Classification of Thoracolumbar Fractures: A Narrative Review

Harvinder Singh Chhabra[1], Jitesh Manghwani[1]

Abstract

Thoracolumbar fractures constitute 75% of the cases of spine trauma. Thoracolumbar classification systems are important to diagnose, stage, determine the management of vertebral lesions, and predict the results of the different treatment options. This narrative review describes how the classification systems evolved over time with the unique features of each historically. Radiographs are the initial step of investigation. Magnetic resonance imaging and computed tomography help in delineating the injury better. This article narrates diagnosing instability and the role of each classification system in aiding to make a decision of a particular thoracolumbar fracture with merits and demerits of each.

Keywords: Thoracolumbar fractures, Thoracolumbar classification, review, AOSpine, TLICS, SCS

Introduction

The thoracolumbar (TL) junction is the area of spine spanned between T10 and L2 vertebral bodies. The harmonious transition of kyphotic thoracic spine into lordotic lumbar spine makes the biomechanics of this region unique. Thoracic spine is relatively rigid due to the support from ribs and sternum. The facets are coronally aligned resisting movements in the thoracic spine. Different from this is the facetal orientation in the lumbar spine which is in the sagittal plane. The orientation of articulation with the absence of rib articulation imparts mobility unique to lumbar spine. The transformation from a rigid, kyphotic, and articulated spine to a mobile, lordotic spine makes it prone to injuries [1, 2].

TL fractures constitute 75% of spinal injuries [3]. Literature reports TL fractures in around 2.4% of the total cases after road traffic accidents [4]. This incidence increases to 6.9% in cases with blunt trauma [5]. Literature reports missed TL injuries in cases with blunt trauma. In fact, a study reports the prevalence of TL fractures in 25% of cases with blunt trauma on computed tomography (CT) scans [6]. Approximately 45% develop neurodeficits of which 26% are incomplete and 19% are complete injuries [3]. Neurodeficit leads to some form of society dependency in around 27% after sustaining these injuries [5].

With the evolution in comprehension of natural history, biomechanics, and forces/vectors leading to injury, scientists have tried to develop the ideal classification system. Designing the ideal classification has certainly been a challenge since the ideal classification system should be simple, good inter- and intra-observer reliability, guiding the treatment, considering associated medical morbidities, and neurology of the patient [7].

Methodology

Literature was searched on the online databases (PubMed, Cochrane, Scopus, and Google Scholar) using the keywords "TL trauma" AND "TL trauma classification" AND "TL fracture classification." All the classification systems of traumatic TL fractures and their implementation and clinical utilization were included in the study. The systematic review has been structured as per the standard guidelines and checklist of narrative review defined in the literature [8]. Appropriate quality of narrative review as per six independent components of the defined scale for the assessment of narrative review articles [9] was also ensured.

Classification systems of TL fractures

Böhler classification

The first attempt at classifying TL fractures was by Böhler et al. in 1930 [10]. They defined five types of fractures as per the anatomy of fracture and the mechanism of injury. The five types were compression, flexion-distraction,

[1]Department of Spine Services, Indian Spinal Injuries Centre, New Delhi, India.

Address of Correspondence
Dr. Harvinder Singh Chhabra,
Medical Director and Chief of Spine service, Department of Spine Services, Indian Spinal Injuries Centre, New Delhi, India.
E-mail: drhschhabra@isiconline.org

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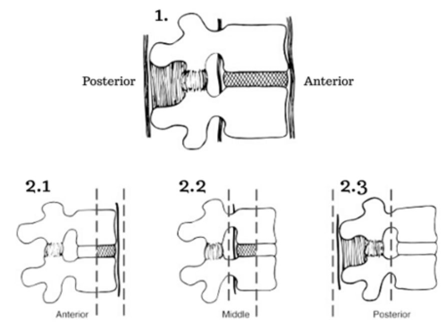

Figure 1: (1) Holdsworth's two-column concept, (2.1-2.3) Denis's three-column concept adding middle column to Holdsworth's anterior and posterior column.

