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ORIGINAL STUDY

Comparison of two temporary fixation techniques for the treatment of type II odontoid fracture

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To evaluate and compare the clinical and radiographic results between temporary C1-C2 pedicle screw fixation and cable-dragged reduction and cantilever beam internal fixation.

Between 2010 and 2013, temporary C1-C2 pedicle screw fixation (Group P, 28 patients) and cable-dragged reduction following cantilever beam internal fixation (Group C, 33 patients) were performed on type II odontoid fracture cases. Implants were removed after fracture union.

All of the 61 surgeries were performed successfully with no iatrogenic neurological worsen. One patient in Group P detected intra-operative vertebral artery injury. All patients gained fracture union. Among the observed indexes, only blood loss in Group P (128.9 ± 73.9ml) is statistically higher than in Group C (97.3 ± 5 4.2ml).

Pedicle screw fixation carries the risk of vertebral artery injury, especially in patients with high-riding vertebral artery. Cable-dragged reduction following cantilever beam internal fixation could avoid the potential risk of vertebral injury, but it prolonged the fixed segments. We thought cable-dragged reduction following cantilever beam internal fixation could be an alternative method for treating type II odontoid fracture.

Keywords : odontoid fracture ; temporary fixation techniques ; cantilever beam ; vertebral artery injury ; cervical range of motion.

INTRODUCTION

Odontoid fracture accounts for 5%-18% of all adult cervical spine injury, with an increasing rate in elder patients *(3,13,15)*. The most commonly used classification system is Anderson-D'Alonzo Classification System, which divides odontoid fracture into 3 subtypes. Type I and Type III fractures are reported to obtain satisfactory fracture union rate through conservative treatments as cervical collar or halo-pelvic distraction. But for Type II fractures, conservative treatments can only achieve a 60% fracture union rate *(13)*. Surgical stabilization procedures are introduced to improve the fracture healing rate.

The best surgical treatment for Type II odontoid fracture is still controversial. Anterior odontoid screw fixation has gained acceptance for treating Type II odontoid fractures for its minimally invasive,

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partially preserving range of motion(ROM) of cervical spine and satisfactory fracture union rate *(5,12)*. However, the application of anterior odontoid screw fixation has many restrictions *(1,15,16)*. Also, the procedure carries associated complications, including screw loosening, loss of reduction, neurological injury, dysphonia and dysphagia *(11,18)*. Thus, we preferred posterior options in our institution.

Posterior options are also widely used surgical option for Type II odontoid fracture with or without atlantoaxial dislocation. This procedure could avoid the spinal cord injury or odontoid dislocation caused by the manipulation of extending cervical spine when placing the patients before anterior surgery *(17)*. However, posterior procedures has risks of injuring vertebral artery, also fusion could cause significant loss in ROM of cervical spine *(6,21)*.

Recent years, temporary fixation was used for fresh type II odontoid fractures. This procedure could offer intra-operative reduction and remove internal fixation after fracture fusion. Researches about posterior reduction and temporary C1-C2 pedicle fixation without fusion showed satisfactory fracture union rate and preserving a higher proportion in ROM of cervical spine *(8,17)*. However, pedicle screw insertion, especially for C1, allows only a small margin of error. C1-C2 pedicle screw carries the risk of vertebral artery injury, especially for patients with high-riding vertebral artery. Also, the procedure is not suitable for patients with anomalies of the C1 posterior arch. Therefore, we devised a novel fixation method: cable-dragged reduction following cantilever beam internal fixation for the treatment of type II odontoid fracture. This study aimed to evaluate and compare the clinical results of temporary C1-C2 pedicle screw fixation and cable-dragged reduction following cantilever beam internal fixation.

