

# Surgery vs conservative treatment for type II and III odontoid fractures in a geriatric population

## A meta-analysis

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### Abstract

**Background:** It is unclear whether surgery or conservative treatment is more suitable for elderly patients with type II and type III odontoid fractures. We performed this meta-analysis to compare the efficacy of surgical and conservative treatments for type II and type III odontoid fractures.

**Methods:** A literature search was performed in PubMed, Embase, Web of Science, and Cochrane Library in January 2017. Only articles comparing surgery with conservative treatment in elderly patients with type II and type III odontoid fractures were selected. After 2 authors independently assessed the retrieved studies, 18 articles were included in this meta-analysis, and the primary endpoints were the nonunion rate and mortality rate. The secondary outcomes were patient satisfaction, complications, and the length of the hospital stay. The quality of the included studies was evaluated using the modified Newcastle–Ottawa scale. Sensitivity analyses were performed for high-quality studies, and the publication bias was evaluated using a funnel plot.

**Results:** Lower nonunion (odds ratio [OR]: 0.27, 95% confidence interval [CI]: 0.18–0.40,  $P < .05$ ) and mortality rates (OR: 0.52, 95% CI: 0.34–0.79,  $P < .05$ ) confirmed the superiority of surgery in treating type II and type III fractures. The secondary outcomes differed. Patients in the surgery group felt more satisfied with the outcome (OR: 3.44, 95% CI: 1.19–9.95,  $P < .05$ ), and the complications were similar in the 2 groups (OR: 1.14, 95% CI: 0.78–1.68,  $P = .5$ ), whereas patients in conservative groups spent less time in the hospital (OR: 5.10, 95% CI: 2.73–7.47,  $P < .05$ ). The results of the subgroup analyses and sensitivity analysis were similar to the original outcomes, and no obvious publication bias was observed in the funnel plot.

**Conclusion:** Most elderly (younger than 70 years) patients with type II or type III odontoid fractures should be considered candidates for surgical treatment, due to the higher union rate and lower mortality rate, while statistically significant differences were not observed in the population with an advanced age (older than 70 years). Therefore, the selection of the therapeutic approach for elderly patients with odontoid fractures requires further exploration. Simultaneously, based on our meta-analysis, a posterior arthrodesis treatment was significantly superior to the anterior odontoid screw treatment.

**Abbreviations:** CI = confidence interval, OR = odds ratio, RCT = randomized controlled trials, WMD = weighted mean difference.

**Keywords:** conservative, meta-analysis, operative, type II or type III odontoid fracture

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LF, DO, and XH contributed equally to the work.

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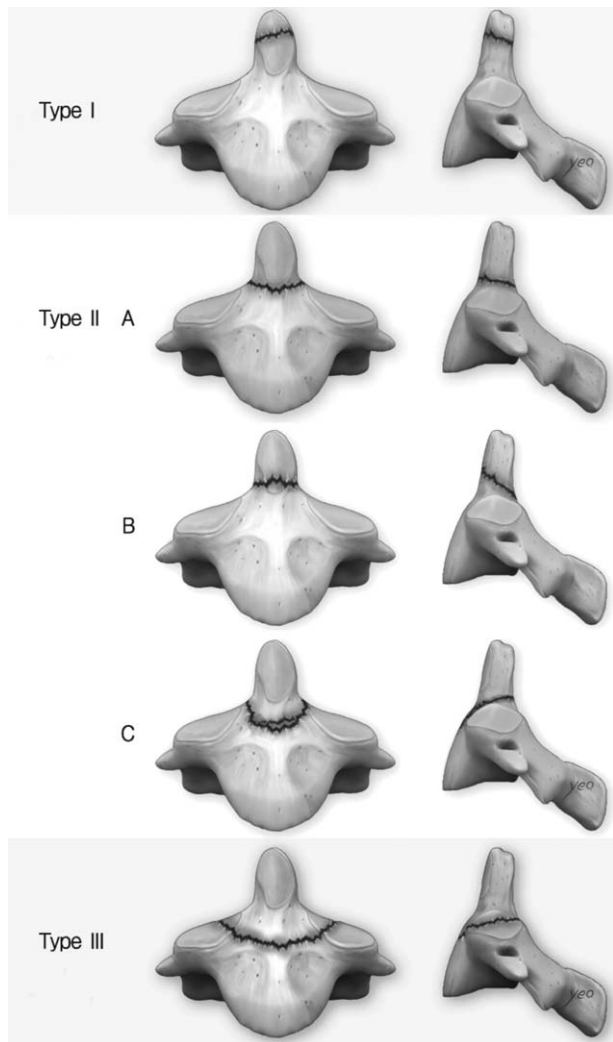
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## 1. Introduction

More than 60% of spinal injuries involve the cervical spine, and approximately 25% of cervical spine injuries affect the axis.<sup>[1]</sup> In the elderly, odontoid fractures are the most common cervical spine fractures.<sup>[2–7]</sup> Odontoid fractures are classified into 3 main categories (Fig. 1). Type I fractures at the tip of the odontoid are rare and usually stable, type II fractures at the base of the odontoid process are the most common and are inherently unstable, and type III fractures occur through the body of the odontoid process and can be unstable.<sup>[8,9]</sup> The optimal treatment for type II and type III geriatric odontoid fractures has been the topic of a substantial number of studies in recent years due to its predisposition toward displacement and nonunion. These adverse effects are observed in the elderly population, as unstable type II and type III odontoid fractures create a challenging physiologic problem for healing due to the combination of osteoporotic bone, a watershed area for the blood supply, and a high-strain location, among other problems. It is unclear whether conservative management (external stabilization) or surgical treatment is more suitable for treating unstable odontoid



**Figure 1.** The Anderson and D'Alonzo classification of odontoid fractures. Type I fractures involve avulsion near the tip of the dens. Type II fractures occur at the base of the odontoid process. Type III fracture lines extend into the body of the axis.

fractures; moreover, there is no consensus on the particular surgical method.

Surgical methods are classified into 2 main groups according to the approach. The posterior approach includes posterior wire/cable bone techniques and rigid segmental techniques (C1-C2 transarticular screws and segmental fixation into the laminae, pars, or pedicles of the axis and lateral mass screw fixation into the atlas).<sup>[10]</sup> A surgical intervention results in a higher union rate. However, the condition of the patient may deteriorate after surgery. In particular, a surgical intervention poses significant risks to the very old population (>80 years of age).<sup>[11]</sup> On the contrary, conservative treatment is also divided into many groups, and the most common treatment is the “Halo-Vest.” Surgeons and patients both consider that conservative treatment decreases the hospital cost, the occurrence of complications, and relevant surgical risks. Nevertheless, many studies have revealed a lower union rate and higher mortality rate for nonsurgical methods. In addition, many patients complain about this treatment due to the long period of bed rest and the deterioration of the cervical spine anatomy. Therefore, the identification of the proper balance between fracture

healing and treatment complications is difficult. In older patients, the achievement of this balance is even more challenging.<sup>[12]</sup>

Therefore, the objective of this meta-analysis is to summarize and compare the outcomes of surgical and conservative treatments for type II and type III odontoid fractures in the elderly, focusing primarily on the nonunion rate and mortality rate, and secondarily on patient satisfaction, complications, and the hospital stay.

