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POSTTRAUMATIC AXIS DENS PSEUDOARTHROSIS: REPORT OF 12 CASES MANAGED VIA MODIFIED CRANIOCERVICAL FUSION AND ANTERIOR SCREW FIXATION

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Abstract:

Objectives*: surgical management of the axis dens pseudoarthrosis remains controversial due to the complex anatomy and biomechanics of this region. The current management strategy for this pathology is posterior atlanto-axial fusion or combined anterior and posterior fusion utilizing various bone and metallic constructs. Anterior fusion or direct screw fixation alone, showed unacceptably high rate of failure and are not currently recommended.*

Methods*: in this paper we report experience of the 12 patients with the axis dens pseudoarthrosis managed utilizing alternative strategy: modified posterior occipitocervical fusion to stabilize the craniovertebral junction, followed by direct odontoid screw fixation to fix the mobile fracture fragment, to perform the destruction of the false joint and permit the refilling of the defect with new fibrocartilaginous callus, drawing osteogenesis from the periosteum across the fracture gap.*

Results*: we were able to achieve excellent clinical results in all patients. Follow-up examinations showed successful bone union at both sides and no hardware-related or infection complications.*

Conclusions*: in axis dens pseudoarthrosis posterior craniocervical fusion must resist movement in eight degrees of freedom, with inclusion to the fixation of the occiput, atlant and the axis and supplemented by odontoid screw fixation to provide proliferative reaction on the bone ends.*

Keywords:

axis dens pseudoarthrosis, craniocervical fusion, odontoid screw fixation, osteogenesis, spinal fixation, surgical technique

INTRODUCTION

Axis dens pseudoarthrosis is relatively common complication of the odontoid process fracture treatment in which the reparative processes have come to complete standstill [2, 3]. Fractures of the dens account for approximately 20% of all cervical fractures, with Anderson and D'Alonzo type II fractures comprising 65 to 74% of odontoid fractures. Type II dens fractures are well known to have a significant rate of nonunion. In addition, Type III fractures, although generally considered to have a better potential for healing, were found to have a nonunion rate of 13% [1-3, 9, 10]. This high nonunion rate has been attributed to several factors. Other factors potentially contributing to nonunion include the difficulty of maintaining an adequate reduction of the dens relative to the body of the axis, as well as the predominantly intersynovial location of the dens itself [1-3, 6, 9, 10, 15].

One of the major factors influencing the fusion rate is the choice of the management strategy for the axis dens fractures. Reported nonunion rates for minimally displaced Type II odontoid fractures with nonsurgical treatment (traction, rigid cervical orthosis, or halo vest immobilization) alone range from 0 to 64% [2, 3, 10, 14], with an average rate of 34% [1, 6, 9, 15]. This high nonunion rate with conservative treatment may be attributed to the inadequacy of stabilization with external immobilization alone [1, 3]. Inadequate stabilization leads to motion at the fracture site and results in non-union or pseudoarthrosis [2, 3, 6]. A majority of authors with unsatisfactory long-term results have therefore recommended early operative management [1-3, 6, 9, 15]. In surgical stabilization procedures one part of surgeons have relied primarily on posterior atlanto-axial or occipitocervical fusion in which they use a variety of bone and wire constructs [4, 7-9, 11-13]. Another part of surgeons supplemented posterior fusion with anterior fusion or direct screw fixation [2, 3, 5, 9]. Whereas another part of surgeons advocate direct anterior screw fixation alone in the treatment of these fractures, claiming that posterior fusion eliminates normal craniocervical rotatory and flexion–extension motion [1, 2, 6, 14, 15]. Nevertheless the reported rate of successful posterior or anterior arthrodesis has ranged from 20 to 90%, with an average non-union rate for posterior techniques of 25-30%, and for the direct odontoid screw fixation of 7-9% [1-3, 6-10, 13-15].

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The current management strategy for the axis dens pseudoarthrosis is posterior atlanto-axial fusion [1-3, 9, 10]. Anterior fusion or direct screw fixation alone, showed unacceptably high rate of failure and are not recommended [1-3]. Some authors advocate combined anterior and posterior fusion utilizing various bone and metallic constructs [1-3, 6, 7, 9, 15].

