Original Article

An experience with Goel-Harms C1-C2 fixation for type II odontoid fractures

ABSTRACT

Objective: Type II odontoid fractures need surgical stabilization for disabling neck pain and instability. Anterior odontoid screw fixation is a well-known technique. However, certain patients require posterior fixation. We present our surgical results and experiences with nine cases managed by the Goel-Harms technique.

Materials and Methods: This is a retrospective review of nine patients operated on between January 2019 and December 2021 for Type II odontoid fractures with posterior fixation technique. Their clinical profile was collected from case files. The radiological data were retrieved from radiology archives. The indications for surgery were instability and refractory neck pain. The surgical decision for posterior fixation was guided by fracture morphology.

Results: The mean age of presentation was 37.22 ± 9.85 years. Seven patients had Type II, and two had Type IIa odontoid fracture. All patients presented with unbearable neck pain. One patient had a quadriparesis. The fracture line was anterior-inferior sloping in six, posterior-inferior sloping in two, and transverse in one case. The anterior-posterior displacement of fracture ranged from 0 to 7 mm (mean 2.44 ± 2.18 mm). Partial transverse ligament tear without the Atlanto Axial Dislocation was present in three patients. The C1-C2 joint distraction was required in five cases. C1-C2 joint spacer was required in two cases. Following surgery, neck pain was relieved in all cases. Complete fracture alignment was achieved in eight patients. There were no postoperative complications. At the mean follow-up of 16.22 ± 9.61 months, there was no implant failure.

Conclusions: Posterior C1-C2 fixation by the Goel-Harms technique is an excellent alternative to anterior fixation in selected cases.

Keywords: C1-C2 fixation, Goel-Harms technique, odontoid fracture, posterior fixation

INTRODUCTION

Odontoid fracture constitutes about 10%–20% of cervical spinal cord injuries.[1,2] Anderson and D'Alonzo classified these fractures into three types based on the fracture line. Type II fractures are most common, and fracture line passes through the body of dens. Although there is no randomized control trial comparing the surgical and conservative treatment modality, the surgical intervention led to early stabilization and complete healing.[3,4] These Type II fractures require careful evaluation and significant neck pain and instability demand surgical intervention. Anterior odontoid screw fixation is a well-known technique for managing type II fractures. However, there are certain patients in which anterior odontoid screw fixation is difficult and requires alternative methods. In the literature, many posterior fixation techniques for managing complex odontoid

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fractures are well described.[5-7] We present our experiences with nine such cases managed by posterior C1-C2 fixation (Goel-Harms technique) in our institute.

MATERIALS AND METHODS

We retrospectively reviewed our operative data from January 2019 to December 2021 in managing Type II odontoid fractures with the posterior fixation technique. During this period, a total of 21 patients underwent surgical management for odontoid fractures. A total of 9/21 patients with Type II odontoid fracture were managed with the posterior fixation technique. Their clinical profile was collected from case files. The radiological data were retrieved from radiology archives. All patients were managed surgically with the Goel-Harms technique. The indications for surgery were instability and refractory neck pain. The surgical decision for posterior fixation was guided by fracture morphology. Those with anterior-inferior sloping fracture line were considered for posterior fixation. Some cases with posterior inferior fracture line with tear of transverse ligament were also selected for the posterior fixation. An intraoperative traction was applied and C1 lateral mass screws and C2 pedicle polyaxial screws were placed and connected with the rods. In cases where the traction did not achieved fracture alignment, C1-C2 joint manipulation with or without spacer was done. The following variables were recorded – age, gender, clinical presentation, type of fracture, the orientation of fracture line, anterior-posterior displacement, vertical displacement, transverse ligament status, associated Atlanto Axial Dislocation, postoperative Goel's clinical grade,[8] radiological alignment, and duration of follow-up. An in-person follow-up was conducted in January 2022 and informed consent was obtained. Statistical analysis was done with JASP software (version 0.14.1.0, Amsterdam). Continuous variables were expressed as mean ± standard deviation.

RESULTS

The mean age of presentation was 37.22 ± 9.85 years. The age range of the patients was 23–52 years. There were eight males and one female. Seven patients had Type II odontoid fractures, and two had Hadley's Type IIa odontoid fractures. All patients presented with unbearable neck pain. The typical history was an increase in neck pain on neck movement, especially during a posture change from supine to recumbent. Neurological deficit in the form of quadriparesis was present in one case (Goel's Grade 4).

