ORIGINAL PAPER
PŮVODNÍ PRÁCE

Clinical and Radiological Findings after Different Treatment of Odontoid Fractures Type Anderson II and III

Klinické a rentgenologické nálezy po různém ošetření zlomenin dentu typu Anderson II a III

P. C. STROHM[1], T. A. BLEY[2], N. GHANEM[2], B. SCHECK[1], N. P. SÜDKAMP[1], CH. A. MÜLLER[1]

[1] Department of Orthopaedic and Trauma Surgery, University of Freiburg Medical Center, Germany
[2] Department for Diagnostic Radiology, Clinic for Radiology, University of Freiburg Medical Center, Germany

ABSTRACT

PURPOSE OF THE STUDY

In the period from 06/00 to 08/02, 31 patients with odontoid fractures type Anderson II and III were treated and stastically recorded. 25 patients were followed up; the progess of 24, documented in detail radiographically, were evaluated independently by a traumatologist and by a radiologist.

The usual time of immobilization when treating odontoid fractures type Anderson type II and III with the halo-fixator is 12 weeks. For this 12 weeks that it is worn, objective assessment of bone healing is performed radiographically and the results critically considered in terms of the length of time that the halo-fixator should be worn and whether this duration should be altered on the basis of the clinical and radiological results obtained.

MATERIALS AND METHODS

16 patients with an odontoid fracture type Anderson type II were treated partly with a halo-fixator and partly by additional operative stabilization. 15 patients with a type III fracture were treated in a halo over 12 weeks. At the time of the accident the patients to be treated had to have conventional radiographic examination and a CT scan as well as a position check following reduction. After 4, 8 and 12 weeks radiographic and CT investigation was repeated. These findings were evaluated independently by a surgeon and a radiologist. The clinical follow-up was carried out using the VAS Score and, in addition, the general activity level before and after the accident was recorded in a similar way on the Tegner/Lysholm subjective activity score.

RESULTS

In most cases, according to the CT scan, the osseous bridging decreased again between the 8th and 12th weeks, as defined by resorption zones seen during the fracture healing period. Radiological evidence of complete osseous bridging was only seen after 12 weeks in three cases.

CONCLUSION

Conventional radiography does not seem to us to be the most suitable technical means to evaluate osseous healing in odontoid fractures. The CT is more reliable for this.

According to our radiological results, osseous healing of different types of odontoid fractures takes more than 12 weeks. Despite of its known complications, the halo fixator is still a good instrument for the treatment of odontoid fractures.

Key words: odontoid fracture, halo fixator, cervical spine injury, radiological findings, fracture consolidation.

INTRODUCTION

Odontoid fractures are a very common injury of the cervical spine. Their incidence in the literature is stated as 9–20% of all injuries of the cervical spine and as 2–5% of all spinal injuries. The odontoid fracture is the most frequent isolated injury to the cervical spine in elderly patients of over 70 years of age (19, 34, 35, 37). Despite the frequency of the injury there is no evidence-based treatment protocol (37). The halo-fixator, despite its possible complications and problems, is an established and recognised treatment for injuries of the upper cervical spine (5, 10, 14, 22, 29, 35). Although an operation should be the treatment of choice for odontoid fractures type II as classified according to Anderson/D'Alonzo, non-operative treatment with the halo-fixator is still frequently indicated in the presence of concomitant injuries or disorders unrelated to the accident. One aim of our study was to see osseous healing of odontoid fractures over 12 weeks on plain radiographs and computed tomography (CT) and compare this two techniques. The other aim of our studies was to examine the clinical results of treatment with the halo-fixator, both subjectively and objectively, by assessing the osseous healing of the fracture and the clinical findings, taking complications into account.

