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Thoracolumbar fracture dislocation (AO type C injury): A systematic review of surgical reduction techniques

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Abstract

Spinal injuries constitute about 3% of all injury cases and most of these injuries affect the thoracolumbar region, but thoracolumbar fracture-dislocations are much rarer. Dislocations (AO Type C injuries) of the thoracic and lumbar vertebrae, with or without associated fractures, happen due to very high energy trauma involving simultaneous, multidirectional, distractive and compressive forces across various spinal elements, which results in translational and rotational instability of the spinal column. Various reduction maneuvers have been described for thoracolumbar fracture-dislocations in the literature aiming to provide standardization in surgery for this situation. The aim of this review article is to systematically review the literature till date and describe various reduction maneuvers which help to achieve adequate sagittal and coronal balance as well as vertebral alignment with minimal soft tissue trauma. We searched the PubMed, the Cochrane Library (the most recent issue), Scopus, Cochrane Bone, Joint and Muscle Trauma Group Specialised Register, Web of Science, International Clinical Trials Registry Platform (WHO), ClinicalTrials.gov and Google Scholar databases, besides other sources and general internet search. The strategy used in the search was briefly("thoracolumbar" OR "dorsolumbar") AND "dislocation" in PubMed. Similar searches were made in the other databases.Reference lists of the relevant papers were also examined and

any further relevant studies, which were also included in the review.

The initial search revealed 332 papers in Pubmed, out of which 302 were human studies. A similar search on Scopus revealed 528 documents and on WoS revealed 289 papers. Searching the Cochrane library revealed 9 trials, which were already revealed in Pubmed search results. All the references were imported into Endnote and we had 632 references after excluding duplicates and 126 papers were left in endnote after manual title screening and duplicate removal. Finally, 70 relevant papers were selected for consideration based on inclusion criteria, after excluding unrelated papers manually. We have summarised the published literature on the surgical management of thoraco-lumbar fracture dislocations and described the reduction maneuvers used in detail.

Previous Next

Keywords

Thoraco-lumbar; Fracture; Dislocation; AO type C; Reduction

1. Introduction

Spinal injuries constitute about 3% of all injury cases[1] and most of these injuries involve the thoracolumbar region, but thoracolumbar fracture-dislocations are much rarer.[2, 3, 4, 5, 6] Thoracolumbar fractures happen more frequently in men, who account for about 2/3rd of cases, than in women who account for 1/3rd and most cases occur between of 20 and 40 years of age.[7, 8, 9, 10, 11]

About 50–60% of thoracolumbar injuries involve the transition levels (T11–L2), 25–40% affect the thoracic spine and 10–14% affect the lower lumbar and sacral areas.[12,13]

Dislocations (AO Type C injuries) of the thoracic and lumbar vertebrae, with or without associated fractures, happen due to very high energy trauma involving simultaneous, multidirectional, distractive and compressive forces across various spinal elements, which results in translational and rotational instability of the spinal column.[14, 15, 16, 17, 18, 19] Denis has reported 412 dorsolumbar spinal injuries; with fracture-dislocations representing 16% of these injuries.[20] Almost same rate was observed in another multicenteric study including 1019 consecutive patients.[21] Most fractures have associated severe spinal cord injury and complete neurological deficit. More than 50% of the fractures have associated dural tears and cerebrospinal fluid leak. Associated trauma to the intrathoracic and intrabdominal organs

are common.

injuries, spinal stabilization, and rehabilitation.

Kyphosis, late neurological decline in cases with preserved neurology, and chronic pain are long-term sequale which can adversely impact the quality of life.[22] Therefore, such injuries should be reduced and fixed suitably without any undue delay.[23], [24], [25] Achievement of good sagittal and coronal alignment and reduction even in cases with complete cord injury (where neurological recovery may not be possible) is still important, as the reduced spine allows biomechanical stability, and thereby facilitates rehabilitation. Also, the necessity of a stable long segment construct enhanced with extra transverse cross-links cannot be overemphasized. Two main principles guide the management: biomechanical stability and neurological optimization[26] There are several reduction manoeuvres for thoracolumbar spine fracture-dislocations described in the literature aiming to provide standardization in surgery for this situation. The purpose of this review article is to describe various reduction manoeuvres, including those involving manipulation of spinous processes, laminae and facets at the level of dislocation, pedicle screw based maneuvers and facetectomy(partial or complete, as necessary) which we have also employed in these situations to achieve adequate sagittal and coronal alignment with little soft tissue trauma.

2. Methods

We searched the PubMed, the Cochrane Library (the most recent issue), Scopus, Cochrane Bone, Joint and Muscle Trauma Group Specialised Register, Web of Science, International Clinical Trials Registry Platform(WHO), ClinicalTrials.gov and Google Scholar databases, besides other sources and general internet search. The strategy used in the search was briefly("thoracolumbar" OR "dorsolumbar") AND "dislocation" in PubMed(Table 1).Similar searches were made in the other databases.Reference lists of the relevant papers were also examined and any further relevant studies, which were also included in the review.

Table 1. Search strategy.

S no	Search terms
1	#1:"thoracolumbar" OR "dorsolumbar"
2	#2: "dislocation"

Final search	#1 AND #2

Inclusion criteria were studies with subjects undergoing posterior reduction and instrumented fusion for thoracolumbar fracture-dislocation. We included case reports, technical notes, case series, prospective or retrospective comparative studies and randomised controlled trials. Only English language papers were considered. Animal studies were excluded. The focus was on the study of reduction techniques. No meta-analysis was attempted. Two authors (MKP and SK) individually performed the searches, screened the titles and abstracts, and assessed them for inclusion. Any disagreement was resolved by mutual discussion and consultation with the senior authors (TB and RK).The protocol of this systematic review has been pre-registered at PROSPERO as per PRISMA guidelines and bears registration number PROSPERO 2019 CRD42019122732, Available at: http://www.crd.york.ac.uk/PROSPERO/display_record.php?ID=CRD42019122732.

3. Results

Initial search revealed 332 papers in Pubmed, out of which 302 were human studies. Similar search on Scopus revealed 528 documents and on WoS revealed 289 papers. Searching the Cochrane library revealed 9 trials, which were already revealed in Pubmed search results. All the references were imported into Endnote and we had 632 references after excluding duplicates and 126 papers were left in endnote after manual title screening and duplicate removal. Finally, 70 relevant papers (Table 2) were selected for consideration based on inclusion criteria, after excluding unrelated papers manually. (Fig. 1 Prisma Flowchart).Reduction techniques elaborated upon in these papers have been briefly discussed here, along with evolution in fixation strategies.

Table 2. Experience of various authors treating thoracolumbar fracture-dislocation.

1	Lorente Aet al 2018	N=1	Described total vertebrectomy (L1) with spine shortening and fixation with eight screws and two Steffee plates and sublaminar wires in five-week-old T12-L1 spine dislocation.
2	Zeng Jet al 2018	N=1	Reported a case of complete facture-dislocation of L1- L2 with intact neurological function treated by posterior reduction and internal fixation with screws and rods.
3	Garg Met al 2018	N=5	Retrospective analysis of patients having lateral-optosis who underwent single-stage posterior surgical reduction and fixation.