In our clinical experience of the surgical management of 12 patients with the axis dens pseudoarthrosis we used alternative strategy: modified posterior occipitocervical fusion followed by direct odontoid screw fixation.

MATERIAL AND METHODS

From 2002 to 2007, twelve patients with the axis dens pseudoarthrosis were referred to our clinic. All patients were men, with a mean age of 35 years (range from 21 to 53 years. They were operated on using the modified posterior occipitocervical fusion followed by direct odontoid screw fixation accomplished in one operative session. All patients had non-union of axis dens fractures of from 8 months to 3 years. Nine patients were immobilized by the plastic cervical collar for a period of 3 to 6 months. Three patients wore a Halo-apparatus for a period of 5 to 12 months. Five patients had displaced fractures, and seven had diastasis at the fractuse site without displacement. Nine patients had type II fracture (Fig. 6 a, b), and three type III (Fig. 9 a, b). The

cause of injury in 8 cases were fall and traffic accident in 4 cases.

Preoperatively we used Halo-traction for reduction in eight patients with displaced fractures. Patients without displacement wore a plastic cervical collar.

SURGICAL TECHNIQUE

Stage 1. Modified posterior occipitocervical fusion

The operation is performed under endotracheal anesthesia, with the patient placed in the lateral position. Some degree of the neck flexion may be useful during the initial exposure and passage of wires. The slight extension is adopted as the wires are tightened on the loop. A midline skin incision expose the occiput, atlant and axis vertebrae. The laminae and spinous processes of the axis and the arch of the atlas are cleared of soft tissues with monopolar electrocautery and a periosteal elevator. Muscles are detached from the occiput in the same manner, from the margin of the foramen magnum to a point near the superior nuchal line (Fig. 1a). Two 4 mm burr holes are made in the occiput, each 2 cm lateral from the nuchal line. A 20 gauge titanium wire is folded upon itself, fashioned into the shape of a hook, passed through the burr hole on one side and drawn out through the opposite hole (Fig. 1b). The hook shaped end of the wire is cut in half exposing two free ends on each side of the occiput (Fig. 2 a, b). One pair of wires is looped around the arch of the atlas and tightened around the spinal process of the axis (Fig. 3 a, b). Second pair of wires is looped and twisted around the spinal process of the axis, tightly connecting occiput with the axis (Fig. 4 a, b). The wires can be optionally reinforced with methylmethacrilate. Given wire-methylmethacrilate construct provides rigid occipitocervical fixation in all directions [17]. The wound is closed in layers and the patient turned in the supine position for the second stage of operation - odontoid fixation with cannulated compression screw.

Stage 2. Odontoid process osteosynthesis with cannulated compression screw

The patient is placed in the supine position. A slight degree of cervical hyperextension is created by a shoulder roll. Portable biplanar fluoroscopy equipment used for imaging of the cervical spine, to verify the proposed trajectory for the screw placement and adequacy of fracture reduction. The technique and specific instruments used for anterior odontoid screw fixation were described by Apfelbaum [1] and Subach [14]. After the skin incision, a Cloward-type dissection is made down to the C5–C6 disc space, transverse retractors are placed under the longus coli musculature. The C2–C3 disc space is identified. Using biplanar fluoroscopy, a 2–mm K–wire is placed at the desired entry point of the C2–C3 disc space and impacted into the anteroinferior aspect of the body of C2. After placement of the guidewire, a hollow–core drill is passed over the K–wire and rotated by hand to cut a shallow groove in the anterior face of C3 and the C2–C3 annulus. The appropriate trajectory is determined, using fluoroscopic guidance, in both the anteroposterior and lateral planes. The optimal drill entry point is the interior endplate of C2. A pilot hole is drilled into the C2 body, across the fracture line, and into the apical cortical surface of the odontoid process. The drill hole is tapped, and a titanium compression screw is placed using fluoroscopic guidance. After the screw has crossed the fracture line, the threads engage the fragment and the lag effect of the screw reduces the displaced fragments. This lag effect not only closes the fracture gap but also directly opposes the fractured bone edges and provides compression (Fig. 5 a, b).

