Original Article

Construct length analysis of type B and C cervical and thoracolumbar fractures

ABSTRACT

Objectives: The purpose of this study is to identify if construct length affects the rate of surgical complications and instrumentation revision following surgical fixation of subaxial and thoracolumbar Type B and C fractures. This study evaluates the effect of ankylosing spondylitis/diffuse idiopathic skeletal hyperostosis (AS/DISH) within this population on outcomes.

Methods: Retrospective review of 91 cervical and 89 thoracolumbar Type B and C fractures. Groups were divided by construct length for analysis: short-segment (constructs spanning two or less segments adjacent to the fracture) and long-segment (constructs spanning more than two segments adjacent to the vertebral fracture).

Results: For cervical fractures, construct length did not impact surgical complications ($P = 0.641$), surgical hardware revision ($P = 0.167$), or kyphotic change ($P = 0.994$). For thoracolumbar fractures, construct length did not impact surgical complications ($P = 0.508$), surgical hardware revision ($P = 0.224$), and kyphotic change ($P = 0.278$). Cervical Type B fractures were nonsignificantly more likely to have worsened kyphosis ($P = 0.058$) than Type C fractures. Assessing all regions of the spine, a diagnosis of AS/DISH was associated with an increase in kyphosis ($P = 0.030$) and a diagnosis of osteoporosis was associated with surgical hardware failure ($P = 0.006$).

Conclusion: Patients with short-segment instrumentation have similar surgical outcomes and changes in kyphosis compared to those with long-segment instrumentation. A diagnosis of AS/DISH or osteoporosis was associated with worse surgical outcomes.

Keywords: Burst fracture, cervical, fusion, thoracolumbar, trauma, vertebral body fracture

INTRODUCTION

Spinal injuries account for 6% of all fractures annually in the United States.[1] The AO Spine Classification was developed to provide a common language that was simple, descriptive, and reproducible for discussing traumatic spinal injuries, while addressing the pitfalls of previous classification systems.[2] The classification categorizes subaxial cervical and thoracolumbar fractures into three major types based on injury severity and instability [Figure 1]. In addition to the fracture pattern and morphology, there are score modifiers in the AO Spine Classification for particular diseases have been shown to increase risk for spinal fractures, including ankylosing spondylitis (AS), diffuse idiopathic skeletal hyperostosis (DISH), and osteoporosis.[3-6]

No standard of treatment exists for the management of spinal fractures, and treatment can vary based on fracture

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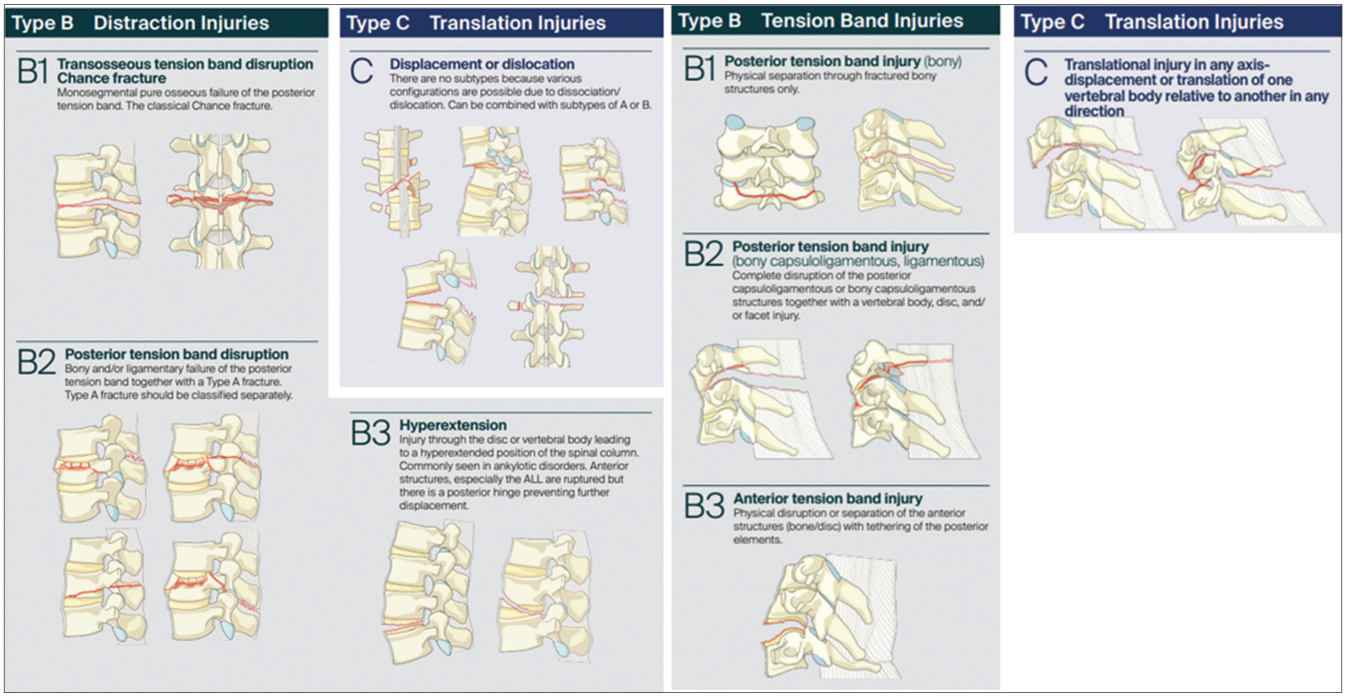

