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Short-Segment Fixation in the Management of Thoracolumbar Burst Fractures – A Meta -analysis

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Learning Point of the Article:

Short- segment instrumentation with intermediate screw fixation is a safe and effective method with excellent radiological and clinical outcomes with very low rates of failure while treating unstable thoracolumbar burst fractures.

Abstract

Introduction: Short- segment fixation is being increasingly used to minimiz e the number of fixation levels in thoracolumbar burst fractures (TLBFs). This study aims to analyze the radiological, functional, and neurological outcomes of short-segment fixation in TLBF.

Materials and Methods: A meta-analysis was conducted through a web search on PubMed with the following keywords; thoracolumbar injury, burst fracture, and short- segment fixation. Scientific papers written in English from January 2001 to April 2024 were screened. PubMed search with the keywords revealed 183 articles which were thoroughly reviewed by all the authors. Of these, 11 studies satisfying the inclusion criteria describing short- segment fixation in TLBF s were included in this study. The minimum follow-up duration in each study was 12 months. The appropriate meta-analysis was carried out, and the forest plot for a single group which accounts for interstudy variation and provides a more conservative effect than the fixed effect model. Potential sources of heterogeneity were assessed using the standard chi-square test. In addition, the statistic I2 was used to investigate heterogeneity by examining the extent of inconsistency across the study results. A sensitivity analysis was carried out to assess the robustness of the results of the meta-analysis. Where heterogeneity was present between the studies, differences in study design were examined. All analyses were performed using online free meta-analysis software (https://metaanalysisonline.com).

Results: The results of this meta-analysis suggested that studies with an added intermediate screw at the level of fractured vertebra showed a better radiological appearance at the final follow- up as compared to traditional short-segment instrumentation. However, clinical outcomes showed no significant difference. A post-surgery neurological improvement was noted in all the studies except those with a complete pre-operative neurological deficit.

Conclusion: Short-segment instrumentation with intermediate screw fixation is a safe and effective method with excellent radiological and clinical outcomes with very low rates of failure while treating unstable TLBFs, where as traditional short-segment posterior fixation can lead to progressive loss of kyphosis correction with higher implant failure rate in patients with unstable fractures.

Keywords: Short-segment; thoracolumbar; burst; fracture; spine.

Introduction

Fractures of the spine most commonly occur in the thoracolumbar region, and burst fractures account for ~21–58% of all thoracolumbar fractures [1-4]. Burst fractures are seen often in young patients [5] and may cause a neurological injury, which has a great impact on patients' daily physical activity and return to work [5,6]. Advances in spinal instrumentation have brought short-segment instrumentation into successful clinical

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Author's Photo Gallery


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Table 1: Frankel grade classification of spinal cord function

Frankel grading	Description
Grade A	Complete neurological injury – No motor or sensory function detected below level of lesion
Grade B	Preserved sensation only – No motor function detected below level of lesion, some sensory function below level of lesion preserved
Grade C	Preserved motor, nonfunctional – Some voluntary motor function preserved below level of lesion but too weak to serve any useful purpose, sensation may or may not be preserved
Grade D	Preserved motor, functional – functionally useful voluntary motor function below level of injury is preserved
Grade E	Normal motor and sensory function

practice. Pedicle screw instrumentation makes it possible to achieve better correction of kyphotic deformity (KD), greater initial stability, early painless mobilization, and indirect decompression of the spinal canal [7-11].

Minimizing the number of vertebral levels involved in fixation of a spine fracture is a common goal of internal fixation. This is achievable by utilizing traditional short-segment posterior fixation (SSPF). SSPF is the use of pedicle screw instrumentation one level cephalad to and one level caudad to the fractured vertebra. However, this method is associated with increased rate of instrumentation failure due to osteoporosis and loss of kyphotic correction [12]. Addition of intermediate screw at the fracture level preserves the number of motion segments and provided adequate stability [13]. According to biomechanical research, adding a screw at the fracture level in a short-segment fixation (posterior fixation including fractured vertebra) strengthens the structure and shields the anterior column from stress [14-17].

Several studies have been conducted showing the clinical and radiological outcomes of posterior short-segment fixation. The objective of this meta-analysis is to identify and summarize the evidence from various studies on the clinical and radiological outcomes of short-segment fixation in thoracolumbar burst fractures (TLBFs).

