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RESEARCH PAPER

Surgical versus conservative treatment for odontoid fractures in older people: an international prospective comparative study

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Abstract

Background: The optimal treatment for odontoid fractures in older people remains debated. Odontoid fractures are increasingly relevant to clinical practice due to ageing of the population.
Methods: An international prospective comparative study was conducted in fifteen European centres, involving patients aged ≥55 years with type II/III odontoid fractures. The surgeon and patient jointly decided on the applied treatment. Surgical and conservative treatments were compared. Primary outcomes were Neck Disability Index (NDI) improvement, fracture union and stability at 52 weeks. Secondary outcomes were Visual Analogue Scale neck pain, Likert patient-perceived recovery and EuroQol-5D-3L at 52 weeks. Subgroup analyses considered age, type II and displaced fractures. Multivariable regression analyses adjusted for age, gender and fracture characteristics.

Results: The study included 276 patients, of which 144 (52%) were treated surgically and 132 (48%) conservatively (mean (SD) age 77.3 (9.1) vs. 76.6 (9.7), $P = 0.56$). NDI improvement was largely similar between surgical and conservative treatments (mean (SE) −11 (2.4) vs. −14 (1.8), $P = 0.08$), as were union (86% vs. 78%, aOR 2.3, 95% CI 0.97–5.7) and stability (99% vs. 98%, aOR NA). NDI improvement did not differ between patients with union and persistent non-union (mean (SE) −13 (2.0) vs. −12 (2.8), $P = 0.78$). There was no difference for any of the secondary outcomes or subgroups.
Conclusions: Clinical outcome and fracture healing at 52 weeks were similar between treatments. Clinical outcome and fracture union were not associated. Treatments should prioritize favourable clinical over radiological outcomes.

Keywords: odontoid fractures; older people; surgical treatment; conservative treatment; treatment outcome

Key Points

- The optimal treatment for odontoid fractures in older people remains controversial.
- Clinical and radiological outcomes at 52 weeks are largely similar between surgical and conservative treatments.
- Clinical outcome and fracture union are not clearly associated.
- Treatments should prioritize favourable clinical over radiological outcomes.

Introduction

Odontoid fractures are the most common cervical spine fractures in older people [1, 2]. The incidence and health care burden are expected to further increase in the ageing population. Between 2000 and 2010, the incidence of C2 fracture hospitalizations in patients >84 years in the USA increased more than three-fold to 9.77 per 10 000 individuals per year [3]. From 2003 to 2017, surgical treatment rates in the USA doubled to 86%, with operative treatments costing twice as much as conservative treatments [4].

The optimal treatment for odontoid fractures is debated. Historically, treatments focused on achieving fracture union to prevent dreaded complications like secondary spinal cord injury [5]. More recently, studies have focused on favourable clinical rather than radiological outcomes [6, 7]. Literature reviews on the optimal treatment were inconclusive, mainly due to heterogeneity between groups, and studies showing superior union after surgery may have been biased [8–11]. There is no convincing evidence that clinical outcome and fracture union are associated [6, 12]. In the absence of high-quality evidence, treatment is often based on local treatment culture and the surgeon's preference, leading to considerable (inter)national practice variation.

The INterNational study on Odontoid frActure Treatment in the Elderly (INNOVATE) trial aimed to prospectively compare effects of surgery with initial conservative treatment on clinical outcome (including NDI improvement), fracture union and fracture stability at 52 weeks in patients ≥55 years with type II/III odontoid fractures.

Methods

Study design

This prospective comparative study was reported in accordance with the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement [13]. Fifteen centres from eight European countries participated. Patient inclusion started in September 2012, with seven centres starting later, and the last patient was enrolled in February 2022. All institutional review boards approved the study. Patients provided written informed consent. The study protocol was published previously [14]. The study was registered in the Dutch Trial Register (NTR3630) [15].

Patient selection

Selection criteria were of age ≥55 years, acute (<2 weeks) type II/III odontoid fracture diagnosed using computed tomography (CT), no rheumatoid arthritis/ankylosing spondylitis, no previous odontoid fracture treatment, and no language barrier/cognitive impairment. Patients admitted to the participating centres were asked to participate if they met these criteria.