The fracture morphology was anterior inferior sloping in six cases, posterior-inferior sloping in two cases, and transverse in one case. The anterior-posterior displacement of fracture ranged from 0 to 7 mm (mean 2.44 ± 2.18 mm). The vertical displacement ranged from 0 to 2 mm (mean 1.00 ± 0.70 mm). Partial transverse ligament tear was seen on the magnetic resonance imaging in three patients, but none was associated with an atlantoaxial dislocation. In three patients, fracture alignment was tried in supine position for an anterior odontoid screw placement, but failing so, the decision was changed in favor of posterior fixation. Multiple skin lacerations with a contaminated neck wound restricted the anterior approach in one patient with a transverse fracture line. One patient was previously operated at another center with anterior plate and screw fixation with implant failure and instability. The C1-C2 joint distraction was required in five cases for fracture alignment. C1-C2 joint spacer was needed in two patients with Grade IV listhesis. Following surgery, neck pain was relieved in all cases. Complete fracture alignment was achieved in eight patients. Complete alignment was not achieved in one case of Grade IV listhesis and bone loss. There were no postoperative complications [Table 1]. A degree of restriction of neck movements was found in all patients. There was no implant failure at a mean follow-up of 16.22 ± 9.61 months (range 4–33 months). For illustration, four different fracture morphologies are showcased in Figures 1-4, respectively.

DISCUSSION

Fracture biomechanics

The odontoid process acts as an axis for atlantoaxial joint movement. Odontoid fractures result from high-velocity forces in the young and may occur with trivial trauma in the elderly. Both hyperextension and hyperflexion injuries may lead to odontoid fracture.[9,10] With acute hyperextension and significant force, the cranium and C1 arch move posteriorly and provide traction at the anteriorly moving odontoid process resulting in fracture at the weakest part of dens, i.e., base. With acute hyperflexion, the cranium and C1 arch move anteriorly, and the transverse ligament tries to limit posterior movement of dens. This, in turn, leads to either dens fracture or disruption of transverse ligament or both.[9,10] The mechanism of injury in our series was not recorded in the case files.

With the fracture of the axis (odontoid process), the whole assembly (atlantoaxial joint and fractured odontoid process) moves in unison on rotation and produces unbearable pain. Surgical interventions are directed to keep the axis intact and strong. This helps in stabilization and arthrodesis. Most Type I odontoid fractures can be managed with cervical collars restricting the mobility of the regions. Type II fractures are

Table 1: Clinical characteristics of type II odontoid fracture patients operated by posterior C1-C2 fixation (Goel-Harms Technique)

Age/gender	Clinical presentation	Fracture type*	Fracture-line orientation	Anterior-posterior displacement (mm)	Vertical displacement (mm)	Transverse ligament status	Associated AAD	Goel's clinical grade (postoperative)	Radiological alignment	Follow-up duration (months)
52/male	Neck pain	II	Posterior-inferior	2	1	Partial tear	No	1	Yes	33
50/male	Neck pain	IIa	Anterior-inferior	5	-	Intact	No	1	Yes	26
29/female	Neck pain	II	Anterior-inferior	1	1	Partial tear	No	1	Yes	22
30/male	Neck pain	II	Transverse	0	1	Intact	No	1	Yes	19
38/male	Neck pain	II	Anterior-inferior	2	2	Intact	No	1	Yes	14
23/male	Neck pain, Quadriparesis (Goel's grade 4)	II	Anterior-inferior	7	-	Intact	No	2	No	13
44/male	Neck pain	IIa	Posterior-inferior	1	1	Partial tear	No	1	Yes	9
37/male	Neck pain	II	Anterior-inferior	2	2	Intact	No	1	Yes	6
32/male	Neck pain	II	Anterior-inferior	2	1	Intact	No	1	Yes	4

*Anderson and D'Alonzo classification (Type IIa - Hadley's classification). AAD: Atlanto axial dislocation

most common and unstable. There are thin bone trabeculae at the base of dens explaining why these fractures are most common and go into nonunion.[2] The watershed zone at the odontoid base increases the risk of nonunion. The nonunion rate with conservative management ranges from 10% to 90%.[11]

Anterior versus posterior fixation techniques

Indications for surgery in Type II fractures are irreducible or unstable fractures, nonunion, and neurological deficits. There is a level II recommendation that patients with age 50 years or more should undergo operative intervention for Type II fractures. Both anterior and posterior fixation techniques are recommended and have equivalent outcomes.[12]

