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Original Article

Efficacy and safety of different treatments for Grauer type II odontoid fractures: a preliminary study

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Abstract: The purpose of this study was to investigate the clinical efficacy of different treatment methods for Grauer type II odontoid fractures (OF). Forty-two cases of type II OF that received treatment in our hospital from 2006 to 2013 were retrospectively analyzed. There were six cases of type II A, 26 of type II B, and 10 of type II C. The six cases of type II A OF first underwent skull traction, followed by the application of a Halo vest; 19 cases of type II B received anterior odontoid stabilization (group A); the other seven cases of type II B patients with obvious fracture displacement and 10 cases of type II C patients underwent posterior atlantoaxial stabilization (group B). The 42 patients were followed up for 12-24 months, and all patients' fractures healed. The screw used in the atlantoaxial complex was loose after six months in one type II C patient in group B, who received a revision to re-set the screw with iliac bone grafting. In that case, union was achieved in the one-year follow-up, with satisfactory clinical efficacy. Type II A OF should be treated with conservative therapy, type II B OF should be treated with anterior odontoid stabilization, and type II C OF and the II B OF with apparent fracture displacement should be treated with posterior atlantoaxial stabilization. Appropriate treatment plans should be applied according to the different types of OF to obtain satisfactory results.

Keywords: Odontoid, fracture, fracture fixation, internal

Introduction

Odontoid fracture is a relatively common cervical spine injury, accounting for approximately 9%-15% of adult cervical spine fractures. It is mainly caused by high-energy injuries in young and middle-aged people and low-energy injuries in older people. Its incidence gradually increases with age, and the incidence rates in males and females are similar. In terms of the pathogenesis of odontoid fractures (OF), the generally accepted current opinion is that it is caused by the excessive extension and flexion of a cervical spine injury, with the incidence of neurological injury ranging from 2% to 27% [1]. However, spinal cord injury often results in fatal consequences. The treatment of odontoid fractures and its clinical efficacy have been regarded as controversial in clinical practices. In this study, a total of 42 cases of type II OF that received treatment in our hospital from 2006 to 2013 and had complete clinical data were retrospectively analyzed. According to Grauer typing, there were six cases of type II A, 26 cases of type II B, and 10 cases of type II C. Of these cases, four were associated with spinal cord injury, including three cases of type II B and one case of type II C. Appropriate treatment methods were applied depending on the fracture type to achieve a curative effect. A retrospective efficacy analysis was performed in this study.

Materials and methods

Patients

The study subjects included 27 males and 15 females, with an age range from 20 to 65 years old and a mean age of 42 years old. The causes of injury included 18 cases of traffic accidents, 13 cases of falling from heights, seven cases of falling on the ground, and four cases of crashes with heavy objects. The time from injury to admission ranged from 4 h to 18 h, with an average of 9.6 h. After injury, all 42 cases experienced occipitocervical pain and limitation of cervical activity; of these cases, four were associated with incomplete spinal cord injury, including two cases of grade C and two cases of grade

D, according to Frankel grading. Routine X-ray examinations of the cervical spine with orthotopic, lateral, and open positions and 3-D occipitocervical reconstructions by computed tomography (CT) and cervical magnetic resonance imaging (MRI) were preoperatively performed for all patients.

Preliminary intervention

Radiography was conducted for the patients immediately after admission, and early cervical CT and MRI were performed if possible. The patients who experienced spinal cord injury were treated for dehydration and provided with hormonal therapy and nutritional nerve therapy, and the patients suffering from spinal cord injury within 8 h were treated for shock using a high dose of methylprednisolone (MP) for 24 h. Glisson's occipital-jaw traction jaw (type II A) or skull traction (some type II A, all type II B and type II C) was applied to all patients as soon as possible. The position of the head and neck and the traction direction and weight were adjusted according to the situations of odontoid and atlantoaxial shifting. For patients with odontoid fracture displacement or atlantoaxial dislocation, the resetting was monitored by radiography every other day, with timely adjustment of the traction weight and direction, and surgery was scheduled according to the reset situation.

Conservative therapy

The six cases of type II A OF patients first underwent Glisson's occipital-jaw traction or skull traction for two weeks, followed by immobilization using a Halo vest for six months. Periodic reviews of X-ray and CT results were conducted to observe the healing or displacement of the fractures.