Treatment

The attending surgeon and patient made a shared decision on the applied treatment modality. All centres were able to facilitate both surgical and conservative treatments.

Data collection

Surgeons and patients completed baseline questionnaires focusing on patient and fracture characteristics, symptoms and treatment modality. Follow-up was at 6, 12, 26, 52 and 104 weeks. Follow-up visits could be concluded earlier by the surgeon in case of (nearly) complete clinical recovery and fracture union and/or stability. Patients were asked to complete questionnaires at home at all follow-up moments.

Outcomes

The co-primary outcomes were (i) clinical outcome in terms of Neck Disability Index (NDI) improvement, (ii) fracture union and (iii) fracture stability, at 52 weeks. NDI improvement was defined as the score difference between baseline and 52 weeks. The NDI is a validated 50-point instrument, with higher scores indicating greater disability [16]. Baseline NDI scores were determined by patients evaluating their current post-injury status, assuming no mobility restrictions were imposed. Union was assessed using CT and defined as evidence of bone trabeculae crossing the fracture site and absence of adjacent sclerotic borders. Stability was assessed with dynamic X-rays, where ≤2 mm movement indicated stability [17]. If union was achieved, the fracture was also classified stable. Secondary outcomes included Visual Analogue Scale (VAS, 0–100 mm) neck pain, 7-point Likert patient-perceived recovery scales for symptoms and neck pain (good results were defined as (nearly) complete recovery) and EuroQol-5D-3L (EQ5D, 0–1 point, 0–100 mm), at 52 weeks [18–20]. Complications included rates of secondary neurological deficits, secondary treatment (repeated surgery or surgery/halo after conservative treatment) and mortality within 52 and 104 weeks. Subgroup analyses were done for age (55–79 and ≥ 80 years), type II fractures and fractures displaced >2 mm. *Post hoc* treatment subtype analyses were done for odontoid screw fixation vs. C1-C2 fusion and cervical collar vs. halo vest.

Statistical analysis

NDI improvement between baseline and 52 weeks was univariably analysed as continuous outcome with independent sample T-tests, with lower NDI scores indicating clinical improvement. The predetermined minimal clinically important difference (MCID) in NDI was 7.5 [21, 22]. Union and stability were dichotomous outcomes univariably analysed with $\chi 2$-tests. Multivariable analyses were done using regression models. Linear regression assessed NDI improvement, also adjusting for baseline NDI. Logistic regression assessed union and stability. To address baseline differences between treatments, variables generally presumed to influence outcome were added: age (continuous), gender (male, female), fracture type (II, III), fracture displacement (≤2, >2 mm), concomitant C1-C2 fractures (no, yes), degree of osteoporosis in C2 (none/mild, moderate/severe) and degree of C0-C2 facet joints degeneration (none/mild, moderate/severe) [23]. Similar analyses were done for the secondary outcomes and subgroups. The influence of individual variables in the models was studied. Linear regression analysed the association between NDI improvement and union, with union status as the predictor and baseline NDI as covariate. For missing items in individual NDI scores, the mean value of available items was inserted for a maximum of two missing items [24]. Radiological follow-up concluded before 52 weeks in case of positive outcomes, resulting in missing data beyond the last follow-up. Five rules were hence applied to complete union and stability data: (i) union implies later union (e.g. if union was achieved at 26 weeks and the patient was discharged, union was also scored at 52 and 104 weeks); (ii) stability implies later stability (similar to rule 1); (iii) union implies stability (union cases were also scored as stable); (iv) non-union implies prior non-union (e.g. in case of non-union at 26 weeks and absence of earlier CT scans, non-union was scored at earlier points) and (v) instability implies prior instability (similar to rule 4). NDI improvement was completely available for 135 (49%) patients, union for 170 (62%) and stability for 201 (73%). The extent of missing data was largely similar across all outcomes between treatments. Missing data were multiply imputed using predictive mean matching ($m = 10$), assuming data to be missing-at-random. Multiple imputation results for union and stability were adjusted to adhere to the five rules. Primary analyses were done with the resulting dataset. Sensitivity analyses were done with the original, non-imputed dataset. Line graphs displayed the proportion of patients achieving outcomes at different timepoints between treatments. Two-tailed P-values <0.05 were considered statistically significant. Intention-to-treat analyses were done using IBM SPSS, version 29, and R, version 4.3.1 in RStudio version 2022.12.0.

