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# Does the Surgical Approach Matter in Treating Odontoid Fractures? A Comparison of Mechanical Complication Rates Between Anterior Versus Posterior Surgical Approaches: A Meta-Analysis and Systematic Review

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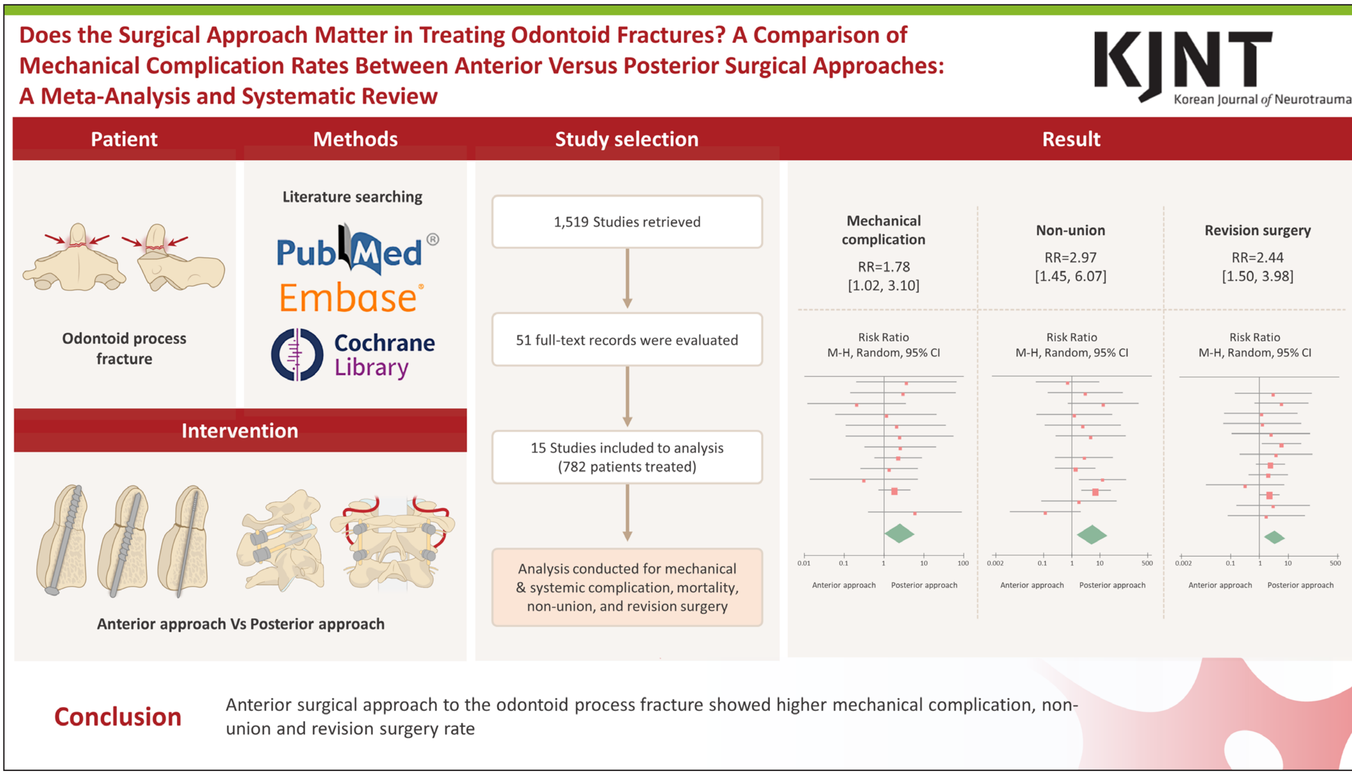
## ABSTRACT

**Objective:** Odontoid fractures are treated surgically through the anterior or posterior approach. Each surgical approach has its advantages and disadvantages, so the preferred approach remains debatable. There are few meta-analyses or systemic reviews on the mechanical complications of surgical treatment for odontoid fractures. This meta-analysis aimed to compare the operation-related morbidity, including mechanical complications, and mortality of patients with odontoid fractures, treated via the anterior or posterior approach.
**Methods:** A systematic search was performed on PubMed/Medline, Embase, and the Cochrane Library for the studies up to October 2023 on the complication rate of the surgical treatment of odontoid fractures, related to the surgical approach. The risk ratios (RR) with the 95% confidence intervals (CIs) were pooled to assess the mechanical complication rates, other complications, revision surgery, and mortality, depending on the surgical approach.
**Results:** A total of 1,519 studies were retrieved using the search strategy, and 782 patients from 15 articles were included in this meta-analysis. Mechanical complications were significantly more frequent in the anterior surgical group with low heterogeneity. The incidences of fracture nonunion and revision surgery were also higher in the anterior surgery group. However, there was no significant difference in systemic complications and mortality rates between the two groups.
**Conclusion:** The posterior approach was more advantageous than the anterior approach in terms of mechanical complications, fusion rates, and incidence of revision surgery. However, further studies, should be performed to strengthen these results.