Anterior odontoid screw fixation is the most popular technique for most Type II acute fractures. It provides immediate stability while preserving motion at the atlantoaxial joint with 80%–100% fusion rates. Anterior odontoid screw fixation is suitable in fractures that are <6 months old and have advantages of motion preservation, limited soft tissue injury, nonrequirement of bone graft, lesser risk to vertebral artery, lesser operative time, lesser blood loss, and lesser pain medications requirements but have more postoperative dysphagia. The architecture of fracture segments is the most essential prerequisite for anterior odontoid screw fixation. There need to be an intact transverse ligament, reduction and alignment with traction, and transverse or posterior inferiorly sloping fracture line without any comminuted segment at the base. The short neck may limit the exposure for anterior odontoid screw placement. The bone quality for screw purchase also needs to be optimal.[13] Anterior extrapharyngeal open reduction and internal fixation have also been successfully demonstrated by Patkar.[14]

A subset of Type II fractures is inappropriate for anterior odontoid screw fixation. This includes Type II-a fractures, associated atlantoaxial dislocation, osteopenia, delayed presentation (>6 months), and anterior obliquely sloping fractures.[15] Hadley *et al*., in 1998, described a new subtype of Type II fracture (Type II-a), which has an additional chip segment at the anterior or posterior base of the dens.[15] In these cases, posterior fixation techniques are of immense help. Posterior fixation techniques are not limited by fracture morphology and can be performed in both recent and remote fractures. They restrict atlantoaxial joint mobility, require a bone graft, increase risk of vertebral artery injury, greater operative time, blood loss, and pain medication requirements but have lesser postoperative dysphagia.[13] In our practice, the decision regarding the operative approach is based on fracture morphology.

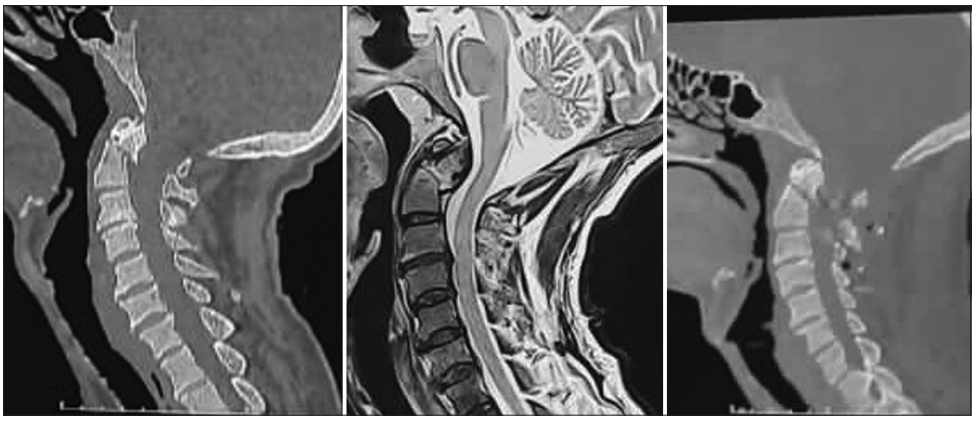

Figure 1: A Type II odontoid fracture with Grade I posterior subluxation of fracture segment (case 1). The fracture line was posterior sloping, and a small chip of fracture was indenting the spinal canal. The upper fracture segment was relatively smaller for adequate screw purchase. There was associated stretching of anterior and posterior longitudinal ligaments along with partial tear of transverse ligament, although there was no associated atlantoaxial dislocation. There was no definite neural compression on magnetic resonance imaging. C1 lateral mass and C2 polyaxial pedicle screws were placed. The C1-C2 joint was manipulated to align the fracture segment. Once the desired reduction was achieved, both polyaxial screws were connected with a rod. A postoperative computed tomography cervical spine showed alignment of fracture segment and fixation (Original)