Surgical procedure

Anterior odontoid stabilization with a hollow screw: After general anesthesia, the patient lay in a supine position with the neck stretching backward and in an opened position. With skull traction, the odontoid reset was observed using a C-arm X-ray in the orthotopic and lateral positions, which were adjusted until satisfactory. A transverse incision was created at the level of the thyroid cartilage, entering the anterior spinal route via the carotid and visceral sheaths. With the C2-3 vertebral bodies and intervertebral space exposed upward, the anterior upper lip edge of the C3 vertebral body was excised. A positioning hole was created at the midpoint of the anterior lower edge of the C2 vertebral body with a bone awl. The entire process was monitored using a C-arm X-ray machine, guided by the sleeve guideline at an inclination of 15-20°. A guiding pin 1.5 mm in diameter was slowly drilled along the longitudinal axis of the odontoid to reach the site under the cortex of the odontoid tip through the fracture line. After drilling a hole using a hollow drill, a UCSS (Medtronic, Inc. Minneapolis, USA) anterior hollow screw 3.5 mm in diameter and of an appropriate length was implanted. After fixation and confirmation with the perspective view, the operative area was rinsed, a drainage tube was set up, and the incision was closed. The patient wore a neck brace for three months after the surgery.

Posterior atlantoaxial stabilization with pedicle screw: After the identical anesthesia as above procedure, the patient was set in the prone position with skull traction, and the cervical spine was placed in mild flexion. Both shoulders were pulled backward with broad tape to an appropriate position for exposure during surgery. An incision was created from the occiput to the middle of the C2 posterior spinal route to expose the lower edge of the occipital bone, the posterior arch of the atlas, and the atlantoaxial lamina. The posterior arch of the atlas was exposed 2.0-2.5 cm from the midline to the sides. The bone cortex at the pin site of the pedicle screw was removed using a power drill, and the yellow ligament between the posterior arch of the atlas and the atlantoaxial lamina was detached from the outer attachment point. After clearing the inner and upper edges of the atlantoaxial pedicle using a nerve dissector, the atlas screw was placed. The posterior tubercle of the atlas was opened from the midpoint to both sides by 18-20 mm, with an intersection 2 mm above the lower edge of the posterior arch and an inward inclination of 5-10°. The atlantoaxial pedicle screw was placed. According to the Roy-Camille method, the anchor site was at the center of the side block (the posterior vertex of the small joint). The entering direction of the screw was 10° between the sagittal plane and the line from the posterior inside pointing to the outer anterolateral to avoid the vertebral artery. After the cortical bone was pierced at the pedicle using a

Table 1. General surgical information of the patients in the two groups (mean ± standard deviation)

Item	Operation time (min)	Intraoperative blood loss (ml)	Preoperative VAS	One year postoperativeVAS
Group A	97 ± 22	217 ± 44	8.6 ± 0.5	0.8 ± 0.3
Group B	153 ± 47	416 ± 61	8.2 ± 0.7	1.0 ± 0.5
P value	0.032	0.026	0.950	0.784

Note: Group A received anterior odontoid stabilization with a hollow screw; group B received posterior atlantoaxial stabilization with a pedicle screw. VAS refers to the Visual Analogue Scale.

sharp hand cone, the screw's channel wall was detected carefully along the pedicle with a spherical probe. After confirming that the bone channel was located in the lateral mass and the vertebral body, a 20 mm hole was slowly drilled. If no abnormality was observed, the drilling was deepened to 30 mm. The same procedure was conducted on the opposite side. As a result, two pedicle screws 3.5 mm in diameter and 22-26 mm in length were placed into the atlas, and two pedicle screws 3.5 mm in diameter and 24-28 mm in length were placed into the atlantoaxial complex. A connection rod of an appropriate length was selected and implanted after pre-bending. The nut was screwed in for temporary fixation. A careful reset was performed under the perspective view, and the nut was also tightened. The cortical bone of the posterior arch of the atlas, the atlantoaxial lamina and the spinal surface was removed using a power drill to form the bone graft bed. A piece of half-plate bone from the posterior upper right iliac spine was taken and trimmed to serve as a strip to place on the surface of the bone graft bed. After covering the graft with a gelatin sponge and setting a suction drainage tube, the incision was sutured in layers.

