Management and long-term outcome of type II acute odontoid fractures: A population-based consecutive series of 282 patients

Abstract

Background context

The surgical fixation rate of type II odontoid fracture (OFx) in the elderly (≥65 years) is much lower than expected if the treatment adheres to current general treatment recommendations. Outcome data after conservative treatment for elderly patients with these fractures are sparse.

Purpose

The main aim of this study was to determine the long-term outcome after conservative and surgical treatments of type II OFx (all age-groups) to evaluate whether nonoperative treatment yields an acceptable outcome.

Study design/setting

Retrospective study based on a prospective database.

Patient sample

282 consecutive patients with type II OFx treated at Oslo University Hospital over an eight-year period.

Outcome measures
Long-term rates of bony fusion, fibrous union, pseudarthrosis, crossover from primary conservative treatment to surgical fixation, new-onset spinal cord injury (SCI), and neck pain were the outcome measures used.

Methods
The present study was based on data extracted from our quality control database for acute cervical spine fractures. All ages were included. In addition, long-term follow-up of alive patients was performed during the years 2018 – 2019. The follow-up included neurological examination, radiological examination, and scoring of bony fusion status, crossover from primary conservative treatment to surgical fixation, new-onset SCI, neck pain, and Neck Disability Index (NDI score). Data are described by counts, percentages, medians, means, ranges and standard deviations where appropriate. For statistical analyses the Mann-Whitney U-test, Wilcoxon signed-rank test, and t-tests were used.

Results
During the eight-year study period, we registered 282 consecutive patients with type II OFx; 54% were males, patient age ranged from 15 – 101 years, 84% were ≥ 65 years of age (WHO definition of elderly), and 51% were ≥80 years of age. Severe comorbidities (American Society of Anesthesiologists, ASA ≥3) were seen in 67%, while nonindependent living was registered in 32%. Severe comorbidities and nonindependent living were significantly associated with increasing age (p<0.001). SCI secondary to the OFx was seen in 5.3%. Primary treatment of the OFx was conservative (external immobilization alone) in 193 patients (68.4%), open surgical fixation in 87 patients (30.9%), and no treatment in two critically injured patients. At the time of
long-term follow-up, 125 patients had died, 9 patients declined the invitation to follow-up, and 5 patients did not respond. Thus, 143 patients were available for follow-up with a median follow-up time of 39 months (range 5-115 months). At long-term follow-up, the fusion status was bony fusion in 39.2% of patients, fibrous union in 57.3%, and pseudarthrosis in 3.5%. The proportion of bony fusion was significantly higher in the primary surgical fixation group (p=0.005). No patients had new-onset SCI presenting after the start of primary treatment. The proportion of crossover from primary external immobilization to surgery was 14.4%, while proportion of revision surgery in the primary surgical group was 9.5%. There was no significant difference between the primary surgical fixation group and the primary conservative treatment group at long-term follow-up with respect to the proportion of pseudarthrosis and degree of neck pain.

Conclusions

Primary conservative treatment of elderly patients with type II OFx appears to be safe and should be regarded a viable treatment option.

Keywords: Odontoid fracture, trauma, surgery, outcome, fusion rate
Abbreviations

ADL: Activities of daily living
ASA: American Society of Anesthesiologists
ASIA: American Spinal Injury Association
CSFx: cervical spine fracture
IQR: interquartile range
HISS: Head Injury Severity Scale
OFx: odontoid fracture
OUH: Oslo University Hospital
SCI: Spinal cord injury
VAS: Visual Analog Scale

Classifications
Clinical study
Introduction

Odontoid fractures (OFx) comprise approximately ~20% of all traumatic cervical spine fractures (CSFx) [1]. The incidence increases with age and are the most common CSFx in the elderly population [1,2]. OFx are subdivided according to the Anderson and D’Alonzo/Grauer classifications into types I, II and III [3,4]. In type II, the fracture line traverses the base of the odontoid process [3]. Type II fractures are the most common OFx and are unstable injuries.