**Keywords:** Odontoid process; Spinal fractures; Meta-analysis; Arthrodesis; Complications; Fracture fixation

## GRAPHICAL ABSTRACT

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**Conflict of Interest**
The authors have no financial conflicts of interest.

## INTRODUCTION

Cervical spine injuries have been reported in up to 2.4% of patients, visiting the emergency departments following blunt trauma.[16] Motor vehicular accidents, older age, and falls increase the risk of cervical spine fractures or dislocations.[12] Among the cervical spine injuries, odontoid fractures are common (7%–15%). However, they are associated with high nonunion, morbidity, and mortality rates.[32] Odontoid fractures were reportedly related to poor functional outcomes, a high risk of non-union of up to 85%, and a mortality rate of 7%–22% within one year of injury.[12,16,32]According to the Anderson and D'Alonzo/Grauer classification, odontoid fractures are subclassified into types I, II, and III.[1,11] Type II fractures, which are the most common, occur at the base of the odontoid process with a tendency for nonunion and displacement.[27] Type I fractures, where the fracture line is located at the tip of the dens, are considered stable. Type III fractures, which become unstable due to poor vascularization, may extend into the cancellous body of the axis, involving a variable portion of the joint.

Odontoid fractures are treated surgically or conservatively, depending on the fracture pattern and the patient's age. Patients with stable odontoid fractures are immobilized, using a cervical collar or halo vest, and then observed. Surgical stabilization can be considered for either unstable or nonunion fractures. Surgical intervention is indicated in patients, presenting with a fracture dislocation greater than 5 mm, angulation greater than 10 degrees, and neurological deficits.[28] The surgical treatment options for stabilization procedures include the anterior Smith Robinson approach, which involves odontoid screw fixation, or

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the posterior approach, which involves either C1-2 arthrodesis or multilevel cervical fixation extending to the occiput to the subaxial cervical spine. The choice of anterior or posterior approach is controversial due to conflicting evidence, regarding the preferred approach. The anterior approach preserves the range of motion of the C1-2 joint, when the transverse ligament is intact and there is good alignment. However, the approach was related to postoperative dysphagia or nonunion. The posterior approach is more beneficial in cases, necessitating the reduction of a subluxation or fracture in C1-2. However, it was related to prolonged operation time and postoperative neck pain. Each approach has its advantages and disadvantages, and they result in different complications.There have been systemic reviews and meta-analyses, comparing the fusion rates of odontoid fractures.[4,31] However, there is a paucity of studies, comparing the mechanical complications, systemic complications, and mortality rates between the two procedures. Hence, this meta-analysis aimed to compare the mechanical complication rates, other complication rates, and mortality in patients with odontoid fractures, treated via the anterior or posterior approach.

## MATERIALS AND METHODS

Studies, involving adults with odontoid fractures, treated via an anterior or posterior surgical approach, were eligible for the meta-analysis. A computerized search was conducted on the PubMed/Medline, EMBASE databases, and the Cochrane Central Register of Controlled Trials. The search keywords used were “odontoid process” OR “odontoid process fracture” OR “dens” OR “C2” AND “odontoid screw” OR “anterior screw” OR “anterior approach” AND “arthrodesis” OR “C1-C2 fusion” OR “transarticular” OR “posterior arthrodesis” OR “posterior fixation” OR “posterior approach.”

### Selection criteria and data acquisition

Studies were selected based on the following criteria: 1) randomized controlled trials, or prospective or retrospective observational comparative analyses, comparing the anterior and posterior surgical approaches for the treatment of odontoid fractures; 2) comparative studies, involving any type of complication, as well as the postoperative morbidity or mortality rate; 3) more than two patients included for each group; and 4) studies published until October 2023. Studies, that did not compare the two surgical approaches or did not analyze the complications, were excluded.

The studies were independently assessed by two review authors (YSK, WRJ) based on the inclusion criteria. For each study, the demographic data, including study population, sample size, fracture type, age, gender, surgical approaches, and clinical outcomes, including the complications, were extracted. The mechanical complication rate was the primary outcome. Complications, related to instrumentation, were defined as mechanical complications (implant failure, such as screw loosening, screw pull out, screw breakage, screw misplacement, fixation failure, k-wire breakage, and incorrect reduction or dislocation of C1-2). The secondary outcomes included perioperative systemic complications, fracture non-union rate, reoperation, and mortality rate.

The risk of bias was assessed by two authors (YSK, WRJ) using the Newcastle-Ottawa quality assessment scale (NOS).[34] NOS has been developed to evaluate nonrandomized studies. This scale consists of three perspectives, including the selection of the study groups, comparability of the groups, and ascertainment of outcome of interest for case-control or cohort studies. The scores 0–3, 4–6, and 7–9 scores correspond to low, middle, and high quality, respectively. Studies with a score of five or higher were used in the analysis.