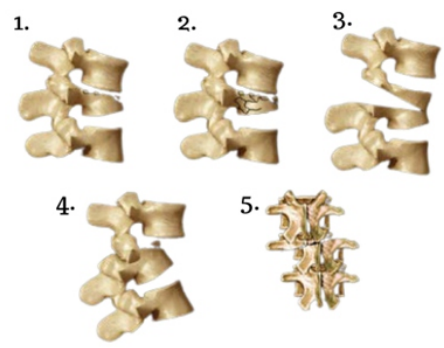

Figure 2: Fracture types as per Denis classification.

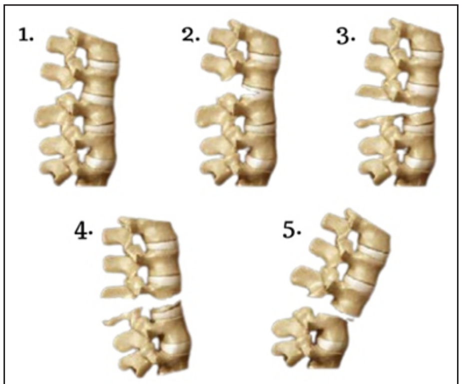

Figure 3: McAfee classification.

extension, shear, and rotational injuries. Bohler et al. described flexion distraction to have anteriorly an element of compression and posteriorly distractive forces that lead to the injury. They also described that extension fracture patterns have injured anterior and posterior ligaments anterior longitudinal ligament and posterior longitudinal ligament (ALL and PLL). The limitation of the classification was that no criteria were defined for instability or unstable fracture patterns [11].

Watson-Jones classification

Recognizing this limitation, Watson-Jones (1938) attempted to define instability by introducing their classification system [12]. They studied 252 fractures and defined three groups and seven patterns in total. The three groups were simple wedge fractures, comminuted fractures, and fracture dislocations. Historically, the importance of the integrity of posterior ligamentous complex was to define instability was discussed for the 1st time. They also discussed reduction techniques and hyperextension to achieve fracture reduction.

Nicoll's classification

In 1949, Nicoll studies 152 fractures and tried to interpret instability. They discussed the significance of four structures (vertebral body, intervertebral disc, facet joints, and the posterior ligamentous structures) contributing to stability. According to them, whether a fracture is stable or not should be decided on the basis of the integrity of interspinous ligament. Nicoll et al. also established the significance of missed or neglected instability. They discussed progressive neurodeficits and deformity in the spine as a cause of missed instability [13].

Holdsworth classification

In the year 1963, Holdsworth studied 1000 patients and introduced the column concept. His ideology divided the entire column into two: Anterior and posterior. Anterior column consists of the entire vertebral body and the intervertebral discs, posterior column consists of intervertebral joints and posterolateral corner (PLC) (Fig. 1). They were in concurrence with Nicoll that instability should be decided as per the integrity of posterior ligamentous structures. The six fracture patterns described by Holdsworth were anterior wedge compression, dislocation, rotational fracture-dislocation, extension injury, burst, and shearing fracture. Researchers challenged this classification secondary to multiple limitations. Holdsworth defined anterior compression as stable, however, multiple studies have now established that vertebral lesions with >50% involvement of vertebral body may be unstable secondary to involvement of posterior ligamentous structures [14]. Studies done on fractures classified as stable as per definitions by Holdsworth reported kyphosis and neurodeficit on follow- up [15, 16]. Hence, it was established that possibly something is missed and maybe it is secondary to oversimplification of TL biomechanics [17].

Kelly's classification

In 1968, Kelly et al. attempted to modify Holdsworth's work [18]. They gave a working classification for TL injuries after studying 11 patients. Kelly et al. defined injuries to be stable or unstable. They for the 1st time pointed out that not all burst fractures are stable as concluded by Holdsworth. Along with this, they discussed iatrogenic instability in these lesions which are secondary to laminectomy.