Figure 1: The AO Spine Classification for subaxial and thoracolumbar Type B and Type C vertebral fractures (Permission granted by AO Spine)

patterns, neurologic deficits, and instability.[7] For patients undergoing operative management, construct length may play a vital role in patient outcomes. Historically, spine fractures were managed with external immobilization or long segment instrumentation, but with the advent of modern pedicle screws, shorter segment fixation became feasible, which can minimize patient morbidity.[8] However, short construct fixation does not ensure adequate stability, and failure to provide appropriate stability risks subsequent kyphosis and/or instrumentation failure.[9,10] To address the high failure rates of early pedicle screw iterations, McCormack *et al*. introduced the load-sharing classification, a system that grades the fracture morphology on its ability to distribute load through the injured vertebrae based on three anatomic findings: comminution of the anterior column, displacement of fracture fragments, and degree of kyphosis. Injury severity was based on a point system, with ≥7 points predicting construct failure.[11] However, the study predominantly analyzed burst fractures, and the system was based on a variable screw placement (VSP) and plate construct that does not provide the same strength and stability as current-generation pedicle screws and rods.

In 2010, authors have shown that short constructs could be used successfully despite highly comminuted thoracolumbar Type B and C fractures.[12] However, further research is needed to confirm if these injuries should be treated similarly with continued advancement of spine instrumentation over a decade later. Furthermore, outcomes for Type B and C fractures have not been adequately explored.

Hence, our study objectives are to (1) identify if construct length affects surgical outcomes, including change in kyphosis, and hardware failure following surgical reduction and fixation of subaxial cervical and thoracolumbar Types B and C fractures and (2) determine the impact of fracture type on surgical outcomes.

METHODS

Following IRB approval (protocol 19D.508), all patients ≥18 years of age who received operative treatment for AO Spine subaxial cervical and thoracolumbar Type B and C spinal fractures between 2007 and 2020 were retrospectively identified from an institutional consult database. Patients with a diagnosis of infection or neoplasm were not included in the analysis. Patients were excluded if a preoperative radiograph, immediate postoperative radiograph, and >3 months radiograph was not accessible for analysis. Patients without computed tomography (CT) scans at the time of admission were also excluded from the analysis.

Data extraction

Patient demographics, fracture characteristics, surgical characteristics, and surgical outcomes were collected through a search of our institution's electronic medical records through query and manual chart review. Demographic data included age, sex, diabetes, Charlson comorbidity index (CCI), smoking status, and race. Surgical characteristics included approach of instrumentation (posterior or combined anterior/posterior), vertebral span of instrumented construct, and number of screws in fracture level. Prior diagnoses of AS or diffuse idiopathic spondylotic hyperostosis (AS/DISH) and osteoporosis were documented. Surgical outcomes documented included surgical complications and hardware revision (or exchange) within 1 year of surgery, as well as kyphotic increase after surgical correction.

Imaging analysis

All images were reviewed by two trained laboratory personnel. Fracture characteristics were determined on preoperative radiograph and included: anatomic location (cervical or thoracolumbar), fracture type (B or C), fracture Type B subclassification (B1, B2, or B3), overall load-sharing classification, comminution and apposition subclassification of the load-sharing classification, and number of facets dislocated for subaxial cervical spine injuries.[11] Increase in kyphosis was defined as the change in segmental lordosis between radiographs taken immediately postoperatively during the hospital admission and those taken at least 3 months after surgical fixation. The segmental lordosis was measured as the sagittal Cobb angle between the superior endplate of the vertebrae immediately above and the inferior endplate of the vertebrae immediately below the fracture. To diagnose osteoporosis, CT scans from the admission during which patients received spine surgery were analyzed. The average Hounsfield units (HU) of the cancellous bone in the L1 vertebral body was measured on three separate axial sections; an average of <110 HUs was defined as osteoporosis.[13] If there were fractures through L1, the closest adjacent vertebrae without a fracture were used for measurement.

Patients were divided into long-segment instrumentation – defined as constructs spanning more than two segments adjacent to the vertebral fracture and short-segment instrumentation – constructs spanning two or less segments adjacent to the fracture.[14] Cervical and thoracolumbar fractures and fracture type. A diagnosis of osteoporosis and AS/DISH were compared among the analyses performed.

