

3D-Printed Titanium Cages Lose Mass and Surface Topography upon Impact

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Introduction: There is a growing appreciation of surface topography in bone formation and an increase in the use of 3D-printing for manufacturing spinal cages to create microscale surface features. Those features may be vulnerable to abrasion and/or delamination during cage impact. The extent of material loss and changes to microscale surface characteristics that occur during surgical manipulation is unknown. Our objective was to quantify the loss of mass and changes in surface topography of 3D-printed titanium interbody cages due to surgical impact.

Methods: Eight surfaces of four 3D-printed titanium modular interbody fusion cages were tested. Cages were impacted into Sawbones models with compression preload of either 200N or 400N using a guided 1-lb drop weight. Mass and surface roughness parameters of each endplate were recorded and compared for differences.

Results: Significant weight loss was observed for pooled data (-0.10 ± 0.08 mg, $p = 0.004$), superior endplate group (-0.12 ± 0.08 mg, $p = 0.031$), 200-N preload group (-0.06 ± 0.02 mg, $p = 0.007$), and 400N preload group (-0.14 ± 0.09 mg, $p = 0.028$). For pooled data comparison, significant post-impact decreases were observed for arithmetic mean roughness (-0.71 ± 0.42 μ m, $p = 0.002$), root-mean-squared roughness (-0.93 ± 0.53 μ m, $p = 0.002$), mean roughness depth (-4.40 ± 2.43 μ m, $p = 0.001$), and total height of roughness profile (-6.08 ± 6.19 μ m, $p = 0.027$), while no significant differences were observed for profile skewness and kurtosis. There were significant changes of almost all roughness parameters in the anterior region of the cage post-impact. There were significant changes in two out of six parameters in the middle, posterior, and central regions post-impact.

Discussion: During benchtop testing replicating physiologic conditions, 3D-printed titanium interbody fusion cages underwent loss of mass and surface topography. There was an endplate- and region-specific post-impact change in roughness parameters. Mass loss and microscale parameter changes were dissimilar for superior and inferior cage surface due to morphologic asymmetry of the vertebral endplates. The anterior surface experienced the largest change in surface parameters post-impact. The generalizability of the study may be limited due to the exclusion of different insertion techniques, cage design, and 3D-printing method.

Significance/Clinical Relevance: Our results have direct implications on future cage designs and suggest that the testing of impact durability and resistance to surgical stresses of 3D-printed implants should be investigated further, standardized, and incorporated into pre-approval testing.

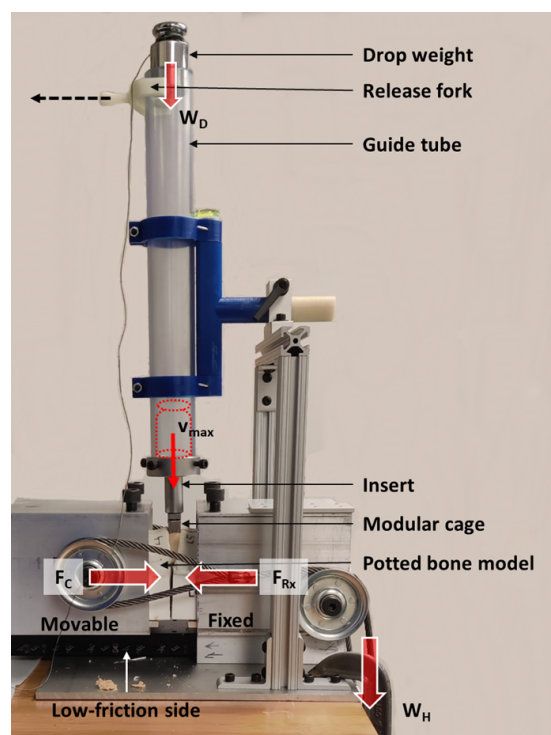


Figure 1: Testing apparatus

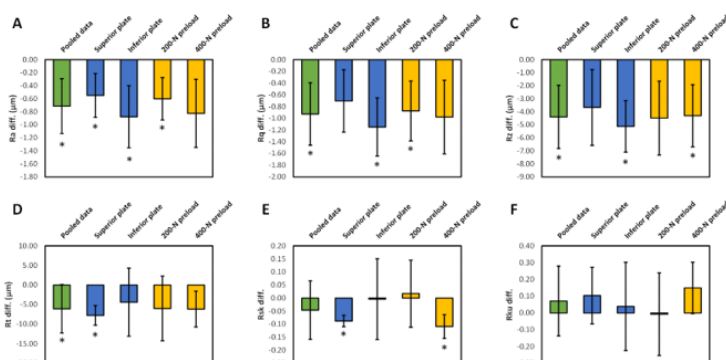


Figure 2: Mean post-impact differences in overall roughness parameters: arithmetic mean roughness [Ra], root-mean-squared roughness [Rq], mean roughness depth [Rz], total height of roughness profile [Rt], profile skewness [Rsk], and profile kurtosis [Rku]. * $p < 0.05$.

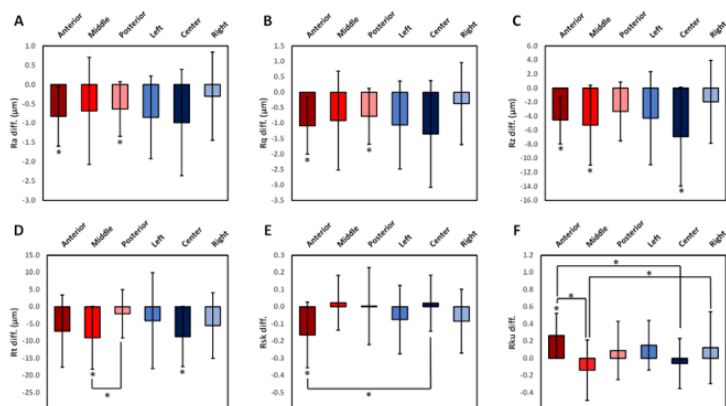


Figure 3: Mean post-impact differences in regional roughness parameters: arithmetic mean roughness [Ra], root-mean-squared roughness [Rq], mean roughness depth [Rz], total height of roughness profile [Rt], profile skewness [Rsk], and profile kurtosis [Rku]. * $p < 0.05$.