Usefulness of titanium mesh cage for posterior C1–C2 fixation in patients with atlantoaxial instability

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Abstract

The aim of this study was to investigate the usefulness of titanium mesh cage as an interlaminar spacer combined with nitinol shape memory loop fixation in patients with atlantoaxial instability.

From April 2009 to March 2017, among the patients with atlantoaxial instability, a total of 30 patients were treated by nitinol shape memory loop fixation combined with titanium mesh cage as a spacer. We retrospectively reviewed 30 enrolled patients. Successful fusion was determined as improvement of symptoms and radiologic findings of bone fusion. We also reviewed surgical complications, instrumentation failure, bony fusion rate, and posterior atlantodental interval (PADI).

After surgery, the symptoms of all patients significantly improved. Successful fusion was documented throughout the follow-up period. Evidence of solid bridging bone was found, and no instability was seen on flexion–extension radiographs and callus formation on 3D cervical spine computed tomography (CT) 6 months postoperatively in all cases. No surgical complications were observed. No cases of instrumentation failure were observed. The mean PADI also improved significantly to 22.45 ± 1.11 mm 6 months postoperatively compared with the preoperative value of 18.37 ± 1.16 mm (P < .05).

We obtained a good fusion rate by using titanium mesh cage spacer with nitinol shape memory alloy loop in patients with atlantoaxial instability. This technique can help surgeons in avoiding vertebral artery injury and reducing bleeding and operation time. Therefore, we suggest that titanium mesh cage spacer combined with nitinol shape memory alloy loop can be a good substitute of autograft for C1–C2 fusion in treating atlantoaxial instabilities.

Abbreviations: PADI = posterior atlantodental interval, CT = computed tomography, MRI = magnetic resonance imaging, C1LM-C2P = C1 lateral mass and C2 pedicle screw.

Keywords: allografts, atlanto-axial fusion, cervical spine, surgical mesh

1. Introduction

The atlantoaxial segment is a unique and complex junction among the intervertebral joints. It accounts for approximately half of the rotational motion and 12% of the flexion–extension of the entire cervical spine. Its stability depends on the ligamentous support and odontoid integrity. Symptomatic atlantoaxial instability occurs easily because of trauma, congenital malformations, inflammatory arthritis, malignancy, and infections. [1,2] In this case of atlantoaxial instability, posterior atlantoaxial fusion is mandatory. However, the fusion rate of atlantoaxial segment is relatively lower than that of the subaxial cervical spine segment. [3–5] Various techniques of atlantoaxial fixation have evolved to achieve a higher fusion rate. Goel and Laheri [6] introduced a method using C1 lateral mass and C2 pedicle screw fixation, which consequently modified by Harms and Melcher [7]; this technique remains the gold standard for posterior C1–C2 fusion. In this technique, a 3-point fixation using an iliac crest autograft or allograft bone at the C1–C2 interlaminar space is a prerequisite to obtain rigid fusion.

Autograft bone has osteoconductive and osteoinductive matrix, and it provides higher fusion rates. [6,8] However, severe donor-site pain, hematoma, and wound infection are common after autologous iliac bone graft. Therefore, allograft bone is widely used despite the low and late fusion rate to prevent donor-site morbidity. Some authors previously reported the efficacy of titanium mesh cage filled with allograft bone in treating patients with atlantoaxial instability. [15,16] They all achieved good fusion rates (97%–100%) and used a spacer combined with transarticular screw fixation or posterior C1 lateral mass and C2 pedicle screw.

We previously introduced the posterior cervical fusion with a nitinol shape memory loop for primary surgical stabilization of
atlantoaxial instability. In this report, we investigate the usefulness of titanium mesh cage as an interlaminar spacer combined with nitinol shape memory loop fixation in patients with atlantoaxial instability.

