

Comparison of occipitocervical and atlantoaxial fusion in treatment of unstable Jefferson fractures

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ABSTRACT

Background: Controversy exists regarding the management of unstable Jefferson fractures, with some surgeons performing reduction and immobilization of the patient in a halo vest and others performing open reduction and internal fixation. This study compares the clinical and radiological outcome parameters between posterior atlantoaxial fusion (AAF) and occipitocervical fusion (OCF) constructs in the treatment of the unstable atlas fracture.

Materials and Methods: 68 consecutive patients with unstable Jefferson fractures treated by AAF or OCF between October 2004 and March 2011 were included in this retrospective evaluation from institutional databases. The authors reviewed medical records and original images. The patients were divided into two surgical groups treated with either AAF ($n = 48$, F/M 30:18) and OCF ($n = 20$, F/M 13:7) fusion. Blood loss, operative time, Japanese Orthopaedic Association (JOA) score, visual analog scale (VAS) score, atlanto-dens interval, lateral mass displacement, complications, and the bone fusion rates were recorded.

Results: Five patients with incomplete paralysis (7.4%) demonstrated postoperative improvement by more than 1 grade on the American Spinal Injury Association impairment scale. The JOA score of the AAF group improved from 12.5 ± 3.6 preoperatively to 15.7 ± 2.3 postoperatively, while the JOA score of the OCF group improved from 11.2 ± 3.3 preoperatively to 14.8 ± 4.2 postoperatively. The VAS score of AAF group decreased from 4.8 ± 1.5 preoperatively to 1.0 ± 0.4 postoperatively, the VAS score of the OCF group decreased from 5.4 ± 2.2 preoperatively to 1.3 ± 0.9 postoperatively.

Conclusions: The OCF or AAF combined with short-term external immobilization can establish the upper cervical stability and prevent further spinal cord injury and nerve function damage.

Key words: Atlas fracture, Jefferson fractures, cervical spine, atlantoaxial fusion, occipitocervical fusion, instrumentation

MeSH terms: Spinal fractures, spinal fusion, atlanto-axial joint, atlanto-occipital joint, atlas, cervical

INTRODUCTION

Atlas fractures account for approximately 25% of the upper cervical spine injuries, roughly 2%–13% of all acute cervical spine fractures, and approximately 1%–2% of all fractures of the human spinal column.¹⁻³ The unstable Jefferson fracture is a C1 burst fracture with concomitant injury of the transverse atlantal ligament (TAL),

characterized by the outward spread of the lateral masses under axial compression.^{2,4-6} Several authors have reported successful surgical stabilization and fusion for Jefferson fractures when they are associated with disruption of the transverse ligament and resultant instability.⁷⁻⁹ Stabilization constructs include either C1–C2 fusion or occiput-to-C2 fusion as surgical treatment is increasingly popular for treatment of these unstable injuries. The relative paucity of patients with atlas fractures treated with surgical stabilization and fusion described in the literature limits the ability to address questions about optimal treatment strategy.¹⁰ This study compares the clinical and radiological outcome parameters between posterior atlantoaxial fusion (AAF)

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and occipitocervical fusion (OCF) constructs in treatment of the unstable atlas fracture.

MATERIALS AND METHODS

Sixty eight consecutive cases with unstable atlas fractures treated between October 2004 and March 2011 with either AAF or OCF fusion were reviewed at a single institution after Institutional Review Board approval was obtained. The study population included 43 males and 25 females ranging in age from 18 to 78 years (average 46 years). The patients were divided into two surgical groups and were treated with AAF ($n = 48$, M/F 30:18) or OCF [$n = 20$, M/F 13:7, Table 1] based on surgeon preference. Forty eight consecutive patients were treated using C1–C2 screw-rod or screw-plate fixation with bicortical iliac crest allograft or autograft bone. All patients had a recent history of trauma, with the most common cause of injury being: fall from a standing height ($n = 44$, 64.7%), motor vehicle accidents ($n = 17$, 25%), and diving injuries ($n = 7$, 10.3%). All conscious patients had complained about the neck pain and restriction of neck movement on admission, 27 (39.7%) patients experienced an associated head or face injury. Five patients (7.4%) had a spinal cord injury. Four patients had an American Spinal Injury Association (ASIA) score of D, and one had an ASIA score of C. All patients with neurologic injury had spondylotic changes, canal narrowing, and posterior osteophytes, which damage the cord by causing kinking in a narrow canal. Forty cases demonstrated TAL rupture (Dickman Type I) with the instability of the atlantoaxial articulation, twenty comminuted fractures of atlas associated with TAL rupture at the attachment site of bony structure of medial-lateral mass of atlas (Dickman Type II). The TAL in eight

