European Spine Journal (2018) 27:1332–1341
https://doi.org/10.1007/s00586-018-5556-6

ORIGINAL ARTICLE

Anterior management of C2 fractures using miniplate fixation: outcome, function and quality of life in a case series of 15 patients

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Received: 15 June 2017 / Revised: 3 March 2018 / Accepted: 20 March 2018 / Published online: 23 March 2018
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Abstract

Purpose The classification systems by Anderson and D'Alonzo, Effendi, Benzel and others have limitations when it comes to morphologically categorising fractures of the second cervical vertebral body (C2) that present with or without an additional fracture of the dens or with or without an extension of the fracture line into the vertebral arch and displacement. Currently, there are no definitive recommendations for the treatment of fractures at the junction of the dens with the vertebral body of C2 on the basis of outcome and stability data. Depending on patient anatomy, either anterior or posterior approaches can be used to fuse C1 and C2 and to achieve definitive surgical stabilisation. The anterior management of C2 fractures without C1–C2 fusion has the theoretical advantage that it preserves rotational motion at this motion segment and that the anterior approach is associated with lower morbidity. In the study presented here, we followed up a group of our patients who underwent anterior miniplate fixation for C2 fractures.

Methods Fifteen patients underwent fixation of C2 fractures with titanium miniplates (Medartis Hand fixation system, 2.0 or 2.3 mm) that were placed using a submental approach. To our knowledge, this construct has not yet been described in the literature. Where necessary, this procedure was combined with screw fixation of the dens as described by Böhler. We retrospectively analysed operative reports and medical records, evaluated the patients' health status using the Short Form (36) Health Survey (SF-36), and performed clinical follow-up examinations.

Results From January 2009 to June 2015, 226 traumatic lesions of the cervical spine were managed at our institution in the inpatient setting. Ninety-two patients underwent conservative treatment. Of the 134 cases that required surgery for fractures and instability, 67 involved the C0–C3 motion segments. In 15 patients, stability was achieved using an anterior miniplate or miniscrews alone ($n=4$) or in addition to other techniques ($n=11$). Anderson and D'Alonzo type II and III dens fractures with involvement of the body or lateral mass of C2 accounted for eight cases. Effendi type II body fractures with or without instability were seen in four cases. There was no perioperative mortality and morbidity in this patient group. All fractures healed and stability was achieved in all cases. No patient had neurological deficits or required revision surgery. An assessment of postoperative quality of life showed that 11 patients (7 men, 4 women) with a mean age of 57 (± 5.3) years reached an SF-36 score that was normal for their age group after a mean period of 33 (± 6.3) months following their injury. Compared to a group of healthy subjects, the patients had a range of motion that was limited only at the extremes.

Conclusions In patients with appropriate indications, anterior fixation with miniplates alone or additionally is a further useful treatment option in the management of fractures at the junction of the dens with the vertebral body of C2. Since this type of treatment preserves motion at the C1–C2 motion segment after fracture healing and since an anterior approach is

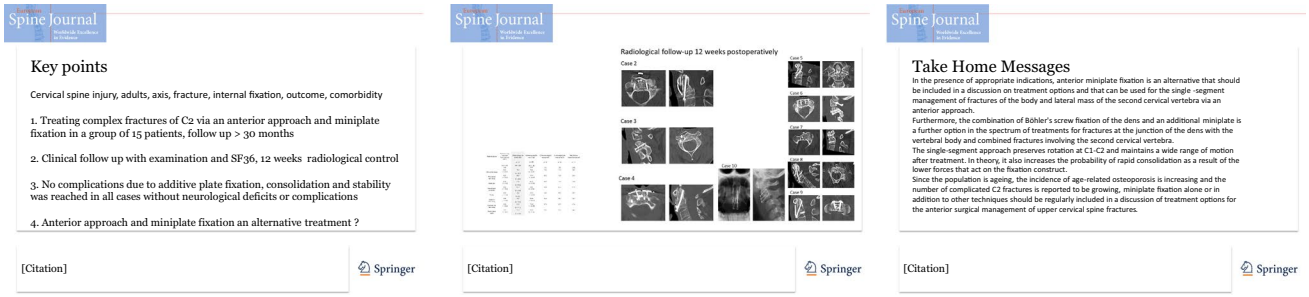
Electronic supplementary material The online version of this article (https://doi.org/10.1007/s00586-018-5556-6) contains supplementary material, which is available to authorized users.

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associated with less surgical trauma than posterior instrumentation, the technique presented here should be included in a discussion on (surgical) treatment options.

Graphical abstract These slides can be retrieved under Electronic Supplementary Material.