### Statistical analysis

The effect sizes for data on the anterior and posterior approaches were represented as risk ratio (RR) with 95% confidence intervals (CIs). *p* values less than 0.05 were considered statistically significant. The heterogeneity of individual studies was evaluated by $I^2$ statistics. An $I^2$ value higher than 50% indicated significant heterogeneity, and a random effect model was used. Review Manager software, version 5.4 (The Cochrane Collaboration, Oxford, UK) was used to conduct the meta-analysis. The $\chi^2$ test was used to compare the mortality and complication rates, which were analyzed using IBM SPSS Statistics 26.0 (International Business Machines Corporation, Armonk, NY, USA).

## RESULTS

### Study selection results and characteristics of the included studies

A total of 1,519 studies (537 from PubMed, 921 from EMBASE, 61 from the Cochrane Library) were obtained using different databases. After removing duplicates, the titles and abstracts of 1,114 records were evaluated. The abstracts and titles were independently screened by two reviewers, and 51 studies went through full-text evaluation. Fifteen studies, involving 782 surgically treated patients (anterior approach 379, posterior approach 403), were selected for the meta-analysis based on the inclusion and exclusion criteria (**FIGURE 1**).[2,8,13,14,19-26,29,30,36] The baseline characteristics and NOS score for risk of bias assessment of the included studies are presented in **TABLE 1**. There were no randomized controlled trials. Among the 15 studies, there were two prospective and 13 retrospective cohort observational studies. All studies were

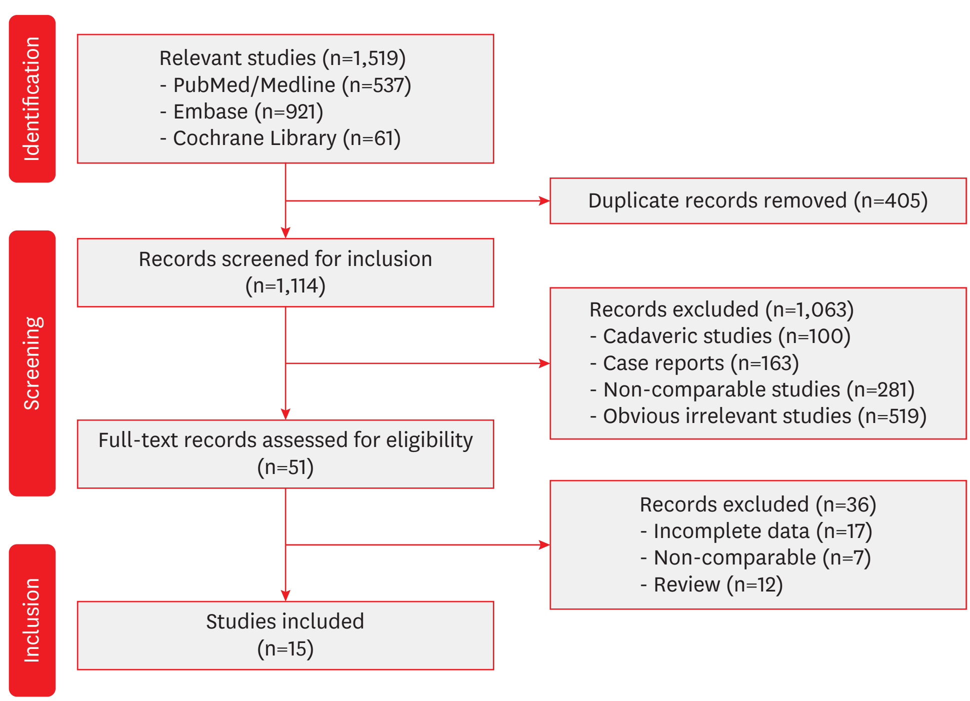


**FIGURE 1.** PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) flowchart detailing the search strategy and studies selection.


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**TABLE 1.** Characteristics of the studies included in this meta-analysis

