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Research Progress in the Treatment of Thoracolumbar Fractures

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Abstract: The thoracolumbar junction is the junction of the thoracic and lumbar spine and is subjected to high biomechanical stress. With the rapid development of the society, the morbidity of thoracolumbar spine increases every year. Thoracolumbar fracture may affect the stability of the spine and even result in paralysis via the compression of the spinal cord. As a result of advancements in modern medicine, the theoretical and practical aspects concerning thoracolumbar fracture have made great progress. However, due to the complexity of thoracolumbar fracture, controversy still exists in the treatment strategies and methods for thoracolumbar fractures. In order to provide reference for clinical practice, the research progress in the treatment of thoracolumbar fracture is reviewed in this paper.

Keywords: Thoracolumbar fracture; Treatment; Surgery; Conservative treatment

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1. Introduction

With the development of industrialization and modern transportation, the incidence of spinal fractures has been increasing year by year. About 40–70% of spinal fractures occur in the thoracolumbar spine (T11–L2) [1]. The thoracolumbar spine is a transitional area connecting the thoracic spine, which has lesser mobility, and the lumbar spine, which has greater mobility. It is located at the junction of the two physiological curvatures of the spine and is subjected to high stress. Therefore, spinal fractures are more common in this area. Thoracolumbar fractures are often caused by high-energy trauma. Car accidents, falls from heights, and sports injuries are some of the common causes [1]. Not only the stability of the spinal column is compromised in thoracolumbar fractures, but in 21–40% of cases, the spinal cord is compressed, thus causing nerve damage [2]. With the advancements in imaging and surgical techniques, the diagnosis and treatment of thoracolumbar fractures have made great progress. However, in current clinical practice, there are still many controversies regarding the treatment strategies and methods for thoracolumbar fractures.

"Thoracolumbar fracture," "treatment," "operation," "nonoperation," "fusion," "surgical treatment," and "conservative treatment" were used as keywords. The database was searched, focusing on screening relevant documents from January 2008 to December 2021, with a total of 1,570 documents found. Literature inclusion criteria: (i) clinical research, including retrospective research, prospective research, and review; (ii) research content related to thoracolumbar fracture surgery or conservative treatment. Exclusion criteria: (i) non-Chinese or -English literature; (ii) research content does not include thoracolumbar fractures and clinical treatment; (iii) only the abstract is available without the full text; (iv) repeated publication or low-quality literature. A total of 73 articles were included, with 72 in English and 1 in Chinese. This article reviews the treatment strategies and methods for thoracolumbar fractures to provide references for clinical

practice.

2. Indications for surgical and non-surgical treatment for thoracolumbar fractures

The current classification systems for thoracolumbar fractures still have numerous defects. Hence, controversies still exist when using these classification systems to select treatment strategies in specific types of fractures. At present, there has been a consensus that non-surgical treatment can be used in pure thoracolumbar wedge compression fractures. However, fractures with neurological involvement or unstable thoracolumbar fractures (such as Type B and Type C fractures according to the new AO Spine classification [3]) (**Table 1**) are absolute indications for surgical treatment. For thoracolumbar burst fractures without neurological involvement (such as A3 and A4 fractures based on the new AO Spine classification), the choice of treatment is still controversial. Although there have been a number of retrospective and prospective studies that compared the efficacy of non-surgical treatment and surgical treatment in this type of fracture [4,5], the results of these studies are not completely consistent. Wood *et al*. [4,5] published the results of a prospective randomized controlled study with the longest follow-up time. Their study included 47 patients with stable thoracolumbar burst fractures without neurological involvement. At follow-up, there was no significant difference in clinical prognosis between non-surgical patients and surgical patients [4], but at long-term follow-up (16 to 22 years), non-surgical patients had lesser pain and better functional status than surgical patients [5]. According to another study, conducted by Siebenga *et al*. [6], AO type A3 fractures should be treated with surgery. In 2005, Vaccaro *et al*. [7] proposed the Thoracolumbar Injury Classification and Severity Score (TLICS) by analyzing previous literature (**Table 2**). In this classification, scores are given based on fracture morphology, neurological function, and PLC integrity. The total score for the three items is 10 points. If the score is less than or equal to 3 points, conservative treatment should be considered; surgical or non-surgical treatment is acceptable when the score is equal to 4 points; surgical treatment should be performed when the score is greater than or equal to 5 points. The TLICS classification system, which is widely used in clinical practice, is simple to use, and many studies have shown that it has good reliability [8]. However, Mattei *et al*. [9] have reported a case of conservative treatment failure in a patient with AO/Magerl classification A3.1.1 with a TLICS score of 2. They claimed that fractures with intact PLC and severe vertebral body fragmentation (*i.e*., A3 and A4 fractures based on the new AO Spine classification) cannot be fully assessed using the TLICS score. For these types of fractures, non-surgical treatment decisions should be made with great care. This view has also been recognized by other scholars [10]. Therefore, there are still many controversies concerning the choice of treatment for the new AO Spine classification A3 and A4 fractures without nerve involvement. High-quality clinical studies are still needed to provide more evidence.

