1. Introduction

The atlantoaxial region is a susceptible anatomic complex that involves an intricate relationship between the C1 and the dens of axis to permit the head to move in all directions. The atlantoaxial instability usually consists of traumas in the atlas and axis, rheumatological diseases, congenital anomalies or the rupture of the transverse ligament (Dickman and Sonntag, 1998). In these patients, the C1-C2 joint is corrected surgically, by performing fusion and stabilization (Bahadur et al., 2010). So far, many surgical methods have been defined for this region such as posterior wiring, and interlaminar clamping. In 1979, Magerl et al. presented the outcomes of a posterior C1-C2 trans-articular screw fixation (Gallie, 1939; Brooks and Jenkins, 1978; Magerl and Seemann, 1987). This technique and combination with posterior wiring is accepted as the gold standard in the surgical treatment of atlantoaxial instability by many authors (Grob et al., 1991; Coyne et al., 1995; Dickman and Sonntag, 1998). This is a very powerful technique biomechanically, but it is technically difficult. In addition, this technique may present some dangerous complications such as vertebral artery injury. From March 2010 to December 2017, 12 consecutive patients who have atlantoaxial instability were surgically treated by modified fixation technique which consists C1 laminar hooks fixation and bilateral C2 trans-articular screw. Twelve patients were operated with this procedure from March 2010 to December 2017. All the patients were checked with flexion-extension x-rays at the end of the twelfth week. The posterior bony fusion formation was observed on imaging in all patients. C2 bilateral pedicle screw combined with C1 laminar hook system is a good method for atlantoaxial instability in the conditions which is not convenient for insertion of C1 lateral mass and C2 trans-articular screw. However, this method may not be available in some cases such as traumatic, infection, neoplastic or degenerative pathologies in which the posterior arch of the atlas is damaged.

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patients were analyzed using computed tomography (CT), and magnetic resonance imaging (MRI) and cervical column X-ray. The radiological images include neutral, flexion-extension lateral radiographs (Figure 1). All patients presented to our institution after traumatic injury such as falls, motor vehicle accidents and motorcycle accidents. Their age ranged from 18 to 65 years. The main symptom is neck pain that spread towards the occipital area in the patients. Their neurological examination was intact in all cases. Physical findings included cervical spasm, cervical tenderness and resistance to range of motion. No other injuries to the thorax, abdomen or extremities were noted. Postoperative radiographic imaging was performed at 3, 6 and 12 months in the first year (Figure 2). The patients used the Philadelphia collar for an average of 8-12 weeks following the surgery. Ethics approval for the study was given by the local ethics committee (2020/10-15.01.2020).

2.2. Surgical Technique
All the operations were performed with general anesthesia. After anesthesia, the patients were given a prone position by applying a head holder on the operating table. The rolled side pillows were used to keep the rib cage under pressure. The surgical incision extending from the occipital protuberance to C3 spinous process was made in the posterior dorsal midline. After the skin and subcutaneous passage, the incision was directed to the midline avascular area and entered between the ligamentum nuchae and paravertebral muscles. The muscle layer was dissected and passed to the sides softly and bluntly. Then, the posterior tubercle of the C1 spine is exposed and slowly, without exerting too much pressure with subperiosteal dissection opened laterally. The pedicle screw insertion was executed under lateral radiographic control. The screw entry hole was created with high-speed surgical drill. Then, the screws are performed in a neutral to 20 degree medial direction and 20 degree superiorly. Then the laminar hooks which are designed for the posterior arch of atlas were placed on the ring of C1. Next the hooks were assembled to the screws with a suitable rod. Then, the rod is placed, and the screw covers are tightened and system integrity is ensured. The C1 posterior ring and axis bone surface prepared for fusion with a high-speed drill. Autogenous cancellous bone graft material which was procured from the posterior superior iliac spine was inserted between the atlas and axis. The surgical area was washed with saline. Then, the surgical area was closed with appropriate sutures and technique.