## 2. Materials and methods

### 2.1. Ethics statement

Basic information was collected from all patients. Written informed consent was not obtained for this meta-analysis and patient information was anonymized and deidentified prior to analysis. The study was approved by the Institutional Review Board and Ethics Committee of the Third Affiliated Hospital, Sun Yat-sen University.

### 2.2. Search strategy

A literature search of PubMed (1952–September 2016), Embase (1952–September 2016), Web of Science (1952–September 2016), and Cochrane Library (1952–September 2016) was performed in January 2017 without restrictions regarding the regions and publication types. Keywords included spinal stenosis, Odontoid fractures (OR Axis fracture OR cervical spine fracture OR Subaxial Cervical Pedicle Fracture OR dens fracture OR second cervical vertebra fracture OR C2 Fracture) AND Philadelphia type collar (OR SOMI brace OR Halo-Vest OR conservative OR Nonsurgical) AND Surgical (OR anterior screw fixation OR posterior C1/C2 fusion OR posterior C1-C2 arthrodesis OR fusion). In addition, the references of the selected articles were all manually examined to also identify additional potentially related studies.

### 2.3. Inclusion and exclusion criteria

The articles including in this meta-analysis were required to meet the following criteria: publication of any type, including randomized controlled trials (RCTs), retrospective studies comparing the outcomes of the surgical and nonsurgical treatments for type II or type III odontoid fractures; and a geriatric population of the included patients. Studies were excluded if the studies were reviews, meta-analyses or meeting abstracts. When multiple reports describing the same sample were published, the most recent or complete report was used.

### 2.4. Data extraction

Data were independently extracted from these selected articles by 2 of the authors who were both blinded to the authors, institutions, and the journals of each article. Each discrepancy was resolved by the senior author. The extracted information included the name of the 1st author, year of publication, the evidence level, number of patients, mean age of included patients, the type of odontoid fractures, follow-up, and the surgical methods.

### 2.5. Interventions and outcome

The therapeutic efficacy of surgical therapy for elderly patients with type II and type III odontoid fractures was compared with

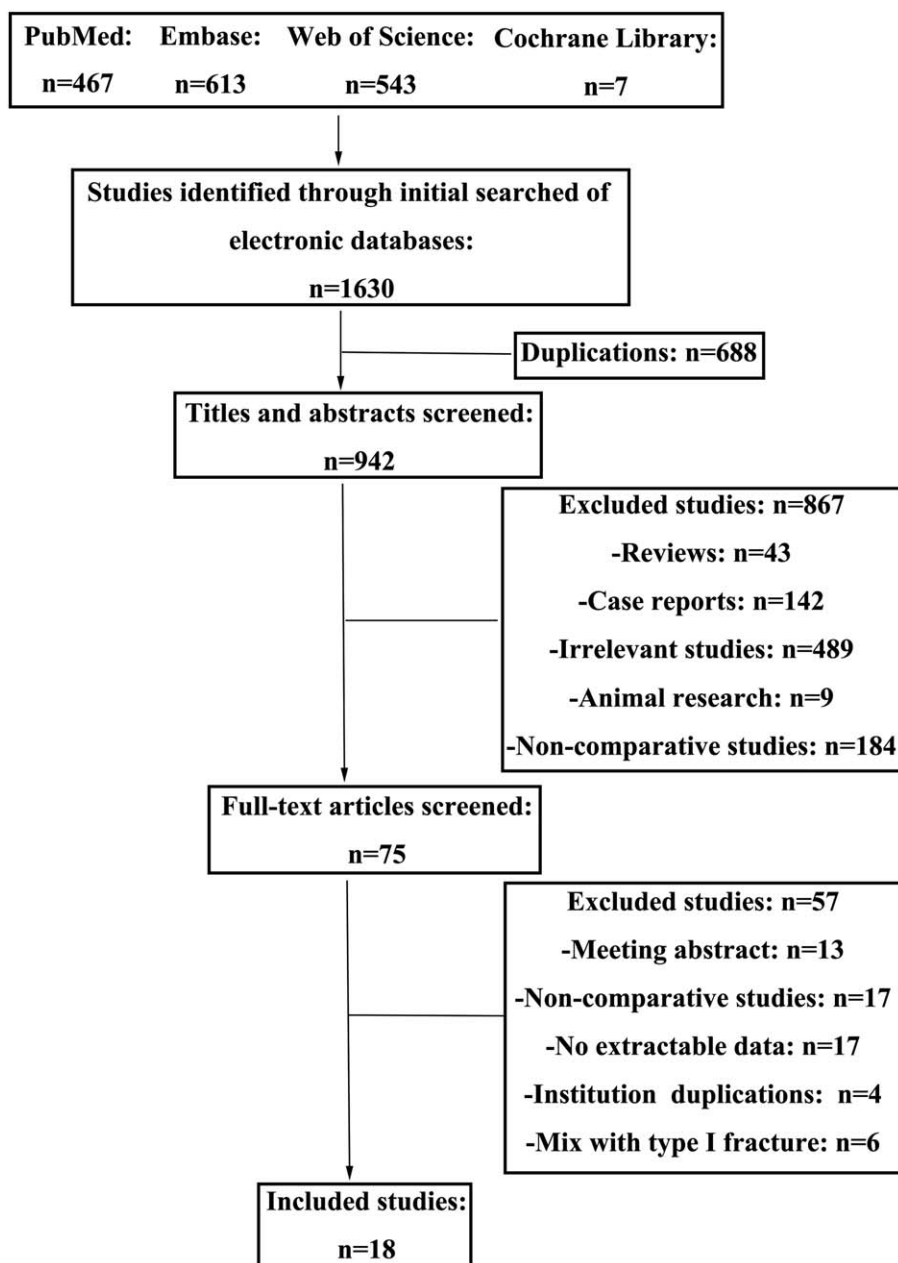


Figure 2. Flow diagram showing the process used to select studies.

conservative treatment. The outcomes were divided into primary (including nonunion rate and mortality rate) and secondary (including patient satisfaction, complications, and the length of the hospital stay) outcomes.

## 2.6. Assessment of the quality of the selected articles

The methodologic quality of cohort and case-control studies was assessed using the modified Newcastle-Ottawa scale, which consists of 3 factors: patient selection, comparability of the study groups, and assessment of outcomes.<sup>[13,14]</sup> The comparability of the study populations was awarded 3 stars based on 6 indexes describing the basic characteristics of patients in the 2 treatment groups. Two main matching indexes, translation and angulation

of fracture, were awarded 1 star each. One star was awarded to the remaining 4 characteristics. The total score was 9 points. We defined these articles that achieved scores >6 points as moderate and high-quality publications.

