



Management of Type II Odontoid Fractures: Experience from Latin American Spine Centers

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■ **OBJECTIVE:** To analyze characteristics of type II odontoid fracture (TII-OF), including clinical and radiographic factors, that influence surgical planning in 8 Latin American centers.

■ **METHODS:** Retrospective chart review was performed of 88 patients with TII-OF between 2004 and 2015 from 8 Latin American centers. Parameters studied included 1) demographic data and causes of TII-OF, 2) clinical and neurologic presentation, 3) characteristics of fracture (degree of odontoid displacement, displacement of odontoid relative to C2 body, anatomy of fracture line, distance between fragments, presence of comminution, contact area between odontoid and C2 body), 4) type of treatment, and 5) clinical and radiographic outcome. Bone fusion was assessed using computed tomography.

■ **RESULTS:** Mean patient age was 45.33 years $\pm$ 23.54; 78.4% of patients were male. Surgery was the primary treatment in 65 patients (73.8%), with an anterior approach in 64.6%. Surgery was usually preferred in patients with posterior or horizontal oblique fracture lines, local pain, and a smaller bone contact surface between the odontoid and the body of C2. A posterior approach was chosen when distance between the fractured bone fragments was >2 mm or after failed conservative or anterior odontoid screw treatment in a symptomatic patient.

■ **CONCLUSION:** The treatment of choice for TII-OF in 8 Latin American trauma centers was surgery through an

anterior approach using screw fixation. Posterior segmental C1-C2 fixation was indicated when distance between bone fragments was >2 mm and in symptomatic patients with nonunion.

INTRODUCTION

Odontoid fractures account for 9%–15% of cervical spine fractures.^{1,2} According to Anderson and D'Alonzo,³ these fractures may be classified as follows: type I, fracture of the odontoid apex; type II, fracture of the odontoid base; and type III, fracture of the vertebral body. Nonoperative treatment is usually the treatment of choice for odontoid fracture types I and III. Type II odontoid fracture (TII-OF) may be treated either surgically or conservatively.⁴

TII-OF is the most common odontoid fracture (65%–74%) and is the most prevalent cervical fracture in patients >70 years old. TII-OF is the most common spine fracture in patients >80 years old, results in a high percentage of nonunions, and is associated with a low prevalence of associated neurologic deficits (2%–27%).^{3,5,6} Numerous treatments have been proposed for TII-OF with the objective of reducing fracture fragments, stabilizing the fracture, enabling fusion, and reducing pain.⁴ However, there is controversy regarding the selection of treatment options, including external immobilization using a halo vest or cervical orthosis as well as anterior versus posterior surgery.^{4,6}

Key words

- Conservative treatment
- Geriatrics
- Latin America
- Surgical procedures
- Type II odontoid fracture

Abbreviations and Acronyms

CT: Computed tomography

TII-OF: Type II odontoid fracture

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The controversy seems to be even greater in geriatric patients.⁵⁻¹⁴ However, primary surgical treatment seems to be the treatment of choice, especially in geriatric patients, as this may reduce mortality.^{6,12,13,15} The objective of this multicenter historical cohort study was to analyze the characteristics of TII-OF, including the clinical and radiographic factors, that influence surgical planning in 8 Latin American centers.

MATERIALS AND METHODS

A retrospective chart review of patients with TII-OF was performed in 8 Latin American centers for the years 2004–2015. Inclusion criteria were acute and isolated TII-OF and charts that offered complete demographic data as well as clinical, neurologic, and preoperative and postoperative radiographic data. Patients who did not have well-documented preoperative and postoperative plain radiographs and computed tomography (CT) images available were excluded from the study. Patients with pathologic fractures and multiple fractures of the cervical spine were also excluded. The study was approved by the ethics committee of the University of Caxias do Sul. Study parameters were 1) patient demographics and causes of TII-OF, 2) clinical and neurologic presentation, 3) characteristics of the fracture, 4) type of treatment, and 5) clinical and radiographic outcome.

General Patient Demographics and Causes of TII-OF

The variables analyzed were sex, age group, type of accident, and time elapsed from fracture to diagnosis and treatment. Comorbidities assessed were smoking, alcohol use, diabetes, hypertension, and drug addiction.

Clinical and Neurologic Presentation

The clinical variables studied were pain, muscle strength, sensibility, and deep reflexes. Pain was assessed as present or absent. Muscle strength, sensibility, and deep reflexes were graded as normal, reduced, or absent.