3. Results
Twelve patients were operated this procedure from March 2010 to December 2017. Four patients were female and eight patients were male. The average age was 36.53 years (range 18-65 years). The average follow-up duration was 23.7 months (range 15-36 months). The mean operating time was 81.9 min (70 to 90 min). The mean intraoperative blood loss was 114.28 mL (90 to 160 mL) (Table 2). There was no dangerous complication such as the spinal cord or vertebral artery injury. Patients are mobilized appropriately on the first day after the operation with a neck collar. All the patients were evaluated with flexion-extension cervical lateral x-rays at the end of the 3rd month. The posterior bony fusion formation was observed on imaging in all patients. Postoperative complications included two superficial wound infections. The complications were successfully treated by the surgical debridement and giving antibiotics.

Fig. 1. 27/F, motor vehicle accident, neurological evaluation intact, Suboccipital and Neck pain: Preoperative sagittal axial coronal planes CT imaging (A, B, C), flexion lateral radiography (D), T2 axial MRI image (E) (Transverse ligament rupture) and postoperative lateral radiography (F) and 3D CT reconstruction images (G, H)
of transverse ligament damage requires surgical treatment as an indicator of instability. The atlantoaxial joint neck movement is one of the most important regions where traumas causing excessive flexion, extension or rotation forces may cause severe dislocation and especially transverse ligament damage in the joint. Upper cervical injuries occur motor vehicle accidents sports injuries falling from height and due to high-intensity traumas. The most common symptoms seen in patients are neck pain, tenderness and limitation of movement in the neck, muscle spasm. Three-dimensional computed tomography (CT) is the gold standard imaging to diagnose atlantoaxial instability.

**Table 2: Details of cases**

<table>
<thead>
<tr>
<th>Age &amp; Gender</th>
<th>Operation Time (minute)</th>
<th>Intraoperative Blood Loss (cubic centimeter)</th>
<th>Complications</th>
</tr>
</thead>
<tbody>
<tr>
<td>19/Male</td>
<td>90 min</td>
<td>110 cc</td>
<td></td>
</tr>
<tr>
<td>59/Male</td>
<td>86 min</td>
<td>160 cc</td>
<td></td>
</tr>
<tr>
<td>27/Female</td>
<td>70 min</td>
<td>125 cc</td>
<td></td>
</tr>
<tr>
<td>34/Male</td>
<td>80 min</td>
<td>105 cc</td>
<td>Wound infection</td>
</tr>
<tr>
<td>28/Male</td>
<td>75 min</td>
<td>95 cc</td>
<td></td>
</tr>
<tr>
<td>46/Male</td>
<td>84 min</td>
<td>115 cc</td>
<td></td>
</tr>
<tr>
<td>56/Female</td>
<td>94 min</td>
<td>120 cc</td>
<td></td>
</tr>
<tr>
<td>23/Male</td>
<td>76 min</td>
<td>100 cc</td>
<td></td>
</tr>
<tr>
<td>18/Male</td>
<td>72 min</td>
<td>90 cc</td>
<td></td>
</tr>
<tr>
<td>24/Female</td>
<td>75min</td>
<td>95 cc</td>
<td></td>
</tr>
<tr>
<td>65/Male</td>
<td>94 min</td>
<td>115 cc</td>
<td>Wound infection</td>
</tr>
<tr>
<td>48/Female</td>
<td>87 min</td>
<td>120 cc</td>
<td></td>
</tr>
</tbody>
</table>

Historically, this condition was generally treated with posterior cervical C1-2 fusion. Various surgical techniques were described by authors such as Brooks, Gallie, Dickmann, and Sonntag (Gallie, 1939; Brooks and Jenkins, 1978; Dickman and Sonntag, 1998). Although posterior binding techniques are less harmful for spinal cord roots and vertebral artery, they are technically easier to apply. Furthermore, it couldn’t provide adequate stability and cause to restriction of neck movements. Magerl is the first surgeon to screw the C1-C2 complex transarticularly in 1986 (Magerl and Seemann, 1987). It provides stronger stabilization compared to the strapping technique and increases the chance of fusion. An important advantage of this method is that it does not require external immobilization (Guo et al., 2009) Although the method is safe, it has been reported that its applicability over time is technically difficult and causes various complication (Richter et al., 2002). The most important disadvantage in the posterior approaches is the loss of axial rotation but they have high fusion rate (Richter et al., 2002; Guo et al., 2009). Therefore, surgical techniques applied for this region have been developed from past to present and many techniques have been reported by some authors (Goel and Laheri, 1994; Goel et al., 2002; Xiao et al., 2008; Guo et al., 2009; Guo et al., 2014). Traditionally, posterior wire stabilization and structural bone grafting doesn’t provide adequate immobilization of atlantoaxial complex. In addition,