Postoperative care and outcome assessment

Patients were treated for dehydration and antibiotics were given based on the patient's condition, with close observation of any changes in vital signs and limb muscle strength. The drainage tube was removed within 24-72 h after surgery. Once extubated, the patient wearing a neck brace started to exercise out of bed. By 12 d after surgery, the stitches were removed, and a cervical spine X-ray in the orthotopic and lateral positions and a CT examination were performed to observe the positioning of the screws and their fixation conditions. Patients wore their neck braces for 3 months postoperatively. In 1, 3, 6 months and 1 year after surgery, X-rays in the orthotopic, lateral and extension/flexion positions of the cervical vertebrae were routinely scanned to observe the fixation position and the condition of the bone fusion. Frankel grading was conducted for patients with spinal cord injury before and after surgery.

Statistical analysis

Statistical analysis was performed with Statistical Product and Service Solutions (version 13.0 for Windows; SPSS, Chicago, IL, USA). Mean ± standard deviation (SD) is used to present measurement data when it satisfied criteria for normality with $P > 0.10$. Otherwise, it should be expressed as median (interquartile range, IQR). Statistical analysis between groups was performed using independent samples t-test when data satisfied criteria for normality and homogeneity of variance. $P < 0.05$ was considered statistically significant.

Results

The preoperative VAS (Visual Analogue Scale) score of the patients in group A was 6-9 points, with an average of 8.6 ± 0.5 points. The postoperative score one year follow-up was 0-3 points, with an average of 0.8 ± 0.3 points. The preoperative VAS score of the patients in group B was 5-9 points, with an average 8.2 ± 0.7 points. The postoperative VAS score one-year follow-up was 0-3 points, with an average of 1.0 ± 0.5 points. The mobility of the cervical spine had significantly improved after surgery. For the two cases of spinal cord injury patients with preoperative neurological function of Frankel grade C, one case recovered to grade D postoperatively, and the other case recovered to grade E postoperatively. The two cases of patients with preoperative grade D were both restored to grade E. The operative time for group A was 97 ± 22 min, and the blood loss was 217 ± 44 mL. The operative time for group B was 153 ± 47 min, and the blood loss was 416 ± 61 mL, which were significantly different in two groups ($P < 0.05$) (**Table 1**). The cervical vertebrae flexion of the patients was close to normal, but rotation was obviously limited. There was no significant decline in quality of

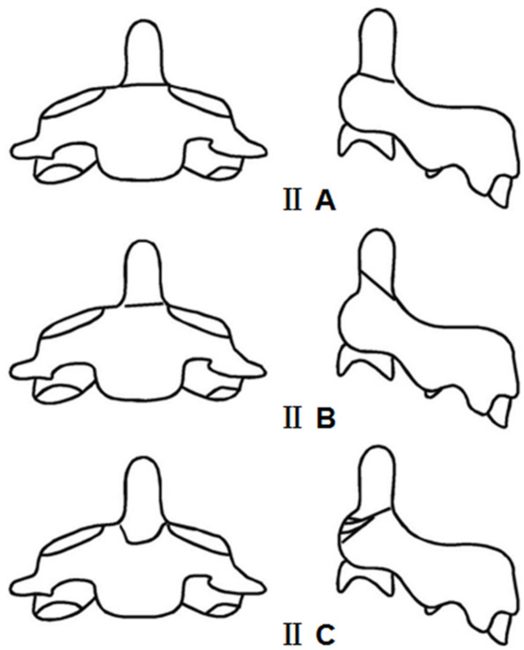

Figure 1. Schematic subtyping of the type II OF [3]. Type II A: non-displaced or minimally displaced fractures, non-comminuted fracture blocks. Type II B: displaced fracture, the fracture line direction is from the upper front to the lower rear or transverse. Type II C: the direction of the fracture line is from the lower front to the upper rear or showing comminuted fracture blocks at the fracture end.

life. No intraoperative spinal cord injuries occurred in either anterior or posterior surgeries. After the 12-24 months of follow-up, with an average of 14.8 months, all patients' fractures were healed. The screw in the atlantoaxial complex was loose six months after surgery in one case of a type II C patient in group B (5.9%). That patient received a revision to re-set the screw with iliac bone grafting, and the follow-up after one year showed good positioning of the screw-rod and bone union (**Figure 3**).