2. Material and methods

2.1. Patient population

From April 2009 to March 2017, 30 patients with atlantoaxial instability were treated with titanium mesh cage at our neurosurgery department. Fixation was performed using nitinol shape memory alloy loop in all cases. The study included 17 men and 13 women, with a mean age of 47.66 years (Table 1). The mean follow-up period was 31.66 months. Sixteen patients had odontoid process fracture with transverse and alar ligament injury, 6 had rheumatoid arthritis, 4 had C1–2 instability due to transverse ligament rupture, and 4 had symptomatic os odontoideum. Patients with indications for anterior odontoid screw fixation were excluded. C1–2 rotational instability was defined as atlantoaxial subluxation or fixation that presented on cervical spine computed tomography (CT) scan. Ligament injuries on magnetic resonance imaging (MRI) were confirmed by a neurosurgeon and a neuroradiologist. Institutional Review Board of Chonbuk National University Hospital approved this study.

2.2. Surgical procedure

The patient was placed in a prone position after induction of general anesthesia. The head was secured in a Mayfield holder and maintained in a neutral position. The neck was flexed to obtain straight alignment of the cervical spine. A midline linear incision was made starting from the unin, and the muscles and fascia were dissected to expose the occiput and posterior C1 and C2 vertebrae. Subsequently, the superior margin of the C1 posterior arch and inferior margin of the C2 lamina were dissected carefully to create a space between the thecal sac and bone. The titanium mesh cage was cut into an appropriate size and packed only with allograft bone, including demineralized bone matrix and cancellous bone. Subsequently, we inserted this tailored titanium mesh cage between the C1 posterior arch and C2 lamina. After inserting the mesh cage as a spacer, we calculated the exact size of the loop using template-measuring instruments and selected a length of memory loop smaller than the measured distance between the C1 arch and C2 lamina to tighten the mesh cage when the loop was reverted to its original shape. Subsequently, the memory loop was cooled in sterilized cold saline to a temperature <10°C (50°F) for at least 30 seconds. The loop became flexible and could be deformed easily to fit between the C1 and C2 rings. One hook was placed behind the C1 posterior arch, and the other was placed behind the C2 lamina. Subsequently, another loop was placed on the opposite side over the midline. After bilateral installation of the 2 loops, they were irrigated with warm saline between 35°C (95°F) and 45°C (113°F), and the loop slowly regained its initial form and rigidity, tightly fixing the C1 posterior arch, mesh cage, and C2 lamina. We assessed the fixation by manually pulling and shaking the loops. After confirmation of the fixation with intraoperative plain lateral radiography, the wound was closed layer by layer. Postoperatively, all patients were treated with immobilization for 8 to 12 weeks in a cervical collar.

3. Results

We retrospectively reviewed 30 enrolled patients. Successful fusion was determined as improvement of symptoms and radiologic findings of bone fusion. We also reviewed surgical complications, instrumentation failure, bony fusion rate, and posterior atlantoaxial interval (PADI). PADI was obtained preoperatively and 6 months postoperatively. It was calculated on plain lateral radiograph from the posterior aspect of the odontoid to the anterior aspect of the posterior C1 ring. Solid bone fusion and instability were assessed with flexion–extension radiographs at intervals and 3D cervical spine CT 6 months postoperatively. Bone fusion was defined as evidence of continuity of trabecular bone between C1 and C2 across the graft. Statistical analysis was performed using the t test. A significance level of P < .05 was used.

3.1. Case illustration

A 54-year-old female patient presented with posterior neck pain after a traffic accident. Initial simple radiographs and CT showed C2 odontoid process fracture with right C1 lateral mass fracture (Fig. 1). MRI revealed transverse ligament injury (Fig. 2). We performed posterior C1–2 fusion using nitinol shape memory loop with tailored titanium mesh cage, and the patient recovered without neurological deficits. Her neck pain improved. Simple cervical spine radiograph showed no instrument failure and no atlantoaxial instability (Fig. 3) 6 months postoperatively. PADI increased from 19.84 to 23.42 mm. In addition, 3D cervical spine CT showed improved bone fusion and solid bridging bone formation between C1 and C2 (Fig. 4).

| Table 1 |
| --- |
| Demographic characteristics of the patients. |
| Parameter | Value |
| Number of patients (male: female) | 30 (17: 13) |
| Mean age | 47.66 y (16–76) |
| Mean follow-up period | 31.66 mo (12–66) |
| Cause of atlantoaxial instability | |
| Odontoid fracture with transverse ligament injury | 16 |
| Rheumatoid arthritis | 6 |
| Rotatory instability due to ligament injury | 4 |
| Os odontoideum | 4 |

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[12]
Figure 1. Preoperative cervical simple radiograph (A) and CT (B) showed C2 odontoid process fracture with right lateral mass fracture. CT = computed tomography.

