

Machined cervical interfacet allograft spacers for the management of atlantoaxial instability

ABSTRACT

Background: The use of cervical interfacet spacers (CISs) to augment stability and provide solid arthrodesis at the atlantoaxial joint has not been studied in detail. The aim of this work is to report the outcomes with the use of machined allograft CISs at C1-2.

Methods: A retrospective review of 19 patients who underwent an atlantoaxial fusion with the use of CISs was performed. All patients had instability documented with flexion and extension lateral radiographs. This instability was due to trauma, degenerative stenosis, symptomatic C1-2 arthropathy, and os odontoideum. Clinical and radiological outcomes were assessed. Fusion was determined based on a lack of hardware failure, absence of motion on flexion and extension plain X-ray films, and presence of bridging trabecular bone which was most often demonstrated by a computed tomography.

Results: The mean age was 69.1 ± 12.9 years. Eight patients had traumatic fractures, six patients had degenerative stenosis, two patients had C2 neuralgia due to C1-2 arthropathy, two patients had C1-2 ligamentous subluxation, and one patient had an unstable os odontoideum. The occiput or subaxial spine was included in the arthrodesis in 10 patients. Rib autograft was utilized in most patients. No patient had postoperative neurological worsening, malposition of hardware, or vertebral artery injury and there were no mortalities. The fusion rate was 95%. The mean follow-up was 12.1 ± 5.5 months.

Conclusions: CIS is a promising adjuvant for the treatment of atlantoaxial instability.

Keywords: Atlantoaxial instability, cervical interfacet spacers, cervical spine, C1-2

INTRODUCTION

A major aim of all spinal fusion procedures is to achieve a solid bony union across the operated level(s). Atlantoaxial arthrodesis is particularly challenging since this segment is the most mobile joint in the spine.^[1] Significant advancements in the posterior atlantoaxial fixation techniques have been made in the past decades which have improved the rate of fusion success.^[2-7] Goel^[8] introduced the use of intra-articular spacers for distraction-reduction-stabilization of the atlantoaxial joint and subaxial cervical spine.^[9,10] (US Patent No. 9668783 B2 - Goel - Devices and method for spondylotic disease) This concept was based on the hypothesis that facet instability is a primary cause of atlantoaxial instability and also cranial settling.^[11] Titanium spacers, corticocancellous autograft and allograft have been placed into the atlantoaxial joint space. Aryan *et al.*^[12] described the use of commercially

made fibular graft spacers to fill the joint and restore height at C1-2. Following Goel's report, others have removed the C1-2 joint cartilage and filled the space with bone (either allograft or autograft) or a cage.^[13,14] Distraction of the C1-2 facets provides an opportunity to treat anterior cervico-medullary compression by reducing the cranial settling.^[15]

We have used machined cortical allograft interfacet spacers (cervical interfacet spacer [CIS]) with polyaxial screw and rod

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fixation for atlantoaxial fusion in patients with instability in the absence of cranial settling. These grafts provide a large osteoconductive surface, maintain adequate distraction, and are under compression.

Our group has demonstrated that subaxial CIS can increase foraminal height and area and maintain cervical lordosis.^[16,17] We have also found the use of CIS to be useful in the management of patients with symptomatic anterior cervical pseudarthroses.^[18] The aim of this study is to report outcomes with the use of CIS at C1-2 for patients with atlantoaxial instability in the absence of basilar invagination.

METHODS

This is a retrospective review of patients that underwent posterior atlantoaxial fixation by the senior author (V.C.T) from 2012 to 2015 at Rush University Medical Center in whom CISs were used as an adjunct to treat C1-2 instability without cranial settling. All patients also underwent C1–C2 posterior screw fixation according to the method originally described by Goel and Laheri^[2] and modified by Harms and Melcher.^[3] The indications for surgery were C1-2 instability due to trauma, degenerative stenosis, C1-2 arthropathy, and os odontoideum. All patients had evidence of instability on flexion and extension studies. Pre- and post-operative clinical and radiological outcomes were reviewed. All patients had magnetic resonance imaging and computed tomography (CT) scans to document the anatomical details including the position of the vertebral artery. All patients were immobilized in a rigid orthosis for 6 weeks following surgery.

