Temporary stabilization of unstable spine fractures

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Abstract

Purpose of Review We will review the recent literature concerning the necessity of supplemental fusion to spinal instrumentation and discuss if temporal spinal fixation is a viable option for the treatment of unstable spine fractures. Advancements in minimally invasive techniques offer an alternative approach to traditional open stabilization for unstable spine fractures. The use of minimally invasive surgery offers many advantages concerning operative morbidity; fusion is not utilized and instrumentation can be removed in a delayed fashion.

Recent Findings There are limited differences in amount of correction loss over time, and multiple studies report equivocal to superior results in patient's functional outcomes when comparing temporary internal stabilization to long segment instrumentation with fusion. Removal of implants can restore segmental motion.

Summary Review of the literature demonstrates that temporary internal stabilization for unstable fractures is a viable option. Close clinical and radiographic follow-up is recommended to avoid delayed spinal deformity.

Keywords Internal bracing · Temporary stabilization · Implant removal · Segmental motion

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Introduction

Approximately 79,000 spinal fractures occur annually in the USA. Nearly 73% of all injuries involve the thoracic or lumbar spine, with the most common location at the thoracolumbar junction [1]. The most common causes of unstable spinal fractures are related to trauma. High-energy falls represent 39% of injuries followed by traffic accidents at 26.5% and then ground level low-energy falls in 20% of the patients [2]. Neurological insults occur in 10–30% of all traumatic spine fractures with higher rates associated with cervical injuries and in those who sustain fractures at multiple spinal levels [2]. These injuries are more common during the second and third decades of life and are disproportionately common in young males.

Clinical exam, mechanism of injury, and imaging [3, 4] are heavily relied upon to make decisions regarding surgical versus non-surgical management. In literature, many efforts are dedicated to the classification of thoracolumbar fractures [3, 5, 4] as well as the description of surgical indications and approaches [6]. The presence of neurological injury secondary to canal compromise and the integrity of the posterior ligamentous complex are two vital components of patient assessment when making decisions concerning non-operative versus operative management.

Despite the large volume of literature published on the management of thoracolumbar burst fractures, the optimum treatment of this injury continues to be debated. There are multiple reports of good clinical outcomes using conservative measures such as bracing and rest in the treatment of patients with stable thoracolumbar fractures [7, 8]. However, there remains a population of patients with TL fractures that are deemed unstable and require surgical stabilization.

Surgical indications for thoracolumbar fractures are well described. Indications for surgery often rely heavily on radiological parameters and varying definitions of “stability.”

Concepts such as surgical stabilization in the treatment of unstable fractures in patients with complete or incomplete SCI and in patients who have a kyphotic deformity $>25^\circ$ have received a significant amount of attention. Identifying risk factors in patients that are neurologically intact is also important.

Biomechanical studies have identified the integrity of the posterior column as a predictor of mechanical stability [9]. In the literature, clinical guidelines have reflected this, defining posterior column compromised by a range of radiographic parameters: kyphosis $>15\text{--}35^\circ$, loss of $>40\text{--}60\%$ of the anterior VB height, and fracture dislocation of the posterior elements [10–12].

The introduction of pedicle screw fixation by Roy Carmille in 1970 revolutionized the surgical treatment of spinal fractures [13, 14]. There have been multiple modifications to the types of instrumentation utilized over the years. The current standard of care for the treatment of unstable spine fractures includes open reduction and internal fixation with the use of pedicle screw instrumentation and supplemental posterolateral fusion. The goals of surgery are to stabilize the spine while maintaining anatomical alignment and protecting the spinal cord from further neurological injury.

The introduction of minimal invasive techniques over the last decade offers an alternative to more conventional open techniques (Fig. 1). The use of minimally invasive surgery offers many theoretical benefits to the trauma patient, including less tissue trauma and blood loss in the already compromised paraspinal musculature. Proponents of minimally invasive spine surgery argue that this approach incorporates less injury to the musculature, blood vessels, and nerves, decreases blood loss, lowers postoperative pain, results in smaller surgical incisions with higher rates of healing, decreases scarring, lessens postoperative pain, and reduces hospital stays with faster post-surgical recovery. Unfortunately, many studies

have failed to show the superiority of minimally invasive spine surgery concerning long-term outcomes compared to traditional open approaches [15–17].