Keywords Cervical spine injury · Adults · Axis · Fracture · Internal fixation · Outcome · Comorbidity

Introduction

Injuries to the first, second and third cervical vertebrae (C1–C3), and in particular fractures of the axis body with or without dens fractures, are a challenge to manage because of their potential instability and the presence of comorbidities in patients, most of whom are of advanced age. Morphological characteristics such as the course of the fracture line and the presence of combined fractures of the dens and/or body and/or displaced fractures of the vertebral arch can make it difficult to accurately categorise C2 fractures using common classification systems. Instability, surgical indications and management options must be assessed carefully since clear evidence-based recommendations for this type of injury are lacking.

Alternative treatment options include conservative treatment in a halo vest with all its disadvantages and a variety of stabilisation procedures [1]. If Böhler's screw osteosynthesis technique, i.e., the fixation of dens fractures with two screws which offers stability and preserves normal rotation, is anatomically feasible and if fracture morphology corresponds to that described for Anderson and D'Alonzo type II and III fractures, Böhler's technique is the easiest way to manage these fractures.

An anterior approach can rarely be used and rarely leads to stable fixation if the fracture is oblique in the sagittal plane and extends from posterior-superior to anterior-inferior or if the fracture involves the base of the dens or the body of the axis. These fractures can be managed by C1–C2 fusion with anterior transarticular screws as described by Apfelbaum [2] or posterior transarticular screws as described by Magerl [3] with or without the placement of bone grafts and sublaminar wires under both the C1 and C2 arches [4]. Alternatively, fusion can be performed using transpedicular screws that are inserted via a posterior approach and a single-segment internal fixation device as described by Goel and Harms [5, 6]. Assaghir described 2016, a comparative study (conservative treatment with the halo vest versus operative fusion C2–C3) on burst C2-fractures, and stated that the ideal management of this fracture entity is yet to be evolved [7].

Both the anterior and the posterior placement of screws can be challenging in many cases because of individual anatomical variations of the cervical spine and the chest. In addition, transarticular atlanto-axial arthrodesis limits head rotation. This can lead to a significant decrease in motion that especially young patients find bothersome and that can be avoided by modifying the surgical procedure [8]. In these cases, anterior miniplate fixation of the base of the dens or the body of the axis in combination with screw fixation of the dens allows fractures to heal in an anatomically correct position. A wide variety of plates and other devices can be used for this purpose and have been described in the past [9–13]. At least in theory, an anterior approach for the single-segment fixation of C2 fractures is associated with lower mortality and wider range of motion of the upper cervical spine after fracture consolidation than, for example, posterior fusion of C1 and C2 [14, 15].

We report on a series of fifteen patients who presented with a C2 fracture with involvement of the dens, a concomitant fracture of the base of the dens or displacement of the fracture line of the vertebral body and who did not appear to be candidates for fixation with screws alone. In these cases, we used small-fragment titanium miniplates (Medartis Hand fixation system, 2.0 or 2.3 mm) for the anterior fixation of the base of the dens or the dens itself or the coronal C2 body fracture and, where necessary, we combined this type of management with screw fixation. We were able to assess the course and quality of life with the Short Form (36) Health

Survey (SF-36) in eleven patients (75%) and to perform clinical follow-up examinations in ten patients.

Methods

Study design and patients

We performed a database review to retrospectively identify patients who, between January 2009 and June 2015, underwent inpatient treatment for cervical spine injuries that had been diagnosed by clinical examination and by radiographic imaging on the basis of injury morphology (ICD-10 codes S12.*, S13.* and S14.*). We reviewed patient medical records to assess the affected motion segments of the cervical spine and evaluated operative reports to identify patients with C2 fractures that were managed surgically with miniplate fixation. These patients were contacted by mail or phone call and were asked for their consent to participate in follow-up.

Data collection and analysis

Patients who agreed to take part were invited to complete an SF-36 questionnaire and underwent clinical follow-up examinations including measurements of the range of motion of the cervical spine in all degrees of freedom (Fig. 4). Clinical and demographic data were pseudonymised and recorded. Health-related quality of life was assessed using the SF-36 questionnaire. The validity and reliability of the German version of the SF-36 health survey has been successfully evaluated in a number of studies and is a recognised tool in German-speaking countries for measuring quality of life, especially in elderly people [16, 17].

Results were expressed as means ± standard deviations. In the absence of a control group, comparisons with published data were made and are shown in Table 3.

Before surgery, thin-slice computed tomography with contrast was performed to visualise the neck vessels for planning the surgical procedure as well as implant and screw positions and lengths.