MATERIALS AND METHODS

Between 06/00 und 08/02, 31 patients (15 male, 16 female) were treated with a halo-fixator and the cases documented statistically. These odontoid fractures treated were Anderson type II fractures (16 patients) and Anderson type III fractures (15 patients). The average age of the patients was 72 years (24/97). All the patients were initially assessed by conventional radiography in two planes and had a CT scan. After the diagnosis had been made, a simple reduction was carried out under image intensification, and retention was provided by the halo-fixator. Subsequently, the position was once again recorded radiographically. For non-operative treatment, radiological and CT investigations were carried out at 4, 8 and 12 weeks. If, in addition, operative stabilization had been carried out, the assessments were performed at the same intervals postoperatively. The non-operative treatment consisted of immobilization of the patient's cervical spine for 12 weeks in a halo-fixator. 10 of the 16 patients with a type II fracture were also treated by operative stabilization (6 Galli operations, 4 screw osteosyntheses). All patients with a Galli fusion and two patients with screw osteosynthesis were also treated for 12 weeks with a halo-fixator because of the poor quality of the bones. Analysis of the radiographs was carried out independently by a traumatologist and a radiologist, the progress of the osseous bridging was assessed at 4, 8 and 12 weeks with scores of 1 (no bridging) – 5 (complete osseous bridging). In our scale (1–5) we gave 2 points, if we could see one ossoeus bridge in one plane, 3 points for two osseous bridges in one or two planes and 4 points for an allready complete osseous healing when we still saw a lack of bridging in one plane.

The clinical follow-up took place on average after 16 (5–30) months and was carried out according to the VAS-Score and activity before and after the accident was recorded as for the Tegner/Lysholm activity score, whereby both scores are subjective scores. Objective mobility was measured in accordance with the neutral-zero-method.

RESULTS

25 out of 31 patients (81%) came to the follow-up examination, 4 patients had died in the interim period, one patient had permanent tetraplegia and could not, therefore, be examined. 24 out of 31 almost complete radiographic series were evaluated (77%). On average, the clinical follow-up examination was carried out after 16 (5–30) months.

The activity score, in accordance with Tegner/Lysholm, was on average 3 (1–6) before the accident, and on average 2 (1–6) at the follow-up examination. The subjectively assessed, persisting symptoms on the VAS-Score at an average of 54 (23–95) out of a possible 100 points were in the medium range.

Table 1. Mobility of the cervical spine measured according to the neutral-zero-method

	Normal value	Median	Min	Max
In-/Reclination	35°–45° / 45°–70°	35° / 20°	0° / 0°	45° / 70°
Lateral flexion right/left	45° / 45°	10° / 10°	0° / 0°	40° / 30°
Rotation right/left	60°–80° / 60°–80°	35° / 32°	0° / 0°	75° / 75°
Distance from point of chin to shoulder	right / left	16 cm / 17 cm	11 cm / 10 cm	24 cm / 24 cm

Table 2. The course of bony consolidation of the fracture, where 1 = no osseous bridging and 5 = complete consolidation

After	4 weeks	8 weeks	12 weeks
Conventional radiograph	1.5	2.4	2.9
Computer tomography	1.3	2.2	2.0

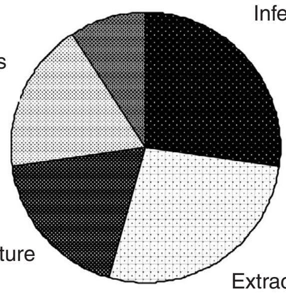
The mobility of the cervical spine, according to the neutral-zero-method, was overall clearly reduced (Tab. 1). On average, the values for forwardbending/backward bending were 35°/0°/20° with a minimum of 0°/0°/0° und a maximum of 45°/0°/70°. Right-/left lateral flexion was on average 10°/0°/10° with a minimum of 0°/0°/0° and a maximum of 40°/0°/30°. Right -/left rotation resulted in an average of 53°/0°/32° with a minimum of 0°/0°/0° and a maximum of 75°/0°/75°. In addition, the distance from the point of the chin to the shoulder was measured at a maximum sideways rotation. These values were on average 16.5 cm (11 cm / 24 cm) on the right hand side and 17 cm (10 cm / 24 cm) on the left hand side.

In reply to the question about the strain caused by the halo-fixator, 16 patients answered with intolerable, six patients with average and two patients with well tolerated. All the patients questioned regarded a shorter treatment time with the halo-fixator as a clear relief.