Results

Patient characteristics

A total of 279 patients were included, of which 146 (52%) were treated surgically and 133 (48%) conservatively. Two surgical patients and one conservative patient withdrew from the study. Hence, 276 patients were included for analysis (Fig. 1, Supplementary Table S1).

Baseline characteristics were largely similar across treatments, except for two variables. Firstly, surgical patients had more type II fractures than conservative patients (81% vs. 56%, $P < 0.001$). Secondly, surgical patients more often had fracture displacement >2 mm (47% vs. 27%, $P = 0.001$, Table 1). Both these variables were among the covariates adjusted for in the multivariable analyses.

Primary outcomes

NDI improvement at 52 weeks did not differ significantly between surgical and conservative patients [mean (SE) decrease −11 (2.4) vs. −14 (1.8), $P = 0.08$, <7.5 MCID]. Union rates at 52 weeks did not differ between surgical and conservative patients (86% vs. 78%, aOR 2.3, 95% CI 0.97–5.7), nor did stability rates (99% vs. 98%, aOR NA, Table 2).

Secondary outcomes

VAS neck pain at 52 weeks was similar between surgical and conservative patients [mean (SE) 28 (7.3) vs. 25 (5.7), $P = 0.22$]. The rate of patients reporting (nearly) complete recovery of symptoms did not differ (27% vs. 36%, aOR 1.0, 95% CI 0.29–3.5), nor did the rate of patients reporting (nearly) complete recovery of neck pain (35% vs. 42%, aOR 1.0, 95% CI 0.40–2.7). EQ5D-VAS health at baseline

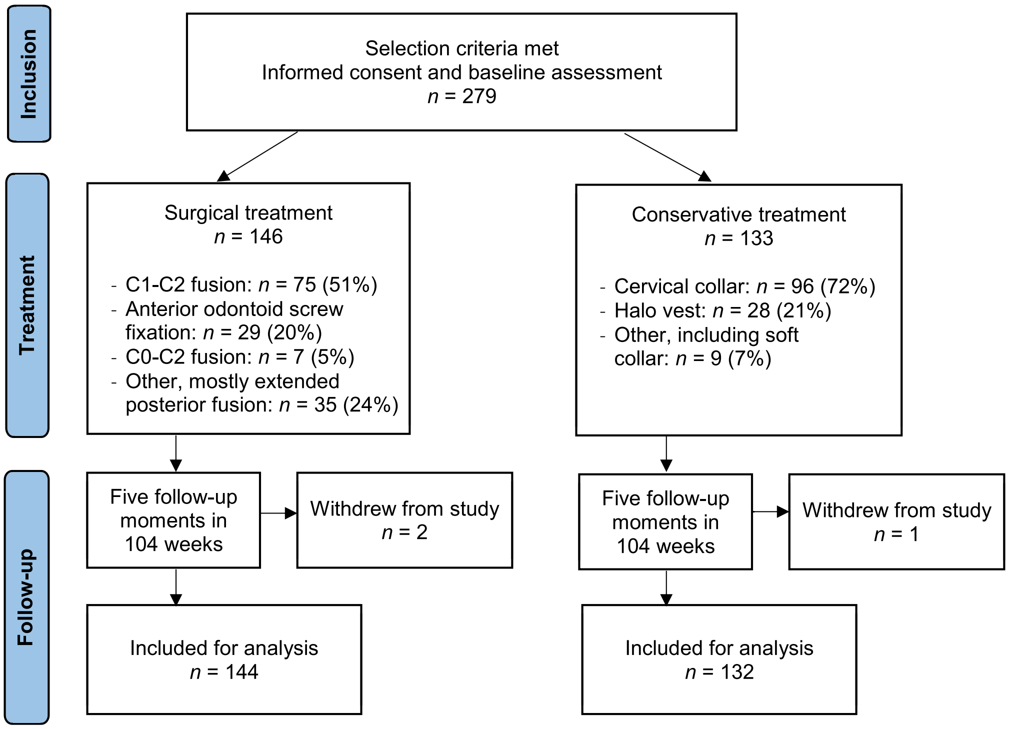

Figure 1. Flow chart depicting the applied treatments and follow-up period for patients with odontoid fractures.

