# C2 Odontoid Fracture Associated with C1-C2 Rotatory Dislocation: A Retrospective Analysis of 2 Surgical Techniques

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■ BACKGROUND: **Odontoid fractures in association with a C1-C2 rotatory luxation reports are seldom found in the literature. The fusion between the lateral mass of C1 and C2 could be of interest to ensure adequate treatment in these particular cases. We report 23 cases where there was coexistence of an odontoid fracture and rotatory subluxation, which were treated surgically using cages between C1 and C2 or just traditional Goel-Harms technique. We evaluated the radiologic fusion rate, reoperation rate, and complications.**

■ METHODS: **This was a single-center, retrospective, cohort study of patients with C2 fractures (mixed type and C1-C2 rotatory luxation according to the Fielding classification) who were treated surgically. Radiologic computed tomography scans were used to assess fusion (presence of bridging trabecular bone end plate or pseudoarthrosis) between 6 months and 1.5 years after the surgery.**

■ RESULTS: **Twenty-three patients were diagnosed with C2 fractures and C1-C2 rotatory luxation that were treated surgically and were suitable for the analysis; 11 patients underwent C1-C2 fusion with intra-articular cages, and 12 underwent a classical Goel-Harms technique. The fusion rate at the C1-C2 joint was higher in the cages group. Only 12 patients exhibited fusion at the level of the odontoid fracture.**

■ CONCLUSIONS: **C2 fractures associated with C1-C2 rotatory dislocation are rare. The fusion rate at the level of the odontoid in these patients appears to be lower than that reported in patients without rotatory dislocation. It may be of special interest to obtain a clear fusion at the C1-C2 joint, where this type of implant seems to offer an advantage.**

## INTRODUCTION

C1-C2 rotatory luxation, also known as atlantoaxial rotatory subluxation, is a condition characterized by abnormal movement and misalignment between the first cervical vertebra (C1, also called the atlas) and the second cervical vertebra (C2, also called the axis). When this condition is associated with a C2 odontoid fracture, it presents a more complex injury pattern. Unfortunately, studies on this specific type of pathology are few.[1] Traumatic dislocation of the atlantoaxial joint associated with an odontoid fracture is an injury rarely reported in the literature.[2,3]

In mild cases of C1-C2 rotatory luxation (Fielding grade 1 or 2) (**Figure 1A**) without significant instability or neurologic deficits, the initial treatment may involve closed reduction. Following closed reduction, the patient is typically placed in a cervical collar or a halo vest to immobilize the neck and allow the structures to heal. Regular monitoring and follow-up imaging are necessary to ensure stability. However, the association of this dislocation with an odontoid fracture implies a different level of instability given the context of a capsular joint injury. There are a few case reports in the literature on the surgical treatment of patients with C2 fractures associated with C1-C2 rotatory dislocation[1,4] (**Figure 1B** and **C**).

Atlantoaxial (C1-C2) fusion is a commonly used surgical technique for managing pathologies such as atlantoaxial instability, subluxation, and C2 fractures.[5-8] The Goel-Harms technique,

**Key words**
- C1-C2 fusion
- Intra-articular spacer
- Rotatory subluxation
- Fracture C2
- Odontoid Fracture

**Abbreviations and Acronyms**
**C1**: First cervical vertebra
**C2**: Secon cervical vertebra
**CT**: Computed tomography
**IRB**: Institutional review board
**MRI**: Magnetic resonance imaging