Table 2: American spinal injury association impairment scale

A	Complete	No motor or sensory function is preserved in the sacral segments S4–S5.
B	Incomplete	Sensory function preserved but not motor function is preserved below the neurological level and includes the sacral segments S4–S5.
C	Incomplete	Motor function is preserved below the neurological level, and more than half of key muscles below the neurological level have a muscle grade < 3
D	Incomplete	Motor function is preserved below the neurological level, and at least half of key muscles below the neurological level have a muscle grade of 3 or more.
E	Normal	Normal sensory and motor functions

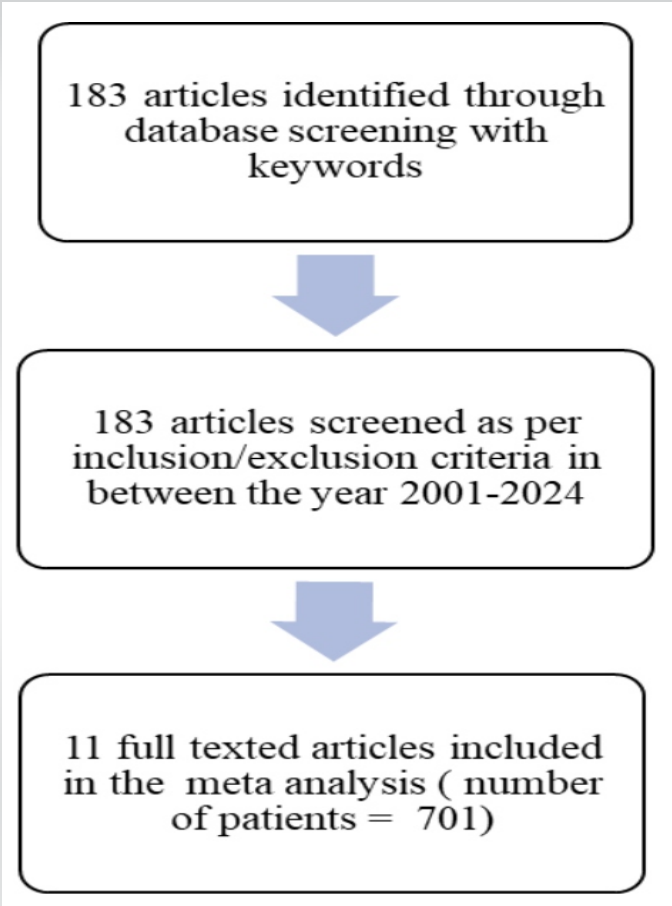

Figure 1: Flow diagram for study selection.

Materials and Methods

A meta-analysis was conducted through a web search on PubMed with the following keywords; thoracolumbar injury, burst fracture, and short- segment fixation. Scientific papers written in English from January 2001 to April 2024 were screened. PubMed search with the keywords revealed 183 articles which were thoroughly reviewed by all the authors. Of these, 11 studies satisfying the inclusion criteria describing short- segment fixation in TLBF s were included in this study [17-26] (Fig. 1). Ethics approval was not necessary as our study did not involve any direct patient intervention or information.

Inclusion criteria

1. TLBF s
2. Adult patients (>18 years)
3. Short- segment instrumentation.

Exclusion criteria

1. Osteoporotic patients
2. Pathological fractures

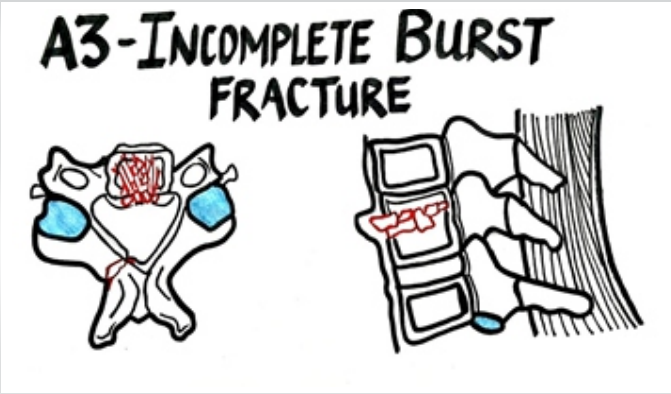

Figure 2: AO type 3 burst fracture.