During the surgical procedure, patients were positioned supine on a carbon-fibre table (Maquet, Rastatt, Germany) with the head placed in a carbon-fibre head rest. Fluoroscopy was performed using an Arcadis C-arm (Siemens Healthcare, Erlangen, Germany). Apart from commercially available retractors and other instruments, we used a reduction and immobilisation (rep-ret) system and cannulated screws (2.7 mm) from Königsee-Implantate (Allendorf, Germany) and a plate and screw system (2.0 and 2.3 mm) from Medartis (Basel, Switzerland).

Closed reduction was performed under fluoroscopic guidance in two planes. Lateral fluoroscopy was used to epicutaneously place a K-wire to determine and document the trajectories for wires in the dens of the axis and in the atlanto-axial joint. If necessary, we were thus able to perform screw fixation as described by Apfelbaum using a triple or quadruple technique [18].

The oesophagus was splinted with a large-diameter feeding tube that was marked. The oral cavity was carefully packed with gauze that was not marked. A 6-cm-long right-sided oblique incision was made in a standardised manner into the skin of the right carotid triangle. The platysma muscle was sharply divided and access to the prevertebral space was obtained. The site was prepared in the midline from inferior to superior until the central anterior surface of C2 was reached. This was documented under fluoroscopic guidance.

If the soft tissues permitted, a small Hohmann retractor was placed cranially onto the central anterior part of the arch of the atlas to facilitate reduction and internal fixation. Before reduction and internal fixation, the centres of C2 and C3 were marked using an electrocauter. Depending on fracture morphology, the fracture was gradually reduced by inserting two wires for cannulated screws into the dens or using the rep-ret system (Königsee-Implantate, Allendorf, Germany). This allowed us to insert a threaded K-wire (1.6 or 1.8 mm) into the cortical bone on the opposite side of the fracture and to close the fracture gap or approximate the fracture fragments using a sleeve and a second (counter) nut (Fig. 1).

The implant was then shaped and internal fixation was performed under continuous fluoroscopic guidance in two planes. Alternatively, rep-ret wires can be inserted through the holes in the plate. Fluoroscopy in two planes was used to confirm correct positioning. A drain was placed, the wound was closed in layers and the patient was immobilised in a Miami J collar®.

Postoperative care

Postoperative CT scans were obtained to document the location of plates and screws. Depending on patient age, compliance and findings as well as on the healing status at follow-up visits, patients were immobilised in a Miami J collar® for 8–12 weeks. The patients were weaned from their cervical orthosis in a standardised manner.

Follow-up visits

Clinical and radiological follow-up was performed immediately after surgery (CT) and at 6 and 12 weeks postoperatively by conventional radiography or CT as determined by the surgeon. Before patients were weaned from the cervical orthosis, CT scans had confirmed the absence of implant