Patients were followed up at 6 weeks, 3 months, 6 months, and 1 year postoperatively. Flexion and extension radiographs were obtained at each follow-up visit beginning at 6 weeks postoperatively. A CT scan was obtained in patients at 1 year postsurgery to verify fusion. Fusion was determined based on a lack of hardware failure, absence of motion on flexion and extension plain X-ray films, and presence of bridging trabecular bone by CT [Figure 1].

Surgical technique

All procedures were performed under general endotracheal anesthesia, with the head secured with a Mayfield clamp and the patient positioned prone using fluoroscopic guidance. Intraoperative monitoring was employed in select cases (patients with significant spinal cord compression at C12) to verify no neurophysiological change when the proper anatomical position was achieved. A midline incision was made and a subperiosteal dissection was utilized to expose the posterior arch of C1 and the posterior elements of C2.

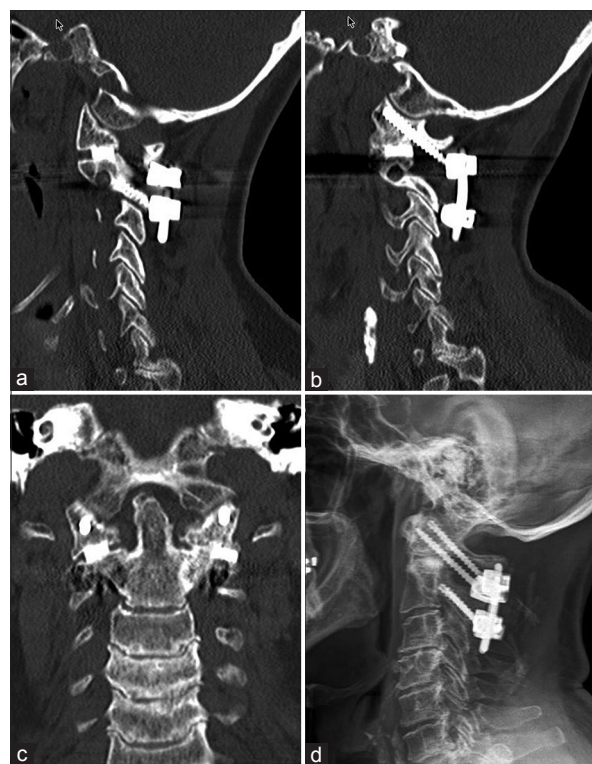


Figure 1: (a and b) Right and left parasagittal and (c) coronal computed tomographic scans images of a patient who underwent C1-2 fusion with placement of cervical interfacet spacers. (d) Postoperative cervical radiographs showing good evidence of bony fusion across the facet joints

Depending on the need for further fixation, the occiput or the subaxial spine was exposed. The C2 nerve root was sectioned proximal to the C2 ganglion in all cases to facilitate clear access to the joint.^[19,20]

The C1-2 facet cartilage was removed using customized rasps. All the rasps had an 8 mm × 10 mm width and depth and varied in height (4–6 mm). All 8 mm × 8 mm × 2 mm rasps were initially used in cases of significant joint collapse. The rasps were increased in size until a very tight fit was achieved. The size of the final rasp determined the size of the implant. Each rasp was used twice before attempting the next size. Occasionally, a small-angled curet was used to help remove cartilage. After rasping each facet articulation, a machined cortical allograft (FacetLift, Medtronic, Memphis) was tamped into place. C1 and C2 polyaxial screws (Vertex, Medtronic, Memphis) were placed and connected to each other with rods. Patients with a competent C1 posterior arch underwent augmentation of the fixation and additional grafting utilizing the interspinous wiring technique.^[21] When using this technique, it is important to tighten the cable before locking down the rod on the screws. One gram of vancomycin powder was placed into the wound before closure. The incision was closed in layers over a wound drain.

RESULTS

Patient demographics

There were 11 females and 8 males with a mean age of 69.1 ± 12.9 years. The mean body mass index was 26.4 ± 6.3 kg/m². Indications for surgery included C2 fracture in eight patients, degenerative myelopathy in six patients, C2 neuralgia with C1-2 arthropathy in two patients, C1-2 ligamentous subluxation in two patients, and unstable os odontoideum in one patient. Of the 19 cases, nine cases had fusion at C1-2 alone and 10 cases included the occiput or subaxial spine [Table 1].