3. Long- segment instrumentation
4. Follow-up duration < 1 year
5. Augmentation procedure – kyphoplasty and vertebroplasty.

A meta-analysis of 11 studies was performed where total number of patients (n) was 701. Each included study was assessed with clinical, radiological, and functional outcomes of posterior short-segment fixation in TLBF s. The minimum follow-up duration in each study was 12 months. The appropriate, meta-analysis was carried out and forest plot for single group which accounts for interstudy variation and provides a more conservative effect than the fixed effect model. Potential sources of heterogeneity were assessed using the standard chi-square test. In addition, the statistic I2 was used to investigate heterogeneity by examining the extent of inconsistency across the study results. Sensitivity analysis was carried out to assess the robustness of the results of the meta-analysis. Where heterogeneity was present between the studies, differences in study design were examined. All analyses were performed using online free meta-analysis software (https://metaanalysisonline.com).

Results

A total number of 701 patients with a mean age of 41.8 years across 11 studies were included in this review. Of the 11 studies, nine were retrospective studies [17,18,20,22-27] and two were prospective studies [19,21]. The most common fracture morphology identified was AO type A3 (Fig. 2) with a mean load sharing classification (LSC) score of 6.22 [17,18,20,22-24,27], with L1 vertebra being the most commonly fractured level [17-27]. The mean follow-up duration was 2.28 years. Mean time to surgery was 2.75 days.

Radiological outcomes

Anterior vertebral height

Mean anterior vertebral height correction loss at the end of follow- up period was 3% . In the forest plot of mean anterior vertebral height (Fig. 3), four studies were analyz ed [17,18,20,26] with a total of 141 subjects. A not significant heterogeneity was detected (P = 0.19) in anterior vertebral height, suggesting inconsistent effects in magnitude and/or direction. The I2 value indicates that 38% of the variability among studies arises from random chance.

Kyphosis correction loss

The correction loss for Cobb's angle was calculated as an aggregate of the difference in segmental kyphotic angle/Cobb's angle immediate postoperatively and at the final follow-up. The mean loss of post-operative kyphosis correction at the end of the follow-up period was 4.62°. In the forest plot mean kyphotic angle correction loss (in degree) (Fig. 4), seven studies [17,18,22,24-26] were analyzed with a total of 395 subjects. A significant heterogeneity was detected (P < 0.01), suggesting inconsistent effects in magnitude and/or direction. The I2 value indicates that 98% of the variability among studies arises from heterogeneity rather than random chance.

Sagittal index (SI)

SI at the fractured vertebra – calculated as KD at fractured vertebra minus the normal contour (NC) (SI = KD – NC) [20]. The mean loss in SI was 3.36 ° . In the forest plot for mean SI (in

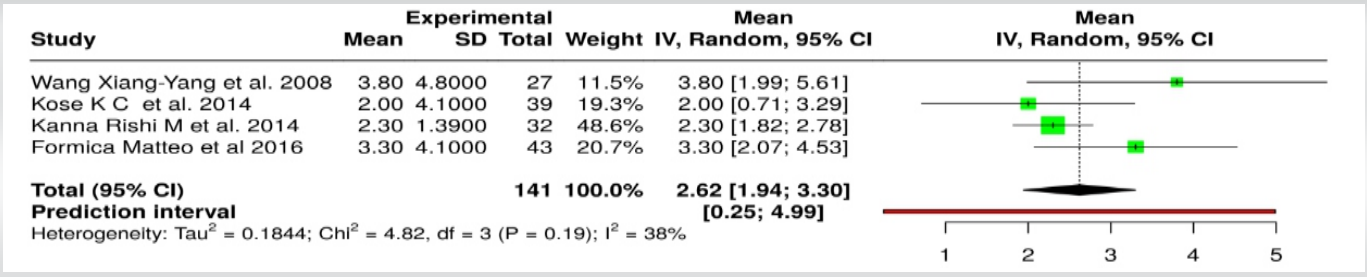

Figure 3: A forest plot of mean anterior vertebral height correction loss of various studies.

