Spinal Decompression in Thoracolumbar Fractures

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Abstract

Background: Surgical management of thoracolumbar (TL) spinal injury is controversial. With no set official guidelines, current broad management of unstable TL fracture usually involves stabilizing the spine and decompressing the spinal canal of any excess pressure. With spinal decompression being broadly split into indirect and direct decompression, sometimes, the decision-making may lack consensus. This literature review aims to gather the available evidence to help provide a more evidence-based approach in managing thoracolumbar injuries.

Methods: PubMed was searched for relevant articles using keywords "thoracolumbar fracture", "ligamentotaxis" and "spinal decompression".

Results: Sixteen articles were relevant to the aim of this study. Both direct and indirect decompression are found to be effective techniques in improving neurologic function in patients with unstable TL injuries. With the less invasive approach, indirect decompression seems to be the more favourable technique in the acute setting.

Conclusion: This review highlights that both techniques are viable methods in providing decompression and that surgical philosophy should be individualized to the case and fracture morphology. A criteria-based approach can be a useful tool in the decision making.

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Introduction

Traumatic injury to the spine can lead to serious consequences if left untreated. The most common site for spinal fractures is the thoracolumbar spine, often because of high-energy injuries.(1) Some fractures lead to the fragments of bone protruding into the spinal canal, increasing the pressure on the spinal cord and causing neurological deficit. Thoracolumbar fracture morphology varies, and can be grouped into several classes (see figure 1).

Damage to the vertebral structure may lead to spinal instability, defined as the inability of the spine to maintain its structure under physiological load without any major pain, deformity, or neurological deficit.(2) Management of spinal trauma can vary from nonsurgical to surgical.(3) It is dependent on both the severity and mechanism of injury, but all managements have an overlying aim of stabilising the spine, restoring alignment, and preventing further neurological deficit.

In unstable fractures the mainstay treatment is surgery in order to restore spinal stability. This can be done for example via screw rod fixation with or without spinal

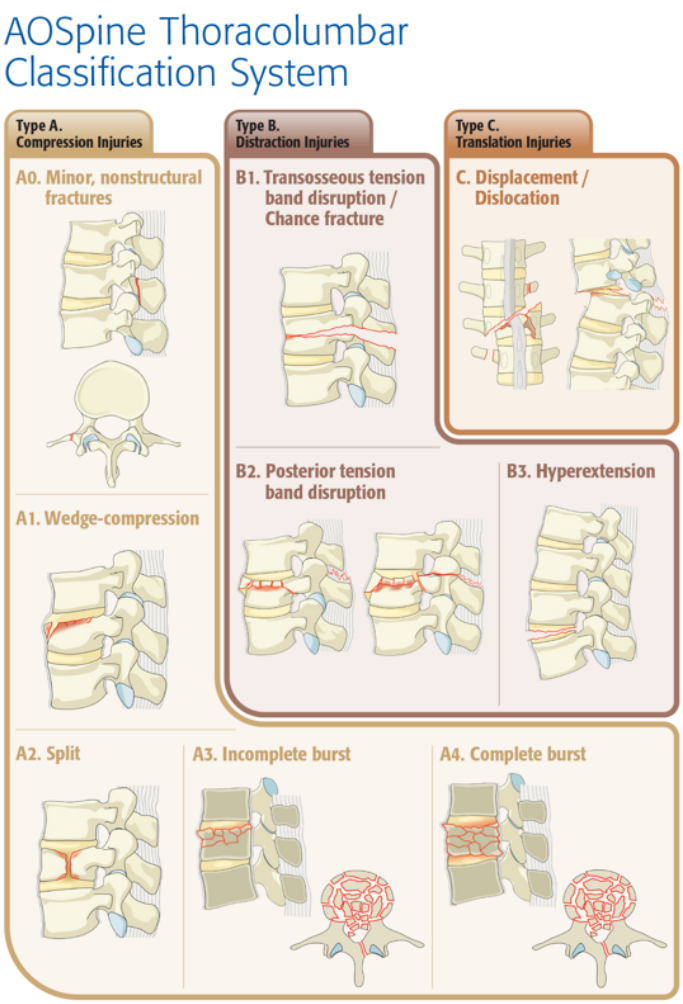
decompression.(4) Decompression is a procedure used to alleviate pressure in the spinal canal that can occur when there is damage to the spine. Currently, most surgeons opt for additional spinal decompression in cases of neurological deficit.