| References | Country of study | Study design | Mean age (years) | Male, No. (%) | Types of fracture | Surgical approaches | Mortality case | Follow up months | NOS score | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | Selections | Comparability | Outcome |
| Andersson et al.[2] (2000) | Sweden | Retrospective | 78 | 6/18 (33.0%) | Type II OR III | AA (11): Böhler technique PA (7): Posterior C1-C2 fusion | 10 | 51 | ★★★ | ★ | ★ |
| Cho and Sung[8] (2011) | South Korea | Retrospective | 47.9 | 9/16 (56.0%) | Type II OR III | AA (8): AOSF<br>PA (8): Posterior C1-C2 transarticular screw fixation, C1 lateral mass + C2 pedicular screw fixation | 0 | 19.7 | ★★★ | ★ | ★★ |
| Konieczny et al.[13] (2012) | Germany | Prospective | 64.5 | 22/38 (57.9%) | Type II OR III | AA (13): AOSF PA (25): Post. Transarticular C1-C2 fusion | AA: 2<br>PA: 2 | 9.7 | ★★★★ | ★ | ★ |
| Kuntz et al.[14] (2000) | USA | Retrospective | 76.3 | 8/11 (73.0%) | Type II OR Type II and C1 Fx. | AA (2): AOSF<br>PA (9): Posterior C1-C2 transarticular screw fixation with a modified Gallie fusion | PA: 1 | 14 | ★★★ | ★ | ★ |
| Moscolo et al.[19] (2021) | Italy | Retrospective | 80.9 | 18/23 (78.0%) | Type II (b or c) | AA (21): AOSF<br>PA (8): C1-C2 arthrodesis | 0 | 3–6 | ★★★ | ★ | ★ |
| Omeis et al.[20] (2009) | Canada | Retrospective | 79.9 | 11/29 (38.0%) | Type II | AA (16): AOSF<br>PA (13): C1-C2 LMSF, C1-C3 LMSF, cervical laminectomy + OC fusion, Transarticular screw fixation + modified Gallie fusion | AA: 1 | 9 | ★★★ | | ★★★ |
| Patterson et al.[21] (2017) | USA | Retrospective | 77.8 | 81/141 (57.0%) | NA | AA (48): AOSF<br>PA (93): C1-C2 fusion or O-C2 fusion | AA: 5<br>PA: 5 | 1 | ★★ | ★ | ★★ |
| Platzer et al.[22] (2007) | Austria | Retrospective | 71.4 | 25/56 (44.6%) | Type II OR III | AA (37): Böhler technique PA (19): C1-C2 arthrodesis | AA: 3<br>PA: 1 | 12–24 | ★★★ | ★★ | ★★ |
| Przkora et al.[23] (2006) | Germany | Prospective | 80.5 | 3/8 (37.5%) | Type II | AA (7): Anterior odontoid double-screw compression osteosynthesis<br>PA (one patient sustained additional C1 fracture): C0-C2 fusion in combination with a C1-C2 fusion according to Magerl | 0 | 18 | ★★ | ★ | ★ |
| Rizvi et al.[24] (2012) | Norway | Retrospective | 73 | 64 (66.0%) | Type II OR III | AA (40): AOSF<br>PA (57): Post. Wiring of C1-C2 with a bone graft from the hip transarticular screw fixation, lat. Mass/pedicle screw, OC fusion | 4 | 37 | ★★★ | ★★ | ★★ |
| Sawarkar et al.[25] (2015) | India | Retrospective | 28 | 127/142 (89.4%) | Type II OR III | AA (85): AOSF<br>PA (57): Magerl technique, Goel-Harms technique, OCF, Gallie's technique etc. | AA: 3<br>PA: 2 | 22 | ★★★ | ★ | ★ |
| Scheyere et al.[26] (2013) | Switzerland | Retrospective | 81.2 | 14/33 (42.4%) | Type II | AA (17): AOSF<br>PA (16): Posterior atlantoaxial fusion | AA: 20.0%<br>PA: 27.7% | 31.1 | ★★★ | ★ | ★ |
| Shousha et al.[29] (2019) | Germany | Retrospective | 76.2 | 45/133 (33.8%) | Type II b | AA (47): AOSF<br>PA (86): Posterior atlantoaxial fusion | AA: 4<br>PA: 8 | 30 | ★★★ | ★ | ★★ |

NOS: Newcastle-Ottawa quality assessment scale, AA: anterior approach, PA: posterior approach, AOSF: anterior odontoid screw fixation, LMSF: lateral mass screw fixation, OC: occipitocervical.

reported from Asia or Europe. The follow-up period of the 15 studies was between one to 51 months. In terms of surgical stabilization, the anterior approach involved an odontoid screw fixation, except for one study, which involved double odontoid screw fixation.[23] Meanwhile, the posterior approaches had various stabilization methods, including C1-2 posterior fixation, occipito-cervical fixation, transarticular screw fixation, and multilevel cervical

