Effect of machined interfacet allograft spacers on cervical foraminal height and area

Laboratory investigation

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Object. Iatrogenic foraminal stenosis is a well-known complication in cervical spine surgery. Machined interfacet allograft spacers can provide a large surface area, which ensures solid support, and could potentially increase foraminal space. The authors tested the hypothesis that machined interfacet allograft spacers increase cervical foraminal height and area.

Methods. The C4–5, C5–6, and C6–7 facets of 4 fresh adult cadavers were exposed, and the cartilage was removed from each facet using customized rasps. Machined allograft spacers were tamped into the joints. The spines were scanned with the O-arm surgical imaging system before and after placement of the spacers. Two individuals independently measured foraminal height and area on obliquely angled sagittal images.

Results. Foraminal height and area were significantly greater following placement of the machined interfacet spacers at all levels. The Pearson correlation between the 2 radiographic reviewers was very strong ($r = 0.971$, $p = 0.0001$), as was the intraclass correlation coefficient ($ICC = 0.907$, $p = 0.0001$). The average increase in foraminal height was 1.38 mm. The average increase in foraminal area was 18.4% (0.097 mm^2).

Conclusions. Modest distraction of the facets using machined interfacet allograft spacers can increase foraminal height and area and therefore indirectly decompress the exiting nerve roots. This technique can be useful in treating primary foraminal stenosis and also for preventing iatrogenic foraminal stenosis that may occur when the initially nonlordotic spine is placed into lordosis either with repositioning after central canal decompression or with correction using instrumentation. These grafts may be a useful adjunct to the surgical treatment of cervical spine disease. (<http://thejns.org/doi/abs/10.3171/2013.11.SPINE131>)

KEY WORDS • iatrogenic foraminal stenosis • cervical facet •
interfacet spacer • facet distraction • cervical fusion • cervical foraminal area

Loss of intervertebral disc height, cervical extension, facet hypertrophy, and retrolisthesis of cervical vertebrae can significantly decrease cervical foraminal area and potentially cause compression of the exiting cervical nerve root.^{6,17,18,20,27,33} Patients with loss of cervical lordosis who are repositioned in lordosis after a dorsal decompression are at risk for symptomatic iatrogenic foraminal stenosis, with an estimated incidence ranging from 2.6% to 50%.^{1,12,13,21,29}

An interfacet allograft spacer may be a potentially useful adjunct in the surgical treatment of cervical spine disease, especially in reducing the risk of iatrogenic foraminal stenosis. This study is designed to test the hypothesis that interfacet allograft spacers can increase foraminal height and area in the cervical spine.

Methods

Four fresh adult cadavers were obtained for the study after screening with radiographs and CT scans to ensure the absence of any significant spinal pathology other than age-appropriate degenerative changes. The cervical spine of each cadaver was imaged using the O-arm surgical imaging system (Medtronic) to establish the baseline foraminal dimensions. The C4–5, C5–6, and C6–7 posterior lateral masses of these cadavers were exposed by the senior author. The cartilage from each facet joint was removed using customized elevators and rasps (Facetlift,

This article contains some figures that are displayed in color online but in black-and-white in the print edition.

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Medtronic) (Fig. 1). The machined interfacet allograft spacers (Facetlift, Medtronic) were then tamped into each facet joint (Fig. 2). The spacers were 8 × 8 mm and varied in height from 2 to 4 mm. The height was determined by the anatomy of each joint. The cervical spine specimens were scanned again with the O-arm imaging system after placement of the interfacet allograft spacers.

The images obtained before and after interfacet spacer placement were analyzed by 2 reviewers independently using Onis viewer (Digitalcore). The foraminal height, width, and area before and after interfacet allograft spacer insertion were measured for each level on sagittal images using the Onis cursor (Fig. 3). The software automatically calculated the linear and area values. Averaged measurements from these reviewers were compared using the paired t-test.