Statistical analysis

Descriptive statistics, including mean and standard deviation, were used to report patient demographics, surgical characteristics, and surgical outcomes. A Shapiro–Wilk test was used to analyze the normality of each continuous variable, and parametric data were compared with independent *t*-tests, while nonparametric data were compared with Mann–Whitney *U*-tests. A multivariable stepwise regression was performed to assess the most significant independent predictor of surgical hardware failure and increase in kyphosis. Dichotomous variables were compared with Pearson's Chi-square or Fischer's exact tests. R software, version 3.6.3 (R Foundation for Statistical Computing, Vienna, Austria) was used for all data analysis. Statistical significance was set at $P < 0.05$.

RESULTS

Demographics of cervical fractures by construct length

A total of 63 patients were treated with long-segment instrumentation while 28 patients were treated with short-segment instrumentation. Patients with short-segment instrumentation were more likely to be younger (52.4 ± 20.9 vs. 68.2 ± 17.0, $P < 0.001$), have a lower CCI (2.10 ± 2.43 vs. 3.64 ± 2.06, $P = 0.002$), be female (28.6% vs. 3.57%, $P = 0.015$), and were less likely to have a diagnosis of AS/DISH (14.3% vs. 60.7%, $P < 0.001$). Patients with long-segment instrumentation were more likely to have Type B3 fractures (94.4% vs. 42.9%, $P < 0.001$). There were no significant differences between groups regarding race, smoking status, diagnosis of diabetes, and Type B versus Type C fractures ($P > 0.05$) [Appendix 1].

Surgical characteristics and outcomes of cervical fractures

Patients with short-segment instrumentation were more likely to have combined anterior-posterior instrumentation (50.8% vs. 17.9%, $P = 0.007$), while patients with long-segment instrumentation were more likely to have posterior-only instrumentation (82.1% vs. 49.1%, $P = 0.007$). A long-segment constructs were significantly associated with a diagnosis of AS/DISH (60.7% vs. 14.3%, $P < 0.001$). There were no significant differences between groups with regard to screws in the fracture level, osteoporosis diagnosis, and load-sharing classification ($P > 0.05$). When comparing shorter and longer constructs, there were no significant differences in the degree of kyphotic angle change (3.98 ± 5.08 vs. 3.96 ± 4.26, $P = 0.994$), surgical complications (4.76% vs. 7.14%, $P = 0.641$), or surgical hardware revision (3.17% vs. 10.7%, $P = 0.167$) [Table 1].

Type B fractures were significantly more likely to be treated with posterior instrumentation alone (76.1% vs. 42.2%, $P = 0.002$), while Type C fractures were more likely to be treated with combined anterior-posterior instrumentation (57.8% vs. 23.9%, $P = 0.002$). Type B fractures were significantly more likely to be in patients with osteoporosis (54.1% vs. 10.5%, $P < 0.001$) and AS/DISH (52.2% vs. 4.44%, $P < 0.001$). However, Type B fractures demonstrated a nonsignificantly greater increase in kyphosis than Type C fractures (5.70 ± 4.20 vs. 1.40 ± 4.77, $P = 0.058$). In addition, screws in the fracture level, AS/DISH diagnosis, surgical complications, surgical

Table 1: Surgical characteristics and outcomes of cervical fractures based on levels of instrumentation

	Short segment construct (*n*=63), *n* (%)	Long segment construct (*n*=28), *n* (%)	*P*[a]
Surgical characteristics			
Instrumentation			
Posterior	31 (49.2)	23 (82.1)	0.007*
Combined	32 (50.8)	5 (17.9)	
Screws in fracture level			
Bilateral	28 (44.4)	14 (50.0)	0.924
None	32 (50.8)	13 (46.4)	
Unilateral	3 (4.76)	1 (3.57)	
AS/DISH			
No	54 (85.7)	11 (39.3)	<0.001*
Yes	9 (14.3)	17 (60.7)	
Osteoporosis			
No	40 (75.5)	11 (50.0)	0.060
Yes	13 (24.5)	11 (50.0)	
Load-sharing classification	3.27 (0.96)	3.61 (1.17)	0.093
Subgroups of load-sharing classification			
Comminution	1.11 (0.37)	1.29 (0.60)	0.167
Apposition	1.10 (0.43)	1.29 (0.60)	0.141
Surgical outcomes			
Increase in kyphosis (°)	3.98 (5.08)	3.96 (4.26)	0.994
Surgical complication			
No	60 (95.2)	26 (92.9)	0.641
Yes	3 (4.76)	2 (7.14)	
Surgical hardware revision			
No	61 (96.8)	25 (89.3)	0.167
Yes	2 (3.17)	3 (10.7)	

*Indicates statistical significance ($P<0.05$), [a]Independent *t*-test, Mann–Whitney *U*-test, or Pearson's Chi-square test. AS/DISH - Ankylosing spondylitis and diffuse idiopathic skeletal hyperostosis

Table 2: Surgical characteristics and outcomes of cervical fractures by fracture type

