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ORIGINAL ARTICLE

Variation in global treatment for subaxial cervical spine isolated unilateral facet fractures

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Abstract

Purpose To determine the variation in the global treatment practices for subaxial unilateral cervical spine facet fractures based on surgeon experience, practice setting, and surgical subspecialty.

Methods A survey was sent to 272 members of the AO Spine Subaxial Injury Classification System Validation Group worldwide. Questions surveyed surgeon preferences with regard to diagnostic work-up and treatment of fracture types F1–F3, according to the AO Spine Subaxial Cervical Spine Injury Classification System, with various associated neurologic injuries.

Results A total of 161 responses were received. Academic surgeons use the facet portion of the AO Spine classification system less frequently (61.6%) compared to hospital-employed and private practice surgeons (81.1% and 81.8%, respectively) ($p = 0.029$). The overall consensus was in favor of operative treatment for any facet fracture with radicular symptoms (N2) and for any fractures categorized as F2N2 and above. For F3N0 fractures, significantly less surgeons from Africa/Asia/Middle East (49%) and Europe (59.2%) chose operative treatment than from North/Latin/South America (74.1%) ($p = 0.025$). For F3N1 fractures, significantly less surgeons from Africa/Asia/Middle East (52%) and Europe (63.3%) recommended operative treatment than from North/Latin/South America (84.5%) ($p = 0.001$). More than 95% of surgeons included CT in their work-up of facet fractures, regardless of the type. No statistically significant differences were seen in the need for MRI to decide treatment.

Conclusion Considerable agreement exists between surgeon preferences with regard to unilateral facet fracture management with few exceptions. F2N2 fracture subtypes and subtypes with radiculopathy (N2) appear to be the threshold for operative treatment.

Keywords Unilateral facet fracture · Treatment · Imaging · Subaxial · AO Spine · Survey · Global

Introduction

The AO Spine Knowledge Forum, a group of international academic surgeons with special interest in trauma classifications for international acceptance and reproducibility, developed a comprehensive classification system for subaxial cervical spine injuries [1–5]. The AO Spine Subaxial Cervical Spine Injury Classification System (AO Spine SCICS) utilizes a clear morphologic framework to guide and standardize patient management based on four

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major criteria: (1) fracture morphology, (2) facet injury, (3) neurologic status, and (4) case-specific modifiers (Supplementary Digital Content 1) [6]. Within the hierarchical classification system, facet injuries are categorized into four subtypes: F1—nondisplaced facet fractures, F2—facet fractures with potential for instability, F3—floating lateral mass fractures, and F4—subluxated or dislocated facet (Fig. 1). The neurologic status of the patient is defined by the N descriptor: N0—neurologically intact, N1—transient neurologic deficit, N2—radicular symptoms, N3—incomplete cord injury or cauda equina, and N4—complete cord injury. This classification scheme has demonstrated adequate interobserver agreement and intra-observer reproducibility in multiple studies [1, 5, 7–9]. Even with an ideal classification scheme, significant heterogeneity remains with regard to the work-up and treatment of subaxial unilateral facet fractures [10–15].

Management of isolated subaxial facet fractures currently lies at the discretion of the surgeon. This may be due in part to its rarity, given that unilateral facet fractures without associated compression, tension band, or translations injuries represent approximately 6% of all cervical injuries, and also due to the significant variation in the morphologic presentation of facet injuries [16, 17]. The facet joint and capsule play an important role in subaxial stability, limiting rotational and linear translation during physiologic motion to protect the underlying neural elements [18]. Despite unilateral facet fractures not meeting the conventional criteria for instability [12, 19], anywhere between 21 and 80% of these fractures fail nonoperative management leading to pain, deformity, and even secondary neurologic deficits [20, 21]. This disparity in outcomes has resulted in a lack of consensus-based algorithms for deciding between operative and nonoperative treatments. Within that, the type of immobilization and surgical approach used for nonoperative and operative management, respectively, is a matter of surgeon preference and experience [10, 14, 19, 21–25]. Computed tomography (CT)- and magnetic resonance imaging (MRI)-based criteria for classifying and predicting failure have also been investigated, but controversy ensues regarding the imaging necessary to appropriately work-up facet fractures [12, 20]. All these factors have contributed to the lack of standardization in the treatment for unilateral facet fractures.

Given the present uncertainty, it is important to understand the effects of regional bias on the treatment for facet fractures and elucidate what surgeon characteristics influence treatment preferences. For one, diversity among international practice patterns may result in a discrepancy between operative and nonoperative management [26]. Additionally, surgeon experience, practice setting, and subspecialty training all have implications on treatment decisions and serve as a potential source of heterogenicity in management [27]. The primary goal of this study is to determine the global management of facet fractures and variables that affect treatment.

