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Technique of Distraction, Compression, Extension, Reduction to Reduce and Realign Old Displaced Odontoid Fracture From Posterior Approach: A Novel Technique

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Objective: Chronic 'displaced' displaced type II fractures, though uncommon, are difficult to manage. They usually require a transoral procedure followed by a posterior instrumented fusion. We describe here, a new method to reduce the fractured displaced odontoid using a posterior cervical approach only.
Methods: Prospective and observational, n = 14 had a 'displaced and irreducible' old fracture dens causing cord compression (type I, 1; type II, 13). They underwent a novel technique to reduce the fracture. The C1 arch was first drilled and removed. The C1 lateral masses on both sides were then drilled completely and a spacer was placed between the occiput and C2 facet. Following this, an intraoperative reducing maneuver was performed, utilizing the spacer as a fulcrum, and then achieving complete reduction and realignment.
Results: All patients improved clinically (mean Nurick preoperative score: 4.07 ± 0.8; the postoperative score was 1.3 ± 0.4). The mean correction in effective canal diameter was 74.3% ± 9.5% and the mean correction in actual canal diameter was 77% ± 8.7%. Solid bone fusion was demonstrated in 12 patients with at least 1-year follow-up (follow-up range, 12–35 months; mean, 21.8 ± 9.8 months).
Conclusion: The new described modification of distraction, compression extension, and reduction seems to be effective for 'displaced' chronic fracture dens with cord compression. It avoids additional transoral surgery in these patients.

Keywords: Fracture, Odontoid, Irreducible, Atlantoaxial dislocation, Type II dens fracture, Reduction

INTRODUCTION

Cervical spine injuries, especially at the C2 level, may be associated with severe morbidity and mortality, especially in the presence of instability and cord compression. It is essential to understand the diversity of C2 fractures before considering their management: lateral mass fractures, extension teardrop fractures, traumatic spondylolisthesis (hangman fractures), and odontoid fractures.[1] Odontoid fractures constitute 10%–20% of all cervical spine injuries and many may be underreported.

The treatment algorithm for odontoid fractures primarily depends on the fracture type and clinical status. The most widely used classification system was that described by Anderson and D'Alonzo in which fractures were classified into 3 main types, and each has been further subcategorized as displaced or nondisplaced. Of the 3 types of fractures, type II is commonest and is also characterized by the highest rate of nonunion . In addition, the treatment paradigm is further influenced by the chronicity of the fracture. Acute fractures may be usually treated by first reducing them with traction, followed by applying an odontoid screw. However, chronic nonunited fractures present a challenge for management. Therefore, treatment may include options like conservative management (with immobilization), especially in elderly,[2] posterior transarticular/C1–2 screw-rod fixation,[3] curetting the margins of the fractured segments followed by placement of an odontoid screw[4] and sometimes a transoral excision of the odontoid process followed by posterior instrumented fixation. The latter has been suggested in long-standing displaced nonunited 'irreducible' fractures.[5]

The authors describe a new innovative technique based on their earlier described method of distraction, compression extension, and reduction (DCER).[6-12] First, after C1 laminectomy, total excision of bilateral C1 lateral masses was performed. Following this, a spacer was placed between the occipital condyle and the C2 facet joint creating an artificial articulation. Following this, a reduction maneuver was performed based on the technique of DCER. This technique has been successfully applied to reduce chronic nonunited, irreducible displaced type II fractures causing cord compression. This is the first that this technique has been used for this pathology.

MATERIALS AND METHODS

1. Patient Population

This study is prospective observational study. The study was conducted per the guidelines of the national council of medical research, and permission was taken from the Institute Review Board of All India Institute of Medical Sciences (AIIMS), New Delhi.

Three hundred fifteen patients with basilar invaginations (BI) and atlantoaxial (May 2010–March 2020) underwent DCER[6-13] (or combined with its modifications) utilizing a single staged posterior approach (PSC). Fourteen patients had chronic displaced 'displaced' type II dens fractures.

2. Exclusion Criteria

The following patients were not included in this study: (1) acute type II fractures of dens; (2) undisplaced fractures or those reducing on traction; (3) polytrauma involving fractures in other areas of the cervical spine; (4) cases with ventral C1–2 or fracture bone fusion, where a reduction was not possible. However, bone fusion at the level of articular facets was not a contraindication, as they could be easily separated with drills; (5) anomalous vertebral artery placed directly over the joints. Hence, a computed tomography (CT) angiogram was performed in all cases to exclude anomalous vertebral artery positions; (6) severe osteoporosis, that may not withstand the correction.

3. Preoperative Assessment

Grading pre- and postoperatively was assessed per Nurick grading system.[14]

4. Radiologic Studies

Dynamic plain x-rays, thin-slice CT scans (0.625 mm) with reconstructed views, and magnetic resonance imaging (MRI) was obtained in all patients preoperatively. All patients had displaced fractures, as confirmed on active dynamic x-rays. All patients underwent plain x-rays and thin-slice CT scans with reconstruction views to define the position of the screws and the extent of reduction within 1 week after the surgery. MRI was performed 3 months later to assess the extent of decompression.

During follow-up, dynamic x-rays and CT scans with reconstruction views were performed from 3 to 6 months and again at one year (in those patients with this period of follow-up available) after surgery to check the position of the implants and bone fusion.

5. Surgical Procedure

All patients underwent awake endoscopic intubation without neck manipulation following the placement of skeletal traction (Gardner Wells). Following general anesthesia, the patient was placed in the prone position on a U-shaped headrest with the neck in a neutral or extended position. This was preferred over Mayfield skeletal pin fixation to allow intraoperative maneuvers. Adequate care was taken to provide padding for the eyes. The procedure has already been described in detail earlier[15] and is also shown in Supplementary video clip 1. Briefly, following occiput, C1 and C2, bilateral C1/C2 joints were exposed (Fig. 1A, B). A C1 laminectomy was first performed along with decompression of the posterior rim of the foramen magnum (if necessary) to decompress the cord and prevent any cord injury while performing the reduction maneuver (Fig. 1C).