4	Zhao Cet al 2017	N=1	Reported a rare case of spontaneous reduction of the fractured thoracolumbar spine with complete dislocation and discussed the management.
5	Hadgaonkar Set al 2017	N=11	Described a levering technique using small parallel rods for open reduction of high-grade thoracolumbar dislocation
6	Rahimizadeh Aet al 2018	N=1	Represented the possibility of existence of a preservation mechanism for functional integrity of cord despite gross spinal fracture dislocation by reproducing the injury on a plastic model and simulating a corresponding model using 3DSlicer software, along with a detailed description the pathomechanism of neurologic sparing.
7	Sugiura Ket al 2016	N=1	Reported a case of complete fracture-dislocation of the T12 vertebral body and multiple injuries following high-energy trauma but no critical neurological deficits and described the pathomechanism of neurologic sparing.
8	Wu Cet al 2017	N=18(3DP) N=24(Control	Evaluated the clinical significance of individualized reference model of sagittal curves and navigation templates of pedicle screw by three-dimensional printing(3DP) technique for thoracolumbar fracture with dislocation
9	Qiu, H. et al. 2016	N=18	Evaluated the clinical effects of subtotal corpectomy and reconstruction with titanium mesh cage implantation and pedicle screw fixation through posterior approach alone in treatment of thoracolumbar burst fracture or thoracolumbar fracture dislocation.
10	Zhong, J. et al. 2016	N=19	Investigated the clinical efficacy of screwing through injured vertebra, posterior intervertebral pressing with single segmental fixation and traditional fixation across injured vertebra while treating thoracolumbar fracture dislocation
11	Feng Zet al 2015	N=16	Treated thoracolumbar fracture dislocations with a pedicle screw system via an entirely posterior approach
12	Liu Hua in 2015	N=100	Compared the effectiveness of vertebral pedicle screw fixation versus cross-segment pedicle screw fixation for thoracolumbar vertebral fracture and dislocation.
13	Tang, H.-Z. et al., 2015	N=17	Evaluated the effect of posterior pedicle screw mono-segmental internal fixation for treatment of the type AO-C1 thoracolumbar fracture-dislocations.

14	Sandquist Let al 2015	N=1	Authors corrected the patient's thoracolumbar spondyloptosis with surgical reconstruction without the use of leveraged instrumented reduction, with a good outcome. They performed a complete L-1 vertebrectomy to facilitate spinal column realignment with- out significant manipulation of the spinal column, thereby preventing potentially fatal manipulation of the vascular structures immediately anterior to the spinal column. This was followed by interbody fusion between T-12 and L-2, using autograft derived from vertebrectomy.
15	Wang XBet al 2014	N=30	A retrospective review of 30 patients who had undergone single stage posterior pedicle screw fixation, decompression and interbody fusion.
16	Wu AMet al 2014	N=36	Retrospective clinical study where evaluate the efficacy and safety of transforaminal decompression and interbody fusion in the treatment of thoracolumbar fracture and dislocation with spinal cord injury.
17	Hao Det al 2014	N=57	RCT trial was aimed at comparing the clinical outcomes of combined posteroanterior (P-A) fusion and transforaminal thoracic interbody fusion (TTIF) in cases of T-L fracture-dislocation.
18	Sundaram PSet al 2014	N=1	Presented a case of extruded disc acting as buttonhole preventing the reduction of lateral dislocation of L1-L2 vertebrae who underwent surgical reduction and TLIF L1-L2.
19	Zhang QSet al 2014	N=53 N=24(no disc removal) N=29(disc removal)	RCT which identified the negative effect on treatment results of reserving damaged intervertebral discs when treating type B and type C spinal fracture-dislocations through a one-stage posterior approach. Concluded that the damaged intervertebral disc should be removed and substituted with a bone graft because reserving the damaged disc in situ increases the risk of treatment failure.
20	Xiong Wet al 2013	N=11	Reported a technique for treating severe thoracolumbar fractures with single-stage decompression, reduction, reconstruction, and stabilization via an entirely posterior approach.
21	Liao XYet al 2012	N=24	Explored efficacy of posterior reduction and interbody fusion in treating thoracolumbar fractures and dislocations.
22	Nakao Yet al 2012	N=1	Reported the surgical management of a man with lateral lumbar dislocations in 2 noncontiguous levels
23	Gao Bet al 2012	N=20	Evaluated the early clinical outcomes of subtotal corpectomy and intervertebral bone grafting through posterior approach alone in the treatment of thoracolumbar burst fracture or thoracolumbar fracture-

			dislocation.
24	Wang Fet al 2012	N=11	Surgical experience with 11 patients who had complete fracture-dislocation of thoracolumbar spine.
25	Moore TAet al 2012	N=1	Presented a novel technique for reducing these injuries that is predictable and reproducible.
26	Aly TA2011	N=23	Analyzed the results and efficacy of spinal shortening combined with interbody fusion technique and decompression with a recapping laminoplasty(T-saw was used for division of the posterior elements, removal of the extruded bone fragments and disc material, the excised laminae were replaced exactly in situ to their original anatomic position then interbody fusion.) for the management of dorsal and lumbar unstable injuries.
27	Obeid Iet al 2012	N=3	Case report of 3 thoracic spine fracture-dislocations with complete spinal cord section treated by total vertebrectomy and spine shortening through a posterior approach.
28	Hidalgo-Ovejero AMet al 2010	N=1	Presented a case report of an L3-L4 dislocation treated by initial closed reduction using a halo-bifemoral system, followed by pedicle instrumentation and arthrodesis from L2 to L5.
29	Xia Qet al 2009	N=34	Analyzed the clinical results of simultaneously combined anterior and posterior surgery for severe thoracolumbar fracture dislocations, clarified the surgical indications for these high-energy injuries. Severe thoracolumbar fracture dislocations that cannot be effectively treated with either an anterior or posterior approach alone, simultaneously combined anterior and posterior surgery is a reliable method that can achieve a sufficient decompression, reduction and reconstruction.
30	Li Tet al 2008	N=35 TLIF=14 PLF=21	Compared the therapeutic effect of transforaminal lumbar interbody fusion (TLIF) and posterior lateral fusion (PLF) in treatment of thoracolumbar spine fracture and dislocation. TLIF was found to be superior to PLF in bony fusion and restoration of spine column height.
31	Hsieh CTet al 2008	N=1	Reported a case of a healthy 50-year-old man who presented with complete fracture-dislocation of T12 through L1 vertebrae without paraplegia. Possible mechanism may be result spontaneous decompressive fractures of the spinal elements with sparing of the spinal cord.
32	Sieradzki	N=1	Reported a case of a 14-month-old child who had suffered a fracture

	JPet al 2008		dislocation at T12-L1 from nonaccidental trauma. The patient was neurologically intact on admission. Treatment consisted of closed manual reduction and hyperextension casting under sedation
33	Domenicucci Met al 2008	N=1	A unique case of pseudo-aneurysm of a lumbar artery after injury of the thoracolumbar spine was presented.
34	Bode KSet al 2007	N=1	Case report of pedicle screw fixation in an infant with nonaccidental spine trauma.
35	Kang YJet al 2007	N=42	Explored the operative strategy (anterior approach-10 cases, posterior approach-28 cases, and anterior combined with posterior approach-4 cases) and clinical outcome of the thoracolumbar fracture dislocation.
36	Ma ZM et al., 2007	N=15	Analyzed the clinical characteristics of fresh thoracolumbar fracture-dislocation combined with paraspinal muscles, ligaments and intervertebral disc ruptures and discussed the surgical procedures- open reduction and internal fixation with pedicle screw-rod system, and intervertebral resection and fusion via posterior approach .
37	Akay KMet al 2003	N=1	Reported a lateral fracture-dislocation of the T12-L1 vertebrae without neurological deficit
38	Yu SWet al 2002	N=20	Evaluated the efficacy and complications of short-segment fixation for the treatment of thoracic or lumbar spine fracture-dislocation. Concluded that thoracolumbar fracture-dislocation required firmer fixation especially in the low lumbar region, and short-segment fixation resulted in a high failure rate. Circumferential anterior and posterior fusion often played a role in certain severely injured cases.
39	Öğün, T.C. et al., 2002	N=15	Presented ten extremely rare neurologically intact fracture-dislocations of the thoracolumbar spine and reported the results of treatment
40	Razak Met al 2000	N=15	Fifteen cases of unstable fracture-dislocation of the thoracolumbar spine have been treated by open reduction, short segment transpedicular fixation and fusion
41	Yazici M et al., 1999	N=1	Reported of a rare complete dislocation of the first lumbar vertebra with incomplete paraplegia without fracture in a 6-year-old girl, who was treated with modified Luque frame with sublaminar wires and had full neurological recovery at 6 months.
42	Phaltankar P M 1997	N=1	Reported a 9-month-old infant with fracture-dislocation at the thoracolumbar junction with locking of vertebral bodies, probably with