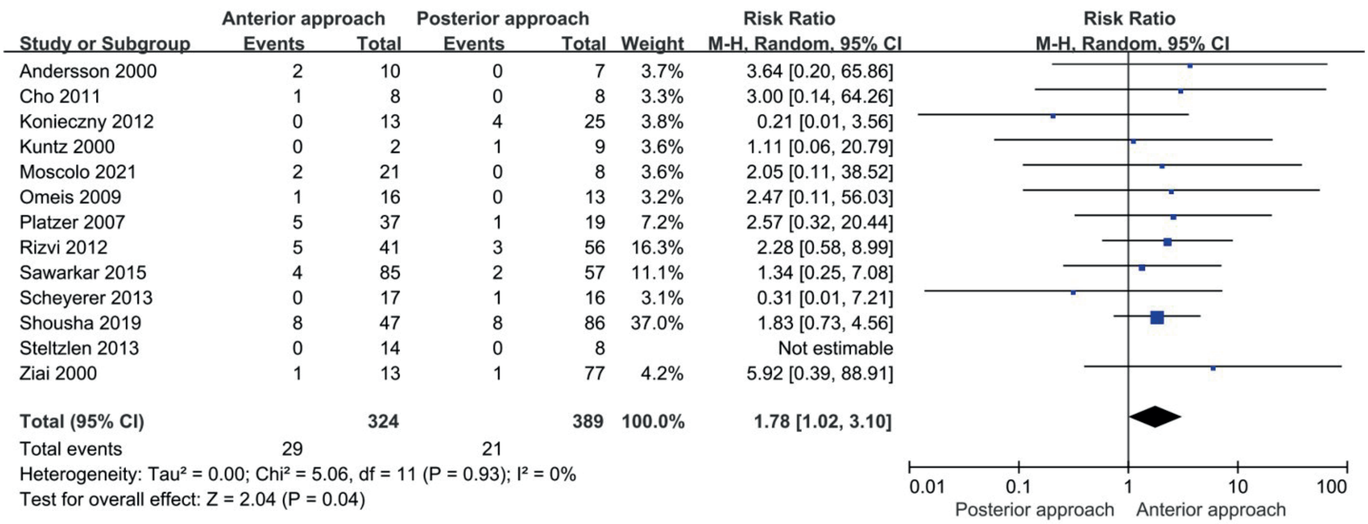


**FIGURE 2.** Forest plot comparing mechanical complication of anterior and posterior approach.
CI: confidence interval.

posterior fixation. Cases, that were treated with a combined surgical approach or other type of treatment, were excluded from the analysis. In terms of the risk of bias, the average NOS score was 5.5, which indicated a fair quality.

## Results of meta-analysis

*Primary outcome*

1) Mechanical complication

Among the included studies, thirteen studies reported mechanical complications, depending on the surgical approach. The mechanical complication rate (8.95% vs. 5.4%) was higher in the anterior approach group, compared to the posterior approach group (RR, 1.78; 95% CI, 1.02–3.10; $p$=0.04). Furthermore, the heterogeneity was low ($\chi^2$=0.00, df=11, $I^2$=0%, $p$=0.93). A detailed review of the mechanical complications is described in **SUPPLEMENTARY TABLE 1** (**FIGURE 2**).

Secondary outcome

1) Systemic complication rates related to operation

For systemic complications, 11 studies reported systemic, surgery-related complications. There was no significant difference in systemic complications between the two surgical approaches, and the heterogeneity was insignificant (RR, 0.93; 95% CI, 0.57–1.50; $p$=0.76) (**FIGURE 3A**).

2) Perioperative mortality rate

Ten studies reported perioperative mortality. Although the posterior approach group had a lower mortality rate, there was no significant difference between the two surgical approaches (RR, 1.29; 95% CI, 0.75–2.22; $p$=0.36) (**FIGURE 3B**).

3) Fracture non-union rate

Twelve studies compared non-union according to the surgical approaches. There were 637 patients, who developed non-union fractures, and 325 were treated via the anterior approach. The non-union rate (12.3% vs. 3.2%) was higher in the anterior approach group (RR, 2.97; 95% CI, 1.45–6.07; $p$=0.003). The non-union data exhibited mild heterogeneity ($\chi^2$=0.20, df=11, $I^2$=13%, $p$=0.32) (**FIGURE 3C**).

4) Incidence of revision surgery

Thirteen studies reported the incidence of revision surgery. The incidence of revision surgery was 7.9% (62/784). The incidence of revision surgery was significantly higher in the anterior approach cohort than in the posterior approach cohort (RR, 2.44; 95% CI, 1.50–3.98; $p$=0.0003). The heterogeneity for revision surgery data was low ($\chi^2$=0.00, df=12, $I^2$=0%, $p$=0.98). This result was likely related to the higher mechanical complication rate and incidence of non-union fractures in the anterior approach cohort (**FIGURE 3D**).

### Publication bias assessment with funnel plot

A funnel plot was created for each outcome of interest to assess the publication bias. The funnel plot for each outcome exhibited slight asymmetry, except for systemic complications. This finding suggested minimal bias (**SUPPLEMENTARY FIGURE 1**).