Following this, the joints were gently distracted using an instrument like a periosteal elevator, and then a distractor was placed between the C1 and C2 posterior lateral arches. In 10 of 14 cases, it was found that the C1 was tightly 'wedged' into C2, and it was quite difficult to separate both of them. Once the joint was 'loosened,' the articulating cartilage and the entire C1 lateral masses were drilled using a fine diamond drill (Fig. 1D). The

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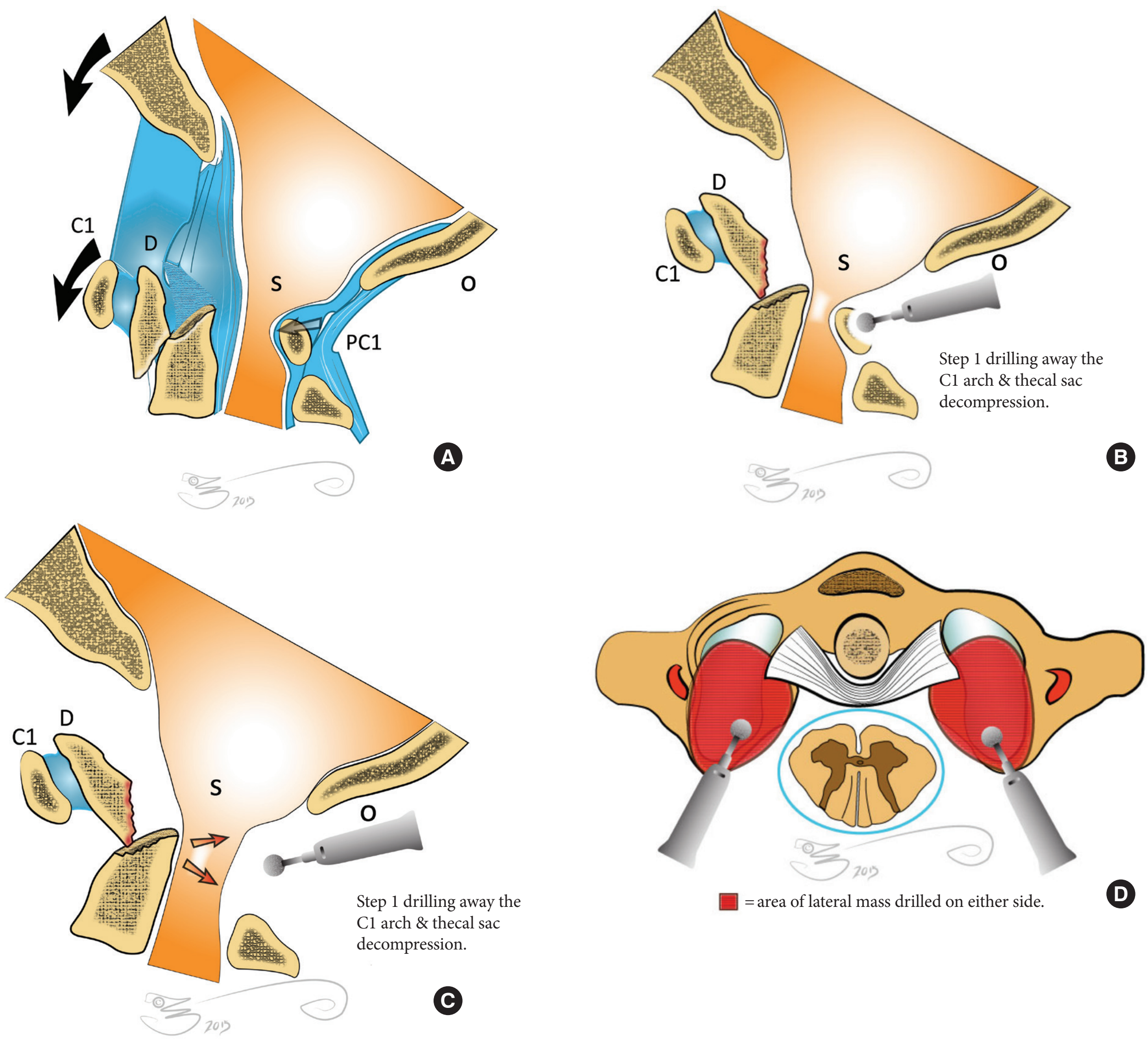

Fig. 1. Schematic diagram showing the surgical technique. Panel A shows how the cord is compressed in fractured and displaced odontoid process. Arrows indicate the lines of force leading to displacement of dens and compression of the cord. The dens slips forward and is 'wedged' between the C2 body and C1 arch. Panel B shows the first step of surgery. Here first, the posterior arch of C1 is drilled. (C) This is followed by decompression of the cord dorsally. (D) Following this, the C1 lateral mass is drilled out completely. The author prefers to first separate the C1–2 joint using an instrument like a periosteal elevator. The drilling of the C1 lateral mass may be performed through the C1–2 joint by starting at the inferior surface of the C1 joint. (*Continued*)

whole lateral masses of C1 vertebrae are drilled medial transverse process. Again, it may be mentioned that drilling the entire C1 lateral mass is unnecessary. It should be drilled enough to provide space to introduce a spacer to articulate between the occiput and C2 articular surface. The lateral portion of the C1 lateral mass may be left behind to protect the vertebral artery. Again, it is prudent to mention that the vertebral artery's exact position must be ascertained using a CT angiogram and 3-dimensional reconstruction. The idea is to provide a pivot between the occiput and C2 articular surface (see below) to provide an axis for the reduction of the deformity. The C2 ganglion and root need to be sacrificed, but C1 may be preserved. This creates enough space to introduce a spacer. The entire drilling must be done with a diamond head drill. Care must be taken not to get into the venous plexus situated laterally, where the vertebral artery will be lodged. If there is some bleeding from the venous plexus, it may be controlled using a wet gel foam with mild tamponade. Next, the cartilage of the joint surfaces of the occiput and C2 were denuded using a fine diamond drill. Bilateral spacers (polyetheretherketone) or special biconvex hollow titanium