	Type B fracture (*n*=46), *n* (%)	Type C fracture (*n*=45), *n* (%)	*P*[a]
Surgical characteristics			
Instrumentation			
Posterior	35 (76.1)	19 (42.2)	0.002*
Combined	11 (23.9)	26 (57.8)	
Screws in fracture level			
Bilateral	22 (47.8)	20 (44.4)	0.561
Unilateral	3 (6.52)	1 (2.22)	
None	21 (45.7)	24 (53.3)	
AS/DISH			
No	22 (47.8)	43 (95.6)	<0.001*
Yes	24 (52.2)	2 (4.44)	
Osteoporosis			
No	17 (45.9)	34 (89.5)	<0.001*
Yes	20 (54.1)	4 (10.5)	
Load-sharing classification	3.28 (0.83)	3.48 (1.21)	
Subgroups of load-sharing classification			0.477
Comminuted	1.13 (0.40)	1.20 (0.51)	0.446
Apposition	1.13 (0.45)	1.18 (0.54)	0.627
Surgical outcomes			
Increase in kyphosis (°)	5.70 (4.20)	1.40 (4.77)	0.058
Surgical complication			
No	44 (95.7)	42 (93.3)	0.677
Yes	2 (4.35)	3 (6.67)	
Surgical hardware revision			
No	41 (89.1)	45 (100)	0.056
Yes	5 (10.9)	0	

*Indicates statistical significance ($P<0.05$). [a]Independent *t*-test, Mann–Whitney *U*-test, or Pearson's Chi-square test. AS/DISH - Ankylosing spondylitis and diffuse idiopathic skeletal hyperostosis

hardware revision, and load-sharing classification ($P > 0.05$) were not significantly different between groups [Table 2].

Demographics of thoracolumbar fractures by construct length

For thoracolumbar fractures, 45 patients were treated with short-segment instrumentation, while 41 patients were treated with long-segment instrumentation. Patients treated with a long-segment construct were more likely to have a higher CCI (2.59 ± 2.5 vs. 1.59 ± 2.08, $P = 0.031$). There were no significant differences between patient demographics and fracture characteristics [Appendix 2].

Surgical characteristics and outcomes of thoracolumbar fractures

Patients with short-segment instrumentation were more likely to have bilateral screws at the fracture level (51.1% vs. 34.1%, $P = 0.039$) and less likely to have no screws in the fracture level (37.8% vs. 63.4%, $P = 0.039$). However, there were no differences in instrumentation location, AS/DISH diagnosis, osteoporosis diagnosis, or load-sharing classification ($P > 0.05$). When comparing patients with short-segment instrumentation to those with long-segment instrumentation, there were no significant differences in the degree of kyphotic angle change (7.04 ± 11.2 vs. 6.68 ± 4.87, $P = 0.278$), surgical complications (8.89% vs. 14.6%, $P = 0.508$), and surgical hardware revision (0.00% vs. 4.88%, $P = 0.224$) [Table 3].

When comparing Type B and C thoracolumbar fractures, patients with Type B fractures were more likely to have a diagnosis of osteoporosis (32.7% vs. 5.88%, $P = 0.030$) and AS/DISH (48.1% vs. 0.00%, $P < 0.001$). Otherwise, there were no significant differences in the surgical characteristics or outcomes between groups, including

Table 3: Surgical characteristics and outcomes of thoracolumbar fractures based on levels of instrumentation

	Short-segment construct (n=45), n (%)	Long-segment construct (n=41), n (%)	P^a
Surgical characteristics			
Instrumentation			
Posterior	40 (88.9)	36 (87.8)	1.000
Combined	5 (11.1)	5 (12.2)	
Screws in fracture level			
Bilateral	23 (51.1)	14 (34.1)	0.039*
Unilateral	5 (11.1)	1 (2.44)	
None	17 (37.8)	26 (63.4)	
AS/DISH			
No	30 (66.7)	25 (61.0)	0.746
Yes	15 (33.3)	16 (39.0)	
Osteoporosis			
No	34 (82.9)	19 (61.3)	0.073
Yes	7 (17.1)	12 (38.7)	
Load-sharing classification	3.62 (1.15)	4.00 (1.43)	0.190
Subgroups of load-sharing classification			
Comminuted	1.27 (0.58)	1.41 (0.67)	0.279
Apposition	1.27 (0.54)	1.39 (0.59)	0.314
Surgical outcomes			
Increase in kyphosis (°)	7.04 (11.2)	6.68 (4.87)	0.278
Surgical complication			
No	41 (91.1)	35 (85.4)	0.508
Yes	4 (8.89)	6 (14.6)	
Surgical hardware revision			
No	45 (100)	39 (95.1)	0.224
Yes	0	2 (4.88)	

*Indicates statistical significance (P<0.05), [a]Independent t-test, Mann–Whitney U-test, or Pearson's Chi-square test. AS/DISH - Ankylosing spondylitis and diffuse idiopathic skeletal hyperostosis

Table 4: Surgical characteristics and outcomes of thoracolumbar fractures by fracture type