Radiographic Evaluation

Radiographic parameters studied in the pretreatment images were the degree of odontoid displacement related to the body of C2, the direction of odontoid displacement, the anatomy of the fracture line, the distance between the bone fragments, the degree of atlantoaxial instability, the presence of comminuted fractures, and the contact surface between the odontoid process and the body of C2:

1. The degree of odontoid displacement related to the body of C2 was analyzed using 6-mm cut sagittal and coronal reconstruction CT images (Figure 1).
2. Anterior displacement, posterior displacement, or no displacement of the fractured part of the odontoid in relation to the body was established using sagittal reconstruction CT imaging (Figure 2).
3. Anatomy of the fracture line was classified as anterior-oblique, posterior-oblique, and horizontal based on sagittal reconstruction CT images (Figure 3). The fracture line of an anterior-oblique fracture slopes superiorly from anterior to posterior,

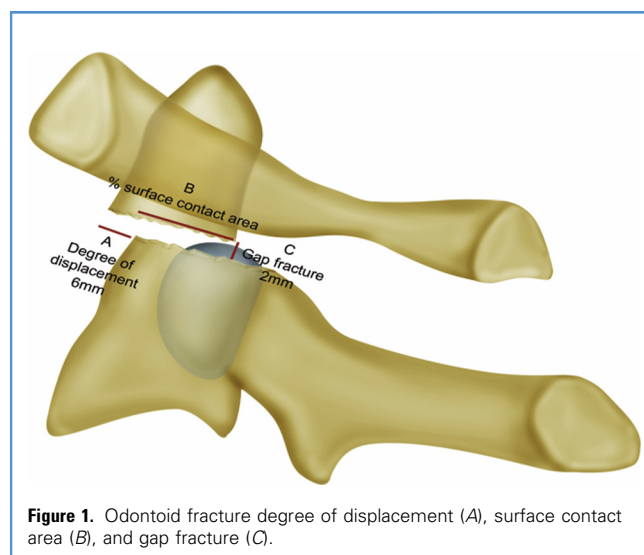


Figure 1. Odontoid fracture degree of displacement (A), surface contact area (B), and gap fracture (C).

whereas a posterior-oblique fracture slopes superiorly from posterior to anterior. A horizontal fracture slopes minimally or not at all.

4. The distance between bone fragments was measured using 2-mm cut sagittal and coronal reconstruction CT images (Figure 1).
5. The degree of atlantoaxial instability was defined as the comparative dislocation of right and left C1-2 joints based on plain x-ray films and reconstruction CT images of the cervical spine.
6. Comminuted fractures were defined as fractures with >2 bone fragments on plain x-ray and reconstruction CT images of the cervical spine.
7. The contact surface between the odontoid process and the body of C2 was measured using sagittal reconstruction of CT images of the cervical spine (Figure 1).