Denis classification

Denis's classification was a revolutionizing classification. Denis studied 412 fracture patterns on CT scans and redefined TL fractures in 1983. They introduced the classification based on the three-column concept. Denis redefined then existing two columns of Holdsworth and introduced the third column-the middle column. As per him, the anterior column spanned from ALL to two-thirds of the vertebral body and anterior intervertebral disc. The middle column has the posterior third of the vertebral body with the annulus and PLL. Posterior column spanned posterior to PLL and included structures posterior to it (Fig. 1). Denis proposed that apart from anatomical aspects of fracture pattern, it is important that the mechanical aspects are understood and focused on too. Denis stated that mechanical instability and neurodeficit can occur together immediately or subsequently. Denis classification has different degrees of injuries. These degrees were based on mechanical and/or neurological component secondary to the injury. The first degree injury is mechanical in isolation, the second degree is neurological in isolation, and the third degree is the presence of both mechanical and neurological components. Apart from this, Denis classified TL fractures into four types: Compression, burst, fracture-dislocation, and seatbelt injuries (Fig. 2). Denis classification and concept remain significant to date [19]. Authors think that the simplicity of classification and reproducibility on CT scans has been of distant advantage. The concept to define instability if two columns are involved out of three still holds relevance [20]. Multiple shortcomings are reported in the literature. It does not aid in deciding the line of management as per the injury [21]. Denis advocated surgical stabilization if two columns are disrupted. However, the literature has discussed good results with conservative treatment in such injuries too. As the researchers discussed the difficulties in diagnosing the integrity of the posterior ligamentous complex, it was realized that Denis's classification had not guided the diagnosis whether these ligaments are injured or not [22]. Literature reports moderate reliability with Denis classification [20].

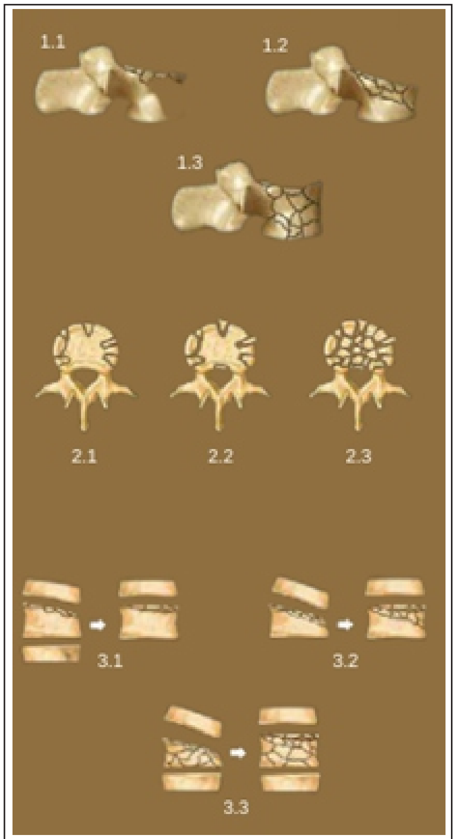

Figure 4: McCormack classification.

McAfee classification

In 1983, McAfee studied CT scans of 100 cases and defined six fracture patterns: Wedge compression fracture, stable burst fracture, unstable burst fracture, chance fracture, flexion-distraction injury, and translational injury (Fig. 3). They subdivided burst fractures into stable and unstable types. According to them, burst fractures may be stable too. The key determinant to define stability is the integrity of PLC [23].
This classification tried to understand instability better. They stated that association with progressive neurodeficit, kyphosis>20°, vertebral body height loss of >50%, facetal disruptions, and fractured fragments in canal should be presumed to be unstable and must undergo surgical management.

McCormack classification (Load sharing classification)

In 1994, McCormack published on whether the anterior column should be supplemented surgically. It involves using CT scans and radiographs to understand whether anterior support should be supplemented. The parameters used to understand this were the amount of vertebral body comminution, apposition of fragments of the vertebral body, and degree of kyphosis. This basically is understanding injury severity. They recommend supplementing a support anteriorly if scores>7 [24] (Fig. 4 and Table 1).