MATERIALS AND METHODS

This was a retrospective, clinical, comparative study. Between January 2010 and December 2013, 125 odontoid fracture with or without atlantoaxial dislocation patients were treated surgically in our hospital. Of them, 61 type II odontoid fracture patients were treated with temporary fixation methods. 28 were treated by temporary C1-C2 pedicle screw fixation (Group P) and 33 were

Fig. 1. — Axial, sagittal and coronal CT image of C2 showed vertebral artery groove of C2 (arrow). Pedicle screw trajectory narrowed. Revealing potential high-riding vertebral artery

Table I. — General information

General information	Data
Sex (number of patients)	
Male	49
Female	12
Age at operation (years)	
Group P	40.3±12.8
Group C	38.5±10.1
Cause of fracture	
Motor-vehicle accident	27
High falling injury	26
Others	8
Frankel classification system	
Frankel C	4
Frankel D	2
Frankel E	55
Time from trauma to surgery (days)	
Group P	10.1±9.2
Group C	13.3±18.8
Preoperative VAS of cervical pain	
Group P	6.8±1.4
Group C	7.1±1.7

Group P Temporary C1-C2 pedicle screw fixation, Group C Cable-dragged reduction following cantilever beam internal fixation, VAS visual analog scale

treated by cable-dragged reduction following cantilever beam internal fixation (Group C). These 61 patients were enrolled in our study. The exclusion criteria were combined with atlas or other segments injury, severe osteoporosis, ankylosing spondylitis, reheumatoid arthritis and remote fracture. Before surgery, posterioanterior and lateral radiographic images and three-dimensional computed tomographic (CT) images were taken to analysis the subtype of fracture and the severity of dislocation of all patients. MRI was taken to assess compression of spinal cord. Three-dimensional CT of vertebral artery was taken for those patients with potential high-riding vertebral artery to assess the risk of injury (Fig 1). The study had been approved by the Ethics Committees of Sichuan University. Every patient gave informed consent. Preoperative general information from the patients was summarized in Table 1.

Patients were performed skull traction (2.5-5kg) while admission if there was no contradiction. All operations were performed by experienced surgeons in our institution.

During both of the two means of surgery, patients were under general anesthesia and placed in a prone position. A Mayfield head holder was used to maintain the cervical spine in proper position. Bandages were applied across patient's shoulders to pull them caudad so that intra-operative lateral radiographic image could be obtained well. Before surgery, lateral radiographic image were taken by C-arm radiography to record the preoperative position of C1 and C2. All operations were under neuromonitoring.

Before incision, diluted epinephrine (1:500000) was injected subcutaneously to minimize blood loss. A midline incision was made in occipitocervical region, and dissection of soft tissue and muscle to expose surgical region— C1 posterior arch, C2 spinous process and pedicles. All procedures were done carefully, the exposing distance from midline bilaterally is less than 1.5cm to avoid injury to vertebral artery and vein *(7)*. C1 pedicle screw and C2 pedicle screw insertion was performed by Harm's technique (10). Most of the screws used in operation were unidirectional or multidirectional screw with proper inserted length (Vertex Max; Medtronic Sofamor Danek, Memphis, TN, USA). Then posterioanterior and lateral intra-operative radiographic image would be taken by C-arm radiography to assess the position of screw. Using rod pusher and rod reducer to bend the rod into proper curve. Pushing the rod into the saddle of screws and fixed the nuts into the saddle to achieve intra-operative reduction. Then, lateral radiographic image was taken to assess whether satisfactory reduction was obtained. Intraoperative photograph of temporary C1-C2 pedicle screw fixation was showed in Fig 2. Then the incision was closed in layer with a drainage tube reserving for 24-48 hours, depending on the amount of drainage.

The surgical region was C1 posterior arch, C2-C3 spinous process and lateral mass. Screws were inserted in C2-C3 lateral mass using Magerl's technique (20). A precontoured U-shaped rod with its head slanting backwards slightly, was pushed into the saddle of screws with temporary nuts fixation. The head-up-arm-down position was to form a cantilever beam. Using a nerve dissector to blunt separate the periosteum from posterior arch of C1 carefully. A cable, with whose head molded into a hook, passed through the interior surface of C1 posterior arch on each side meticulously. Then the cables crossed the head of cantilever beam, and fastened the cable. Through this procedure, the atlas and odontoid gradually move posteriorly relative to C2 vertebral. Once satisfactory reduction was obtained, and confirmed by C-arm radiography, the needless part of cables was removed and sheared into