Postoperative Follow-Up Monitoring

Postoperative follow–up monitoring included clinical examinations at 1, 3, and 6 months. Patients were examined periodically, for assessment of continued functional status and symptomatic improvement. Radiographic imaging, consisting of plain radiographs of the upper cervical spine in

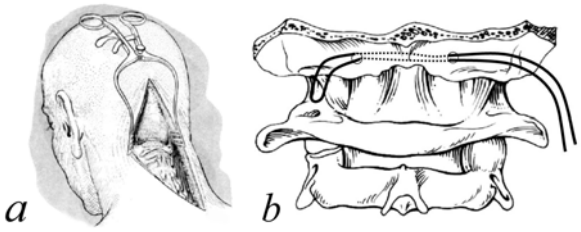

Fig. 1. Modified posterior occipitocervical fusion. a – approach to the occipitocervical junction; b – passage of the folded wire

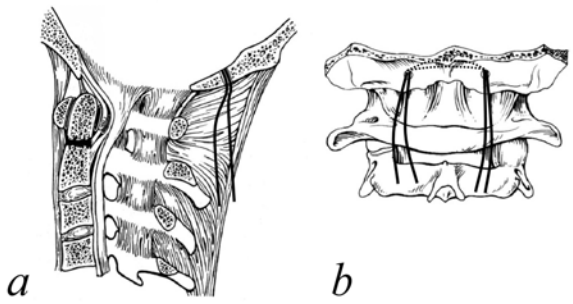

Fig. 2. Modified posterior occipitocervical fusion. Free ends of the wires coming out of the occiput. a – lateral view; b – back view

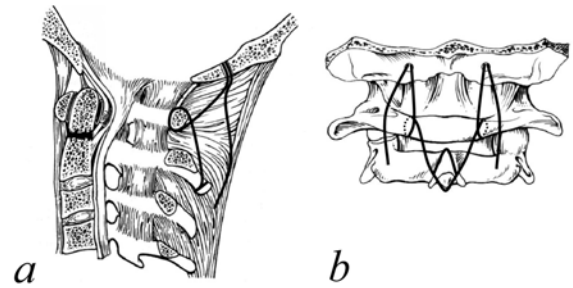

Fig. 3. Modified posterior occipitocervical fusion. One pair of wires is looped around the arch of the atlas and tightened around the spinal process of the axis. a – lateral view; b – back view

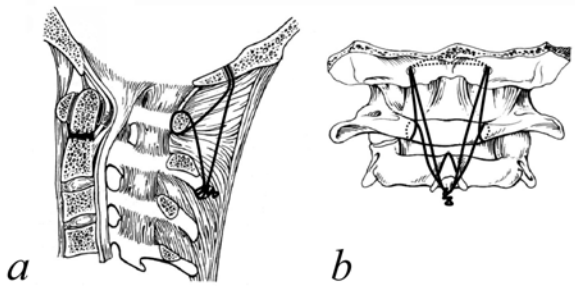

Fig. 4. Modified posterior occipitocervical fusion. Second pair of wires is looped around the spinal process of the axis, connecting occiput with the axis. a – lateral view; b – back view

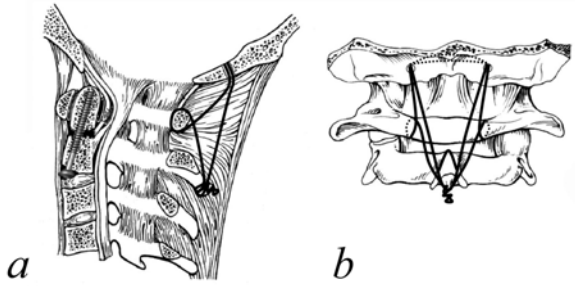

Fig. 5. Odontoid process osteosynthesis with cannulated compression screw. a – lateral view; b – back view

the open–mouth and lateral projections, with flexion and extension views, was performed before discharge and at the 1, 3, and 6 months follow-up visits (Fig. 8, 10). Additional fine-cut helical computer tomography and 3-D reconstruction scans were obtained to additionally determine the adequacy of fusion (Fig. 7, 11, 12).