Bone Fusion Assessment

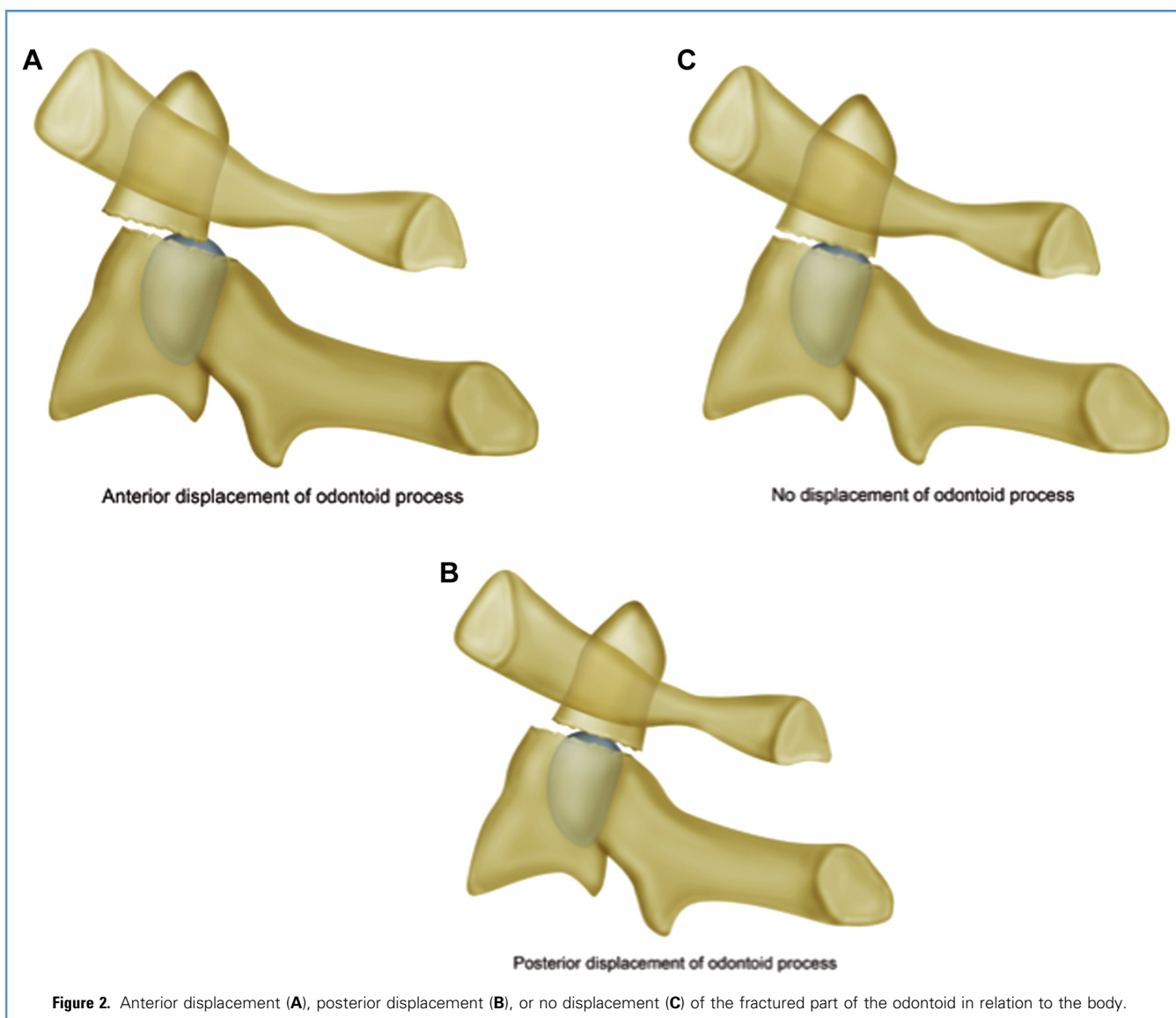
Bone fusion was defined by evidence of bony trabeculae crossing the fracture site and absence of sclerotic borders adjacent to the fracture site using sagittally reconstructed CT images. Nonunion was defined as a definite fracture gap with abnormal motion of the fractured dens on dynamic radiographs and CT scan.

Management

Management was based on the surgeon's expertise, anesthesia risk, and patient's choice. The type of conservative or surgical treatment was recorded as well as the clinical and radiographic data that seemed to have inspired the choice.

Statistical Analysis

Statistical analysis was conducted using SPSS for Windows version 16 (SPSS, Inc, Chicago, Illinois, USA). The categorical variables were



presented as proportion. The continuous variables were submitted to the Kolmogorov-Smirnov test to verify normal distribution and were presented as mean $\pm$ SD or median $\pm$ minimum and maximum, depending on distribution. The comparative analysis between the groups was conducted using the Fisher exact test for categorical variables and Student *t* test or Mann-Whitney test for continuous variables, when applicable. Statistical significance was accepted as $P < 0.05$.

RESULTS

In the 8 participating Latin American centers for the years 2004–2015, 113 patients with TII-OF were identified. There were 25 patients excluded because of lack of relevant information. The remaining 88 patients were included in the current study.

Patient Demographics and Causes of Fracture

The mean age of the study population was 45.3 years $\pm$ 23.54. There was a preponderance of male patients (78.4%; 69 of 88). Motor vehicle accidents accounted for 67% (59 of 88) of the fractures, followed by falls (29.5%; 26 of 88) and sports injuries (3.4%; 3 of 88). The average time elapsed between the accident and definitive treatment was 7 days (range, 1–180 days) (Table 1). A statistically significant difference was observed between patients >60 years old compared with patients <60 years old regarding higher incidence of falls ($P = 0.001$), more comorbidities ($P = 0.001$), posterior displacement of the odontoid process ($P = 0.041$), and smaller contact surface between the odontoid process and the body of C2 ($P = 0.003$) (Table 2).