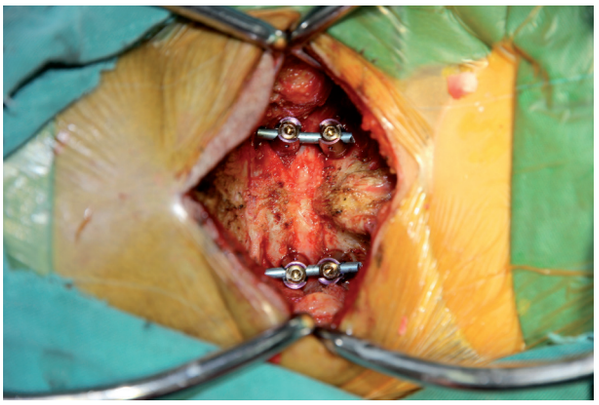

Fig. 2. — Intra-operative photograph of temporary C1-C2 pedicle screw fixation

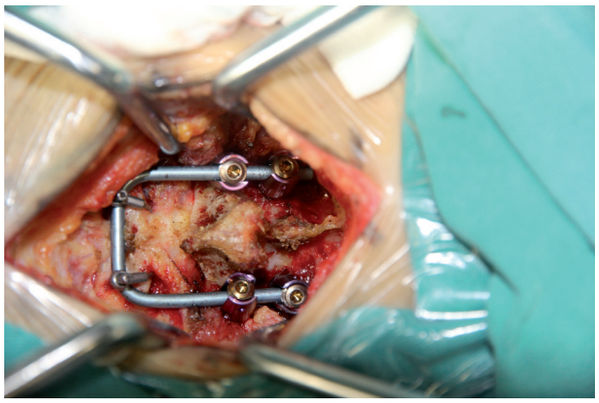

Fig. 3. — Intra-operative photography of cable-dragged reduction following cantilever beam internal fixation

blunt surface to avoid injury of soft tissue. The nuts were then fixed into the saddle of screws. Bone graft was not used after internal fixation. Intraoperative photograph of cable-dragged reduction following cantilever beam internal fixation was showed in Fig 3. The incision was closed with a drainage tube reserving for 24-48 hours, depending on the amount of drainage.

After surgical procedure, patients were asked to remain lying in bed for three days before ambulation with proper cervical collars protecting the neck. Anterioposterior and lateral radiographic images were taken once the drainage tube was removed (Figure 4, 5 showed with preoperative lateral radiographic image). The cervical collar was applied for additional protection for 6-8 weeks.

All the 61 patients were followed up every three months after discharge. Once fracture union was confirmed by three-dimensional CT images (Fig 6), the internal fixation was removed through a second operation. Neck pain (evaluated by visual

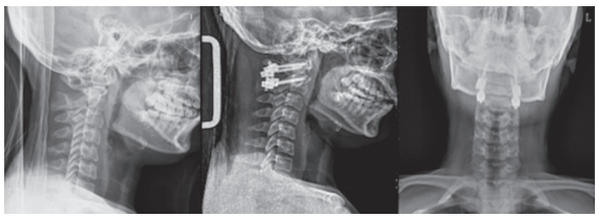

Fig. 4. — Preoperative and postoperative radiographic images of patient who underwent temporary C1-C2 pedicle screw fixation. Postoperative lateral image showed satisfactory reduction of C1-C2

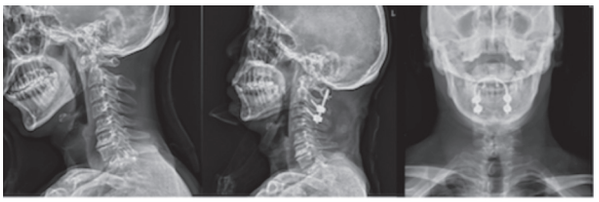

Fig. 5. — Preoperative and postoperative radiographic images of patient who underwent cable-dragged reduction following cantilever beam internal fixation. Postoperative radiographic images revealed good internal fixation's position and reduction

analog scale) was recorded at admission and after inner fixation. Neck disability index (NDI) were evaluated before and after removing inner fixation. Patient's satisfaction was recorded at the final follow-up.

The values were presented as means, standard deviations and ranges. The significance of differences between means was analyzed by Student's t tests. The level of significance was set as 5%. Data was analyzed using SPSS 19.0 software.