While traditional techniques have good outcomes, there are many unresolved issues surrounding spinal fixation with fusion (Table 1). The use of spinal fusion in the treatment of spinal fractures has many shortcomings including loss of segmental motion, increased incidence of adjacent level disease, delayed deformity, higher patient dissatisfaction scores, and overall patient disability. Recently, multiple papers have been published that examine the long-term outcomes of spinal fractures treated surgically with and without fusion [18•, 19••] which highlight this dilemma: Is fusion necessary? Here, we will review the treatment of unstable spine fractures with temporary stabilization (Table 2), analyze recent literature regarding the role of supplemental fusion after spinal instrumentation, and discuss if temporary spinal fixation is a viable option for the treatment of unstable spine fractures.

Time-related loss of deformity correction

One of the most important questions to answer concerning temporary spinal fixation is if deformity correction is maintained over time. There is a body of literature that scrutinizes traditional open stabilization. The traditional technique encompasses fusion across multiple spinal levels in order to create multiple fixation points surrounding the fracture segment. The purpose of segmental fusion is to immobilize the fracture, allowing bony healing. Studies have shown that long segment fixation with fusion leads to fracture stabilization and healing [25, 26]. Unfortunately, the long-term outcomes of spinal fusion may include adjacent deformity and correction loss. One proposed benefit of temporary stabilization is to allow fracture healing without bony fusion. Without fusion,

Fig. 1 Sagittal CT shows a T12 fracture dislocation in the setting of DISH. The patient underwent percutaneous open reduction with internal stabilization three levels above and below the fracture. A K-wireless technique was utilized for the instrumentation while using intraoperative navigation. Postoperative upright lateral X-ray shows good fracture reduction

Table 1 Theoretical pros and cons of temporal fracture stabilization compared to stabilization with fusion

Pros	<ul style="list-style-type: none"> -Preserved motion segments -Lower operative times -Less blood loss -Decreased postsurgical pain
Cons	<ul style="list-style-type: none"> -Second surgery for hardware removal -Higher operative cost -Loss of deformity correction over time -Delayed deformity on implants are removed -Limited effectiveness in injuries with ligamentous disruption

it is possible to restore spinal mobility and unload adjacent segments with the goal of decreasing junctional degeneration in the future.

The issue of correction loss has received much attention. Kocanli et al. reviewed the radiographic and clinical outcomes of 45 patients: Half underwent posterior instrumented fixation with fusion and the remainder without fusion for the treatment of thoracolumbar fractures. The loss of correction was significant for both anterior wedge angle and segmental kyphosis at the fractured segment [27•], but there was no statistical difference between fusion versus non-fusion.

Chou et al. reported progression of both anterior wedge angle and kyphosis. In their study, the average kyphosis was 13.8° for the non-fusion group and 14.7° in the fusion group, which leads to questions about the necessity of fusion [19••].

They presented a prospective study of 46 patients with pedicle screw instrumentation including the level above and below the fracture level and randomized to either fusion or no fusion. Both groups had significant loss of vertebral body height and kyphosis correction on follow-up imaging. The average loss of kyphosis over the 10-year period was 10.7° and 12.3° in the fusion and non-fusion groups, respectively. There was progressive decline in the amount of kyphotic angle correction as time progressed over a 10-year period [19••]. There were also statistically significant differences in regional segmental motion (4.2° in the non-fusion group compared to 0.9° in the fusion group). Although there were differences in the ability of the fusion group to maintain segmental mobility, there were no differences in clinical outcomes as measured by visual analog scale for back pain and Greenough Low-Back Outcome Score. The authors concluded that the long-term outcomes were similar when comparing fusion versus non-fusion in the treatment of thoracolumbar fractures. The added benefits of non-fusion included motion preservation, no graft donor site complications, less blood loss, and shorter operative time [19••].