The incidence of preoperative comorbidities in the conservative treatment and surgical treatment groups is summarized in Table 3. The surgical treatment group had statistically more comorbidities

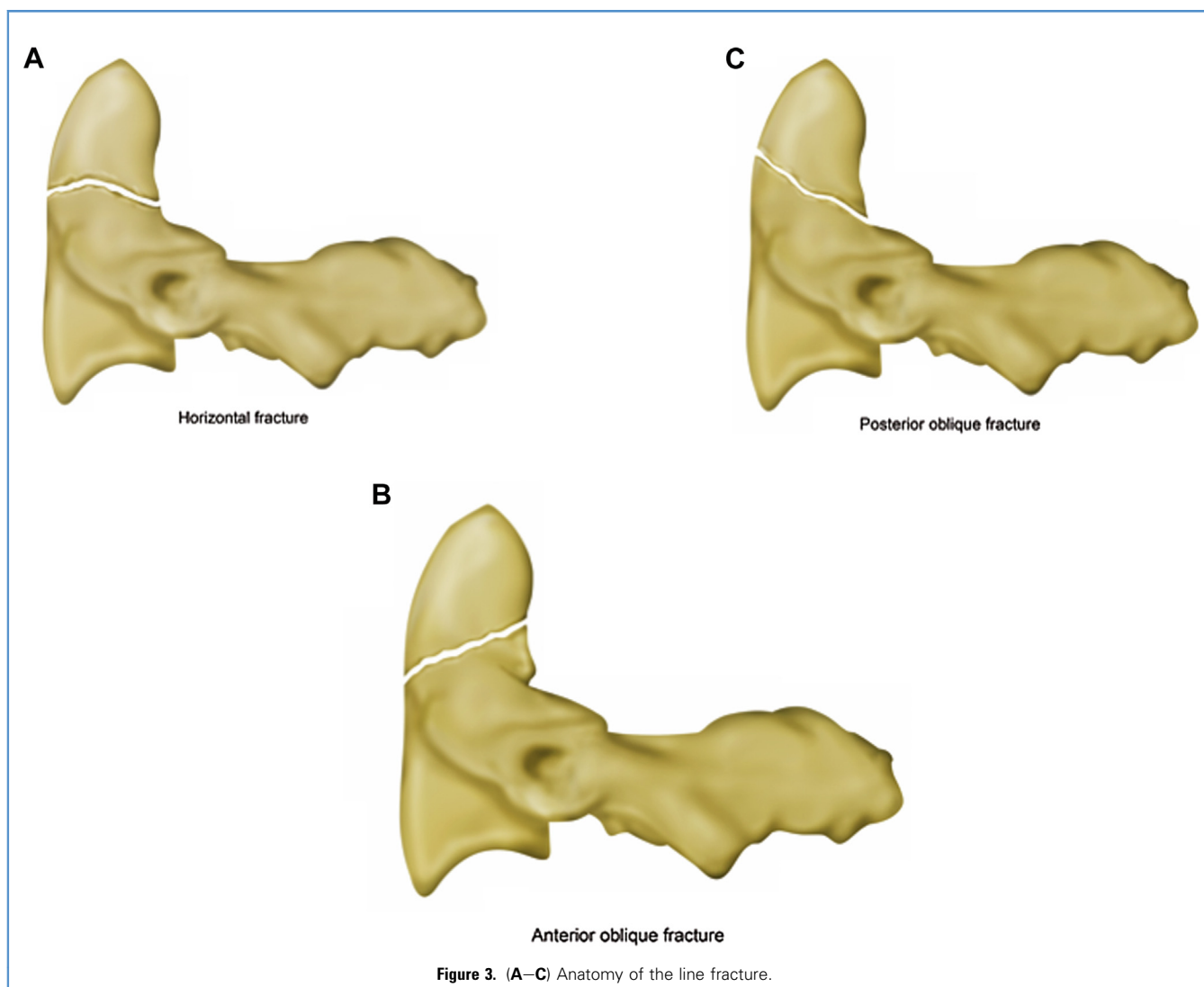


Figure 3. (A–C) Anatomy of the line fracture.

than the conservative treatment group (36 patients vs. 6 patients; $P = 0.028$).

Clinical and Neurologic Presentation

Pain at the fracture site was the most common symptom at presentation (86.4%; 76/88) (Table 1). There were 12 patients (21.6%) who did not present with pain in the preoperative period; 6 were treated conservatively, and 6 were treated surgically. The surgical indication for the 6 patients without pain was the presence of motion and dens displacement on dynamic radiographs and CT scan. Motor deficit after the trauma was observed in 7 cases (8%).

CHARACTERISTICS OF FRACTURE

On radiographic analysis, degree of odontoid displacement >6 mm was observed in 26% of the group (Table 1). The odontoid

process was not displaced in 42 patients (47.7%). In cases with displacement, posterior displacement was observed in 27 patients (30.7%), and anterior displacement was observed in 19 cases (21.6%). The most prevalent fracture line was horizontal in 42 cases (47.7%), followed by a posterior-oblique line in 34 patients (38.6%) and an anterior-oblique line in 12 patients (13.6%). The distance between the borders of the fracture was >2 mm in 25% of cases. The average contact surface between the odontoid and the body of C2 was $70.91\% \pm 26.63$ (Table 1).