			incomplete neurologic injury and partial postoperative recovery.
43	Devilee R et al., 1995	N=33	Thirty-three patients with fractures/dislocations of the thoracolumbar spine were treated by fusion and Harrington instrumentation (rod-long-fuse-short technique) after early reduction and stabilization by postural reduction or halo-bifemoral traction.
44	Chavda DV et al., 1994	N=1	Described technique of reduction and internal fixation of thoracolumbar fracture-dislocation using pedicle screws and variable screw placement plates in a case with L1L2 fracture dislocation with paraplegia.
45	Villanueva Cet al 1994	N=1	Reported a patient with a lateral distraction injury of the lumbar spine without any thoracic or abdominal injury that reduced had spontaneously prior to surgery. Lateral bending in the frontal plane probably caused unilateral disruption of the ligamentous and osseous restraints.
46	Milicić Aet al 1994	N=42	Studied operative (short internal fixation with Roy-Camille plates) versus conservative treatment of the fractures or dislocations of the thorocolumbar spine associated with neurological deficiency
47	Stavrev P1994	N=35	Reported patients with unstable injuries, with and without neurologic deficit who underwent spinal stabilization using Meurig-Williams plates and screws with encouraging results.
48	Sándor L1994	N=1 presented	Used lever-type internal fixateur, the LS-8 system for reduction and stable fixation of fractures and fracture-dislocations of the thoraco-lumbar and lumbar spine. The LS-8 combined the advantages of the spinal fixateur interne and conventional plate fixation, while largely avoiding their disadvantages, like the fixed position of the screw hole and the mechanical overloading of the fixing points, as in the previous hook-type systems. To minimize these drawbacks, a plate of variable length was added to the system, creating a fulcrum that prevents overloading. The reinforced 8mm diameter screws functioned as lever arms around this fulcrum, conducting and counterbalancing the active forces. Since the LS-8 ″lever fixateur” was a reinforced system, any plaster or brace was no longer necessary.
49	Hutchinson, M.R. et al., 1993	N=4	Reported 4 cases with thoracic or lumbar fracture-dislocations who were initially treated and reduced with halo-bifemoral traction. Fracture reduction with halo-bifemoral traction decreased pain, controlled instability, relieved skin pressure. In addition, use of halo-bifemoral

			traction allowed for the resolution of spinal shock, allowed time for complete presurgical planning, and simplified the reduction portion of the operative procedure, and therefore reduced the operative time and blood loss as per authors.
50	Zou DW in 1992	N=26	Reported cases with unstable burst fractures, chance fractures and fractures dislocations of the lower thoracic and lumbar spine treated with a spinal pedical screw reduction fixation system (RF system), designed by Chinese scientists. In biomechanical testing, it provided three-dimensional reduction forces. The special design of angle pedicle screw provided accurate angle to restore and maintain the normal thoracic lumbar alignment.
51	Denis Fet al 1992	N=12	Reported thoracolumbar fracture dislocation cases treated with Cotrel-Dubousset or Harrington distraction rods supplemented with either a midline compression rod or interspinous wiring. The use of Harrington distraction rods alone was associated with overdistraction and nonanatomic alignment of the spine.
52	Sim E1991	N=35	Fixation was done with the fixateur interne (F·I.) in 28 patients (combined with remodeling in 2), while 7 patients underwent plating with Teinturier plates and screws from the USI program.
53	Esses SIet al 1991		Reported operative treatment of spinal fractures with the AO internal fixator. Pedicle screw-rod system was effective in stabilizing a variety of unstable fracture patterns. It was effective in decompressing the canal of retropulsed bony fragments associated with burst fractures. By the use of this implant, sagittal plane deformity was easily corrected.
54	Kinoshita Het al 1989	N=30	Open reduction and wiring of the spinous processes were carried out in patients with a thoracolumbar fracture dislocation. In comparison to spinal instrumentation with the use of large long metallic implants, wiring of the spinous processes has several advantages such as limited surgical invasion, firm fixation, no effect on spinal mobility and no need for repeat surgery for removal.
55	Jiang HZet al 1988	–	Reported treatment of unstable fracture-dislocation of the thoracolumbar spine with Luque's U-shaped rod
56	Wang GJet al 1988	N=10	A fiberglass tubular traction bow with continuous adjustable elastic tension was designed for the application of skeletal traction. When used to treat thoracic or thoracolumbar fractures and/or dislocations,

			maintained distraction forces in an uninterrupted fashion. Spinal deformities and pain showed dramatic improvement within the first 3h of treatment and those with incomplete neurologic loss showed improvement of their neurologic function. All cases tolerated the device well and were able to undergo radiologic examination and, ultimately achieve spinal fusion.
57	Yuan FYet al 1986		Treatment of fracture-dislocation of the thoracolumbar spine with paraplegia by a prop-up instrument.
58	Floman Yet al 1986	N=30	Reported use of compressive wire and Harrington rods act in concert which enabled correction of kyphosis and restoration of vertebral and discal height while protecting the cord against traction
59	Aebi Met al 1986	N=30	Analysis of 75 operated thoracolumbar fractures and fracture dislocations with and without neurological deficit. Harrington instrumentation, Luque rods with segmental sublaminar wiring, the locking-hook distraction-rod system of Jacobs used.
60	Munson Get al 1984	–	Reported experimental evaluation of Harrington rod fixation supplemented with sublaminar wires for stabilizing thoracolumbar fracture-dislocations.Grossly unstable lesions were created by resecting a 2-cm segment from the central spinal segment. Testing on an Instron tester documented improvement in stability due to sublaminar wires in this grossly unstable experimental fracture. Improved stability was seen in resisting axial loading, lateral bending, and forward flexion. Rotational stability was improved in particular.
61	Gaines RWet al 1984	N=17	Reported stabilization of thoracic and thoracolumbar fracture-dislocations with Harrington rods and sublaminar wires. (Harrington double-distraction rod technique supplemented by doubled 18-gauge stainless-steel wires applied to two intact laminae above and below the injury)
62	Rosenthal REet al 1980	N=22	Reported unstable fractures or fracture-dislocations of the thoracolumbar spine, treated by Harrington rod instrumentation and spinal arthrodesis, all arthrodeses became solid.
63	Schlicke Let al 1980		Reported simultaneous use of Harrington compression and distraction rods in a thoracolumbar fracture-dislocation.
64	Wang GJet al 1979	–	Reported treatment of fracture dislocations of the thoracolumbar spine with halofemoral traction and Harrington rod instrumentation.Halofemoral traction alowed early decompression of

			injured neural elements in the spinal canal by anatomic realignment of the spinal column. It also acted to stabilize the very unstable thoracolumbar fracture dislocation and prevent displacement as well as further neurologic trauma. The body jacket was easy to make and apply. It allowed early mobilization of patients when utilized in conjunction with the posterior spinal fusion and Harrington rod fixation.
65	Yosipovitch Zet al 1977	N=16	Reported Open reduction of unstable thoracolumbar spinal injuries and fixation with Harrington rods.The treatment allowed easier postoperative nursing and early mobilization of the patient. Nine patients with incomplete paraplegia showed marked neurological recovery, while five with complete paraplegia regained only some sensation. Two patients had no neurological involvement.
66	Benner Bet al 1977	N=13	Reported usage of Harrington instrumentation for fracture dislocations in children with neurological improvement and maintenance of reduction at 2–10 years follow up.
67	Kaufer H et al., 1966	N=21	Reported cases of lumbar fracture dislocation treated by open reduction. Wire fixation and two-segment fusion were used there was not a single instance of recurrent dislocation. Meuhrig-Williams spine plates and four-segment fusion are usually excessive treatment and may contribute to postoperative disability as per the authors.
68	Castillo Odena I 1952	–	Reported treatment of fracture-dislocation of the dorsolumbar vertebrae by dorsal suspension.
69	Nicoll EA	N=166	Treatment of thoracolumbar fractures and dislocations was discussed, dividing cases into stable and unstable types, the recognition of which wasof crucial importance.
70	Stanger JK 1947		Reported Fracture-dislocation of the thoracolumbar spine; with special reference to reduction by open and closed operations

