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Editor
Nancy E. Epstein, MD
Clinical Professor of Neurological Surgery, School of Medicine, State U. of NY at Stony Brook

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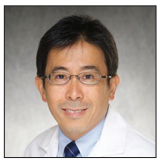
Original Article

Healing process of Type II odontoid fractures after C1-C2 posterior screw fixation: Predictive factors for pseudoarthrosis

Satoshi Yamaguchi[1], Brian J. Park[1], Masaaki Takeda[2], Takafumi Mitsuhara[2], Kiyoharu Shimizu[2], Pei-Fu Chen[3], Royce W. Woodroffe[1]

[1]Department of Neurosurgery, University of Iowa Hospitals and Clinics, Iowa City, United States, [2]Department of Neurosurgery, Graduate School of Biomedical and Health Sciences, Hiroshima University, Hiroshima City, Hiroshima, Japan, [3]Department of Anesthesiology, Far Eastern Memorial Hospital, New Taipei City, Taiwan.

E-mail: *Satoshi Yamaguchi - satoshi-yamaguchi@uiowa.edu; Brian J. Park - brian-j-park@uiowa.edu; Masaaki Takeda - tkdmsk@hiroshima-u.ac.jp; Takafumi Mitsuhara - mitsuhara@hiroshima-u.ac.jp; Kiyoharu Shimizu - d186564@hiroshima-u.ac.jp; Pei-Fu Chen - andy698087@gmail.com; Royce W. Woodroffe - royce-woodroffe@uiowa.edu



***Corresponding author:**
Satoshi Yamaguchi,
Department of Neurosurgery,
University of Iowa Hospitals
and Clinics, Iowa City,
United States.

satoshi-yamaguchi@uiowa.edu

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ABSTRACT

Background: The healing process after C1-C2 posterior screw fixation (C1-C2 PSF) for odontoid fractures is not well understood. Here, we evaluated such processes and identified factors potentially contributing to pseudoarthroses following fusions for Type II odontoid fractures.

Methods: Pre- and post-operative cervical radiographs and computed tomography (CT) images from 15 patients with preoperative Type II odontoid fractures who underwent C1-C2 PSF were retrospectively reviewed.

Results: CT images identified three areas of bone fusion: The primary fracture site in the dens (9/15 patients, 60%), the atlanto-dental interspace (ADI) (10/15, 67%), and C1-C2 interlaminar space after onlay bone grafting (4/15, 27%). All patients showed bone fusion in at least one of three areas, while only one patient (6.7%) achieved bone fusion in all three areas. With these overall criteria, nine of 15 patients (60%) were considered fused, while six patients (40%) were determined to exhibit pseudoarthroses. Univariate analyzes showed that the preoperative C2-C7 SVA for the nonunion group was significantly larger versus the union group, and bone fusion at the level of the ADI was significantly more common in the nonunion versus the union group.

Conclusion: CT studies identified three anatomical areas where bone fusion likely occurs after C1-C2 PSF. Increased sagittal balance in the cervical spine may negatively impact the fusion of odontoid fractures. Further, bone fusion occurring at other sites, not the primary fracture location, through stress shielding may contribute to delayed or failed fusions.

Keywords: Bone fusion, C1-C2 posterior screw fixation, Odontoid fracture

INTRODUCTION

Anderson and D'Alonzo Type II odontoid fractures are the most common among three types of odontoid fractures.[1] These are treated surgically sometimes right after the injury or after failed conservative management. Surgical fixation can include either an anterior or posterior approach.[3] The C1 and C2 posterior screw fixation (C1-C2 PSF) is one of the posterior surgical

options particularly in cases with a high-riding vertebral artery in the C2 pars/pedicle.[3,7] Here, we further assessed/correlated the healing and fusion versus pseudoarthrosis processes of the odontoid fractures fixation.