Results

The Pearson correlation between the 2 radiographic reviewers was very strong, with $r = 0.971$ ($p = 0.0001$), and the intraclass correlation coefficient (ICC) was 0.907 ($p = 0.0001$). The average foraminal height, width, and area were significantly increased at all levels following insertion of the machined interfacet allograft spacers, as can be seen in Tables 1–3, which present the data acquired from 8 foramina at each level (C4–5, C5–6, C6–7). The overall average foraminal height increase was 1.38 mm. The average height increases were 1.23, 0.85, and 2.05 mm at C4–5, C5–6, and C6–7, respectively. The overall average increase in foraminal area was 18.39% (0.097 mm²). The average area increases were 18.48%, 10.56%, and 26.12% at C4–5, C5–6, and C6–7, respectively.

Discussion

Iatrogenic foraminal stenosis is a well-documented complication in cervical spine surgery, especially in posterior cervical spine fusion with instrumentation.^{1,12,13,21}

FIG. 2. Photograph demonstrating machined interfacet allograft spacers inserted in the facet joints at C4–5, C5–6, and C6–7 in a cadaveric specimen.

This complication may occur when a patient presenting with loss of cervical lordosis is repositioned into lordosis after central canal decompression or undergoes correction of alignment using instrumentation during surgical treatment of cervical spine disease. Lu et al. examined the relationship between intervertebral disc height and foraminal area in a cadaveric study.¹⁸ They found that 1-, 2-, and 3-mm narrowing of the intervertebral disc space corresponded to foraminal area reductions of 20%–30%, 30%–40%, and 35%–45%, respectively. Yoo et al. found that cervical extension of 20° was associated with 10% reduction in foraminal diameter and cervical extension of 30° was associated with 13% reduction in diameter.³³ This is equivalent to reductions in foraminal area of 19% and 24.3%, respectively. In vivo studies by Muhle et al.²⁰ and Kitagawa et al.¹⁷ have also confirmed that cervical ex-

FIG. 1. Photographs of facet elevator (A), 3 × 8 × 8-mm facet rasp (B), initial graft holder (C), and final tamp (D). The instruments have a stop to avoid overinsertion into the joint.

FIG. 3. Left C4–5 foraminal area before (upper) and after (lower) interfacet allograft spacer placement.

tension can significantly reduce the foraminal area. These publications are consistent with our results showing that 1–2 mm of facet distraction significantly increases facet height and area.

Estimates of the risk of developing symptomatic iatrogenic foraminal stenosis from posterior cervical spine fusion range from 2.6% to 50%.^{1,12,13,21,29} The C-5 nerve root is especially prone to injury, and the risk of C-5 palsy has been reported to be 11.6 times greater in patients treated with instrumentation as compared with those without.²⁸ The exact cause of C-5 palsy is unknown, but it is likely multifactorial, with one of the major risk factors being the presence of foraminal stenosis.²¹ Katsumi et al. advocate prophylactic foraminotomy to decrease the incidence of C-5 palsy.¹⁶ However, foraminotomy reduces

TABLE 1: Mean foraminal height before and after interfacet allograft placement

Level	Height in mm*		Increase (mm)
	Baseline	After Graft	
C4–5	10.13 ± 1.84	11.36 ± 1.32	1.23
C5–6	10.18 ± 1.42	11.03 ± 1.24	0.85
C6–7	10.06 ± 1.32	12.11 ± 1.48	2.05
overall	10.12 ± 1.51	11.50 ± 1.40	1.38

* Mean ± SD.