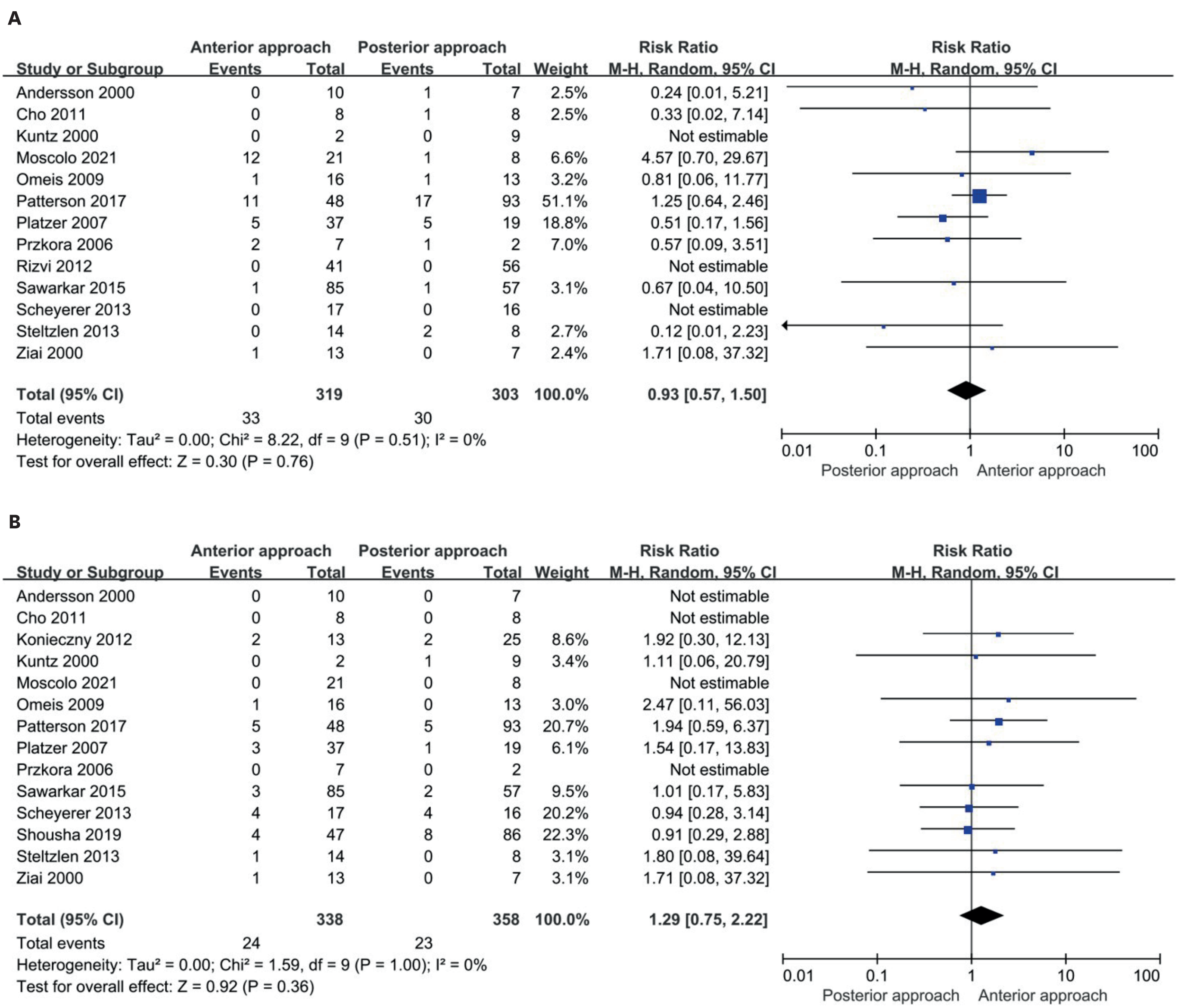


**FIGURE 3.** (A) Forest plot comparing systemic complication of anterior and posterior approach. (B) Forest plot comparing mortality of anterior and posterior approach. (C) Forest plot comparing non-union of anterior and posterior approach. (D) Forest plot comparing revision surgery of anterior and posterior approach. CI: confidence interval.

(continued to the next page)


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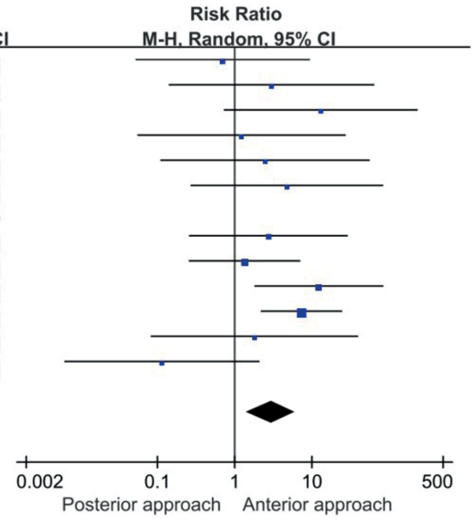
**C**

| Study or Subgroup | Anterior approach Events | Anterior approach Total | Posterior approach Events | Posterior approach Total | Weight | Risk Ratio M-H, Random, 95% CI |
|---|---|---|---|---|---|---|
| Andersson 2000 | 1 | 10 | 1 | 7 | 6.8% | 0.70 [0.05, 9.41] |
| Cho 2011 | 1 | 8 | 0 | 8 | 5.0% | 3.00 [0.14, 64.26] |
| Konieczny 2012 | 3 | 13 | 0 | 25 | 5.6% | 13.00 [0.72, 234.17] |
| Moscolo 2021 | 1 | 21 | 0 | 8 | 4.9% | 1.23 [0.05, 27.39] |
| Omeis 2009 | 1 | 16 | 0 | 13 | 4.9% | 2.47 [0.11, 56.03] |
| Platzer 2007 | 4 | 37 | 0 | 19 | 5.7% | 4.74 [0.27, 83.64] |
| Przkora 2006 | 0 | 7 | 0 | 2 | | Not estimable |
| Rizvi 2012 | 2 | 41 | 1 | 56 | 8.0% | 2.73 [0.26, 29.12] |
| Sawarkar 2015 | 4 | 85 | 2 | 57 | 14.4% | 1.34 [0.25, 7.08] |
| Scheyerer 2013 | 10 | 13 | 1 | 16 | 11.5% | 12.31 [1.80, 84.03] |
| Shousha 2019 | 12 | 47 | 3 | 86 | 22.8% | 7.32 [2.17, 24.65] |
| Steltzlen 2013 | 1 | 14 | 0 | 8 | 4.9% | 1.80 [0.08, 39.64] |
| Ziai 2000 | 0 | 13 | 2 | 7 | 5.5% | 0.11 [0.01, 2.10] |
| **Total (95% CI)** | | **325** | | **312** | **100.0%** | **2.97 [1.45, 6.07]** |
| Total events | 40 | | 10 | | | |