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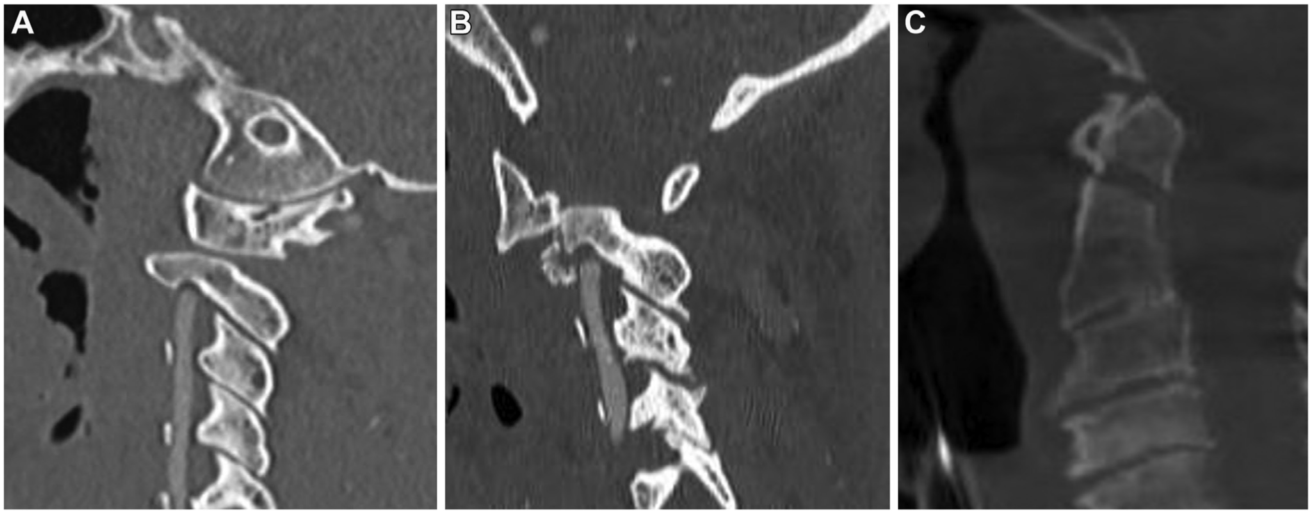


**Figure 1.** (**A**) Sagittal computed tomography scan showing a mild Fielding grade 1 luxation. (**B**) CT scan showing complete luxation of the C1 lateral mass over the C2 articular facet (Fielding grade 4). (**C**) Alonzo II fracture.

which involves transpedicular screw placement and lateral mass screws, is the classical method for C1-C2 screw placement.[9,10]

Bone grafts may be used to promote fusion and enhance stability. Since there is a disruption of the articular capsule between C1 and C2, we believe that there is a particular interest in attempting fusion at this specific anatomic site rather than attempting fusion at the odontoid level only.

The use of C1-C2 spacers, or cages, was first described for the treatment of basilar invagination and has been shown to result in a good fusion rate.[11,12] C1-C2 facet spacers are typically used in the context of spinal fusion surgeries.[13] These spacers are small devices designed to maintain the natural height and alignment of the facet joints during fusion procedures, and they are placed between the facet joints to create space and promote stability. While facet spacers have been used in other areas of the spine, such as the lumbar region, their use specifically at the C1-C2 level is less common.[14] Recent cadaveric studies have demonstrated the potential benefits of using an intra-articular spacer between C1 and C2 to increase the stability of the fixation.[15] Both techniques (with and without C1-C2 cages) can be used to perform atlantoaxial fusion, but it is unclear which technique is more effective in achieving successful fusion or improving clinical outcomes. To date, no studies have provided a comprehensive comparison of the 2 techniques beyond basilar invagination. Therefore, this study aimed to compare the outcomes of C1-C2 screw placement with and without an intra-articular spacer in atlantoaxial fusion for C2 fracture associated with C1-C2 rotatory dislocation, contributing to the available evidence base in spinal surgery.

## METHODS

We performed a single-center, retrospective, cohort study of patients treated between 2007 and 2022 with a diagnosis of C2 odontoid fractures associated with C1-C2 rotatory luxation or facet dislocation in whom C1-C2 fixation was performed with or without cage placement. Approval was obtained from the institutional review board (IRB). Patients were classified into 2 groups based on the presence or absence of C1-C2 interarticular cages. Patients who had a previous surgery for the same lesion or with less than 1 year of follow-up and no computed tomography (CT) scan after 6 months follow-up were excluded. All patients underwent preoperative CT and magnetic resonance imaging (MRI) to characterize pathology. The decision to utilize a C1-C2 intra-articular cage was primarily based on the surgeon who was responsible for the case; in our center, 2 surgeons were accustomed to the use of these implants, and another surgeon, also experienced in performing C1-C2 fusions, did not use these implants and used only posterolateral bone grafting. All patients underwent postoperative cervical CT scans and radiography at the 1-year follow-up. Images were reviewed by an experienced radiologist, and the definition of fusion was determined by the presence of >50% of a bone bridge at the C2 odontoid fracture and/or >50% of a bone bridge in the C1-C2 articulation on both sides without any sign of microinstability (pseudoarthrosis). Examinations were performed on CT scans (GE LightSpeed Ultra, Chicago, Illinois, USA, GE Revolution, GE Discovery CT 750HD; 1.25-mm thick).