A variety of applicable methods can be used to decompress the spine, and these can broadly be categorised into either direct or indirect decompression. Indirect decompression, or ligamentotaxis, is a posterior approach which utilises the posterior longitudinal ligament (PLL).(5) A longitudinal distraction force is placed on the band, realigning the fractured bony fragments of the vertebral body and reducing any pressure on the cord itself. This approach is regarded as a less invasive procedure, thus reducing complications seen in direct decompression.

Multiple techniques are used to carry out direct decompression and these can generally be divided into anterior and posterior approaches.(6) The posterior approach involves removing the spinous process, lamina, and ligamentum flavum, all of which are components of the posterior ligament complex, with the aim of creating more space for the spinal cord.(7) This more invasive procedure possesses a risk of tearing the dural sack leading to cerebrospinal fluid (CSF) leakage, and if not immediately repaired, it may lead to serious complications such as meningitis, epidural abscess, and CSF fistula formation.(8) Anterior decompression is an alternative approach, and involves removing and replacing the vertebral body to decrease the pressure on the spinal cord.(9)

Aims and Objectives

Although common practice, there are no set official guidelines which outline the indication and technique of spinal decompression within trauma. A consensus on spinal decompression would be very beneficial in determining optimum treatment pathways. The aim of this literature review is to compile and evaluate available spinal decompression studies to present the overall evidence about the indications and clinical outcomes of spinal decompression in thoracolumbar fractures.



Case courtesy of AO Foundation, Radiopaedia.org, rID: 59354

Figure 1. AO Classification of TL Injuries. AO classification broadly splits TL fractures into 3 main categories (A,B,C) based on the mechanism of injury. Subtypes of these are then described depending on the anatomical consequence of injuries.(10)

Methods

PubMed was used to search for relevant peer-reviewed articles regarding spinal decompression in thoracolumbar fractures. The search terms used were "thoracolumbar fracture", "ligamentotaxis" and "spinal decompression". See Table 1 for inclusion criteria.

Inclusion Criteria
Thoracolumbar fractures
Papers written in English
Surgical techniques consisting of direct and/or indirect decompression
Full-text available

Table 1. Inclusion criteria of literature review.

Results

Sixteen papers contained relevant evidence regarding the aims of this review. A summary of the key points of these articles have been summarised into Table 2.

Study	Surgical Decompression	Spinal Injury	Neurology? (Yes/No)	Outcome + Conclusion
(Alhashash and Shousha 2022) Prospective Study	Direct	Osteoporotic	Mixed	(32.6±8.4 month mean follow-up) **Oswestry Disability Index:** From 24.4±8.2 to 12.6±6.5. **Visual Analog Score:** From 8.12±1.5 to 2.3±2. **Cobb angle:** From 6.3°±4.2° to 12.5°±4.3°. **Conclusion:** Direct decompression is an effective technique for osteoporotic fractures.
(Ataka et al. 2009) Prospective Study	Indirect	Osteoporotic	Y	(25 month mean follow-up) **Kyphosis angle on flexion:** From 14.6° to 9.9°. **Modified Frankel Grade:** Minimum one grade improvement. **Back Pain:** Improved in all patients. **Conclusion:** Indirect decompression is an effective technique for osteoporotic fractures.
(Been and Bouma 1999) Retrospective Study	Direct + Indirect	Trauma	Mixed	(6-year mean follow-up) **Frankel Grade:** **Direct:** 10 out of 10 patients with neurology improved by at least one grade.