Table 1. New AO Spine classification system of thoracolumbar injury

Morphological classification		
A		Compression injuries
	A0	No vertebral body fracture or clinically insignificant fracture of transverse process/spinous process
	A1	Wedge compression or impaction fracture involving a single endplate but not the posterior wall of the vertebral body
	A2	Split or pincer fracture involving both the superior and inferior endplates but not the posterior wall of the vertebral body
	A3	Vertebral fracture affecting a single endplate and involving the posterior wall of the vertebral body and the spinal canal
	A4	Vertebral fracture involving both the superior and inferior endplates as well as the posterior wall of the vertebral body
B		Distraction injuries
	B1	Bony structural destruction of the posterior tension band of a single segment, extending to the anterior vertebral body
	B2	Posterior tension band injury with or without bony structural destruction
	B3	Injury involving the anterior longitudinal ligament
C		Displacement injuries
Classification of neurological dysfunction		
	N0	Normal
	N1	Transient neurological dysfunction
	N2	Symptoms or signs of nerve root injury
	N3	Incomplete spinal cord or cauda equina injury
	N4	Complete spinal cord injury
Case-specific correction parameters		
	M1	Fracture is accompanied by uncertain tension band injury found by imaging or clinical examination
	M0	Patient-specific complications that may affect surgical decisions

Table 2. Thoracolumbar Injury Classification and Severity Score (TLICS)

Injury characteristics	**Description**	**Scoring**
I Injury morphology		
Compression	–	1
	Burst	+1
Translation/rotation	–	3
Distraction	–	4
II Neurologic status		
Intact	–	0
Nerve root	–	2
Cord, conus medullaris	Incomplete	3
	Complete	2
Cauda equine		3

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Injury characteristics	Description	Scoring
III Posterior ligamentous complex		
Intact	—	0
Suspected/indeterminate	—	2
Injured	—	3

3. Non-surgical treatment for thoracolumbar fractures

Although the conservative treatment for thoracolumbar fractures has a long history, there is still no accepted standard. The traditional idea is that thoracolumbar fractures require long-term bed rest or bracing to promote bone healing. However, in recent years, studies have advocated early activities and stretching exercises [11]. The role of braces has also been prospectively controlled by multiple randomized controls [12,13]. With regard to thoracolumbar fractures, these studies have demonstrated that wearing a brace has equivalent clinical effects and imaging outcomes to not wearing one, and that the latter lowers the costs incurred on patients and length of hospital stay. On the other hand, Hitchon *et al*. [14] has shown that early activities can cause conservative treatment failure in up to a quarter of patients with thoracolumbar fractures. Therefore, when weighing the options of treatment, a more detailed assessment of the fracture, including the kyphotic angle and spinal canal occupation, is necessary. In addition, there is a lack of high-quality research on the effectiveness, treatment strategies, and treatment time of physiotherapy or other adjuvant treatments for thoracolumbar fractures.

4. Surgical treatment for thoracolumbar fractures

The main purpose of surgery in thoracolumbar fractures is to promote the repair of spinal cord nerve injury, correct spinal deformity, rebuild spinal biomechanical stability, and reduce surgical complications and mortality. With the advancements of modern surgical techniques and spinal fixation devices in recent years, the surgical methods and techniques for thoracolumbar fractures are also changing with each passing day. In clinical practice, treatment should be selected according to the actual conditions of the patients.