### Surgical Technique

All surgeries were performed under general anesthesia with the patient in the prone position using neuromonitoring. The patient's head was secured with a Mayfield (Integra, Princeton, New Jersey, USA) pin fixation head holder. A navigation reference array was clamped to the Mayfield rigidly and draped in sterile fashion for some cases; for others, a spinous process clamp was used.

In all surgeries where cages were used, the C2 nerve root was identified microsurgically on both sides. To obtain sufficient

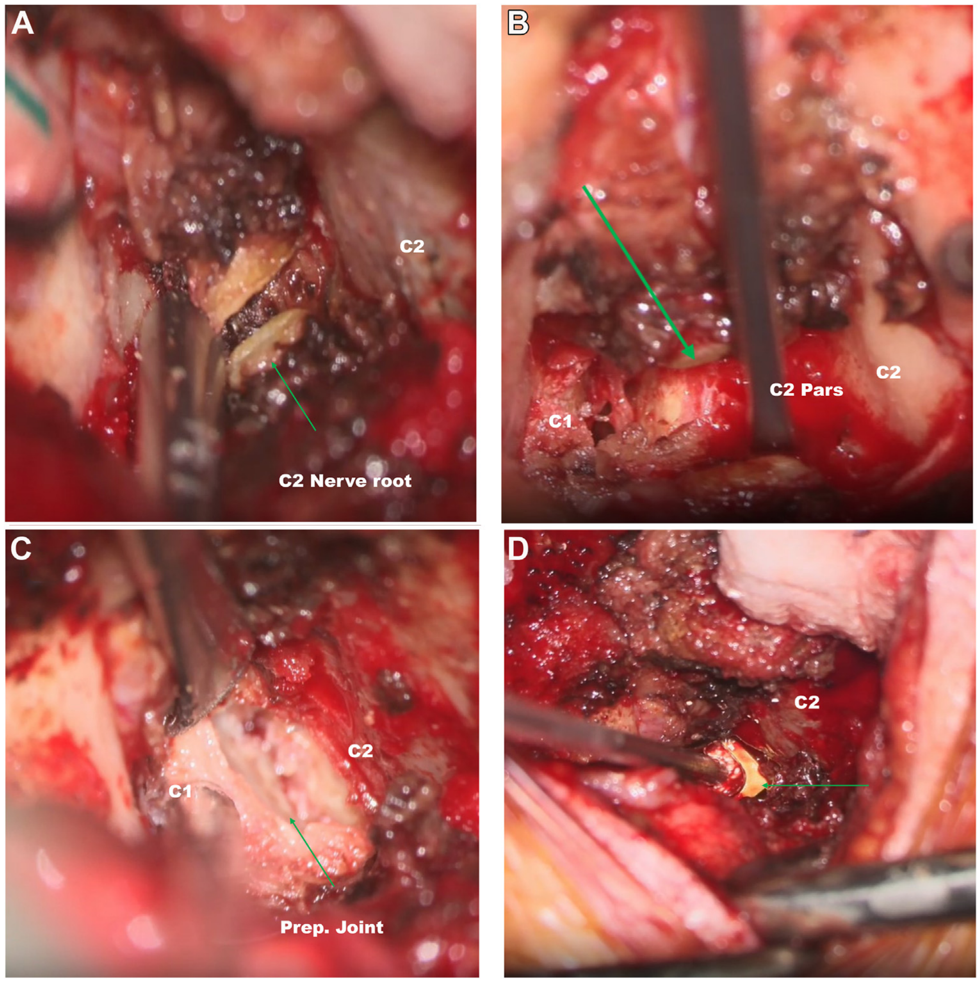


**Figure 2.** (**A**) Surgical picture of a C1-C2 joint dissection, with a preganglionic cut of the C2 root, to completely expose the capsule of the joint. (**B**) Complete dissection and opening of the C1-C2 joint (*green arrow*). Cutting the root allows for a good view of the pars, the facet of C2, and the complete lateral mass. (**C**) Preparation of the joint to fit in the cage. (**D**) Titan cage inside the C1-C2 joint, filled with bone graft.