Type of Treatment

Characteristics of patients according to treatment are reported in Table 3. External immobilization was the primary treatment in 23 patients (26.1%). The Philadelphia neck brace was used in 52.2% of patients, the halo vest was used in 34.8% of patients, and sternal occipital mandibular immobilization was used in 13% of patients. Surgical treatment was the primary treatment in 65

Table 1. General Characteristics of Sample (N = 88)

Characteristics	Values
Patient details	
Age, years*	45.33 (23.54)
Male sex	69 (78.4)
Accidental causes	
Traffic accident	59 (67.0)
Fall injuries	26 (29.5)
Sports accident	3 (3.4)
Preoperative symptoms	
Pain	76 (86.4)
Strength deficit	7 (8.0)
Paresthesia	7 (8.0)
Time from accident to treatment, days†	7.0 (1–180)
Pretreatment radiology assessment	
Degree of displacement >6 mm	23 (26.1)
Direction of displacement	
No displacement	42 (47.7)
Anterior	19 (21.6)
Posterior	27 (30.7)
Fracture line anatomy	
Anterior oblique	12 (13.6)
Posterior oblique	34 (38.6)
Horizontal	42 (47.7)
Gap fracture >2 mm	22 (25.0)
Subluxation across C1-2	2 (2.3)
Comminuted fracture	2 (2.3)
Surface contact area (%)*	70.91 (26.63)
Primary management	
Conservative treatment	23
Philadelphia neck brace	12 (52.2)
Halo vest	8 (34.8)
SOMI	3 (13.0)
Primary surgical treatment	65
Odontoid screw	42 (64.6)
C1-2 segmental fixation	13 (20.0)
Cable	7 (10.7)
Transarticular C1-2 screw	3 (4.6)
Post–primary treatment radiology assessment	
Radiographic union	76 (86.4)
Continues	

Table 1. Continued

Characteristics	Values
Secondary management	10
Failure conservative treatment	6 (6.8)
Failure surgical treatment	4 (4.5)
Last clinical assessment	
No pain	72 (81.8)
Pain	13 (14.8)
Hyperesthesia	3 (3.4)
All values are presented as number (%) unless otherwise noted. SOMI, sternal occipital mandibular immobilization. *Mean ± SD. †Median (minimum–maximum).	

patients (73.9%). The anterior approach using an odontoid screw was performed in 42 patients (64.6%), and the posterior approach using a segmental screw fixation of C1-2 was performed in 13 cases (20.0%).

Significant clinical and radiographic factors were present in the surgery group, including the presence of a posterior-oblique fracture line, a smaller surface contact area between the odontoid and the body of C2, and greater preoperative morbidity (Table 3). The radiographic characteristics of posterior-oblique fracture lines and fragment distance <2 mm were observed in patients in whom the anterior approach was performed (Table 4). The radiographic features observed in patients in whom the posterior approach was performed were fragment distance >2 mm and anterior-oblique fracture lines. Fusion failure was observed after the anterior approach or conservative treatment (Table 4).

Clinical and Radiographic Outcome

The average patient follow-up time was 23.41 months ± 25.06. At final follow-up evaluation, 72 patients (81.8%) were pain-free and had a normal neurologic examination; 13 patients (14.8%) complained of local tenderness; and 3 patients (3.4%) complained of hyperesthesia of the C2 dermatome, probably caused by the surgical intervention (segmental fixation of C1-2) (Table 1). There were no patient deaths in this series.

Bone fusion was observed in 76 patients (86.4%). Of the patients treated conservatively, 6 later underwent surgery (26.2%), and 4 (4.5%) of the patients who were originally treated surgically through an anterior approach underwent reoperation using a posterior approach (Table 1). Radiographic union was observed in 76 of 88 patients (86.4%) evaluated. The abnormal displacement of the fractured odontoid process on dynamic radiographs was observed in 9 of 12 patients without fusion on CT assessment. Surgery was performed in the patients with abnormal motion. Failure of conservative treatment was a significant cause in two thirds of the cases (n = 6) and in the remaining one third of cases (n = 3) after anterior odontoid fixation (Table 3). The therapeutic decision for those cases was a posterior approach