Similarly, Zhao et al. retrospectively reviewed the radiographic and clinical outcomes of posterior instrumented fusion including screw placement in the fracture level compared to short segment instrumentation one level above and below the fracture level. The instrumentation was removed 12–18 months post-injury with subsequent radiographic follow-up for 1 year. The posterior fixation group with fracture level instrumentation had a significant loss of vertebral height

Table 2 Temporary internal stabilization for unstable spine fractures

Chou et al. [19••]	Prospective randomized trial comparing short segment fusion versus non-fusion temporary internal stabilization with no fusion for burst fractures. No statistically significant differences in clinical or radiographic outcomes with at least 10-year follow-up between the groups. Motion was preserved in the non-fusion group with a mean of 4.2°. Benefits of non-fusion include less donor site complications, maintained motion segments, and reduced blood loss and operative time.
Jeon et al. [20•]	Case-control study of 45 patients with treated burst fractures with implant removal at a mean 18.3 months from index surgery compared to control cohort of similar patients with retained instrumentation. The VAS and ODI were significantly better at 1- and 2-year follow-ups in the temporary implant group. Segmental motion increased significantly to 5.9° at the 2-year follow-up after hardware removal.
Kim et al. [21•]	Mixed group of 23 patients with either burst fractures or flexion-distraction injuries. All patients had documented injury to PLL. Mean time to implant removal was 9.7 months. At follow-up at 18 months, the mean sagittal kyphotic angle was 2.4° which represents a loss of correction of 5.2°. In flexion-extension, the range of motion was 14.2°.
Kim et al. [22••]	Paralleled the outcomes of temporary stabilization with hardware removal after 12 months. Range of segmental motion was >10° once the implants were removed.
Axelsson et al. [23•]	Showed that implant removal may restore segmental mobility after temporal internal bracing pedicle screw fixation. Implants were removed in 7 patients in their cohort. Tantalum indicators were implants at the time of pedicle screw removal, and radiostereometry was used to confirm maintained segmental motion.
Toyone et al. [24•]	Treated 12 patients with thoracolumbar burst fractures with short segment instrumentation without fusion. Implants were removed within 1 year from the index surgery. At the 10-year follow-up, segmental motion was maintained with an average range of motion of 12° in flexion/extension.

correction of 3.78% compared to 8.31% in the traditional short segment group and a loss of correction of the Cobbs' angle of 2.6° and 5.51°, respectively. Clinically, the Denis Pain Scale scores over 1 year were equal. All patients treated had type A3.1 and A3.2 fractures, which makes it difficult to generalize treatment strategies for other types of fractures. However, these results support placement of an additional level of fixation in the fractured segment as it appears to maintain deformity correction over time. Also, the authors stress the importance of the load sharing classification to determine which spinal injuries can be treated with instrumented stabilization alone. The PLC and annulus of the disc must be intact for indirect reduction and restoration of wedge angle [18•].

The role of fusion in the management of burst fractures by short segment instrumentation was examined and reported by Jindal et al. in 2012. This prospective randomized study showed no significant loss of kyphosis correction at final follow-up of nearly 2 years in both fusion and non-fusion groups. Furthermore, there were no differences in functional clinical outcomes. Interestingly, the mean operative time was increased by one third, and the need for postoperative transfusion was significantly increased in the fusion group [28•].

Jindal et al. reported a mean loss of correction of 5.5° in the fusion group compared to 3.6° in the non-fusion group which approached but did not reach significance. They hypothesize that the loss of correction in the fusion group may be related to detaching the soft tissues during decortication in preparation of arthrodesis. Disruption of the supraspinous and interspinous ligaments releases the posterior tension band, shifting the load of force back onto the anterior column resulting in anterior wedging during bony remodeling and loss of correction [29]. Similar observations have been made by Wang et al. [30••].

Fracture type amenable to temporary stabilization

Most of the aforementioned literature included patient populations with burst-type fractures. The disruption of the anterior and middle column potentially destabilizes the spine and may put some patients at risk for delayed deformity and neurological injury. Not all burst fractures are unstable however, and there have been many reports of adequate bony healing without surgical stabilization. Injury to the posterior ligamentous complexes offers unique challenges when treating spinal fractures. Instrumentation is used to immobilize the fracture segment to allow fracture healing, but questions remain concerning the potential for ligamentous injury. If temporary stabilization is used for internal bracing, then subsequent removal, once the fracture is healed, raises questions if patients with ligamentous injuries become unstable after instrumentation removal.