Discussion

OF is a common cervical spine injury. In 1974, Anderson et al. [2] divided OF into three types according to the fracture site. In type I, the fracture is at the odontoid tip, with small fracture bone blocks, an intact transverse ligament, and good atlantoaxial stability. In type III, the fracture is at the vertebral body axis; the incidence of this type of injury is approximately 32%-40%. Because the fracture line runs through the cancellous bone in the vertebral axis, the fracture healing rate is high. Therefore, type I and type III OF are commonly treated with traction, Halo vest fixation and other conservative treatment methods. In type II, the fracture is at the connection of the odontoid and the pivot of the vertebral body, with an incidence of approximately 35%-74%. Due to direct damage to the nourishing blood vessels of the base, insufficient blood supply can be present in the odontoid, and inaccuracy of the external fixation could lead to nonunion or delayed union, with a high incidence of pseudoarthrosis. In 2005, Grauer et al [3] further divided the type II odontoid fracture into three subtypes: type II A, with nondisplaced or minimally displaced fractures and non-comminuted fracture blocks; type II B, with displaced fractures, and the fracture line direction is from the upper front to the lower rear or transverse; and type II C, with the direction of the fracture line from the lower front to the upper rear or exhibiting comminuted blocks at the fracture end (**Figure 1**). In this study, type II odontoid fractures were subtyped using the Grauer method, and our results indicate that the subtyping of the Grauer method based on the fracture anatomy is simple and applicable. This method has a strong guiding value for the choice of treatment and prognosis inference.

Currently, the treatment of type II OF remains controversial [4, 5]. In this study, six cases of type II AOF patients were first treated with Glisson's occipital-jaw traction or skull traction for two weeks, followed by Halo vest immobilization for six months. Although many external fixation braces, such as the Halo vest, the Philadelphia cervical collar and the Miami neck collar, are available, due to particular features of the upper cervical spine in terms of anatomy and biomechanics, we chose the Halo vest instead of the Philadelphia cervical collar or the Miami neck brace, which are more comfortable and convenient to wear, mainly because the latter is far worse than the former in terms of both braking effect on the cervical vertebrae and safety [6, 7].

The union rate for conservative treatment is low, and direct anterior surgery or indirect posterior surgery can maintain fracture stability. Previous studies have focused on the complications and surgical treatment options for type II OF. The nonunion rate for conservative treatment for type II OF has been reported in the range of 13%-85% [8-11], and overall fixation could not improve the fusion rate.