Table 2. Comparison Between Patients <60 Years Old and >60 Years Old

Characteristics	<60 Years Old (n = 57)	>60 Years Old (n = 31)	P Value
Patient details			
Male sex	44 (77.2)	25 (80.6)	0.791
Accidental causes			0.001
Traffic accident	47 (82.5)	12 (38.7)	
Fall injuries	8 (14.0)	18 (58.1)	
Sports accident	2 (3.5)	1 (3.2)	
Preoperative symptoms			
Pain	49 (86.0)	27 (87.1)	1
Strength deficit	4 (7.0)	3 (9.7)	0.663
Paresthesia	4 (7.0)	3 (9.7)	0.663
Presence of morbidity	21 (36.8)	21 (67.7)	0.001
Presence of complications	6 (6.8)	3 (3.4)	0.769
Pretreatment radiology assessment			
Degree of displacement >6 mm	14 (24.6)	9 (29.0)	0.800
Direction of displacement			0.041
No displacement	28 (49.1)	14 (45.2)	
Anterior	16 (28.1)	3 (9.7)	
Posterior	13 (22.8)	14 (45.2)	
Fracture line anatomy			0.084
Anterior oblique	11 (19.3)	1 (3.2)	
Posterior oblique	19 (33.3)	15 (48.4)	
Horizontal	27 (47.4)	15 (48.4)	
Gap fracture >2 mm	11 (19.3)	11 (35.5)	0.123
Subluxation across C-C2	1 (1.8)	1 (3.2)	1
Comminuted fracture	2 (3.5)	0 (0)	0.538
Surface contact area*	75.61 (24.42)	62.26 (33.83)	0.003
Primary management			
Conservative treatment	19	4	0.245
Philadelphia neck brace	8 (42.1)	4 (100)	
Halo vest	8 (42.1)	0 (0.0)	
SOMI	3 (15.8)	0 (0)	
Primary surgical treatment	41	24	0.066
Odontoid screw	27 (65.9)	18 (75.0)	
Cable	3 (7.3)	1 (4.2)	
C1-2 segmental fixation	8 (19.5)	5 (20.8)	
Transarticular C1-2 screw	3 (7.3)	0 (0)	
Post-primary treatment radiology assessment			

Continues

Table 2. Continued

Characteristics	<60 Years Old (n = 57)	>60 Years Old (n = 31)	P Value
Radiographic union	51 (89.5)	25 (80.6)	
Last clinical assessment			0.357
No pain	46 (80.7)	26 (83.9)	
Pain	10 (17.5)	3 (9.7)	
Hyperesthesia	1 (1.8)	2 (6.5)	
All values are presented as number (%) unless otherwise noted. SOMI, sternal occipital mandibular immobilization. *Mean $\pm$ SD.			

with C1-2 screw fixation. The 3 asymptomatic patients who had no fusion and no motion of the dens on dynamic radiographs and on CT scan were observed.

Complication Rates

Complications were observed in 6 patients (6.8%) <60 years old and in 3 patients (3.4%) >60 years old (Table 2). Table 3 shows that complications occurred in 6 patients (6.8%) in the surgical treatment group and 3 patients (3.4%) in the conservative treatment group. There were 9 complications observed in this series. The most common complication was symptomatic nonunion in 6 cases; the other 3 complications observed were cerebrospinal fluid leak, screw displacement, and dysphagia.

DISCUSSION

The treatment of odontoid fractures is influenced by many factors, such as type of fracture, association with other lesions, patient age, and comorbidities.^{16,17} There is still controversy regarding the benefits of surgical treatment versus nonsurgical treatment as well as the type of surgical approach and technique for TII-OF.^{6,16} In the present multicenter study of TII-OF, surgery was the primary choice in two thirds of the patients, and the anterior odontoid screw technique was used in 64.6% of cases. The patients who underwent posterior segmental C1-2 fixation had a >2 mm distance between the dislocated fracture fragments and symptomatic nonunion.

Patient Demographics and Causes of Fracture

The distribution of odontoid fractures according to age shows 2 peaks: 1 in younger patients (17–30 years old), associated with high-energy traumas, and 1 in geriatric patients (>70 years old), associated with low-energy traumas, such as falls.^{16,17} The incidence of TII-OF is growing proportionally with the aging of the world population.^{7,8,11–13} In geriatric patients, the trauma mechanism is usually low energy and related to falls.^{10,12} This was observed in the present series in 18 of 31 patients >60 years old (58.1%).