MATERIALS AND METHODS

This was a retrospective IRB approved review of 15 cases of Anderson and D'Alonzo Type II odontoid fractures treated with C1-C2 PSF by one surgeon (2011-2015).[1] All patients underwent pre- and post-operative cervical spine plain radiographs and computed tomography (CT) scans. The gender, age, time from injury to surgery, and material for onlay graft over the C1-C2 interlaminar space were recorded. The primary goal of the surgery was fusion of the odontoid process.

Clinical patient data

There were 15 patients who underwent C1-C2 PSF for Anderson and D'Alonzo Type II odontoid fracture.[1] Eight out of 15 patients were male. They averaged 71.3 years of age. Fractures were due to 11 ground level falls, two motor vehicle accidents, and two unwitnessed falls. The median time from injury to surgery was 119 days. All patients underwent CT scans to evaluate bone fusion an average of 12 months postoperatively.

Use of CT studies to document fusion

We examined pre- and post-operative CT characteristics associated with fracture nonunion using Hounsfield units at the odontoid base and fractured odontoid tip (i.e., regarding bone density) and maximum bone gap of the fracture site [Figure 1]. Other parameters were also studied [Table 1].

Surgery

Out of 30 total C2 screws inserted, 24 screws were placed in the pars interarticularis, and six screws in the C2 lamina (i.e., due to high-riding vertebral arteries). After the installation of screws and rods, the laminae of C1 and C2 were decorticated for the subsequent placement of onlay bone grafting. In the first five cases, cancellous bone was harvested from the ilium, while in the last ten cases, we utilized allograft/demineralized bone matrix (DBM). Patients were instructed to use a cervical collar for 6 weeks after the surgery.

Statistical analysis

Statistical analysis was performed by a computer software (SPSS Inc., IBM, Chicago, IL). Tests utilized included: the Shapiro–Wilk test, Student's *t*-test, nonparametric Mann–Whitney U-test, and the Fisher's exact test.

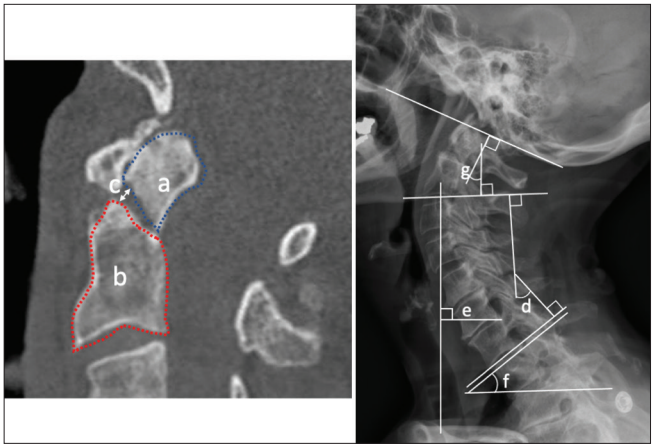

Figure 1: Radiological parameters examined as possible factors associated with fracture union/nonunion from preoperative images. Left: (a) region of interest (ROI) for Hounsfield unit (HU) of fractured odontoid process, (b) ROI for HU of the base of odontoid process, (c) maximum separation of the fracture. Right: (d) cervical lordosis measured by C2-C7 Cobb angle, (e) C2-C7 sagittal vertical axis, (f) T1-slope, (g) Occiput-C2 angle.

Table 1: Studied parameters.

From medical records
Sex (male/female)
Age (years old)
Type of bone graft (autograft/allograft)
The median days from injury to surgery (days)
From preoperative imaging study
HU of the fractured odontoid process
HU of the base of odontoid process
Maximum separation of the fracture (mm)
Cervical lordosis (degrees)
C2-C7 SVA (mm)
T1 slope (degrees)
O-C2 angle (degrees)
Cervical mismatch (=T1 slope - cervical lordosis; degrees)
From postoperative CT images
Radiolucent area around the screws
Fusion in ADI
Fusion in C1-C2 interlaminar space

HU: Hounsfield unit, SVA: sagittal vertical axis

RESULTS

Incidence of bone fusion in 1–3 areas

Bone fusion was seen in three different areas in the atlantoaxial cervical spine [Figure 2]: The primary fracture site in the odontoid process (9/15 patients), the atlantodental interspace (ADI) (10/15 patients), and the C1-C2 interlaminar space after onlay bone grafting (4/15 patients).