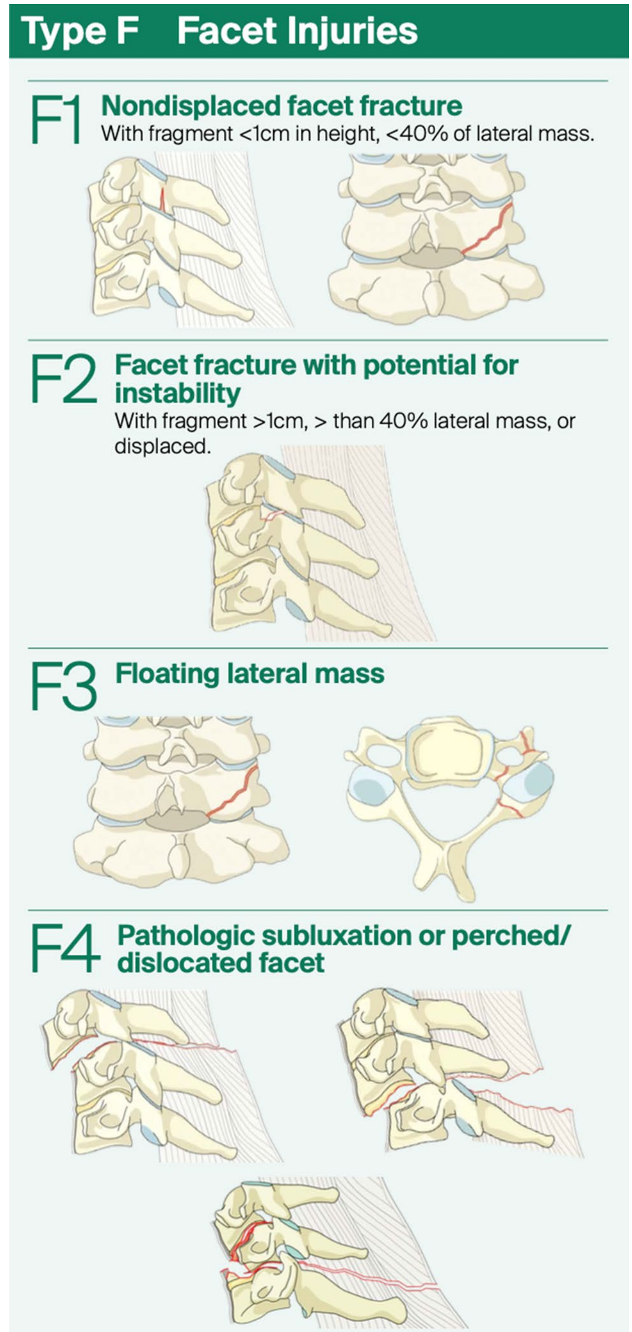

Fig. 1 Graphic representation of the AO spine facet fracture classification system

Methods

A 22-question survey (Supplemental Digital Content 2) including surgeon demographics and treatment preferences for nine clinical vignettes consisting of unilateral facet fractures was sent to the members of the AO Spine Subaxial Injury Classification System Validation Group. Surgeon demographics included years of experience (< 5, 5–10, 11–20, > 20), surgical subspecialty (Orthopedic Spine, Neurosurgery Spine, Other), region (North/Latin/South America, Europe, Africa/Asia/Middle East), and practice setting (academic, hospital-employed, private practice). Academic practice setting is defined by significant time dedicated to patient care, research, and education of medical trainees while hospital-employment is defined by focus only on patient care. Both academicians and hospital-employed surgeons are employees of the hospital, in contrast to private practitioners. These spine surgeons represent six world regions: North America, Latin and South America, Europe, Africa, Asia, and the Middle East. Clinical vignettes consisted of fracture types F1–F3 with various associated neurologic injuries (N0–N2). Given F4 injuries are a sign of severe disruption of the posterior tension band, they were not included in the survey as they are an indicator of instability for which surgery is recommended. Questions surveyed surgeon preferences with regard to diagnostic work-up and treatment. Some questions allowed for the possibility of multiple answer choices from the respondent. Only surveys containing complete demographic information and at least one valid answer to the clinical vignettes were analyzed.

Descriptive statistical analysis was performed for categorical and continuous data. For categorical data, frequencies were calculated based on the number of nonmissing replies. Continuous data were analyzed using median and interquartile range (IQR). Regional variations were compared between surgeons from North/Latin/South America combined, Africa/Asia/Middle East combined, and Europe. Geographic regions were combined due to low number of participants from the designated region. Differences in the treatment algorithm were analyzed by Chi-square test or Fisher's exact test. The significance level was defined at $\alpha = 0.05$. All analysis was performed using the statistical software SAS version 9.4 (SAS Institute Inc., Cary, NC, USA).

Results

A total of 272 surgeons were surveyed with 161 (59.2%) surgeons responding. A summary of surgeon demographics is presented in Table 1. The median number of spine trauma patients treated per year per surgeon was 50 (IQR 20-100). "Surgeon variation" will refer to the differences among surgeon respondents with regard to years of experience (< 5, 5–10, 11–20, > 20), surgical subspecialty (Orthopedic Spine, Neurosurgery Spine, Other), region (North/Latin/South America, Europe, Africa/Asia/Middle East), and practice setting (academic, hospital-employed, private practice). Academic practice setting includes significant time dedicated to patient care, research, and education of medical trainees, while hospital employment focuses mainly on patient care. Both academicians and hospital-employed surgeons are employees of the hospital, in contrast to private practitioners.

Table 1 Summary of surgeon respondent demographics

	$n = 161$
Region	*n* (%)
North America	17 (10.6)
Latin and South America	41 (25.5)
Europe	49 (30.4)
Africa	10 (6.2)
Asia	30 (18.6)
Middle East	14 (8.7)
Years of experience	*n* (%)
< 5	28 (17.4)
5–10	55 (34.2)
11–20	52 (32.3)
> 20	26 (16.1)
Subspecialty	*n* (%)
Orthopedic spine	101 (62.7)
Neurosurgery spine	53 (32.9)
Other	7 (4.3)
Work setting	*n* (%)
Academic	79 (49.1)
Hospital employed	58 (36.0)
Private practice	24 (14.9)
Number of spine trauma patients per year	50 (IQR 20;100) *n* (%)
1–25	46 (28.6)
26–100	90 (55.9)
> 100	25 (15.5)

Preferred subaxial spine classification system

The preferred subaxial spine injury classification system for all respondents was as follows: AO Spine SCICS 71.9%, Subaxial Cervical Spine Injury Classification system (SLIC) 18.1%, and Magerl system 2.5%. Of respondents, 7.5% do not routinely use a classification system (Table 2). The AO Spine SCICS is used by the majority

Table 2 Grouped comparison of the preferred subaxial classification system and use of the facet portion of the AO Spine SCICS based upon region, years of experience, practice type, and subspecialty