cases was intact. In OCF group, twenty cases of burst atlas fracture had combined occipito-atlanto articulation instability or other injuries. Sixteen patients underwent C0–C2 fixation and fusion, four underwent C0–C3 fixation and fusion. In the AAF group, 17 patients with typical unstable Jefferson fractures and ten fractures with involvement of only one-half of the C1 ring underwent C1–C2 fixation and fusion. Twenty seven patients with atlas fractures also sustained associated axis fractures (39.7%) [Table 2]. All patients were treated with autologous iliac bone graft or allograft. The shadow from the retropharyngeal soft tissue in front of C1–C3 on a lateral radiograph measured average 10.5 mm wide (range 4.3–13.4 mm). Patients were followed at regular intervals after surgery. Each patient was immobilized postoperatively using a cervical collar for 6–8 weeks.

We retrospectively reviewed radiographs, clinical records, and hospital charts for all patients. Data collected included age, gender, diagnosis, treatment, and postoperative complications. Operative time, estimated blood loss (EBL), Japanese Orthopaedic Association (JOA) score, visual analog scale (VAS) score, and the fusion status were recorded. Operative time and EBL were determined from combining the anesthesia and surgical nursing records. Surgical time was calculated from the skin incision until wound closure. Atlas fractures were evaluated using open mouth odontoid view, lateral, flexion extension radiographs, and CT scan. An open mouth odontoid view shows the overlap of the C1 and C2 facets. Any displacement of the C1 lateral mass lateral to the lateral borders of the C2 facets is suggestive of an atlas burst fracture. On lateral views, a prepedal space >3 mm in adults is highly suggestive of a ruptured transverse

Table 1: Clinical details of patients

Characteristic	Value			P
	Total	AAF group	OCF group	
Number of patients	68	48	20	
Sex (male/female)	43/25	30/18	13/7	
Average age (years, range)	46 (18-78)	42 (18-65)	53 (35-78)	
TAL disruption				
Type I	40	28	12	
Type II	20	12	8	
Mechanism of injury (n,%)				
MVA	17 (25%)	12	5	
Fall	44 (64.7%)	31	13	
Diving	7 (10.3%)	5	2	
ASIA scale				
C	1	0	1	
D	4	2	2	
EBL (ml, range)	650 (200-1600)	500 (200-1200)	800 (500-1600)	0.008
Operation time (min, range)	110 (70-180)	90 (70-120)	130 (90-180)	0.001
FU (months, range)	28 (12-46)	20 (12-38)	30 (24-46)	

There is statistically significant difference in the EBL and operation time of AAF and OCF using two-sample *t*-test for independent samples ($P < 0.05$). TAL=Transverse atlantal ligament, MVA=Motor vehicle accident, ASIA=American Spinal Cord Injury Association, EBL=Estimated blood loss, FU=Followup, AAF=Atlantoaxial fusion, OCF=Occipitocervical fusion

Table 2: Associated injuries, treatment, and adverse outcomes in 27 patients of atlas fracture associated with axis fractures

Number (%) of patients	Associated injury	Patients with abnormal cord signal	Treatment	Adverse outcome
9 (13.2)	Odontoid fracture (Type II)	1	C1-C2 fusion (eight cases)	12 months: Independent, mild disability painful
7 (10.3)	Odontoid fracture (Type III)	0	Oc-C2 fusion (one case)	hardware-removal (one case)
4 (5.9)	Hangman fracture (Type II)	0	C1-C2 fusion	
5 (7.4)	Hangman fracture (Type III)	2	C1-C2 fusion Oc-C3 fusion (four cases)	6 months: Moderate disability (two cases)
2 (2.9)	Miscellaneous fractures of axis	0	C1-C2 fusion (one case) C1-C2 fusion	