RESULTS

We have observed immediate stabilization in all patients, as shown radiographically by fracture realignment and correction of pathologic atlanto-axial motion (Fig. 7, 8, 10, 11). Successful positioning of the odontoid screws occurred in 11 patients. In one patient, the screw was placed laterally, not entirely within the body of the odontoid process and extending 3 mm beyond the tip of the dens (Fig. 12 a, b). He was not reoperated and showed excellent results without complications on a follow-up.

Follow-up examinations showed successful bone union at both sides in all cases. We did not encounter any hardware-related or infection complications.

DISCUSSION

The development of the axis dens pseudoarthrosis following conservative treatment is due a missed diagnosis, improper reduction of the fracture, prolonged Halo-traction causing a diastasis at the fracture site, improper positioning of the head and neck in the external fixation device, or an inadequate period of external fixation [1-3, 9, 10].

In our opinion another important cause of the axis dens pseudoarthrosis is improper choice of the surgical management strategy for the acute odontoid fracture. Many surgeons perform posterior fusion with total disregard to the complex craniovertebral biomechanics.

Several factors must be evaluated when determining the craniovertebral stability. Head serves as a cantilever above the cervical spine. The axial load created by the weight of the head and traction forces of anterior cervical muscles yields a natural-occurring moment arm anterior to the spine. Due to these factors the head tend to be in flexion and if the anterior column of the craniovertebral junction is disrupted, as in axis dens fracture, the flexion deformity increases substantially leading to anlanto-axial subluxation [7, 11, 14, 17].

Greater than 50% of the total range of motion in the cervical spine lies between the occiput and C-2. There are six normal and eight pathological degrees of freedom. Normal sagittal motion at occiput-C1, rotation at C1-C2, and small amounts of lateral bending in both directions must be countered. In cases of posttraumatic deformity, compression or distraction also occurs and must be restrained. The spine may be dislocated into either a flexed or an extended posture. In occipito-atlanto-axial dislocation, the deformity is more in flection and distraction. Hence, a uniformly successful fusion construct must resist movement in eight degrees of freedom [5, 11, 17]. This is possible only with occipito-atlanto-axial fixation.

For many surgeons fusion and instrumentation strategies focused only on the atlanto-axial junction [1-4, 7-9, 12]. A widely accepted mis-statement says that odontoid fracture causes purely atlanto-axial instability and, does not require fusion of the occiput to the upper cervical spine [3, 4, 8, 12, 14]. This is why the reported rate of failed atlanto-axial fusion has ranged from 20 to 90%, with an average non-union rate of 25-30% [1-3]. Numerous authors presented own experience and extensive review of literature on the issue of failed atlanto-axial fusion and the necessity of craniocervical fusion in axis dens pathology [7, 12, 13] .

There are only two arguments in favor of localized atlanto-axial fusion [7]. First, that the tightening of interlaminar wires reduces posterior displacement. Second, that craniocervical fusion significantly impairs range of motion in this region. In our opinion both arguments are invalid. In fact, with occipito-atlanto-axial fixation in our modification, the reduction is easily achieved with traction for the wire looped around the arch of the atlas and then tightened around the spinal process of the axis. Second wire (the one looped around the spinal process of the axis, tightly connecting occiput with the axis), prevents slippage of the re-

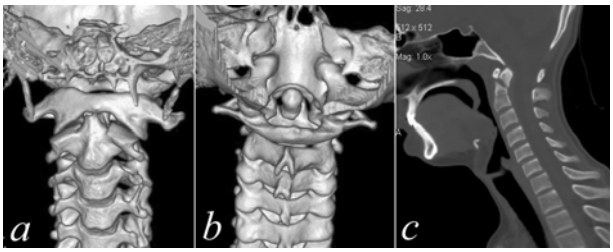

Fig. 6. Type II dens fracture non-union 22 months postinjury before treatment. a, b – CT 3-D reconstruction; c – fine-cut helical CT