	World Region				Years of Experience					Work Setting				Subspecialty			Total
	North/Latin/South America	Europe	Africa/Asia/Middle East	*p* value	< 5 years	5–10 years	11–20 years	> 20 years		Academic	Hospital employed	Private Practice		Orthopedic Spine	Neurosurgery Spine		
	$N=58$	$N=49$	$N=54$		$N=28$	$N=55$	$N=52$	$N=26$	*p* value	$N=79$	$N=58$	$N=24$	*p* value	$N=101$	$N=53$	*p* value	$N=161$
Preferred subaxial spine classification, *n* (%)	58	48	54	0.983‡	28	55	52	25	0.798‡	79	57	24	0.304‡	101	53	0.105†	160
Magerl	1 (1.7)	2 (4.2)	1 (1.9)		0 (0.0)	1 (1.8)	2 (3.8)	1 (4.0)		3 (3.8)	1 (1.8)	0 (0.0)		0 (0.0)	3 (5.7)		4 (2.5)
Subaxial Cervical Spine Injury Classification (SLIC) system	11 (19.0)	8 (16.7)	10 (18.5)		3 (10.7)	10 (18.2)	12 (23.1)	4 (16.0)		19 (24.1)	9 (15.8)	1 (4.2)		18 (17.8)	10 (18.9)		29 (18.1)
The new AO Spine Subaxial Classification system	42 (72.4)	35 (72.9)	38 (70.4)		23 (82.1)	39 (70.9)	36 (69.2)	17 (68.0)		51 (64.6)	43 (75.4)	21 (87.5)		76 (75.2)	35 (66.0)		115 (71.9)
I do not routinely use a classification system	4 (6.9)	3 (6.3)	5 (9.3)		2 (7.1)	5 (9.1)	2 (3.8)	3 (12.0)		6 (7.6)	4 (7.0)	2 (8.3)		7 (6.9)	5 (9.4)		12 (7.5)

Table 2 (continued)

	World Region				Years of Experience					Work Setting				Subspecialty			Total
	North/ Latin/ South America	Europe	Africa/ Asia/ Middle East	*p* value	< 5 years	5–10 years	11–20 years	> 20 years		Aca-demic	Hospital employed	Private Practice		Orthope-dic Spine	Neuro-surgery Spine		
	N = 58	*N* = 49	*N* = 54		*N* = 28	*N* = 55	*N* = 52	*N* = 26	*p* value	*N* = 79	*N* = 58	*N* = 24	*p* value	*N* = 101	*N* = 53	*p* value	*N* = 161
Regular use of the facet portion of the AO Spine Subaxial Classification, *n* (%)	58	48	54		28	55	52	25		79	57	24		101	53		160
No	19 (32.8)	15 (31.3)	20 (37.0)		7 (25.0)	20 (36.4)	18 (34.6)	9 (36.0)		34 (43.0)	14 (24.6)	6 (25.0)		31 (30.7)	22 (41.5)		54 (33.8)
Yes	39 (67.2)	33 (68.8)	34 (63.0)		21 (75.0)	35 (63.6)	34 (65.4)	16 (64.0)		45 (57.0)	43 (75.4)	18 (75.0)		70 (69.3)	31 (58.5)		106 (66.3)
Regular use of the facet portion of the AO Spine Subaxial Classification,* *n* (%)	54	45	49	0.907†	26	50	50	22	0.689†	73	53	22	0.029†	94	48	0.219†	148
No	15 (27.8)	12 (26.7)	15 (30.6)		5 (19.2)	15 (30.0)	16 (32.0)	6 (27.3)		28 (38.4)	10 (18.9)	4 (18.2)		24 (25.5)	17 (35.4)		42 (28.4)
Yes	39 (72.2)	33 (73.3)	34 (69.4)		21 (80.8)	35 (70.0)	34 (68.0)	16 (72.7)		45 (61.6)	43 (81.1)	18 (81.8)		70 (74.5)	31 (64.6)		106 (71.6)

*Subgroup of patients who use routinely at least any classification system. Participants who answered with "I do not routinely use a classification system" were excluded.

‡Fisher's exact test

†Chi-square test

Table 3 Respondent answers to initial treatment types of various F1, F2, and F3 fracture subtypes