Heterogeneity: Tau² = 0.20; Chi² = 12.60, df = 11 (P = 0.32); I² = 13%
Test for overall effect: Z = 2.99 (P = 0.003)




**D**

| Study or Subgroup | Anterior approach Events | Anterior approach Total | Posterior approach Events | Posterior approach Total | Weight | Risk Ratio M-H, Random, 95% CI |
|---|---|---|---|---|---|---|
| Andersson 2000 | 0 | 10 | 0 | 7 | | Not estimable |
| Cho 2011 | 1 | 8 | 0 | 8 | 2.5% | 3.00 [0.14, 64.26] |
| Konieczny 2012 | 3 | 13 | 1 | 25 | 5.1% | 5.77 [0.66, 50.11] |
| Kuntz 2000 | 0 | 2 | 1 | 9 | 2.8% | 1.11 [0.06, 20.79] |
| Moscolo 2021 | 1 | 21 | 0 | 8 | 2.5% | 1.23 [0.05, 27.39] |
| Omeis 2009 | 1 | 16 | 0 | 13 | 2.5% | 2.47 [0.11, 56.03] |
| Patterson 2017 | 6 | 48 | 2 | 93 | 9.8% | 5.81 [1.22, 27.71] |
| Platzer 2007 | 3 | 37 | 0 | 19 | 2.8% | 3.68 [0.20, 67.85] |
| Rizvi 2012 | 7 | 41 | 4 | 56 | 17.7% | 2.39 [0.75, 7.63] |
| Sawarkar 2015 | 6 | 85 | 2 | 57 | 9.8% | 2.01 [0.42, 9.62] |
| Scheyerer 2013 | 0 | 17 | 1 | 16 | 2.4% | 0.31 [0.01, 7.21] |
| Shousha 2019 | 11 | 47 | 9 | 86 | 36.8% | 2.24 [1.00, 5.01] |
| Steltzlen 2013 | 2 | 14 | 0 | 8 | 2.8% | 3.00 [0.16, 55.72] |
| Ziai 2000 | 1 | 13 | 0 | 7 | 2.5% | 1.71 [0.08, 37.32] |
| **Total (95% CI)** | | **372** | | **412** | **100.0%** | **2.44 [1.50, 3.98]** |
| Total events | 42 | | 20 | | | |

Heterogeneity: Tau² = 0.00; Chi² = 4.17, df = 12 (P = 0.98); I² = 0%
Test for overall effect: Z = 3.58 (P = 0.0003)

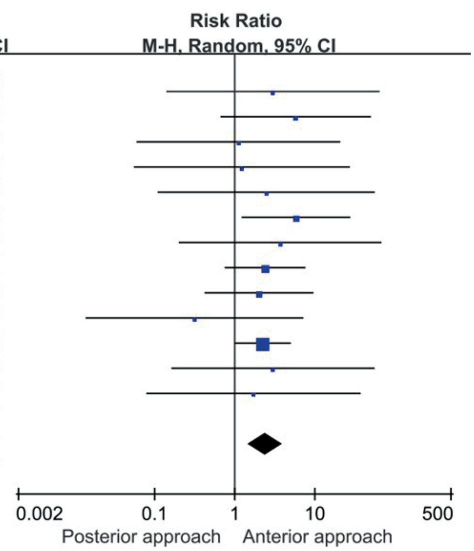



**FIGURE 3.** (Continued) (A) Forest plot comparing systemic complication of anterior and posterior approach. (B) Forest plot comparing mortality of anterior and posterior approach. (C) Forest plot comparing non-union of anterior and posterior approach. (D) Forest plot comparing revision surgery of anterior and posterior approach.
CI: confidence interval.