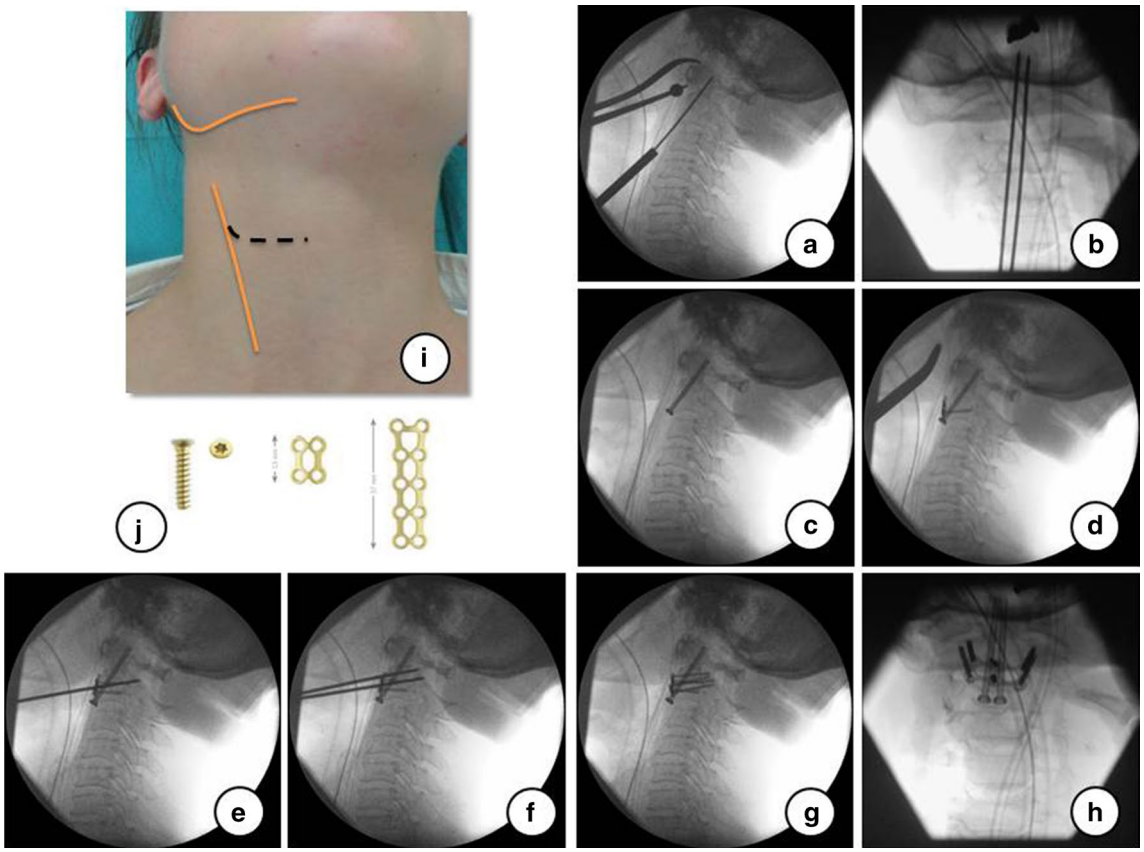


Fig. 1 Material and surgical procedure (case 1)

loosening, the absence of a loss of reduction and the presence of fracture consolidation.

Results

We identified 226 patients who received treatment for significant traumatic lesions of the cervical spine at our institution from January 2009 to June 2015 (78 months). This corresponds to 2.9 cases per month. Significant lesions were defined as fractures that were seen on CT scans, disruptions of ligaments and discs that were detected by magnetic resonance imaging (MRI), and posttraumatic segmental instability that was revealed by fluoroscopy and functional testing (functional imaging). Ninety-two patients (40.7%) had minimally displaced fractures without incongruity of joints and without steps (< 1 mm) or gaps (< 1 mm) at the affected joint surface. These patients were managed conservatively and healing was achieved by immobilisation in a Miami J collar.

Of the 134 cases that required surgery for fractures and instability from 2009 to 2015, 67 (29.6% of the total patient group) involved the C0–C3 motion segments. Table 1 provides an overview of the affected segments and the type of (surgical or non-surgical) treatment in our overall study population. Fractures of the upper cervical spine (C0–C3) were managed using an anterior approach in 56 patients and a posterior approach in 11 patients. Table 1 provides an overview of the surgical procedures performed. In 15 cases, stable fixation was achieved using

Table 1 No. of affected segments of the cervical spine in the whole study group ($n = 226$) and divided into surgical (operation) or conservative (no operation) treatment

Affected segment	C0	C1	C2	C3	C4	C5	C6	C7	C0–C3	C4–C7
Operation	1	7	56	3	6	21	28	12	67	67
No operation	8	3	24	8	5	10	16	18	43	49
Total no.	9	10	80	11	11	31	44	30	110	116

an anterior plate alone ($n=4$) or in addition to other techniques ($n=11$) (Table 2).

Two patients were managed by anterior screw fixation of a displaced fracture at the junction of the C2 body and lateral mass. Anderson and D'Alonzo type II and III dens fractures with involvement of the body or lateral mass of C2 were seen in eight cases. Four patients presented with Effendi type II body fractures with or without instability. It should be noted that two patients with C2 fractures were managed with screw fixation alone (a Herbert screw in one case and a 2.3-mm miniscrew in the other). Three patients with fractures of the C2 body and traumatic C2–C3 listhesis underwent C2–C3 fusion with miniplate fixation and the addition of a cancellous bone graft (see Fig. 2 cases 2–4 for examples).

There was no perioperative mortality or morbidity in this patient group. All fractures consolidated within 12 weeks and the patients were weaned from their cervical orthosis in a standardised manner. No patient had neurological deficits or needed revision surgery. One patient had to be transferred to a short-term care facility because of concomitant diseases. The youngest patient had to stay on the intensive care unit for a considerably longer time than the other patients. This, however, was caused by concomitant injuries and was not associated with his cervical spine injury or the surgical procedure. Figure 3 provides an overview of the age of the patients in relation to the length of their hospital stay (LOS) and the length of their intensive care unit (ICU) stay.

An assessment of postoperative quality of life showed that 11 of the 15 patients (9 men, 6 women) with a mean age of 57 (±5.3) years reached an SF-36 score that was normal for their age group after a mean period of 33 (±6.3) months following their injury. Table 3 compares the SF-36 scores of our patient group and patient samples that were investigated in two studies by Koller et al. in 2009 [19].

Compared to a group of healthy subjects, the patients ($n=10$ of 15) who attended follow-up had a range of motion that was limited only at the extremes (Fig. 4). Radiological follow-up at 12 weeks after surgery assured ongoing fracture consolidation without loosening. Figure 5 show 12 weeks CT scan of cases 2–4 and additional six cases.