Table 2

| Case | Age/sex | Diagnosis                              | Follow-up period, mo | Complications | Preop. PADI, mm | Postop. PADI, mm |
|------|---------|----------------------------------------|-----------------------|---------------|-----------------|------------------|
| 1    | 61/F    | RA                                     | 116                   | None          | 17.82           | 20.86            |
| 2    | 29/M    | Rotational injury due to ligament injury| 16                    | None          | 20.52           | 24.01            |
| 3    | 49/M    | Odontoid fracture (Type II)             | 10                    | None          | 19.74           | 23.12            |
| 4    | 41/M    | Odontoid fracture (Type III)            | 7                     | None          | 18.67           | 22.91            |
| 5    | 31/F    | Os odontoideum (orthotopic)             | 49                    | None          | 17.38           | 20.96            |
| 6    | 35/F    | RA                                     | 86                    | None          | 16.88           | 21.54            |
| 7    | 61/F    | RA                                     | 83                    | None          | 18.56           | 21.34            |
| 8    | 76/M    | Odontoid fracture (Type IIA)            | 7                     | None          | 19.37           | 23.74            |
| 9    | 58/F    | Os odontoideum (orthotopic)             | 64                    | None          | 18.67           | 22.77            |
| 10   | 28/M    | Odontoid fracture (Type III)            | 15                    | None          | 18.67           | 23.00            |
| 11   | 73/M    | Os odontoideum (orthotopic)             | 32                    | None          | 18.62           | 22.86            |
| 12   | 54/F    | Odontoid fracture (Type IIA)            | 53                    | None          | 19.84           | 23.42            |
| 13   | 16/M    | Odontoid fracture (Type IIA)            | 13                    | None          | 17.74           | 20.92            |
| 14   | 46/F    | RA                                     | 50                    | None          | 19.38           | 23.58            |
| 15   | 22/M    | Odontoid fracture (Type III)            | 9                     | None          | 17.25           | 22.06            |
| 16   | 54/F    | Odontoid fracture (Type III)            | 13                    | None          | 17.36           | 21.08            |
| 17   | 57/F    | Rotational instability due to ligament injury| 14                   | None          | 17.39           | 22.83            |
| 18   | 55/F    | Rotational instability due to ligament injury| 42                   | None          | 17.81           | 23.51            |
| 19   | 17/M    | Odontoid fracture (Type III)            | 31                    | None          | 17.32           | 21.80            |
| 20   | 66/M    | RA                                     | 7                     | None          | 17.67           | 22.19            |
| 21   | 21/M    | Odontoid fracture (Type IIA)            | 18                    | None          | 20.31           | 24.35            |
| 22   | 57/M    | Odontoid fracture (Type IIA)            | 16                    | None          | 17.72           | 21.31            |
| 23   | 34/M    | Odontoid fracture (Type IB)             | 17                    | None          | 20.99           | 23.38            |
| 24   | 72/F    | Odontoid fracture (Type II)             | 24                    | None          | 18.01           | 22.30            |
| 25   | 58/M    | RA                                     | 16                    | None          | 18.75           | 22.47            |
| 26   | 23/M    | Rotational instability due to ligament injury| 47                   | None          | 19.10           | 24.68            |
| 27   | 54/F    | Odontoid fracture (Type IIA)            | 12                    | None          | 18.71           | 22.45            |
| 28   | 69/M    | Odontoid fracture (Type IIA)            | 14                    | None          | 16.56           | 22.25            |
| 29   | 57/F    | Os odontoideum (orthotopic)             | 67                    | None          | 17.52           | 20.49            |
| 30   | 76/M    | Odontoid fracture (Type IIA)            | 6                     | None          | 18.73           | 21.48            |

Mean value*  

*PADI = posterior atlantodental interval.  