## 2.7. Statistical analysis

Relevant data were extracted from the included studies and input into Cochrane RevMan 5.1 software for the meta-analysis. Continuous outcomes are reported as weighted mean differences (WMDs) and respective 95% confidence intervals (CIs). Dichotomous outcomes are presented as odds ratios (ORs) with 95% CIs. Statistical significance was set to  $P < .05$  to summarize the findings across the trials.<sup>[14-17]</sup> Heterogeneity between

**Table 1**  
Characteristics of included studies.

Study	Level of evidence	Patients' no.		Age, yr	Type	Matching*	Operative methods	Follow-up, yrs	Quality score
		Ope*	Con*						
Daniel et al (2016)	4	NA*	NA	Mean 75	II	1,4	NA	1.0	★★★★★
Di Paolo et al (2014)	4	48	60	NA	II	4	Ant*/Post*	2.0	★★★★★
Barrett et al (2014)	2b	24	51	Mean 82.5	II/III	1,4,5,6	Ant/Post	5.0	★★★★★★
Max et al (2013)	2b	33	14	Mor* 65	II	1,4,5,6	Ant/Post	2.6	★★★★★★
Alexander et al (2013)	2b	101	58	Mor 65	II	4,6	Ant/Post	1.0	★★★★★★
Markus et al (2012)	4	38	31	Mean 75	II/III	1	Ant/Post	0.8	★★★★★★
Silke et al (2011)	2b	25	21	Mean 64	II	4,6	Ant	2.0	★★★★★★
Maximilian et al (2011)	2b	31	57	Mor 65	II	1,4	Ant/Post	0.5	★★★★★★
Seung et al (2011)	2b	16	15	NA	II/III	2,4,5	Ant/Post	2.0	★★★★★★
Ali et al (2010)	2b	11	9	Mor 70	II	1,2,4,5	Ant/Post	0.3	★★★★★★
Arjun et al (2009)	4	24	29	NA	II/III	4	Ant/Post	NA	★★★★★★
Harvey et al (2008)	2b	32	40	Mor 80	II	1,2,4,6	Ant/Post	NA	★★★★★★
Charles et al (2000)	2b	11	14	Mor 65	II	1,2,4,5,6	Ant/Post	2.5	★★★★★★
Susanna et al (2000)	2b	18	11	Mor 65	II/III	5,6	Ant/Post	4.3	★★★★★★
Wendy et al (2000)	2b	20	64	Mean 57	II/III	1,3,5	Ant/Post	NA	★★★★★★
Muller et al (1999)	2b	22	55	Mean 70	II/III	1,4	Ant/Post	3.7	★★★★★★
Eric et al (1998)	2b	6	51	Mean 60	II/III	1,2,4	Post	10.0	★★★★★★
William et al (1993)	2b	14	30	Mor 80	II/III	1,2,6	Post	2.4	★★★★★★

1 = Translation of fracture, 2 = angulation of fracture, 3 = age, 4 = type, 5 = spinal cord injury, 6 = comorbidity, Ant = anterior screw fixation, Con = conservative treatment, Mor = more than, NA = data not available, Ope = operative treatment, Post = posterior C1-C2 fusion or posterior transarticular screw fusion.

different studies was evaluated using the  $I^2$  statistic that describes the percentage of variation among studies due to heterogeneity rather than chance. Both fixed and random effects models were applied to the collected dataset and the final choice between the 2 models was guided by the  $I^2$  statistic for heterogeneity. The random-effects model was used if heterogeneity existed ( $I^2 > 50\%$ ), otherwise, the fixed-effects model was applied.<sup>[14]</sup> Sensitivity analyses were performed for high-quality studies. Funnel plots were constructed to screen for potential publication bias.<sup>[18]</sup> We performed 3 main subgroup analyses. The purpose of the subgroup analyses was to explore the sources of heterogeneity and compare the clinical effects between different surgical

approaches and different age groups. Moreover, type II odontoid fractures were also discussed individually, because they are the most frequent fracture type occurring in the geriatric population.

### 3. Results

#### 3.1. Search result

A literature search retrieved 1630 potentially relevant articles from the 4 databases (467 articles from PubMed, 543 articles from Web of Science, 7 articles from Cochrane Library, and 613 articles from Embase). After 2 reviewers independently browsed

**Table 2**  
Qualities of including articles are evaluated by modified Newcastle–Ottawa scale.

Study	Selection				Comparability			Outcomes		Quality score
	Case definition	Representativeness	Selection of controls	Definition of controls	Comparable for 1 2*	Comparable for 3 4 5 6*	Assessment of outcome	Integrity of follow-up		
Daniel et al	Yes	No	Yes	Yes	No	3 4	Yes	Yes	★★★★★	
Di Paolo et al	Yes	No	Yes	Yes	No	4	Yes	Yes	★★★★★	
Barrett et al	Yes	No	Yes	Yes	No	3 4 5 6	Yes	Yes	★★★★★★	
Max et al	Yes	No	Yes	Yes	No	3 4 5 6	Yes	Yes	★★★★★★	
Alexander et al	Yes	Yes	Yes	Yes	No	4 6	Yes	Yes	★★★★★★	
Markus et al	Yes	No	Yes	Yes	No	3	Yes	Yes	★★★★★★	
Silke et al	Yes	No	Yes	Yes	No	4 6	Yes	Yes	★★★★★★	
Maximilian et al	Yes	No	Yes	Yes	No	3 4	Yes	Yes	★★★★★★	
Seung et al	Yes	No	Yes	Yes	1	4 5	Yes	Yes	★★★★★★	
Ali et al	Yes	No	Yes	Yes	1	3 4 5	Yes	Yes	★★★★★★	
Arjun et al	Yes	No	Yes	Yes	No	4	Yes	Yes	★★★★★★	
Harvey et al	Yes	No	Yes	Yes	1	3 4 6	Yes	Yes	★★★★★★	
Charles et al	Yes	No	Yes	Yes	1	3 4 5 6	Yes	Yes	★★★★★★	
Susanna et al	Yes	No	Yes	Yes	No	5 6	Yes	Yes	★★★★★★	
Wendy et al	Yes	No	Yes	Yes	2	3 5	Yes	Yes	★★★★★★	
Muller et al	Yes	No	Yes	Yes	No	3 4	Yes	Yes	★★★★★★	
Eric et al	Yes	No	Yes	Yes	1	3 4	Yes	Yes	★★★★★★	
William et al	Yes	No	Yes	Yes	1	3 6	Yes	Yes	★★★★★★	

1 = translation of fracture, 2 = angulation of fracture, 3 = age, 4 = type, 5 = spinal cord injury, 6 = comorbidity.

**Table 3**  
The results of comparison of surgery and conservative treatment.

Outcomes of interest	Study No.	Ope* Patient no.	Con* Patient no.	WMD/OR* (95% CI)	P-value	Study heterogeneity			P-value
						$\chi^2$	df*	I <sup>2</sup> , %	
Primary outcomes									
Nonunion rate	15	409	495	0.27 (0.18–0.4)	<.001	16.89	14	17	.26
Mortality	11	322	371	0.52 (0.34–0.79)	.002	13.04	10	23	.22
Secondary outcomes									
Complication	8	253	314	1.14 (0.78–1.68)	.5	13.58	7	48	.06
Satisfactory	4	67	151	3.44 (1.19–9.95)	.02	1.8	3	0	.61
Hospital stay, d	4	79	125	5.10 (2.73–7.47)	<.001	2.11	3	0	.55

CI=confidence interval, Con=conservative treatment, df=degrees of freedom, Ope=operative treatment, WMD/OR=weighted mean difference/odds ratio.

the titles and abstracts of these studies, the full articles of 75 studies were reviewed. After excluding 57 articles that did not meet our criteria, 18 articles analyzing 1084 geriatric patients were included in this meta-analysis (Fig. 2). The characteristics of these selected articles are presented in Table 1, and the risk of bias of each included study is described in detail in Table 2.