access to the atlantoaxial joint, the nerve root of the C2 segment was then coagulated proximal to the ganglion and transected (Figure 2A). C1-C2 was prepared using a combination of a high-speed drill and curettes (Figure 2B and C). In all cases, titanium cages were used (Globus Medical, Audubon, Pennsylvania, USA,) (Figure 2D). The rest of the procedure was similar for both groups; in brief, the entry points for the C1 lateral mass screws and the C2 pars screws were identified, drilled, and tapped using navigation to achieve optimal screw trajectory and length. Autologous bone was used either in between the C1 and C2 joint inside the cages or posteriorly.

### Statistical Analysis

The statistical analyses were performed using SPSS, version 18.0 (SPSS, INC, Chicago, Illinois, USA). A $P$ value $< 0.05$ was considered significant. Normally distributed data were compared using the unpaired $t$ test, and the chi-square test was used to analyze categorical data.

## RESULTS

We identified 17 patients with a C2 fracture and C1-C2 rotatory dislocation who underwent C1-C2 fusion using the Goel-Harms technique. We excluded 5 patients because of a lack of follow-up CT scans.

We identified 14 patients who had a C2 fracture with at least Fielding grade 1 rotatory luxation in whom intra-articular cages were placed. Three patients were excluded because of a lack of a CT scan after at least 6 months.

In total, 12 patients underwent a classic Goel-Harms C1-C2 fixation (without cages) and 11 patients Goel-Harms technique with the C1-C2 intra-articular cages for a total of 23 surgical patients.

The mean follow-up was 9 months, with a range from 6 to 18 months. Twenty-three patients underwent surgery for C1-C2 fixation. Eight (34%) patients underwent initial conservative treatment, and failure of conservative treatment was considered secondary displacement or persistent mechanical symptoms (Figure 3A-D).

All cases were classified according to the Anderson and D'Alonzo classification into 3 grades (1, 2, and 3) (Figure 3A), and rotatory dislocation was classified according to the Fielding classification (grades 1 to 4) (Figure 4B and C, Table 1).

Implantation of the cage into the C1-C2 joint space and coagulation and transection of the C2 spinal nerve root on both sides were performed in all patients to facilitate the approach to the C1-C2 joint space for cage implantation.

In 17 of 23 patients, the dislocation was grade I according to the Fielding classification, 5 patients were classified as grade 2, 1 as grade 3, and no cases of grade 4 were noted. In all cases, rotatory subluxation was visible on the CT scan (Figures 3 and 4). MRI showed a hypersignal inside the C1-C2 joint in all cases (Figure 3C and 4D).

According to the criteria established by the radiology team, fusion was not observed in only 2 cases, 1 in each group. In the