	Type B fracture (n=64), n (%)	Type C fracture (n=22), n (%)	P^a
Surgical characteristics			
Instrumentation			
Posterior	57 (89.1)	19 (86.4)	0.711
Combined	7 (10.9)	3 (13.6)	
Screws in fracture level			
Bilateral	28 (43.8)	9 (40.9)	0.929
None	31 (48.4)	12 (54.5)	
Unilateral	5 (7.81)	1 (4.55)	
AS/DISH			
No	33 (51.6)	22 (100)	<0.001*
Yes	31 (48.4)	0	
Osteoporosis			
No	37 (67.3)	16 (94.1)	0.030*
Yes	18 (32.7)	1 (5.88)	
Load-sharing classification	3.69 (1.23)	4.14 (1.46)	0.108
Subgroups of load-sharing classification			
Comminuted	1.31 (0.61)	1.41 (0.67)	0.554
Apposition	1.28 (0.55)	1.45 (0.60)	0.238
Surgical outcomes			
Increase in kyphosis (°)	7.27 (9.14)	5.84 (4.61)	0.887
Surgical complication			
No	57 (89.1)	19 (86.4)	0.711
Yes	7 (10.9)	3 (13.6)	
Surgical hardware revision			
No	63 (98.4)	21 (95.5)	0.448
Yes	1 (1.56)	1 (4.55)	

*Indicates statistical significance (P<0.05), [a]Independent t-test, Mann–Whitney U-test, or Pearson's Chi-square test. AS/DISH - Ankylosing spondylitis and diffuse idiopathic skeletal hyperostosis

a similar number of screws in the fracture level and load-sharing classification ($P > 0.05$). Similarly, there was no significant differences in change in kyphosis ($P = 0.887$), surgical complications ($P = 0.711$), or surgical hardware revision ($P = 0.448$) [Table 4].

Multivariable analysis of outcomes

Multivariable stepwise analysis found that a diagnosis of osteoporosis was an independent predictor of surgical hardware revision (odds ratio = 38.71, $P = 0.006$). In addition, a diagnosis of AS/DISH was identified as an independent predictor of increase in kyphosis (estimate = 5.37, $P = 0.030$).

DISCUSSION

Several classification systems for vertebral fractures have been proposed but have failed to be universally accepted due to numerous limitations.[15,16] The AO Spine classification was created to address some of these limitations and one of its strengths is its simplicity whereby the classification is categorized by injury stability: Type A (compression/burst) fractures are the most stable, Type B injuries (tension band failures) have an intermediate amount of stability, and Type C (dislocation) fractures are the least stable. Due to anatomical differences in the mobile and nonmobile spine, the spine is divided into four segments – upper cervical, subaxial, thoracolumbar, and sacral.[15] Because these anatomical differences often lead to different management strategies, our study analyzed cervical spine and thoracolumbar spine fractures separately. Nevertheless, the findings from our analysis suggest that regardless of if the fracture is in the cervical or thoracolumbar spine, short construct fixation is adequate for Type B and C fractures. These findings persist despite differences in patient demographics, including AS/DISH diagnosis and fracture characteristics, which were categorized based on the load-sharing classification.

In one of the first studies on the topic, McCormack *et al*. analyzed outcomes after surgical reduction and fixation of vertebral fractures with short-segment fixation in 28 patients (21 burst fractures, 4 dislocation fractures, and 3 distraction fractures) with VSP plates and first-generation VSP screws.[11] Short-segment fixation resulted in 10 patients with screw breakage in their constructs. The load-sharing classification was first proposed from the analysis of these patients. The classification uses the magnitude of vertebral comminution, apposition of fragments, and postsurgical kyphosis correction to determine the risk of hardware failure (high risk = ≥7 points). This system assumes that vertebrae with more comminution, wider apposition of fragments, and more kyphotic deformity correction are associated with worse load distribution, resulting in higher strain on the construct. The authors noted that because the classification system did not address ligamentous disruption, it should not be used to make decisions on surgical indications. The publication concluded that short-segment fixation was not appropriate for burst fractures or fracture/dislocations with severe comminution of the vertebral body with a load-sharing classification score of seven or more.[11] However, this recommendation is based on a limited cohort that was significantly underpowered for distraction and dislocation injuries. In addition, the instrumentation used was first-generation VSP screws and plates. Recent advances in instrumentation void a possible comparison of newer constructs to these VSP constructs as the VSP system used earlier generation pedicle screws with a variable angle plate, which we now no longer use. The construct stability depended on the interface between the screw and the variable angle plate and created overly rigid constructs, which likely contributed to instrumentation failure.[17,18]