ligament. Posterior arch fractures can be assessed on lateral or 60° oblique X-rays.¹¹ Anterior arch fractures are often difficult to diagnose from plain X-rays. However, Levine and Edwards¹ showed that the shadow from the retropharyngeal soft tissue at C1–C3 was often significantly widened (>9.5 mm) in the presence of an anterior arch fracture compared with a posterior arch fracture. Magnetic resonance imaging (MRI) and thin-cut computerized tomography (CT) scans (including sagittal and coronal reconstructions) were available for each patient. We utilized previously proposed criteria to identify TAL injury including a sum of the displacement of the lateral masses of C1 on C2 of more than 8.1 mm on plain X-rays corrected for magnification (Rule of Spence¹²) and MRI evidence of ligamentous disruption or avulsion. Axial CT cuts may reveal Dickman Type II injuries of the transverse ligament even when the lateral mass spread is <7 mm and does not imply instability under the Rule of Spence. When available, high-resolution MRI is the modality of choice to assess the integrity of the transverse ligament.¹³ MRI is capable of diagnosing Dickman Type I injuries of the transverse ligament that may exist without the significant spread of the lateral mass. Atlanto-occipital instability is mostly judged by Powers ratio and occipito-dental interval. A Power's ratio >1 indicates anterior subluxation or dislocation of the atlanto-occipital joint has occurred; Occipito-dental interval >6 mm similarly indicates dislocation or subluxation of atlanto-occipital joint. Change in the occipito-dental interval on lateral flexion extension radiographs of >1 mm also is indicative of occipitocervical instability. In summary, unstable atlas burst fractures are diagnosed by any of the following radiographic criteria: Lateral mass displacement (LMD) >6.9 mm on open-mouth odontoid view, atlanto-dens interval (ADI) >3 mm in adults on lateral radiographs suggestive of transverse ligament rupture of atlas, ADI change on dynamic flexion extension radiography >1 mm, and high-resolution MRI showing transverse ligament injury.

Statistical analysis

Data from the two surgical groups were analyzed to compare groups, as well as preoperative and postoperative variables, using a paired *t*-test for preoperative and postoperative

variables, and a two-sample *t*-test for independent samples for comparing different surgical groups. Chi-square test was used to compare the satisfaction of these two surgical groups. Significance was assumed for $P < 0.05$.

RESULTS

All patients were followed for between 12 and 46 months (average 28 months). The average operative time was 110 min (range 70–180 min) and mean blood loss was 650 ml (range 200–1600 mL). There were statistically significant difference in the EBL and operation time of AAF and OCF ($P < 0.05$).

Clinical and radiological outcomes between atlantoaxial fusion group and occipitocervical fusion group

At final followup, the patient who presented with an ASIA C injury preoperatively improved to Grade D postoperatively, and all four patients with Grade D injuries improved to Grade E postoperatively. All five patients with incomplete neurologic injuries (7.4%) showed postoperative improvement in their ASIA impairment scale. All patients with neck pain had a significant improvement. The average VAS score of the AAF group decreased from 4.8 ± 1.5 preoperatively to 1.0 ± 0.4 postoperatively ($P < 0.01$), the VAS score of the OCF group decreased from 5.4 ± 2.2 preoperatively to 1.3 ± 0.9 postoperatively ($P < 0.01$). There was no significant difference in average VAS score between two groups ($P > 0.05$). The JOA score of the AAF group improved from 12.5 ± 1.6 preoperatively to 14.2 ± 2.1 postoperatively ($P < 0.01$), while the JOA score of the OCF group improved from 12.2 ± 2.3 preoperatively to 13.8 ± 1.2 postoperatively ($P < 0.01$). There was no significant difference in JOA score between two groups ($P > 0.05$). There was a statistically significant improvement in postoperative JOA score [$P < 0.01$, Table 3]. The average preoperative LMD values for the AAF and OCF groups were 12.5 mm (range 8.2–16 mm) and 14.6 mm (range 10–19 mm), respectively, measurements which imply a rupture of the transverse ligament. After surgery, the average LMD for the AAF and OCF groups

measured 4.0 mm (range 1.2–7.4 mm) and 5.2 mm (range 3.0–9.0 mm), respectively. The average ADI for the AAF and OCF groups before surgery were 3.6 mm (range 3.0–5.0 mm) and 4.2 mm (range 3.8–6.2 mm), respectively, and decreased after surgery to 1.8 mm (range 1.0–3.2 mm) and 2.5 mm (range 1.4–4.0 mm), respectively [Table 4]. Based on radiograph and CT imaging, no patient developed postoperative upper cervical spine instability or loss of reduction after surgery.