Question	X = F1	X = F2	X = F3
Imaging modality routinely used to evaluate neurologically intact patient (choose all)	n = 161 (%)	n = 161 (%)	n = 161 (%)
CT scan	157 (97.5)	154 (95.7)	156 (96.9)
Upright AP and lateral radiographs	91 (56.5)	91 (56.5)	82 (50.9)
Flexion/Extension radiographs	43 (26.7)	47 (29.2)	35 (21.7)
MRI	68 (42.2)	93 (57.8)	109 (67.7)
Initial treatment of FX N0 patient	n = 161 (%)	n = 158 (%)	n = 158 (%)
Nonoperative without collar	7 (4.3)	1 (0.6)	0 (0.0)
Nonoperative with soft collar	18 (11.2)	6 (3.8)	3 (1.9)
Nonoperative with hard collar	134 (83.2)	100 (63.3)	43 (27.2)
Nonoperative with halo	1 (0.6)	9 (5.7)	15 (9.5)
Operative with ACDF	1 (0.6)	24 (15.2)	39 (24.7)
Operative with posterior cervical fusion	0 (0.0)	17 (10.8)	52 (32.9)
Operative with combined anterior–posterior fusion	0 (0.0)	1 (0.6)	6 (3.8)
At initial presentation of FX N0 patient, treatment would change based upon	n = 161 (%)	n = 161 (%)	n = 161 (%)
Subaxial spine level (i.e., C3, C4, C5, C6, C7)	16 (9.9)	18 (11.2)	18 (11.2)
Gender	1 (0.6)	0 (0.0)	0 (0.0)
Age	19 (11.8)	23 (14.3)	40 (24.8)
Ability of patient to closely follow up	29 (18.0)	45 (28.0)	37 (23.0)
Severe pain	52 (32.3)	68 (42.2)	51 (31.7)
No change in treatment plan	94 (58.4)	67 (41.6)	81 (50.3)
Initial treatment of FX N1 patient	n = 160 (%)	n = 158 (%)	n = 157 (%)
Nonoperative without collar	2 (1.3)	0 (0.0)	0 (0.0)
Nonoperative with soft collar	13 (8.1)	5 (3.2)	2 (1.3)
Nonoperative with hard collar	122 (76.3)	85 (53.8)	33 (21.0)
Nonoperative with halo	5 (3.1)	11 (7.0)	16 (10.2)
Operative with ACDF	11 (6.9)	32 (20.3)	44 (28.0)
Operative with posterior cervical fusion	7 (4.4)	24 (15.2)	53 (33.8)
Operative with combined anterior–posterior fusion	0 (0.0)	1 (0.6)	9 (5.7)
Initial treatment of FX N2 patient	n = 160 (%)	n = 158 (%)	n = 157 (%)
Nonoperative without collar	1 (0.6)	0 (0.0)	0 (0.0)
Nonoperative with soft collar	3 (1.9)	2 (1.3)	1 (0.6)
Nonoperative with hard collar	49 (30.6)	24 (15.2)	7 (4.5)
Nonoperative with halo	4 (2.5)	2 (1.3)	4 (2.5)
Operative with ACDF	47 (29.4)	61 (38.6)	55 (35.0)
Operative with posterior cervical fusion	51 (31.9)	57 (36.1)	63 (40.1)
Operative with combined anterior–posterior fusion	5 (3.1)	12 (7.6)	27 (17.2)

of respondents from all world regions except for North America, where it is used by 47.1% of surgeons and the SLIC system is used by 41.2% of surgeons (Supplemental Table 1). Academicians used the AO Spine SCICS less frequently (64.6%) compared to hospital-employed and private practice surgeons (75.4% and 87.5%, respectively) (p = 0.304). There were no statistically significant differences in the preferred subaxial cervical injury classification system based on surgeon variation.

Use of AO spine facet fracture classification system

Overall, 106 (71.6%) respondents regularly use the facet portion of the AO Spine SCICS. Significantly fewer academic respondents (61.6%) used this portion of the classification system than did hospital-employed and private practice surgeons (81.1% and 81.8%, respectively) (p = 0.029) (Table 2). There was no significant difference in the use of the facet portion of the AO Spine SCICS when grouping raters by

Table 4 Grouped comparison of operative versus nonoperative management of facet fracture subtypes based upon surgeon region, years of experience, practice type, and subspecialty

	World Region				Years of Experience					Work Setting				Subspecialty			Total
	North/ Latin/ South America	Europe	Africa/ Asia/ Middle East		< 5 years	5–10 years	11–20 years	> 20 years		Aca-demic	Hospital Employed	Private Practice		Orthope-dic Spine	Neuro-surgery Spine		
	$N=17$	$N=49$	$N=10$	p value	$N=28$	$N=55$	$N=52$	$N=26$	p value	$N=79$	$N=58$	$N=24$	p value	$N=101$	$N=53$	p value	$N=161$
F1 N0, n (%)	58	49	54	0.304‡	28	55	52	26	0.658‡	79	58	24	1.000‡	101	53	0.344‡	161
Nonsurgical treatment	58 (100.0)	48 (98.0)	54 (100.0)		28 (100.0)	55 (100.0)	51 (98.1)	26 (100.0)		78 (98.7)	58 (100.0)	24 (100.0)		101 (100.0)	52 (98.1)		160 (99.4)
Surgical treatment	0 (0.0)	1 (2.0)	0 (0.0)		0 (0.0)	0 (0.0)	1 (1.9)	0 (0.0)		1 (1.3)	0 (0.0)	0 (0.0)		0 (0.0)	1 (1.9)		1 (0.6)
F1 N1, n (%)	58	49	53	0.150†	28	54	52	26	0.067‡	78	58	24	0.660†	100	53	**0.012**†	160
Nonsurgical treatment	48 (82.8)	44 (89.8)	50 (94.3)		27 (96.4)	51 (94.4)	43 (82.7)	21 (80.8)		70 (89.7)	52 (89.7)	20 (83.3)		93 (93.0)	42 (79.2)		142 (88.8)
Surgical treatment	10 (17.2)	5 (10.2)	3 (5.7)		1 (3.6)	3 (5.6)	9 (17.3)	5 (19.2)		8 (10.3)	6 (10.3)	4 (16.7)		7 (7.0)	11 (20.8)		18 (11.3)
F1 N2, n (%)	58	49	53	0.142†	28	54	52	26	0.460†	78	58	24	0.433†	100	53	0.280†	160
Nonsurgical treatment	15 (25.9)	21 (42.9)	21 (39.6)		11 (39.3)	22 (40.7)	18 (34.6)	6 (23.1)		24 (30.8)	24 (41.4)	9 (37.5)		39 (39.0)	16 (30.2)		57 (35.6)
Surgical treatment	43 (74.1)	28 (57.1)	32 (60.4)		17 (60.7)	32 (59.3)	34 (65.4)	20 (76.9)		54 (69.2)	34 (58.6)	15 (62.5)		61 (61.0)	37 (69.8)		103 (64.4)
F2 N0, n (%)	58	49	51	0.593†	28	53	51	26	0.655†	78	56	24	0.133†	99	52	0.491†	158
Nonsurgical treatment	43 (74.1)	38 (77.6)	35 (68.6)		19 (67.9)	42 (79.2)	37 (72.5)	18 (69.2)		52 (66.7)	46 (82.1)	18 (75.0)		71 (71.7)	40 (76.9)		116 (73.4)
Surgical treatment	15 (25.9)	11 (22.4)	16 (31.4)		9 (32.1)	11 (20.8)	14 (27.5)	8 (30.8)		26 (33.3)	10 (17.9)	6 (25.0)		28 (28.3)	12 (23.1)		42 (26.6)