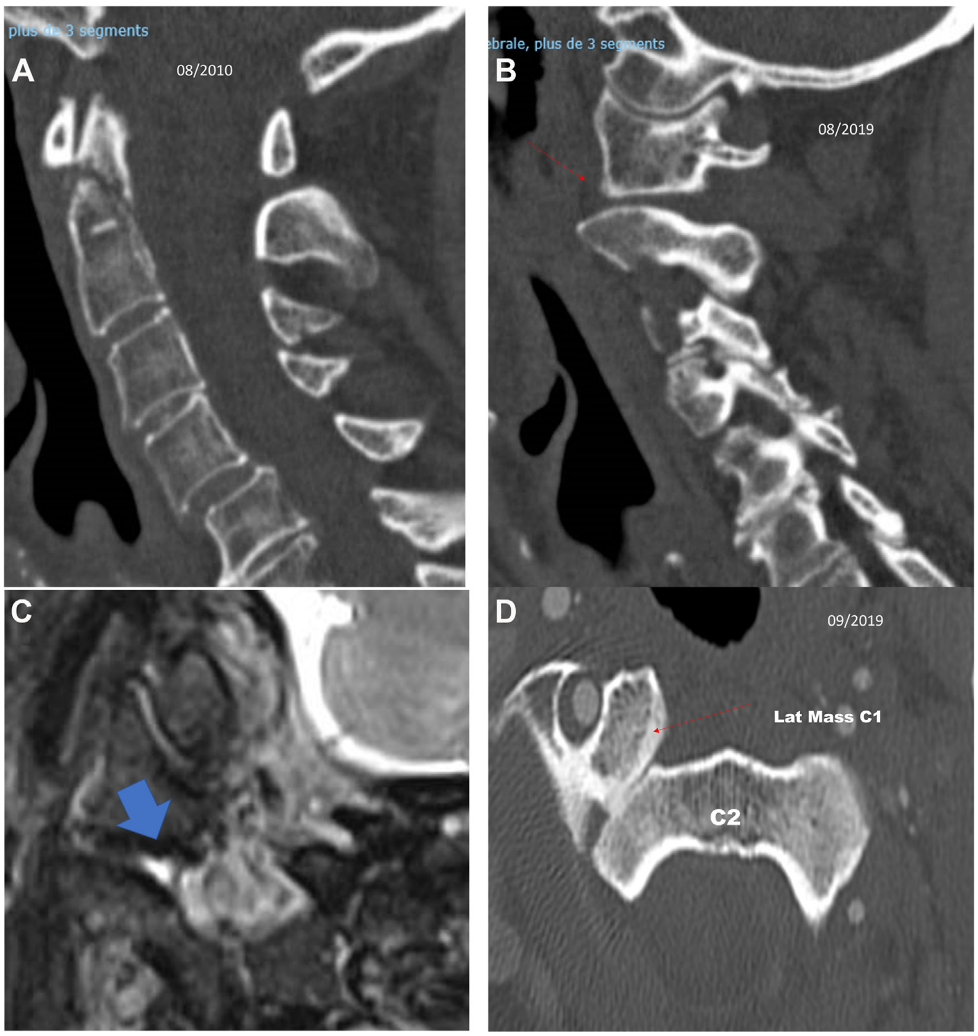


**Figure 3.** (**A**) Sagittal computed tomography (CT) scan showing a typical Alonzo II fracture. (**B**) The same patient with a mild rotatory luxation (Fielding grade 1). (**C**) Magnetic resonance imaging showing a hypersignal on T2-weighted Dixon inside the C1-C2 joint that correlates with a lesion over the capsule joint (*blue arrow*). (**D**) Axial CT scan of the same patient after using a collar for over a month, showing aggravation of rotatory subluxation.