Cui et al. demonstrated that adolescent patients with spinal fractures treated with percutaneous instrumentation without

fusion had motion arcs that were maintained at all levels, and no evidence of pseudo-arthritis occurred even in patients with rotational shear-type injuries and pure ligamentous injuries. Unlike most studies, their cohort included not only burst-type fractures but also distraction injuries and pure ligamentous injuries. All instrumentation were removed within 1 year. They noted significant fracture remodeling and healing. Postoperative vertebral body height restoration and wedge angle were improved and maintained with an average follow-up time of 19.5 months post-injury [31••].

Similarly, Kim et al. reported the treatment of spinal fractures with temporal internal bracing. All of these patients had a documented disruption of the posterior ligamentous complex. The implants were removed on average 9.6 months post-injury and followed both clinically and radiographically for 18 months. There was slight loss of correction once the implants were removed with the average loss of sagittal correction of 4.5°. They noted the highest level of correction loss in the sagittal plane in patients with disc space involvement and those with greater than 20° of focal kyphosis preoperatively [21•].

Maintained segmental motion

Temporary instrumentation is used to stabilize the fractured segment to promote fracture healing. Once the fracture is healed, the implants are removed. The utility of removing the hardware is to restore segmental mobility and to decrease degenerative changes at the adjacent levels. But does removing the hardware maintain or restore segmental motion, and does this improve patient's clinical outcomes?

Lindsey et al. showed that once the hardware was removed, residual mobility is most evident at the caudal end of the instrumented segment [32] through the use of flexion and extension radiographs 1 year following implant removal and 2 years after the original surgery. Similarly, Wang presented their prospective clinical trial comparing the results of fusion versus non-fusion for surgically treated burst fractures in 2006. A total of 58 patients were included in their study: 30 patients in the fusion group and 28 patients in the non-fusion group. The patients without fusion had instrumentation removed 1 year from surgery. Dynamic flexion-extension X-rays were completed approximately 2 years from injury. The average segmental motion was 1° for the fusion group and 4.8° for the non-fusion group [30••].

Recently, Axellon reported the use of radiostereometry at the time of implant removal, showing that late implant removal may restore segmental mobility after posterior fixation of thoracolumbar fractures [23•]. It was noted that motion was restored in the lumbar segments, but not the thoracic levels, once the hardware was removed. This is in agreement with Lindsey's observation of limited return of mobility of the rostral segments. As a high percentage of the fractures in the

aforementioned papers occurred in the thoracolumbar junction, the rostral portion of the implants was placed in the thoracic spine. Even in the absence of trauma, the thoracic spine has very little mobility at baseline secondary to the ribs and the orientation of the facet joints.

Akbarnia et al. demonstrated that motion was maintained following spinal instrumentation in burst fractures [33]. They treated 13 patients with burst fractures using the rod-long fuse short technique. In this technique, pedicle screws were placed in multiple levels rostral and caudal to the fracture level but posterolateral arthrodesis was completed only at the fracture segment. The pedicle screws and rods were removed at 6 months post-injury, and the fusion mass was explored. Twelve of 13 patients did have fusion of the injured segment. Forty-three of the 44 facet joint complexes outside the intended fusion bed maintained physiologic motion once instrumentation was removed [33].

In 2014, Kim et al. [22•] compared the range of motion between flexion and extension in patients undergoing hardware removal following short segment instrumentation including pedicle screws placed in the fracture level. All patients had thoracolumbar burst fractures with $>30^\circ$ of kyphosis and vertebral body height loss $>40^\circ$. The study was divided into two groups based on the presences of osteoporosis. The osteoporotic cohort received bone cement fracture augmentation with polymethylmethacrylate. The implants were removed at 12 months following screw fixation and followed for 1 year. There was a significant restoration of the intersegment mobility across attempted flexion and extension (approximately 10°) in both groups.