				Indirect: 7 out of 8 patients with neurology improved by at least one grade. **Loss of postoperative kyphotic correction:** Significantly greater in indirect group. **Conclusion:** Indirect decompression is as effective as direct decompression in providing neurological recovery.
(Ge et al. 2011) Prospective Study	Direct	Trauma	Y	(Minimum 24-month follow-up) **Modified ASIA Grade:** 35/38 patients improved by at least one grade. **Kyphotic correction:** From 22.4°to 4.6° **Spinal Canal Encroachment:** From 61.5% to 8.7% **Conclusion:** Direct decompression allowed excellent canal clearance and improved neurological deficit.
(Jaiswal et al. 2020) Randomised Controlled Trial	Direct + Indirect	Trauma	Y	**Canal diameter:** No significant difference in improvement between indirect and direct decompression. **ASIA Grade:** No significant difference in improvement between indirect and direct decompression. **Conclusion:** No significant difference in clinical outcomes were found between direct and indirect decompression.
(Jun et al. 2011) Retrospective Study	Direct	Trauma	Y	(Immediate follow-up) **Canal encroachment:** From 84% to 9%. **Kyphosis:** From 20.5° to 1.5°.

				Frankel Grade: 1.7 grade improvement. **Conclusion:** Direct decompression is an effective technique for burst fractures.
(Mallepally et al. 2022) Prospective Study	Indirect	Osteoporotic	Y	(Minimum 2-year follow-up) **Kyphosis correction:** From 27.12° ± 9.63° to 13.7° ± 7.29°. **ASIA:** 60/61 patients improved by at least one grade. **Back pain:** Improved in all patients. **Conclusion:** Indirect decompression is an effective technique for osteoporotic fractures.
(Marco et al. 2010) Prospective Study	Direct	Trauma	Y	**Frankel Grade:** All patients with neurology improved by at least one grade. **Kyphotic Angle:** From 17° to 7° **Conclusion:** Direct Decompression is an effective technique on burst fractures with neurological deficit.
(Mueller et al. 2006) Prospective Study	Indirect	Trauma	N	**Stenosis of Spinal Canal Area:** From 29% to 19% **Conclusion:** Indirect decompression does not fully remove canal encroachment.
(Peng et al. 2015) Prospective Study	Direct + Indirect	Trauma	Mixed	**Conclusion:** Indirect decompression is effective if width of intracanal fracture fragment is <75% of transverse diameter of vertebral canal and the height is <47% of height of injured vertebrae.
(Piccone et al. 2020) Prospective Study	Direct	Trauma	Y	(Mean follow-up 26 ± 5.3 months) **ASIA:** All patients improved by at least one grade.

				Visual Analog score: 7° improvement. **Kyphotic angle:** From 21.8° to 14.8°. **Operative blood loss:** Average blood loss = 756mL **Conclusion:** Direct decompression is a safe and successful approach.
(Sjostrom et al. 1996) Prospective Study	Indirect	Trauma	Mixed	**Spinal Canal Encroachment:** From 40% to 20%. **Conclusion:** Indirect decompression shows more favourable outcomes when there is minimal canal encroachment.
(Wang et al. 2017) Retrospective Study	Indirect	Trauma	Mixed	(2-year follow-up) **ASIA:** All patients between Grades B-C showed at least one grade improvement. No significant improvement in neurological recovery between patients with unreduced and reduced fragments after indirect decompression. **Conclusion:** Indirect decompression cannot always reduce fracture fragments. Despite this, there were no significant differences in ASIA recovery between patients with either reduced or unreduced fragments.
(Yang et al. 2011) Retrospective Study	Indirect	Trauma	Mixed	(40.1 months mean follow-up) **Canal encroachment:** From 41.4% to 13.7% **ASIA:** All patients grouped B-C showed at least one grade improvement. **Kyphotic angle:** From 18.9° to 10.2°.