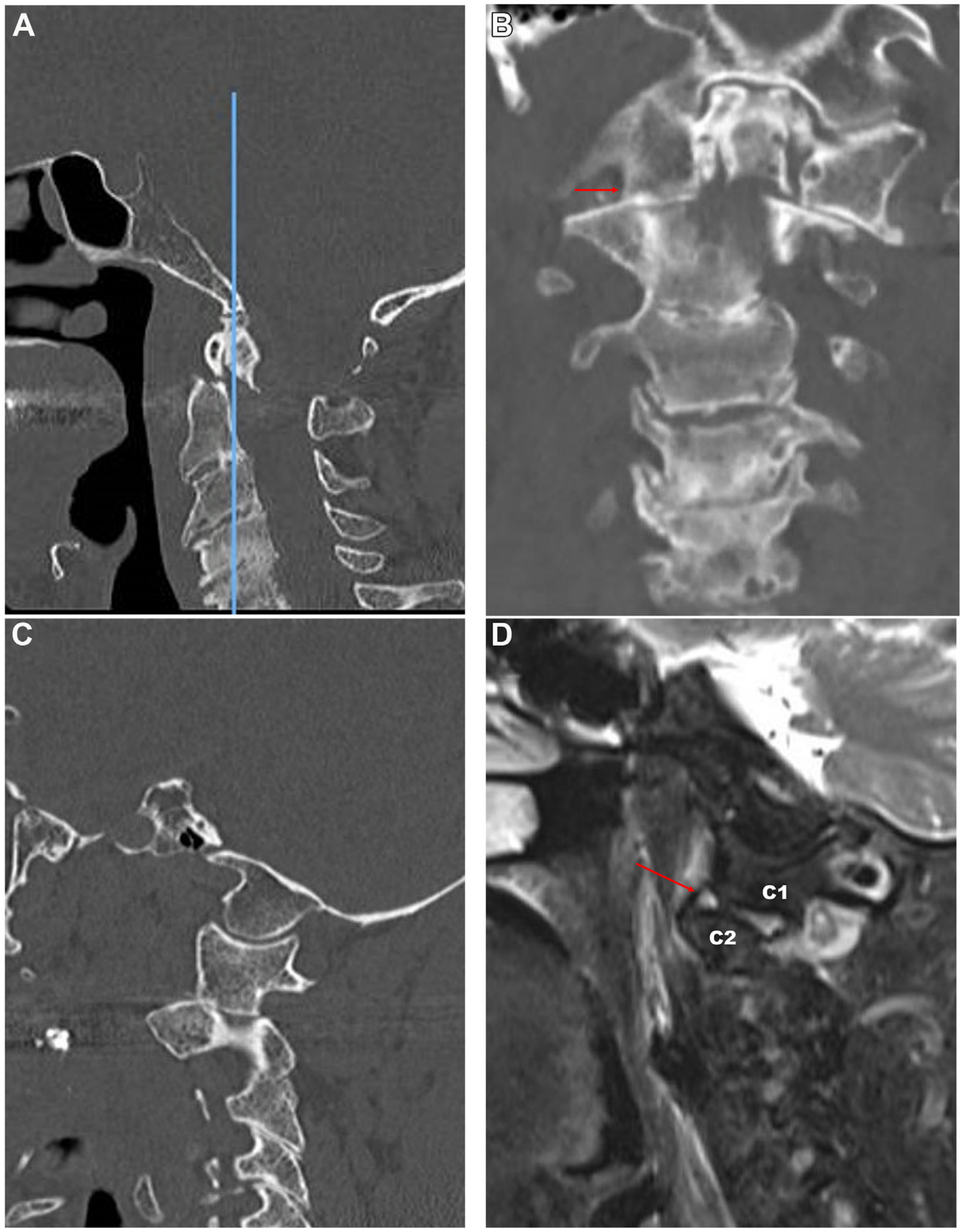


**Figure 4.** (**A-C**) Severe combined C2 Alonzo II fracture with a high-grade rotatory luxation (grade 4). (**D**) Hypersignal on the T2-weighted Dixon magnetic resonance imaging.

patient without a cage, pseudoarthrosis was also evident, caused by loosening of the screws. No further action was taken because both patients remained asymptomatic.

Interestingly, only 12 patients exhibited fusion at the level of the odontoid fracture in the long term (Figure 5A): 7 in the group with cages and 5 in the group without cages. No significant difference was noted, with a P value of 0.292.

In all patients with cages, the fusion was mainly concentrated between the C1 and C2 joint (Figure 5B and C), and in patients without cages, posterolateral fusion was observed, except for 1 case where some fusion at the level of the joint was observed (Figure 5D, Table 1). An overall fusion rate of 83% was noted in the Goel-Harms group and 90% in the cages group. The difference again was not significant, with a P value of 0.58.

**Table 1.** Characteristics and results of the groups examined

| | Goel-Harms | Goel-Harms + Cages C1-C2 | Variation |
|---|---|---|---|
| Alonzo classification | Grade 1 (0) | Grade 1 (0) | |
| | Grade 2 (7) | Grade 2 (8) | |
| | Grade 3 (5) | Grade 3 (3) | |
| Fielding classification | Grade 1 (9) | Grade 1 (8) | |
| | Grade 2 (3) | Grade 2 (2) | |
| | Grade 3 (0) | Grade 3 (1) | |
| Odontoid fusion | 5 (41%) | 7 (63%) | 0.292* |
| C1-C2 joint fusion | 1 (8.3%) | 10 (90%) | 0.00007* |
| Overall fusion (including posterolateral) | 10 (83%) | 10 (90%) | 0.58* |
| Nonunion | 2 | 1 | |
| Reoperation | 0 | 0 | |
| EBL (ml) | 511 ml (± 189) | 333 ml (± 78.1) | *P*. 0.18† |
| Operative time | 257 min | 304 min | *P*. 0.13† |

EBL, estimated blood loss.
*$\chi^2$ test.
†t test.

We did not find a statistically significant difference in estimated blood loss (Table 1); however, there was a slight tendency of less estimated blood loss in the group where we placed the cages.