Table 4 (continued)

	World Region				Years of Experience					Work Setting				Subspecialty			Total
	North/ Latin/ South America	Europe	Africa/ Asia/ Middle East		< 5 years	5–10 years	11–20 years	> 20 years		Academic	Hospital Employed	Private Practice		Orthopedic Spine	Neurosurgery Spine		
	N = 17	N = 49	N = 10	p value	N = 28	N = 55	N = 52	N = 26	p value	N = 79	N = 58	N = 24	p value	N = 101	N = 53	p value	N = 161
F2 N1, n (%)	58	49	51	0.768[†]	28	53	51	26	0.329[†]	78	56	24	0.342[†]	99	52	0.983[†]	158
Nonsurgical treatment	35 (60.3)	32 (65.3)	34 (66.7)		17 (60.7)	39 (73.6)	29 (56.9)	16 (61.5)		47 (60.3)	40 (71.4)	14 (58.3)		63 (63.6)	33 (63.5)		101 (63.9)
Surgical treatment	23 (39.7)	17 (34.7)	17 (33.3)		11 (39.3)	14 (26.4)	22 (43.1)	10 (38.5)		31 (39.7)	16 (28.6)	10 (41.7)		36 (36.4)	19 (36.5)		57 (36.1)
F2 N2, n (%)	58	49	51	0.804[†]	28	53	51	26	0.618[‡]	78	56	24	0.743[†]	99	52	0.665[†]	158
Nonsurgical treatment	9 (15.5)	10 (20.4)	9 (17.6)		3 (10.7)	12 (22.6)	9 (17.6)	4 (15.4)		14 (17.9)	11 (19.6)	3 (12.5)		18 (18.2)	8 (15.4)		28 (17.7)
Surgical treatment	49 (84.5)	39 (79.6)	42 (82.4)		25 (89.3)	41 (77.4)	42 (82.4)	22 (84.6)		64 (82.1)	45 (80.4)	21 (87.5)		81 (81.8)	44 (84.6)		130 (82.3)
F3 N0, n (%)	58	49	51	**0.025**[†]	28	53	51	26	0.333[†]	78	56	24	0.497[†]	99	52	0.628[†]	158
Nonsurgical treatment	15 (25.9)	20 (40.8)	26 (51.0)		8 (28.6)	24 (45.3)	17 (33.3)	12 (46.2)		27 (34.6)	25 (44.6)	9 (37.5)		36 (36.4)	21 (40.4)		61 (38.6)
Surgical treatment	43 (74.1)	29 (59.2)	25 (49.0)		20 (71.4)	29 (54.7)	34 (66.7)	14 (53.8)		51 (65.4)	31 (55.4)	15 (62.5)		63 (63.6)	31 (59.6)		97 (61.4)
F3 N1, n (%)	58	49	50	**0.001**[†]	27	53	51	26	0.318[†]	78	55	24	0.309[†]	98	52	0.914[†]	157
Nonsurgical treatment	9 (15.5)	18 (36.7)	24 (48.0)		5 (18.5)	20 (37.7)	16 (31.4)	10 (38.5)		23 (29.5)	22 (40.0)	6 (25.0)		31 (31.6)	16 (30.8)		51 (32.5)
Surgical treatment	49 (84.5)	31 (63.3)	26 (52.0)		22 (81.5)	33 (62.3)	35 (68.6)	16 (61.5)		55 (70.5)	33 (60.0)	18 (75.0)		67 (68.4)	36 (69.2)		106 (67.5)

Table 4 (continued)

	World Region				Years of Experience					Work Setting				Subspecialty			Total
	North/Latin/South America	Europe	Africa/Asia/Middle East		<5 years	5–10 years	11–20 years	>20 years		Academic	Hospital Employed	Private Practice		Orthopedic Spine	Neurosurgery Spine		
	$N=17$	$N=49$	$N=10$	p value	$N=28$	$N=55$	$N=52$	$N=26$	p value	$N=79$	$N=58$	$N=24$	p value	$N=101$	$N=53$	p value	$N=161$
F3 N2, n (%)	58	49	50	0.388‡	27	53	51	26	0.402‡	78	55	24	0.460‡	98	52	0.515‡	157
Nonsurgical treatment	3 (5.2)	6 (12.2)	3 (6.0)		1 (3.7)	6 (11.3)	2 (3.9)	3 (11.5)		4 (5.1)	6 (10.9)	2 (8.3)		6 (6.1)	5 (9.6)		12 (7.6)
Surgical treatment	55 (94.8)	43 (87.8)	47 (94.0)		26 (96.3)	47 (88.7)	49 (96.1)	23 (88.5)		74 (94.9)	49 (89.1)	22 (91.7)		92 (93.9)	47 (90.4)		145 (92.4)

‡Fisher's exact test

†Chi-square test

years of experience, surgical subspecialty, or by region. Ungrouped summary of the preferred subaxial classification system and use of the facet portion of the AO Spine SCICS is presented in Supplemental Table 1.