Spiegel et al. examined disc movement in flexion and extension in patients undergoing temporary stabilization and found maintained disc movement and overall disc height when comparing the levels adjacent to the fracture segment to control discs distal to the fixated levels. The fracture level and associated disc space did have decreased mobility in extension after fracture healing [34].

Similarly, Jeon reported that the segmental motion spine increased from 1.6° of the time of implant removal to an average of 5.8° at the 1-year follow-up. The degree of motion was maintained at the operative levels during the 2-year follow-up [20•]. Toyone et al. [24•], treated 12 patients with thoracolumbar burst fractures with short segment instrumentation without fusion. Implants were removed within 1 year from the index surgery. At the 10-year follow-up, segmental motion was maintained with an average range of motion of 12° in flexion/extension [24•].

Functional outcomes

While examining the literature, nearly all studies confirm comparable functional outcomes in patients receiving spinal

instrumentation with fusion and those in which no fusion was performed. Likewise, implant removal has shown equivalent outcomes compared to retained instrumentation. Proponents of hardware removal claim improved long-term pain control, less hardware complications secondary to failure, and less incidence of adjacent level disease and iatrogenic fusion. Though these benefits would seemingly justify the second procedure, the literature is equivocal with most showing minimal differences in functional outcomes in patients with the implants removed versus those patients who retain instrumentation [19•, 28•, 29].

Similar results comparing non-operative versus operative management of thoracolumbar fractures were reported by Gnanenthiran [35]. This meta-analysis showed no association between the degree of residual kyphosis and pain on visual analog scale or functional status (RMDQ). In contrast, Jeon in 2015 [20•] reported a series of patients with unstable thoracolumbar fractures who received long segment instrumentation 2–3 levels rostral and caudal to the fracture site with fusion at the fracture level. In this series, half of the patients (45) had the instrumentation removed at 18 months. The visual analogue scale for back pain and Oswestry Disability Index was significantly worse at 1 and 2 years postop for the hardware-retained group compared to the instrumentation-removed group ($P = 0.000$) [20•].

Alpert et al. studied the outcomes following removal of instrumentation after posterior fusion and found that 40% of patients that had delayed implant removal had significant improvement in back pain [36]. The removal of spinal implants was cautioned by Ak et al., though they showed improved pain scales on VAS in 80% of patients undergoing a second procedure for implant removal [37].

Likewise, there have been reservations concerning temporary stabilization in unstable fractures because of reported high instrumentation failure rates. A systematic review of the literature concerning fusion versus non-fusion in the treatment of unstable thoracolumbar fractures from up to 2012 by Tian et al. showed that the average hardware failure rate was 5%. Pooled estimates failed to show that the fusion group achieved less implant failure when compared to non-fusion ($p = 0.28$) [38].

There have been multiple reports of donor graft site complications and morbidity associated with posterolateral arthrodesis [18•, 19•, 22•, 28•, 29, 30•, 31•]. These include postoperative neuralgia, pain at the graft site, hematoma formation requiring delayed evacuation, and infection. Although the use of allograft in place of autograph eliminates donor site pain and complications, costs are elevated and fusion potential may be negatively affected [39]. The length of surgery is also increased by fusion surgery which increases operative costs and may influence infection rates [38, 40].

Postoperative blood loss has been documented to be higher in the fusion groups compared to the non-fusion groups in

nearly every study [38, 41]. The increase in intraoperative blood loss raises the need for perioperative blood transfusion which imparts inherent risk to patients due to a higher rate of infection, transfusion reactions, and blood-transmitted diseases [42]. The need for transfusion also increases hospital length stay and cost [43]. Multiple studies have shown that the need for a blood transfusion increases the rate of perioperative complications, especially infection [42].