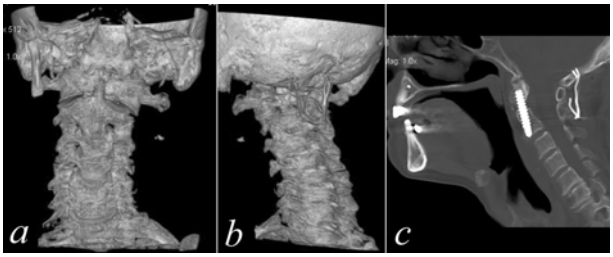

Fig. 7. Type II dens fracture non-union managed with modified posterior occipitocervical fusion followed by direct odontoid screw fixation. a, b – CT 3-D reconstruction; c – fine-cut helical CT

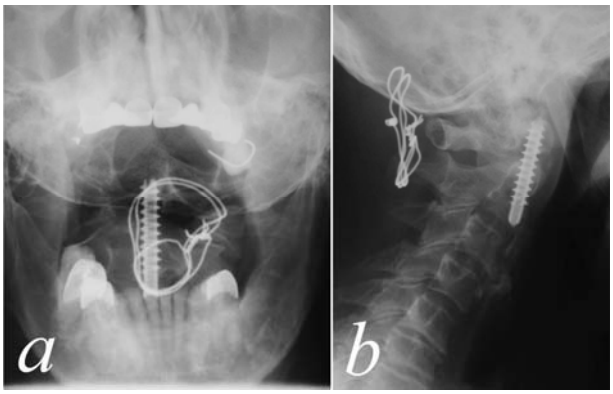

Fig. 8. X-ray of type II dens fracture non-union managed with modified posterior occipitocervical fusion followed by direct odontoid screw fixation. a – front view; c – lateral view

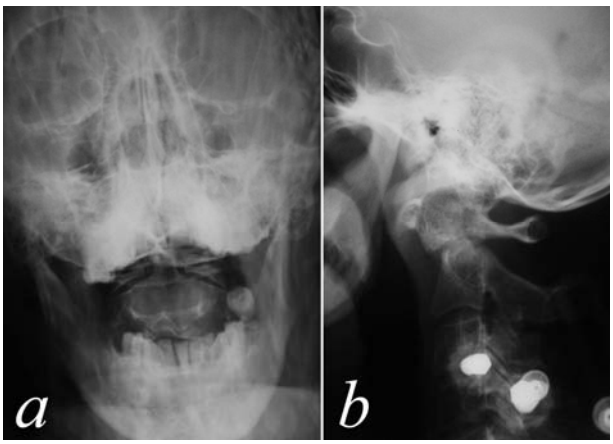

Fig. 9. X-ray of type III dens fracture non-union 28 months postinjury before treatment. a – front view; c – lateral view

duced process and stabilizes the construction in all possible degrees of freedom. Besides, partial reduction is enough for the firm union, provided that adequate stability is obtained [7, 12, 13].

The extent in limitation with flexion, extension and lateral bending in case of occipito-atlanto-axial fixation is not much larger than in atlanto-axial fusion. There is virtually no rotation at the occipito-atlantoid joint, the range of flexion-extension is no more than 13^0, and lateral bending is about 8^0. With the total range of flexion-extension in the cervical spine of 140^0, and lateral bending of 90^0, the contribution of occipito-atlantoid joint is insignificant. On the contrary, in the atlanto-axial joint the range of flexion-extension constitutes $47\text{-}50^0$, and about 10^0 in lateral bending. The fusion on this level provides significant loss in range of normal motion [7, 17].

Our experience in the surgical management of the axis dens fractures with modified occipito-atlanto-axial wiring in 42 patients (unpublished data), showed 0% of non-union and hardware complications. This modification of fixation showed to be simple, safe, reliable and cost-effective. We did not use direct odontoid screw fixation for fresh fractures. In our opinion, although it restores the anatomical integrity of the axis dens, it is not able to do so in biomechanical aspect, requiring external immobilization in order to limit the range of motion in this region.