Analysis of the radiological findings showed that the osseous bridging seen on conventional radiographs increased during the course of 4/8/12 weeks continuously from 1.5/2.4/2.9 on average. Analysis of the CT scans showed a consolidation of the fractures over a period of 4/8/12 weeks of 1.3/2.2/2.0 (Tab. 2). Subsequently, the osseous consolidation decreased again after the 8^{th} week and, after the 12^{th} week, small osteolytic zones were increasingly seen on the CT scans in the fracture zone. Complete osseous bridging was only found in 3 patients (12.5%) on the CT scan at 12 weeks, of which, two patients had an Anderson type III-fracture und one patient had an Anderson type II fracture stablized by screw osteosynthesis.

The course of healing for patients with operative stabilization was uneventful, whereby one patient with an Anderson type III-fracture who had received initial non-operative treatment with the halo fixator dismantled it himself after three weeks and secondary operative stabilization had to be performed. Complications with the halo-fixator occurred in 9 cases (31%) (Tab. 3). These were three pin infections, three pin-extractions, two necroses under the halo-vest and one traumatic screw penetration intra-cranially following another accidentally fall. One year after non-operative treatment of an Anderson type II-fracture, refracture occurred as the result of adequate trauma and was stabilized surgically. One further case of a refracture following an Anderson type II fracture occurred after 14 months due to a trivial misfortune and was stabilized by a secondary operation. In both cases, dorsal stabilization was performed and an occipito-cervical internal fixator system was applied.

Table 3. Complications of treatment with the halo-fixator / vest



DISCUSSION

The correct management and treatment protocol for odontoid fractures is still the object of discussion. It has not been possible to work out a definitive treatment plan even in evidence-based studies (24, 37).

The odontoid fracture is a frequent injury of the human spine, the numbers in the literature describe an incidence of 9–20% of cervical spinal injuries, in which the injuries of the cervical spine comprise up to 60% of spinal injuries (37). The incidence of odontoid fractures is, therefore, 1–2% of all spinal injuries (3, 7, 9, 26, 30, 34, 37). Bühren et al. have calculated that in Germany 400 patients suffer paralysis at the cervical spine each year (9). According to the Anderson/D'Alonzo classification, surgical intervention should be reserved for type II fractures and rare indications for type III fractures since the type I fracture is always treated non-operatively. Statistically, the type II fracture, at 66% of all odontoid fractures, is clearly more frequent than the type III fracture, and the proportion even increases to 80% in old age (7, 8). In their study, Amling et al. were able to fully substantiate that type II fractures; are the predominant odontoid fractures this fact can already be explained embryologically as, of course, the odontoid process is part of the atlas and does not fuse with the axis until later (1, 2).

In older patients (>60 years) the odontoid fracture is generally the most frequent injury to the cervical spine, the decision about treatment must, therefore, also concern this age group as a matter of priority.

The causes of injury to the cervical spine are, above all, road traffic accidents, followed by falls from a height (9, 26); in old age the domestic fall comes to the fore as the cause of dens fractures (7, 20). Indirect traumatic violence is regarded as the causal pathogenetic mechanism for odontoid fractures (30).

The conventional radiograph has been retained for the diagnosis of odontoid fractures, possibly supplemented by special images, e.g. the close-up transboccal view of the odontoid process (9, 26, 30, 33). It is also sensible, however, to carry out computed tomography (CT) even at the time of the initial diagnosis in order to reliably classify the odontoid fracture and, thus, choose the optimal treatment plan. Coronal and sagittal reconstructions are to be strongly recommended in this context (27, 38).

Many concepts for therapeutic procedure have been described; some authors incline more towards a non-operative procedure. However, in more recent literature it is recommended that a differentiated approach should prefer non-operative treatment for type III fractures only, and type II fractures should – whenever possible – be stabilized by surgical intervention, even in older patients (3, 7, 19). Many studies make reference to the high risk of pseudarthrosis in type II fractures (14). Several authors describe a correlation between odontoid process displacement and the formation of a pseudarthrosis (8, 13, 14, 34).

Treatment with the halo-fixator has been retained as the non-operative treatment approach for unstable odontoid fractures – that is, all type II fractures and some type III fractures. In various studies, including biomechanical ones, the halo-fixator has shown itself to be superior to other orthotic devices (e.g. Miami-J, Philadelphia) and also to Minerva-plaster of Paris, which do not achieve comparable immobilization (10, 17, 29). For optimal bone consolidation, there should be as little motion as possible at the fracture gap. The use of orthotic devices should be reserved for the slightly dislocated type III fractures in patients with good compliance.

