Compression Strength of Human Cervical Endplates in an Anterior Fusion Model

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INTRODUCTION: Anterior cervical discectomy and corpectomy techniques are commonly employed in the treatment of radiculopathy and myelopathy. Occasionally, these procedures are complicated by graft collapse or extrusion, endplate failure, or nonunion. Presently, the optimal compressive force to decrease bone graft extrusion and encourage fusion is not known. Compression is limited by the ability of the endplate to resist without fracture and graft subsidence. We postulate three main variables affecting ultimate failure strength of cervical endplates in anterior fusion procedures: bone geometry, bone quality, and endplate preparation technique. Our measures for geometry included vertebral level and endplate area. Our measures of bone quality included patient age, gender, and bone mineral density (BMD). Endplates were left intact, perforated, or burred.

METHODS: A total of 28 fresh frozen cadaveric cervical spines were obtained. Sixty percent were female; average age at demise was 72 years (range 49-95). Anteroposterior (AP) and lateral radiographs were obtained to exclude lytic lesions or other anomalies. A DEXA scan was then obtained to quantify mineral content at C4. After screening, 21 cadavers were selected for further study.

55 cervical endplates were randomly selected and the endplate cartilage was removed from all specimens. Endplate geometry was calculated using a direct measure of AP width and length. Area was calculated assuming elliptical geometry. A sample was then randomly selected for further endplate preparation, including perforation with a curette or removal with a burr.

A polycarbonate rod fashioned to simulate a typical intervertebral graft was used to load the test subject at a rate of 0.2mm/second on an Instron loading device. Endplate failure was defined as reversal of the force-displacement curve wherein decreasing force was needed to continue to deflect the rod. A stepwise linear regression was then used to compare failure load with bone mineral density, gender, age, vertebral level, endplate geometry, and endplate preparation method.

RESULTS: Mean BMD in these specimens was 0.713 gm/cm2 (range 0.509-1.185). The male specimens had a greater mean BMD (0.8133 gm/cm2) than the female (0.648 g/cm2). However, the male specimens were also, on average, younger (66.2 years vs. 75.8 years). Finally, males had a greater mean maximum load than females (0.911 kN vs. 0.650 kN).

A mean 0.754 kN (range 0.25-1.966 kN) force was required before endplate failure occurred. In the intact specimen, failure was a relatively sudden occurrence (at a mean 0.897 kN) as the cortical endplate gave way. There was continued resistance to rod advancement, however, through the compressive trabeculae of the underlying cancellous bone. Perforated specimens demonstrated a similar pattern of vertebral penetration at a somewhat lower mean force (0.590 kN). Burred specimens exhibited a gradual failure with slow impaction of the subendplate bone. This failure required less force than in either the perforated or intact specimens (0.403 kN).

A stepwise, univariate linear regression was used to compare the point of endplate failure with the vertebral level, endplate area, gender, age, BMD, and preparation technique. Trends toward increasing compression strength were noted with decreasing area and increasing BMD. Increasing age (p = 0.0203), caudal vertebral level (p < 0.0001), endplate burring (p = 0.0068), and female gender (p = 0.0452) were associated with statistically significant lower endplate compression strength. Overall, however, these variables together were only able to account for 48% of the variability in the ultimate load to failure in the specimens tested.

DISCUSSION/CONCLUSION: We theorized that ultimate endplate compression strength could be predicted based on three variables: endplate geometry, bone quality, and endplate preparation method. Endplate geometry may predict endplate compression strength in that strut grafts transmitting axial force closer to the cortical rim of the vertebral body may exhibit higher strength to failure. In our study, larger elliptical area was not significantly related...
to lower endplate compression strength. However, the smaller upper vertebral endplates survived greater loading forces than more caudal levels.

Inferior bone quality, as measured by increasing age and female gender, was also associated with lower compression strength measures. Female gender may also affect vertebral geometry, however, this was not directly measured. BMD measures, via DEXA scanning, did not correlate with endplate compression strength in a statistically significant manner. Cervical DEXA of ex vivo specimens remains technically limited by the lack of a readily available scanner protocol.(6)

More aggressive means of endplate preparation are often used to encourage graft incorporation. However, intact endplates were significantly stronger than their perforated or burred counterparts. In some cases, the endplate strength was significantly higher than that of commonly employed grafts.(7)

Ultimately, our ability to predict endplate compression strength was limited to approximately 50% of the variation encountered. These elderly, cadaveric specimens represent a worst-case scenario. However, in patients with significant osteoporosis, less aggressive methods of endplate preparation and longer term bracing should be considered. Perhaps sizing the graft such that bearing edges lie near the anterior and posterior margins of the vertebral body will increase endplate-bearing capacity.


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