On the contrary, in the axis dens pseudoarthrosis, we followed another surgical strategy: modified posterior occipitocervical fusion to stabilize the craniovertebral junction, followed by direct odontoid screw fixation. In this case, direct odontoid screw fixation is justified for the capability to both fix the mobile fracture fragment and mainly to perform the destruction of the false joint and permit the refilling of the defect with new fibrocartilaginous callus, drawing osteogenesis from the periosteum and endosteum across the fracture gap [16].

The turning point in the development of the axis dens pseudoarthrosis is the inability of fibrocartilage to promote new bone formation by induction. Microarchitecture of a functioning pseudoarthrosis had been described as the products of tissue injury, excessive scar formation between bone ends, myxomatous change and remodeling of the bony callus. Fibrinoid degeneration of connective tissue in the interior of the callus is the universal process of non-union. It occurs in the space ordinarily occupied by fibrocartilaginous callus. The function of the fibrinoid and mucinous fluid, which forms when the callus splits, is to create and preserve false joint space. If posterior fusion is the choice of management, providing only immobilization, there is no definite time after which a pseudoarthrosis can unite. Some authors noted that fibrocartilaginous callus is replaceable tissue rather than a barrier. The reasonable strategy here seems to be the supplementation of internal immobilization (occipitocervical fusion) with internal osteosynthesis of the axis dens to promote new bone formation by induction between the fracture ends. In this instance, cannulated odontoid screw functions as an inductor, keeping the bone ends in contact and thus providing proliferative reaction on the bone ends [16].

Based on our experience and the literature data, we have developed management strategy for posttraumatic axis dens pseudoarthrosis. The evaluation starts with clinical examination. Radiographic imaging, consist of plain radiographs of the upper cervical spine in the open–mouth and lateral projections, with flexion and extension views (Fig. 9 a, b). Fine-cut helical computer tomography and 3-D reconstruction scans are obtained to determine the type, and degree of fracture displacement (Fig. 6 a, b). Magnetic resonance imaging addresses the ligamentous integrity.

In our opinion, the presence of the axis dens pseudoarthrosis is an absolute indication for operation. We propose modified posterior occipitocervical fusion to stabilize the craniovertebral junction, followed by direct odontoid screw osteosynthesis to promote new bone formation by induction of osteogenesis between the fracture ends.

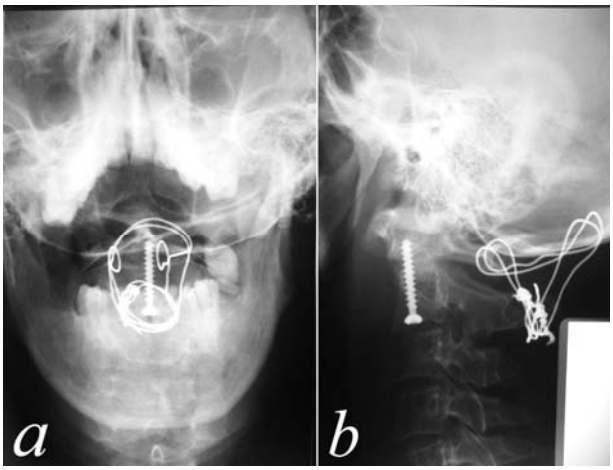

Fig. 10. X-ray of type III dens fracture non-union managed with modified posterior occipitocervical fusion followed by direct odontoid screw fixation. a – front view; c – lateral view

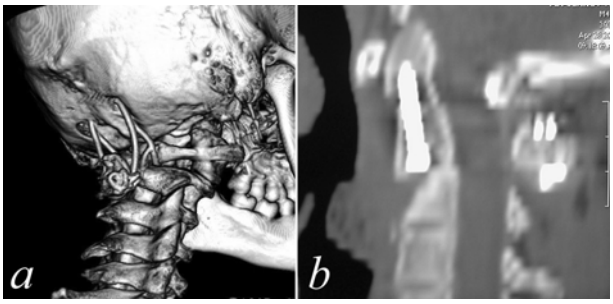

Fig. 11. Type III dens fracture non-union managed with modified posterior occipitocervical fusion followed by direct odontoid screw fixation. a – CT 3-D reconstruction; b – fine-cut helical CT