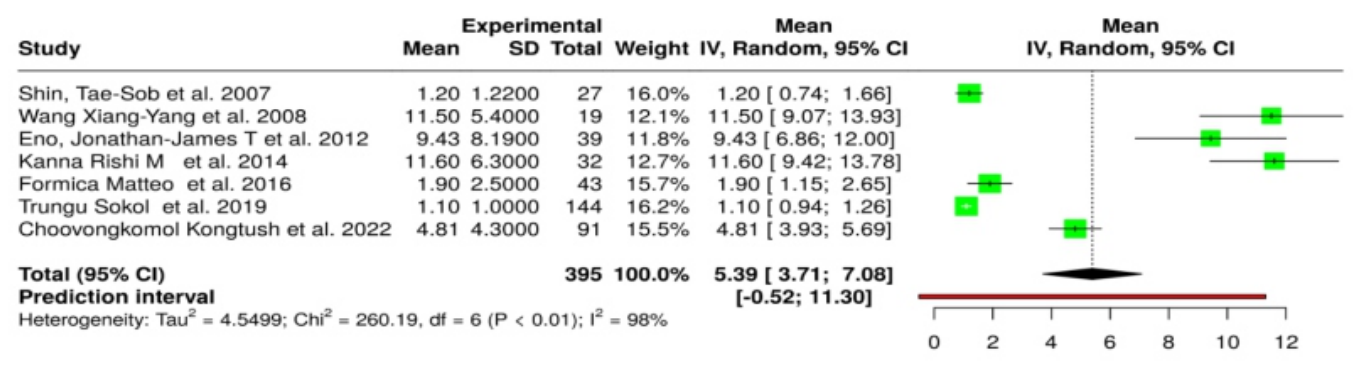

Figure 4: A forest plot of mean kyphotic angle correction loss (in degree) of various studies.

degree) (Fig. 5), four studies [20,24-26] were analyzed with a total of 229 subjects. A significant heterogeneity was detected (P < 0.01) in mean SI (in degree), suggesting inconsistent effects in magnitude and/or direction. The I2 value indicates that 99% of the variability among studies arises from heterogeneity rather than random chance. The mean SI (in degree) was more observed by Wang et al. as compared to Kose et al., Trungu et al., and Shin et al.

Vertebral canal compromise

Mean vertebral canal compromise due to retropulsed fragments as recorded on pre-operative computed tomography scans was 48.3% with an improvement to 25.3% at the final post-operative scan. In the forest plot mean vertebral canal compromise (Fig. 6), three studies [20-22] were analyzed with a total of 67 subjects. A significant heterogeneity was detected (P < 0.01) in mean vertebral canal, suggesting inconsistent effects in magnitude and/or direction. The I2 value indicates that 100% of the variability among studies arises from heterogeneity rather than random chance. Kim et al. found more in mean vertebral canal compromise as compared to Kose et al. and Tang et al.

Functional outcomes

Post-operative visual analogue scale (VAS) score for back pain was reported in five studies [17-19,21,25]. The mean VAS score at the final follow-up was 1.86 with a significant improvement in the score at final follow-up. In the forest plot of VAS score (Fig. 7), five studies were analyzed with a total of 247 subjects. A significant heterogeneity was detected (P < 0.01) in VAS score, suggesting inconsistent effects in magnitude. The I2 value indicates that 96% of the variability among studies arises from heterogeneity rather than random chance.

Pooled data from four studies [17,18,22,25] revealed a mean Oswestry disability index (ODI) score of 18.9% at the final follow-up. In the forest plot mean ODI score (Fig. 8), four studies were analyzed with a total of 244 subjects. A significant heterogeneity was detected (P < 0.01) in mean ODI score, suggesting inconsistent effects in magnitude. The I2 value indicates that 98% of the variability among studies arises from heterogeneity rather than random chance.

A modified version of McNab criteria characterizing the clinical outcome at final follow-up showed the rate of excellent and good outcomes at 94.7% [19] and 100% [21], respectively.