Until recently, primary surgical fixation was recommended for type II fractures, especially in patients ≥50 years [5-7]. The main argument for this recommendation was an observed low bony fusion rate after external stabilization alone [6]. This recommendation has in recent years been challenged due to the high surgical risk in these elderly and often severely comorbid patients [8]. Some recent reports indicate that many patients with type II OFx, when treated with external immobilization alone for 12-16 weeks, achieve stability without bony fusion on CT (fibrous union) [9-11]. This “fibrous union” has been defined as the lack of pathological movement of the odontoid fragment on flexion/extension x-ray at 12-16 weeks, despite the absence of radiologically evident bony fusion [8,12,13].

We have recently shown that primary surgical fixation of type II OFx was only performed in 33% of our patients in the 4-year time period 2015 – 2018 [14]. The reasons given for choosing primary external immobilization instead of primary surgical fixation for these patients were a combination of age and comorbidity in 88%, nonsurvivable injury in 6% and delayed diagnosis in 6%. This treatment practice raises several important questions: what is the rate of crossover from primary external immobilization to surgical fixation?; what is the rate of new-onset SCI due
to insufficient stabilization with external immobilization alone compared to surgical fixation?; is a stable fibrous union at 3-4 months still stable years later? These questions should be answered to accept fibrous union as an acceptable outcome after external immobilization alone.

The main aims of this study were to determine the proportion of bony fusion and fibrous union after both primary surgical fixation and primary external immobilization of type II OFx, the proportion and reasons for crossover from primary external immobilization to surgical fixation, and the proportion of new-onset SCI due to insufficient stabilization with external immobilization compared to surgical fixation. The results will be discussed in order to determine whether fibrous union at 3-4 months is a stable, lasting and acceptable outcome in the long-term.

**Materials and methods**

Oslo University Hospital (OUH) is a level 1 trauma center situated in Oslo and is the only major trauma-care facility in the South-Eastern Norway Regional Health Authority (Norwegian: Helse Sør-Øst RHF) with 3.0 million inhabitants (2018). OUH is the only hospital in this region with neurosurgical service and performs >95% of trauma-related neurosurgical procedures in this population, including all procedures for cervical spine injuries. There are 20 hospitals within our region with general and/or orthopedic surgeons and radiological services that refer patients with head and cervical spine injuries to our department. The patients are either admitted to OUH for treatment, or nonsurgical treatment is carried out locally after consultation with the Department of Neurosurgery at OUH.
This is a retrospective study based on a prospective database of all type II OFx patients diagnosed with cervical CT in Southeast Norway in the eight-year period from 2009 – 2011 and 2013 - 2017. The year 2012 has been omitted due to incomplete registration this year. Only patients with a unique 11-digit Norwegian Social Security Number living within Southeast Norway are included. The following patients were excluded: 1. patients with pathological fracture, and 2. patients with delayed diagnosis not having started primary treatment within 90 days of trauma.

The present study was based on data extracted from our quality database for acute cervical spine fractures. The following data were extracted: date of injury, date of diagnosis, gender, age at time of injury, injury mechanism, living status at time of injury (home – self-reliant, home – with assistance or institutionalized), pre-injury American Society of Anesthesiologists (ASA) score [15], type of OFx according to Anderson and D’Alonzo’s [3] classification supplied by Grauer’s et al. [4] subclassification, measurements of translation, angulation and diastasis of the odontoid fragment (direction and magnitude) [16,17], other cervical fractures, Head Injury Severity Score (HISS) [18], concomitant thoracolumbar fracture (yes/no), spinal cord injury (SCI) (yes/no), primary treatment (external immobilization with stiff collar alone, open surgical fixation, or no treatment), length of collar treatment, fusion at end of primary treatment (bony fusion, fibrous union, pseudarthrosis), crossover from primary external immobilization to surgery, reasons for crossover, surgical failures and revision surgeries.