**3.2. Results of the meta-analysis**

**3.2.1. Primary outcomes.** Fifteen articles reported the nonunion rate (Table 3).<sup>[10,19–32]</sup> A significantly higher rate was observed in the conservative treatment group (OR: 0.27, 95% CI: 0.18–0.40,  $P < .05$ ). Furthermore, heterogeneity was very low ( $\chi^2 = 16.89$ ,  $df = 14$ ,  $I^2 = 17\%$ ,  $P = .26$ ). The mortality rate was

described by 11 studies.<sup>[19–21,23,25,27,29,30,32–34]</sup> Compared with surgical treatment, patients receiving conservative treatment had a higher mortality rate (OR: 0.52, 95% CI: 0.34–0.79,  $P < .05$ ). Heterogeneity was still low ( $\chi^2 = 13.04$ ,  $df = 10$ ,  $I^2 = 23\%$ ,  $P = .22$ ).

**3.2.2. Secondary outcomes.** Patient satisfaction was reported by 4 articles.<sup>[23,24,29,31]</sup> Patients in the operative group were much more satisfied with the outcomes (OR: 3.44, 95% CI: 1.19–9.95,  $P < .05$ ). Almost no heterogeneity was observed ( $\chi^2 = 1.8$ ,  $df = 3$ ,  $I^2 = 0\%$ ,  $P = .61$ ).

Eight articles including 567 patients did not reveal significant differences in complications between the 2 groups (OR: 1.14,

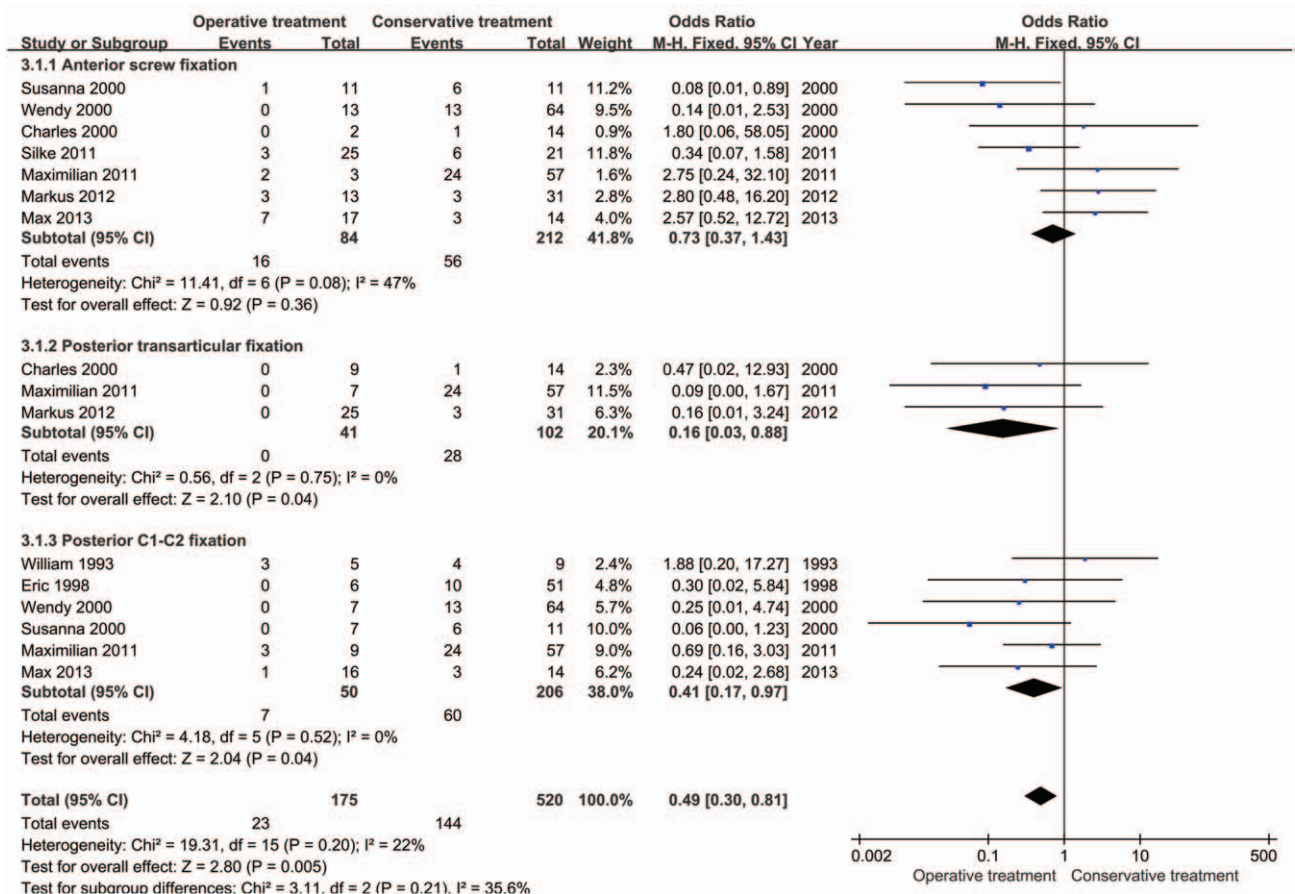


Figure 3. Forest plot comparing the nonunion rate in the subgroup analysis of different surgical approaches. CI=confidence interval.