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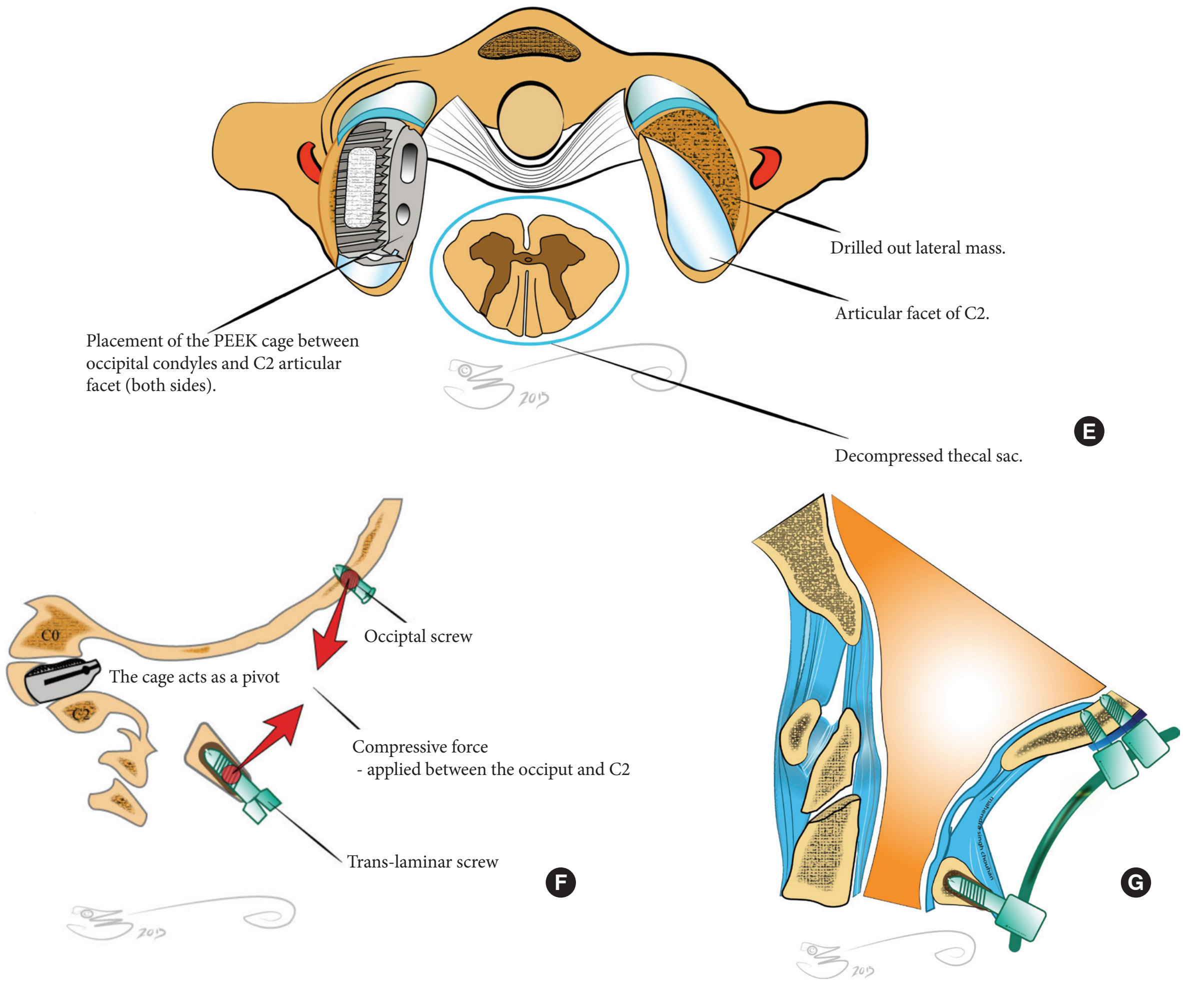

Fig. 1. (E) This is followed by the placement of a spacer (polyetheretherketone, PEEK) between the occiput and C2 joints. (F) The spacer now acts like a fulcrum of a type II pivot joint. Thus, a compressive force (converging arrows, F) now applied between the occiput and the C2 will lead to the forward movement of the C2 body. This forms the fundamental principle of distraction, compression extension, and reduction. (F) Next, a temporary screw is placed over the occiput. Compression is now provided by placing the arms of the calipers between the inferior surface of C2 and an offset placed over the occipital screw (converging arrows, F). Now acting like a fulcrum (F), the spacer moves the C2 body forwards and 'slips it' under the fractured dens. (G) Final fixation is now provided by connecting a rod between the occiput and C2 translaminar screw. In 1 case (case 3, Table 1), both laminar and pars screws were provided on C2. It should be noted that this technique is only advised for patients with chronic displaced odontoid fracture, which causes severe cord compression by becoming wedged between the C1 arch and the body of the C2. S, spinal cord; O, occiput; D, dens; C1, C1 anterior arch; PC1, posterior arch of C1. (Continued)

cages filled with bone grafts were inserted, the size approximately corresponding to the height from the base of the dens to the fracture level (Fig. 1E). This step resulted in the distraction of the margins of both the fractured segments to allow reduction. The height of the spacers required ranged from 8 mm to 14 mm. Next, a screw (to be removed later) was placed on the occiput, followed by C2 translaminar screws. An offset was next applied on the occipital screw.