Of note, all four of five patients receiving iliac autograft fused versus none using allograft/DBM.

Only 1 (6.7%) patient showed bone fusion in all three areas while six patients fused in two areas, while eight patients had bone fusion in only one area, (i.e., either at the primary fracture [$n = 2$] or ADI [$n = 6$] sites) [Table 2].

Differences in SVA and ADI fusion rates

The preoperative C2-C7 SVA was significantly greater for the nonunion versus union group patients and these patients were typically older [Table 3]. Bone fusion at the level of the ADI was significantly more frequent in the nonunion (6/6 patients) versus the union patients (4/9 patients) [Table 4].

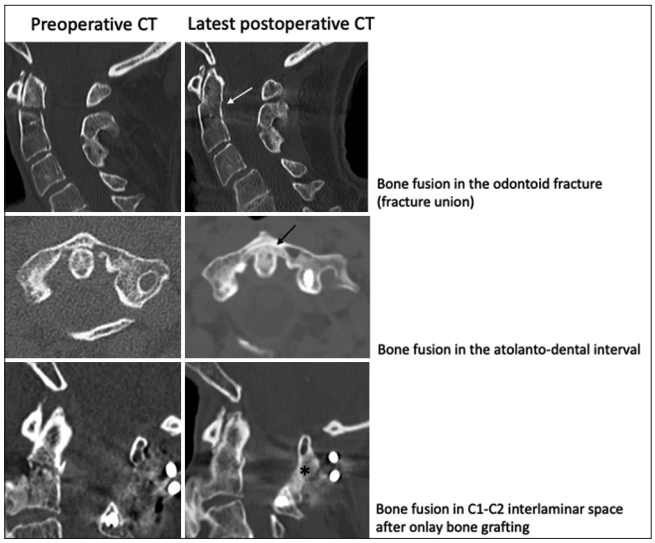

Figure 2: Three anatomical areas where bone fusion occurred. Top row: white arrow indicates bone fusion in the odontoid fracture. Middle row: Black arrow indicates bone fusion in the atlanto-dental interval space. Bottom row: asterisk indicates bone fusion in the C1-C2 interlaminar space after onlay bone grafting.

DISCUSSION

Stress shielding effect in ADI as a possible cause of fracture nonunion

Considering that the directions of the screws in C1-C2 PSF are not perpendicular to the fracture line but more parallel to the axial plane of the C1 lamina, those screws appear to press fractured odontoid process toward the anterior arch of the atlas more than its basal part. Once a bone fusion in ADI is established, it may lead to a stress shielding effect to the fracture site with subsequent delayed or failed fracture union. This hypothesis may explain why a bone fusion in ADI was significantly more common in the fracture nonunion group (100%) than union group (44%).

The union rate of fractured odontoid process after C1-C2 PSF evaluated by CT scan

Several studies used CT scans to evaluate the union rates of odontoid fracture safer C1-C2 PSF.[2,4-8] Ours and Wang's study showed union rates of 60% and 65%, respectively.[7] The remaining five studies showed much higher union rates ranging from 92% to 100. The overall mean ages of ours and Wang's study, which showed generally lower union rates, were 71.3 years and middle forties (precise number not provided), respectively.[7] The union rate and mean ages of Huang's, Yuan's, Bisson's and Faure's studies were 94.8% and 40.7 years, 96% and 42 years, 92% and 75 years, and 100% and 85.5 years, respectively.[2,5,6,8]

Cervical sagittal balance and bone union in odontoid fractures

The influence of cervical sagittal balance on the fracture angle in odontoid fractures and postoperative fracture union rate has rarely been discussed. Wang *et al.* revealed that advanced age (>45 years), long duration of the fracture (>2 months), and preoperative separation of the fractured dens (>4 mm) were

Table 2: The areas and numbers of the bone fusion after C1-C2 posterior screw fixation for odontoid fractures.