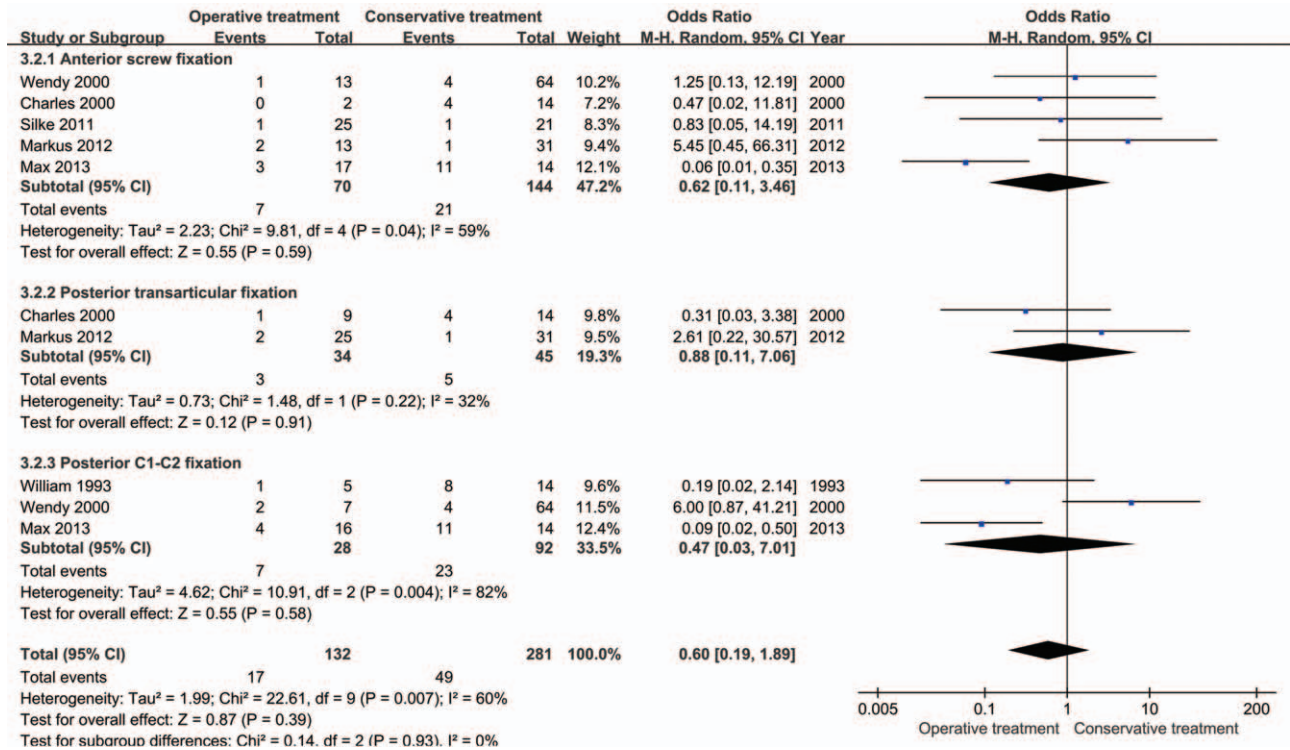


Figure 4. Forest plot comparing the mortality rate in the subgroup analysis of different surgical approaches. CI=confidence interval.

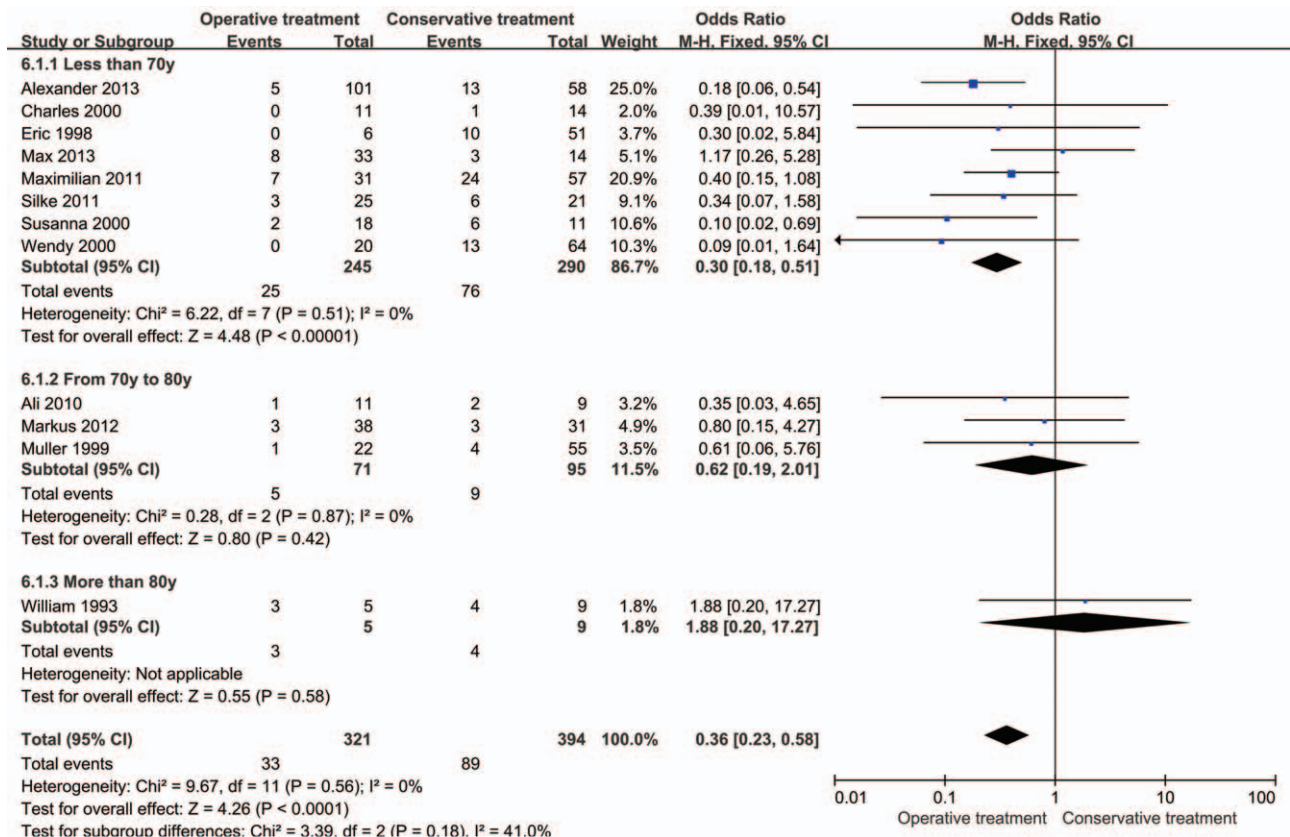


Figure 5. Forest plot comparing the nonunion rate in the subgroup analysis of different age groups. CI=confidence interval.