Discussion

The objective of this study was to assess the quality of life and upper cervical spine mobility in a small group of 15 patients who underwent anterior fixation of a C2 fracture with a miniplate system. We discussed our surgical technique and compared it with data reported in the literature on classification systems, indications and postoperative outcomes including quality of life.

In general, anterior plate fixation of C2 allows Anderson and D'Alonzo type II and III odontoid fractures with a fracture line that is unsuitable for Böhler's screw fixation to be managed with an implant that acts as an anti-glide plate or for the single-segment management of a C2 fracture. The use of anterior plate fixation in combination with other techniques is not new and has been described in the literature [9–13]. Since a posterior approach is associated with a higher rate of mortality and morbidity [20, 21], we prefer anterior fixation and have gradually extended the indications for anterior plate fixation.

Clinical implications

The technique described here can be reliably applied in cases where a relatively large bone fragment is separated from the vertebral body at the junction of the arch with the body and

Table 2 Surgical procedures involving the upper cervical spine (C0–C3) from January 2009 to June 2015

Segment	Number	Conservative management	Surgical management		
C0–C3	$n=110$	$n=43$	$n=67$		
(% of 226)	48.7%	19.0%	29.6%		
Procedures performed ($n=67$)				Anterior approach	Posterior approach
Screw fixation of the dens as described by Böhler			28	$n=56$	
Screw fixation of the dens as described by Böhler and C1–C2 fusion as described by Apfelbaum			10		
C1–C2 fusion alone (Apfelbaum's technique)			3		
Anterior fusion of C2–C3 with miniplate fixation and the addition of a cancellous bone graft			3		
C2 lateral mass screw fixation alone			2		
Anterior miniplate fixation of C2 alone			4		
Miniplate fixation of a C2 fracture and screw fixation of the dens as described by Böhler			6		
Posterior fusion of C1–C2 as described by Magerl/Gallie			8		$n=11$
Posterior screw fixation of C2 as described by Judet			1		
Posterior fusion of C0/C1/C2 and internal fixation			2		