				Conclusion: Indirect decompression is an effective technique for TLB fractures.
(Yuan et al. 2020) Retrospective Study	Direct + Indirect	Trauma	N	(12-month follow-up) **Spinal canal volume ratio:** No significant difference between direct and indirect decompression. **Cobb angle:** No significant difference between direct and indirect decompression. **American society of spinal injury motor score:** No significant difference between direct and indirect decompression. **Conclusion:** Indirect decompression was just as effective as direct in non-neurological thoracolumbar injuries if fracture vertebral body was restored, cobb angle was reduced and volume ratio of spinal canal was improved.
(Zhang et al. 2015) Prospective Study	Indirect	Trauma	Y	(32.8 ± 11.6 months mean follow-up) **Pain:** Relieved in all patients **ASIA motor:** From 25.4 ± 10.8 to 42.1 ± 10.5. **Vertebral Canal diameter:** From 5.5 ± 1.3 to 11.1 ± 2.2 mm. **Kyphotic angle:** 25.9° ± 3.4° to 7.9° ± 2.0°. **Conclusion:** Indirect reduction is effective for TL burst fractures.

Table 2. Papers Included from Literature Review. Papers which were included in this literature review have been summarised to highlight the decompressive technique, neurological status of included participants, relevant measured objectives, and conclusions. Decompression has been grouped into either indirect or direct. Specific decompressive technique and spinal fixation has not been specified. Stated follow-up has been included if mentioned.

Discussion

Direct Decompression

The necessity of spinal decompression brings up much controversy in the literature. Although some suggest the procedure should be specified to those with neurological deficit, others have found the procedure to reduce the risk of both delayed neurological deficit and kyphotic deformity associated with back pain.(11) Alhashash and Shousha evaluated an anterior direct decompression technique in osteoporotic vertebral fractures, finding it to be an effective technique in reducing both kyphotic deformity and back pain in both patients with neurology and without.(12) Direct decompression's effectiveness in inducing neurological recovery has also been shown by Jun et al.(13) Following 10 patients under the age of 40, Piccone et al. found that 9 out of 10 of patients neurologically recovered to a normal status (ASIA E).(14)

Ge et al. reported a new technique involving direct posterior decompression along with interlaminar fusion in thoracolumbar burst fractures.(15) Here they suggested that a degree of posterior instrumentation failures were due to large bone defects in the fractured vertebrae created during indirect decompression. This may suggest that ligamentotaxis may limit standard spinal fixation procedures. In their study of direct decompression, it was found that most patients showed neurological recovery, with no instrumentation failures noted. This may suggest direct decompression to carry less risk in surgical failure. Alternatively, to address instrumentation failure in indirect decompression, others have suggested that a gradual mobilisation protocol may be effective in limiting these failures in patients receiving indirect decompression.(16)

With both indirect and direct decompression being shown to be effective procedures, specific parameters instructing one method over the other may be beneficial. Marco et al. set the parameters of conducting a direct decompression to >50% spinal canal encroachment.(17) This was based on previous evidence suggesting over 50% encroachment meant there was a high chance the PLL was not intact and thus ligamentotaxis was impractical.(18)

Indirect Decompression

Ataka et al. investigated the efficacy of indirect decompression in osteoporotic vertebral fractures (OVF).(19) Their findings suggested direct decompression was not always needed to improve neurological outcome. Instead of a constant pressure of bone fragments directly on the spinal cord, it was suggested that the incomplete neurological deficit occurred due to the dynamic instability of the osteoporotic vertebrae itself. This hypothesis was further investigated by Mallepally et al.(20) Their use of dynamic MRI utilising the flexion-extension protocol provided direct evidence of dynamic instability. Instead of carrying out direct decompression, involving higher operative times and surgical morbidity, indirect decompression was an effective and less invasive alternative for osteoporotic fractures. Additionally, a benefit of indirect decompression involves leaving the posterior ligamentous complex intact. As this is an integral component of spinal stability, this may further support its use in unstable fractures.