4.1. Posterior surgery

Compared with anterior surgery, posterior surgery is relatively safe, preventing injuries to important organs and blood vessels that are located in front of the spine. At present, posterior surgery is the main surgical treatment method for thoracolumbar fractures. The pedicle screw system is used as an internal fixation system for posterior surgeries. Its strong biomechanical stability enables the achievement of good fracture reduction and stabilization. The traditional posterior surgery involves internal fixation across the injured vertebrae, and the fixed segments are 1–2 vertebrae above and below the injured vertebrae. When using this technique, long-segment fixation (upper and lower 2/2 vertebrae) tends to maintain a better fracture reduction effect in long-term follow-up [15], but there are also studies showing no difference in the reduction effect between short-segment fixation (upper and lower 1/1 (2 vertebrae) and long-segment fixation. In recent years, a number of prospective and retrospective studies have shown that the placement of nails through the injured vertebrae can provide stronger biomechanical stability to the spine, achieve better kyphosis correction effects, and reduce the risk of internal fixation failure [16-22]. A recent study has confirmed through the detection of the level of bone metabolism that nail placement through the injured vertebrae can accelerate bone healing and promote clinical recovery of patients [23]. At present, the mainstream surgical method for posterior thoracolumbar fractures is short-segment fixation with nail placement through the injured vertebrae, in which two-segment fixation from the upper vertebral body to the lower vertebral body of the injured vertebra is commonly done. Compared with long-segment fixation

without screw placement through the injured vertebrae, short-segment fixation with nail placement through the injured vertebrae can achieve similar or even better clinical effects [18]. Some scholars have reported satisfactory results with single-segment fixation that fixes the upper vertebral body and the injured vertebrae in mild to moderate thoracolumbar fractures [24-26], but this ultra-short-segment fixation method lacks clinical validation.

In the aforementioned studies, posterior short-segment fixation is often used for less severe thoracolumbar burst fractures. For severe burst fractures, the failure of internal fixation following posterior short-segment fixation is commonly reported. Therefore, the stability of posterior short-segment fixation for severe thoracolumbar burst fractures has always been controversial. McCormack *et al*. [27] proposed the Loading Sharing Classification (LSC) in 1994 (**Table 3**) to address this problem. It has been suggested that the failure rate of posterior short-segment fixation is higher when the LSC score is more than or equal to 7. The LSC system has many limitations. First, only 28 patients were included in McCormack *et al*.'s study, thus lacking large sample verification; second, the internal fixation equipment used in the study was different from the current one since the study was published earlier; third, the degree of kyphosis correction in LSC is a retrospective index. The anterior and posterior convex angle is often used in preoperative evaluation, which may affect the accuracy of LSC assessment [9,28,29]. Despite these limitations, the LSC score has good reliability and provides a reference for the choice of anterior or posterior surgery [29,30]. Its value in predicting the failure of posterior short-segment fixation has also been determined [31-34]. However, some studies have shown that the failure of posterior fixation or the loss of kyphosis correction is not significantly correlated with LSC score [35]; instead, the loss of kyphosis correction may be related to the injury of the adjacent segment of the intervertebral disc [36]. In recent years, many studies have shown favorable results with posterior short-segment fixation of thoracolumbar fractures with LSC ≥ 7 as a result of the advancement of modern internal fixation devices [37-39]. Based on the above studies, the LSC system needs to be further improved and refined to adapt to the current clinical environment. Recently, through a retrospective study of 121 patients, Iure *et al*. [40] proposed a quantitative indicator of the degree of LSC fracture displacement, "fracture fragment distribution ratio," which can be measured on preoperative cross-sectional computed tomography (CT) and predict fixation failures with posterior surgeries. However, this indicator has a large number of "gray areas," and its clinical application is limited; in addition, further studies are required to confirm its reliability and effectiveness. Therefore, selecting an appropriate surgical plan for severe thoracolumbar burst fractures is still a key issue of future thoracolumbar fracture research.