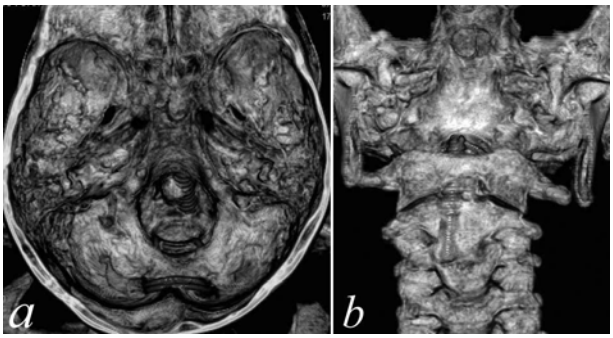

Fig. 12 a, b. CT 3-D reconstruction scans shows type II dens fracture non-union managed with modified posterior occipitocervical fusion followed by direct odontoid screw fixation. The screw was placed laterally, not entirely within the body of the odontoid process and extending 2 mm beyond the tip of the dens. The patient was not reoperated and showed excellent results without complications on a follow-up

CONCLUSION

Important cause of the axis dens pseudoarthrosis is improper choice of the management strategy for the acute odontoid fracture. Axis dens fractures necessitates the need for craniocervical fusion. Posterior craniocervical fusion should be performed with regard to the complex craniovertebral anatomy and biomechanics, with inclusion to the fixation of the occiput, atlant and the axis and must resist movement in eight degrees of freedom. The technique of

occipito-atlanto-axial fixation in our modification, correspond to this requirements and is simple, safe, reliable and cost-effective.

Surgical management of the axis dens pseudoarthrosis in 12 patients of our series consisted of modified posterior occipitocervical fusion to stabilize the craniovertebral junction, followed by direct odontoid screw fixation to fix the mobile fracture fragment and to perform the destruction of the false joint and permit the refilling of the defect with new fibrocartilaginous callus, drawing osteogenesis across the fracture gap.

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ПОСТТРАВМАТИЧЕСКИЙ ЛОЖНЫЙ СУСТАВ ЗУБОВИДНОГО ОТРОСТКА АКСИСА: ОПЫТ ЛЕЧЕНИЯ 12 ПАЦИЕНТОВ С ИСПОЛЬЗОВАНИЕМ МОДИФИЦИРОВАННОГО ЗАДНЕГО ОКЦИПИТОСПОНДИЛОДЕЗА И ВИНТОВОГО ОСТЕОСИНТЕЗА ЗУБОВИДНОГО ОТРОСТКА

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РЕФЕРАТ

***Цель**: хирургическое лечение ложного сустава зубовидного отростка аксиса является широко дисскутабельной проблемой вследствие сложности анатомии и биомеханики краниовертебральной области. В настоящее время хирургическое лечение проводится посредством заднего спондилодеза или его комбинациями с передними методиками. Изолированное использование передних методик при данной патологии даёт не удовлетворительные результаты.*

***Материал и методы**: нами проведено хирургическое лечение 12 пациентов с застарелыми переломами зубовидного отростка аксиса и образованием в нем ложного сустава. Первым этапом проводился модифицированный окципитоспондилодез для репозиции перелома и иммобилизации поврежденного отдела позвоночника; вторым этапом проводился остеосинтез зубовидного отростка компрессионным винтом для фиксации перелома, разрушения ложного сустава и создания возможностей для остеогенеза между отломками.*

***Результаты**: во всех случаях хирургического лечения нами были достигнуты хорошие результаты, с образованием анкилоза в области перелома зубовидного отростка. Инфекционных осложнений или осложнений со стороны металлоконструкций нами не наблюдалось.*

***Выводы**: ложный сустав зубовидного отростка аксиса является абсолютным показанием к операции. Хирургическое лечение состоит из фиксации и иммобилизации краниовертебральной области во всех плоскостях движений посредством окципитоспондилодеза, и остеосинтеза зубовидного отростка компрессионным винтом для фиксации перелома, и создания возможностей для остеогенеза между отломками.*

Ключевые слова:

ложный сустав зубовидного отростка аксиса, краниовертебральная область, окципитоспондилодез, остеосинтез зубовидного отростка, фиксация позвоночника, оперативная техника .