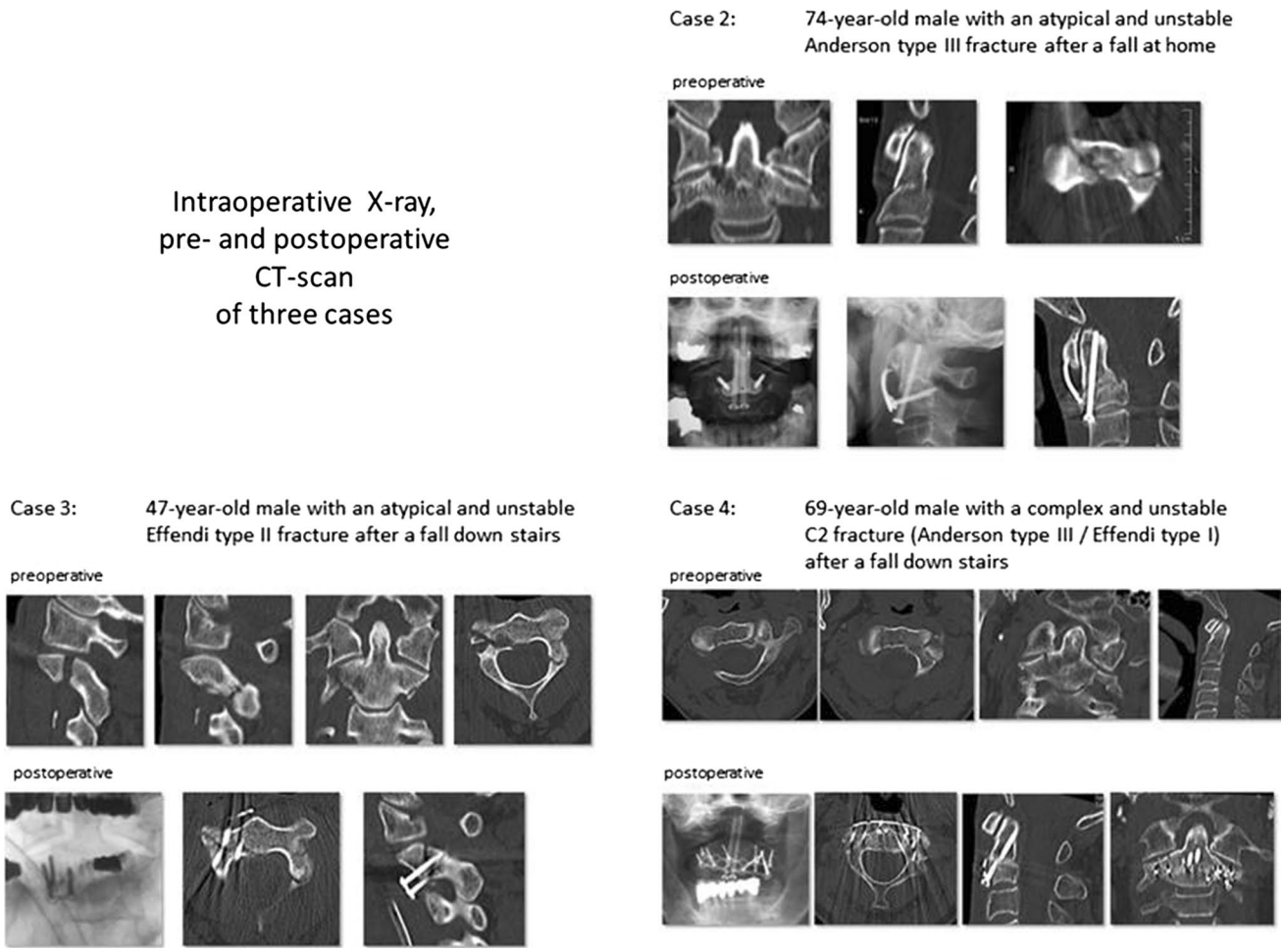


Fig. 2 Preoperative and postoperative radiological findings (case 2–4)

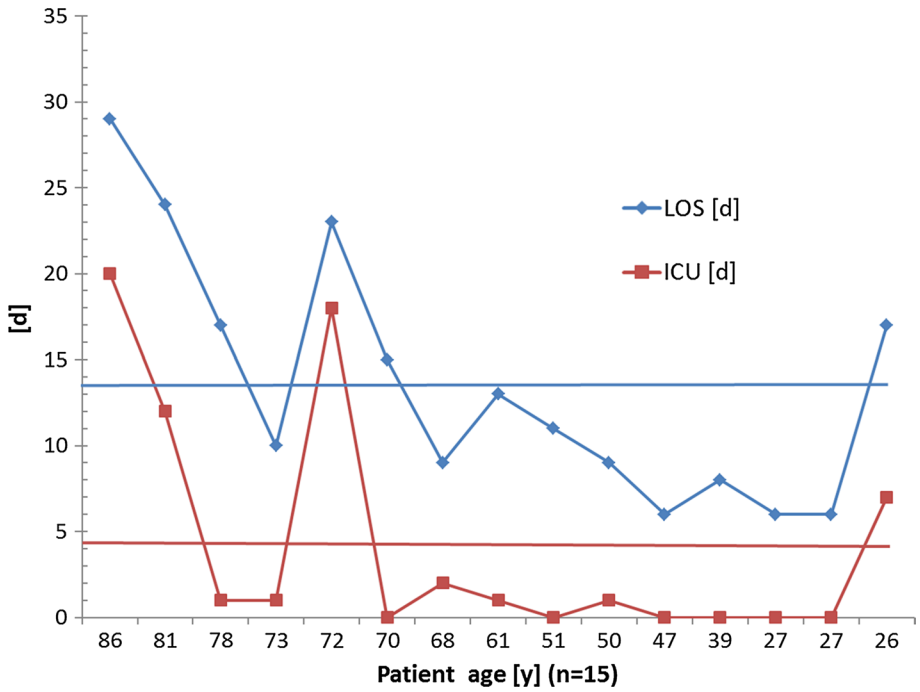


Fig. 3 Patient age in relation to the length of hospital stay (LOS) in days (d) and the length of intensive care unit (ICU) stay in days (d) (horizontal lines indicate mean values)

Table 3 Comparison of SF-36 scores calculated for different groups of patients

Health dimension	Reference values reported by Maurischat et al. [26] MV ± SD [26]	Patient group in the present study $n = 11$ MV ± SD	Reference group (60 + years of age) $n = 690$ MV ± SD [17]	C2 fractures (surgical management) $n = 35$ [19]	Atlanto-axial injuries (surgical fusion) $n = 26$ [27]	Dens fractures (surgical management) $n = 44$ [28]
Physical functioning	85.9 (± 20.1)	79.1 (± 19.1)	74.41 (± 23.8)	76.5	77.3	38.5
Physical role functioning	82.9 (± 32.2)	90.9 (± 16.9)	70.47 (± 24.87)	63.2	72.4	42.0
Bodily pain	67.9 (± 25.8)	57.9 (± 30.4)	67.25 (± 25.85)	62.4	72.3	45.6
General health perceptions	66.6 (± 18.2)	61.7 (± 21.6)	58.41 (± 19.6)	69.6	67.9	47.9
Vitality	60.4 (± 17.8)	52.3 (± 23.3)	59.72 (± 18.35)	58.1	63.2	49.7
Social role functioning	86.9 (± 19.6)	79.5 (± 19.6)	83.86 (± 20.97)	81.6	88.5	44.7
Emotional role functioning	89.9 (± 26.4)	81.8 (± 31.1)	78.19 (± 24.89)	67.4	85.3	47.4
General mental health	72.7 (± 16.5)	71.6 (± 17.9)	70.93 (± 17.2)	70.5	77.1	48.5