Table 3: Visual Analogue Scale and Japanese Orthopaedic Association scores in pre- and post-operation (mean±standard deviation) between atlantoaxial fusion group and occipitocervical fusion group

Groups	VAS	JOA
AAF group (n=48)		
Preoperative	4.8±1.5	12.5±1.6
Postoperative	1.0±0.4*	14.2±2.1*
OCF group (n=20)		
Preoperative	5.4±2.2	12.2±2.3
Postoperative	1.3±0.9*	13.8±1.2*

*P<0.05, compared with the preoperative data using paired t-test, the difference was not significant between groups AAF and OCF using two-sample t-test for independent samples (P>0.05). VAS=Visual analog scale, JOA=Japanese Orthopaedic Association, AAF=Atlantoaxial fusion, OCF=Occipitocervical fusion

Range of movement and patient satisfaction

Forty six out of 48 patients (95.8%) with AAF subjectively estimated their global cervical spine flexion extension range of motion >50% of their preillness status and were satisfied with the outcome of treatment. The remaining two patients who reported more limited range of motion self-reported that obesity and short neck morphology contributed to their deficit. All twenty patients with OCF complained of significant restriction of cervical spine flexion extension range of motion, and only 14 patients (70%) were satisfied with their outcome. There was a statistically significant difference in the satisfaction of these two surgical methods (P = 0.0085). The rotation was restricted in both groups at 12 months. However, the combined restriction of flexion extension and rotation produced significant self-reported disability more commonly in the OCF group.

Fusion rate and complications

Successful posterior fusion was obtained in 67 of 68 patients (98.5%) with the exception being one patient treated with OCF [Figures 1 and 2]. Thirty four out of 68 patients (50%) showed fusion as early as 3 months after surgery. In the AAF group, 28 out of 48 patients (58.3%)

Table 4: Radiographic outcome between atlantoaxial fusion and occipitocervical fusion in pre- and post-operation

Groups	LMD (mm)		ADI (mm)	
	Preoperative	Postoperative	Preoperative	Postoperative
AAF group (n=48)	12.5 (8.2-16)	4.0 (1.2-7.4)*	3.6 (3.0-5.0)	1.8 (1.0-3.2)*
OCF group (n=20)	14.6 (10-19)	5.2 (3.0-9.0)*	4.2 (3.8-6.2)	2.5 (1.4-4.0)*

*P<0.05, compared with the preoperative data using paired t-test; the difference was not significant between groups AAF and OCF using two-sample t-test for independent samples (P>0.05). LMD=Lateral mass displacement, ADI=Atlanto-dens interval, AAF=Atlantoaxial fusion, OCF=Occipitocervical fusion