Table 1: Summary of patient characteristics of 19 patients in whom C1-C2 interfacet-machined cortico-cancellous allografts were inserted

Clinical demographics	Number
Age	
Female	11
Male	8
Years	
Average	69.1 ± 12.9
Range	35-91
BMI	
Average	26.4 ± 6.3
Range	16.4-41.4
Indication for surgery	
Trauma (C1/C2 fracture)	8
Degenerative myelopathy	6
C2 neuralgia with C1-C2 arthritis	2
C1-C2 ligamentous subluxation	2
Os odontoideum	1
Previous surgery	
C1-C2 posterior fusion	1
Anterior subaxial	1
Posterior subaxial	1
Surgical parameters	
C1-C2 fusion alone	9
Inclusion of occiput/subaxial spine	10
Bone graft	
Autograft rib	16
Allograft iliac crest	3
BMP used	5
Neuromonitoring used	4
Atlantoaxial wiring done	4
Estimated blood loss (mL)	
Average	637.5 ± 491.4
Range	50-1600
Operating time (min)	
Average	255.1 ± 126.8
Range	136-561
Follow-up (months)	12.1 ± 5.5 (3-24)
> 6-month follow-up	18/19 (95%)
Average follow-up	12.7 ± 5.2

BMI - Body mass index; BMP - Bone morphogenetic protein

Operative results

Neuromonitoring was used for positioning in four patients. Sixteen patients had a rib harvest autograft and iliac crest allograft was utilized in three patients. Recombinant human bone morphogenetic protein (Infuse, Medtronic, Memphis, TN) was used in five patients who had multiple comorbidities, which would adversely affect the fusion rate. Atlantoaxial cable fixation with a graft was done in four patients.

Fusion rate

The mean follow-up was 12.7 ± 5.2 months. Of the 18 patients with follow-up >6 months, 17 (94%) patients demonstrated successful arthrodesis on either CT or plain lateral flexion-extension radiographs. One patient who did not develop solid arthrodesis remained asymptomatic at last follow-up with complete resolution of his pain [Table 2].

Complications

There were no neurologic or vascular injuries or screw malposition. Seven patients did experience C2 numbness and one patient had mild C2 neuralgia. There were one wound infection and one cerebrospinal fluid leak [Table 2].

DISCUSSION

Rationale for the use of cervical interfacet spacers

Given its relatively large size and surface area, biomechanical strength, and firmness, the C1-2 facet is a strategic location for fusion. The use of machined cortical allografts, especially designed for placement in the C1-2 joints, provided solid fusion in all but one of our patients. The natural compressive forces applied by the weight of the head and the ligaments surrounding the C1-2 joint create an ideal environment for fusion. The spacers stiffen the segment when deployed bilaterally^[22] and help facilitate load-bearing fusion.^[23] The facet cartilage must be completely removed, and modest decortication and interpositioning of bone graft into the joint space may make an important contribution to the fixation properties by increasing friction.^[24]

Distraction of the interspace improves the stability of the atlantoaxial complex because of the increased tension of ligamentous structures of the atlantoaxial joint when the spacer is inserted within the joint.^[25] An important advantage of CIS is that they can be used in patients with an incompetent or absent the C1 posterior arch which precludes interspinous wiring and lessens the area for placing graft substrate.^[26] This was the case for the majority of the patients reported in this communication. The augmented stability provided by the spacers obviates the need to extend the fusion to the occiput in some cases.^[27]

Table 2: Surgical outcomes

Surgical outcomes	Number (percentage)
Successful fusion in patients with >6 months follow-up	17 (94%)
Complications	
Neurologic injury	0
Screw malposition	0
C2 numbness	7
C2 neuralgia	1
Vertebral artery injury	0
Wound infection	1
CSF leak	1
Donor-site morbidity	0
Revision surgery	1 (wound infection) 1 (extension to occiput)
Mortality	0

CSF - Cerebrospinal fluid

Biomechanical studies

Daniel *et al.*^[22] investigated the biomechanics of the posterior realignment of the craniovertebral junction and also made comparisons with different methods of obtaining posterior fixation in cadaveric specimens. Stand-alone interfacet spacers at C1-2 provided stability in all three loading modes – flexion-extension, lateral bending, and axial rotation. Posterior screw and rod fixation increased the stability as compared to stand-alone spacers. The third point of fixation, carried out using midline wiring, increased the stability further. However, there was no significant difference in the stability imparted by the three methods. Cadaveric models do not provide muscular support, and most testing is done acutely as compared to after fatigue and these issues may impact the findings. Goel^[8] proposed that interfacet spacers could provide enough stability to be used as a stand-alone technique in select cases; however, we are reluctant to use CIS without posterior instrumentation, especially at the atlantoaxial joint.