Since McCormack *et al.*'s publication, the management of vertebral fractures and construct length used for fixation has been a source of debate.[10] Although some studies demonstrate worse outcomes with short-segment fixation, suggesting long constructs may be beneficial,[9,11] many recent studies have shown similar radiographic outcomes between short- and long-construct fracture fixation.[14,19] Early studies by McLain *et al*. and McCormack *et al*. demonstrated high rates (77% and 53%, respectively) of hardware failure in posterior-only short-segment fixation (construct involving one vertebra above and one vertebra below the fractured level) of unstable thoracolumbar burst fractures.[9,11] In a prospective study of 52 patients, Chen *et al*. demonstrated that short-segment fixation for traumatic L3–L5 fractures can correct kyphosis deformity, restore vertebral body height, and avoid the need for anterior reconstruction.[20] Another prospective analysis of 30 patients by Ozdemir *et al*. similarly suggested that short-segment constructs can restore vertebral height for the treatment of unstable thoracolumbar fractures better than constructs involving two vertebrae above and two below the fractured level without screw fixation of the fractured level.[14] The present study adds to this literature by demonstrating no significant difference in hospital readmissions, hardware failure rates, or change in kyphosis between constructs spanning two fracture adjacent vertebral levels or less versus those spanning more than two adjacent vertebral levels for Type B and C fractures, both in the cervical region and in the thoracolumbar region. Given that the body of evidence on construct length for vertebral fracture management suggests that smaller constructs result in similar surgical outcomes to longer constructs, surgeons should consider the present study's results as an opportunity to consider shorter construct fixation, which may minimize patient morbidity as well as reduce costs to the health-care system. However, future high-quality research is needed to corroborate these findings.

There is a lack of literature comparing the outcomes associated with various AO classification types. A retrospective study of 101 patients assessed outcomes associated with the treatment of various vertebral fracture morphologies secondary to high-energy trauma. The authors reported that out of 15 revision surgeries, 6% were associated with type B fractures while 0% were associated with Type C fractures. This same study also demonstrated worse patient-reported outcomes associated with Type B or C fractures over Type A fractures.[21] The current study indicates that cervical Type C fractures are more likely treated with combined constructs and may become less kyphotic after 3 months postoperatively than Type B fractures, indicating that fracture reduction and fixation with a combined anterior-posterior approach may be less likely to increase kyphosis. There were no other differences in surgical outcomes between Type B and C fractures in the cervical and thoracolumbar spine.

Another consideration to make when determining construct length is underlying patient comorbidities. The AO spine classifications are associated with modifiers, one of which includes patient-specific conditions that increase susceptibility to fractures such as AS and diffuse idiopathic skeletal hyperostosis (DISH). Vertebral fractures are four times more common in patients with AS and DISH due to the spine's limited ability to dissipate energy effectively.[3-5] Due to the change in biomechanics, studies have reported the successful use of posterior fixation of at least three levels above and three levels below the construct to avoid failure of fixation in patients with AS/DISH.[22-25] The present study identified a diagnosis of AS/DISH as an independent predictor of increased kyphosis in our cohort. Similar findings have been reported in a descriptive study characterizing the association between DISH and kyphosis in the thoracic spine. Katzman *et al*. and Nardo *et al*. reported similar findings of increased kyphosis in populations of patients with AS/DISH.[26,27] Thus, the results of our analysis provide support for the hypothesized relationship between AS/DISH and increased kyphosis. In addition to AS/DISH, osteoporosis is a variable of interest in orthopedic trauma, given the known association between osteoporosis and increased fracture risk.[6] Prior literature has also demonstrated an association between AS and osteoporosis, with bone loss predominating in the spine.[28-30] Our multivariant analysis revealed that osteoporosis was a predictor of surgical hardware failure.

This study was not without its limitations. First, this study is subjected to limitations inherent to a retrospective analysis. In addition, due to our poor follow-up rate, our study was at risk for selection bias, a challenge often cited when working with patients seen for orthopedic trauma consults.[31] The study period encompassed 14 years and instrumentation implanted for spine fractures changed throughout the study period. However, Type B and C injuries are less common fracture variants than Type A fractures and this period was necessary to adequately power the analysis. Both fractures treated by orthopedic spine surgeons and neurosurgeons were evaluated to improve the overall sample size, which may have added additional heterogeneity to the analysis although this may be a strength given that the study is generalizable to both orthopedic surgeons and neurosurgeons. Even with the long study period, our data set was not large enough to run a multivariate regression analysis including more than a single variable for each outcome. Although there may be other variables that are related to our outcomes, the most significantly associated variables were identified and reported in our study. It would be an avenue for future research with larger sample sizes for other significant independent predictors to be identified. Ideally, we would be able to assess more variables and separate the analysis by anatomic group. This would also reduce the risk of type 2 error.

CONCLUSION

Construct lengths used for spinal fixation have been debated over the years. Unstable spinal fractures, defined as Type B and C fractures, are often treated with surgical reduction and fixation, but there has been limited literature identifying an optimal construct length in these more unstable injury variants. Our study suggests that patients with these fractures who are treated with short-segment instrumentation have similar surgical outcomes compared to patients with long-segment instrumentation.

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Conflicts of interest

There are no conflicts of interest.