Operative versus nonoperative management

Respondent preferences for initial management strategy regarding facet fracture subtypes with various degrees of neurologic injury are presented in Table 3. For all clinical scenarios, there was no statistically significant difference in management choice based on surgeon experience or practice setting (Table 4). When evaluated by subspecialty, the only significant difference in treatment was for F1N1 fractures where neurosurgeons were more likely to recommend surgical treatment than orthopedic spine surgeons, 20.8% vs 7.0%, respectively ($p=0.012$). When evaluated by region, there was only a significant difference in management of floating lateral mass fractures, specifically F3N0 and F3N1 fractures. For F3N0 fractures, 74.1%, 59.2%, and 49.0% of North/Latin/South America, Europe, and Africa/Asia/Middle East respondents chose operative treatment, respectively ($p=0.025$). And while the majority agreed on operative treatment for F3N1 fractures, significantly less surgeons from Africa/Asia/Middle East (52.0%) and Europe (63.3%) recommended surgery than respondents from North/Latin/South America (84.5%) ($p=0.001$). Ungrouped summary of operative versus nonoperative management preferences for facet fracture subtypes is presented in Supplemental Table 2.

Preferred type of operative/nonoperative management

For the preferred type of operative and nonoperative management, not all participants had the possibility of answering the question depending on their response to the overlying question of operative vs nonoperative management. As a result, no statistical comparisons could be performed due to conditional probability. Ungrouped summary of the preferred nonoperative and operative method of management for fracture subtypes is presented in Supplemental Tables 3 and 4, respectively.

Preferred imaging in work-up and treatment

Summary of imaging modalities used in the work-up of F1, F2, and F3 fractures is presented in Table 5. More than 95.7% of surgeons routinely use CT imaging regardless of facet fracture subtype. Comparison of the need for MRI in the decision between operative and nonoperative treatment is presented in Table 6. There was no statistically significant difference in the use of MRI for decision making for facet fracture subtypes based on surgeon variation, with a

Table 5 Summary of imaging modalities used in the work-up for facet fractures based upon region, years of experience, practice type, and subspecialty

	World Region						Years of Experience				Work Setting			Subspecialty			Total
	North America	Latin & South America	Europe	Africa	Asia	Middle East	< 5 years	5—10 years	11—20 years	> 20 years	Academic	Hospital employed	Private Practice	Orthopedic Spine	Neurosurgery Spine	Other	
	$N = 17$	$N = 41$	$N = 49$	$N = 10$	$N = 30$	$N = 14$	$N = 28$	$N = 55$	$N = 52$	$N = 26$	$N = 79$	$N = 58$	$N = 24$	$N = 101$	$N = 53$	$N = 7$	$N = 161$
Imaging modalities routinely used when evaluating F1N0 fracture, *n* (%) (choose all)	17	41	49	10	30	14	28	55	52	26	79	58	24	101	53	7	161
CT scan	16 (94.1)	41 (100.0)	49 (100.0)	8 (80.0)	29 (96.7)	14 (100.0)	28 (100.0)	53 (96.4)	50 (96.2)	26 (100.0)	77 (97.5)	57 (98.3)	23 (95.8)	98 (97.0)	52 (98.1)	7 (100.0)	157 (97.5)
Upright AP and lateral XRs	14 (82.4)	24 (58.5)	22 (44.9)	7 (70.0)	16 (53.3)	8 (57.1)	13 (46.4)	30 (54.5)	32 (61.5)	16 (61.5)	47 (59.5)	33 (56.9)	11 (45.8)	65 (64.4)	25 (47.2)	1 (14.3)	91 (56.5)
Flexion/Extension XRs	4 (23.5)	13 (31.7)	10 (20.4)	2 (20.0)	10 (33.3)	4 (28.6)	9 (32.1)	12 (21.8)	13 (25.0)	9 (34.6)	21 (26.6)	17 (29.3)	5 (20.8)	25 (24.8)	15 (28.3)	3 (42.9)	43 (26.7)
MRI	8 (47.1)	15 (36.6)	22 (44.9)	3 (30.0)	15 (50.0)	5 (35.7)	11 (39.3)	21 (38.2)	21 (40.4)	15 (57.7)	33 (41.8)	24 (41.4)	11 (45.8)	44 (43.6)	22 (41.5)	2 (28.6)	68 (42.2)
Imaging modalities routinely used when evaluating F2N0 fracture, *n* (%) (choose all)	17	41	49	10	30	14	28	55	52	26	79	58	24	101	53	7	161
CT scan	16 (94.1)	41 (100.0)	48 (98.0)	8 (80.0)	28 (93.3)	13 (92.9)	26 (92.9)	51 (92.7)	51 (98.1)	26 (100.0)	77 (97.5)	54 (93.1)	23 (95.8)	97 (96.0)	50 (94.3)	7 (100.0)	154 (95.7)
Upright AP and lateral XRs	13 (76.5)	28 (68.3)	22 (44.9)	6 (60.0)	15 (50.0)	7 (50.0)	14 (50.0)	29 (52.7)	31 (59.6)	17 (65.4)	46 (58.2)	32 (55.2)	13 (54.2)	65 (64.4)	25 (47.2)	1 (14.3)	91 (56.5)
Flexion/Extension XRs	3 (17.6)	14 (34.1)	13 (26.5)	3 (30.0)	11 (36.7)	3 (21.4)	11 (39.3)	16 (29.1)	13 (25.0)	7 (26.9)	22 (27.8)	21 (36.2)	4 (16.7)	25 (24.8)	19 (35.8)	3 (42.9)	47 (29.2)
MRI	13 (76.5)	23 (56.1)	30 (61.2)	2 (20.0)	18 (60.0)	7 (50.0)	16 (57.1)	31 (56.4)	29 (55.8)	17 (65.4)	43 (54.4)	34 (58.6)	16 (66.7)	57 (56.4)	33 (62.3)	3 (42.9)	93 (57.8)

Table 5 (continued)