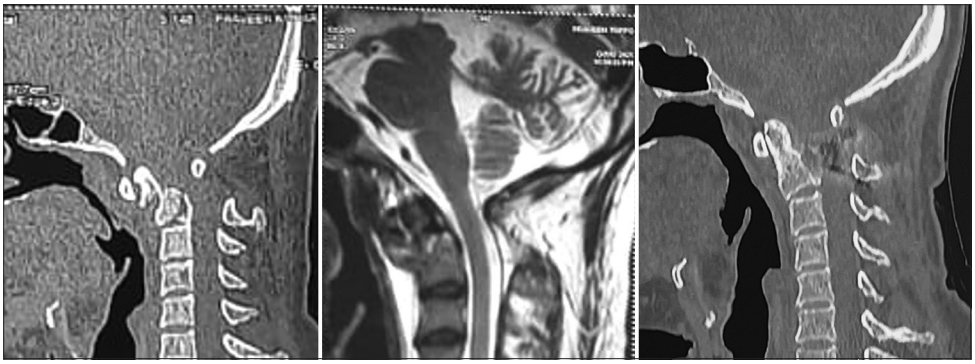

Figure 2: A Type II odontoid fracture with a comminuted segment at the posterior aspect (case 2). The fracture line is anterior sloping. There was no neural compression on magnetic resonance imaging. Fracture segment realigned with intraoperative traction. Postoperative radiological evaluation with computed tomography scan showed complete reduction and stabilization after posterior C1-C2 fixation (Original)

The fusion rates after anterior and posterior fixations have been compared in various studies. Baogui and Juwen, in a recent meta-analysis (13 studies, 761 patients), found better fusion rates with posterior fixations.[16] Similar results have been reflected in an older meta-analysis.[17] With the current popular posterior fixation technique of Goel-Harms, the fusion rates had approached nearly to perfect.[8,18-21]

Posterior fixation techniques

The various posterior fixation techniques have evolved in the last century. Dr Gallie in 1939 described posterior C1-C2 sublaminar wiring with bone graft placed between posterior arch of C1 and spinous process of C2. Brookes in 1978 modified the procedure and used wires on both sides passed under the lateral arch of C1 and lamina of C2 with bone graft in between. The results were suboptimum, immediate stabilization was not achieved, and patients still required external cervical spine immobilization. Dr. Magerl, in 1979, introduced trans-articular C1-C2 fixation with excellent fusion rates.[5] Magerl's technique has limitations in the case of fixed C1-C2 subluxation, and vertebral artery anomaly poses another challenge. To address this issue, Dr. Goel in 1994 and subsequently Dr. Harms in 2001 demonstrated C1 lateral mass and C2 pars or pedicle screw fixation with excellent fusion rates. This technique is popularly known as the Goel-Harms technique.[6,7]

Goel-Harms technique

Goel and Laheri, in 1994, first described C1-C2 fixation using screws and plates. Subsequently, a titanium cage was added to the technique for joint distraction and load bearing.[6] Harms and Melcher in 2001 described the use of polyaxial screws and rod systems.[7] The Goel technique has an added advantage as it provides vertical distraction, thereby reducing and maintaining it through anterior load sharing with the help of a cage. This cage increases stabilization and fusion rates.[22] Harms technique mainly relies on posterior cantilever construct. We used the Goel-Harms C1-C2 fixation technique in all patients and achieved excellent results. The Goel-Harms technique requires C1 lateral mass and C2

pedicle polyaxial screws insertion under image guidance, opening and distraction of C1-C2 joints, and scrapping of the articular cartilage. In five cases where fracture segment alignment was not possible with traction, distraction achieved the required alignment. An appropriately sized cage stuffed with bone chips can be placed between joints to maintain alignment. In two of our cases with Grade IV listhesis, the titanium cage was used to maintain alignment and fusion.

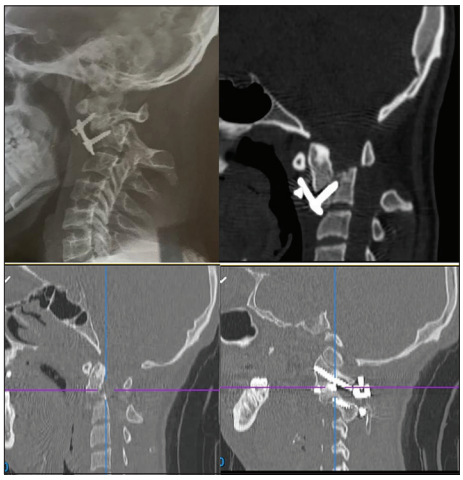

Figure 3: A Type II odontoid fracture underwent anterior reduction and fixation by plate and screws 1 month back at another center (case 4). The patient presented with progressively increasing neck pain and quadriparesis. X-Ray cervical spine showed the failure of the implant to hold fracture segments. CT cervical spine revealed an anterior Grade IV listhesis of the upper fracture segment over the base of C2. The base of the odontoid is seen compromising the neural canal due to anterior subluxation of the upper fracture complex. First, the loosened implant was removed through an anterior approach. There was bone loss with a fracture chip at the lower screw site. With intraoperative traction, the fracture segment did not realign. The patient was turned prone, and traction was reapplied, but the fracture did not reduce. C1 lateral mass and C2 pedicle screws were placed, C1-C2 joint opened and distracted with cage. Intraoperative fluoroscopy showed an incomplete but satisfactory reduction. A rod was connected to C1 and C2 screws and tightened. Follow-up CT scan confirmed reduction with residual Grade I anterolisthesis of fracture segment. The posterior vertebral line was realigned, relieving neural compression resulting in neurological improvement (Original). CT: Computed tomography