Investigating indirect decompression in TLB fractures with no neurological deficit, Mueller et al. found indirect decompression to significantly increase spinal canal area (SCA) in fractures involving vertebrae T10-L2.(21) This technique did not however appear effective in L3-4 fractures. This is likely due to the anatomy of the PLL, where beyond L3, the ligament is much less prevalent. L2-3 showed the best improvement in SCA. Another criteria found to affect feasibility for indirect decompression was the fragment shape. Trapezoid fragments of bone were found to be very difficult to reposition, thus making this procedure ineffective in decompressing the spinal canal. Although postoperative canal encroachment significantly reduced after indirect reduction, the authors still did not recommend indirect decompression for patients experiencing neurological deficit. This was reasoned by an insufficient reduction in SCA.

Supporting the recommendation by Mueller et al. that due to insufficient SCA widening, indirect decompression should not be conducted in cases of neurological deficit,(21) Sjostrom et al. found neurological impairment to be worse when spinal canal encroachment was higher.(22) This supports the theory behind decompression, where the neurological deficit is caused due to an increase pressure within the spinal canal, and by relieving this pressure, neurological deficit is reduced. The authors found indirect decompression to be a successful technique in patients under 40 years with burst fractures consisting of minimal canal encroachment. With indirect decompression reducing encroachment by only 50% however, it was implied that this procedure may have less favourable outcomes in severe encroachment with neurological deficit, as a significant amount of encroachment may remain.

Many discussed studies have based their recommendations on the degree of post-operative canal encroachment. This has been rationalised by the idea that indirect reduction does not

provide sufficient reduction in canal encroachment, and thus would not relieve canal pressure enough to improve neurology. However, despite this reasoning, none of the discussed studies have directly measured neurological deficit. Conversely, other studies have suggested SCA to have no correlation with neurological recovery.(23-25) Yang et al. showed promising results in patients with TLB fractures using indirect decompression.(26) Importantly, this study did measure patient neurological deficits, and improvements were noted in most patients regardless of spinal canal encroachment. The authors suggested the only requirement for indirect decompression was an intact PLL, and that spinal canal encroachment had no effect.

Wang et al. found 2 criteria in which indirect decompression was not viable.(27) If the displacement of the fracture was greater than 0.85 cm, or the fracture was rotated by more than 55^{o}, then appropriate reduction of the fragments was not achieved. Despite this, 2 years post-procedure, no significant difference was shown in neurological recovery between successful and unsuccessful reduction by indirect decompression. This ambiguity in the mechanisms behind neurological recovery in Thoracolumbar fractures highlights the discrepancy in the literature about whether canal compromise is responsible for neurological deficit.(28, 29) It may also suggest that both fracture reduction and post-surgical SCA are not accurate predictors of the patient's neurological recovery.

Dennis type B fractures were reported by Zhang et al. to be effectively treated by indirect decompression.(30) Neurological deficit as well as structural deformity were significantly improved post-procedure. A significant decrease in operative time and blood loss compared to direct posterior decompression was also noted. Not only did this study highlight the utilisation of indirect decompression but also showed that indirect reduction carried less risk in comparison to direct decompression, which is a crucial component of treatment choice.