Neurological outcome

A total of 79 patients with neurological deficit across seven studies [17-20,22,24,26] (complete deficit = 7, incomplete

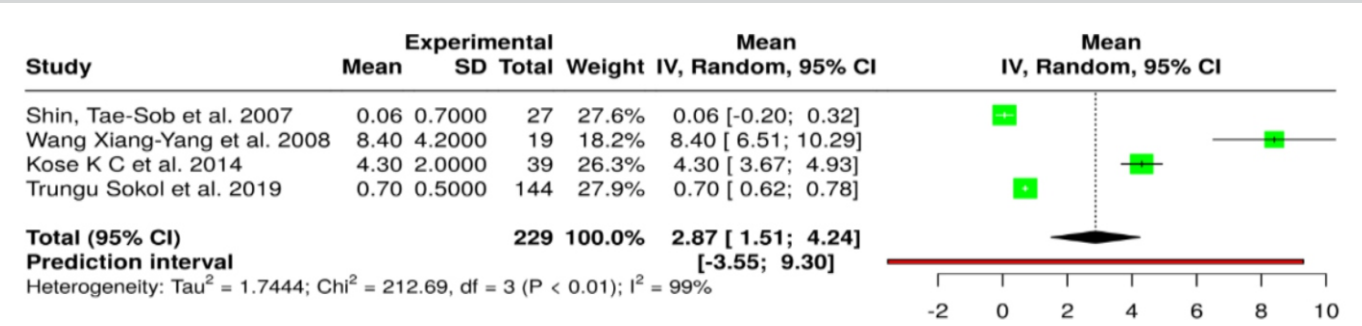

Figure 5: A forest plot of sagittal index (in degree) of various studies.

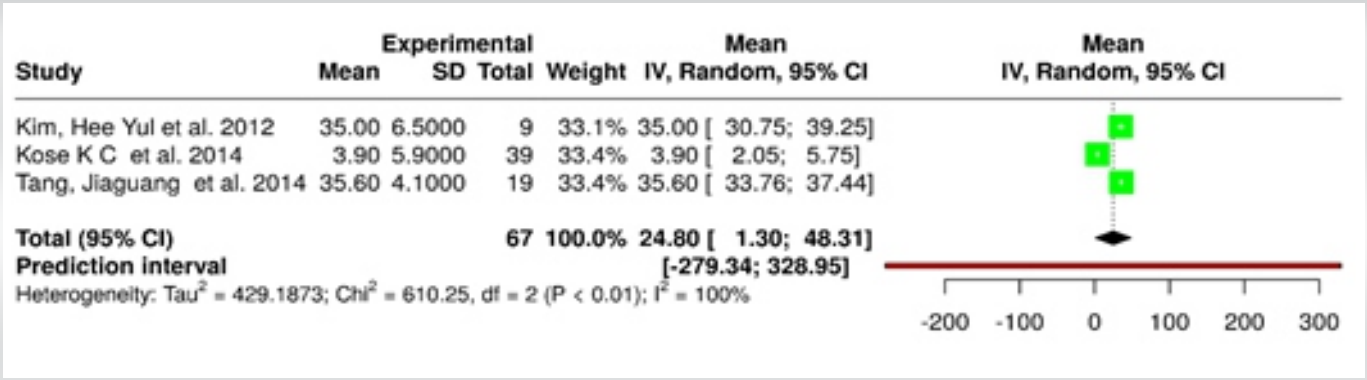

Figure 6: A forest plot of vertebral canal compromise of various studies.