Goel *et al*., in a series of 124 patients, achieved a complete reduction in all patients. There was no implant failure in the short or long term.[8] Excellent fusion rates of the Goel-Harms technique have been reproduced in many studies.[18-21] In many studies and in a meta-analysis, the Goel-Harms technique was found to have better fusion rates and lesser injury to the vertebral artery than Magerl's technique.[23-25] Intraoperative Doppler and neuronavigation may help in preventing vertebral artery injuries. In our case series, there was no incident of vertebral artery injury. Some authors have reported higher blood loss and operating time with the Goel-Harms technique, which can be reduced with surgical experience.[19] We did not require any blood transfusion in any case.

The Goel-Harms technique was intended to provide a stable and rigid construct. Stability occurs at the cost of immobility. Park *et al*. compared the range of motion after Goel-Harms fixation method in a cadaveric study.[22] They found excellent union rates. Compared to an intact spine, the flexion-extension movement was reduced by 40%–80%, rotation was limited by 80%–90%, and there was no limitation on lateral bending. Saro *et al*. found the lateral bending restriction of 17% on either side in live subjects.[1] For this reason, some surgeons prefer temporary fixation of the C1-C2 joints without fusion and subsequent implant removal.[26] In our series, we achieved a rigid construct in all cases with an acceptable limitation of neck mobility.

Odontoid fractures in geriatric patients

The management strategies for Type II odontoid fractures in the geriatric population are controversial.[27] There is no randomized controlled trial to compare conservative and surgical management of odontoid fractures. Uppsala Study on Odontoid Fracture Treatment in the Elderly and INNOVATE trial are undergoing, and results are yet to be disclosed.[28,29] Many surgeons prefer surgical stabilization due to high

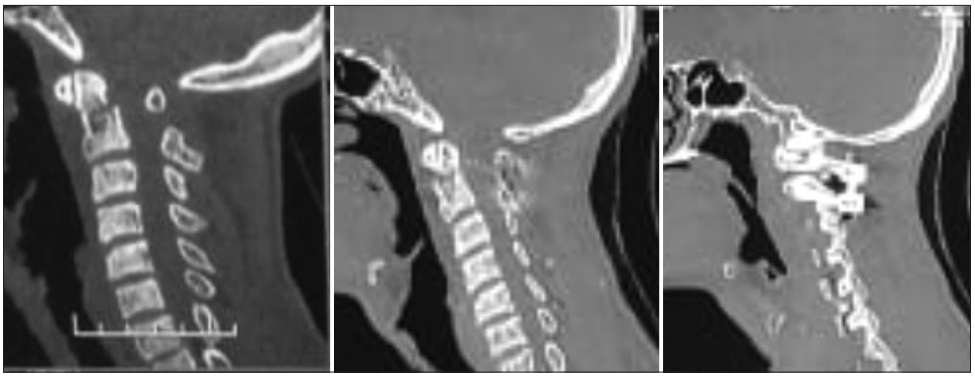

Figure 4: An un-displaced Type II odontoid fracture (case 6). The fracture line is transverse without any anterior-posterior dislocation. The indication of surgery was refractory pain. The multiple contaminated lacerations at the anterior aspect of the neck limited the anterior approach. Postoperative computed tomography cervical spine confirms alignment and stabilization after posterior C1-C2 fixation (Original)

nonunion rates.[27,30] Although anterior odontoid screw is a lesser invasive method in geriatric patients, better healing rates are observed with posterior atlantoaxial fusions.[25] Revision rates are found to be higher with anterior odontoid screw fixation in geriatric patients due to osteopenia.[31] In our series, there was no geriatric patient.

CONCLUSIONS

Posterior stabilization with C1-C2 fixation provides gratifying results in odontoid fractures. When anterior odontoid screw placement is limited by fracture morphology, the Goel-Harms technique achieves desired results. Goel's C1-C2 fixation technique is versatile to be used in many complex CV junction problems.

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Conflicts of interest

There are no conflicts of interest.

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