Table 3. Loading Sharing Classification (LSC)

Scoring item	Scoring
Sagittal comminution degree	
Comminution degree <30%	1
30% ≤ comminution degree ≤ 60%	2
Comminution degree > 60%	3
Degree of bone mass displacement (plain CT scan)	
Displacement 0–1 mm	1
Displacement ≥ 2 mm, spinal canal encroachment < 50%	2
Displacement > 2 mm, spinal canal encroachment ≥ 50%	3
Kyphosis correction degree	
Kyphosis correction ≤ 3°	1
4° ≤ Kyphosis correction ≤ 9°	2
Kyphosis correction ≥ 10°	3

Most scholars believe that bone graft fusion should be combined with posterior internal fixation for thoracolumbar fractures because it is believed that bone graft fusion enables the spine to reach its final stable state even after the removal of the internal fixation device, thus reducing the possibility of internal fixation failure and maintaining the fracture reduction effect. In recent years, a number of prospective randomized controlled studies have challenged this traditional view. The study conducted by Wang *et al*. [41,42], which included 58 cases of Denis A and Denis B fractures that were randomly divided into the autogenous bone posterior fusion group and the non-fusion group and underwent short-segment fixation of the injured vertebrae, mid-term follow-up (average 41 months), and long-term follow-up (mean 134 months), showed no significant differences in the imaging indicators and clinical functions between the non-fusion group and the fusion group; in addition, the non-fusion group had lesser blood loss during the surgery, a shorter operation time, more local segmental mobility being preserved, and no risk of complications in the bone removal area. Dai *et al*. [43], Jindal *et al*. [44], Ko *et al*. [45], and Tezeren *et al*. [46] have also reached similar conclusions. However, it is worth noting that these studies only included Denis A or B fractures with relatively low severity. Hence, there is still a lack of evidence to support whether non-fusion techniques can be used for other more severe types of fractures.

In recent years, with the advancement of minimally invasive techniques, especially minimally invasive percutaneous plate osteosynthesis (MIPPSO), minimally invasive surgery has become a popular direction in the study of posterior thoracolumbar fractures. Traditional open surgery requires extensive dissection and prolonged traction of soft tissues in the back. At long-term follow-up, the incidence of muscle denervation is as high as 15–20%, while that of muscle atrophy is as high as 10–15% [47]. Minimally invasive surgery, on the other hand, can effectively prevent the above complications. Minimally invasive surgery has certain advantages, including less surgical trauma, less bleeding, shorter hospital stay, and less soft tissue injury. However, poor vertebral body reduction and difficulty in inserting transverse connecting rods are observed in minimally invasive surgery due to its technological limitations. It is difficult to decompress the spinal canal, bone graft, and other defects, so the indications of minimally invasive surgery are narrower than traditional open surgery. At present, there is no recognized standard for the indications and contraindications of MIPPSO for treating thoracolumbar fractures. It is generally believed that the indications are as follows: fresh thoracolumbar vertebral fractures, <1/2 vertebral compression, unaffected spinal canal, or ≤ 30% displacement of posterior edge fractures of the vertebral body into the spinal canal. In such cases, no spinal canal decompression is required. The contraindications are as follows: severe comminuted fractures, obvious bone space in the spinal canal, spinal canal exploration for spinal cord injury, and old fractures [48]. When using minimally invasive surgery to treat thoracolumbar fractures, spine surgeons must strictly grasp the indications and contraindications.

4.2. Anterior surgery

The widely accepted indications for anterior surgery include fragmented fractures occupying more than 67% of the spinal canal area, severe burst comminution of the anterior and middle column of the vertebral body, a kyphosis angle of more than 30°, old burst fractures, and fracture reduction following posterior surgery [49]. In anterior surgery, the fragmented vertebrae are revealed, and the fractures that invade the spinal canal can be directly removed. In theory, spinal canal decompression can be better achieved with anterior surgery. The results of a prospective controlled study by Esses *et al*. [50] and Wood *et al*. [51] also showed that the effect of anterior surgery on spinal canal enlargement was better than that of posterior surgery. However, it is interesting to note that although anterior surgery has a better decompression effect, there is no significant difference in the degree of neurological improvement as compared with posterior surgery [50, 52-54]. Recent meta-analyses [55,56] have also shown that there are no significant differences between anterior and posterior thoracolumbar burst fractures in terms of kyphotic deformity correction and surgical

complications; however, the operation time in anterior surgery is longer, and there is significantly more bleeding in anterior surgery compared with posterior surgery.