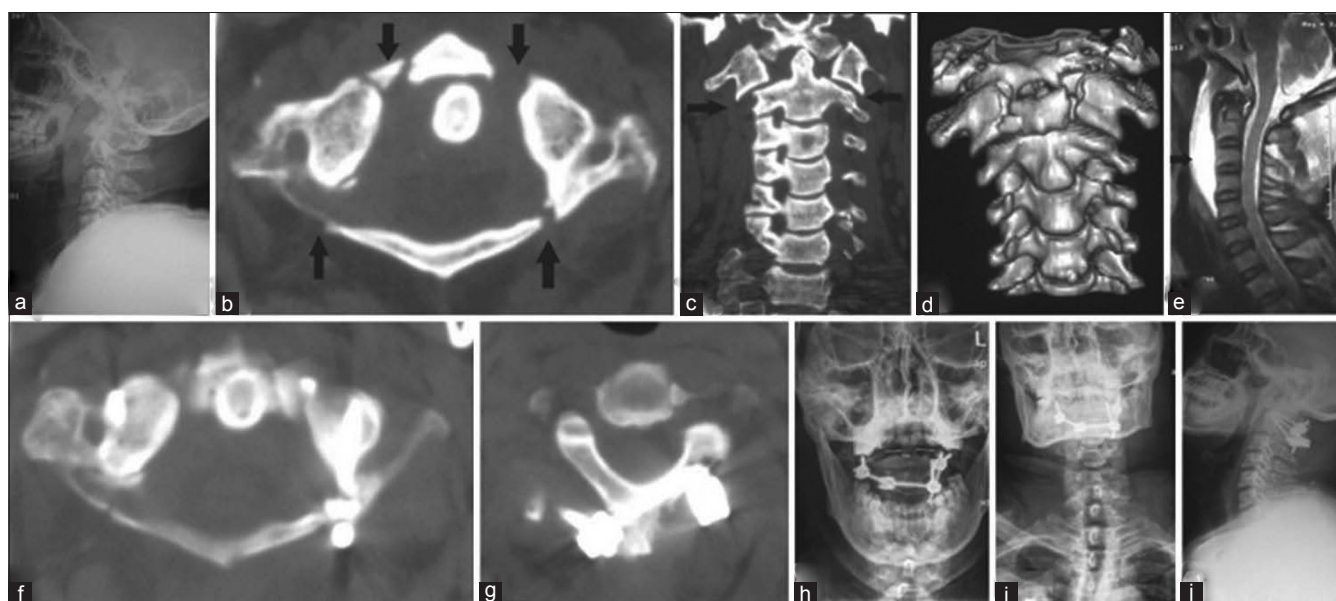


Figure 1: A 56-year-old male involved in a motor vehicle accident. (a) preoperative lateral X-ray of cervical spine showing bilateral posterior arch fractures of atlas, (b-d) preoperative axial, coronal, and three-dimensional computerized tomography reconstruction images showing bilateral anterior and posterior arch fracture, typical Jefferson fracture, lateral mass displacement = 7.0 mm, (e) preoperative T2W magnetic resonance imaging of cervical spine showing the shadow width from the retropharyngeal soft tissue at C1–C3 was 10.6 mm, no abnormal signal within the spinal cord was observed, (f and g) postoperative CT scan showing that bilateral lateral mass screws, a C2 lamina screw, and a C2 pedicle screw are well positioned, (h-j) postoperative open-mouth, anteroposterior and lateral views showing satisfactory cervical alignment