Although the difference in the operative time was again not significant, we noted a tendency toward longer operative time in the group of patients where we placed the cages.

## DISCUSSION

There are few reports throughout the literature on the use of this type of implants between the C1 and C2 joints to treat fractures of the upper cervical spine. This is probably one of the most extensive reports documenting the use of these devices to treat C2 fractures associated with C1-C2 rotatory subluxation.

These cages seem a logical way to reduce the risk of pseudoarthrosis, in this type of cases, since there is a particular interest in creating a fusion at the level of the C1-C2 joints as well as of the odontoid. We did not find any difference between the patient groups in terms of reoperations due to pseudoarthrosis; no patients needed revision surgery due to a lack of fusion, which indicates that both treatments are truly effective for this type of pathology even if complete fusion does not occur.

It is important to note that the percentage of fusion at the level of the odontoid was relatively low in both groups (Table 1); in fact, stability was more likely achieved in both groups by either a posterolateral fusion or fusion between the C1 and C2 joints.

The rationale for using the C1-C2 facet cages is to restore alignment by lifting the atlantoaxial joints into place, allowing ligamentotaxis to take place. A concern about this type of implants could be a dislocation of the implant, although the use of posterior screws and rod fixation should prevent the spacer from severe dislocation and loosening, the spacer could potentially slide posteriorly, although no reports exist in the literature.

In our patients, we observed no complications related to the insertion of the cages, and we did not detect any statistically significant differences between the groups. In both groups, the fusion was adequate, and no patients in either group needed reoperation, although 1 patient in the group without cages exhibited some loosening of the instrumentation.

It is important to note that opening the C1-C2 joint capsules and placing the cages could have a benefit on the reduction of the dislocation in complex cases of dislocation (Fielding 3 or 4).

One of the negative points may be the need to cut the nerve roots for proper placement of the spacers, which has been previously reported by other authors. C2 root preservation rather than sacrificing the C2 nerve root has long been debated in fusions involving C1 and C2. In our patients, the C2 root was sacrificed in all cases where spacers were used, which was of course associated with occipital numbness. Although we could not obtain enough information for documentation, it seems that the numbness had very benign consequences for patients, which has also been reported by other authors.[16]

We believe that it is very likely that rotatory dislocation in association with an odontoid fracture is underdiagnosed because it is often not clearly visible, and we documented some patients with grade 1 dislocations with an associated capsular lesion on MRI who clearly progressed even with the use of a collar (Figure 5). Whether the signal change in the capsule on MRI can be of prognostic value will be the subject of another ongoing study; if it is of prognostic value, it should be studied in cases we try to treat conservatively since few studies have been published on this topic.