**Bony fusion** at the end of primary treatment was defined as either bone trabecula traversing the fracture line on cervical CT and/or posterior fusion in the graft after surgery.
We used the following criteria to define fibrous union at the end of primary treatment. If criteria 1-4 were fulfilled, we concluded that fibrous union had occurred, and flexion/extension x-ray was not performed. If the patient failed on criteria 2, 3 or 4, a flexion/extension x-ray was performed. If movement of the odontoid fragment in the anterior-posterior direction between flexion and extension x-ray was $\leq 2$ mm, we concluded that fibrous union had occurred.

1. Lack of bone trabecula traversing the fracture line on cervical CT
2. No change in the position of the odontoid fragment on cervical CT at the end of primary treatment
3. Neck pain $\leq 3$ on a VAS and no new-onset myelopathy at the end of primary treatment and before collar removal
4. No increase in neck pain after collar removal
5. No pathological movement of the odontoid fragment ($\leq 2$ mm) at the flexion/extension x-ray performed at 12-16 weeks

Pseudarthrosis at the end of primary treatment (conservative or surgical fixation) was defined as lack of bony fusion and $>2$ mm movement of the odontoid fragment in the anterior-posterior direction at the flexion/extension x-ray study [9]. This definition of pseudarthrosis deviates slightly from the most used definition, as we use the phrase before 6 months has elapsed from start of treatment.
In each case, the choice of primary treatment was determined by the treating surgeon. The surgical techniques used were anterior odontoid screw fixation, posterior fixation with screws or wire, or occipitocervical fixation [19-22]. All patients treated with surgical fixation had a rigid collar for 6-12 weeks. Patients treated with a rigid cervical collar alone had the collar for at least 12 weeks. Our standard follow-up during primary treatment, for both conservatively and surgically treated patients with OFx, was outpatient visits 1-, 4- and 12 weeks after injury and included cervical-CT and clinical examination. If the CT scan at 12 weeks did not show bony fusion, the need for flexion/extension x-ray was evaluated with the criteria described earlier. Follow-up beyond 12 weeks was only done in selected cases. For this study an additional long-term follow-up was done.

**Long-term clinical follow-up**

Long-term follow-up evaluations were performed during 2018-2019 (clinical examination, cervical CT and flexion/extension x-ray study if indicated (done in 43/87 patients without bony fusion)). The following outcome variables were recorded: time from injury to clinical follow-up (months), ASIA impairment scale [23], self-reported neck stiffness (none/mild/severe), neck pain using a Visual Analog Scale (VAS) [24], living status at time of follow-up (home – self-reliant, home – with assistance or institution), hoarseness (yes/no) and swallowing difficulties (yes/no), bony fusion of odontoid fragment (yes/no), posterior bony fusion (yes/no), fracture in implanted devices (yes/no), changed position of graft (yes/no), fibrous union of odontoid fragment (same criteria as used at end of primary treatment), and pseudarthrosis (same criteria as used at end of primary treatment). The last registered vital status (dead or alive) and time of death were obtained from the Norwegian Population Registry (Folkeregisteret) on 1st September 2019.
Ethics

The study was approved by the data protection official (DPO) at Oslo University Hospital (OUH - DPO approval no 2016/7495) and the Regional Ethical Committee (approval no 2018/1887). Data were extracted from our hospital-approved quality database for acute cervical spine fractures (OUH - DPO approval no 2014/12304). The database was developed in Medinsight and maintained by the Department of Neurosurgery. Written informed consent was obtained from all patients at follow-up.

Database and statistical analysis

Data are described by counts, percentages, medians, means, ranges and standard deviations where appropriate. Overall survival (OS) analyses were performed using Kaplan-Meier curves, which measured survival from the time of surgery to the time of death. In non-normally distributed data, we used the Mann-Whitney U-test between two independent samples, while the paired Wilcoxon signed-rank test was used for paired data. In cases of normally distributed data, t-tests were performed. A $p$ value < 0.05 was considered statistically significant. The statistical analyses were performed using SPSS v25.0 (SPSS Inc., Chicago, IL, USA).