A compressor was next applied with its calipers respectively over the offset of the occipital screw and under the C2 spinous process. Compression (converging arrows, Fig. 1F) was performed so that the occiput and C2 were approximated to each other. This maneuver was conducted under fluoroscopic guidance. Careful monitoring of intraoperative motor evoked potentials and D wave was also performed. Slow and progressive compression resulted in the C2 body 'slipping' forward (arrowhead, Fig. 1F) and under the fractured segment due to the extension of the head (Fig. 1F, G). This reduction was facilitated because the

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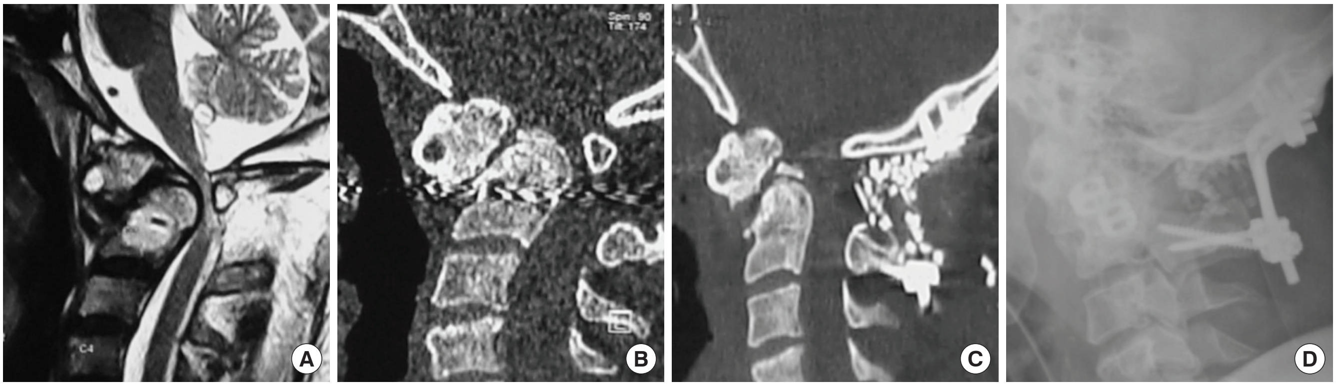

Fig. 2. A 34-year-old male had a fall from a tree 4 months ago (case 6, Table 1), following which he developed complete quadriplegia. He was provided treatment at a local hospital with traction and other medical treatment (possibly also methylprednisolone, but details were not available). He improved over the next month but was severely hindered (Nurick score was 4) and severely restricted neck movements. On referral to us, magnetic resonance imaging (A) showed a type II dens fracture with a large ventrally displaced fragment wedged between the C1 arch and the C2 body (computed tomography scan; B) with evidence of severe cord compression. (C, D) Following a modified distraction, compression extension, and reduction as described in the text, there was a satisfactory fracture reduction. The effective canal diameter improved b 83% and the actual canal diameter by 63% (see Table 1).

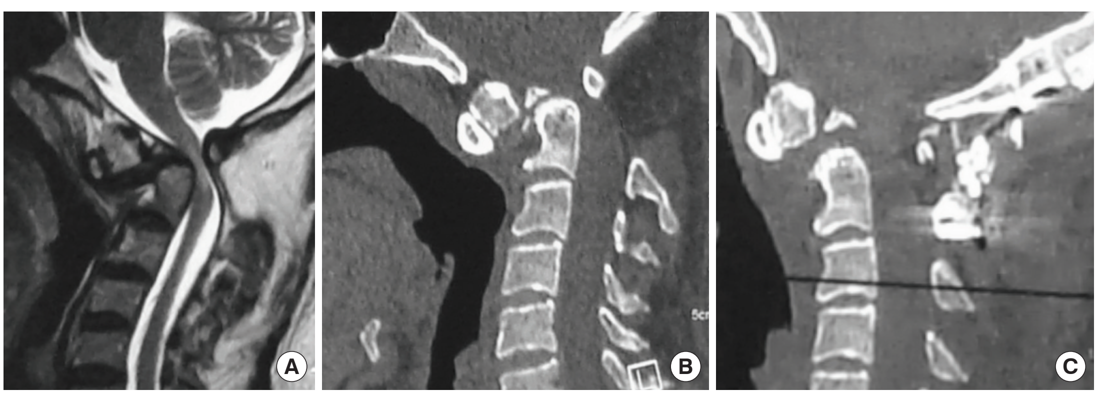

Fig. 3. A 45-year-old female sustained a type II fracture following a road traffic accident 6 months ago (case 10, Table 1). He was initially treated for a head injury and was on ventilator support for almost 2 weeks (diffuse axonal injury). He improved gradually and was then referred to us. Magnetic resonance imaging (A) showed severe cord compression and a sizeable fractured fragment (computed tomography scan, B) wedged between the C1 arch and the C2 body. There was also evidence of 2 small comminuted fractured fragments. Following modified distraction, compression extension, and reduction (C), the fracture reduced satisfactorily (the effective canal diameter improved by 86.4%, and the actual canal diameter improved by 68%).

spacer now functioned like a fulcrum of a type II pivot joint (black dot, Fig. 1F). This forms the fundamental principle of DCER (also see Figs. 2–6).

The length of (3.5 mm, diameter) C2 translaminar screws[16] varied from 24 to 32 mm. While the assistant maintained the compression, the occipital-cervical rod was placed on one side and fixed. Following this, the compressor was removed, and a similar fixation was performed on the other side. Following surgery, the occipital and C2 spinous bone exposed areas were decorticated using a fine diamond drill. Bone chips harvested from the iliac crest mixed with hydroxyl-apatite were placed between the occiput and C2 spinous process. The wound was closed in layers. A drain was placed if felt necessary.

All patients were electively ventilated overnight and slowly weaned off the ventilator, and extubated the next day. Patients were advised to use Philadelphia rigid cervical collar for 6–9 months until bone fusion was demonstrated.