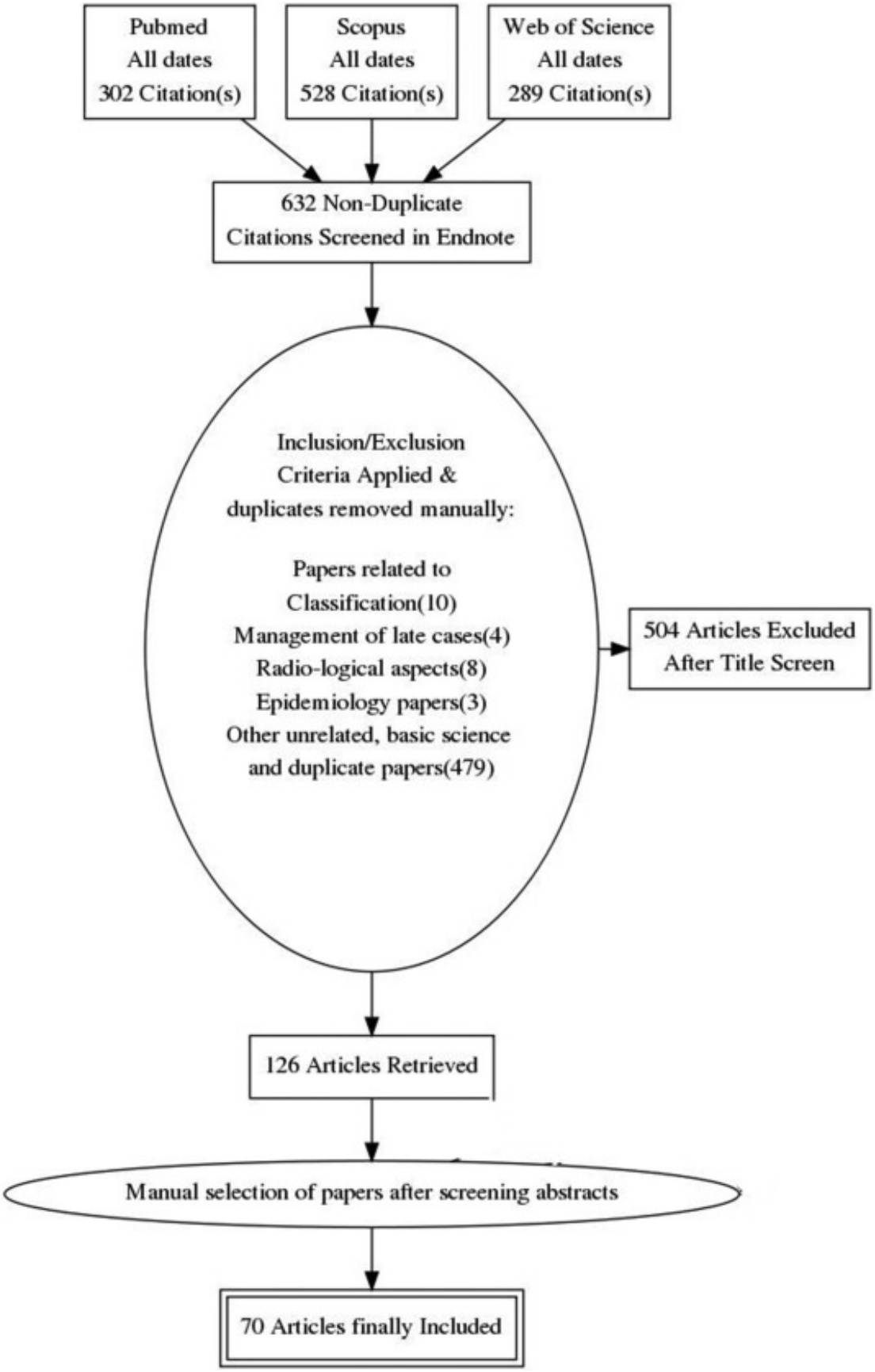

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Fig. 1. Prisma flowchart.

4. Discussion

Vertebral dislocations involve high-energy transfer, and are usually caused by high-velocity road traffic accidents or falls from height, although some underlying problems, like rheumatoid arthritis or spinal bifida might predispose to these injuries, even with lesser degrees of trauma. Several surgical techniques are described in the literature for the reduction and fixation of thoracolumbar dislocations. Some amount of postural reduction might occur in many cases as the case is positioned prone on the operation table. Perched or locked facets are manipulated and any sagittal or coronal plane malalignments are usually suitably corrected via a posterior approach using Cobb elevators, lamina spreaders, or towel clips. Usually in fracture dislocation of the thoracic spine, the facet(s) can be jumped, perched, impacted or fractured. The facet joint can sometimes be reduced simply by manually introducing a large Penfield instrument underneath the dislocated facet. Open reduction manoeuvres have been discussed here in detail, including manual reduction by distracting the spinous processes with towel clips or by utilizing interspinous lamina spreaders, using small curettes or Penfield to manipulate the jumped superior facet out of locked position. These maneuvers have a high failure rate, thereby necessitating further invasive procedures, like partial or complete facetectomy, laminectomy, ligamentum flavum resection or removal of other bony or soft-tissue remnants (which might be hindering reduction). One should prefer to leave the facet intact for the sake of stability if the reduction seems achievable; however, if the reduction cannot be achieved, then undertaking resection of a part or whole of superior and/or inferior facets of one or both sides may become necessary, particularly in old cases. This is also preferred in cases with incomplete neurology. Posterior approach also allows thorough posterior nerve root decompression and permits posterolateral fusion by intertransverse bone grafting. However, is no general consensus on the optimal surgical reduction strategy.[27,28] Halo-bifemoral traction in the pre-surgery period may facilitate easier and safer reduction during surgery. However, closed pre-surgical traction carries dangers due to overstretching of lumbar nerve roots or brachial plexus; or due to immobilization (e.g. DVT). Techniques of posterior fixation e.g. hook and Harrington rods, Luque rods, Hartshill rectangle with sublaminar wires, etc have evolved over the past few decades. However, finally pedicle screw system, which offers a 3 column fixation from a posterior approach, has led to achievement of revolutionary change in fixation strength in spine surgery.[29]

Hannon KM in 1976 utilized Harrington instrumentation for thoracolumbar fracture-dislocations.[28] In the beginning of 1980s, Harrington and Luque systems were used by Aebi et al. to treat thoracolumbar fractures and fracture-dislocations.[27] One third of the cases

required revision-surgery because of insufficient or failed implants. These technically unsatisfactory outcomes facilitated further evolution of the internal fixation systems.

Uriarte E et al., in 1987 described the use of halopelvic traction in an 18-year-old male with thoracic spine fracture-dislocation, which showed marked displacement, but had intact neurology.[29] Later, Carl et al., in 1992 used Cotrel-Dubousset pedicle screws for thoracolumbar fracture-dislocations; 9 of their 38 cases had broken or bent screws in up to 2 years follow up, but most of them were satisfied with the overall result.[30]

Yadla S et al. retrospectively reviewed 4 cases with sagittal-plane thoracolumbar spondyloptosis, and 1 case with coronal-plane spondyloptosis with spinal cord injury over a period of 10-years (1997–2007).Reduction of the dislocation required distraction, reducing impacted vertebral bodies, translation, restoration of normal coronal alignment; and stable internal fixation for maintaining spinal alignment while allowing bony arthrodesis. Authors have described their reduction technique in detail. Multiple bony anchor sites were obtained below and above the level of injury. Authors used 3 bony anchor sites below and above the site of the deformity. More severely impacted injuries might require bigger constructs. A pair of provisional rods were placed, and wedding-band rod connectors functioned as stops near injury level. A pedicle-screw distractor was used for distraction between the wedding-band connectors, which restored normal vertebral column height, thereby allowing correction of sagittal and coronal plane deformity. Rod holders were used for correction of translation in the coronal plane. The two rods were then connected with wedding bands, or a new rod was placed.[31]