RESULTS

All the surgery was operated successfully. The operation time lasted from 107-142 min (mean 119.7 ± 13.6) for Group P and from 110-134 min (mean 122.9 ± 11.4) for Group C. Blood loss during operation is 128.9±73.9ml for Group P and 97.3±54.2ml for Group C. Five patients detected high-riding vertebral artery through pre-operative examination and treated with cable-dragged reduction following cantilever beam internal fixation. Six patients suffered neurological deficit (four Frankel C, two Frankel D) obtained partial recovery. One patient in Group P detected vertebral artery injury intra-operative when inserting C2 pedicle screw on the right side, with tamping gelatin sponge and pressing slightly, bleed stopped eventually. Post-operative three-dimensional CT of vertebral artery showed the diameter of right vertebral artery narrowed, no symptom of infarction was detected during follow-up.

The follow-up period is 23.8 months. No cases of screw pullout, instrumentation loosening, or rod rupture was detected before bone healing. Four patients in Group C with titanium cable broke were

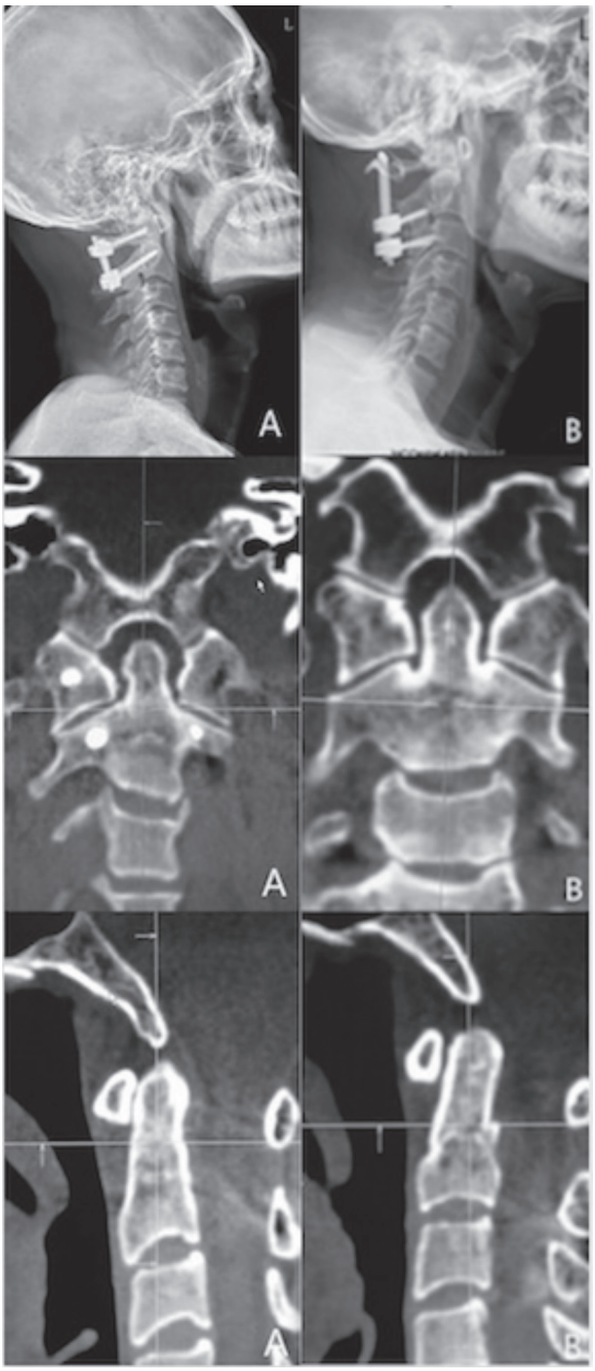

Fig. 6. — Radiographic and CT images of patient who underwent temporary C1-C2 pedicle screw fixation, three dimensional CT confirmed fracture union (a). Radiographic and CT images of patient who underwent cable-dragged reduction following cantilever beam internal fixation, CT images confirmed fracture union (b)

detected during inner fixation removing. But the fracture fusion was satisfactory. We did not detect any additional fusion between joints of C2-C3 during the follow-up. In Group P, the VAS of cervical pain dropped from 6.8±1.4 preoperatively to 1.1 ± 0.8 at the second admission, NDI decreased from 9.2 ± 3.3 before removing inner fixation to 1.4±1.2 after removing. In Group C, these two indexes are 7.1 ± 1.7 to 1.0±0.9 and 8.5 ± 2.9 to 1.5 ± 1.5. Patient's satisfaction at the final follow-up is 9.5 ± 1.1 and 9.4 ± 0.7 respectively. All patients in our research gained fracture union. Once fracture union was confirmed by three-dimensional CT image and internal fixation was removed. No statistic difference was found in baseline data of patients between two groups—age at operation, time from trauma to surgery, preoperative VAS of cervical pain, operation time and duration between fixation insertion to removing. Still we found no statistic difference between two groups in postoperative VAS of cervical pain, change of NDI, patient's satisfaction and ROM of cervical spine. Average blood loss during operation for the Group C was significantly less than for the Group P. Statistic results were listed in table 2.

