-randomized observational studies. Statistical significance was set at $p < 0.05$.
RESULTS: Twelve comparative studies (four randomized trials, eight cohort studies) fulfilled the eligibility criteria, comprising 627 patients and 812 fused levels (477 3D-Ti; 335 Ti-PEEK). Final follow-up ranged from 12 to 24 months. Pooled single-arm analysis showed high fusion rates for both 3D-Ti (91% [95% CI 0.87-0.94]) and Ti-PEEK (88% [0.79-0.94]), with similar rates of subsidence (19% [0.10-0.35] vs. 20% [0.10-0.36]) and re-operation (3.3% [1.2-8.8%] vs. 4.6% [1.9-11.1%]). However, direct comparison in the meta-regression found no significant difference between cage materials for fusion rate (OR 0.68, 95% CI 0.30-1.50), subsidence rate (OR 1.04, 95% CI 0.33-3.22), or re-operation rate (OR 1.23, 95% CI 0.29-5.24). While mean final back-pain scores were numerically lower for Ti-PEEK, the meta-regression confirmed this difference was not significant (mean difference -0.88, 95% CI -2.49 to 0.73) (Table 1). Between-study heterogeneity was moderate to high ($I^2 \approx 60–80\ \%$), but the cage material variable did not explain it ($R^2 \approx 0\ \%$). The risk of bias assessment revealed methodological weaknesses; the Cochrane RoB-2 tool identified "some concerns" in two randomized trials, while the ROBINS-I tool classified five non-randomized studies as having a "serious risk" of bias.
DISCUSSION: This meta-analysis of the current literature found that 3D-printed porous titanium and Ti-PEEK cages demonstrate similarly high fusion success, comparable subsidence and re-operation rates, and equivalent short-term pain relief in degenerative lumbar TLIF. While the average results showed a slight trend favoring 3D-Ti for fusion and Ti-PEEK for pain reduction, these differences did not reach statistical significance. The overall evidence is limited by methodological weaknesses; with five of eight cohort studies at serious risk of bias and half the randomized evidence carrying "some concerns," the current literature offers only low-to-moderate-quality support for either material's superiority. Therefore, while both cage types appear safe and clinically effective, definitive conclusions about any meaningful advantage will require larger, rigorously designed randomized trials with longer follow-up.
SIGNIFICANCE/CLINICAL RELEVANCE: This study confirms that both 3D-Ti and Ti-PEEK cages are effective options for TLIF but finds no evidence of clinical superiority for 3D-printed technology, highlighting the need for large-scale randomized trials to guide surgical decision-making.
REFERENCES: [1] B. I. Martin +. Spine 2019. [2] D. Yavin +. Neurosurgery 2017. [3] W. Singhatanadgige +. World Neurosurg 2022. [4] T. Hasegawa +. Spine 2020. [5] D. Moher +. PLoS Med 2009.

Table 1: Meta-Regression Analysis of Clinical Outcomes

A

Outcome	Odds Ratio (95 % CI)*	*p* -value
Fusion rate	0.68 (0.30 – 1.50)	0.335
Subsidence rate	1.04 (0.33 – 3.22)	0.951
Re-operation rate	1.23 (0.29 – 5.24)	0.777

OR > 1; the event is more common in Ti-PEEK and less common in 3D-Ti.

B

Outcome	Mean Difference (95 % CI)†	*p* -value
VAS Back pain	–0.88 (-2.49 to 0.73)	0.286

†Negative values favour Ti-PEEK (lower pain / disability).