Alobaid et al. in his technical note on reduction of dorsal spine fracture dislocation in 2006 advocated that side-opening pedicle screws allowed implant placement in a manner which allowed generation of greater reduction force, and thereby facilitated spinal reduction to the pre-contoured rods with suitable coronal and sagittal alignment. The screws were kept proud in the posteriorly translated segment, and flush in the anteriorly translated segment. The side opening proximal screw ports were kept towards the side on which the vertebral column was coronally translated, that is, if the proximal segment is translated to left, then the 4 screws proximal to the dislocated level will be open to the left, while the distal 4 screws will be open to the right. The rod was cut and bent to suitable sagittal contour. The 2 rods were then attached to the distal pedicle screws and a cross-link was applied distally. With complex reduction forceps, the proximal part of the dislocated vertebral column was reduced to the 2 rods both in the coronal and sagittal planes by pulling the proximal spine posterio-medially. Over reduction does not happen during these reduction manoeuvres due to metal flexibility and bone and soft tissue elasticity. Both the sagittal and coronal offset of the screws allowed strong axial, sagittal and coronal forces that facilitated the achievement of spinal reduction. In cases with locked facets, distraction manoeuvre was used. In cases of neglected fracture dislocation,

reduction manoeuvres were applied to both the rods simultaneously with 2 complex reduction forceps to reduce the stresses.[32]

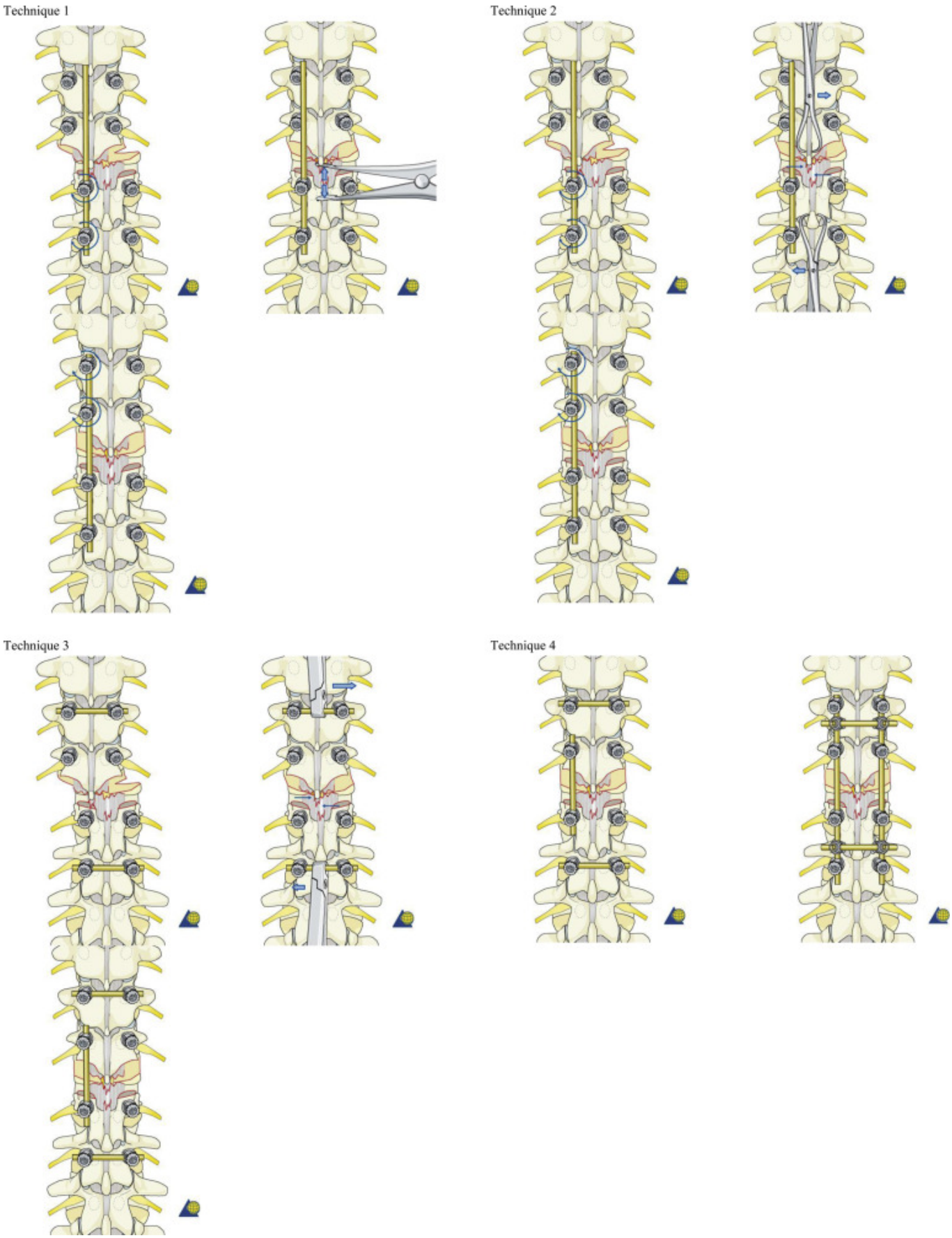
Wang and Yue Zhu in his study "Treatment of Complete Fracture-dislocation of Thoracolumbar Spine" treated 11 cases between 2005 and 2009. Initially armpit pelvic traction was utilized to achieve as much reduction as possible. A small jacket with bands under armpits was used for traction in cephalic direction. A pelvic frame with screws in the ilium was used for traction in caudal direction. A traction weight of 10kg was applied till the patient underwent surgery. Bilateral transpedicular fixation was performed for at least two levels cranial and two levels caudal to the fracture-dislocation. The cranial and caudal laminae were resected for achieving further decompression and visualisation of the dural sac. Reduction was obtained by distraction with forceps applying pressure on the pedicle screws, while visualizing the dura. Traction was applied by 2 persons pulling on the lower limbs and shoulders at the same time, and subsequently, the surgeons manipulated the pedicle screws to achieve reduction. Complete spinal realignment was achieved with rod placement.[33]

Chandrashekhara et al. reported management a rare case of traumatic spondyloptosis with complete cord transection.[34] Denis F et al. reported fracture-dislocation of the thoracic and lumbar spine caused by forceful hyperextension (lumberjack paraplegia) with eleven patients having complete paraplegia, and one having incomplete paraplegia. Dura was torn in six cases. Eleven cases received posterior instrumented fusion, and one was treated with orthotic support. Three cases received Harrington distraction rods only, six received Harrington distraction rods along with a central Harrington compression rod or interspinous wiring, and two received Cotrel-Dubousset instrumentation.[35]

Timothy A. Moore reported that these injuries could be reduced by partial removal of the superior facets of the distal vertebra and pulling the proximal vertebra posteriorly, so that the instrumentation gets fixed with the vertebrae reduced.[36] The benefit facet preserving techniques offer is maintaininance of the integrity of vertebral bony articulations. Preserving the superior facets may lead to better stability after surgery. Also, there is lower risk to the neural tissues as they are not exposed by facet complex resection. Pedicle screws were usually inserted 1 level proximal and distal to the level of dislocation. Temporary rods were inserted in the pedicle screws of the same level and at a level above and below the dislocation. The screw caps were then tightened without full torqueing. Rods were held in between the proximal and distal screws for segmental control. The reduction manoeuvre consisted of distraction for unlocking the facets and a ventrally directed force on the caudal segment to "cover" the superior facets of the caudal segment. Rods were then removed and decortication and fusion was performed.