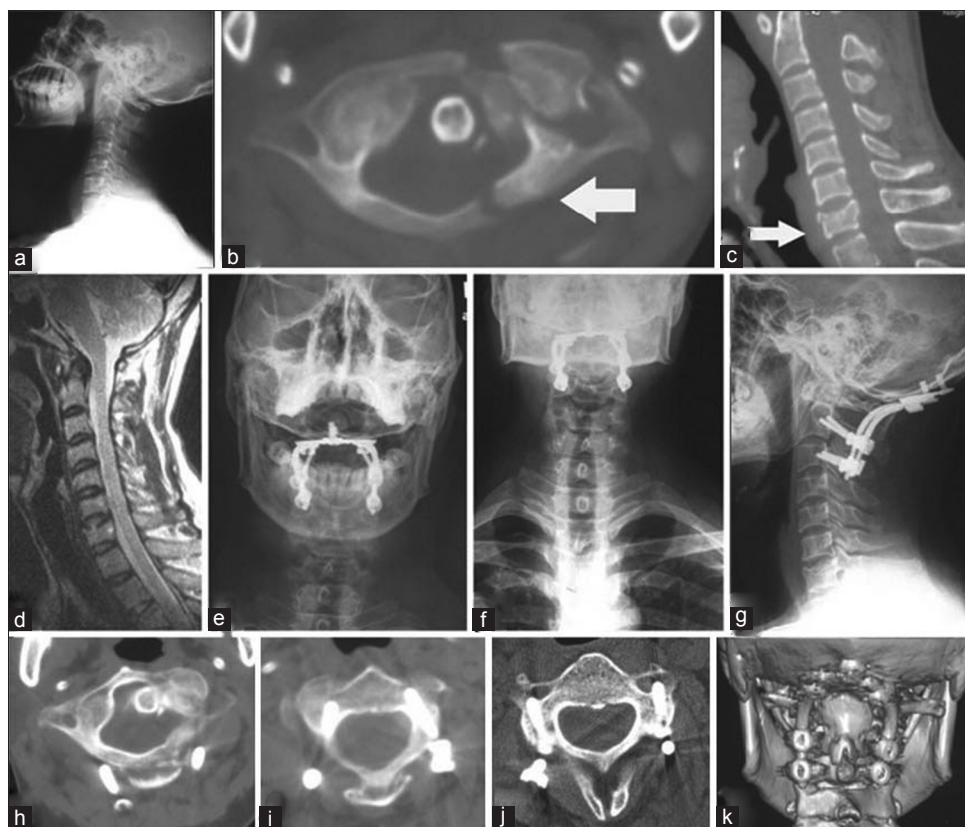


Figure 2: A 37-year-old male presented after a fall. (a) preoperative X-ray lateral view of cervical spine showing posterior arch fracture of atlas with a compression fracture of the superior endplate of C7, (b and c), preoperative axial and coronal computerized tomography images showing posterior arch fracture of atlas on left side and comminuted fracture of lateral mass, with extension into the atlanto-occipital articulation and the C7 vertebral compression fracture, (d) preoperative T2W magnetic resonance imaging showing no abnormal signals of spinal cord, (e-g) at 2-year followup, open-mouth, anteroposterior, and lateral views showing that occipitocervical articulation was well fixed, and bony fusion was achieved. (h-k) Computerized tomography scan showing that the atlas lateral mass fracture and occipitocervical articulation have fused, C2 bilateral pedicle screws are well-positioned, C3 bilateral mass screws partially breach the transverse foramen of C3 but without clinically detectable vertebral artery or nerve injury

fused completely by 3 months and the fusion was complete in all patients by 9 months after surgery. In the OCF group, six patients (30%) fused by 3 months and 16 (80%) by 9 months [Figure 3]. As mentioned above, one OCF patient developed nonunion at last followup at 24 months. Breakage of a single C2 pedicle screw was seen in a different patient who still went on to successful fusion. Superficial occipital headache or numbness occurred in five (25%) cases of OCF. Two patients complained of postoperative occipital neuralgia. This was transient in one patient having settled at 2 months followup, while the other patient still had persistent neuralgia at 2-years after surgery, necessitating referral to the Clinical Pain Service. A dural puncture during drilling of the skull occurred in one patient. Delayed wound healing was seen in one patient. In the AAF group, two patients had superficial wound infections, but no patient developed deep wound infections. There were no cases of implant failure or loosening. Fracture of the posterior arch of C1 occurred during drilling of the entry point for the C1 lateral mass screw in two patients. Hemorrhage from the C1–C2 venous plexus occurred in five cases in the OCF group and 12 cases in the AAF group after damage

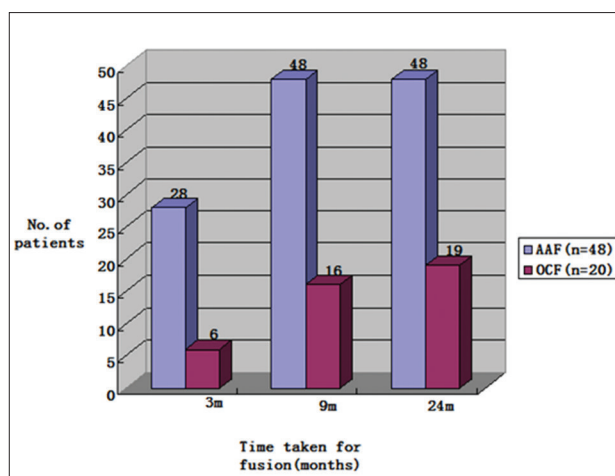


Figure 3: A bar diagram showing atlantoaxial fusion and occipitocervical fusion in follow up at regular intervals

to the C1–C2 venous plexus from electrical cauterization or sharp dissection but was controlled through the use of hemostatic gauze and cotton packing. Postoperative CT scans showed that three screws placed in C1 (one screw in AAF group, two screws in OCF group) and four screw

placed in C2 (two screws in AAF group, two screws in OCF group) breached the medial cortex, and three screws (two patients) partially breached the transverse foramen of C3 in the OCF group. There were no cases of neurologic deterioration after surgery or at followup related to the procedure. No occurrences of VA (vertebral artery) injury or neural element injury were detected intraoperatively or postoperatively.