Table 1. Baseline characteristics of included patients.

	No (%)		
	Surgical (*n* = 144)	Conservative (*n* = 132)	*P*-value
Demographic data			
Age, mean (SD), y	77.3 (9.1)	76.6 (9.7)	0.56
Age groups			
55–79 years	81 (56)	72 (55)	0.78
≥ 80 years	63 (44)	60 (45)	
Male gender	72 (50)	53 (40)	0.10
Fracture characteristics			
Type II fractures (vs. III)	116 (81)	74 (56)	**<0.001**
Fracture displacement > 2 mm (vs. ≤2 mm)	67 (47)	36 (27)	**0.001**
Other C1-C2 fractures present	35 (24)	30 (23)	0.76
Moderate/severe osteoporosis in C2 (vs. none/mild)	76 (53)	62 (47)	0.34
Moderate/severe degeneration C0-C2 facet joints (vs. none/mild)	39 (27)	33 (25)	0.69
Neurological deficits			
Medullary induced	5 (3)	4 (3)	0.84
Radicular induced	5 (3)	1 (1)	0.16

Abbreviations: SD, standard deviation. Values in bold represent statistical significance.

was higher for surgical patients [mean (SE) 50 (2.1) vs. 42 (2.5), $P = 0.01$]. EQ5D at 52 weeks did not differ between treatments [mean (SE) 0.53 (0.1) vs. 0.62 (0.1), $P = 0.40$], nor did VAS health at 52 weeks [mean (SE) 57 (8.2) vs. 61 (6.6), $P = 0.48$, Table 2].

Association NDI improvement and union

NDI improvement did not differ between patients with union and non-union at 52 weeks [mean (SE) −13 (2.0) vs. −12 (2.8), $P = 0.78$]. NDI improvement similarly did not differ between patients with union and non-union when analysed separately for each treatment [mean (SE) −11 (2.3) vs. −10 (4.3), $P = 0.78$ for surgical treatment; −15 (2.0) vs. −14 (3.3), $P = 0.82$ for conservative treatment].

Outcomes throughout follow-up

NDI improvement, union and stability were largely similar between treatments throughout the follow-up period, as were the secondary outcomes (Fig. 2). NDI improvement between baseline and 104 weeks did not differ between

Table 2. Results for primary and secondary outcomes.

	No. (%)			
	Surgical (*n* = 144)	**Conservative (*n* = 132)**	**Univariable analysis**	**Multivariable analysis**
Primary outcomes				
NDI improvement (decrease) baseline-52 weeks, mean (SE)	−11 (2.4)	−14 (1.8)	$P = 0.13$	$P = 0.08$
NDI at baseline, mean (SE)	27 (0.9)	29 (0.8)	$P = 0.10$	$P = 0.07$
NDI at 52 weeks, mean (SE)	16 (2.4)	15 (1.7)	$P = 0.47$	$P = 0.43$
Union at 52 weeks	124 (86)	103 (78)	OR 1.8 (CI 0.93–3.3)	aOR 2.3 (CI 0.97–5.7)
Stability at 52 weeks	143 (99)	130 (98)	OR 2.2 (CI 0.20–25)	aOR NA
Secondary outcomes				
VAS neck pain				
VAS at baseline, mean (SE)	48 (2.2)	50 (2.8)	$P = 0.66$	$P = 0.67$
VAS at 52 weeks, mean (SE)	28 (7.3)	25 (5.7)	$P = 0.47$	$P = 0.22$
Likert patient-perceived recovery				
(Nearly) complete recovery of symptoms	39 (27)	48 (36)	OR 0.65 (CI 0.39–1.1)	aOR 1.0 (CI 0.29–3.5)
(Nearly) complete recovery of neck pain	50 (35)	55 (42)	OR 0.74 (CI 0.46–1.2)	aOR 1.0 (CI 0.40–2.7)
EQ5D				
EQ5D at baseline, mean (SE)	0.40 (0.03)	0.34 (0.03)	$P = 0.22$	$P = 0.15$
VAS health at baseline, mean (SE)	51 (2.1)	42 (2.5)	$P =$ **0.02**	$P =$ **0.01**
EQ5D at 52 weeks, mean (SE)	0.53 (0.06)	0.62 (0.06)	$P = 0.10$	$P = 0.40$
VAS health at 52 weeks, mean (SE)	57 (8.2)	61 (6.6)	$P = 0.44$	$P = 0.48$