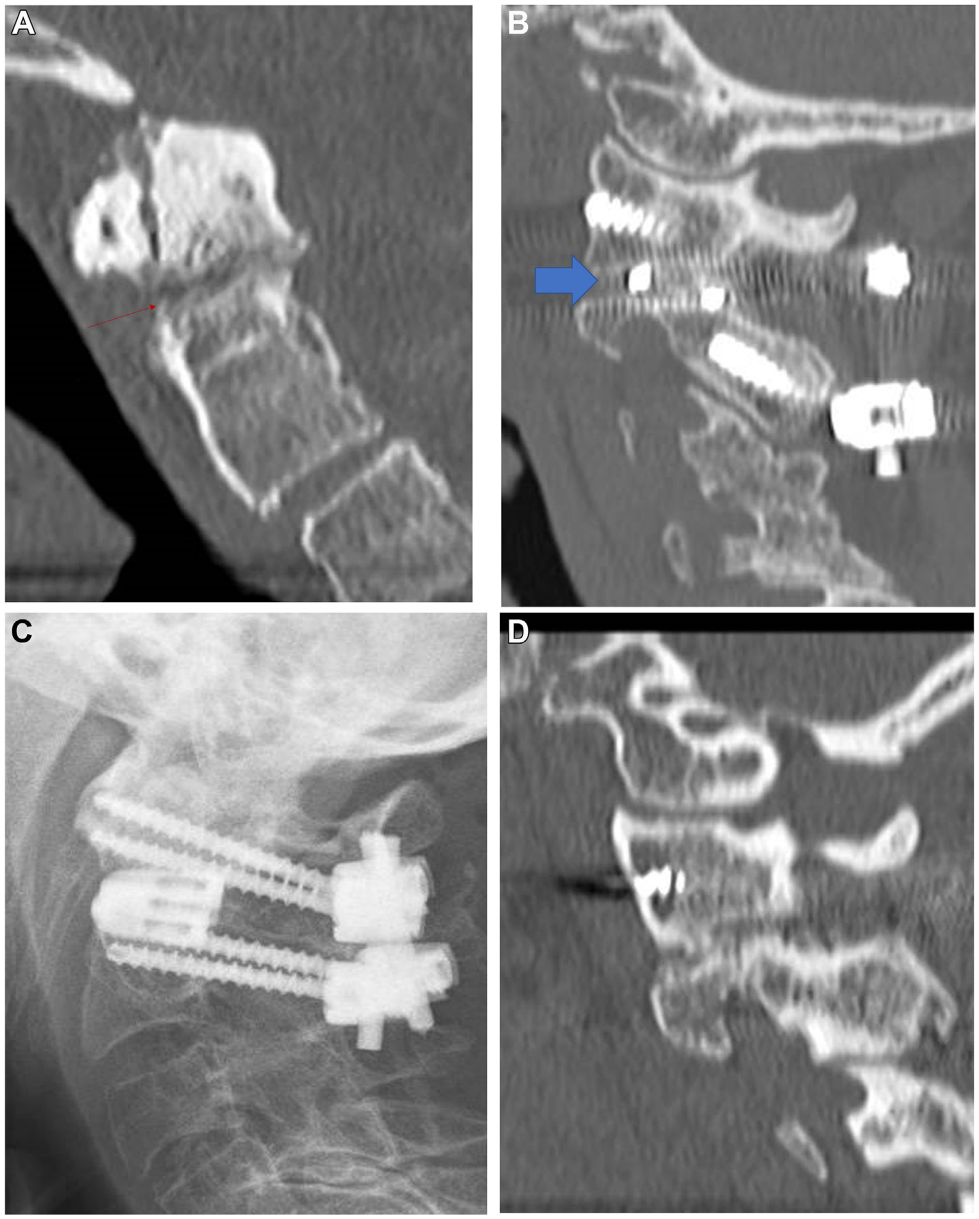


**Figure 5.** (**A**) Follow-up scan after 3 years of a patient with a C2 Alonzo II fracture treated with a C1-C2 Goel-Harms technique + a cage. No fusion over the odontoid is observed (*red arrow*). (**B**) Solid fusion observed at the C1-C2 joints (*blue arrow*). (**C**) X ray showing the C1-C2 Goel-Harms technique + a cage. (**D**) Patient treated with a standard Goel-Harms technique, with some incomplete bone bridges visualized at the joint but not a solid fusion as in the case with spacers/cages.

We found that 34% of patients who were initially treated with a collar presented with secondary displacements and thus needed surgery after a few weeks (**Figure 3**).

Interestingly, this group of patients presented a low rate of fusion at the odontoid (only 12 of the 23); the rupture of the capsule with the C1-C2 dislocation possibly offers a poor prognostic factor to obtain a fusion. This type of implant offers a high percentage of interarticular fusion, which could be important in patients with high risk of nonunion.

## CONCLUSION

In conclusion, this study explored the use of C1-C2 interarticular cages for the treatment of odontoid fractures with rotatory dislocation. The results showed that the use of intra-articular cages did not increase the rate of complications but also do not seem to have an impact on the risk of reoperation vs. using the standard technique without intra-articular implants. This result was apparently not relevant for the clinical outcome, which may be due to the small population. The study highlighted the importance of proper diagnosis of rotatory dislocation, which may have prognostic value for selecting adequate management.

Overall, these findings support the safety and effectiveness of using intra-articular devices for the treatment of odontoid fractures with rotatory dislocation. Further studies with larger sample sizes could provide more vigorous evidence on the efficacy of using C1-C2 spacers.

## CRediT AUTHORSHIP CONTRIBUTION STATEMENT

All authors contributed to the study conception and design. The first draft of the manuscript was written by Simon Diaz and Juan Barges-Coll and all authors commented on previous versions of the manuscript. All authors read and approved the final manuscript.

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