CERVICAL SPINE LOADING CHARACTERISTICS IN A C5 CORPECTOMY MODEL USING A STATIC AND DYNAMIC PLATE

Introduction: Degenerative and traumatic conditions of the cervical spine are often treated surgically with corpectomy and anterior strut grafting. Anterior plates increase the initial stability of anterior cervical spine fusions (ACF), but can result in graft stress shielding. Stress shielding of the graft may be increased if the graft is undersized (due to graft subsidence, resorption or incorrect sizing)\(^1\). Recent work has focused on the ability of an anterior plate to load share with the graft\(^2\), without quantifying load transmission through the posterior elements. Cervical spine trauma often results in disruption of the posterior elements. The impact of posterior element destruction on the overall loading pattern of ACF has not been quantified. The objectives of this study were: 1. To quantify plate, graft and posterior element load transmission in optimal and undersized graft configurations with static and dynamic plating in a C5 corpectomy model. 2. To quantify the changes in graft and plate load when the posterior elements are removed.

Methods: Six fresh-frozen human cervical spines (C3 – C7) were potted and affixed to a materials testing machine (MTS Bionix 858). A C5 corpectomy was performed on each spine, maintaining anatomical specimen height. Optimal graft height and plate size were determined for each specimen from radiographs and verified by physical measurement of the corpectomy site. A height adjustable graft was constructed using a subminiature load cell to allow direct measurement of load transmission through the graft. The dynamic cervical plate (Premier Anterior Cervical Plate, Medtronic/Sofamor-Danek) was instrumented with 2 uniaxial strain gages to allow measurement of the axial load transmitted through the plate. The plate functions dynamically by permitting sliding of the upper screws through slotted holes. To create a static configuration, an additional screw was placed against the upper border of the plate to prevent screw sliding (1 specimen could not be rendered static due to the small height of C4 so that for dynamic results n=6 and for static results n=5). Five configurations were tested for each specimen with the posterior elements intact: 1. Graft only, 2. Plate (dynamic) with optimally sized graft, 3. Plate (rendered static) with optimally sized graft, 4. Plate (static) with graft size reduced by 1mm, 5. Plate (dynamic) with graft size reduced by 1mm. The posterior elements were then removed and two further configurations were tested: 6. Plate (dynamic) with undersized graft, 7. Plate (static) with undersized graft. Following preconditioning, the specimens were loaded in axial compression in each configuration cyclically from –10N to ~90N at a rate of 1 Hz, representing twice the average head weight.

With no posterior elements present, the plate load equals the applied load minus the graft load. This calculated plate load was correlated with the measured plate strain to yield a factor for converting plate strain to plate load. Loads transmitted through the posterior elements were calculated by subtracting the sum of the graft and plate loads from the applied force. The graft load and plate strains for the seven configurations were statistically analyzed using a repeated measures ANOVA design.

Results: Posterior Elements Intact: In the unplated configuration the graft takes 91.2% of the applied load with 8.8% transmitted by the posterior elements (Fig 1). With the attachment of the anterior plate, load is diverted from the graft through both the plate and the posterior elements. When an undersized graft is used in the dynamic configuration, the posterior element load rises significantly from 10.7% of the applied load to 40.9% (p=0.039), while there is no significant increase in plate loading (n=6, p=0.992). In the static configuration reducing graft size, increases posterior element load (20.3% to 38.2%, n=5, p=0.224) and plate load (22.9% to 36.7%, n=5, p=0.028), reducing load transmission through the graft (56.9% to 25.2%, n=5, p=0.062).

Posterior Elements Removed: When the posterior elements are removed, the graft transmits significantly more load when the dynamic plate is used 65.7N as compared to the static configuration 48.7N (n=5, p=0.045). Removing the posterior elements causes no significant change in plate load in either the static (n=5, p=0.898) or dynamic configurations (n=6, p=0.256). Removal of the posterior elements results in a significant change in graft load in the dynamic configuration, from 33.8N to 65.7N (n=6, p=0.028), and in the static configuration from 19.7N to 48.7N (n=5, p=0.066).

Discussion: Axial compressive load sharing in a single level corpectomy model is affected by the type of plate used (dynamic or static), the sizing of the graft and the integrity of the posterior elements. The addition of a plate in a single level corpectomy model results in stress shielding of the graft. A dynamic plate, which allows sliding of the upper screws, increases the percentage of the load carried by the graft and reduces the load carried by the plate, as compared to a static configuration. This trend is statistically significant when an undersized graft is used and when the posterior elements are removed. Undersized graft loading is improved by dynamic plating but does not reach load levels found with an optimally sized graft, thus a dynamic plate cannot compensate for poor grafting technique. The balance of the load in this dynamic configuration is not carried by the plate but rather by the posterior elements.

It is not appropriate to discount the posterior elements in modeling ACF. In a degenerative disease model, the intact posterior elements transmit significant amounts of axial load, particularly if an undersized graft is used. When the posterior elements are removed, as might be representative of a trauma model, this load is diverted almost entirely to the graft. Thus, the strength of the graft used may be more critical in trauma cases.

Rapoff et al\(^2\) used a calf thoracic spine model in which the orientation of the facets effectively precludes load transmission and found the graft load share with a static anterior plate was 41% of the applied 90N load. The comparative figures from our study show 85.5% of the load transmitted by the graft in the no posterior elements configuration when the plate functions dynamically and 62.0% when static. The addition of a blocking screw to prevent sliding of the upper screws was able to adequately represent a static configuration in 5 of the 6 specimens tested. It is possible that this technique did not fully prevent plate sliding. Such a bias in our results would, if present, underestimate the improvement in graft loading due to the motion of the dynamic plate.

With the development of anterior plates, Casper showed that plated anterior procedures provided stability without external or posterior stabilization even in the presence of posterior instability\(^4\). It is now common practice to treat such injuries with corpectomy, anterior strut grafting and plating to achieve an anterior cervical fusion. A better understanding of load transmission though anterior cervical spine fusions is important in graft and plate design and should be considered independently in degenerative fusions and traumatic fusions with posterior element compromise.

Conclusions: The use of a dynamic plate minimizes stress shielding compared to a static plate and compensates to a degree for suboptimal graft height. The posterior elements play a significant role in load transmission, particularly, when an undersized graft is used.


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