Abbreviations: SE, standard error. OR, odds ratio. CI, 95% confidence interval. aOR, adjusted odds ratio. Values in bold represent statistical significance. Odds ratios affected by non-convergence are reported as not available (NA).

surgical and conservative patients [mean (SE) −12 (2.5) vs. −16 (2.4), $P = 0.06$, <7.5 MCID]. NDI did hence not clearly improve further between 52 and 104 weeks. Union at 104 weeks did not differ between treatments (94% vs. 91%, aOR 1.9, 95% CI 0.34–11), nor did stability (99% vs. 98%, aOR NA).

Complications

No secondary neurological deficits were identified in either treatment group. Secondary treatment was applied less often after surgical than conservative treatment (OR 0.32, 95% CI 0.14–0.72). Nine (6%) surgically treated patients required secondary surgery: C1-C2 fusion ($n = 2$), odontoid screw fixation ($n = 1$), extended posterior fusion ($n = 3$), hardware removal ($n = 2$) and wound revision ($n = 1$). Of these 9 patients, 3 were ≥80 years. Twenty-three (19%) conservatively treated patients required secondary treatment: C1-C2 fusion ($n = 10$), odontoid screw fixation ($n = 2$), extended posterior fusion ($n = 10$), and halo vest placement ($n = 1$). Of these 23 patients, 7 were ≥80 years. Reasons for secondary treatment were prolonged fracture instability ($n = 2$ surgical, $n = 11$ conservative), prolonged non-union ($n = 3$ surgical, $n = 8$ conservative), persistent symptoms ($n = 4$ conservative), collar non-compliance ($n = 1$ conservative) and various other reasons ($n = 5$ surgical, $n = 8$ conservative). Time to secondary treatment did not differ between treatments (median (IQR) 12 (3–23) vs. 6 (3.5–16) weeks, Mann–Whitney U = 84, $P = 0.41$). Mortality within 52 and 104 weeks did not differ between treatments. Twelve (8%) surgical and 15 (11%) conservative patients died within 52 weeks (OR 0.71, 95% CI 0.32–1.6). Of these 27 patients, 17 were ≥80 years, of which 5 treated surgically. Fourteen (10%) surgical and 18 (14%) conservative patients died within 104 weeks (OR 0.68, 95% CI 0.33–1.4). Of these 32 patients, 21 were ≥80 years, of which 6 treated surgically. Time to death did not differ between treatments [median (IQR) 7 (3.9–20) vs. 26 (6.5–55) weeks, Mann–Whitney U = 105, $P = 0.13$, Supplementary Fig. S1].

Subgroup analyses

In patients aged 55–79 years, NDI improved less after surgical than conservative treatment (mean (SE) −11 (2.7) vs. −17 (2.2), $P = 0.04$), although the difference was not clinically relevant (<7.5 MCID). Union and stability did not differ between treatments in this age group. In patients ≥80 years, NDI improvement, union and stability similarly did not differ between treatments. Union rates for type II fractures were higher after surgery in univariable analysis, but not in multivariable analysis (84% vs 65%, aOR 2.4, 95% CI 0.93–6.2), and again NDI improvement and stability did not differ between treatments. NDI improvement, union and stability did not differ between treatments for fractures displaced >2 mm (Table 3).

Treatment subtypes

NDI improvement did not differ between patients treated by odontoid screw fixation and C1-C2 fusion (mean (SE) -13 (2.9) vs. −9 (2.6), $P = 0.22$), nor did union (76% vs. 88%, aOR 0.35, 95% CI 0.06–2.1) and stability (100% vs. 99%, aOR NA). Similarly, NDI improvement did not differ between patients treated with cervical collar and halo