Ventral screw osteosynthesis with a cannulated lag screw is increasingly preferred in operative procedures for recent type II odontoid fractures. The benefit of the previously described osteosynthesis with two screws could not be reliably proven in any study and biomechanical tests have confirmed that there are no clear advantages to it (3, 12, 25, 31). Even the lag screw principle with the double-threaded Knöringer screw has not been accepted as a standard procedure (18). There is consensus, however, that where it is possible to operate on a type II fracture there is an indication to do so. Because of the higher level of access morbidity, lower stability, and more pronounced ankylosis, dorsal procedures such as the Galli or Brooks stabilization techniques are still only seldom used. Dorsal spondylodesis with Magerl

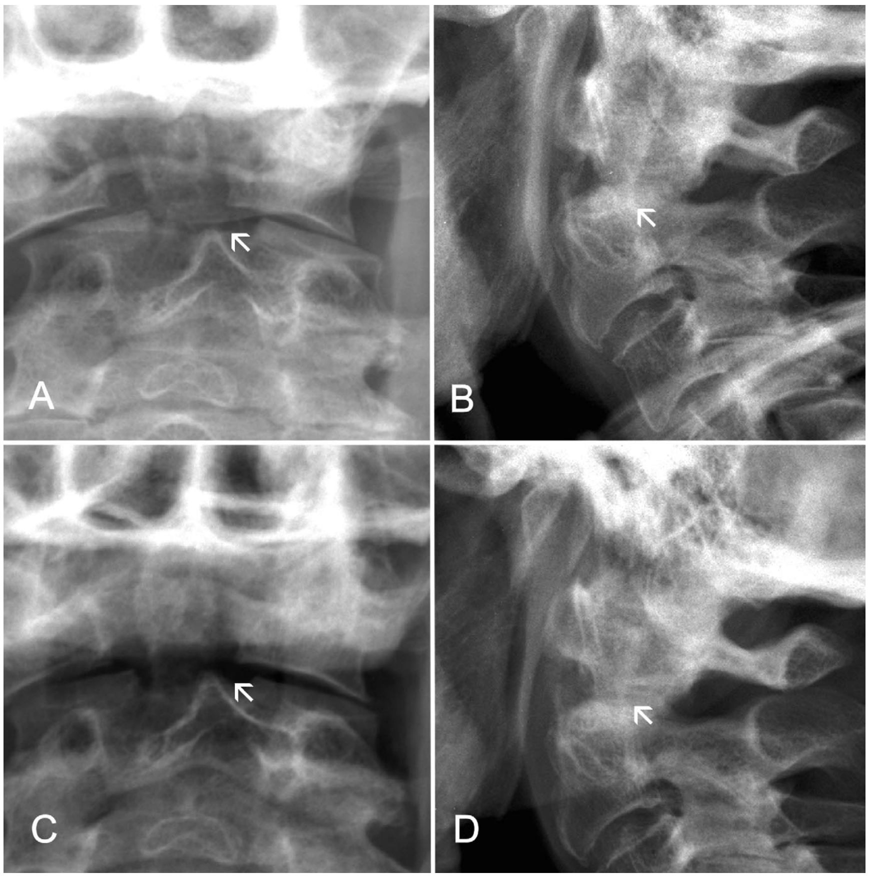


Figure 1. Conventional radiograph: Preoperative, a.p. (A) and lateral (B). Follow-up radiograph after 12 weeks, a.p. (C) and lateral (D). Based on the conventional radiographs, the observer can assume that bone consolidation has commenced.

