Artificial atlantoaxial and subaxial facetal joint - Proposal of models

Atlantoaxial and subaxial facetal articulation is the fulcrum of all major spinal movements. The muscles that facilitate lifelong standing human posture are located on the back of the spine, and their activity is focused on the facets that form the fulcrum of movements. On the other hand, only thin strands of muscles are located on the ventral aspect of the spine in relationship with the vertebral body, intervertebral disc, and odontoid process. Incompetence of the muscles related to their disuse, abuse, or injury results in instability of the spinal segment that is first manifested at the facets. In 2010, we identified that rather than disc degeneration or disc space reduction, it is “vertical” spinal instability related to muscle weakness that is the nodal point of pathogenesis of spinal spondylosis.\textsuperscript{[1-3]} Stabilization or fixation of the facets, ultimately aiming at arthrodesis of the spinal segments, formed the basis of treatment of degenerative spinal disease. Our proposed philosophy has the potential for revolutionizing the surgical treatment of degenerative spinal disease.\textsuperscript{[1-13]}

Atlantoaxial joint is the most mobile joint of the entire spine and is potentially most liable to become unstable. From our experience in the field of nearly 40 years, it appears that atlantoaxial instability is an under-recognized and under-treated clinical entity. Identifying atlantoaxial instability and fixing the atlantoaxial joint and aiming at its arthrodesis form one of the most daunting surgical challenges. Successful stabilization of an unstable atlantoaxial joint is a remarkably gratifying surgical procedure. On the other hand, any complication can have serious consequences for limb function and life activity.

Atlantoaxial joint is a flat and round joint, as no other joint in the spine, and caters to circumferential movements of the region.

Atlantoaxial instability can be anteroposterior, rotational, lateral, and vertical, or it is essentially circumferential.\textsuperscript{[14-18]} In chronic situations, atlantoaxial joint can be unstable even when the facets are in alignment, there is no atlantodental interval disturbance, and there is no evidence of neural or dural compression. We have labeled such instability as central or axial atlantoaxial instability.\textsuperscript{[18,19]}

The subaxial facets have a smooth cup and shallow saucer shape. The orientation and angulation of the facetal articulation vary in cervical, dorsal, and lumbar spines.

In 2004, we first proposed intra-articular atlantoaxial implants that were used to provide stability to the region in addition to distraction of the facet.\textsuperscript{[20]} The net effect was reduction and fixation of the joint, and the procedure was ultimately aimed for atlantoaxial arthrodesis. We introduced similar intra-articular spacer implant for subaxial spine.\textsuperscript{[21,22]} The facetal distraction technique for degenerative spinal disease introduced a new hypothesis, regarding the nodal point of generation of spinal spondylotic disease and its subsequent secondary consequences.

The question to be answered is can mobility of the joint be retained or restored while affecting stabilization of atlantoaxial and subaxial spinal segments. Although artificial joints have been successfully deployed in various joints of the body – most popularly in the knee joint, deployment in the most mobile atlantoaxial joint of the body and subaxial facetal articulation has not received any significant success and the concept has not even received universal acceptance. Isolated attempts have been made to restore movements by providing an “artificial joint”. However, considering the surgical complexities in the region, potential of failure, and possibility of devastating complication such efforts have not made real
headway in such a management protocol. Search for an ideal implant that can provide for both stability and mobility in addition to safety is still ongoing, albeit on a slow pace.\cite{23,24}

We modified our subaxial spinal intra-articular facetal spacers and introduced a ball-and-socket–type articulation. Although not deployed clinically, such artificial joints have a potential of providing for both mobility and stability to the spinal segment. We propose that the same implants that are used for subaxial spinal facets can be effectively used for atlantoaxial joint.

Our current philosophy for atlantoaxial and subaxial spinal instability is to achieve fixation with the aim of arthrodesis. The techniques of achieving arthrodesis have been developed and perfected over the years. However, keeping the aim of retaining or restoring movements of the region, we continued our attempts to improve our implant and develop it to make it suitable, safe, and simple for implantation in the region. In 2012, we proposed a specially designed implant with a ball-and-socket configuration.\cite{23,24} The implant allows the possibility of circumferential movements at the atlantoaxial and subaxial spinal joints.

The implant that may reach the level of universal acceptability has to be necessarily safe and simple to introduce, sturdy, strong, and lasting, apart from being functionally able to provide optimum and closest to normal movements of the neck.

We present two models of implants that may be suitable options for deployment as artificial atlantoaxial and subaxial facetal joints [Figures 1-2]. In addition to providing distraction, stabilization, and reduction of unstable and dislocated facets, they have the potential of allowing movements. The implants have not yet been clinically tested but do have a potential of facilitating the twin function of mobility and stability.

Figures 1 and 2 illustrate the implants. As can be seen, the implant comprises upper (rostral) and lower (caudal) plates. Both these plates have arrangement that allows it to be firmly fixed with the underlying bone. The outer surface of the plate that is in proximity to the facetal bone surface has ragged edges for stabilization. The articular surface has a ball-and-socket–type joint that permits movements in x, y, and z axes.

![Image of the implant (Prototype I). (a) Lateral profile (A), superior view (B), and joint view (C) of the implant. The implant comprises upper (rostral) and lower (caudal) plates. Both these plates have arrangement that allow it to be firmly fixed with the underlying bone. The outer surface of the plate that is in proximity to the facetal bone surface has ragged edges for stabilization. The articular surface has a ball-and-socket–type joint that permits movements in x, y, and z axes. (b) End on view (A) of the implant showing the ball-and-socket joint. B and C showing the mobility of the implant with the ball-and-socket joint. (c) A and B showing the lateral movement of the implant](image-url)
Goel: Artificial facetal articulation

The critical issue that needs to be addressed in such a design is to avoid excessive or more than normal movements of the neck. A locking device that can prevent such excessive movements is under design.