DISCUSSION

Type II odontoid fracture is the most common type of dens fracture and require surgical treatment. The surgical options have been controversial in the past half century. Since anterior odontoid screw fixation technique was firstly introduced in early 1980s, it has been used widely. But for its restriction in application, many patients who suffered odontoid fracture are not suitable for this procedure (1,15,16). Also, complications and high technique requirement restricted its application (11,18).

Posterior C1-C2 pedicle screw fixation has been established by Harms in 2001 (10), and since then this procedure has been applied widely. This procedure avoids damage to C1-C2 facet joint, thus iatrogenic C1-C2 arthritis could be avoided. Hong et al assessed biomechanical stability of various C1-C2 posterior fixation techniques, result showed C1-C2 pedicle screw fixation have no

Table II. — Average age, time from trauma to surgery, preoperative and postoperative VAS of cervical pain, blood loss during operation, , duration between fixation insertion to removing, change of NDI after removing fixation, patient's satisfaction and average ROM of cervical spine between Group P and Group C and statistic results

	Group P	Group C	P value
Age at operation (years)	40.3±12.8	38.5±10.1	0.672
time from trauma to surgery (days)	10.1±9.2	13.3±18.8	0.685
preoperative VAS of cervical pain	6.8±1.4	7.1±1.7	0.460
blood loss during operation (ml)	128.9±73.9	97.3±54.2	<0.05□
postoperative VAS of cervical pain	1.1±0.8	1.0±0.9	0.651
duration between fixation insertion to removing (months)	8.7±2.2	9.2±1.9	0.762
change of NDI after removing fixation	7.7±2.6	7.0±2.4	0.279
patient's satisfaction	9.5±1.1	9.4±0.7	0.669
ROM of cervical spine (°)	32.1±3.5	31.5±3.1	0.558

Group P Temporary C1-C2 pedicle screw fixation, Group C Cable-dragged reduction following cantilever beam internal fixation, VAS visual analog scale, NDI Neck disability index; $p<0.05$ significant difference, $p\geq0.05$ no significant difference

statistic difference in biomechanical stability with transarticular screw fixation *(19)*. Fusion decreases a great amount of cervical ROM, witch reduces quality of living. Recent years, posterior reduction and temporary fixation is used in type II odontoid fracture patients. Researches about temporary C1-C2 pedicle screw fixation applied in odontoid fracture have mainly focused on the rate of fracture union and range of motion especially rotation because atlantoaxial joint accounts for 50%-60% of axial rotation in cervical spine *(4)*. Han et al reported 13 odontoid fracture patients underwent temporary C1-C2 pedicle screw fixation, all patients achieved fracture union with no implant failure *(8)*. Dynamic CT of these 13 patients showed a 20% decrease in total axial neck rotation after fixation removing compared with normal values. Another research showed a 95.5% fracture healing rate and a higher decrease in total axial neck rotation due to short follow-up time and local scar tissue contracture *(17)*.

Vertebral artery injury was one of the most severe complications when inserting pedicle screw *(23)*. The risk increased when patients combined with high-riding vertebral artery. Vertebral artery injury can cause brain stem infarction, massive bleeding, pseudoaneurysm or even death. Though the technique has been improved, vertebral artery injury sometimes happened. Aota et al reported one case of vertebral artery injury due to malposition of C1 pedicle screw fixation and cause a blood loss of 750ml during surgery *(2)*. Yeom et al reported one case of delayed unilateral vertebral artery occlusion after C2 pedicle screw fixation *(24)*. Even though sometimes malposition of pedicle screw into the transverse foramen may not appear clinical manifestation, it still carries potential risk. Yeom et al simulated inserting C1-C2 pedicle screw with 1-mm-sliced CT scan and 3D reconstruction software in 269 patients, 8% of C2 pedicle screws violated the C2 vertebral artery groove. And when evaluating patients with high-riding vertebral artery, the rate increased to 49%, which is relatively dangerous *(25)*. Pedicle screw insertion is not suitable for cases with anatomic anomalies of posterior arch and lateral mass *(22)*. In our research, if preoperative three-dimensional CT showed the diameter of C2 pedicle is not enough for inserting pedicle screw or the potential existing of high-riding vertebral artery, cable-dragged reduction following cantilever beam internal fixation was selected. Five patients with potential high-riding vertebral artery were all treated with cable-dragged reduction following cantilever beam internal fixation. One patient treating with pedicle screw emerged right