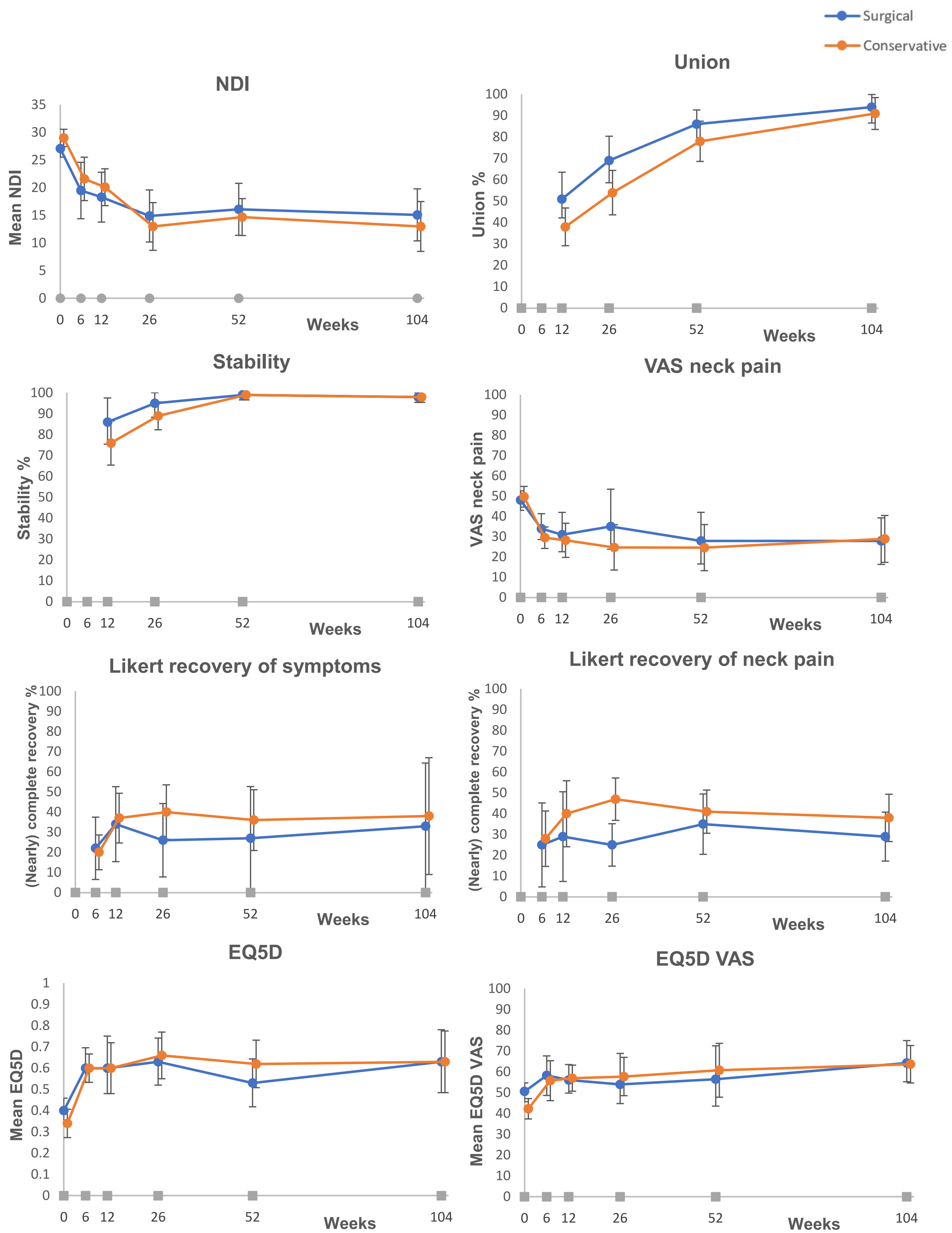

Figure 2. Line graphs displaying outcomes with 95% confidence intervals at various timepoints between treatments.

vest (mean (SE) −13 (2.1) vs. −20 (2.6), $P = 0.13$), nor did union (76% vs. 86%, aOR 1.03, 95% CI 0.21–4.9) and stability (99% vs. 100%, aOR NA, Supplementary Table S2).

Influence of baseline characteristics

Type III fractures showed substantially more union than type II fractures (aOR 11, 95% CI 1.7–76), while NDI

Table 3. Results for primary outcomes for age subgroups, type II fractures and displaced fractures.