Table 1: McCormack classification

Score	Amount of comminution (%)	Apposition between fragments	Kyphosis	Total
1	30	1 mm	3	3
2	>30	2 mm	9	6
3	60	>2 mm	>10	9

AO-Magerl classification

In 1994, AO and Magerl et al. proposed a mechanistic classification based on the anatomy of the injury. The classification was devised after studying 1445 fracture patterns. They studied the fracture anatomy, vectors of injury with progressive increase of injury. They defined three basic types subclassifying into 53 different types. This requires utilizing CT scans and magnetic resonance imaging (MRI) in detail to assess the fracture anatomy [25]. Even though detailed, the use is finite in clinical practice due to more than 50 fracture patterns [26].

TL injury classification and score

MRI helps to diagnose whether the PLC is intact or not. This is specially so in cases with occult injuries. It was important to include the status of the PLC complex as a part of classification as well. Along with this, the ideal classification system must be simple with good inter- and intra-observer reliability. Before this, no classification systems could propose line of management. Realizing these shortcomings, spine trauma study group and Vaccaro et al. in the year 2005 proposed the TL injury classification and severity score scale. They also assessed how reliable the score

Table 2: Components of TLICS		
Category		
Injury morphology	Compression	1
	Burst	1
	Translational/rotational	3
	Distraction	4
Neurological status	Intact	0
	Nerve root	2
	Cord/conus medullaris incomplete	3
	Cord/conus medullaris complete	2
	Cauda equina	3
PLC	Intact	0
	Suspected/indeterminate	2
	Injured	3

PLC: Posterolateral corner, TLICS: Thoracolumbar Injury Classification and Severity Score

was. The scoring imparts scores as per injury severity, neurological deficit, integrity of PLC (Fig. 5 and Table 2).

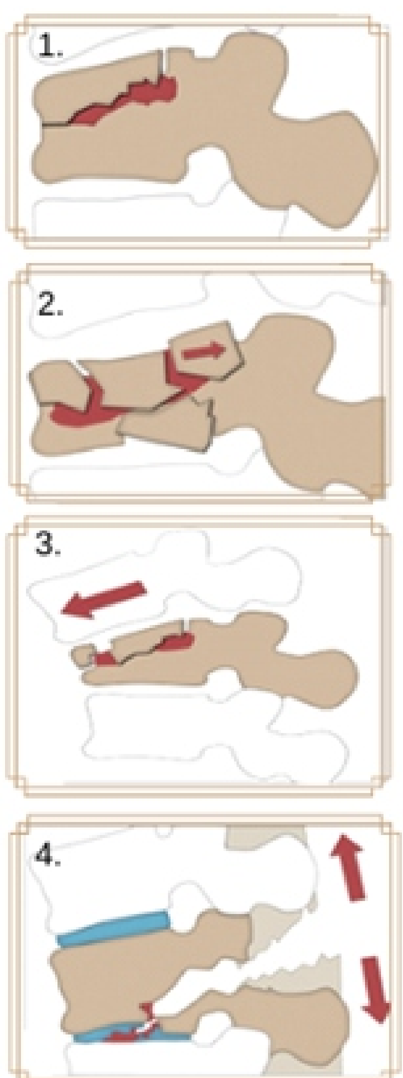

Figure 5: Fracture morphology Thoracolumbar Injury Classification and Severity Score.

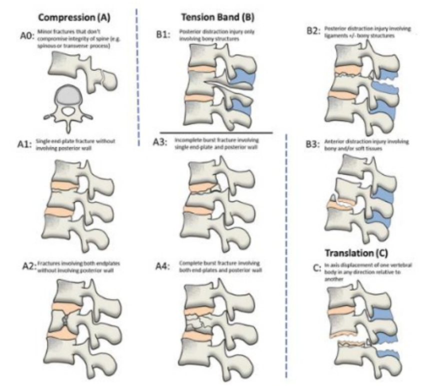

Figure 6: AOSpine thoracolumbar classification.