TABLE 2: Mean foraminal width before and after interfacet allograft placement

Level	Width in mm*		Change (mm)
	Baseline	After Graft	
C4–5	5.71 ± 2.33	6.66 ± 2.50	0.95
C5–6	6.09 ± 2.19	5.85 ± 2.06	–0.25
C6–7	5.95 ± 2.32	6.51 ± 2.43	0.56
overall	5.92 ± 2.24	6.34 ± 2.32	0.42

* Mean ± SD.

the amount of bone available for screw purchase and may adversely impact overall stability. The machined interfacet allograft spacer is a facet distraction device with a large surface area that provides solid support for the spinal column and distracts the facet joint, thereby stiffening the spinal segment, which should facilitate arthrodesis.^{5,23} It also increases foraminal height and area, which can indirectly decompress the exiting nerve roots. Goel and Shah have described their experience with titanium interfacet spacers in the treatment of cervical spondylotic myelopathy and radiculopathy,¹⁰ reporting an average of 2.2 mm increase in foraminal height in a group of 36 patients. This finding is consistent with the data from our cadaveric study. Additionally, Goel et al. reported that interfacet distraction produced a significant increase in the facet height, disc height, and interspinous height, as well as reducing buckling of the posterior longitudinal ligament and ligamentum flavum. All of the patients in their series had clinical improvement in myelopathy and radiculopathy. Bony fusion also occurred in all patients. These results suggest that the use of interfacet spacers not only can increase the foraminal area via facet distraction but also can affect overall cervical spine biomechanics by facet arthrodesis and may have favorable effects in the degenerative process. In the setting of mild or moderate foraminal stenosis it is possible that the placement of facet spacers alone may be adequate to relieve clinical symptoms, and they may prevent radiculopathy in patients with asymptomatic severe stenosis.

It is commonly believed that degeneration in the spine begins with loss of water content in the intervertebral disc as part of the aging process, which may lead to loss in disc height, osteophyte formation, spondylolisthesis, facet arthropathy, and ligamentous hypertrophy. These spondylotic changes may lead to compression of

TABLE 3: Mean foraminal area before and after interfacet allograft placement

Level	Area in mm ² *		Increase (%)
	Baseline	After Graft	
C4–5	0.53 ± 0.17	0.63 ± 0.16	18.48
C5–6	0.48 ± 0.10	0.53 ± 0.13	10.56
C6–7	0.55 ± 0.16	0.69 ± 0.18	26.12
overall	0.52 ± 0.14	0.62 ± 0.17	18.39

* Mean ± SD.

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neural elements and clinical signs of radiculopathy and myelopathy. Goel et al. have challenged this widely held perspective and have proposed an alternative theory, in which spinal spondylosis may actually begin with facet instability and the disc degeneration and other spondylotic changes occur secondarily.⁸⁻¹⁰ The support for this alternative hypothesis lies in the reversal of cervical spondylotic changes seen after facet distraction using titanium interfacet spacers in their patients.¹⁰

The facet joint has been shown to be responsible for up to 25% of axial load sharing in the lumbar spine.³² Finite element models of the ligamentous cervical spinal segments have estimated that cervical facet joints can be responsible for up to 23% of axial loading.^{11,22} In addition, the facet joint provides resistance to shearing, distraction, and lateral bending forces, which is important in maintaining the normal biomechanics of the spine.^{4,25,26,34} Similar to other synovial joints, the facet joint can undergo progressive degeneration as a result of aging, inflammation, infection, and mechanical trauma.^{15,19,30} Since the intervertebral disc and facet joint both participate in load sharing in the spine, loss of disc height or spondylolisthesis could change the normal spine biomechanics and theoretically increase the mechanical stress on the facet joint and lead to accelerated facet degeneration.¹⁵ The cartilage in the articulating surface is one of the first components affected in the degeneration process, which can be manifested by cartilaginous loss, sclerosis, exposure of underlying bony pillars, osteophyte formation, synovial cyst formation, and capsule calcification. The degenerative changes eventually occur in the bony articular surfaces of the facet joint. The increase in mechanical stress can stimulate osteoblasts to synthesize bone, forming osteophytes or bone spurs and leading to facet hypertrophy.⁷ Several studies have shown osteophyte formation along the facet capsule attachment where to stress from the hyper-mobile joint is the greatest.^{2,3} The bone on bone contact in a degenerative facet can also lead to pain from both afferent nerves in the facet joint and the inflammatory cytokine leakage from the joint capsule to surrounding tissue.¹⁴ In addition, synovial cyst or facet hypertrophy may also cause direct neural element compression. Facet degeneration can be graded based on CT imaging as described by Pathria et al., where Grade I corresponds to facet joint space narrowing, Grade II corresponds to facet sclerosis or hypertrophy, and Grade III corresponds to osteophyte formation.²⁴