Fig. 4 Assessment of range of motion at 6 months after surgery (case 1)

where the fracture can be reduced by ligamentotaxis and a threaded wire of the rep-ret system can be inserted into the cortical bone on the opposite side of the fracture in an oblique upward direction at 10°–20°. Otherwise, the technique should not be used and two-segment fusion should be performed via an anterior or posterior approach to achieve

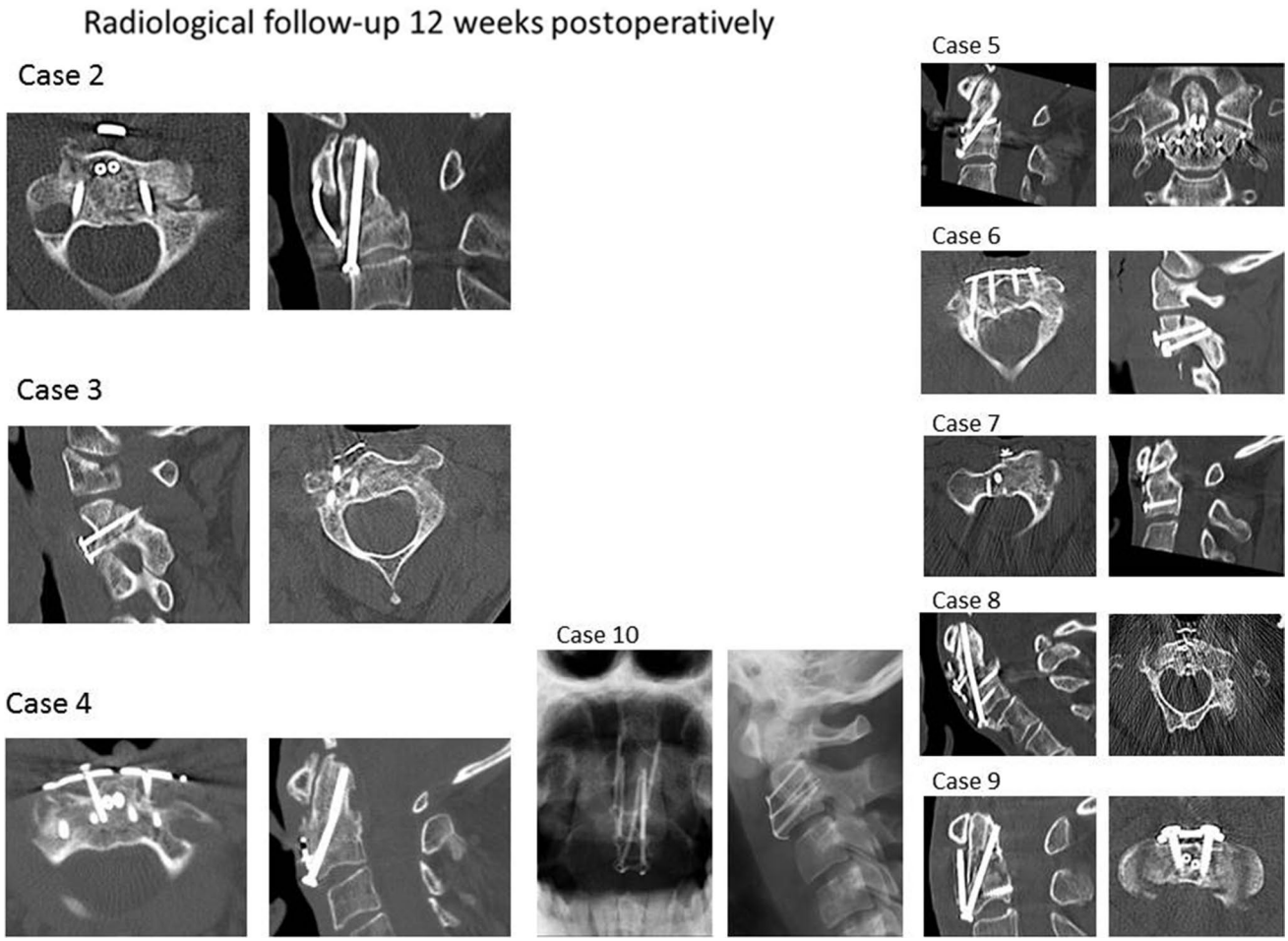


Fig. 5 Radiological follow-up demonstrating fracture consolidation without dislocation at 12 weeks after surgery

stability. This means that preoperative CT scans must be carefully evaluated to detect rotational displacement of the axis, displacement of the dens or articular surface incongruity and thus to identify instability and the potential risk of pseudo-arthrosis or arthrosis.