In another biomechanical study, Park *et al.*^[28] showed that the placement of interfacet spacers at C1-2 combined with placement of a screw/rod construct resulted in additional construct rigidity beyond the screw/rod technique and appeared to be more useful in very unstable cases. The spacers added significant stability to the screws and rods alone in axial rotation and lateral bending. This load sharing is particularly important in patients with osteoporosis.

Contrary to the previously noted work, Li *et al.*^[25] performed a cadaveric biomechanical study using a spacer, which the authors called a “fusion cage” and reported no increased stability compared with the C1–C2 pedicle screw and rod fixation alone. In certain directions, paradoxically, the range of motion after destabilization was smaller when compared with previously published data. The authors speculated that

the differences might have resulted from performing the ligamentous disruption without odontoidectomy.

Interfacet spacer material

All patients in this study were treated with allograft spacers. Goel^[1,8,29] reported using custom-made titanium spacers. However, in a recent editorial, Goel acknowledged that “opening of the joints and denuding of articular cartilage and subsequent introduction and packing of bone graft within the joint not only can provide distraction, realignment, and fixation and a material for bone fusion but also can avoid the need for placement and impaction of metal spacers within the joint.”^[29]

Aryan *et al.*^[12] used fibular spacers in the C1-2 joint in 39 patients. All patients demonstrated bridging bone across the joint space on plain X-ray films and CT. Simsek *et al.*^[30] used demineralized bone matrix combined with allograft spacers to increase the fusion rate after reduction of the deformities. They did not mention details of the spacers since the study focused on accuracy of atlantoaxial screw placement, but all patients achieved adequate fusion at 1 year.

Salunke *et al.*^[31-33] described a technique of facet drilling in cases of congenital irreducible atlantoaxial dislocation where the reduction was maintained with the use of spacers (bone alone or metallic spacers packed with bone) and C1-2 was fused using sublaminar wires or polyaxial screws. Chandra *et al.*^[34,35] used polyetheretherketone spacers in patients with atlantoaxial instability, but the majority of the patients in their experience had significant basilar invagination or complex congenital deformities.

C2 neuropathy and interfacet spacers

While trauma and degenerative myelopathy are the most frequent indications for C1-2 fusion, an underemphasized indication is C2 or occipital neuralgia due to arthritis of the C1-2 joint.^[11] Sectioning the nerve and fusing the joint with the use of CIS has resulted in recovery of pain in all our cases and is a very gratifying operation. Recently, Yeom *et al.*^[36] described a novel technique in 15 patients for the same condition preserving the C2 root and causing interfacet distraction with an autogenous iliac corticocancellous block. If the autogenous bone block was not strong enough, an allogeneic cortical bone block, which was originally produced for open-door laminoplasty, was reshaped using a high-speed burr and inserted. The typical size of the reshaped bone block was 8 mm × 10 mm in width and 4–6 mm in height, sufficient to decompress the root by causing distraction. For posterior fixation, they used C1 posterior arch screws rather than lateral mass screws, concerned that the latter would irritate the C2 nerve root. This technique demonstrated a greater reduction in pain compared to a different cohort of eight patients, in which the C2 root was sectioned.

CONCLUSIONS

CIS is a promising adjuvant for the treatment of atlantoaxial instability. It allows for a solid fusion, particularly when the posterior elements of C1 are incompetent. Furthermore, CIS placement stiffens the segment, which can help load share with instrumentation, particularly when there is osteoporosis.

Declaration of patient consent

The authors certify that they have obtained all appropriate patient consent forms. In the form the patient(s) has/have given his/her/their consent for his/her/their images and other clinical information to be reported in the journal. The patients understand that their names and initials will not be published and due efforts will be made to conceal their identity, but anonymity cannot be guaranteed.

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Nil.

Conflicts of interest

Dr. Traynelis is a consultant for Medtronic and he also receives royalties from Medtronic. The Rush University Neurosurgical Spine Fellowship receives institutional support from AO and Globus. The other authors report no disclosures.

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