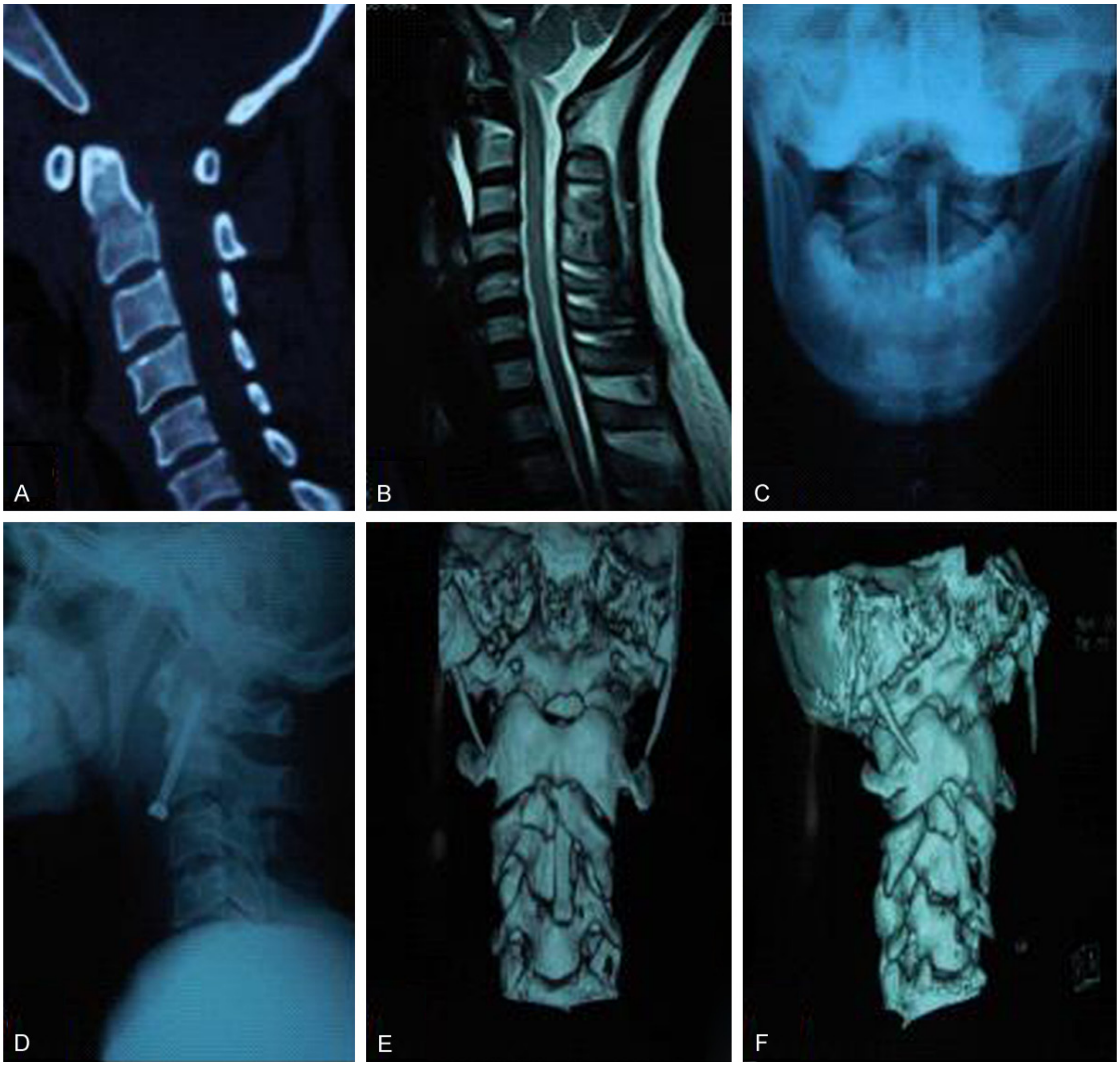

Figure 2. Radiological data from a typical case. Female patient, age 37, type II B odontoid fracture (with no obvious displacement). A. Preoperative Two-dimension-computed tomography (2D-CT) reconstruction shows a discontinuity of the odontoid cortical bone, with a transverse fracture line and no obvious displacement in the fracture. B. MRI shows an odontoid fracture with a slight displacement and no sign of spinal cord compression. C, D. One year after surgery, the cervical spine X-ray in the orthotopic and lateral positions shows satisfactory positioning of the internal fixation and a blurry fracture line. E, F. One year after surgery, the Three-dimension-computed tomography (3D-CT) reconstruction shows good positioning of the internal fixation and a healed fracture.

Contraindications include the elderly and patients suffering from claustrophobia syndrome [8, 12]. It is generally believed that the causes of low union rate include age, blood supply, the direction and location of fracture displacement, fracture angulation, and lack of timely fixation after injury. Previous studies have shown that an adequate blood supply is an important factor to promote fracture union [13, 14]. The current consensus of the surgical indications are: fracture displacement exceeding 6 mm; displacement after fracture; the patient is older than 40 years old; the fracture occurred over three weeks ago; and the fracture angle exceeds 10° [15-17]. The surgical options include anterior odontoid stabilization with a hollow screw and posterior atlantoaxial stabilization with a pedicle screw.