<u>Comparison</u>

In a randomised prospective analysis comparing direct and indirect decompression by Jaiswal et al., their data highlighted the viability of both procedures in decompressing thoracolumbar fractures.(31) No significant differences were seen in changes to canal diameter or dural sac compromise between both decompressive techniques. Neurological improvement between both procedures also remained insignificant. Although the authors seemed to favour ligamentotaxis due to reduced surgical complications, they were hesitant to advocate this technique as the superior approach. As has been discussed in this review, further factors may influence the efficacy of each technique, and treatment needs to be determined on a case-by-case basis. For example, it was suggested that performing ligamentotaxis on retropulsed fragments that rotate 180^{o} whilst demonstrating a reverse cortical sign may worsen the patients neurological status by pushing the fragment further into the dura.(32) Unfortunately this study followed-up for only 6 months, and thus long-term differences between both procedures were not considered. Further factors that could influence indirect decompression was suggested by Yuan et al.(33) Indirect decompression was found only to be effective if the volume ratio of the spinal canal, vertebral body height,

and the degree of kyphosis significantly improved immediately after indirect reduction. Otherwise, direct decompression was advised.

Been and Bouma compared indirect and direct decompression.(34) It was found that there was no significant difference in neurological outcome between both procedures. Although improved long-term maintenance of kyphosis correction was seen in direct decompression, the kyphotic correction remained at an acceptable angle in indirect decompression 6-years later. They concluded that due to the less invasive manor; indirect decompression was a valid approach in most thoracolumbar burst fractures with neurological compromise. This study did not however randomise the patients, and it seemed that most cases with directly protruding fragments underwent direct decompression. Therefore, this study cannot confidently support the use of indirect decompression in direct canal compromise.

As previously discussed, parameters for deciding between indirect and direct decompression is lacking. Investigating this, Peng et al. recruited 64 patients with TLB fractures and conducted indirect reduction on all.(35) Patients were then divided into two groups; the reduced group, which showed significant reduction of fragments, and the unreduced group, which did not. The unreduced group proceeded to receive direct decompression. Comparing these groups, new parameters were suggested for successful indirect reduction. In injuries where the PLL covered the fractures, the intra-canal fracture fragment needed to be less than 75% of the transverse diameter of the vertebral canal, along with the height of the fragment less than 47% of the vertebrae. However, if the fracture fragments were in the apterium of the PLL, indirect decompression was not effective no matter these values.

Spinal canal remodelling

Numerous studies have found evidence of spontaneous canal remodelling.(36-38) Canal remodelling occurs in both surgically treated fractures as well as in non-operative approaches.(37) It occurs within 2-3 weeks post-operatively,(39) and has been shown to continue months after surgical treatment. The degree of reduction achieved by ligamentotaxis has been shown to correlate with an increase in canal remodelling.(40) Improving canal remodelling could therefore be another benefit of indirect decompression. A less invasive indirect reduction may be sufficient in providing decompression acutely, whilst allowing time for spontaneous remodelling to further alleviate cord compression long-term.

Limitations

Spinal canal decompression is a complicated technique, with many varying methods available. To keep this review concise, all decompressive techniques were grouped either indirect or direct. This left large variability in comparing findings, as many different direct decompressive techniques are available. Recent studies now compare the anterior and posterior approaches in direct decompression. Comparing ligamentotaxis individually to

each method may provide more clarity on this in future studies. Thoracolumbar fractures are also very heterogenous, and this study did not consider whether varying fracture morphology may respond differently to decompressive techniques. Another key factor is the timing of surgery, which has been shown to influence patient outcome and could potentially influence decompressive treatment choice.

Most studies included in this review investigated one technique only. More studies directly comparing indirect and direct decompression within thoracolumbar fractures would provide a higher confidence in distinguishing the strengths of each method.

Conclusion

Direct and indirect decompression is a widely debated subject. This review has shown both techniques to reduce canal compression, as well as improving neurological recovery. Although direct decompression may improve canal encroachment to a greater degree, this has not directly been associated with superior neurological recovery. Considering the reduced risk involved in indirect decompression, this is an effective method to consider in most cases of TL fractures, whether there is neurological deficit or not. However, not one technique can be regarded as the gold-standard. Many factors have been shown to influence the efficacy of both procedures, such as fragment shape and location, and the spinal level of injury. Decompressive techniques must be decided on a case-by-case basis, and this review explores certain parameters which may help outline the decision-making process.

Word count = 2537

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