DISCUSSION

The unstable Jefferson fracture is a common upper cervical injury. In this series, the most common causes of this injury were fall ($n = 44$, 64.7%) and motor vehicle accidents ($n = 17$, 25%). Because of the relatively capacious spinal canal at C1, neurological deficits are very unusual after Jefferson fractures.^{1,14} Jefferson fractures are associated with other traumatic cervical injuries in up to 50% of cases, most commonly with posteriorly displaced Type II odontoid fractures.^{1,14} Unstable Jefferson fractures are characterized by a rupture of the transverse ligament of the atlas, resulting in the lateral displacement of the lateral masses after excessive axial loading.^{4,7,15} Lateral mass overhang of >6.9 mm was found to be associated with rupture of the transverse ligament in cadavers and became known as the "Rule of Spence."¹² However, after correction for magnification on standard radiography technique, a lateral mass overhang of more than 8.1 mm on open-mouth odontoid X-rays was widely adopted as diagnostic of transverse ligament rupture.¹⁶ The TAL plays an important role as a checkrein for the movement of the dens. Rupture of the TAL can lead to an anterior C1 dislocation with backward movement of the dens leading to spinal cord injury. Dickman *et al.*¹³ thought that even without TAL rupture, fracture through the anterior half of the atlas still carries a risk of atlas dislocation because the anterior arch alone cannot restrain the dens. Injuries in which the ring is disrupted twice on a single side without TAL rupture also has the potential for associated dislocation because the TAL cannot prevent the LMD nor control the rotational displacement of the ring and must be considered to be an unstable fracture. In our study, average postoperative LMD decreased to 4.0 mm and 5.2 mm, respectively, in the AAF and OCF groups. The average postoperative ADI decreased to 1.8 mm and 2.5 mm, respectively, in the AAF and OCF groups. The shadow width from the retropharyngeal soft tissue at C1–C3 averaged 10.5 mm (4.3–13.4 mm). According to Levine and Edwards,¹ soft tissue shadow width at C1–C3 >9.5 mm is more commonly associated with anterior arch atlas fractures than posterior arch fractures. Although some form of external immobilization is the accepted treatment for stable Jefferson fractures, there is no established standard of care for the treatment

of unstable Jefferson fractures. If treated appropriately and in a timely manner, good results can be achieved. Many different treatment methods have been reported for the treatment of unstable Jefferson fractures.^{7-9,17,18} Because of the lack of larger comparative series, relative advantages or disadvantages of any one treatment method remain hypothetical. Advantages of surgical fixation in unstable Jefferson fractures are immediate stability, better rates of reduction, and patient avoidance of Halo use and its potential complications.^{5,19} Moreover, it is also highlighted in a review summarized by Ryken²⁰ that the complications associated with halo immobilization of atlas fractures should be paid more attention in the elderly. Riesner²¹ suggested that isolated stable C1 fracture without dislocation can be treated conservatively (cervical collar), unstable fracture, depending on the general condition, should be referred to surgical therapy or halo extension. Surgical stabilization strategies most commonly used are AAF or OCF in the treatment of the unstable Jefferson fractures. We attribute satisfactory clinical results to the excellent stability imparted by these instrumentation strategies. All patients in our study had a significant relief of neck pain. While we found no difference in VAS score and JOA score between AAF and OCF groups, both groups demonstrated a statistically significant improvement after surgery and also had a significant improvement in neurologic status.

Fowler *et al.*²² reported that indications for surgery in patients with unstable Jefferson fractures include (1) atlas burst fracture with TAL injury, (2) concomitant odontoid fracture or Hangman's fracture, (3) associated lower cervical spine injury, (4) associated neurological deficit, and (5) atlantoaxial or occipitocervical instability. Vieweg *et al.*²³ believed that surgical indications for stabilization of atlas fractures are met in the setting such as unstable atlas fractures, stable atlas fracture combined with Type II/III odontoid fracture or Type III Hangman's fracture. A relative indication for surgery is persistent neck pain after atlas fracture nonunion. For atlas fractures associated with atlanto-occipital joint instability, OCF is necessary; for unstable atlas fractures with bilateral posterior arch fracture, OCF should be selectively employed. In the present study, twenty patients with atlas burst fractures associated with atlanto-occipital joint instability underwent occipitocervical fixation and fusion, while four cases of atlas fractures associated with Levine and Edwards Type III Hangman's fractures received occipitocervical fixation and fusion surgery. Postoperatively, one patient treated with OCF had bone absorption, which may be due to the small amount of bone graft and graft shielding. Breakage of a single C2 pedicle screw was seen in this patient. This, however, did not interfere with successful OCF.