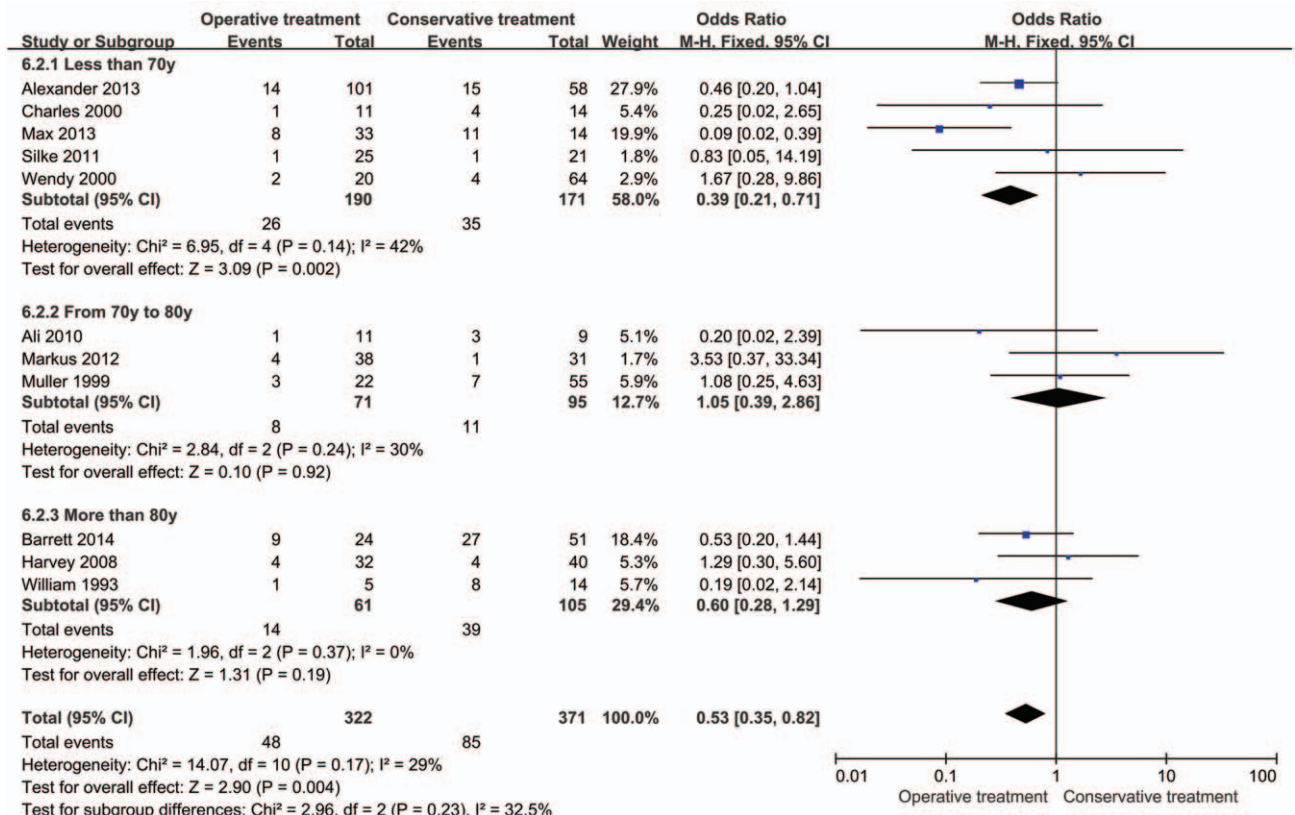


Figure 6. Forest plot comparing the mortality rate in the subgroup analysis of different age groups. CI = confidence interval.

95% CI: 0.78–1.68, P = .5).<sup>[19,23,27–30,33,34]</sup> The heterogeneity was slightly higher, whereas I<sup>2</sup> was <50% (χ<sup>2</sup> = 13.58, df = 7, I<sup>2</sup> = 48%, P = .06).

The hospital stay was evaluated by 4 studies including 204 patients.<sup>[22,27,32,34]</sup> Patients in the operative group had a much longer stay in the hospital (OR: 5.10, 95% CI: 2.73–7.47, P < .05). Meanwhile, almost no heterogeneity was observed (χ<sup>2</sup> = 2.11, df = 3, I<sup>2</sup> = 0%, P = .55).

### 3.3. Subgroup analysis

We performed subgroup analyses to compare primary outcomes among conservative treatment, anterior fixation, and posterior fusion. Overall, the nonunion rate in the subgroup analysis was similar to the rate observed in the original analysis (Fig. 3). However, in the subgroup analysis, the nonunion rate was not significantly different between the conservative treatment and anterior screw fixation groups. In contrast, the outcomes were significantly different when both posterior interventions were compared with conservative treatment. However, the mortality rate differed from the original outcomes (Fig. 4). No significance differences were observed in the subgroup analyses or the original analysis.

We also divided patients into groups according to age and compare the 2 therapeutic strategies between subgroups. As shown in Figures 5 and 6, the total nonunion rate and mortality rate were still better in the surgery groups. However, when we divided patients into 3 subgroups according to age, the same differences in the nonunion rate and mortality rate were only

observed in patients aged <70 years. Mortality and nonunion rates were not significantly different in octogenarians.

The main complications, including neurologic deficits, cardio-pulmonary complications, thrombotic diseases, severe infections, and a loss of reduction, were subjected to subgroup analyses. As shown in Figure 7, significant differences were not observed in the total complications or each main complication. However, the heterogeneity decreased from 48% to 0%, indicating that the type of complication was the main source of heterogeneity. When we compared surgery with conservative treatment in patients with type II odontoid fractures, both primary outcomes were similar to the results of the original analysis (Fig. 8A, B).

### 3.4. Sensitivity analysis and publication bias

Fourteen moderate and high-quality retrospective articles, which were evaluated using the Newcastle–Ottawa scale, were analyzed to identify any differences compared with the original outcomes (Table 4). The results were similar to the original outcomes. In addition, with the exception of complications, the heterogeneity of the other indicators was generally lower.

Publication bias was evaluated using a funnel plot that contains 15 studies describing the nonunion rate. All articles were within the 95% CI and the distribution was symmetrical, indicating a lack of obvious publication bias (Fig. 9).

## 4. Discussion

We searched 4 main databases to identify as many articles that met our criteria as possible. Eighteen studies were selected from