Timing of hardware removal

In 2002, Chang et al. described the radiographic characteristics of three groups of patients treated for thoracolumbar fractures. The groups were: conservative treatment with bracing and immobilization, instrumented stabilization with fusion, and an instrumentation only group. The instrumentation was removed in those undergoing instrumentation stabilization without fusion at 6 months post-injury. X-rays were used to measure vertebral body height, kyphotic angle, disc height, and facet hypertrophy. CT scans were used preoperatively, at the time of instrumentation removal and at 1 year postop to examine the continuity of the anterior column, cleft formation, vertebral body sclerosis, and new bone formation. This study showed significant differences in loss of vertebral body height and kyphotic angle in the conservative group compared to both surgical groups. There were no differences in the surgical groups regardless of whether fusion was performed. Degenerative changes in the facet joints were noted much more frequently in the fusion group. In 18 of the 20 patients in the non-fusion group, CT revealed new bone formation at the fracture site, continuity of the anterior column cortical structure, and bony sclerosis [44]. This is the first paper to study the timing of bony healing using CT scan.

Similarly, in 2013, Cox et al. confirmed adequate fracture stabilization with temporary internal fixation using surveillance CT scans. The patient's instrumentation was removed 6 months after the primary surgery without any negative consequences [45]. Older studies looking at the timing of instrumentation with temporary Harrington rods by Gardner and Armstrong showed sclerosis of the facet joints in 33% of patients and facet fusion in ~3% [46] after 18 months of immobilization.

In contrast, Spiegl et al. argued that patients demonstrated worse radiographic outcomes when instrumentation was removed before 12 months post-injury. They showed significantly reduced disc space height and decreased disc space angle during extension on lateral radiographs in those patients who had the instrumentation removed less than 12 months from the original injury compared to those who had retained the instrumentation for at least 2 years before removal. They recommend waiting at least 1 year from injury to remove the

internal fixators to allow the best outcomes for preservation of disc space height and mobility [34].

To date, there is no consensus concerning the optimal timing of instrumentation removal. The use of CT and weight-bearing radiographs should be used to support complete bony fracture healing before instrumentation is removed [44–46].

Conclusions

Review of the literature demonstrates that temporary internal stabilization for unstable fractures is a viable treatment option. There are limited differences in amount of correction loss over time, and multiple studies report equivalent to superior results in functional outcomes when comparing temporary internal stabilization to long segment instrumentation with fusion. Non-fusion techniques reduce the amount of intraoperative blood loss and operative time and decrease the rate of perioperative transfusion and, in some studies, the total length of hospital stay. These techniques also offer the unique ability to preserve motion segments and overall spine mobility which may deter adjacent level disease and future deformity.

There are multiple important points that can be drawn on review of the current literature:

- Most studies showed better outcomes with younger patients. Older populations may require cement augmentation if osteoporosis is present.
- Temporary stabilization is a viable option for multiple fracture types including unstable burst fractures and flexion-distraction-type injuries.
- Injuries to the posterior ligamentous complex does not necessarily limit the use of this technique.
- It is highly recommended to obtain an MRI if non-fusion and implant removal is planned. Injury to the disc space is correlated with higher levels of correction loss with resulting kyphosis once the implants are removed.
- Placement of pedicle screws in the fractured level decreases correction loss over time and should be considered if the pedicles are intact.
- CT scans should be used to confirm fracture healing and new bone formation at the fracture site, continuity of the anterior column cortical structure, and bony sclerosis.
- Timing of implant removal is up to the operating surgeon. Recommendations for timing of removal vary between 6 months and 2.8 years. Multiple authors recommend removing instrumentation as soon as there is radiographic evidence of bony healing
- If implants are removed, close clinical and radiographic follow-up is recommended to identify delayed development of spinal deformity

Compliance with ethical standards

Conflict of interest Aaron P Dansion and Darrin Lee declare that they have no conflict of interest. Ripul Panchal reports personal fees from Baxter, grants and personal fees from Globus, personal fees from GS Medical, personal fees from Medtronic, personal fees from MizuhoOSI, personal fees from Precision Spine, grants from SpineGuard, and personal fees from ZimmerBiomet, outside the submitted work.

Human and animal rights and informed consent This article does not contain any studies with human or animal subjects performed by any of the authors. With regard to the authors' research cited in this paper, all procedures were followed in accordance with the ethical standards of the responsible committee on human experimentation and with the Helsinki Declaration of 1975, as revised in 2000 and 2008. All institutional and national guidelines for the care and use of laboratory animals were followed.

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