In a large series of patients, Koller et al. impressively highlighted the difficulty of evaluating these aspects and classifying C2 fractures on the basis of fracture morphology [19]. They identified malalignment of the C1–C2 segment, articular surface incongruity, and restriction of rotation at C1–C2 as risk factors for the development of pseudo-arthrosis. The focus of their study, however, was on investigating fractures of the dens. Only a paucity of studies address isolated fractures of the C2 body [22].

The age distribution of our patient group demonstrates that the technique described here is used not only for elderly patients but also for young patients who have sustained a high-energy trauma. None of the patients had preoperative or postoperative neurological deficits. Nevertheless, classic C2 fractures predominantly occur in elderly patients. As a result of population ageing, the incidence of unstable injuries to the upper cervical spine (C1–C3) is likely to continue to increase [23]. Age-related osteoporosis as well as degenerative conditions associated with stiffness can have unpredictable effects on the morphology of fractures of these segments.

If anatomically feasible, additional miniplate fixation as described in this study offers another option in the spectrum of treatments for fractures that can be managed using an anterior approach. Indications for surgery, however, should be strictly adhered to. Conservative treatment must have and will continue to have its place in the range of management options [24].

All patients in this retrospectively identified study group had a clinical course without complications. There were no infections or wound-healing problems. All fractures healed, there were no instances of malalignment. In a meta-analysis that was conducted in 2013, the median rate of short-term complications was 15.4% of all fractures after upper cervical spine trauma. The main complications of surgical treatment were dysphagia and respiratory problems. The median 3-month mortality rate was 9.2%. The mean age of

the patients was 76 years [25]. Our patients, who had a mean age of 57 (±5.3) years, were younger and the study group was more inhomogeneous in terms of injury mechanisms and especially age. Compared with data reported in the literature, surgical management had no adverse effects on the patients.

The patients who attended follow-up in this study had an SF-36 score that was only slightly lower than the quality-of-life score calculated for a healthy reference group [17]. In 2009, Koller et al. [19] used the SF-36 to assess the course and outcome of an original group of 121 patients with C2 fractures. Thirty-five patients with C2 fractures were compared with 21 patients who received non-surgical treatment for compression fractures (T11-L4) and 26 patients who underwent surgery for subaxial cervical spine injuries. Functional outcome was similar to that in our patient group and quality-of-life scores were slightly lower than those calculated for our patients.

In conclusion, these results suggest that the surgical technique described here, i.e., miniplate fixation of C2 fractures alone or in combination with other techniques, does not adversely affect outcome and is thus another option for the anterior single-segment management of fractures of the upper cervical spine.

Limitations of the study

Our study included only a small number of patients who were reviewed retrospectively. There is no control group (e.g., we did not compare our patient group with a group in which a posterior approach was used for surgery of the upper cervical region during the study period).

Moreover, preoperative SF-36 scores were not available so that we had to compare the postoperative SF-36 scores of our patients with historical control subjects and with data published for similar groups.

The physical examination included an assessment of the range of motion of the entire cervical spine, and therefore, allowed us to draw only limited conclusions on the postoperative range of motion of the C0–C3 motion segments.

Further studies should be conducted and, if possible, use a prospective approach to compare the technique described here with other (especially posterior) stabilisation procedures and to document the advantages of an anterior approach.

Key messages

In the presence of appropriate indications, anterior miniplate fixation is an alternative that should be included in a discussion on treatment options and that can be used for the single-segment management of fractures of the body and lateral mass of the second cervical vertebra via an anterior approach.

Furthermore, the combination of Böhler's screw fixation of the dens and an additional miniplate is a further option in the spectrum of treatments for fractures at the junction of the dens with the vertebral body and combined fractures involving the second cervical vertebra.

The single-segment approach preserves rotation at C1–C2 and maintains a wide range of motion after treatment. In theory, it also increases the probability of rapid consolidation as a result of the lower forces that act on the fixation construct.

Since the population is ageing, the incidence of age-related osteoporosis is increasing and the number of complicated C2 fractures is reported to be growing, miniplate fixation alone or in addition to other techniques should be regularly included in a discussion of treatment options for the anterior surgical management of upper cervical spine fractures.

Compliance with ethical standards

Conflict of interest The authors declare that this research was not sponsored. The authors maintain full control of all primary data and declare no conflict of interest in relation to this work. None of the authors received financial support from any of the manufacturers of products mentioned in this article.

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