Results

Patient characteristics

Patient characteristics are given in Table 1 and Fig. 1. A total of 282 consecutive patients with type II OFx were treated at Oslo University Hospital in the eight-year study period. There were
153 (54.3%) males, patient age ranged from 15 – 101 years, the mean age was 76.8 years (range 15 – 101 years), 84.0% of the patients were above 65 years (WHO definition of elderly) and 51.4% were above 80 years. The injury mechanism was falls in 86.2%.

5 **Comorbidity**

As measures for comorbidity, we used the pre-injury ASA score and pre-injury living status (Fig. 2A and B). Severe comorbidity, measured as ASA score ≥3, was seen in 189/282 patients (67.0%), while nonindependent living (home with assistance or institutionalized) was registered in 91/282 patients (32.3%). Severe comorbidity and nonindependent living were significantly associated with increasing age (p<0.001).

**Fracture morphology**

The OFx was classified according to Anderson and D’Alonzo’s classification and subclassified according to Grauer into type IIA in 19 patients (6.8%), type IIB in 255 patients (90.4%) and type IIC in 8 patients (2.8%). We defined major translation of the odontoid fragment as ≥5 mm dislocation anterior or ≥3 mm dislocation posterior, major angulation as ≥11° in either the anterior or posterior direction, and major fracture diastasis as ≥3 mm in the sagittal plane (Fig. 3 and Table 2). Major translation was seen in 85/282 patients (30.1%), major angulation in 123/282 patients (43.6%), and major fracture diastasis in 65/282 patients (23.0%). Some patients had major displacement of the odontoid fragment in more than one orientation. Major displacement in any orientation was registered in 153 patients, while 129 patients had no or minor displacement. For concomitant spine fractures, see Table 1.
Spinal cord injury (SCI)

At the time of primary diagnosis, 15/282 patients (5.3%) had spinal cord injury (ASIA A-D) caused by dislocation of the odontoid fragment (Table 1 and Fig. 3). The median age of patients with SCI related to the OFx was significantly lower than the median age of patients without SCI (70 years versus 80 years, p=0.015). Another six patients (2.1%) had SCI due to a concomitant subaxial cervical spine fracture, and none had SCI due to concomitant thoracolumbar spine fracture.

Primary treatment

Primary treatment of the odontoid fracture was external immobilization alone in 193 patients (68.4%) and open surgical fixation in 87 patients (30.9%). Two severely injured patients (0.7%) died during the hospital stay and were not treated (Fig. 4). Of the 15 patients with SCI secondary to the OFx, 11 were treated with surgical fixation, and four multitraumatized old patients with severe comorbidity were treated conservatively with a rigid collar. The surgical techniques used in primary surgical fixation were anterior fixation with one odontoid screw in 62 patients, posterior fixation with screws/wires in 21 patients, occipitocervical fixation in 2 patients, and combined anterior and posterior fixation in 2 patients (Fig. 5).

When comparing patients treated with primary surgical fixation to patients treated with primary external immobilization alone, the surgery patients were younger (median 74.0 years, IQR (interquartile range) [65 – 80] versus median 84.0 years, IQR [74 - 89] (p<0.001)) (Fig. 4), had a lower comorbidity ASA score (mean 2.40 ± 0.08 versus mean 2.73 ± 0.05 (p<0.001)), had greater fracture translation (median 3.5 mm, IQR [1.6 - 6.8] versus median 0.0 mm, IQR [0.0 –
2.4] (p<0.001)), had greater fracture angulation (median 12.0 degrees, IQR [0.0 – 24.8] versus median 5.4 degrees, IQR [0.0 – 20.0] (p=0.001)), and had greater fracture diastasis (median 2.0 mm, IQR [1.0 – 3.4] versus median 1.4 mm, IQR [1.0 – 2.2] (p=0.002)). There was no significant difference between the primary surgical fixation group and the primary external immobilization group with respect to Grauer classification (p=0.058). The presence of SCI was significantly higher in the primary surgical fixation group than in the primary conservative treatment group, 11/87 (12.6%) versus 4/193 (2.1%) (p=0.033).