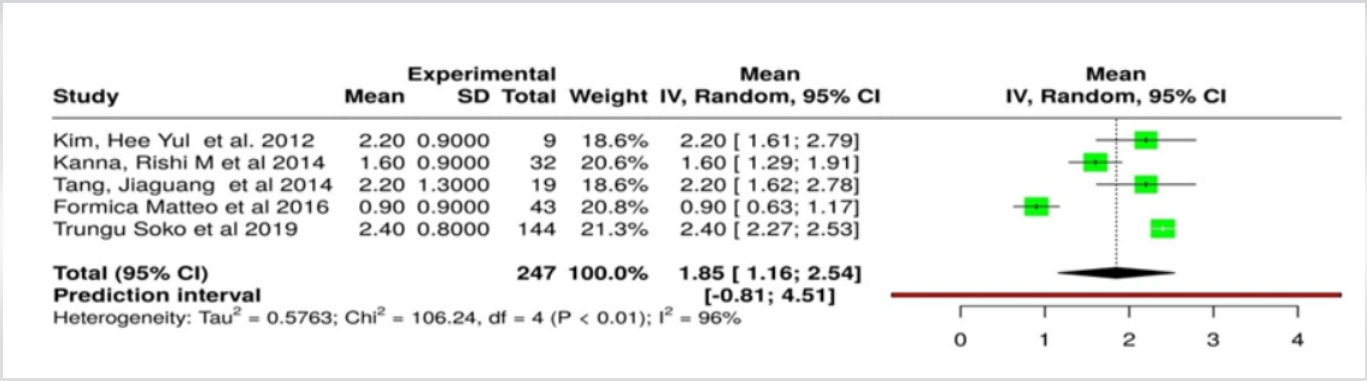

Figure 7: A forest plot of visual analogue scale score of various studies.

deficit = 72) were assessed for neurological recovery using Frankel grade (Table 1) / American spinal injury association impairment score (Table 2). All patients with partial deficits showed improvement in neurological recovery post operatively. Complete neurological recovery was observed in 16 patients with incomplete deficit [17,18,20,26]. While seven patients with a complete neurological deficit pre operatively showed no improvement in the status after surgery, none of the deficits were attributed to the pedicle screw fixation.

Discussion

From the available pooled data in the studies, traditional posterior short- segment fixation with or without posterolateral fusion (one level above and one level below the fractured vertebra) provided adequate restoration of vertebral body height and segmental kyphosis at immediate post -operative radiograph, but there was a significant progression of segmental kyphosis and loss of correction noted at final follow- up as measured by common radiological parameters such as Cobb's angle, anterior vertebral body height, and SI . Eno et al. [22]

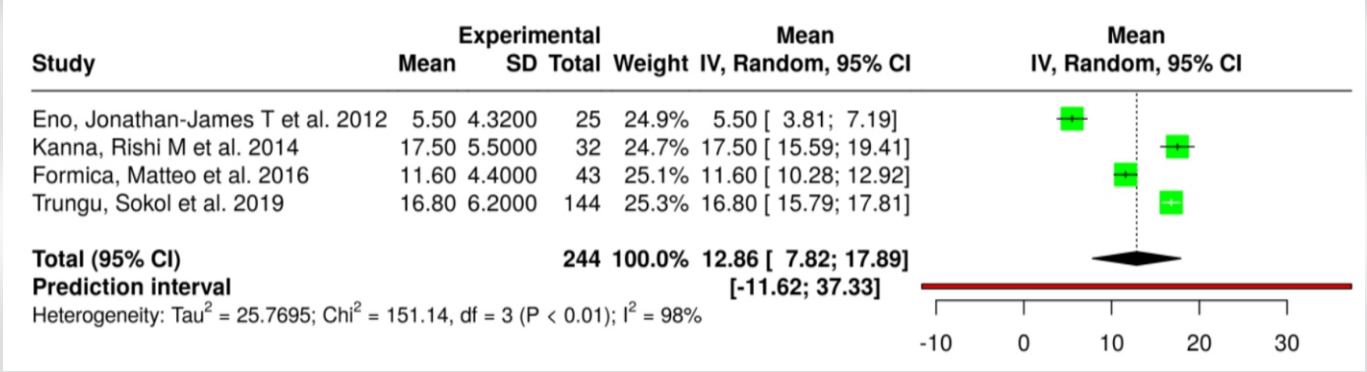

Figure 8: A forest plot of mean Oswestry disability index score of various studies.

documented some loss of kyphosis correction at final follow- up ; however, it was not associated with a statistically significant long- term clinical outcome. This loss of correction could be attributed to the degree of comminu tion of the vertebral body as noted on the pre-operative radiographs [34]. According to McCormack et al., [30] patients with a high load sharing score (LSC ≥ 7) require anterior stabilization in addition to SSPF; nevertheless, numerous studies demonstrate that SSPF alone may not always be enough or safe enough for treating thoracolumbar fractures. Kanna et al. [18], however, advised the use of an intermediate screw in the fractured vertebra to maintain reduction and avoid the need of anterior fixation. This was supported by Trungu et al. [25] in a comparative study concluding better radiological outcomes with the intermediate screw group, but not better clinical outcomes. Overall, short-segment instrumentation with intermediate screw fixation (SSI + IS) at the fracture level along with a one level above and one level below construct offered positive radiological outcomes and significant reduction in pain as documented by VAS and ODI scores.