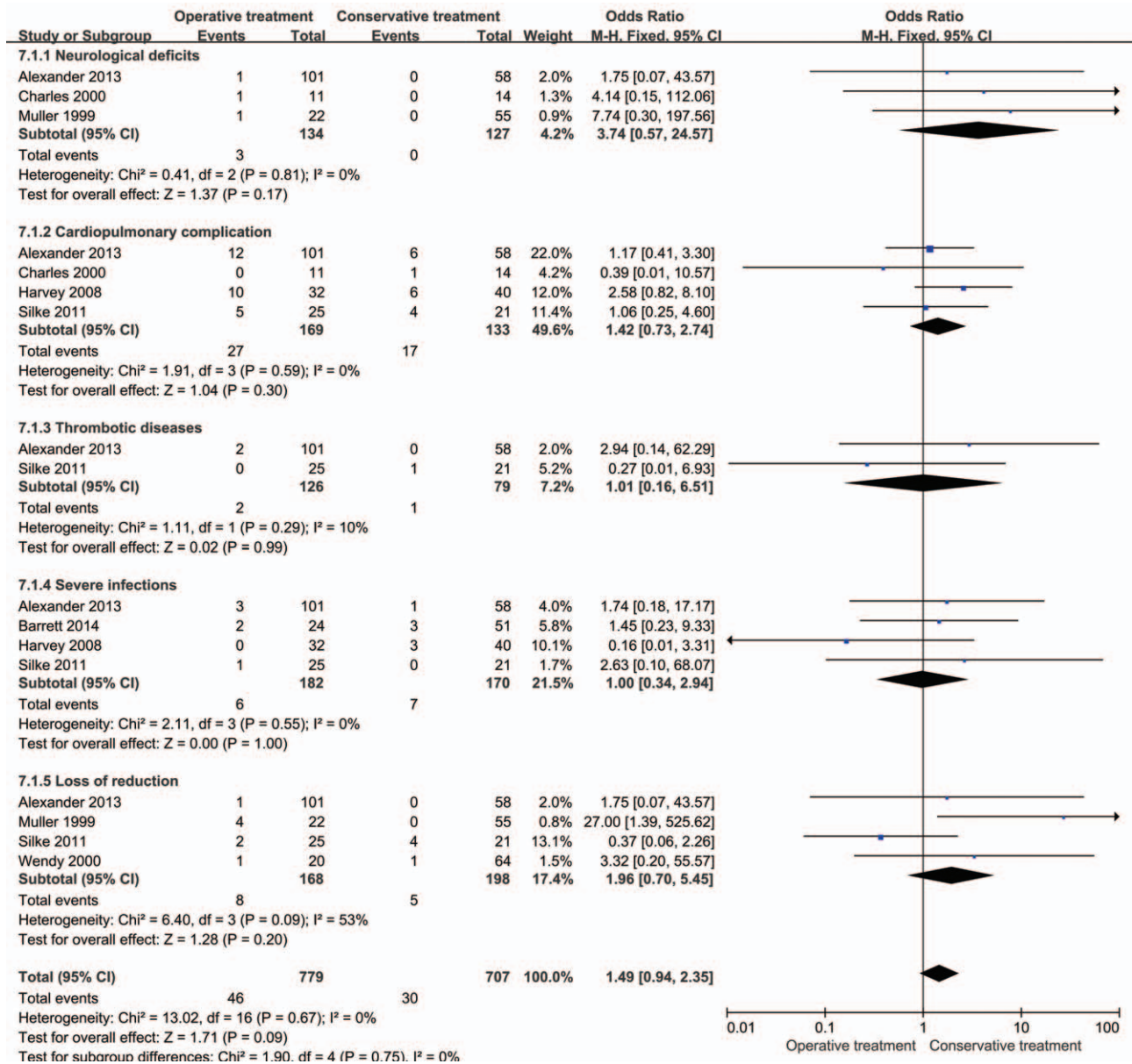


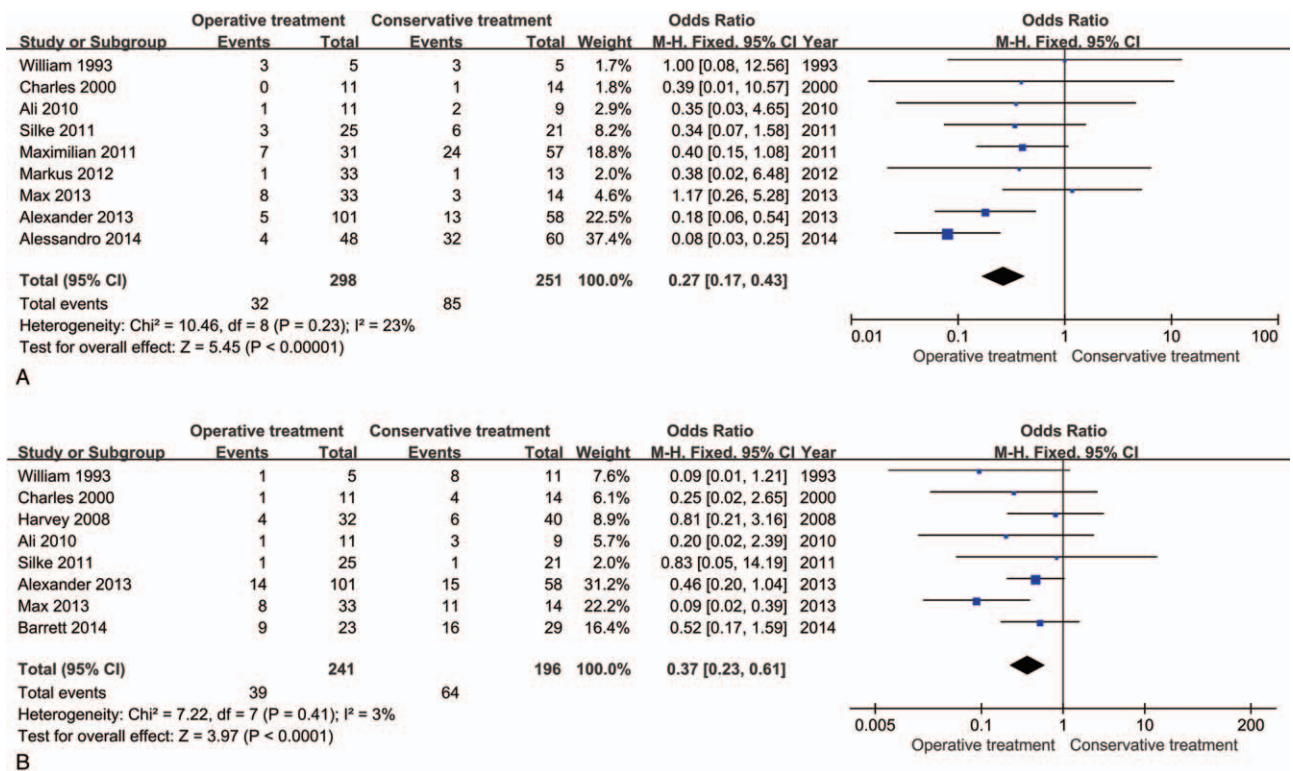
Figure 7. The results of the subgroup analysis of the five main complications are presented in a forest plot. CI=confidence interval.

1630 potential articles by 2 authors. The data in which we were interested were the nonunion rate, mortality rate, complications, patient satisfaction, and the hospital stay, which were divided into primary and secondary outcomes. Regarding the primary outcomes, the nonunion rate was significantly lower in the operative group, consistent with the report by Di Paolo et al showing that patients undergoing surgery had a higher rate of fusion (91.6% vs 46.6%, statistically significant:  $P < .05$ ). Moreover, the bone healing periods were also shorter (17 weeks compared to 21 weeks) in patients who received operative treatment.<sup>[10]</sup> Meanwhile, a statistically significant difference in mortality rates was observed, as the operative cohort had an overall lower mortality rate than the nonoperative group. First, an advanced age has been clearly defined as a risk factor that increases mortality in elderly patients after odontoid fractures. Furthermore, a low baseline physiologic reserve, poor rehabili-

tation potential, and the presence of medical comorbidities all increase the mortality rate in elderly patients after odontoid fracture.<sup>[33]</sup> The lower percentage of surviving patients who received conservative treatment may be attributed to an increased risk of cardiopulmonary complications, including pneumonia and cardiac arrest, resulting in a prolonged bed rest. Secondary outcomes included complications, patient satisfaction, and hospital stay. A significant difference in total complications was not observed. Four articles all reported that patient satisfaction was quite comparable between the operative group and patients receiving conservative treatment. However, patients in the conservative treatment group were discharged from the hospital earlier than patients who underwent surgery.

The purpose of the subgroup analysis was to explore the sources of heterogeneity and compare the clinical effects between different surgical approaches and different age groups. The total





**Figure 8.** Forest plots comparing the mortality and nonunion rates of type II odontoid fractures. (A) Analysis of the mortality rates in subgroups treated for type II odontoid fracture. (B) Analysis of the nonunion rate in subgroups treated for type II odontoid fractures. CI = confidence interval.