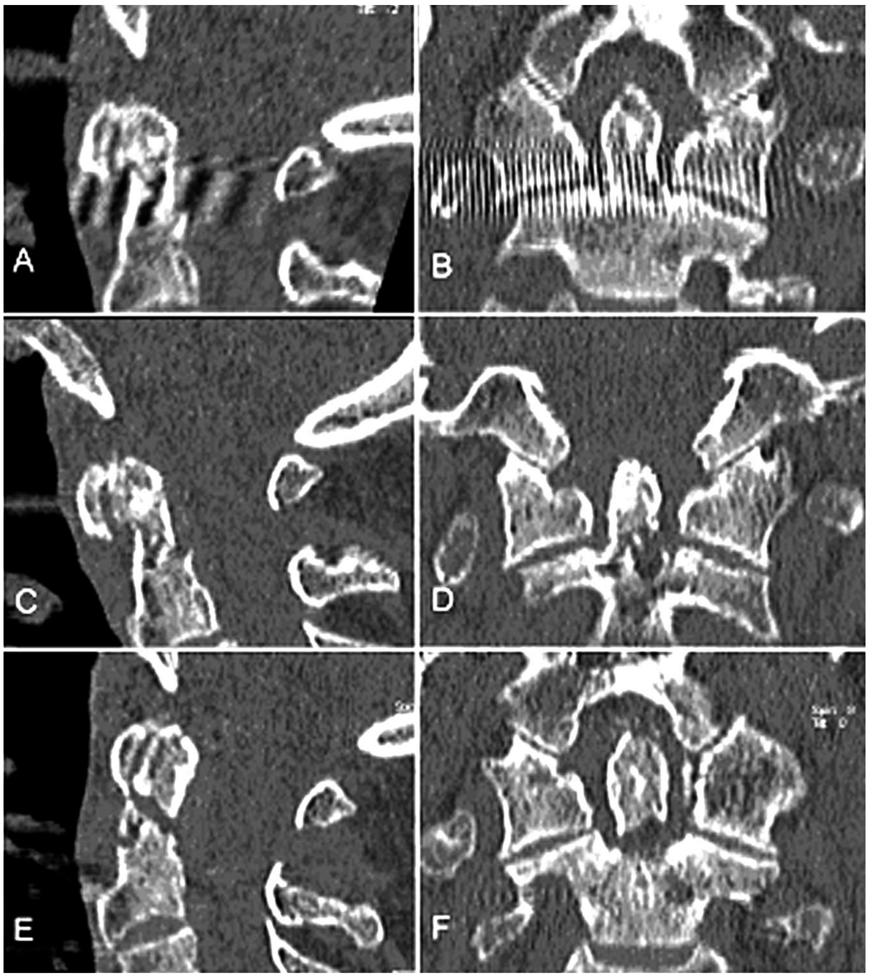


Figure 2. Computer-tomographic documentation of the same fracture: Preoperative radiograph, sagittal (A) and coronary (B), follow-up radiographs after 8 weeks (C,D) and 12 weeks (E,F). An increase in osteolyses in the fracture zone is clearly visible after 12 weeks.

screws has been retained for pseudarthroses or for definite indications in recent fractures (23).

The figures for osseous consolidation and pseudarthroses for the different treatment approaches vary widely. In our opinion, it is necessary to take a differential view of the various numbers given as frequently no clear distinction is made between the different fracture types. Furthermore, it is often not evident how osseous consolidation was ensured. In our opinion, this can only be reliably shown by computed tomography since, according to our results, the conventional radiographs often show a falsely positive result. It is also known that on functional radiographs or under image intensification a compact pseudarthrosis can look like union, but these pseudarthroses are actually very susceptible to renewed dislocations as a result of a trivial incident, like in the one of our cases.

There is agreement, however, about the complete healing of bones following type III fractures, the pseudarthrosis rate is stated in most studies as 0% (7, 13, 18, 21, 26, 30). In type II fractures, a pseudarthrosis rate of 100% is reported for the use of cervical orthotic devices apart from the halo-fixator (7). In the literature overviews, pseudarthrosis rates for type II fractures, treated solely by immobilization in the halo-fixator are given as between 9–50%, and as 0–20% for screw osteosynthesis (6, 7, 26, 28, 32, 35). Many authors describe greater mobility following ventral screw osteosynthesis compared with treatment with the halo-fixator (34), this cannot, however, be confirmed by all authors (3). A treatment period of 8–16 weeks, depending on fracture type, has been reported for treatment with the halo-fixator alone (32, 35); up until now we have left the halo in situ for a standard 12 weeks.

The complication rates following treatment with the halo-fixator are given as between 10–60% (11, 13, 16, 32, 36), and 18–24% following screw osteosynthesis (3, 15). Our complication rate of 31% for treatment with the halo-fixator corresponds to the lower range of figures reported in the literature. In our clinic the halo fixator was used in many cases in addition to an operation since, in principle, the risk of screw migration in old bone is a known risk and, therefore, the operative procedure chosen might not guarantee sufficient stability. This is also described by other authors (3). Needless to say, a further indication for a combined procedure is given when there are multiple injuries to the cervical spine.

