# Experimental Evaluation of Endplate-Spanning Expandable Implants for Lumbar Fusion

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INTRODUCTION: Lumbar disc degeneration is a normal part of the aging process that occurs to some degree in all individuals over the age of 35, and in severe cases, can be associated with intense back pain and functional impairment. Anterior lumbar interbody fusion (ALIF) is a surgical procedure that involves fusing two or more lumbar vertebrae to stabilize the spine and relieve pain caused by lumbar disc degeneration. Implant subsidence is a known complication of ALIF that can result from improper positioning and/or incorrect sizing of the implanted cage. Subsidence is defined as decrease in the vertebral disc space prior to complete fusion and can compromise segmental stability, contribute to postoperative pain, and increase the risk of requiring revision surgery. Although previous studies have indicated that maximization of implant contact with the epiphyseal rim is associated with a reduced risk of subsidence, there is a lack of quantitative biomechanical data comparing the performance of expandable versus static implant designs. The current study aims to identify whether using endplate-spanning expandable ALIF implants over standard-sized static implants increases resistance to ALIF subsidence. Given their ability to maximize contact with the epiphyseal rim, we hypothesized that expandable implants would exhibit a greater subsidence load.

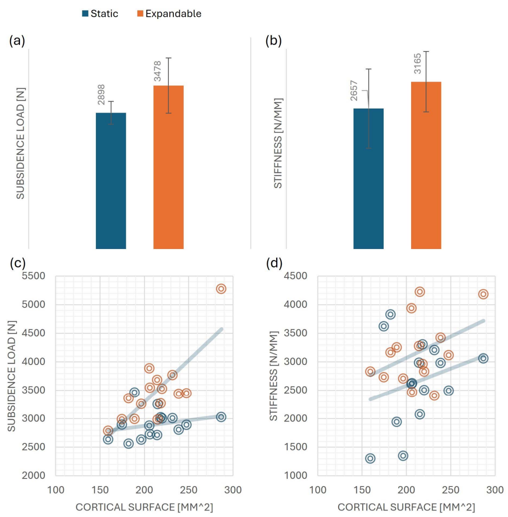
METHODS:

Experimental data were obtained from tests on CT-based surrogates replicating the cortical and trabecular regions of L4 and L5 vertebrae, reconstructed from 15 cadaveric spines (mean age 80 ± 7 years; 40% male, 60% female) using CT scans of the L5 vertebrae, with endplates and the cortical shell isolated from the inner trabecular core. The novel implant was positioned on each bone surrogate in the unexpanded (control) or expanded to match the endplate size (endplate-spanning expandable) and compressed at a rate of 5 mm/min using an Instron 8874 testing system. The subsidence load was recorded as the compression load at 2 mm displacement, and the construct stiffness was evaluated as the slope of the linear portion of the load-displacement curve. Data normality was assessed using the Shapiro–Wilk test, and statistical differences between the two groups were evaluated using paired t-tests or Wilcoxon signed-rank tests, as appropriate.

RESULTS: The experiments demonstrated that endplate-sized expandable ALIF implants, with a subsidence load of 3478 ± 588 N, significantly increased resistance to subsidence compared to static implants, which exhibited a load of 2898 ± 243 N ($p = 0.002$) (Fig. 1a). No difference was found in construct stiffness ($p>0.05$) (Fig. 1b). While subsidence load in the control group showed no correlation with epiphyseal rim surface area, the expandable group demonstrated a significant positive correlation ($r = 0.589$, $p = 0.021$), suggesting that increased rim contact enhances resistance to subsidence (Fig. 1c and 1d).

DISCUSSION AND CONCLUSION:

Increasing resistance to subsidence is paramount in lumbar interbody fusion. This study presents the first quantitative evidence demonstrating the biomechanical advantage of endplate-sized expandable ALIF implants over static implants in resisting subsidence. Our findings indicate that expandable implants designed to maximize epiphyseal rim coverage achieved a 20% increase in subsidence load compared to static implants. This design may offer clinical benefits such as reduced implant inventory, lower costs, and shorter surgical times. Furthermore, the strong correlation between subsidence resistance and epiphyseal rim surface area also suggests potential for CT-based preoperative planning. Although these findings require future studies on cadaveric specimens, the results of this study highlight the potential clinical advantage of expandable, customizable implants in improving resistance to subsidence in spinal fusion.


Static
Expandable
(a)
SUBSIDENCE LOAD [N]
2898
3478
(b)
STIFFNESS [N/MM]
2657
3165
(c)
SUBSIDENCE LOAD [N]
CORTICAL SURFACE [MM^2]
(d)
STIFFNESS [N/MM]
CORTICAL SURFACE [MM^2]