Many patients with cervical myelopathy and radiculopathy have loss of normal cervical lordosis. Surgical management in these cases may require decompression and fusion. Restoration or maintenance of lordosis after decompression is desirable because it facilitates posterior shift of the spinal cord and contributes to normal sagittal balance. As discussed previously, an increase in lordosis can produce a decrease in foraminal area and may result in radiculopathy due to foraminal stenosis. When the anterior approach is used, the interbody graft can add at least 5° of lordosis at each level. Although the increase in intervertebral distance created by the anterior interbody graft may help to increase foraminal height, the relative cervical extension may negate this effect. Significant mul-

tilevel cervical spinal deformities secondary to disease processes such as rheumatoid arthritis may require anterior, posterior, or combined approaches.³¹ In these cases, the use of interfacet spacers may be useful to increase foraminal area, facilitate decompression of the cervical nerve root, and decrease the risk of iatrogenic foraminal stenosis. Interfacet allograft can be used in combination with laminectomy or laminoplasty for management of spinal cord compression. The interfacet allograft spacers also have a large surface area and thus can provide solid support and stability. The axial load placed on the facets also facilitates arthrodesis and bony fusion, and thus may potentially improve overall surgical outcome.

The major limitation of this study is the small sample size. However the high degree of accuracy of our measurement technique mitigates this shortcoming. Further research into foraminal changes after instrumentation and attempted segmental correction would be of interest. Although the surface area available for grafting is larger than normal we do not know from this biomechanical study whether fusion will occur. Nevertheless, our clinical experience has been excellent with a high rate of fusion success when interfacet grafts are used with instrumentation.

Conclusions

Our data confirm the hypothesis that machined interfacet allograft spacers increase cervical foraminal height and area. The modest distraction of the facets produced by the machined interfacet allograft spacers increase the foraminal area and therefore can indirectly decompress the exiting nerve root. These grafts should prevent the foraminal stenosis that may occur when the initially nonlordotic spine is placed into lordosis with either repositioning after decompression or with correction using instrumentation. This is particularly important at C4-5 due to the exquisite sensitivity of the C-5 root. Machined interfacet allografts provide solid support and should be associated with a high rate of arthrodesis since the facets bear axial load that places the grafts under compression. These grafts may be a useful adjunct to the surgical treatment of cervical spine disease and may help to reduce incidence of iatrogenic foraminal stenosis.

Disclosure

This study was funded by Medtronic. In addition, Dr. Traynelis reports having a consultant and patent holder relationship with Medtronic and receiving institutional fellowship support from Globus Medical. Dr. Anderson reports having an ownership interest in Pioneer Surgical, SI Bone, Spartec, Expanding Orthopedics, and Titan Surgical; having a consultant relationship with Pioneer Surgical, Aesculap, and Medtronic; and receiving royalties from Stryker and Pioneer Surgical.

Author contributions to the study and manuscript preparation include the following. Conception and design: Traynelis. Acquisition of data: Traynelis, Tan, Gerard. Analysis and interpretation of data: Traynelis, Tan, Gerard. Drafting the article: Tan. Critically revising the article: all authors. Reviewed submitted version of manuscript: all authors. Approved the final version of the manuscript on behalf of all authors: Traynelis. Statistical analysis: Traynelis. Study supervision: Traynelis.

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