REFERENCES

1. Wilde H, Gamblin AS, Reese J, Garry JG, Guan J, Mortenson J, *et al.* The effect of hospital transfer on patient outcomes after rehabilitation for spinal injury. World Neurosurg 2020;133:e76-83.
2. Vaccaro AR, Oner C, Kepler CK, Dvorak M, Schnake K, Bellabarba C, *et al.* AOSpine thoracolumbar spine injury classification system: Fracture description, neurological status, and key modifiers. Spine (Phila Pa 1976) 2013;38:2028-37.
3. Westerveld LA, van Bemmel JC, Dhert WJ, Oner FC, Verlaan JJ. Clinical outcome after traumatic spinal fractures in patients with ankylosing spinal disorders compared with control patients. Spine J 2014;14:729-40.
4. Caron T, Bransford R, Nguyen Q, Agel J, Chapman J, Bellabarba C. Spine fractures in patients with ankylosing spinal disorders. Spine (Phila Pa 1976) 2010;35:E458-64.
5. Jacobs WB, Fehlings MG. Ankylosing spondylitis and spinal cord injury: Origin, incidence, management, and avoidance. Neurosurg Focus 2008;24:E12.
6. MacLean C, Newberry S, Maglione M, McMahon M, Ranganath V, Suttorp M, *et al*. Systematic review: Comparative effectiveness of treatments to prevent fractures in men and women with low bone density or osteoporosis. Ann Intern Med 2008;148:197-213.
7. Mirza SK, Mirza AJ, Chapman JR, Anderson PA. Classifications of thoracic and lumbar fractures: Rationale and supporting data. J Am Acad Orthop Surg 2002;10:364-77.
8. Mahar A, Kim C, Wedemeyer M, Mitsunaga L, Odell T, Johnson B, *et al.* Short-segment fixation of lumbar burst fractures using pedicle fixation at the level of the fracture. Spine (Phila Pa 1976) 2007;32:1503-7.
9. McLain RF, Sparling E, Benson DR. Early failure of short-segment pedicle instrumentation for thoracolumbar fractures. A preliminary report. J Bone Joint Surg Am 1993;75:162-7.
10. Girardo M, Massè A, Risitano S, Fusini F. Long versus short segment instrumentation in osteoporotic thoracolumbar vertebral fracture. Asian Spine J 2021;15:424-30.
11. McCormack T, Karaikovic E, Gaines RW. The load sharing classification of spine fractures. Spine (Phila Pa 1976) 1994;19:1741-4.
12. Gelb D, Ludwig S, Karp JE, Chung EH, Werner C, Kim T, *et al.* Successful treatment of thoracolumbar fractures with short-segment pedicle instrumentation. J Spinal Disord Tech 2010;23:293-301.
13. Zaidi Q, Danisa OA, Cheng W. Measurement techniques and utility of Hounsfield unit values for assessment of bone quality prior to spinal instrumentation: A review of current literature. Spine (Phila Pa 1976) 2019;44:E239-44.
14. Ozdemir B, Kanat A, Erturk C, Batcik OE, Balik MS, Yazar U, *et al.* Restoration of anterior vertebral height by short-segment pedicle screw fixation with screwing of fractured vertebra for the treatment of unstable thoracolumbar fractures. World Neurosurg 2017;99:409-17.
15. Schnake KJ, Schroeder GD, Vaccaro AR, Oner C. AOSpine classification systems (subaxial, thoracolumbar). J Orthop Trauma 2017;31 Suppl 4:S14-23.
16. Magerl F, Aebi M, Gertzbein SD, Harms J, Nazarian S. A comprehensive classification of thoracic and lumbar injuries. Eur Spine J 1994;3:184-201.
17. Hadgaonkar S, Vincent V, Rathi P, Sancheti P, Shyam A. Revision of steffee plate instrumentation – Challenges and technical tips. Int Neurosurg 2021;24:101095.
18. McLain RF, Kabins M, Weinstein JN. VSP stabilization of lumbar neoplasms: Technical considerations and complications. J Spinal Disord