The number of the area with bone fusion per the patient	The area of bone fusion			Number (% per total 15 cases)
	Primary fracture in the odontoid process	Atlanto-dental interval space	Interlaminar space between C1 and C2	
3	○	○	○	1 (6.7)
2	○	×	○	3 (20)
2	○	○	×	3 (20)
1	○	×	×	2 (13.3)
1	×	○	×	6 (40)
Total number of the cases (%)	9 (60%)	10 (67%)	4 (27%)	

Table 3: The values of total patients and the comparison between fracture union and fracture nonunion group.

Variables	Total patients (*n*=15)	Fracture union group (*n*=9)	Fracture nonunion group (*n*=6)	*P*-value	Statistical tests
Sex (male/female)	8/7	5/4	3/3	1.00	Fisher's exact test
Age (mean±S.D.)	71.3±13.5	66.2±7.1	78.5±14.8	0.08	Student's *t*-test
graft type (autograft/allograft)	5/10	4/5	1/5	0.58	Fisher's exact test
The median from injury to surgery (days: IQR)	119: 43-140	94.5: 39.25-122.75	119: 61-169	0.33	Mann-Whitney U-test
HU of the fractured odontoid process	683.9±181.8	658.9±169.0	721.6±209.7	0.53	Student's *t*-test
HU of the base of odontoid process	429.3±101.2	443.5±97.3	408.0±112.3	0.53	Student's *t*-test
Maximum separation (mm)		3.8±2.8	3.7±1.9	0.96	Student's *t*-test
Parameters for sagittal balance					
Cervical lordosis (degree)	9.5±16.3	12.2±14.9	5.5±18.9	0.46	Student's *t*-test
C2-C7 SVA (mm)	37.5±19.3	28.8±17.7	50.5±14.3	0.03*	Student's *t*-test
T1 slope (degree)	35.3±11.6	33.5±13.2	38.1±9.0	0.47	Student's *t*-test
O-C2 angle (degree)	26.5±10.1	24.5±8.7	29.6±12.0	0.36	Student's *t*-test
Cervical mismatch (degree)	25.8±13.0	21.3±8.7	32.5±16.2	0.1	Student's *t*-test

*Statistically significant difference. IQR: Interquartile range, HU: Hounsfield unit, SVA: sagittal vertical axis, O-C2: occiput-C2

Table 4: Studied postoperative factors associated with fracture union

	Fracture union group (*n*=9)	Fracture nonunion group (*n*=6)	*P*-value
Radiolucent area around the screws			
Yes	2	3	0.33
No	7	3	
Fusion in ADI			
Yes	4	6	0.04*
No	5	0	
Fusion in C1-C2 interlaminar space			
Yes	4	0	*P*=0.1
No	5	6	

*Statistically significant difference. ADI: Atlanto-dental interval

independently associated with fracture nonunion after C1-C2 PSF.[7] In addition, our study revealed that C2-C7 SVA was positive correlated with the patients' age (Pearson's correlation coefficient; $r = 0.627$, $P = 0.012$, data not shown in the table). This could suggest that an increased C2-C7 SVA secondary to advanced age was contributing to fracture nonunion.

CONCLUSION

Our study identified three anatomical areas where bone fusion likely occurs after C1-C2 PSF. Increased sagittal balance in the cervical spine may negatively impact the fusion of odontoid fractures. Bone fusion occurring at other sites besides the primary fracture location may causing stress-shielding effect to the odontoid fracture and may contribute to delayed or failed fusions.

Declaration of patient consent

Institutional Review Board (IRB) permission obtained for the study.

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Nil.

Conflicts of interest

There are no conflicts of interest.

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