	World Region						Years of Experience				Work Setting			Subspecialty			Total
	North America	Latin & South America	Europe	Africa	Asia	Middle East	< 5 years	5—10 years	11—20 years	> 20 years	Academic	Hospital employed	Private Practice	Orthopedic Spine	Neurosurgery Spine	Other	
	N = 17	*N* = 41	*N* = 49	*N* = 10	*N* = 30	*N* = 14	*N* = 28	*N* = 55	*N* = 52	*N* = 26	*N* = 79	*N* = 58	*N* = 24	*N* = 101	*N* = 53	*N* = 7	*N* = 161
Imaging modalities routinely used when evaluating F3N0 fracture, *n* (%) (choose all)	17	41	49	10	30	14	28	55	52	26	79	58	24	101	53	7	161
CT scan	16 (94.1)	41 (100.0)	48 (98.0)	9 (90.0)	29 (96.7)	13 (92.9)	27 (96.4)	52 (94.5)	51 (98.1)	26 (100.0)	78 (98.7)	55 (94.8)	23 (95.8)	99 (98.0)	50 (94.3)	7 (100.0)	156 (96.9)
Upright AP and lateral XRs	7 (41.2)	24 (58.5)	21 (42.9)	6 (60.0)	15 (50.0)	9 (64.3)	12 (42.9)	25 (45.5)	28 (53.8)	17 (65.4)	40 (50.6)	31 (53.4)	11 (45.8)	58 (57.4)	22 (41.5)	2 (28.6)	82 (50.9)
Flexion/Extension XRs	4 (23.5)	8 (19.5)	9 (18.4)	2 (20.0)	9 (30.0)	3 (21.4)	5 (17.9)	12 (21.8)	12 (23.1)	6 (23.1)	17 (21.5)	14 (24.1)	4 (16.7)	17 (16.8)	15 (28.3)	3 (42.9)	35 (21.7)
MRI	15 (88.2)	29 (70.7)	32 (65.3)	5 (50.0)	22 (73.3)	6 (42.9)	21 (75.0)	35 (63.6)	33 (63.5)	20 (76.9)	52 (65.8)	41 (70.7)	16 (66.7)	66 (65.3)	39 (73.6)	4 (57.1)	109 (67.7)

Table 6 Need for MRI in the decision of operative and nonoperative treatment for F1, F2, and F3 fractures based upon region, years of experience, practice type, and subspecialty

	World Region (grouped)				Years of Experience					Work Setting				Subspecialty			Total
	North/Latin/South America	Europe	Africa/Asia/Middle East	*p* value	< 5 years	5–10 years	11–20 years	> 20 years	*p* value	Academic	Hospital employed	Private Practice	*p* value	Orthopedic Spine	Neurosurgery Spine	*p* value	
	N = 58	*N* = 49	*N* = 54		*N* = 28	*N* = 55	*N* = 52	*N* = 26		*N* = 79	*N* = 58	*N* = 24		*N* = 101	*N* = 53		*N* = 161
Need of MRI to decide the treatment in F1 facet fractures, *n* (%)	58	49	54	0.859†	28	55	52	26	0.378†	79	58	24	0.927†	101	53	0.807†	161
No	35 (60.3)	27 (55.1)	31 (57.4)		17 (60.7)	34 (61.8)	31 (59.6)	11 (42.3)		46 (58.2)	34 (58.6)	13 (54.2)		57 (56.4)	31 (58.5)		93 (57.9)
Yes	23 (39.7)	22 (44.9)	23 (42.6)		11 (39.3)	21 (38.2)	21 (40.4)	15 (57.7)		33 (41.8)	24 (41.4)	11 (45.8)		44 (43.6)	22 (41.5)		68 (42.2)
Need of MRI to decide the treatment in F2 facet fractures, *n* (%)	58	49	54	0.365†	28	55	52	26	0.861†	79	58	24	0.561†	101	53	0.486†	161
No	22 (37.9)	19 (38.8)	27 (50.0)		12 (42.9)	24 (43.6)	23 (44.2)	9 (34.6)		36 (45.6)	24 (41.4)	8 (33.3)		44 (43.6)	20 (37.7)		68 (42.2)
Yes	36 (62.1)	30 (61.2)	27 (50.0)		16 (57.1)	31 (56.4)	29 (55.8)	17 (65.4)		43 (54.4)	34 (58.6)	16 (66.7)		57 (56.4)	33 (62.3)		93 (57.9)

Table 6 (continued)

	World Region (grouped)				Years of Experience					Work Setting				Subspecialty			Total
	North/Latin/South America	Europe	Africa/Asia/Middle East	*p* value	< 5 years	5–10 years	11–20 years	> 20 years	*p* value	Academic	Hospital employed	Private Practice	*p* value	Orthopedic Spine	Neurosurgery Spine	*p* value	
	$N=58$	$N=49$	$N=54$		$N=28$	$N=55$	$N=52$	$N=26$		$N=79$	$N=58$	$N=24$		$N=101$	$N=53$		$N=161$
Need of MRI to decide the treatment in F3 facet fractures, *n* (%)	58	49	54	0.227[†]	28	55	52	26	0.469[†]	79	58	24	0.829[†]	101	53	0.297[†]	161
No	14 (24.1)	17 (34.7)	21 (38.9)		7 (25.0)	20 (36.4)	19 (36.5)	6 (23.1)		27 (34.2)	17 (29.3)	8 (33.3)		35 (34.7)	14 (26.4)		52 (32.3)
Yes	44 (75.9)	32 (65.3)	33 (61.1)		21 (75.0)	35 (63.6)	33 (63.5)	20 (76.9)		52 (65.8)	41 (70.7)	16 (66.7)		66 (65.3)	39 (73.6)		109 (67.7)

[†]Chi-square test

stepwise increase in the use of MRI for F1–F3 fractures (42.2–68.7%).