Selection and efficacy analysis of the surgical procedure

Anterior odontoid stabilization with a hollow screw: This surgical procedure can maintain the stability of atlantoaxial rotation and can

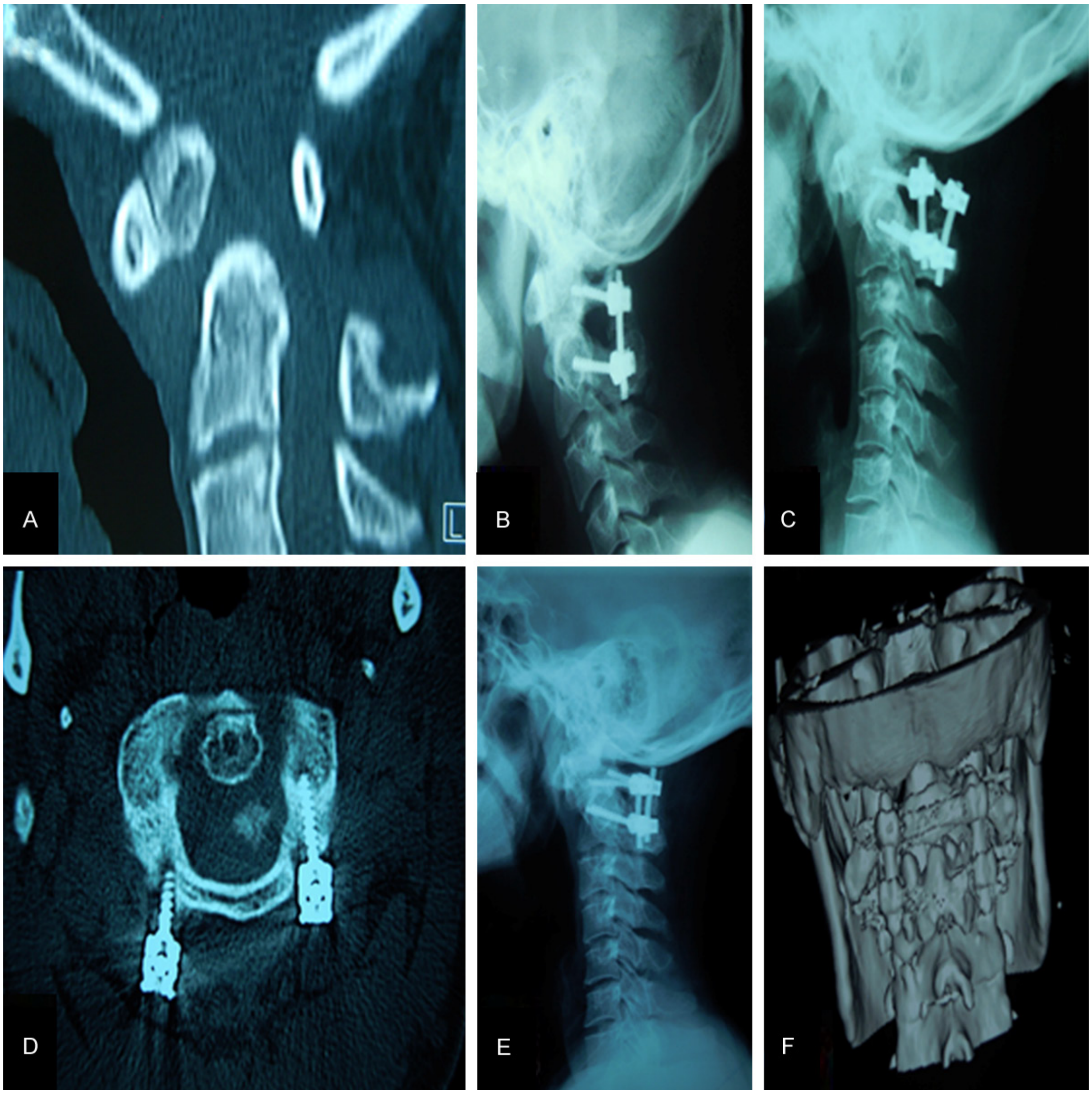

Figure 3. Radiological data from a typical case. Male patient, age 66, type II B OF (with obvious displacement). A. 2D-CT reconstruction shows a discontinuity in the odontoid cortical bone with obvious displacement of the fracture. B. A postoperative lateral cervical spine X-ray shows satisfactory positioning of the internal fixation. C. In the follow-up six months after surgery, the lateral cervical spine X-ray shows that the screw in the atlantoaxial complex was loose. D. In the follow-up six months after surgery, the cervical vertebral 2D-CT reveals the extrusion of the atlas pedicle screw on the right side. E. After revision, the lateral cervical spine X-ray shows satisfactory positioning of the internal fixation. F. One year after the revision, the 3D-CT reconstruction shows good screw-rod positioning and fusion of the bone graft.