As noted in Fig. 1F, an occipital screw coupled with a translaminar screw provided a greater distance from the fulcrum, which is now located in the center of the spacer lodged between

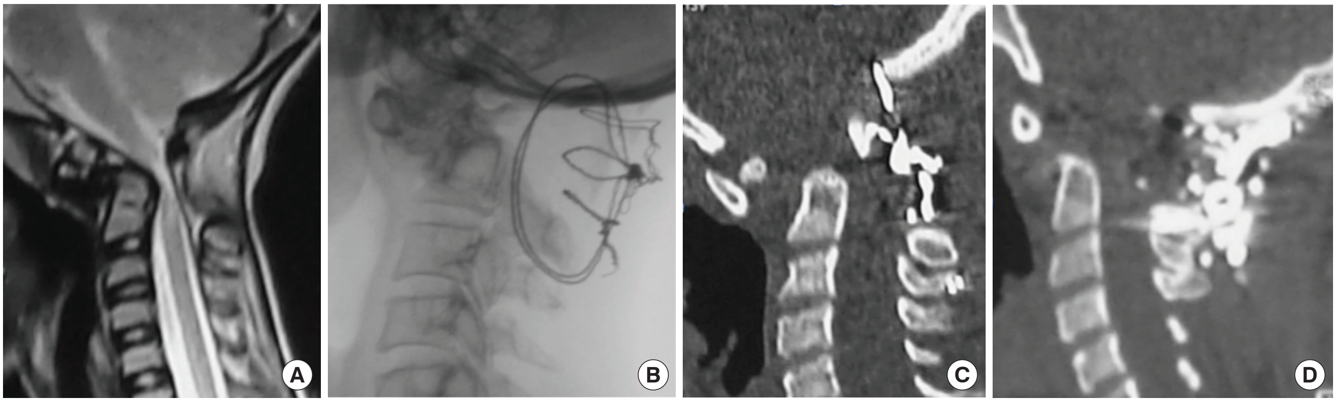

Fig. 4. (A) A 22-year-old male (case 11, Table 1) sustained a type II dens fracture and suffered a fall from a rooftop 5.5 months ago while flying a kite. He underwent an unsatisfactory surgery elsewhere (wiring done posteriorly; B, C). Following our referral, the computed tomography also showed a fracture through one lateral mass of C1. (D) Thus, he underwent a modified distraction, compression extension, and reduction, which provided a satisfactory fracture reduction and realignment of the dens.

the occipital condyle and the C2 articulating surface (class III lever). Thus, the forces required to perform the reduction were also significantly more, allowing an optimal removal of the deformity. However, there is a word of caution that such an extent of intraoperative maneuvering requires the presence of good integrity of the bone and a good purchase of a screw. Hence, it is essential to exclude osteoporosis. In addition, the reduction should be performed slowly in small increments taking about 15–20 minutes, rather than doing it rapidly, which will have a greater chance of fracture or loosening of the screws. Finally, keeping an escape option in place is essential in case this strategy fails.

RESULTS

1. Patient Population

The patient population comprised 9 males (and 5 females) ranging from 9 to 48 years (mean age, 24.7 ± 9.3 years).

The clinical presentations included progressive myelopathy in 12, restriction of neck movements with or without nuchal pain (11), paraesthesias (10), sensory loss (8), incontinence (3), and respiratory compromise (2). The interval between the time of trauma till surgical intervention varied from 3–36 months (mean, 6.6 ± 8.2 weeks). The nature of trauma included falls (10), road traffic accidents (5), and assault with a blunt weapon (1). Initial treatment was provided in 7 in the form of skeletal traction at a local hospital. The other 6 were advised a rigid cervical collar and then referred to a tertiary hospital, and 2 refused any immediate surgery. One patient underwent unsatisfactory surgery (posterior wiring) and was referred to us. All had a type II dens fracture except one (case 4, Table 1).

2. Surgery

Occipital-C2 DCER, along with total bilateral excision, was performed in all 14 patients (Figs. 2–6). There was no need to complete a transoral procedure on any patients. C2 laminae were suitable in all cases, and the thickness varied from 4.2–5.8 mm. The length of C2 laminar screws went from 24–32 mm. One patient required translaminar and pars-pedicle screws for the C2 vertebra (Fig. 5). The duration of the surgery ranged from 70 to 160 minutes (mean, 105 ± 22 minutes), and blood loss ranged from 90 to 400 mL (mean, 210 ± 125 mL, see also Figs. 2–6).

3. Clinical Outcome

All patients improved clinically compared to the preoperative Nurick scores (Nurick grade I: 9 patients, and grade II:5 patients; follow-up: 12–35 months, mean: 21.8 ± 9.8 months). The mean preoperative Nurick score was 4.07 ± 0.8, and the mean postoperative score was 1.3 ± 0.4. All patients with nuchal pain improved postoperatively. One patient with respiratory compromise required postoperative ventilation and subsequent tracheostomy that was weaned off and removed after 6 weeks. The other 2 patients with respiratory compromise improved. One patient developed a wound gaping at the upper part as he was chronically bedridden. This healed in 6–8 weeks with appropriate antibiotics and daily sterile dressings.

4. Radiologic Outcome

X-ray and CT scans were performed 1 week, 3 months, and 6 months to 1 year after surgery. They were performed until bone fusion was confirmed. Solid bone fusion was demonstrated in