5. AO techniques

Numerous other robust techniques are preferred by modern surgeons to reduce a dislocation of the thoracolumbar spine, and AO Spine group recommends five such different techniques(Fig. 2). The basic necessity in such cases is usage of long segment fixation with minimum two screws above and below the level of dislocation.[37]



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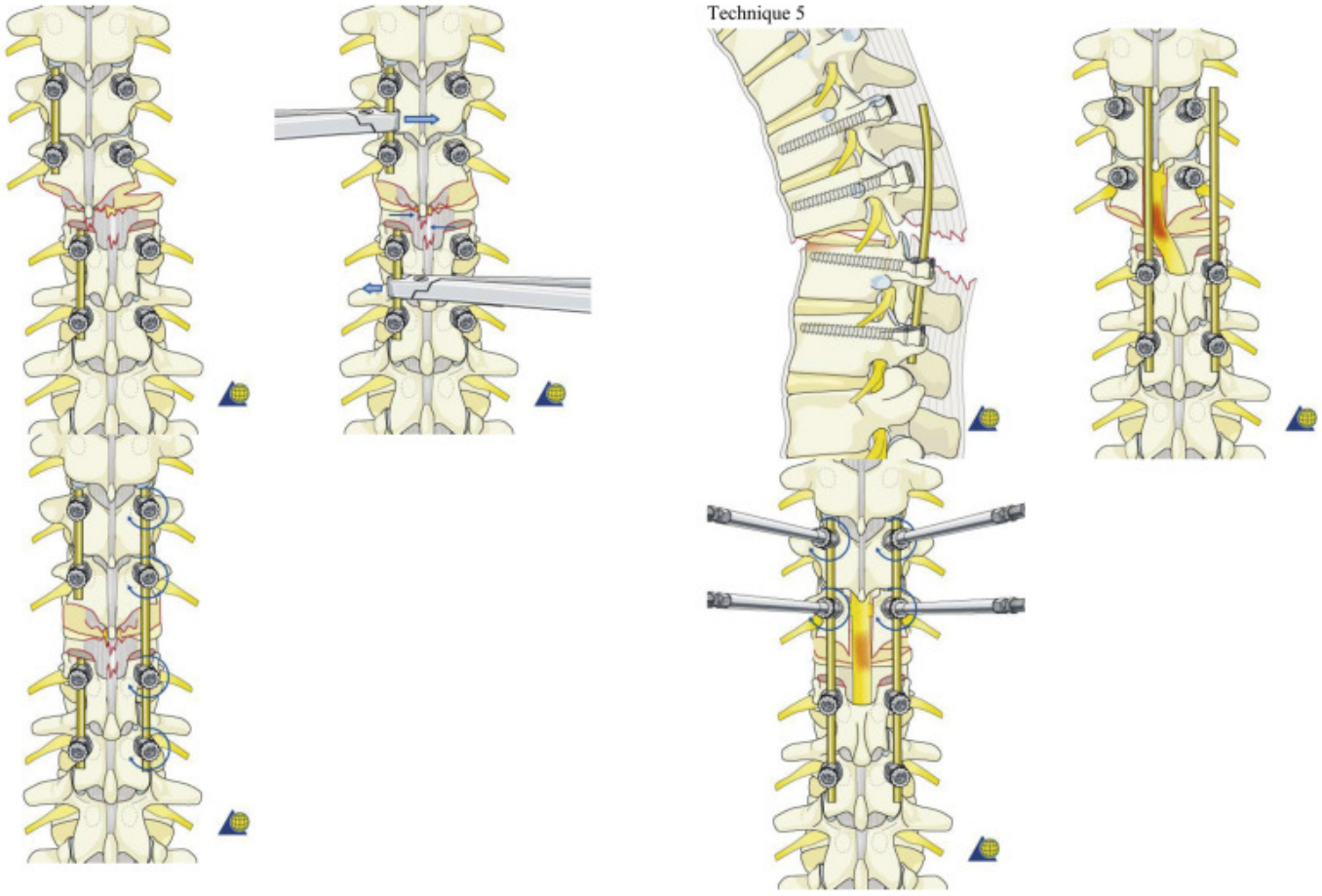

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Fig. 2. AO reduction techniques.Source: AO Surgery Reference, www.aosurgery.org. Reproduced with permission from AO Foundation, Copyright by AO Foundation, Switzerland.

5.1. Technique 1

A long rod is fixed to the distal two pedicle screws on one side. Due to the unreduced dislocation, the rod lies away from the proximal screw heads. A lamina spreader is then put between the spinous processes at the level of dislocation and gentle distraction is applied. If the dislocation gets reduced, the rod is fixed to the proximal screw heads to secure the reduction thus achieved. Another rod is then fixed on the other side and two cross links are added to enhance stability. Advantages are that it is a relatively simple technique, and no facetectomies are necessary and therefore reduction if achieved is stable. Drawback is that reduction may be difficult to achieve, particularly in old cases. Risk of neurological insult is also there.

5.2. Technique 2

A long rod is fixed to the distal two screws. The rod lies away from the proximal screw heads due to misalignment produced by dislocation. The spinous processes of the proximal and distal vertebrae at the level of dislocation are manually distracted with reduction forceps. Gentle pull and manoeuvring of the distal segments, allows the dislocation to be reduced and the rod is then fixed to the proximal pedicle screws heads. Advantage, like technique 1, is the relative simplicity of the maneuvers. As only spinous processes are manually distracted, theoretically lesser risk of neurological insult is there. Disadvantages are higher risk of cut-out of the towel clips through spinous processes, particularly in osteoporosis cases, and hence failure to achieve reduction.