The classic anterior surgical methods for thoracolumbar fractures include subtotal resection of the injured vertebrae, bone block/titanium mesh bone graft fusion, and anterior nail rod or nail plate fixation. This type of surgery requires the removal of the upper and lower intervertebral discs of the injured vertebra in addition to the injured vertebrae, which would greatly affect spine mobility. Therefore, in recent years, anterior single-segment surgery has been used for burst fractures of the lower half of the injured vertebrae and intact discs, that is, only the upper half of the injured vertebrae and upper intervertebral discs are removed so as to preserve the function of the spine as much as possible [57,58]. Autogenous bone blocks, such as iliac bones/ribs, or titanium mesh/fusion cages filled with fragmented bones, are usually used for anterior bone grafts. Autogenous bone fusion is considered the gold standard for anterior fusion. However, recent studies have shown that the fusion rate of autogenous ilium and autogenous ribs is significantly lower than that of titanium mesh filled with fragmented bones [59]. Considering that the iliac bone is taken out of the bone, the procedure is often accompanied by persistent pain and discomfort [60]. Therefore, a titanium mesh/fusion cage filled with fragmented bones may be a better choice for anterior implants. However, the titanium mesh/fusion cage also faces the problem of implant settlement, that is, the implant sinks into the vertebral body, especially in patients with poor bone quality. Careful handling of the vertebral body endplates and vertebral body cement reinforcement can reduce the occurrence of this complication [61].

4.3. Combined anterior and posterior surgery

The indications of combined anterior and posterior surgery for thoracolumbar fractures are still controversial. Combined anterior and posterior surgery should be considered when there is risk of internal fixation failure in simple posterior surgery (such as LSC $\geq$ 7 points) or in cases of fractures with intervertebral disc injury [27,62]. Complete decompression can be achieved with combined anterior and posterior decompression, bone grafting, fusion, and internal fixation surgery. The biomechanical stability of the spine can be reliably and lastingly restored with these procedures [63-65]. A number of retrospective studies have shown that the combined anterior and posterior surgery allows for a better imaging prognosis, and its effect of correcting and maintaining kyphosis is also better than that of posterior surgery alone [66-68]. Recently, Scholz *et al.* [69] have conducted a prospective randomized controlled study of 21 patients and found that the sagittal shape of the spine of patients undergoing anterior and posterior surgery was significantly better than that of patients who underwent posterior surgery alone; the Oswestry Disability Index (ODI) was also significantly lower in these patients compared with those who underwent simple posterior surgery. However, due to the limitations of the sample size, the difference in ODI did not reach the minimum clinically significant change value.

Compared with simple anterior or posterior surgery, the traditional combined anterior and posterior surgery has many disadvantages, such as higher risk of surgical trauma, longer operation time, more blood loss, and higher surgical risk. Therefore, with the advancements in surgical technology, improved surgical procedures have been established in recent years. Schmid *et al.* [70] used posterior lumbar interbody fusion to treat patients with thoracolumbar fractures and achieved satisfactory imaging and clinical results. Kwon *et al.* [71] performed a modified circumferential fusion procedure on 18 patients through the lateral approach and achieved satisfactory results. The procedure involved pedicle resection, anterior expandable cage support, and lateral and posterior short-segment fixation. With the advancement of minimally invasive techniques, some experts have carried out thoracoscopic-assisted vertebral body resection combined with percutaneous pedicle screw fixation to treat thoracolumbar fractures. It has shown reliable clinical effects, with certain advantages, including less trauma and bleeding. However, thoracoscopic surgery has a long learning curve, and there are challenges to promoting its practice clinically.

5. Conclusion

Thoracolumbar fractures are one of the most common conditions requiring spinal surgery. However, due to the complexity of spinal anatomy and fracture mechanics, there is no recognized classification system for thoracolumbar fractures. Further research is needed to improve the existing thoracolumbar fracture classification systems. The development of a reliable, easy-to-use, and effective classification system will assist academic exchanges and guide clinical decision-making. Controversies still exist in the treatment of thoracolumbar fractures. With the advancements in surgical techniques and internal fixation materials, surgical indications and contraindications are constantly changing. When managing patients with thoracic and lumbar fractures, spine surgeons should evaluate the type, severity, clinical prognosis, and other factors thoroughly, with the goal of reconstructing the biomechanical stability of the spine, restoring the patients' neurological function, and formulating a personalized treatment plan to achieve the best clinical effect.

Disclosure statement

The authors declare no conflict of interest.

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