avoid the complications of bone grafting. Especially for young patients or those who need to maintain atlantoaxial activity, this option can balance between fracture union and atlantoaxial activity, as this method achieves a union rate of 91-100%. However, although atlantoaxial activity can be theoretically retained, a clinical study indicated that postoperative atlantoaxial activity remains limited [18]. In current study, the 26 patients with type II B injuries underwent the above procedure (**Figure 2**). A high fracture union rate was observed, and the patients experienced rapid postoperative recovery, with normal neck flexion and rotation. After 12-20 months of follow-up, soft tissue injury, screw breakage, fracture displacement, nonunion or screw attack out of the odontoid causing spinal cord injury and other complications did not occur. We believe that a carefully performed operation conducted under dualplane X-ray can avoid the mistakes in placing the pedicle screw. First, this method fully revealed that during the surgical procedure, the drill should be close to the end to better protect the soft tissues. The drilling should be performed especially carefully to avoid any soft tissue involvement that can cause vascular injury. If the surgery is performed in strict accordance with the indications for surgery, if attention is paid to the operational details in the surgical procedure and if premature and excessive postoperative neck exercise is avoided, anterior odontoid stabilization with a hollow screw can achieve a good result.

Posterior atlantoaxial stabilization with a pedicle screw: Traditionally, posterior atlantoaxial fixation is considered a preferred treatment option for type II OF. Gallie, Brooks and Jenkins et al recommended the wire cerclage technology [19, 20], and Magerl later proposed a stronger internal fixation-pedicle C1-2 screw stabilization [21]. The surgical indications are: type II C OF; type II B OF with severe odontoid displacement or that have been poorly reset; old fractures or those accompanied by transverse ligament injury; odontoid pathological fractures; patients unsuitable for or who do not accept the Halo vest; and patients exhibiting nonunion or failure in odontoid screw fixation who require revision surgery. The main complications of this procedure include vertebral artery injury, pedicle screw failure, potential nerve injury, and implant fracture. It has been reported that if C1 is not preoperatively reset, the risk of vertebral artery injury and pedicle screw failure is significantly increased [22, 23]. In this study, seven type II B cases with apparent fracture displacement and 10 type II C cases underwent the above procedure, with no evidence of intraoperative injury in the spinal cord and vertebral artery. Bone unions were achieved in the postoperative follow-up. Although the patients' rotational activity was obviously limited, neck flexion was normal, there was no significant decrease in quality of life, and no delayed spinal cord compression or injury occurred. It is believed that surgeons need to perform a comprehensive preoperative assessment for pedicle size, direction, and the existence of anatomic variations and should be aware of the screw diameter, length, direction and other parameters to reduce the incidence of complications. Ultimately, an accurate anchor site and a good entering angle for the screw are the keys to success for this type of surgery. The Roy-Camille method for pedicle screw placement achieved good efficacy in this study, with low incidence rates of intraoperative and postoperative complications and exhibiting clinical significance. It is worth noting that the extrusion of the screw in the lateral atlas occurred in one patient in the 6th postoperative month. The reason for this extrusion might be related to use of the wrong size screw, insufficient grafting bone used and poor patient compliance (performing exercises too early). This patient underwent posterior atlantoaxial fixation revision plus iliac surgery under general anesthesia, and a coarse screw was used to strengthen the firmness of the pedicle screw placement. The one year follow-up CT after the revision procedure showed that the position of screw-rod was good and the bone graft was fused.

Limitations of the study

Finally, it is unavoidable that the study has several limitations. Considering the small sample size, short follow-up period, and the fact that the patients were from a single center in this study, the above conclusion needs to be confirmed with a multi-center long-term study with a large sample size.

Conclusion

In summary, OF should be differentially treated based on type. The key to success with these types of procedures is to rebuild the stability of the upper cervical spine while attempting to retain the physiological atlantoaxial activity. Conservative therapy, such as traction and Halo vest use, can be appropriate for type II A OF, while anterior odontoid stabilization with a hollow screw can obtain satisfactory results for type II B OF with no obvious displacement. The type II B cases with obvious fracture displacement and type II C cases should be treated with posterior atlantoaxial stabilization with a pedicle screw.

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Disclosure of conflict of interest

None.

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