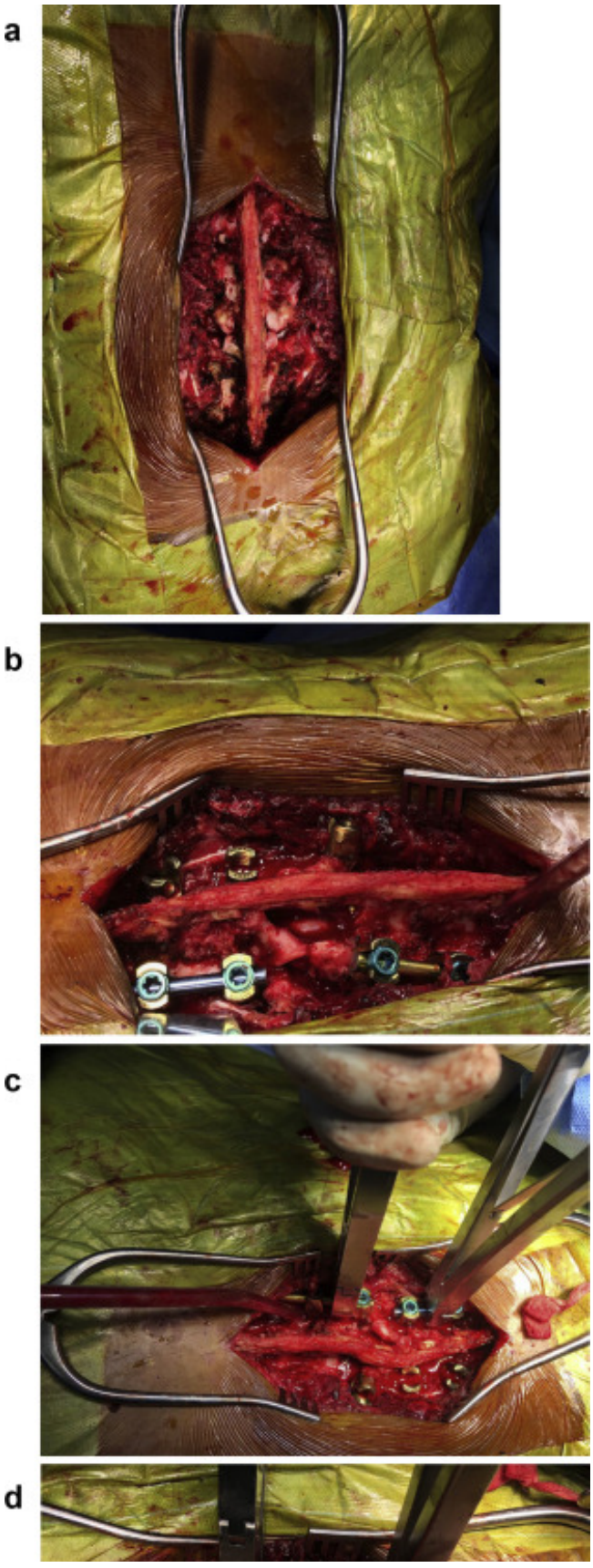
5.3. Technique 3

Two temporary rods are provisionally fixed horizontally into the two proximal and distal pedicle screws just above and below the dislocated level. These rods are held with rod holders and are used to achieve reduction. This allows the surgeon to use stronger forces for manipulation of the dislocated segments. After the reduction is achieved, it is stabilized by using a short rod on one side. Then the two horizontal rods are removed and a long rod is finally fixed on the opposite side. The short temporary rod is removed and another long definitive rod is fixed, followed by application of cross links. Advantages are better 3 column symmetrical hold on the dislocated segments allows precise and robust manipulation, and hence better chance of achieving reduction, lower risk of neurological injury, reduced iatrogenic soft tissue injury, and relative preservation of biomechanically valuable posterior osteoligamentous structures. Disadvantages are possible loss of pedicle screw hold at the levels manipulated, as some minor fracture lines might be pre-existing which might open up with manipulation, particularly in osteoporotic spine. Also, it prolongs surgical time as it needs repeated rod exchanges. Reduction achieved can't be held by applying rods, as both the sides are engaged.

5.4. Technique 4

Two little vertical rods are provisionally fixed above and below the dislocated level on one side only. These small rods are held with rod holders and are used for gentle manipulation and reduction of the dislocation. After the reduction is achieved, a long final rod is fixed on the opposite side. Small rods are removed and replaced by another definitive long rod and two cross links are added. This technique has been illustrated here in two of our cases(Fig. 3, Fig. 4).Advantages, like that of technique 3 are 3 column (but, unlike technique 3, asymmetrical) hold on the dislocated segments, which still allows precise and robust manipulation, and hence better chance of achieving reduction, lower risk of neurological injury, reduced iatrogenic soft tissue injury, and relative preservation of biomechanically valuable posterior osteoligamentous structures. Also, unlike technique 3, the reduction achieved can be fixed by

applying final rod on the other side, as all four pedicle screw hubs are empty on this side and are ready to receive the final suitably contoured rod. Disadvantages are that all four pedicle screws might get loose on one side due to manipulation, particularly in cases with osteoporosis.



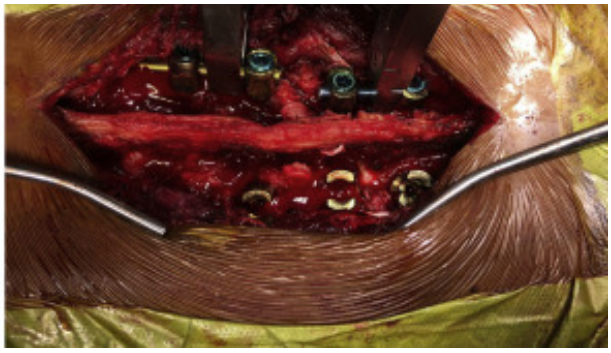


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Fig. 3. Illustration of the reduction technique in a thoracolumbar (D12-L1) dislocation case.

3A: D21-L1 vertebral dislocation, with facets seen exposed in dislocated position. Superior facet of L1 lied posteriorly. Patient was a young boy who had presented after trauma with incomplete paraplegia with bladder bowel involvement. 3B: Two little vertical rods are provisionally fixed above and below the dislocated level on one side only. 3C: These rods were held with rod holders and were used for gentle manipulation and reduction of the dislocation 3D: Reduction achieved. At 3 months follow up, Patient had recovered to ASIA D, achieved bladder bowel control, and was able to ambulate with walker.

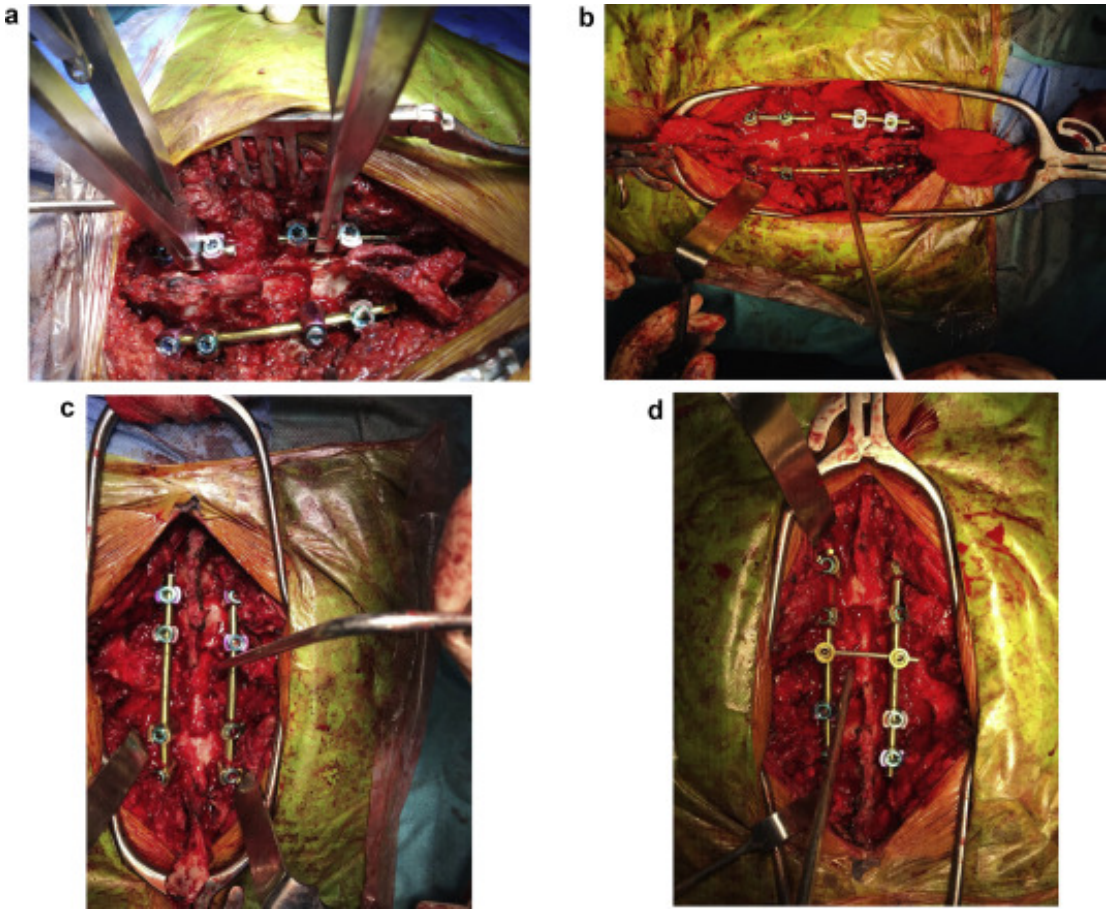

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Fig. 4. Illustration of the technique in a dorsal (D4-D5) dislocation case.

4A: Two little vertical rods are provisionally fixed above and below the dislocated level on one side only and held with rod holders and are used for gentle manipulation and reduction of the dislocation, and reduction is held till a long rod is applied on the opposite side. 4B: After the reduction is achieved, a long final rod is fixed on the opposite side. 4C: Small rods are removed and replaced by another definitive long rod. 4D: Cross link is added.