Failure of primary external immobilization was defined as crossover to surgery within 16 weeks of trauma and was registered in 16/193 (8.3%) patients. Reasons for converting to surgery were increased dislocation/angulation in 15 patients and pseudarthrosis at the end of primary treatment in one patient. There was statistically insignificant difference between major displacement and failure of primary external immobilization (Wilcoxon signed-rank test, p=0.059). New-onset SCI was not seen within the first 16 weeks of trauma.

Failure of primary surgical fixation was defined as the need for a revision surgery within 16 weeks of trauma and was performed in 4/87 (4.6%) patients. Revision surgery was performed due to secondary displacement of the odontoid fragment. The primary surgical fixation techniques in these patients were anterior odontoid screws in three patients and posterior wiring in one patient. None of the patients had new-onset SCI within the first 16 weeks of trauma.

*Long-term follow-up*
At the time of long-term follow-up, 125 patients had died, 9 patients declined the invitation to follow-up, and 5 patients did not respond. Thus, 143 patients were available for follow-up with a median follow-up time of 39 months (range 5-115 months). When grouping the long-term follow-up patients according to primary intention to treat, 82 belonged to the primary external immobilization group and 61 to the primary surgical fixation group.

After the primary treatment was finalized, 5/82 (6.1%) patients in the primary conservative group had surgical fixation due to radiological evident pseudarthrosis (including one patient diagnosed at the time of follow-up), and 3/61 (4.9%) patients in the primary surgical fixation group had revision surgery due to radiological evident pseudarthrosis (p=0.762). Pseudarthrosis in the surgical group was seen in two patients after anterior odontoid screw fixation and in one patient after posterior wiring fixation. No patients in either group had new-onset SCI presenting after ending primary treatment.

Fusion status

At long-term follow-up, the fusion status was bony fusion in 56/143 (39.2%), fibrous union in 82/143 (57.3%), and pseudarthrosis in 5/143 (3.5%) patients. The proportion of bony fusion was significantly higher after primary surgical fixation than after primary conservative treatment, 32/61 (52.5%) versus 24/82 (29.3%) (p=0.005) (Table 3). Within the surgery group, the proportion of bony fusion was significantly higher after posterior screw/wire fixation than after anterior screw fixation, 10/14 (71.4%) versus 20/45 (44.4%) (p=0.032). Only one of the five patients with radiologically evident pseudarthrosis had movement-related neck pain and was referred to surgery at follow-up. Of the five patients with radiologically evident pseudarthrosis at
the time of follow-up, three belonged to the primary external immobilization group and two to the primary surgical group. The median age of patients with bony fusion, fibrous union, and pseudarthrosis were 70 years, 78 years, and 74 years, respectively.

5 **Neck pain (VAS score)**

For neck pain, the median VAS score at long-term follow-up was 0 (range 0-10), with a mean score of 1.26. The VAS score was ≤3 in 120/143 (83.9%), between 4-6 in 19/143 (13.3%), and ≥7 in 4/143 (2.8%) patients. There was no significant difference in the long-term follow-up VAS score between the primary surgical fixation and primary external immobilization groups (mean 1.26 ± 0.28 versus mean 1.26 ± 0.23 (p=0.986)) or between patients with bony fusion and non-bony fusion (mean 1.61 ± 0.31 versus mean 1.03 ± 0.21 (p=0.117)).