# DISCUSSION

Although odontoid fractures are among the most common cervical spine injuries, the optimal treatment for this entity remains controversial. Some reports favored anterior odontoid screw fixation because it preserved atlantoaxial motion, decreased procedure-related morbidity, and achieved an acceptable fusion rate.[6,18] Factors that influence the choice of surgical approach include the presence of a transverse ligament injury, severe osteoporosis, irreducible fractures, body habitus, and fracture morphology. Furthermore, pseudoarthrosis, screw-related complications, and residual neck pain are problematic long-term outcomes, associated with the anterior approach.[27] Others advocated a posterior surgical approach due to the better fusion rates and fewer implant-related complications. However, this approach was associated with a higher morbidity due to its invasiveness, increased risk of soft tissue injury, and decreased atlantoaxial motion.[24] There are conflicting meta-analyses, comparing the clinical outcomes of the anterior and posterior approaches to odontoid fractures.[4,31] Lvov et al.[17] showed that anterior odontoid screw fixation had a lower rate of fusion and a higher rate of reoperation with no difference in technical failure or mortality. Bao et al.[4] reported that the anterior approach had a shorter operative time and greater motion retention with no difference in complications and mortality. The fusion rate, rather than the mechanical complication rate, was primarily used to evaluate the outcome of the surgical treatment of odontoid fractures. However, mechanical complications are also an important cause of revision surgery, which may result in further morbidity and medical costs. Therefore, this analysis aimed to compare the clinical outcomes, including mechanical complications, fracture non-union rate, systemic complications, and mortality, depending on the surgical approach.In the analysis, the overall mechanical complication rate was higher in the anterior approach group than in the posterior approach group (8.95% vs. 5.4%). According to Andersson et al.[2], anterior odontoid fractures have a higher complication rate in the elderly. This was possibly related to the presence of osteoporosis, comminuted fractures, or cervical spine stiffness, which hinder the ideal trajectory of the odontoid screw. Platzer et al.[22] also reported a higher technical failure rate (13.5%), related to anterior screw fixation. This technical failure was likely due to the various odontoid screw insertion techniques with different alternative screw entry points. Based on some authors, inserting the odontoid screw at the anterior-inferior lip of the C2 body increased the risk of a screw cut out.[3,33] The systemic complication rates, that were surgically related, and mortality rates were not different between the two groups. Similar results were also reported by White et al.[35].

In the present study, the rate of non-union was higher in the anterior approach group. This result was similar to that of other studies (RR, 2.97; 95% CI, 1.45–6.07; $p$=0.003). Odontoid fractures have intrinsic anatomical characteristics, particularly small bony surfaces and limited vascular supply for fracture healing.[10] Various factors, such as patient age, osteoporosis, fracture stability, operative technique, implant loosening, and fracture re-displacement were possibly related to the fusion rates. Among these factors, age was the most important factor, based on previous research. Pseudoarthrosis reportedly increased with age, affecting up to 12.5% of patients, aged 70 years old and 58.6% of those, aged 90 years old.[5,7] Lakshmanan et al.[15] also evaluated computed tomography scans of odontoid fractures in elderly patients, and osteoporosis was found at the dens-body junction in 13 of 24 patients. The results of the present analysis may be explained by two points. First, most of the included studies involved older age groups, except for two studies. Second, the anterior approach aimed to induce osteosynthesis of a small osseous surface in the poorly vascular fracture site. These two factors contributed to a higher nonunion rate among patients, who underwent the anterior approach. Moreover, older patients have poor cancellous bone quality, which adversely affects the osteosynthesis in the fracture site.

The analysis showed that the revision surgery rate was significantly higher among patients, who underwent the anterior approach (RR, 2.44; 95% CI, 1.50–3.98; $p$=0.0003). Other reports presented similar results. Faure et al.[9] reported a surgical revision rate of 13.6% due to construct loosening in anterior surgery. The higher revision surgery rate, associated with the anterior approach, may be attributed to mechanical complications and non-union, as shown in the analysis. The surgery-related systemic complication rates and mortality rates were not different between the two groups. Based on these results, the systemic complication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and mortality rates were not associated with the surgical approach. Rather, they were related to the patient's comorbidity.

### Study limitation

Several factors limited the present study. There could be methodological bias and heterogeneity in that most of included studies were retrospective studies. This possibly weakened the conclusion. Complication rates, including mechanical complications, systemic complications, and nonunion rates, served as the most important outcome for the analysis. However, other potentially important outcomes, such as the radiological and clinical outcomes, were not covered to verify the efficacy of the surgical approach since the relevant data were insufficient.

The occurrence of mechanical complications was associated with other factors, such as age, osteoporosis, surgical technique, and surgeon's experience. It is difficult to exclude these confounders without a randomized controlled study. The results of the selected studies were susceptible to bias because most studies, included in this analysis, were retrospective cohort studies. However, most odontoid fracture cases present as trauma cases in the emergency room. Thus, performing a randomized controlled trial is difficult. Publication bias may also be possible, so the results should be interpreted carefully.

However, this analysis had some strengths. In the detailed review, only studies that compared both surgical approaches and described the complications according to the approach used were included. Thus, it provided an informative guide for the choice of surgical approach for odontoid fractures.

## CONCLUSION

In the management of patients with odontoid fractures, the anterior surgical approach was associated with a higher risk of mechanical complications and fracture non-union. These findings were related to the high incidence of revision surgery. The posterior surgical approach was a more favorable option, that decreased the rates of mechanical complications, nonunion, and revision surgery. However, further studies, involving a larger sample size, or prospective randomized trials are necessary to verify the results of this analysis.

## SUPPLEMENTARY MATERIALS

### SUPPLEMENTARY TABLE 1

Complications of the studies included in this meta-analysis

Click here to view

### SUPPLEMENTARY FIGURE 1

Funnel plots of publication bias in the mechanical complication (A), systemic complication (B), mortality (C), non-union (D) and revision surgery (E).

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