The significance of thoracolumbar injury classification and severity score (TLICS) is that an attempt was made to combine morphology, neurology, and PLC integrity. TLICS guides in deciding the line of management as per the total scores of the three components. Vaccaro et al. concluded that scores <4 should undergo a conservative line of management and ones with scores >4 should be surgically stabilized [17, 27].

AOSpine TL classification

Vaccaro et al. realized that the possible limitation of widespread application of TLICS is the regional or local guidelines are followed to decide the management of these injuries [28]. Hence, in 2013, AOSpine Trauma Knowledge Forum got together an internationally renowned spine expert together to devise and validate a new classification for TL fractures [28]. The idea was to combine the morphology, neurology, and other aspects which guide in the decision making of these fractures. The classification has the following heads:

a. Morphology/anatomy
b. Neurological status
c. Clinical modifiers.

Morphology is on the lines of Magerl's concept. Type A injuries are compression injuries. Type A1 injuries are involving a single end plate without posterior wall of vertebral body involved. A2 is a split or pincer type of fractures involving both the end plates sparing the posterior wall of the vertebral body. A3 fractures are incomplete burst involving one of the end plates with the posterior wall. A4 is complete burst injuries involving both the end plates with the posterior body.

Type B is tension band injuries. They may be associated with type A injuries. Type B1 is transosseous failures, that is, single-segment involvement. They are the classic Chance fractures. Type B2 fractures are a combination of the involvement of bones and ligaments. Type B3 is hyperextension injuries through the body or disc. They represent a failure of ALL. Type C is dislocation or rotations or translation (Fig. 6).

Neurological status:

- NO – No neurological deficit
- N1 – Transient deficit
- N2 – Signs of nerve root compression
- N3 – Incomplete spinal cord injury or cauda equina injury.
- N4 – Complete spinal cord injury
- NX – Cannot be assessed (e.g., associated head injury).

Clinical modifiers: Two modifiers influencing the decision-making:

- M1: Indeterminate injury to PLC. It is significant since the management of some injuries may be decided as per the status of PLC
- M2: Patient-specific conditions which may affect the decision on the line of management. For example, ankylosed spine, patient with burns over the prospective surgical site.

Simplified TL spine fracture classification system (SCS)

An expert ISCoS panel concluded that the till date defined classification systems still could not fulfill the desired objectives [29]. It is important to have good reliability with least complexity is important at the initial stages of career at resident level. To address this, Chhabra et al. proposed simplified classification system in the year 2021. The classification involved undergoing validation by ISCoS STSG group with expert consensus and prospective

Figure 7: Fracture morphology as per simplified classification.

application to TL fractures [30]. The classification involves four components:

a. Injury morphology (X-rays, CT, and MRI) (Fig. 7)

b. Injury stability (as per bony and ligamentous involvement)

c. Neurological status of the patient

d. Modifiers.

The neurology of the patient was graded as:

1. N0: No deficit

2. N1: Incomplete deficit or incomplete cauda equina

3. N2: Complete deficit or complete cauda equine.

The vertebral lesion's stability is also documented.

1. Stable: S

2. Unstable: US

As per Chhabra et al., the following modifiers are important in deciding the line of management:

M0 – No modifier

1. M1 – Polytrauma

2. M2 – Ankylosing disorders

3. M3 – >75 years

4. M4 – Osteoporosis

5. M5 – Poor general condition

6. M6 – Contiguous vertebral injuries

• Compression

• Burst

• Chance

• Fracture dislocation

• Others:

o Mixed injury is a combination of burst and chance fracture (as in figure) or fracture dislocation with burst

o Hyperextension injury.