13 **Patients not available for long-term follow-up**

At the time of long-term follow-up, 139 patients were unavailable due to either death, that they rejected control or failed to respond. Chart review of these patients revealed that one patient treated with primary external immobilization underwent surgical fixation after ending primary treatment. None of the patients treated with primary surgical fixation underwent revision surgery after finalized primary treatment. We did not receive reports of new-onset SCI for any of these patients in the period after primary treatment.

21 **Survival**
The 30-day, 6-month and 12-month survival rates were 84.4%, 78.4% and 73.5%, respectively (Fig. 6). The mean age of patients who succumbed within 30 days of trauma was 84.4 years (range 57 - 99), and 76.3% of these patients had a pre-injury ASA score ≥ 3.

Discussion

In this population-based observational cohort study of 282 consecutive patients with type II OFx, 84.0% of the patients were above 65 years, and 67.0% had severe comorbidities. Primary treatment was external immobilization alone in 68.4% of the patients and open surgical fixation in 30.9% of the patients. The proportion of crossover from primary external immobilization to surgery was 14.4% (8.3% within 14 weeks of trauma and 6.1% later), while the proportion of revision surgery in the primary surgical group was 9.5% (4.6% within 14 weeks of trauma and 4.9% later). None of the patients developed new-onset SCI after initiation of treatment. At the time of follow-up, 84% reported no/minimal neck pain.

Patients suffering a type II OFx represent a challenge with respect to the treatment decision. The majority of patients are elderly with a high proportion of severe comorbidities [8,25,26]. Older age and a high burden of disease are associated with an increased risk of complications and mortality after trauma, more often related to the patients’ comorbidities than the injury itself [8]. Our patient cohort corroborates this, with 84% of the patients older than 65 and more than half of them older than 80 years of age. In addition, 2/3 of the patients had severe comorbidities, and 1/3 were in need of help with daily living, either in their own home or at an institution.
The medical complexity of OFx patients is probably one of the reasons why we lack Class I evidence supporting treatment decisions [7]. There are, however, ongoing studies which we hope will provide increased knowledge [27,28]. Since a large fraction of these patients are too old and frail to tolerate general anesthesia and open surgery within acceptable risk, randomized controlled trials (RCTs) to compare surgical versus conservative treatment would be biased by the need to exclude a major portion of the patients in question. For this reason, a large population-based cohort series including all patients is important to provide insight into outcomes following different treatment modalities, even though this will not provide Class I evidence.

The treatment recommendation for type II OFx in patients ≥50 years of age has been to consider surgical fixation in all patients, irrespective of alignment [7]. The main basis for this recommendation was the superior bony fusion rates after surgery compared to external immobilization [6,7].

If we had adhered to the treatment recommendation, 95% of our patients should have been treated with surgical fixation. However, the proportion of surgical fixation in our cohort was only 30.9%. This discrepancy has been attributed to high surgical risk due to older age and high comorbidity [14]. We will discuss if this is a good practice based on this population-based follow-up study. It is well known that external immobilization alone compared to surgical fixation results in a much lower bony fusion rate and a higher rate of fibrous union at end of primary treatment. Refraining from primary surgical fixation can be acceptable in old patients with comorbidities if fibrous union also gives long-term stability. Surrogate measures for long-
term stability are rate of new-onset SCI, rate of conversion from conservative treatment to surgery, and the intensity of neck pain at follow-up. Fibrous union can be regarded as sufficiently stable if treatment-related new-onset SCI is close to zero, severe neck pain at long-term follow-up is not higher than in the surgery group, and the rate of conversion from conservative treatment to surgery is low.

Recent reports have challenged the recommendation of surgical fixation of almost all type II OFx and indicated that fibrous/nonbony fusion can be a satisfactory outcome in frail elderly patients [8,9,14,29]. Among our patients available for long-term follow-up, 39% had bony fusion, 57% had fibrous union, and only 4% had pseudarthrosis. The proportion of bony fusion was higher after surgery than after external immobilization. Within the surgical group, the proportion of fusion was higher after posterior fixation than after anterior odontoid screw fixation. This is in accordance with other reports [8].