No neurological deterioration was seen due to the pedicle screw fixation, instead all the patients with partial deficits showed improvement in neurological recovery post operatively. Although there is a debate regarding the timing of surgery, Aono et al. [27] showed that unless there is neurological deficit that the timing of the surgery did not affect results of fracture reduction and had a better reduction rate by short -segment fixation in patients with young age, larger pre- operative vertebral body angle and higher load sharing score (LSC).

Although there is a debate in the comparison of clinical and radiological outcomes of short versu s long- segment instrumentation, Tezeren and Kuru [30], in their study comparing traditional short- segment (without intermediate screw) versus long- segment fixation in TLBF s, demonstrated that long -segment instrumentation is an effective way to manage TLBF s. Short-segment pedicle instrumentation had a high rate of failure. However, long-segment instrumentation prolonged the operative time and increased the amount of blood loss significantly. Another meta-analysis comparing traditional short- v ersus long- segment fixation methods found no significant difference in terms of improvement in back pain, return to work, and correction of kyphosis. However, due to a high clinical heterogeneity in the studies included in this meta-analysis, as shown by the high I2 values, a definitive conclusion cannot be drawn for comparison of the surgical techniques [32]. As suggested by Kanna et al., [18] addition of intermediate screw at fractured level prevented loss of kyphosis. This was supported in a comparative study by Al Mamun Choudhury et al. [34] showing short-segment fixation with fracture level inclusion (SSFIFL) which provided similar clinical and radiological outcomes to long -segment instrumentation. Furthermore, SSFIFL leads to lesser blood loss, shorter operative time, and lesser implant cost. The general consensus suggests that addition of an intermediate screw at the level of fractured vertebra provided that the pedicles are intact as documented on pre- operative imaging is as effective as long-segment fixation in maintaining the kyphosis correction with statistically significant reduction in pain at follow- up. Interestingly, Xiong et al. [13], in a comparative study, concluded that short- segment internal fixation with inclined angle polyaxial screw maintained a greater interface strength and fracture vertebral height in comparison to short- segment internal fixation with straight monoaxial screw and long-segment fixation.

Very few meta-analysis comparing the efficacy of long-segment fixation with short- segment fixation highlight in which patients long -segment screw fixation is a more preferable option [33]. Interestingly, Formica et al. [17] found a positive correlation between obesity (Body mass index > 30) and kyphosis progression. Such obese patients had a higher risk of post-operative loss of kyphosis correction (odds ratio [OR] = 3.2) and benefitted from a rigid multilevel fixation.

Kyphosis progression was reported to be more strongly associated with unstable fractures– posterior ligamentous complex injury, LSC ≥6, severe canal compromise, fractures with AO type A3 and beyond, ≥50% loss of vertebral height, and angular deformity >20 °, sagittal index >15°[32], were associated statistically significant risk for post-operative kyphosis progression (P < 0.04, OR = 3.14), which has to be considered before opting for short-segment fixation [15,23,28]. Addition of intermediate screw at the level of fractured vertebra in such unstable fractures is a preventive factor against post-operative kyphosis progression while opting for a short-segment construct [29].

The main drawback of our study was dissimilarity in the data leading to inconsistent results. However, the variability was more due to heterogeneity in the data rather than random chance. This gives potential to conduct more studies with more homogenous, matched data for consistent results in the management of TLBF s.

Conclusion

Short-segment instrumentation with intermediate screw fixation is a safe and effective method with excellent radiological and clinical outcomes with very low rates of failure while treating unstable TLBF s , w hereas traditional SSPF can lead to progressive loss of kyphosis correction with higher

implant failure rate in patients with unstable fractures.

Clinical Message

Short- segment fixation with intermediate screw fixation is a safer surgical method with excellent outcomes comparable to long-segment instrumentation for unstable TLBF s than traditional short - segment screw fixation.

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

Conflict of interest: Nil **Source of support:** None

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Conflict of Interest: Nil
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