*P < .05, analyzed by t test.
3.2. Discussion

Because atlantoaxial segment is a unique and complex biomechanical junction, atlantoaxial instability leads to neck pain and neurological deficits. Various surgical techniques have been used to achieve atlantoaxial stability and bone fusion, including wiring technique,\(^\text{[13]}\) interlaminar clamps,\(^\text{[14]}\) transarticular fixation,\(^\text{[10,15]}\) and C1 lateral mass and C2 pedicle screw (C1LM-C2P) fixation.\(^\text{[7,11]}\) Transarticular fixation is biomechanically considered more rigid than the wiring method and yields a higher fusion rate. Although the fusion rate is high, this technique remains technically demanding, and has a risk of vertebral artery injury.\(^\text{[16]}\)

Nowadays, C1LM-C2P fixation has been widely performed because of the low risk for vertebral artery injury.\(^\text{[17]}\) The advantage of this technique lies in the direct manipulation of the atlantoaxial segment, which simplifies the subsequent reduction and fixation. Moreover, a slightly higher fusion rate than that for transarticular fixation has been reported.\(^\text{[18]}\) However, many donor-site morbidities including pain, hematoma, and infection occur, because this technique needs autograft.

Ryu et al.\(^\text{[11]}\) recently reported that C1LM-C2P fixation with a titanium mesh cage is a valuable procedure in the treatment of atlantoaxial instability. They used a mesh cage packed with demineralized bone materials as a structural graft. Although fusion rate is higher when using autologous bone than when using allograft due to more superior osteoinductive and osteoconductive properties, several studies did not show a difference in fusion rates, clinical outcome, and graft complications between autograft and allograft.\(^\text{[7,19,20]}\) According to the Ryu et al.,\(^\text{[11]}\) the mesh cage spacer showed several advantages, including no donor-site morbidity, good fusion rate, and immediate rigid fixation.

We previously introduced a posterior C1–C2 fixation method with nitinol shape memory loop for atlantoaxial instability and obtained good outcomes.\(^\text{[12]}\) On the basis of these studies, we used this technique and a titanium mesh cage as a spacer in treating the patient with atlantoaxial instability. Nitinol is a shape memory alloy of nickel and titanium. It is flexible and easily deformed \(< 10^\circ\)C, but regains its original shape \(> 30^\circ\)C. Hence, it becomes rigid and produces large forces. It also has high fatigue strength, moderate impact resistance, and biocompatibility.\(^\text{[21]}\)

Nitinol memory loop can be easily applied in spine surgery because this technique is similar to that using interlaminar clamps wherein immediate fixation is achieved, and the risk associated with sublaminar wire can be avoided. In addition, this technique needs only small muscle dissection and can reduce bleeding and operation time. In addition, we can obtain a good reduction of the os odontoideum through this technique. As described in Table 2, PADI increased in all patients with os odontoideum.

In all of our cases, we could achieve 100% bony fusion rate without any surgical complications. Thus, we speculate that the titanium mesh cage improved atlantoaxial stability and durability. The edge of the mesh cage is saw toothed, and this shape can tightly fit the cage to the C1–C2 interlaminar space. Because nitinol memory loop can create a compressive force along the titanium mesh cage between C1 and C2 interlaminar space, the fusion rate may be increased, according to Wolff law. Using this technique with titanium mesh cage, we can also avoid donor-site morbidity.

In patients with atlantoaxial instability, the ideal posterior atlantoaxial fusion technique needs to have higher bony fusion
rate, easy surgical technique, and low risk for spinal cord or vertebral artery injury. We achieved a good result utilizing nitinol shape memory loop with titanium mesh cage and suggest this technique as a good alternative surgical technique. However, this technique can only be used in case of intact posterior C1 and C2 elements. Thus, it cannot be used when laminectomy is required or trauma-induced disruption of posterior elements or bifa or congenital absence. Further investigations may be needed, and a longer follow-up period is required for the titanium mesh cage spacer.

4. Conclusion

In our study, we obtained a good fusion rate by using titanium mesh cage spacer with nitinol shape memory alloy loop in patients with atlantoaxial instability. This technique can help surgeons in avoiding vertebral artery injury and reducing bleeding and operation time. Therefore, we suggest that titanium mesh cage spacer combined with nitinol shape memory alloy loop can be a good substitute of autograft for C1–C2 fusion in treating atlantoaxial instabilities.

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