Clinical and Radiographic Presentation

Surgeons seem to recognize morbidity as an important factor during the decision-making process and have concluded that

Table 3. Characteristics of Patients with Surgical Treatment and with Conservative Treatment

Characteristics	Conservative (n = 23; 26.1%)	Surgical (n = 65; 73.9%)	P Value
Patient details			
Male sex	15 (65.2)	54 (83.1)	0.085
Accidental causes			0.363
Traffic accident	13 (56.5)	46 (70.8)	
Fall injuries	9 (39.1)	17 (26.2)	
Sports accident	1 (4.3)	2 (3.1)	
Preoperative symptoms			
Pain	17 (73.9)	59 (90.8)	0.072
Strength deficit	1 (4.3)	6 (9.2)	0.671
Paresthesia	2 (8.7)	5 (7.7)	>0.999
Presence of morbidity	6 (26.1)	36 (55.4)	0.028
Presence of complications	3 (3.4)	6 (6.8)	0.480
Pretreatment radiology assessment			
Degree of displacement >6 mm	4 (17.4)	19 (29.2)	0.408
Direction of displacement			0.162
No displacement	15 (65.2)	27 (41.5)	
Anterior	3 (13.0)	16 (24.6)	
Posterior	5 (21.7)	22 (33.8)	
Fracture line anatomy			0.001
Anterior oblique	8 (34.8)	4 (6.2)	
Posterior oblique	4 (17.4)	30 (46.2)	
Horizontal	11 (47.8)	31 (47.7)	
Gap fracture >2 mm	4 (17.4)	18 (27.7)	0.409
Subluxation across C1-2	0 (0)	2 (3.1)	>0.999
Comminuted fracture	1 (4.3)	1 (1.5)	0.457
Surface contact area*	82.61 (23.97)	66.77 (29.16)	0.014
Post–primary treatment radiology assessment			
Radiographic union	20 (87.0)	56 (86.2)	>0.999
Last clinical assessment			0.582
No pain	20 (87.0)	52 (80.0)	
Pain	2 (8.7)	11 (16.9)	
Hyperesthesia	1 (4.3)	2 (3.1)	

All values are presented as number (%) unless otherwise noted.

*Mean ± SD.

morbidity is not an absolute contraindication to surgery. Morbidity that is relevant to surgery is also relevant to nonoperative treatment. In our series, surgery was the primary treatment of choice when there was refractory pain, bone displacement >6 mm, or a

Table 4. Comparison Between Anterior and Posterior Approach to Odontoid Fracture Type II and Radiographic Features

Characteristics	Anterior (n = 42)	Posterior (n = 23)	P Value
Degree of displacement >6 mm	10 (23.8)	9 (39.1)	0.256
Direction of displacement			0.509
No displacement	19 (45.2)	8 (34.8)	
Anterior	11 (26.2)	5 (21.7)	
Posterior	12 (28.6)	10 (43.5)	
Fracture line anatomy			0.134
Anterior oblique	2 (4.8)	2 (8.7)	
Posterior oblique	23 (54.8)	7 (30.4)	
Horizontal	17 (40.5)	14 (60.9)	
Gap fracture >2 mm	7 (16.7)	11 (47.8)	0.010
Subluxation across C1-2	1 (2.4)	1 (4.3)	>0.999
Comminuted fracture	0 (0)	1 (4.3)	0.354
Surface contact area*	69.29 (27.26)	62.17 (32.46)	0.184

All values are presented as number (%) unless otherwise noted.

*Mean ± SD.

smaller contact surface between the odontoid and the body of C2 as well as after failure of nonoperative treatment.

Characteristics of Fracture

Cho and Sung¹⁸ studied 41 patients with an average age of 46.6 years (range, 15–79 years) treated with anterior odontoid screws and found that fusion was 21 times more likely to fail in patients presenting with fragments displaced at a distance >2 mm. In the present series, the posterior C1-2 segmental fixation was usually indicated when the distance between bone fragments was >2 mm and in failed conservative or surgical cases. The most prevalent fracture line was horizontal in 42 cases (47.7%), followed by posterior-oblique in 34 cases (38.6%). The most common characteristics of the fracture line observed in the present series allowed for anterior odontoid screw placement.

Type of Treatment

The critical management decision in patients with TII-OF is to establish the best treatment that will allow better results with lower morbidity.¹⁹ On one hand, nonoperative treatments have a high incidence of nonunion and instability that may lead to progressive myelopathy and spinal cord injury.^{5,14,20} On the other hand, surgery may be challenging because of the potential higher risk of complications, anatomic variations of the fracture, and poor bone quality.⁵ Operative treatment was indicated in two thirds of the patients in the present series, despite the morbidity.