**Fig. 2.** 19/M motorcycle accident, neurological evaluation intact, Suboccipital and Neck pain, odontoid fracture (motorcycle accident): preoperative coronal, sagittal and axial CT images (A, B, C) postoperative 12-month lateral radiography (D)

4. Discussion

The upper cervical region is the anatomical structure that be formed occipital bone, C1 and C2. Therefore, traumatic injuries are encountered in this region due to occipital condyles, atlantooccipital insertion, atlas, atlantoaxial joint, axis and especially odontoid. Especially the neck lateral bending and rotation movements take place mostly in this region. Presence
this technique increases the risk of neural injury. Furthermore, the patients need to external support in the postoperative period, including the use of halo devices. In our study, C1 ring grapples assemble with axis transpedicular screw and bone graft and we didn’t encounter any neural and vascular injury. Another surgical procedure is The Harms C1–2 Fixation method. Harm’s technique is a highly effective and robust technique compared to wire fixation and interlaminar clamping techniques. There is no need to use halo in the postoperative period.

In addition, C1 and C2 vertebrae posterior structures, which must have a solid integrity in wire fixation technique, do not need to be solid in this technique. Furthermore, the risk of injury to the vertebral artery and its surrounding venous plexus has been reported for this technique. Because C1 lateral mass is surrounded by a venous plexus with rich anastomosis. So, C1 posterior ring grapple safer for venous injury than C1 lateral mass screw. With the trans-articular screw fixation technique, there has been a significant increase and improvement in bone fusion rates (Magerl and Seemann, 1987; Suchomel et al., 2004). But this technique can’t be used with some conditions such as, cervicothoracic kyphosis, medially located vertebral artery (Paramore et al., 1996). However, researchers using this technique have reported that the risk of vertebral artery injury in 3.7–8.2 percent of cases (Grob et al., 1991; Wright and Laurysen, 1998; Suchomel et al., 2004). In our study, we did not see any vertebral artery damage. However, there is a damage of vertebral artery when inserting the axis pedicle screw. In the previous study, it has been shown by authors that C1 laminar hooks fixation and C1-2 trans-articular screws have been shown to be biomechanically more stable and robust by the authors (Guo et al., 2009). In the other study, six different techniques were biomechanically compared invitro by non-destructive testing. In this biomechanical study, it has been emphasized that although the best technique for neck rotation and sideways movement is trans-articular screwing, this technique is not always possible for some cases (Richter et al., 2002). In the same study, the axis transpedicular screwing system combined with the atlas hook system was reported to be stable. In another study, it was mentioned that the trans-articular screw cannot be placed successfully in twenty percent of the cases (Paramore et al., 1996). However, the risk of damage to vascular and neural structures in the atlas hook and axis transpedicular screw technique is relatively lower (Ni et al., 2010). All the posterior cervical stabilization procedures provide a 74 to 100% fusion rate (Goel and Laheri, 1994; Julien et al., 2000; Huang et al., 2015). Similarly, the present study has a satisfactory fusion rate of about 100 percent.

Our limitations about this study are, since our study is retrospective, we couldn't have the long term follow up results and we could use only the flexion extension X-ray for control. Therefore, the atlas hook and axis transpedicular screw system should be included in our surgical options in appropriate cases. Because, this method is more reliable posterior atlantoaxial fusion technique. In this technique, the upper cervical spine area should be scanned certainly with preoperative CT. If the bone structure is normal, technique should be applied. Especially the atlas posterior ring must be intact

Conflict of interest
I declare that we have no conflicts of interest in the authorship or publication of this contribution.

Informed consent
This is a retrospective study and no new treatment was used. Ethics approval for the study was given by the local ethics committee (2020/10-15.01.2020).

References