outcome of the nonunion rate in the subgroups was similar to the original analysis. Regarding the posterior C1-C2 fusion and posterior transarticular screw fixation, the fusion rates were both significantly higher than nonoperative treatment. The subgroup analysis of the mortality rate produced different results from the original analysis, which did not reveal a significant difference between the 2 groups. The discrepancy may be due to the use of a more conservative random-effects model for studies with heterogeneity >50%. We subdivided the patients according to age and compared the 2 therapeutic strategies in every subgroup. The same differences in the nonunion rate and mortality rate were only observed in patients aged <70 years. Mortality and nonunion rates were not significantly different in octogenarians. After excluding 3 articles that did not report the patients' ages, most articles (9) included patients aged <70 years. These data

support the findings of Harris et al, who reported a high mortality in this population (older than 75 years of age), regardless of the treatment type.<sup>[35]</sup> Advanced age has been clearly defined as a risk factor that increases mortality in elderly patients after odontoid fractures. A low baseline physiologic reserve, poor rehabilitation potential, and the presence of medical comorbidities all increase mortality in elderly patients after odontoid fractures. The 5 main complications, neurologic deficits, cardiopulmonary complications, thrombotic diseases, severe infections, and a loss of reduction, were also subjected to subgroup analyses. Although a tendency toward a higher proportion of subjects with any complication was observed in the nonsurgically treated cohort, this difference was not significant. Although the rates of thrombotic diseases and severe infections were approximately the same, other common complications, including neurologic

**Table 4**  
**Sensitivity analysis of comparison of surgery and conservative treatment.**

Outcomes of interest	Study No.	Ope* Patient no.	Con* Patient no.	WMD/OR* (95% CI)	P-value	Study heterogeneity				
						χ <sup>2</sup>	df	I <sup>2</sup> , %	P-value	
Primary outcomes										
Nonunion rate	6	164	169	0.23 (0.11–0.48)	<.001	4.73	5	0	.45	
Mortality	6	180	199	0.50 (0.28–0.90)	.02	3.76	5	0	.58	
Secondary outcomes										
Complication	4	164	176	1.77 (0.57–5.44)	.32	7.54	3	60	.06	
Satisfactory	3	42	130	6.33 (1.14–35.17)	.03	0.64	2	0	.73	
Hospital stay, d	3	48	68	5.94 (2.07–9.81)	.003	1.83	2	0	.4	

CI = confidence interval, Con = conservative treatment, df = degrees of freedom, Ope = operative treatment, WMD/OR = weighted mean difference/odds ratio.

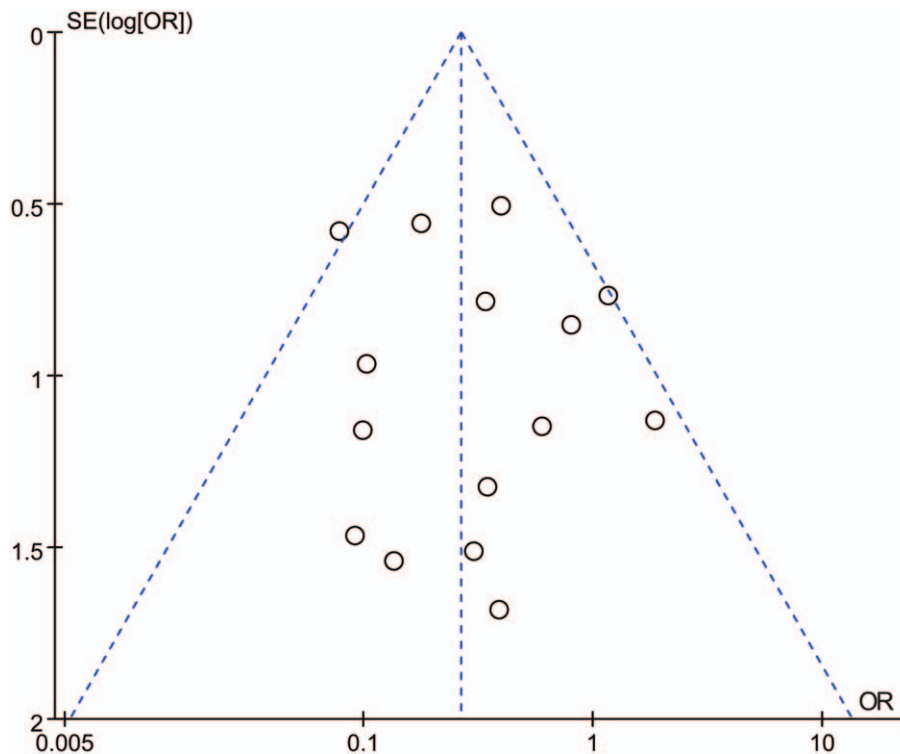


Figure 9. Funnel plot of publication bias in the nonunion rate. OR=odds ratio.

deficits, cardiopulmonary complications, and loss of reduction, were more likely to occur in the nonsurgical group. However, each main complication was not significantly different between patients receiving the 2 interventions. Simultaneously, the heterogeneity decreased from 48% to 0%, indicating that the type of complication was the main source of heterogeneity.

In geriatric populations, type II odontoid fractures were the predominant fracture identified (95.7%) among all axis fractures.<sup>[30]</sup> Therefore, we compared the primary outcomes between surgical and conservative treatments in patients with type II odontoid fractures. The nonunion rate and the mortality rate in the subgroup analyses were similar to the original outcomes. The fusion rate was higher and the mortality rate was lower in operative groups, and the outcomes were both significantly different. In addition, the heterogeneity was still very low.

All 18 included studies were assessed using the Newcastle–Ottawa scale, and 14 moderate and high-quality articles had scores ranging from 6 to 7 points, whereas the other 4 low-quality studies had scores of 4 points. Overall, the study quality was relatively high. Notably, the studies included in the meta-analysis were graded 2B, which may have avoidable selection bias, measurement bias, and performance bias. The sensitivity analysis was performed on moderate and high-quality studies with comparable patient characteristics, particularly the stability of fractures. Fractures were classified as stable or unstable according to previously described criteria: fractures with an initial displacement of  $<5$  mm and initial angulation of  $<11^\circ$  on the computed tomography scans.<sup>[21]</sup> We awarded 2 main matching indexes, the translation and angulation of fracture, a score of 1 point each. Then, 1 point was awarded to the combination of the remaining 4 characteristics: age, type, spinal cord injury, and

comorbidity. The outcomes of the sensitivity analysis were all similar to the original results, and except for the complications, the heterogeneity of other indexes generally decreased.

However, this meta-analysis has several potential limitations. First and most importantly, the articles included in this meta-analysis were all retrospective cohort studies. Due to the characteristics of odontoid fractures and surgical procedures, most of the treatments were provided in emergent circumstances. The limited number and poor quality of the included studies limits the strength of the results reported in this meta-analysis, although the quality of most studies was high. Therefore, additional RCTs are required in this field. Furthermore, type II and type III fractures were analyzed as 1 group and only type II odontoid fractures were analyzed individually. However, an evident type II fracture is more frequently treated with surgery, whereas an evident type III fracture is most frequently treated conservatively. This difference in the treatment pattern may have flattened the findings. We chose this approach because the differentiation of these types of fractures is often difficult. Therefore, more articles reporting the therapeutic strategy for unstable type III axis fractures in the elderly are needed.

## 5. Conclusion

In conclusion, most elderly (younger than 70 years old) patients with type II or type III dens fractures who are healthy enough to receive general anesthesia should be considered candidates for surgical treatment, due to the higher union rate and lower mortality rate. However, the same statistically significant difference was not observed in the older age population (older than 70 years old). Therefore, further studies are needed to determine the therapeutic approach for patients with an

advanced age presenting with odontoid fractures. Based on the findings of our meta-analysis, posterior arthrodesis treatment is significantly superior to the anterior odontoid screw treatment.

### Author contributions

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