Conservative treatment of TII-OF may be accomplished using a cervical brace or a halo vest. Although the latter is highly effective to achieve bone fusion, the incidence of complications and increased morbidity are equally high, and thus a halo vest is not

recommended for elderly patients.^{14,16,21-23} Patients >65 years old with TII-OF and an odontoid dislocation of <50% show satisfactory clinical results when treated with a cervical brace for 12 weeks, despite the high incidence of radiographic nonunion.^{24,25} In the present series, 23 patients (26.13%) were treated conservatively; a halo vest was used only in patients <60 years old, and a cervical brace was used in patients >60 years old.

The literature has not established which surgical approach, anterior or posterior, is better in TII-OF.^{4,6-8,13,14,24} Anterior fixation with an odontoid screw allows direct fracture osteosynthesis, preserving the mobility of C1-2.^{4,6,26} This technique is preferable in patients without severe osteoporosis who present with a fracture line perpendicular to the vector of compression and with minimal bone comminution to enable adequate bone contact and stability.⁴ The disadvantages of an anterior approach are the difficulties in maintaining the reduction, the impossibility of exposure in certain patients, poor bone quality, and a high risk of screw loosening as well as dysphagia, pulmonary insufficiency, a compromised airway, and low rates of bone fusion.⁹ Thus, advanced age and poor bone quality are relative contraindications for this technique.⁴ In the present series, among 65 patients who underwent surgery, the odontoid screw technique using 1 screw was performed in 42 patients (64.6%), and the posterior segmental screw fixation of C1-2 was performed in 13 patients (20.0%). The anterior surgical approach was chosen based on radiographic characteristics of the fracture and the surgeon's personal preference.

A nondisplaced odontoid fracture was observed in 47% of patients, and most of them underwent surgical intervention. Management was based on the surgeon's expertise, anesthesia risk, and patient's choice. After the results were compiled, a meeting was held among the investigators and the conclusions were as follows: 1) the patients' choice was against wearing the Philadelphia neck brace or halo vest over a long-term period; 2) the patients were worried about undergoing a bigger posterior fixation surgery if fusion was not achieved after the conservative treatment, instead of having an anterior screw placement; 3) most of the surgeons thought that the anterior approach in general had good results with a lower incidence of complications.

The posterior approach techniques have evolved from poorly stabilizing wires and rods that required autologous bone grafts and external fixation to more rigid instrumentations with screws placed into the lateral masses of C1 and C2 pars, pedicle, or laminar screws.⁴ The preferable technique is one that offers greater stability, ensuring quick mobility without the need for external immobilization.^{4,6} Risks associated with the placement of posterior screws are vertebral artery lesions, damage or dysfunction of the root of C2, inadequate placement of the screws, and excessive bleeding during dissection.⁴ In the present study, 23

patients (27.3%) underwent primary fixation using a posterior approach, and the segmental C1-2 fixation was the most commonly used technique, being chosen for 13 patients. Patients who underwent posterior C1-2 fixation had symptomatic malunion secondary to conservative treatment (6 cases) or failed anterior screw treatment (3 cases).

Clinical and Radiographic Outcome

Surgical treatment in patients with TII-OF achieves fusion rates similar to nonoperative treatment, regardless of the degree of bone displacement.⁶ In the present series, patients >60 years old treated surgically or conservatively had similar results in regard to bone fusion and the rate of complications.

Predisposing factors for the development of nonunion in elderly patients are reduced trabecular bone, degree of displacement between the odontoid and the vertebral body, and distance between fractured bone fragments.²⁷ In the present series, the incidence of symptomatic nonunion was greater in the conservative group (6 cases) than after anterior odontoid screw fixation (3 cases). Patients with symptomatic nonunion underwent C1-2 posterior fixation. At the end of the follow-up period (23.41 months $\pm$ 25.06), 72 patients (81.8%) were pain-free and had a normal neurologic examination. Local tenderness and hyperesthesia of the C2 dermatome were present in 13 patients (14.8%) and 3 patients (3.4%), respectively.

Study Limitations

The limitations of this study are its retrospective design, which made it necessary to exclude 25 patients owing to the loss of data. Assessment of the severity of osteoporosis in older patients was not standardized. The relatively small sample size stratified into age groups did not allow appropriate statistical analysis of the controversial group of elderly patients. A strength of this study is the correlation between the radiographic classification between the different odontoid fracture types with surgical planning and outcome.

CONCLUSIONS

The surgical decision for treatment of TII-OF must be tailored to the individual characteristics of each patient, the possible acceptable complications for each case, the surgeon's experience, the patient's preference, and the technical resources available. The treatment of choice for TII-OF in this multicenter study was surgical using the anterior odontoid screw technique. A posterior approach and segmental C1-2 fixation were usually indicated when the distance between the dislocated fracture fragments was >2 mm and when conservative or primary surgical treatment with the anterior screw technique failed.

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