Although the proposed models can have clinical implications in the future, further evaluation and studies are necessary. Moreover, biomechanical studies on the subject are necessary to confirm their viability and effectiveness. Ethical considerations in duly applying these experimental models in humans have to be evaluated.

ATUL GOEL1,2,3

1Department of Neurosurgery, Lilavati Hospital and Research Center, 2Department of Neurosurgery, R. N. Cooper Hospital and Medical College, 3Department of Neurosurgery, Bombay Hospital Institute of Medical Sciences, Mumbai, Maharashtra, India

Address for correspondence: Dr. Atul Goel, Department of Neurosurgery, Lilavati Hospital and Research Center, Bandra, Mumbai, Maharashtra, India. E-mail: atulgoel62@hotmail.com

REFERENCES

1. Goel A. Facet distraction spacers for treatment of degenerative disease of the spine: Rationale and an alternative hypothesis of spinal degeneration. J Craniovertebr Junction Spine 2010;1:65-6.
2. Goel A. Facet distraction-arthrodesis technique: Can it revolutionize spinal stabilization methods? J Craniovertebr Junction Spine 2011;2:1-2.
3. Goel A. Vertical facetal instability: Is it the point of genesis of spinal spondylotic disease? J Craniovertebr Junction Spine 2015;6:47-8.
4. Goel A. 'Only fixation' as rationale treatment for spinal canal stenosis. J Craniovertebr Junction Spine 2011;2:55-6.
5. Goel A. Only fixation for cervical spondylosis: Report of early results with a preliminary experience with 6 cases. J Craniovertebr Junction Spine 2013;4:64-8.
6. Goel A. Alternative technique of cervical spinal stabilization employing lateral mass plate and screw and intra-articular spacer fixation. J Craniovertebr Junction Spine 2013;4:56-8.
7. Goel A, Shah A, Patni N, Ramdasi R. Immediate postoperative reversal of disc herniation following facet distraction – fixation surgery: Report of 4 cases. World Neurosurg 2016;94:339-44.
8. Goel A, Dharurkar P, Shah A, Gore S, More S, Ranjan S. Only spinal fixation as treatment of prolapsed cervical intervertebral disc in patients presenting with myelopathy. J Craniovertebr Junction Spine 2017;8:305-10.
9. Goel A, Dharurkar P, Shah A, Gore S, Bakale N, Vaja T. Facetal fixation arthrodesis as treatment of cervical radiculopathy. World Neurosurg 2019;121:e875-81.
10. Goel A. Not neural deformation or compression but instability is the cause of symptoms in degenerative spinal disease. J Craniovertebr Junction Spine 2014;5:141-2.
11. Goel A. Beyond radiological imaging: Direct observation and manual physical evaluation of spinal instability. J Craniovertebr Junction Spine 2017;8:88-90.
12. Goel A, Vaja T, Shah A, Rai S, Dandpat S, Vutha R, et al. Outcome of osteophytes after only-fixation as treatment for multilevel cervical spondylosis-A minimum of 12 months follow-up. World Neurosurg 2021;146:e876-87.
13. Goel A, Dandpat S, Shah A, Rai S, Vutha R. Muscle weakness-related spinal instability is the cause of cervical spinal degeneration and spinal stabilization is the treatment: An experience with 215 cases surgically treated over 7 years. World Neurosurg 2020;140:614-21.
14. Goel A, Laheri V. Plate and screw fixation for atlanto-axial subluxation. Acta Neurochir (Wien) 1994;129:47-53.
15. Goel A, Shah A, Rajan S. Vertical mobile and reducible atlantoaxial dislocation. Clinical article. J Neurosurg Spine 2009;11:9-14.
16. Goel A, Nadkarni T, Shah A, Ramdasi R, Patni N. Bifid anterior and posterior arches of atlas: Surgical implication and analysis of 70 cases. Neurosurgery 2015;77:296-305.
17. Goel A, Shah A. Lateral atlantoaxial facet dislocation in craniovertebral region tuberculosis: report of a case and analysis of an alternative treatment. Acta Neurochir (Wien) 2010;152:709-12.
18. Goel A. A Review of a new clinical entity of ‘central atlantoaxial instability’: expanding horizons of craniovertebral junction surgery. Neuropsone 2019;16:186-94.
19. Goel A. Goel’s classification of atlantoaxial “facetal” dislocation. J Craniovertebr Junction Spine 2014;5:3-8.
20. Goel A. Atlantoaxial joint jamming as a treatment for atlantoaxial dislocation: a preliminary report. Technical note. J Neurosurg Spine 2007;7:90-4.
21. Goel A, Shah A. Facetal distraction as treatment for single- and multilevel cervical spondyloitic radiculopathy and myelopathy: A preliminary report. J Neurosurg Spine 2011;14:689-96.
22. Goel A, Shah A, Jadhav M, Nama S. Distraction of facets with intraarticular spacers as treatment for lumbar canal stenosis: Report on a preliminary experience with 21 cases. J Neurosurg Spine 2013;19:672-7.
23. Goel A. Artificial atlantoaxial joint: Is it a possible option? J Craniovertebr Junction Spine 2015;6:147-8.
24. Goel A. Letter to the Editor. Artificial atlantoaxial joint. J Neurosurg Spine 2018;29:729-31.