Discussion

The AO Spine SCICS remains the most widely used classification system among surgeons worldwide. The SLIC system remains the next most frequently used overall with a higher frequency of use by North American surgeons (41.2%). Due to the number of respondents, North American, Latin American, and South American surgeons were grouped together for statistical analysis. Because only 9.8% of Latin and South American surgeons use the SLIC system, this regional grouping attenuated any statistically significant differences in classification system preferences by region. Albeit not statistically significant, less experienced surgeons (< 5 years of training) were noted to use the AO Spine SCICS more frequently (82.1%) compared to the remainder of surgeons (69.7%). The newer AO Spine SCICS was published in 2015, meaning less experienced surgeons likely learned the AO Spine SCICS during their training [1]. Those surgeons with training > 5 years have likely adapted to the respective classification system learned during their training. The same can be said for the use of the facet portion of the AO Spine SCICS, with only 69.7% of surgeons with > 5 years of experience using the facet portion compared to 80.8% of surgeons with < 5 years of experience. Interestingly, academic surgeons used the facet portion of the AO Spine SCICS significantly less than hospital-employed or private practice surgeons. Given that the classification system is used to help reliably classify and communicate fractures for both research and clinical purposes, one would expect greater use among academicians. This could be explained by academic surgeons using the SLIC system more frequently as noted previously, which does not incorporate a facet scoring system.

The AO Spine SCICS is a hierarchical system in which each morphologic type is subdivided into increasing numerical subtypes based on the energy of injury, with higher numbers inferring increased injury severity. The benefits of such a hierarchical system tie into the development of treatment algorithms, in that there may be a line drawn after a particular subtype where fractures are deemed unanimously unsuitable for nonoperative management. When evaluating surgeon preferences for operative versus nonoperative management from around the world, F2N2 fractures appear to draw that threshold. The majority of surgeons surveyed agree that any fracture classified as F2N2 or above should be treated surgically. Additionally, all fractures with radiculopathy (N2), regardless of subtype, also indicate operative treatment for the majority of surgeons. Some regional exceptions exist, however, with surgeons from Africa/Asia/Middle East significantly less likely to recommend surgical treatment for F3N0 fractures than surgeons from the remainder of global regions. This may be secondary to limited resources and infrastructure—reserving surgery for more severe cases, patient socioeconomic factors, as well as cultural differences in patient expectations and outcomes in that particular region [28–31]. Interestingly, while the treatment for F2N0 fractures is highly controversial in the scientific literature, 73.4% of surgeons recommended nonoperative care, with no significant region or experiential variation [14, 20, 32].

The preferred nonoperative treatment by the majority of respondents is the placement of a hard cervical collar irrespective of fracture subtype. Less than 10% of all respondents, regardless of surgeon variation, preferred treatment without a collar or with a soft collar, underscoring the importance of immobilization. The preference for treatment of patients in a halo increased for F3N0 fractures and above (i.e., F3N1, F3N2); however, a hard collar is still preferred by the majority of surgeons surveyed. Both anterior and posterior approaches have been shown to be successful in the surgical management of facet fractures which explains the variation found in the preferred approach [14, 19, 22–25]. However, combined anterior and posterior treatment for facet fractures was the least preferred approach regardless of subtype.

Although multiple imaging modalities were allowed to be chosen by respondents, CT scans were the preferred option for over 95% of surgeons, whereas flexion/extension radiographs were preferred in less than 30% of all cases. CT remains the standard for the work-up of cervical spine trauma, providing significant detail of fracture morphology not seen in plain radiographs [33, 34]. Non-displaced unilateral facet fractures do not meet physiologic criteria for instability and therefore would not be detected on flexion/extension radiographs. Thus, it seems flexion/extension radiography may not provide additional information that would help guide management. The majority of surgeons felt that MRI was necessary to decide the treatment for F2 and F3 fractures. While 57.8% surgeons with > 20 years of experience also noted the need for MRI in F1 fractures, the majority of all lesser experienced surgeons felt it was unnecessary. This may highlight generational differences in training and more recent advancements in multidetector CT technology negating the need for MRI in lower energy injuries [35].

While it was demonstrated that the majority of surgeons from around the world agree in the management of unilateral facet fractures, this study is not without limitations. While the response rate of our survey is 59%, the demographic percentages of AO Spine membership are proportionate to our study's respondent profiles underscoring low nonresponse bias. The study design, however, provides a small sample of surgeons with uneven numbers across geographic regions. Limited participation by some world regions required grouping by proximity for statistical analysis. The differences in preferences between operative and nonoperative treatment among North, South, and Latin America, for example, may have been muddled as a result of grouping them together. Moreover, the regional variability in available equipment and resources may confound management preferences [36, 37]. Furthermore, study participants were all members of AO Spine and may not represent a true cross section of surgeons globally. Surgeon practice setting for respondents suggests a participation bias toward academic and hospital-employed surgeons, which would be expected for members of an academic global community. Accordingly, use of the AO Subaxial Classification system may be overrepresented in this population. Additionally, it may also be suggested that surgeons of the same academic community may be more likely to agree with one another regarding treatment practices. Lastly, there were a higher proportion of orthopedic spine surgeon respondents compared to neurosurgery spine respondents, which is suboptimal in a surgical survey. With the exception of F1N1 fractures however, management practices were similar between both groups, as has been demonstrated in management of spinal trauma between orthopedic and neurosurgery spine surgeons [27, 38].

Conclusion

To our knowledge, this is the first study to evaluate global variation in the treatment for unilateral subaxial facet fractures. While not unanimous, our results find agreement between the majority of surgeons within most practice management clinical vignettes with few significant differences based on surgeon variation. Most notable was the observation that F2N2 fracture subtypes and subtypes with radiculopathy (N2) appear to be the threshold for operative management. Further research should focus on clinical outcomes assessments based upon treatment modality in order to develop international guidelines to reduce practice variety and offer patients the optimal care.

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Data availability The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

Declarations

Conflict of interest The authors declare that they have no conflict of interest.

Ethics approval This study was approved by the Institutional Review Board at the Thomas Jefferson University Hospital. Each author certifies that his or her institution approved the human protocol for this investigation and that all investigations were conducted in conformity with ethical principles of research.

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