vertebral artery injury due to malposition of C2 pedicle screw. The intra-operative blood loss of this patient was 300ml. No cases of vertebral artery injury were detected in Group C.

Cable-dragged reduction following cantilever beam internal fixation was firstly used in treating irreducible old atlantoaxial subluxation *(14)*. This treatment is an alternative choice of occipitocervical fusion and anterior reduction, with the advantage of effective reduction, less invasive and partial preservation of ROM. Huang et al compared the mechanical stability of cable-dragged reduction following cantilever beam internal fixation with other three posterior surgical options. The result showed that cable-dragged reduction following cantilever beam internal fixation was only lower than Magerl screws fixation in the stability of the extension, but in other ROM, it has no statistic difference *(9)*. This technique was now used as temporary fixation for treating Type II odontoid fracture. Inserting lateral mass screws of C2-C3 reduces the risk of vertebral artery injury significantly. Cable-dragged reduction following cantilever beam internal fixation requires intact C1 posterior arch to obtain reduction and fixation. The cable needs to pass through the interior surface of C1 posterior arch, which may injury the spinal cord. There is no case of neurologically worsen in our research.

In our study, excellent bone fusion rate were achieved in both groups. No statistic difference was found in VAS of cervical pain, NDI and patient's satisfaction. Blood loss in temporary C1-C2 pedicle screw fixation is statistically higher than cantilever beam internal fixation. We consider it may due to bleeding of screw track when inserting screws. The length of inserting screws was measured pre-operatively. Compared to lateral mass screw, inserting pedicle screw required more attention in order to avoid neurological complication or vertebral artery injury. The screw track was firstly drilled to a safe length and then prolonged 2 mm each time. Screw inserting time was longer than that in Group C.

The major disadvantage of cable-dragged reduction following cantilever beam internal fixation is prolonged the fixed segments to C3. Thus increases the surgical trauma and may lead to fusion of C2-C3 joints. Prolonged fixed segments may influence the cervical ROM, especially flexion-extension. In our research, no fusion was detected on three-dimensional CT of C2-C3 joints and flexion-extension radiographic images showed no statistic difference between two groups. But we thought fusion may happen for patients with a longer duration between fixation insertion to removing. Despite of this, we considered cable-dragged reduction following cantilever beam internal fixation as an optimal salvage maneuver for treating type II odontoid fracture patients, especially for cases not suitable for placement of pedicle screws.

There were limitations to our study. Firstly, it was a retrospective, comparative study without randomization. Secondly, lack of assessment of the axial neck rotation. Finally, the number of subjects in our research was small. We had insufficient power for full statistic study. Future studies, enrolling more patients with axial neck rotation assessment will be necessary to evaluate the clinical and radiographic efficiency.

CONCLUSION

Temporary C1-C2 pedicle screw fixation and cable-dragged reduction following cantilever beam internal fixation all achieve satisfactory reduction and fracture union rate. We did not experience serious complications in the population when performing the procedures. No statistic difference was found between two groups in VAS of cervical pain, NDI, patient's satisfaction and ROM of cervical spine. Pedicle screw fixation carries the risk of vertebral artery injury, especially in patients with high-riding vertebral artery. Cable-dragged reduction following cantilever beam internal fixation could avoid the potential risk of vertebral injury and reduce the amount of blood loss during surgery, but it prolonged the fixed segments. We thought cable-dragged reduction following cantilever beam internal fixation could be an alternative method for treating type II odontoid fracture.

Conflict of interest

All authors disclose any financial and personal relationship with other people or organizations that could inappropriately influence (bias) this work.

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