The reported success rate of bony fusion using posterior wiring techniques ranges from 75% to 80%, while with the Magerl technique it is 90%.²⁴⁻²⁶ In 2002, Goel *et al.*²⁷ published the results of a group of 160 patients treated between 1988 and 2001 using an original stabilization method. It is noteworthy that both Harms *et al.*²⁸ and Goel *et al.*²⁷ succeeded in achieving the C1–C2 bony fusion in 100% of cases. Wang *et al.*²⁹ reported all 319 cases (100%) achieved solid fusion between C1 and C2. Stulík *et al.*¹⁷ published the results of a group of 57 patients underwent occipitocervical fixation. Five patients died of associated injuries or serious medical complications shortly after the operation. Of the remaining 47, bony union was achieved in 44 patients (93.6%). Pseudoarthrosis developed in three elderly patients who had minimal complaints and therefore did not require revision surgery. We found no difference in union rate between short (C0–C2) and long (C0–CX or C-T) fixation constructs or when different bone grafting strategies were used (autograft vs. morselized allograft vs. structural allograft). While patients treated with autograft tended to achieve fusion much earlier than those treated with allograft, we confirmed that even patients treated with allograft achieved solid fusion by 3 months after surgery. The use of autograft may be advisable in those patients with risk factors for nonunion. CT scan is essential for evaluation of successful union in patients treated surgically for Jefferson fractures as radiographs have a very limited ability to demonstrate bridging trabecular bone in this region of the spine. In contrast, open-mouth, anteroposterior, lateral, and flexion extension radiographs are useful for the evaluation of instrumentation and upright alignment. Because of the use of CT scan, we have high confidence in the accuracy of the fusion rate reported in our series at 24 months of 98.5% for patients treated with OCF with 34 out of 68 patients (50%) showing fusion by 3 months. In the AAF group, 28 out of 48 patients (58.3%) fused by 3 months after surgery and the fusion was complete in all patients by 9 months. In the OCF group, six patients (30%) fused by 3 months and 16 (80%) by 9 months. One patient did not heal by 24 months. Breakage of a single C2 pedicle screw was seen in a different patient, but this did not interfere with eventual fusion. Nonunion was not associated with pain.

Our data demonstrate that patients treated with AAF with short-segment structural bone grafting successfully fuses similarly to those patients treated with long-segment constructs for unstable Jefferson fractures. About 95.8% patients with AAF subjectively graded the cervical spine flexion extension movement as slightly more than 50% of the preillness status and were satisfied with the outcome of treatment. All twenty patients with OCF complained of significant restriction of spinal movements, and only 14 patients (70%) were satisfied with the outcome. Rotations were restricted in both groups at 12 months.

However, the combined restriction of flexion extension and rotation produced significant self-assessed disability in the OCF group. In summary, fusion rates and patient satisfaction rates were significantly higher in AAF group compared to the OCF group.

Superficial occipital pain and scalp numbness occurred in five (25%) cases of OCF. Of the two patients with postoperative occipital neuralgia, one had only transient pain which resolved by 2 months after surgery, while the other patient still had pain at final followup which was adequately but incompletely controlled with pain management. Potential causes of postoperative occipital neuralgia include irritation of the nerve root by the C1 lateral mass screw and traction on the dorsal root ganglion during screw insertion. C1 lateral mass screws with an 8 mm threadless section were used to reduce the likelihood of irritation of the C2 nerve root.³⁰ Bleeding from the venous plexus around the greater occipital nerve occurred in five cases and 12 cases in the OCF group and the AAF group, respectively, due to damage to the C1–C2 venous plexus from electrocautery or sharp dissection. Hemostatic gauze or cotton sponge packing was used to control bleeding. Goel *et al.*²⁷ recommended dissection to identify the C2 nerve and control of venous bleeding by direct bipolar coagulation. Bleeding instead from the C1 screw tracts was treated by Stulík *et al.*³¹ by prompt insertion of a screw into the C1 lateral mass and by tamponad. Wang *et al.*,²⁹ in contrast, recommend against placing screws to stop bleeding in case the bleeding represented vertebral artery injury which could then result in vertebral artery occlusion. A dural puncture during drilling of the skull occurred in one patient. There were no cases of neurologic deterioration after surgery or at followup related to the procedure. No VA injuries or neural injury was detected intraoperatively and postoperatively. The main limitation of the current study is the relatively small number of patients in each surgical group which increases the risk of group heterogeneity.

The traditional view is that OCF is the better option for the patient with unstable Jefferson fracture with associated occipito-atlantal instability, and the AAF is only used to treat the patients with atlantoaxial instability. However, that is not exactly because the disadvantages of the OCF have a strong impact on the movable function of occipitocervical region. Hence, in the young patients, we suggest to use the AAF and halo vest for 3 months and observe the status of bony fusion.

CONCLUSIONS

Our results showed that the OCF or AAF combined with short-term external immobilization can establish the upper

cervical stability and prevent further spinal cord injury and nerve function damage. The patients treated with AAF demonstrated higher fusion rates and greater patient satisfaction than those treated with OCF, AAF patients developed fewer complications.

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Conflicts of interest

There are no conflicts of interest.

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