1991;4:359-65.
19. Formica M, Cavagnaro L, Basso M, Zanirato A, Felli L, Formica C, *et al.* Which patients risk segmental kyphosis after short segment thoracolumbar fracture fixation with intermediate screws? Injury 2016;47 Suppl 4:S29-34.
20. Chen Z, Wu J, Lin B, Wu S, Zeng W. Posterior short-segment fixation including the fractured vertebra for severe unstable thoracolumbar fractures. Zhongguo Xiu Fu Chong Jian Wai Ke Za Zhi 2018;32:59-63.
21. Muratore M, Allasia S, Viglierchio P, Abbate M, Aleotti S, Masse A, *et al*. Surgical treatment of traumatic thoracolumbar fractures: A retrospective review of 101 cases. Musculoskelet Surg 2021;105:49-59.
22. Okada E, Shimizu K, Kato M, Fukuda K, Kaneko S, Ogawa J, *et al.* Spinal fractures in patients with diffuse idiopathic skeletal hyperostosis: Clinical characteristics by fracture level. J Orthop Sci 2019;24:393-9.
23. Okada E, Yoshii T, Yamada T, Watanabe K, Katsumi K, Hiyama A, *et al.* Spinal fractures in patients with diffuse idiopathic skeletal hyperostosis: A nationwide multi-institution survey. J Orthop Sci 2019;24:601-6.
24. Westerveld LA, Verlaan JJ, Oner FC. Spinal fractures in patients with ankylosing spinal disorders: A systematic review of the literature on treatment, neurological status and complications. Eur Spine J 2009;18:145-56.
25. Hishiya T, Ishikawa T, Ota M. Posterior spinal fixation using penetrating endplate screws in patients with diffuse idiopathic skeletal hyperostosis-related thoracolumbar fractures. J Neurosurg Spine 2021;34:936-41.
26. Katzman WB, Parimi N, Mansoori Z, Nardo L, Kado DM, Cawthon PM, *et al.* Cross-sectional and longitudinal associations of diffuse idiopathic skeletal hyperostosis and thoracic kyphosis in older men and women. Arthritis Care Res (Hoboken) 2017;69:1245-52.
27. Nardo L, Lane NE, Parimi N, Cawthon PM, Fan B, Shepherd J, *et al.* Diffuse idiopathic skeletal hyperostosis association with thoracic spine kyphosis: A cross-sectional study for the health aging and body composition study. Spine (Phila Pa 1976) 2014;39:E1418-24.
28. El-Maghraoui A. Osteoporosis and ankylosing spondylitis. Joint Bone Spine 2004;71:291-5.
29. Reid DM, Nicoll JJ, Kennedy NS, Smith MA, Tothill P, Nuki G. Bone mass in ankylosing spondylitis. J Rheumatol 1986;13:932-5.
30. Will R, Palmer R, Bhalla AK, Ring F, Calin A. Osteoporosis in early ankylosing spondylitis: A primary pathological event? Lancet 1989;2:1483-5.
31. Lambrechts MJ, D'Antonio ND, Karamian BA, Kanhere AP, Dees A, Wiafe BM, *et al*. Does displacement of cervical and thoracolumbar dislocation-translation injuries predict spinal cord injury or recovery? J Neurosurg Spine 2022;37:821-7.

APPENDIXES

Appendix 1: Demographics for the cervical spine by construct length

	Short-segment construct (n=63), n (%)	Long-segment construct (n=28), n (%)	P^a
Age	52.4 (20.9)	68.2 (17.0)	<0.001*
Sex			
Male	45 (71.4)	27 (96.4)	0.015*
Female	18 (28.6)	1 (3.57)	
Race			
Asian	1 (1.59)	0	0.528
Black/African American	9 (14.3)	4 (14.3)	
Hispanic	2 (3.17)	2 (7.14)	
White/Caucasian	46 (73.0)	22 (78.6)	
Not reported	5 (7.94)	0	
Smoker			
No	55 (87.3)	24 (85.7)	1.000
Yes	8 (12.7)	4 (14.3)	
Diabetes			
No	56 (88.9)	25 (89.3)	1.000
Yes	7 (11.1)	3 (10.7)	
CCI	2.10 (2.43)	3.64 (2.06)	0.002*
Fracture type			
Type B	28 (44.4)	18 (64.3)	0.128
Type C	35 (55.6)	10 (35.7)	
Type B fracture			
B1	1 (3.57)	0	<0.001*
B2	15 (53.6)	1 (5.56)	
B3	12 (42.9)	17 (94.4)	

*Indicates statistical significance (P<0.05), [a]Independent t-test, Mann–Whitney U-test, or Pearson's Chi-square test. CCI - Charlson Comorbidity Index

Appendix 2: Demographics of thoracolumbar fractures by construct length

	Short-segment construct (n=45), n (%)	Long-segment construct (n=41), n (%)	P^a
Age	46.8 (24.3)	56.2 (22.8)	0.074
Sex			
Female	34 (75.6)	32 (78.0)	0.986
Male	11 (24.4)	9 (22.0)	
Race			
Asian	0	1 (2.44)	0.979
Black/African American	5 (11.1)	4 (9.76)	
Hispanic	2 (4.44)	1 (2.44)	
White/Caucasian	36 (80.0)	34 (82.9)	
Not reported	2 (4.44)	1 (2.44)	
Smoker			
No	41 (91.1)	38 (92.7)	1.000
Yes	4 (8.89)	3 (7.32)	
Diabetes			
No	38 (84.4)	37 (90.2)	0.630
Yes	7 (15.6)	4 (9.76)	
CCI	1.59 (2.08)	2.59 (2.51)	0.031*
Fracture type			
Type B	35 (77.8)	29 (70.7)	0.617
Type C	10 (22.2)	12 (29.3)	
Type B fracture			
B1	7 (20.0)	3 (10.3)	0.154
B2	11 (31.4)	5 (17.2)	
B3	17 (48.6)	21 (72.4)	

*Indicates statistical significance (P<0.05), [a]Independent t-test, Mann–Whitney U-test, or Pearson's Chi-square test. CCI - Charlson Comorbidity Index