The summary of the management of fractures as per simplified TL fracture classification (Table 3) is as follows:

Table 3: Management as per simplified TL fracture classification

Morphology	Stability	Management		
		N0	N1	N2
Compression	Stable	Conservative*	N/A	N/A
	Unstable	N/A	Posterior stabilization	Posterior stabilization
Burst	Stable	Conservative*	N/A	N/A
	Unstable	Posterior#/Anterior stabilization or conservative	Posterior# /Anterior stabilization +/− decompression	Posterior# /Anterior stabilization
Chance	Stable	No stable injuries		
	Unstable	Posterior/anterior stabilization$	Posterior/anterior stabilization	Posterior/anterior stabilization
Fracture dislocation	Stable	No stable injuries		
	Unstable	Posterior reduction with stabilization	Posterior reduction with stabilization	Posterior reduction with stabilization
Hyperextension	Stable	No stable injuries		
	Unstable	Posterior stabilization with/without anterior fusion	Posterior stabilization with/without anterior fusion	Posterior stabilization with/without anterior fusion
Mixed morphological injury	Stable	Treatment is decided by the most unstable injury; however, other morphology has a bearing on treatment		
	Unstable			

*Surgical management is indicated if there is an unacceptable increase of kyphosis on follow-up. #Anterior augmentation is to be decided by McCormack-Gaines load-sharing classification. $ Posterior stabilization or conservative management with bed rest for 6 weeks can be done in case of osseous chance fractures. Courtesy: Chhabra HS, Yelamarthy PKK, Moolya SN, Erli HJ, Theron F, Abel R, Haak M, Tuli S, Yadav SL, Hoque MF. Development and validation of a simplified TL spine fracture classification system. Spinal Cord. 2021 Dec;59(12):1268-1277. doi: 10.1038/s41393-021-00706-5. Epub 2021 Sep 27. PMID: 34580417

Discussion

The need for the development of an ideal system that classifies the traumatic TL fractures is to understand and develop a protocol to guide on the line of management – conservative or surgical. The ideal classification system should have ease of application with good reliability and reproducibility. It also should aid to diagnose the stability and consider neurodeficit along with other patient specific features affecting the line of management. Majority of experts follow either the TLICS or AOSpine classification system. However, these systems also have limitations. This article discusses how the classification systems evolved but it also emphasizes that there is still a need for an ideal system that guides the treatment with universal acceptance.

As researchers understood and published more on the biomechanics, it was realized that the recommended anterior surgery is generally morbid and motion segment preservation became the choice in younger patients [31, 32]. Researchers also discussed that the study design of McCormack et al. had short-segment instrumentation using four screws only. Studies have established that the newer implants and introduction of concepts such as intermediate screws, cement augmentation at fracture site aids in avoiding implant failure even if the fracture is stabilized posteriorly isolation without anterior column support [31, 33, 34].

The ideal system should be reproducible in day-to-day practice. Wood et al. reported moderate reliability and reproducibility with Magerl classification. It was concerning since the same surgeon classified fracture differently after 3 months [20]. Other studies reported kappa coefficients of 0.33 and 0.62 with Magerl classification [35, 36]. The literature has established good intra- and inter-observer reliability of TLICS. Furthermore, reliability is tested amongst orthopedic and neurosurgeons and clinicians with varied experience [37, 38, 39, 40]. However, the literature has also reported a discrepancy in injuries with burst fracture with no neurological compromise as per TLICS guidelines and the actual clinical decisions [27, 41, 42].

Retrospectively, a study analyzing 148 surgical patients, reported that 53% had a TLICS score between 1 and 3, 5% had scores of 4. The literature has established the paucity of Level I evidence and lack of guidelines which lead to conflicting actual clinical management and the guidance by TLICS [43]. The literature also has questioned the reliability and reproducibility of diagnosis of PLC injuries on MRI [40]. The three parameters of TLICS were studied separately to access the reliability. It was seen that the K coefficient of diagnosing PLC injury was 0.455 which signifies low reliability. This was further studied by Rihn et al. who found these values to be 0.58 among the spine experts and 0.37 among the radiologists [44].

A study by Kaul et al. [45] showed moderate inter-rater and intrarater reliability for grading fracture type and status of PLC (fracture type: k = 0.43 ± 0.01 and 0.59 ± 0.16, respectively, PLC: k = 0.47 ± 0.01 and 0.55 ± 0.15, respectively), and fair to moderate reliability (k = 0.29 ± 0.01 interobserver and 0.44 ± 0.10 intraobserver, respectively) for total TLIC score. In regard to the assessment of reliability of AOSpine classification, it was shown to have moderate inter-rater (k = 0.59 ± 0.01) and substantial intrarater reliability (k = 0.68 ± 0.13) [45].