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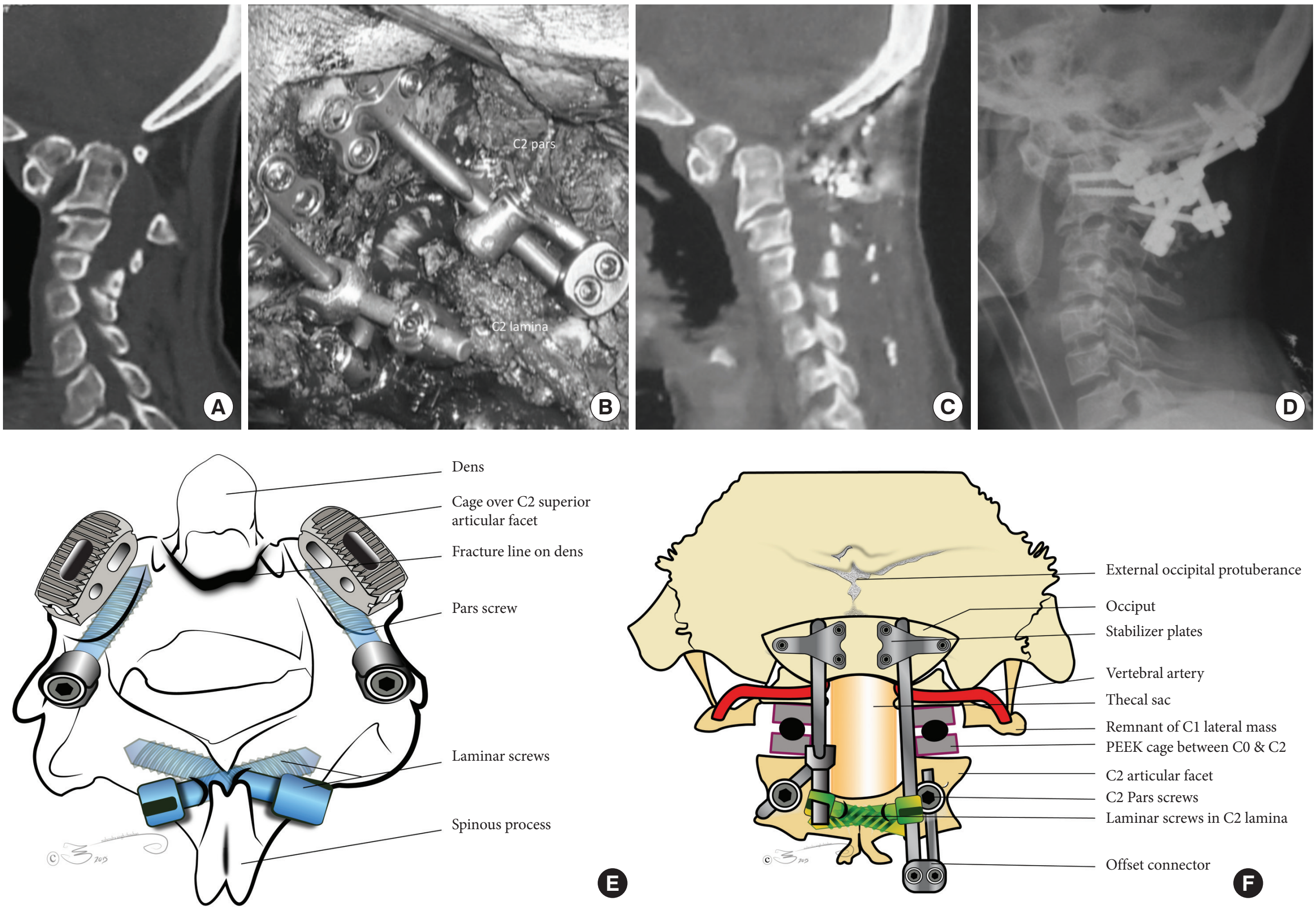

Schematic diagram showing placement of spinous and pars screws in C2 during surgery.

Fig. 5. A 34-year-old female sustained a fall from stairs 36 months ago (case 3, Table 1, see also video). She developed complete quadriplegia initially and was provided medical treatment (with methylprednisolone) at a local hospital with traction. She made minimal improvement, but the patient refused to seek surgical treatment initially. On referral to us, she was bedridden although she was still continent (Nurick score of 5). (A) Computed tomography scan showed a large, fractured dens fragment wedged between the C1 arch and the C2 body with severe compression of the cord between the C1 posterior arch and C2 body. A modified distraction, compression extension, and reduction (DCER) was performed as described in the text. (B) During surgery, the author preferred placing both C2 laminar and pars screws interconnected. (C, D) Following a modified DCER, the effective canal diameter improved by 72% and the actual canal diameter by 61%. The patient made a satisfactory improvement to Nurick score of 2 over 32 months. Panels E and F show the schematic diagrams of the placement of both C2 pars and C2 laminar screws and the method by which they have been connected. PEEK, polyetheretherketone.

all patients with at least 1-year follow-up. The following method was used to calculate the degree of spinal canal restoration. The formula, which was applied, included calculating the actual canal diameter (ACD; distance between the posterior border of the dens and posterior margins of the foramen magnum), preoperative effective canal diameter (pre-ECD: distance between the posterior margin of the upper edge of the C2 body at the level of the fracture and anterior border of the C1 arch) and postoperative ECD (post-ECD: the distance between the posterior wall of fractured dens and occiput:). Two parameters were used to calculate the degree of improvement of canal diameter. One is the degree of improvement of ECD (cECD), calculated using the formula cECD = pre-EDC/post-ECD × 100. The other parameter was the degree of improvement in ACD (cACD); this was calculated using the formula cACD = post-ECD/ACD × 100. The mean cECD was 74.3% ± 9.5% and the mean cACD was 77% ± 8.7%.

DISCUSSION

Acute odontoid fractures are a surgical emergency that should be treated immediately. Type II fractures are the commonest