5.5. Technique 5

This technique is used for cases with incomplete neurological deficit where major reduction forces cannot be used. Two long appropriately contoured rods, are fixed to the distal two pedicle screws on each side. Due to dislocation, the rods lie away from the proximal pedicle screw heads. Posterior neural decompression and visualisation achieved by wide laminectomy and facet joints at the dislocated level are removed on each side. Reduction screws with long heads are used for the proximal part. Reduction is gently affected by using two rod holders, one for each rod by applying gentle force in the direction of the proximal pedicle screws. After

the reduction is achieved with the rods in place in the proximal screw heads, the inner nuts are tightened with the screw extenders. Advantages are the least risk of further neurological injury, and relatively easy reduction without much manoeuvring as facets have been cut. Drawbacks are lesser stability and lesser surface area for fusion, as facets and laminae have been resected. Also, opening the canal and exposing the dura at initial stage somewhat increases the chances of accidently hitting the cord with instruments, although this is believed to be very rare.[37,38]

5.6. Levering technique by Hadgaonkar S et al.

This reduction manoeuvre is similar to AO reduction technique 4, but in some cases he used 4 provisional small rods (two on each side) in some of the cases and held proximal small rod on one side and distal small rod on the other side for affecting reduction. This allowed for more symmetrical application of reduction force. Although this construct aids in making the reduction markedly easier in these problematic situations, it makes it difficult to accomplish the final fixation due to the need for changing small longitudinal temporary rods (on both sides) with longer final rods.[38]

Special benefits of these pedicle screw and rod based reduction techniques(like AO Techniques 3 and 4 and levering technique by Hadgaonkar S et al.) include lower risk of neurological injury, reduced iatrogenic soft tissue damage, and relative preservation of biomechanically valuable posterior osteoligamentous structures. In grossly dislocated spine cases, the cranial and caudal segments behave as separate entities, having undergone anteroposterior and lateral shift, tilt, and rotational displacement, along with overlapping. The maneuvers described basically involve serial manipulations, after initially getting cranial and caudal anchorage to all 3 spinal columns, with 2 short pedicle screw-rod constructs. Further manoeuvring involves control of 2 segments, with using vice grips or rod holders applied on the rods on both sides. A 3-step manoeuvre is then performed for reduction, with the first step being traction for disimpaction, and the second step being partial exaggeration of the displacement by controlled manipulation of the segments in the same direction as their posttraumatic displacements. One must keep in mind that if unreasonable force is used while performing these maneuvers, additional iatrogenic damage to the spinal cord and neural structures might occur. Finally, once disimpaction is ensured, force is applied in the direction opposite to the initial direction of dislocation and reduction is maintained with gentle sustained pressure. It's important to note that initial manoeuvre of exaggerating the deformity may cause further canal narrowing and can pull back disc material or bone fragments during reduction. Discectomy and removal of bony fragments lying anteriorly may therefore be needed subsequently. Anteriorly located vascular structures may also be affected due to stretching and therefore the surgeon must be gentle and patient while performing the manoeuvres described above. Surgeons having knowledge of all these techniques can decide about appropriate technique suitable for a particular case during preoperative planning or intraoperatively, and can even use a judicious

combination of these procedures as felt necessary.

Aggressive facetectomy or too much removal of bony structures should generally be avoided. Usually, with the help of these maneuvers one can achieve precise reduction with relative preservation of important bony elements including facets and uninjured portions of the posterior ligaments complex. However, if one faces difficulty in mobilizing the vertebrae, the process must be temporarily halted and possible structures obstructing the reduction should be searched for. Releasing structures hampering reduction (including, facet capsules, ligamenta flava, loose bone fragments, etc) becomes important now. After this the reduction maneuvers are gently repeated again. Posterior decompression of the spinal nerve roots is also performed.[38]

Zeng J et al., in 2018 performed a case of complete facture-dislocation with intact neurological function. L1- L2 posterior reduction followed by internal fixation with pedicle screws and rods was done where bilateral transpedicular screws were inserted in the T12, L1, L3, L4, and L5 vertebrae. Another pedicle screw was inserted in the vertebral body of L2 for fixation and reduction. Realignment of thoracolumbar spine was achieved with the rods. He also concluded that long instrumentation with bony fusion is the recommended surgical method.[39]

5.7. Vertebrectomy

Garg M et al., in 2018 performed retrospective analysis of 5 patients having lateral-optosis who treated by one-stage posterior open reduction and fixation. In one of his cases, an 18-year-old male presented with a history of road traffic accident and diagnosed as L1-L2 fracture dislocation where screws were placed on both sides at T12, L1 and L4. One pedicle screw was put on the left side in L3. The L1-L2 dislocation could not be reduced after distraction. Any further manoeuvres were abandoned to avoid any collateral damage to the surrounding structures. L2 vertebrectomy was done for aligning the L3 vertebra under the L1 vertebral body.[40]

Lorente A et al., in 2018 managed a fracture dislocation at D12-L1 level by performing a L1 vertebrectomy for reducing the dorsolumbar hinge. Eight screws and two Steffee plates were placed and sublaminar wires were added to reinforce the osteosynthesis.[41]

5.8. Transforaminal fusion

Machino et al. initially reported transforaminal fusion technique in thoracic and thoracolumbar regions for reconstructing the anterior and middle columns through a posterior only approach.[42] They then compared this technique with anterior/posterior/combined surgery in lower thoracic spine region and reported that it achieved rigid reconstruction and enabled early ambulation. Schmid et al. reported

management of 100 cases with thoracolumbar trauma by anterior reconstruction with monocortical strut grafts using a technique similar to PLIF/TLIF. In 82 cases the anterior column was restored satisfactorily.[43]

Xiao-Bin Wang et al. retrospectively reviewed 30 cases with spinal fracture dislocation who had undergone one stage posterior surgery between 2007 and 2011. Pedicle screw fixation, decompression and interbody fusion was performed in all. The ruptured disc and bone fragments in the spinal canal were removed via the posterolateral approach, just like the transforaminal lumbar interbody fusion (TLIF) technique. Intervertebral disc and endplates were also removed. Once the bone graft bed was prepared, autologous bone harvest from the resected posterior arch was implanted and packed tightly into the gap.[44]

Thoracolumbar fracture-dislocation severely reduces spinal stability. Long segment fixation is therefore important to ensure distribution of stress and for reducing hardware failure rate. Intraoperative removal of the facet joints, if necessary, further compromises stability and increases burden on the internal fixation. Short segment fixation by pedicle screws only is reported to fail in 26% cases in the thoracolumbar spine, and in 83% in lower lumbar spine.[45] This is closely related to achievement of fusion. Z Fang et al. utilized different fusion techniques as per the site of injury to anterior and middle columns in cases with dislocation or fracture-dislocation.[46] If the injury was located at the level of vertebral body, the reduced spine ensured mutual apposition the bone within the vertebral body. As the dislocated segment was firmly fixed, the anterior and middle columns of the spine were able to achieve bony fusion quickly, so for this group of case a posterolateral fusion only was found to be sufficient. In cases with dislocation at the level of the intervertebral disc, the injured disc was totally removed and a titanium mesh cage filled with morselized autologous bone graft was placed in the anterior gap, followed by a posterolateral fusion. Long segment fixation was used, and a good fusion was achieved in all cases.

Authors concluded that posterior transforaminal approach is safe because working zone could be acquired without retraction on the spinal cord. Fragments of disc and bone located anterior to the dura could be removed and it was possible to resect the interbody discs and endplate cartilage and place interbody bone graft. Authors argue that fracture dislocations are usually accompanied by laminae and facet fractures. Dural tear and CSF leak is also common in this kind of severe injury and dislocated, locked facets are usually an impediment to reduction. Authors did laminectomy and at least one side facetectomy at the injured level. The aim, besides neural decompression, was to clean up the intracanal fractured laminae and facets fragments, repair the dural sac to control CSF leak, facilitate reduction and help in performing the interbody fusion with visualisation of dural sac.[46]

6. Conclusion

The techniques described above provide guidance for management of thoracolumbar dislocations and fracture-dislocations. Experience and expertise of the operating surgeon is also important, as unintended neural injury can happen if appropriate care is not taken. Overall, these techniques can be very helpful in achievement of accurate reduction and appropriate sagittal and coronal balance safely.

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Conflicts of interest

No conflict of interest to be disclosed.

Appendix A. Supplementary data

The following is the Supplementary data to this article:

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Multimedia component 1.

Special issue articles Recommended articles Citing articles (1)

Research data for this article

Data not available / No data was used for the research described in the article

About research data

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