The most feared complication of OFx is SCI. The initial rate of SCI in our cohort of type II OFx was 5.3%. Others have reported the rate of SCI in OFx patients to be in the range of 2-7.5% [30-32]. Some previous publications have argued against accepting fibrous union as an acceptable outcome due to a potentially high risk of late SCI [33,34]. No patients in our large cohort developed secondary SCI, either during treatment or later. Thus, in this study conservative treatment of type II OFx is not associated with an increased risk of late SCI.

In addition to SCI, chronic severe neck pain (defined as VAS≥7) secondary to pseudarthrosis is the other main long-term sequela of concern. In our cohort, only 3% reported severe neck pain at
the time of follow-up, and 84% reported no/minor neck pain. There was no statistically
significant difference with respect to neck pain between the surgical and conservative groups.
Thus, in this study conservative treatment of type II OFx is not associated with an increased risk
of severe neck pain.

The proportion of crossover from primary external immobilization to surgery was 14.4% (8.3%
within 14 weeks of trauma and 6.1% later), while the proportion of revision surgery in the
primary surgical group was 9.5% (4.6% within 14 weeks of trauma and 4.9% later). In our
opinion, a conversion rate to surgery of 14.4% is acceptable, especially in light of the rather high
revision rate in the surgical group. This means that > 85% of frail elderly patients was well
treated without primary external immobilization alone.

Fibrous union after conservative treatment of type II OFx is associated with very low risk of
new-onset SCI, low rate of later surgical fixation, and no more long-term neck pain than after
surgical fixation. Thus, conservative treatment of selected OFx in old patients with severe
comorbidities appears to be safe. In younger patients with less comorbidity we still believe that
surgical fixation should be considered.

Limitations of this study

The patients received treatment based on the best judgment of the treating neurosurgeon, both in
terms of surgical versus nonsurgical treatment and regarding choice of surgical technique. There
will always be room for divergent judgment between physicians. A large fraction of patients died
between the time of injury and planned follow-up, leading to missing data at follow-up.
Strengths

This is a large patient cohort from a defined total population, providing us data on essentially all patients with type II OFx within this population in the defined timeframe without bias.

Conclusion

In this population-based observational cohort study of 282 consecutive patients suffering a type II OFx, 84% of patients were ≥ 65 years of age, and 67% had severe comorbidities. Primary treatment was external immobilization alone in 69% and open surgical fixation in 31% of the patients. The proportion of crossover from primary external immobilization to surgery was 14.4%, while the proportion of revision surgery in the primary surgical group was 9.5%. None of the patients developed new-onset SCI after initiation of treatment, and only 3% reported severe neck pain at the time of follow-up. Primary conservative treatment for elderly comorbid patients with type II OFx appears to be safe and should be regarded as good clinical practice.

Data availability

The research data is confidential because it contains clinical and personnel information about our patients which can lead to identification of the patients. According to the organization restrictions and regulations the data cannot be made public available. Data are however available from the authors upon reasonable request and with permission of the Data Protection Officer at OUH.

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All authors have a full-time position at OUH. No external financial support was received for any aspect of this study.
References


Figure legends

Fig. 1. Age groups and gender.

Fig. 2A. Pre-injury ASA score in different age groups.

Fig. 2B. Pre-injury living status in different age groups.

Fig. 3. Examples of patients with major anterior translation (A), major posterior translation (B), major anterior angulation (C), major fracture diastasis and posterior angulation (D), and SCI injury secondary to posterior translation and angulation of odontoid fragments (E & F – same patient).

Fig. 4. Primary treatment strategy in different age groups.

Fig. 5. Surgical techniques for fixation of type II odontoid fractures. A. Anterior odontoid screw. B. Posterior screw fixation. C. Posterior wire fixation. D. Occipitocervical fixation.

Fig. 6. Kaplan-Meier curve showing overall survival.