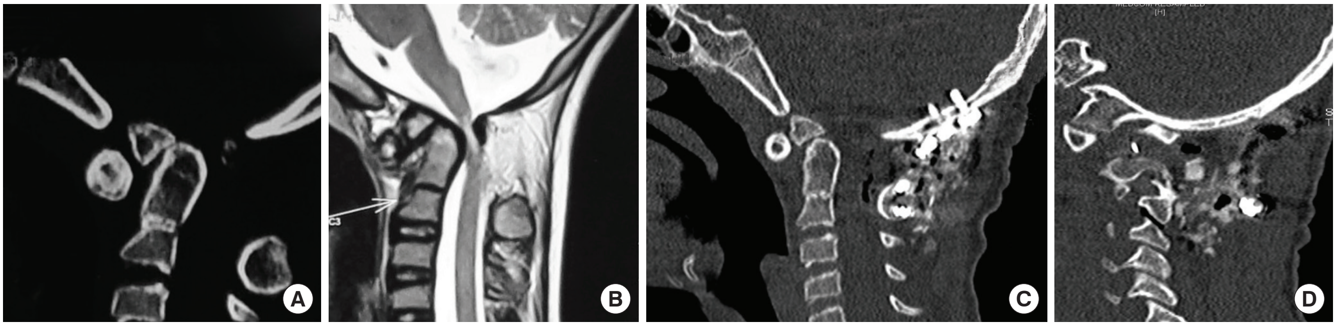

Fig. 6. A 9-year-old-boy tripped over the ground running while playing cricket 4 months ago (case 4, Table 1). He developed a type I dens fracture (fracture of os odontoideum; A). Magnetic resonance imaging (B) showed severe compression of the cord between the body of C2 and the C1 arch. A modified distraction, compression extension, and reduction (DCER) was necessary as the fractured fragment was in front of the C2 body. Following a modified DCER, there was a satisfactory reduction of the fracture (C). Panel D shows the polyetheretherketone cage placed between the occiput and C2 facet.

Table 1. Table showing the summary of age, sex, time after presentation of trauma, preoperative (preop) and postoperative (postop) Nurick score, % of reduction, follow-up, and bone fusion

No.	Age (yr)	Sex	Time for presentation after trauma (mo)	Preop Nurick score	Postop Nurick score	cECD (%)	cACD (%)	Follow-up (mo)	Bone fusion
1	22	M	3	4	1	66.7	66.7	35	Yes
2	24	M	4	5	2	71.4	77.8	34	Yes
3*	34	F	36	5	2	72.7	61.1	32.5	Yes
4†	9	M	4	4	1	46.7	78.9	31	Yes
5	25	F	2	3	1	80.0	78.9	29	Yes
6†	32	M	4.2	4	1	83.3	63.2	25	Yes
7	26	M	4.7	5	2	68.8	80.0	24	Yes
8	13	M	3	4	1	73.3	83.3	20	Yes
9	35	F	3.8	3	2	76.5	89.5	18	Yes
10†	45	M	6.2	3	1	86.4	68.8	16	Yes
11†	22‡	M	5.5	4	1	75.0	76.2	17	Yes
12	28	F	5.8	3	2	81.3	80.0	12	Yes
13	17	M	4.3	5	1	83.3	90.0	8	NA
14	15	F	4.4	5	1	75.0	84.2	4	NA
Mean	24.7 ± 9.3	-	6.4 ± 8.2	4.07 ± 0.8	1.3 ± 0.4	74.3 ± 9.5	77.0 ± 8.7	21.8 ± 9.8	-

Nurick grading: grade 0: signs or symptoms of root involvement but without evidence of spinal cord disease; grade 1: signs of spinal cord disease but no difficulty in walking; grade 2: slight difficulty in walking which does not prevent full-time employment; grade 3: difficulty in walking which prevented full-time employment or the ability to do all housework, but which was not so severe as to require someone else's help to walk; grade 4: able to walk only with someone else's help or with the aid of a frame; grade 5: chair bound or bedridden.
cECD, the degree of improvement in effective canal diameter; cACD, the degree of improvement in actual canal diameter; NA, not applicable.
*Case mentioned in figure and also shown in Supplementary video clip 1. †Cases mentioned in Figures. ‡Patient underwent an unsatisfactory surgery (posterior wiring) at a local hospital and was then referred to us.

and are associated with the highest rates of nonunion.[17,18] Type I and type III fractures are uncommon and rarely require surgical intervention and usually may be managed by rigid immobilization only.[1,18] Most acute fractures may be reduced with traction followed by an odontoid screw placement, a posterior transarticular, or a C1/C2 instrumented screw fixation.[19] Chronic fractures are commonly found in the elderly and are associated with a high incidence of nonunion. Given this, elderly patients with type II fractures are often advised conservative treatment with immobilization only. The underlying principle of treatment

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is not just to relieve the compression but also to provide optimal stability and correction of deformity.

Chronic displaced ‘irreducible’ nonunited type II fractures are uncommon. They are more commonly found in elderly patients but may also be seen in settings where immediate treatment is unavailable at the site of injury and due to lack of optimal referral systems, due to which they may be left untreated.

Accurate diagnosis of an odontoid fracture depends heavily on good quality x-rays and thin-slice plain CT scan films with reconstruction. CT imaging is much more sensitive to determining the fracture’s extent, looking for minor fractures and bone fragments, planning surgical trajectory, and making out the soft tissues. A type I fracture[17] is considered an avulsion of the attached alar ligament. Though the least common, the diagnosis may be often missed, mainly if a CT scan is not performed. It is usually considered a stable fracture with a high chance of fusion. A type III odontoid fracture[18] involves the cancellous portion of the C2 body. Most of these may be treated with external bracing only and are usually associated with reasonable fusion rates. Rarely, they may become unstable and may require surgery.[20] Type II odontoid fracture involves the junction of the odontoid process and vertebral body of C2. These are the commonest, are highly unstable, and are associated with high rates of nonunion.

The treatment strategy for type II odontoid fractures aims to protect neural elements, establish spinal stability, and improve clinical symptoms. The optimal treatment strategy, based on evidence, is not well established because of the significant rate of nonunion. This is primarily because dens has very few trabeculae, which form the site of reparative callus formation. This, coupled with other factors like decreased vascularization at the odontoid base, the low bone strength quality at the junction of the dens and C2 body, and decreased trabecular mass with aging, make treatment of this pathology challenging, especially in the elderly.[1] Both rigid (halo-vest immobilization) and nonrigid immobilization, considered viable alternate options especially for elderly patients, are not without significant morbidity (sometimes up to 42%). There are no validated guidelines to suggest which surgical option would provide the best choice for optimal treatment. The proposed surgical intervention indications are based on retrospective analysis. They include displacement of fracture fragment > 5 mm, displacement of 20% of the fracture surface area, age > 50 years, and disruption of transverse ligament.