The advantage with AOSpine system being widely accepted was primarily that it had higher degree of correlation with neurodeficits as compared to other classification systems [20]. Furthermore, it determined failure better if certain lesions were managed conservatively as compared to other classification systems. TLICS is widely used as it is regarded to be safe primarily in regard to neurodeficit irrespective of surgical or conservative treatment [46]. Even though the use of AOSpine and TLICS classification systems is widespread, they are associated with limitations. Pre-existing conditions were not considered in detail in the previous classifications. The AOSpine classification system has only two modifiers, one of which is a PLC injury. The others are clubbed within one modifier only. The scores of TLICS can be inflated falsely due to poor reproducibility in the diagnosis of PLC injury on MRI. The severity scoring may also be influenced by culture or geography and may not truly reflect global preference. AOSpine classification is challenged secondary to fracture identification. The fracture morphology may be truly depicted on dynamic imaging rather than static images, and hence, AOSpine classification was also challenged since it is based on static imaging in isolation, for example, flexion distraction injury may be misdiagnosed as a type A injury [47].

The simplified classification system by Chhabra et al. considers six modifiers which are important in deciding the line of management. Modifiers are important since the plan of surgery may be influenced greatly by these conditions. For instance, with the application of M2 modifier, long-segment fixation is mandatory (M2 – ankylosed spine), similarly with M4 modifier, cement augmentation may be used (M4 – osteoporotic spine).

Even though the presence of neurodeficit is a marker of instability, the literature mentions the criteria of diagnosing instability on plain or dynamic imaging [48]:

Loss of more than or equal to 50% of vertebral body height.

≥30° of kyphosis.

Interspinous widening.

These criteria are significant in deciding instability of a lesion. For the 1st time, this was included in decision-making in the simplified classification system. However, no other classification system defines instability using static/dynamic imaging. Ideally, plain X-rays, MRI, and/or for CT should be available for the classification of TL fractures. In the majority of cases, plain radiographs are sufficient for classifying TL fractures as per SCS, and in only some cases, MRI and/or CT is required. This is especially useful in emerging countries where many patients cannot get MRI and/or CT done.

Injury morphology of SCS was a modification of Denis classification since the Denis's classification has been established to be superior in regard to practical implementation [28]. The fracture patterns in simplified classification defined are compression, burst, Chance, fracture-dislocation, isolated spinous process/transverse process/pars fractures, and others. Others include hyperextension injury and mixed morphological injury (combination of different patterns). The first five types are as per defined by Denis et al. The sixth type introduced is very important as hyperextension injuries are unique due to tensile failure of the spinal column. Mixed patterns are equally important since many a times, a presenting fracture may have a blend of different patterns.

However, the SCS also has limitations. The cohort of the study could have been larger. Prospective and multicentric studies to establish reliability are not yet published. In this manuscript, we have discussed established classification systems. The quest for development of an ideal classification system is to form a guideline to manage these TL vertebral lesions which also resonates globally. The management should consider different factors and discussion with the family about the pros and cons of each. It is vital to point that whatever system is followed, the outcome is primarily dependent on pre-operative neurology and status. We would recommend level I studies which establish comparative efficacy of TLICS, AOSpine, and simplified classification system.

Conclusion

With the evolution in better understanding of TL fractures, multiple attempts have been done in the past to classify these fractures and scientists are still trying to improve on it. With several modifications to older classification systems, newer ones such as TLICS, AOSpine, and simplified classification system can be utilized by clinicians for better communication, reproducibility, reliability, and deciding the line of management.

Declaration of patient consent: The authors certify that they have obtained all appropriate patient consent forms. In the form, the patient has given his consent for his images and other clinical information to be reported in the Journal. The patient understands that his name and initials will not be published, and due efforts will be made to conceal his identity, but anonymity cannot be guaranteed.

Conflict of Interest: NIL; **Source of Support:** NIL

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