	No. (%)			
	Surgical ($n = 144$)	Conservative ($n = 132$)	Univariable analysis	Multivariable analysis
NDI improvement (decrease) baseline-52 weeks, mean (SE)				
55–79 years	−11 (2.7)	−17 (2.2)	P = **0.03**	P= **0.04**
≥80 years	−11 (2.9)	−11 (2.2)	P = 0.83	P = 0.74
Type II fractures	−11 (2.5)	−13 (2.4)	P = 0.35	P = 0.22
Fractures displaced > 2 mm	−11 (3.0)	−15 (2.7)	P = 0.19	P = 0.14
Union at 52 weeks				
55–79 years	72/81 (89)	61/72 (85)	OR 1.4 (CI 0.56–3.7)	aOR 2.1 (CI 0.38–12)
≥80 years	52/63 (83)	42/60 (70)	OR 2.0 (CI 0.86–4.8)	aOR 2.7 (CI 0.80–9.2)
Type II fractures	97/116 (84)	48/74 (65)	**OR 2.8 (CI 1.4–5.5)**	aOR 2.4 (CI 0.93–6.2)
Fractures displaced > 2 mm	62/67 (93)	32/36 (89)	OR 1.6 (CI 0.39–6.2)	aOR 3.1 (CI 0.47–20)
Stability at 52 weeks				
55–79 years	80/81 (99)	72/72 (100)	OR 0.37 (CI 0.01–9.2)	aOR NA
≥80 years	63/63 (100)	58/60 (97)	OR NA	aOR NA
Type II fractures	115/116 (99)	72/74 (97)	OR 1.6 (CI 0.22–12)	aOR NA
Fractures displaced > 2 mm	67/67 (100)	36/36 (100)	OR NA	aOR NA

Abbreviations: SE, standard error. OR, odds ratio. CI, 95% confidence interval. aOR, adjusted odds ratio. Values in bold represent statistical significance. Odds ratios affected by non-convergence are reported as not available (NA).

improvement and stability were similar. None of the other baseline characteristics (age, gender, fracture displacement, other C1-C2 fractures, osteoporosis in C2, C0-C2 facet joints degeneration) were relevant predictors for the primary outcomes at 52 weeks (Supplementary Table S3).

Sensitivity analysis

The sensitivity analysis using non-imputed data showed less NDI improvement for surgical patients [mean (SE) −13 (1.6) vs. −18 (1.3), $P = 0.004$), although the difference was not clinically relevant (<7.5 MCID). Union rates were higher after surgery (92% vs. 84%, aOR 4.8, 95% CI 1.5–16), but NDI improvement for patients with union and non-union was similar. Stability did not differ between treatments (100% vs. 99%, aOR NA). Baseline NDI was higher in conservative patients, although the difference between means was 2 (<7.5 MCID, Supplementary Tables S4-S5). NDI improvement, union and stability were largely similar between treatments throughout the follow-up period, as were the secondary outcomes (Supplementary Fig. S2). NDI improvement at 104 weeks was greater after conservative treatment, although the difference between means was 5 (<7.5 MCID). Union and stability at 104 weeks did not differ between treatments (Supplementary Table S6). NDI improvement for patients aged 55–79 years and with displaced fractures was greater after conservative treatment, although the differences between means were 6.5 and 7.4 (<7.5 MCID). For type II fractures, union rates were superior after surgical treatment, but NDI improvement and stability were similar between treatments (Supplementary Table S7). NDI improvement was greater after odontoid screw fixation than C1-C2 fusion, although the difference was not clinically relevant, and union and stability did not differ. The primary outcomes did not differ between treatments with cervical collar and halo vest (Supplementary Table S8).

Discussion

This multicentre prospective comparative study of older patients with odontoid fractures represents the most extensive comparison of outcomes between surgical and conservative treatments. At 52 weeks, outcomes between treatments did not differ in terms of NDI improvement, union and stability, nor for any of the secondary outcomes, also after adjusting for patient- and fracture characteristics. Furthermore, NDI improvement did not differ between patients with union and non-union, providing evidence that clinical outcome and union status are not clearly associated, and that a favourable clinical rather than radiological outcome should be the aim of treatment. Nevertheless, the proportion of (nearly) complete patient-perceived recoveries was disappointingly low in both groups.