Analysis of various surgical techniques shows a significant evolution over the past 2 decades. There has been a steady evolution in the development of strategies, which provide more stability. Thus, the surgical techniques initially started with posterior spinous wiring, progressed to interspinous wiring, then to sublaminar wiring. This gave way to screw placement techniques, which included transarticular screws (Magerl), C1 lateral mass, and C2 pedicle/isthmus screw-rod constructs (Goel’s/Harms)[3,21] and odontoid screw.[22] Transarticular and C1/C2 rod/screw constructs are biomechanically more stable than wire and hooks.[3,21,23] Odontoid screw placement (osteosynthesis) was first described by Bohler in 1982 and is currently one of the most standard techniques for type II fractures. The main indications include fractures < 3 weeks old, intact transverse ligament, horizontal or posterior oblique fractures, and optimal bone quality. The main advantages include improvement of postoperative neck movement, absence of the need for halo-vest immobilization, and reported healing rates ranging from 83% to 100%.[24,25]

Chronic displaced ‘irreducible’ type II fractures with cord compression are uncommon. They commonly occur in elderly persons or patients who did not receive treatment immediately.[26] They may be more commonly found in situations where treatment may not be available in the immediate vicinity and there is a delay due to referral to a tertiary center due to a treatment gap, which could be because of a knowledge gap or social or financial reasons. Such fractures usually require transoral excision of an odontoid fractured fragment followed by a posterior instrumented fixation (C1/C2 or a trans articular screw fixation). The authors have described a single staged posterior approach technique, which provides all 3 treatment objectives, i.e., cord decompression, stabilization, and correction of the deformity. The author has named the surgical procedure DCER as it utilizes all 3 components of motion, i.e., distraction, followed by compression and extension, leading to the removal of the deformity. This technique has effectively been utilized in over 200 congenital craniovertebral junction anomalies with moderate to severe BI and atlantoaxial dislocation.[6,13,27-30] The principle of the method is based on using the spacers as a pivot, which converts the C1/C2 joints into a type II pivot (in the present study, occipital-C2 joint after drilling the lateral mass of C1 thoroughly). Thus, compression applied posteriorly translates into a movement of extension, resulting in the dens’ forward movement, effectively reducing the atlantoaxial dislocation. This is the first time in the literature that such a technique has been used to reduce certain severe chronic displaced odontoid fractures. The authors have used this technique to correct over 200 BIs cases and atlantoaxial dislocation (AAD).

Following its practical application in BI and AAD, the authors applied the same technique with minor modifications on patients with chronic displaced 'irreducible' type II fractures.[6-8,12,27-30] The main modification included performing a C1 laminectomy, posterior decompression of the rim of the foramen magnum, complete drilling of the C1 lateral masses, and denudating the occipital and C2 joint surfaces by a spacer placement between the occiput and C2 joints. This is followed by compression between the occiput and C2 spinous process (Fig. 1). This movement results in the 'slipping back' of the C2 body under the fractured dens (with the spacer now acting as a fulcrum), thus reducing the fracture. Here occipital-C2 fusion was performed instead of C1/C2 fixation. The initial distraction brought the margins of the fractured segment of the dens to the same level. The subsequent compression and extension allowed the C2 body with the base of dens to 'slip forward' under the fractured odontoid segment.

We used 3 measurements to assess the degree of spinal canal widening. These included ACD: measured between the posterior margin of the dens to the posterior margin of the foramen magnum; pre-EDC: measured between the posterior margin of the C2 body at the level of the fracture and anterior border of posterior C1 arch before surgery; post-ECD: measured between the posterior margin of the C2 body at the level of the fracture and the posterior margin of the occiput after surgery (as the C1 posterior arch is drilled away after surgery). Using these measurements, we used 2 parameters to assess the degree of spinal canal widening. These included: cECD = degree of improvement of ECD, calculated as pre-EDC/post-ECD × 100; cACD: degree of improvement of ACD, calculated as post-ECD/ACD × 100. The mean improvement of ECD was 74.3% ± 9.5% (compared to the pre-ECD), and the mean improvement of canal compared with the ACD was 77% ± 8.7% (as compared to the preoperative ACD). This also correlated with an improvement in clinical scores. The mean preoperative Nurick score was 4.07 ± 0.8, and the mean postoperative score was 1.3 ± 0.4. To the best of our knowledge, this is the first time such a technique has been applied to reduce a displaced 'irreducible' type II fracture.

The main advantages of DCER include the ability of performing a 3-axis correction which is required for correction of any deformity. It is to the best of our knowledge, the first procedure to describe correction of severe deformities at the craniovertebral junction (i.e., atlantoaxial dislocation, BI).

CONCLUSION

The technique of DCER has been used effectively by the authors in over 300 patients with BI and AAD. We have modified the same method to realign chronic 'displaced' displaced type II odontoid fracture (with cord compression) through a single staged posterior approach. To create a fulcrum, the C1 lateral mass was excised bilaterally, and an artificial articulation was made between the occipital condyle and the C2 facet joint. The mean improvement of ECD was 74.3% ± 9.5% (compared to the pre-ECD) and the mean improvement of ACD was 77% ± 8.7% (compared to the preoperative ACD). The technique provides movement in 2 axes, i.e., in vertical and horizontal directions, and utilizes the spacer as a fulcrum between the occiput and C2 joint to effectively correct the displaced fragments. However, there is a word of caution for patients with osteoporosis, as the bone may not be strong enough to withstand the corrective forces. We also agree that the current series is not very large. However, publishing the current series aims to provide proof of concept. We aim to publish a more extensive series at a later date.

NOTES

Supplementary Material: Supplementary video clip 1 can be found via https://doi.org/10.14245/ns.2244406.203.

The supplementary video clip 1 shows the surgical technique of modified DCER (case 3, Fig. 5, Table 1).

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