No cases of secondary neurological deficit were identified, indicating that historical fears of undertreatment are unjustified. As expected, secondary surgery was more common after initial conservative treatment. No difference in mortality between treatments was identified. In patients aged 55–79 years, NDI improved more in conservative patients, although the difference was not clinically relevant, and union and stability were similar. Primary outcomes were similar between treatments of patients ≥80 years, type II fractures and fractures displaced >2 mm.

The authors conclude that initial conservative treatment is justified, and that surgery can be reserved as secondary treatment in relatively rare cases of persistent symptomatic non-union.

Perspective

In recent decades, the treatment approach for odontoid fractures has shifted. In the 1990s, case series reported in-hospital mortality following rigid immobilization and flat bed rest of over 25% [25]. Since then, rigid immobilization (halo-vest) gradually waned in popularity [26, 27]. Advancements in surgical care, like improved implants and intraoperative imaging, have made surgery on older people more common [28–30]. This was assumed to enhance union rates, but the clinical benefit remained unclear. In more recent years, the focus has shifted to prioritize favourable clinical outcomes.

In 2013, the only other prospective study comparing surgical and conservative treatments involved 159 patients, of which 101 were treated surgically [31]. Union rates were higher after surgery (95% vs. 79%). Surgical patients had less NDI deterioration compared to conservative patients, in contrast to the NDI improvement observed in both treatments in the present study. This difference is (partially) explained by the former study using pre-injury status for NDI scores, whereas the present study used post-injury status assuming no mobility restrictions were imposed. NDI scores at 52 weeks did not differ between treatments in both prospective studies, despite variations in the scores between the studies.

In 2021, a prospective uncontrolled study reported on 260 patients treated conservatively by semi-rigid collar for 6 weeks, followed by 6 weeks by soft collar [32]. Short Form 12 (SF-12) health survey showed excellent functional outcome in 95%. NDI and SF-12 did not differ between patients with union and pseudo-arthrosis (stability). Interestingly, 36% of patients did not follow the prescribed treatment by discontinuing or not wearing the collar, yet still achieved good functional outcomes. Building on this, a current randomized controlled trial is comparing outcomes of 12-week collar treatment with no immobilization at all [33].

Limitations

This study has several limitations, mainly being a non-randomized study. Even after adjusting for age, gender, and various fracture characteristics, results may still have been influenced by residual confounding. A randomized controlled trial was deemed impracticable due to differences in treatment culture among participating centres. At the time of designing this study, there was a widespread belief that surgery was necessary for many odontoid fractures, rendering conservative treatment ethically questionable. The present study was therefore proposed, and many of Europe's major spine centres were keen to participate.

The involvement of older people, the multicentre nature, and the relatively frequent five follow-up moments unavoidably led to considerable missing data, impacting the data's reliability. Missing data posed challenges for the statistical analysis. A simple last observation carried forward approach was avoided because it would underestimate the treatment effect at 52 weeks, merely reflecting outcome at last follow-up. Sensitivity analyses using non-imputed data showed greater, albeit not clinically relevant, NDI improvement after conservative treatment, superior union after surgery, and similar NDI improvement for patients with union and non-union. These findings further affirm the robustness of the presented results.

Unlike the common focus on type II fractures, this study included type II and III fractures, for which was accounted in multivariable analyses and type II subgroup analysis. Different forms of surgical (anterior/posterior) and conservative (collar/halo) treatments were analysed in their respective groups, which may have influenced outcomes, although outcomes of *post hoc* analyses for treatment subtypes showed no evidence for a difference. The inclusion period of over nine years, although relatively lengthy, did not introduce methodological issues since treatment modalities have not changed considerably during this period. No standardized assessment was done for baseline health status, likely favouring generally healthier surgical patients [4]. Notably, the study included patients ≥55 years, rather than the more common ≥65 years. This difference should be taken into account in future study comparisons.

Conclusions

Conservative treatment yielded similar clinical outcome and fracture healing compared to surgical treatment in older patients with odontoid fractures. Clinical outcome was not clearly associated with fracture union. No cases of secondary neurological deficits were identified, indicating that historical fears for undertreatment are unjustified. Treatments should prioritize favourable clinical over radiological outcomes.

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Declaration of Conflicts of Interest: None.

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