CONCLUSION

On the basis of the results obtained in our study and the evaluation of the current literature we recommend the following procedural concepts:

Odontoid fractures type Anderson III can be treated non-operatively, immobilization in a halo-fixator is worth recommending, a treatment period of 8 weeks is sufficient. After that, a soft cervical support should be worn for another 4 weeks. A similar recommendation has already been put forward by other teams (35). In exceptional cases, where type III fractures are not dislocated, treatment with a cervical orthotic device, such as the Miami-J, is sufficient. In contrast to various other cervical orthotic devices, the Miami-J has proven effective and is routinely used in our clinic for this reason (4, 29).

For type II fractures operative stabilization should, in principle, always be aimed for, and, if possible, should be a ventral screw osteosynthesis. Where there is a relevant indication, alternative treatment with a halo-fixator is possible. The treatment period should last for at least 8 weeks depending on the CT findings; a treatment period of over 12 weeks makes no sense in our opinion. Subsequent treatment with a Miami-J or a soft cervical support is optional. Functional radiographs and or investigation under image intensification should be carried out to assess functional stability and healing. For a specific diagnosis it may be worthwhile carrying out a functional CT.

Our findings indicate that conventional radiographs are not suitable to assess the progress of fracture healing of dens fractures. An assessment of position using conventional radiography is only recommended if there is a risk of renewed dislocation; bone consolidation can only be reliably assessed by CT (Fig. 1, 2).

ZÁVĚR

V období od června 2000 do srpna 2002 bylo ošetřeno 31 pacientů se zlomeninou dentu typu Anderson II a III a výsledky byly statisticky vyhodnoceny. Z těchto pacientů bylo 25 dlouhodobě sledováno a u 24 byl pooperační průběh nezávisle hodnocen traumatologem a radiologem na základě podrobné rtg-dokumentace.

Při ošetření C2 fraktur typu Anderson II a III je 12 týdnů obvyklá doba pro pooperační aplikaci halo-korzetu. Po dobu, kdy je nošen, se provádí radiologicky objektivní hodnocení průběhu kostního hojení a výsledky jsou kriticky posuzovány z hlediska doby, po kterou by měl být korzet ponechán a zda by doba přiložení měla být upravena podle získaných klinických a radiologických nálezů.

Ze 16 pacientů se zlomeninou dentu typu II bylo šest ošetřeno konzervativně přiložením halo-korzetu, u deseti byla stabilizace provedena operačně. U 15 pacientů se zlomeninou dentu typu III byl přiložen halo-korzet na dobu nejméně 12 týdnů. U pacientů těsně po úraze bylo před ošetřením provedeno běžné rentgenologické vyšetření a vyšetření počítačovou tomografií a kontrola postavení po repozici. Vyšetření rentgenem a CT bylo opakováno za 4, 8 a 12 týdnů a výsledky byly nezávisle hodnoceny chirurgem a radiologem. Při klinickém sledování bylo použito hodnocení bolesti na základě VAS. Úroveň aktivity před a po úraze byla sledována podle subjektivních pocitů s použitím Tegnerova/Lysholmova systému hodnocení.

Ve většině případů se podle výsledků CT vyšetření kostní přemostění zredukovalo mezi osmým a dvanáctým týdnem, což bylo patrno z přítomnosti resorpčních zón v průběhu hojení zlomeniny. Úplné kostní zhojení bylo radiologicky prokázáno ve 12. týdnu pouze u tří případů.

Klasické rtg-vyšetření nepovažujeme za nejvhodnější metodu pro hodnocení kostního hojení u zlomenin dentu. Spolehlivější je CT vyšetření. Podle našich radiologických výsledků trvá kostní hojení různých typů zlomenin dentu déle než 12 týdnů. Přes možné známé komplikace je stabilizace v halo-korzetu stále spolehlivým způsobem léčby zlomenin dentu.

Klíčová slova: zlomenina dentu, halo-korzet, poranění krční páteře, rtg-nález, zhojení fraktury.

References

1. AMLING, M., POESL, M., WENING, V., RITZEL, H., HAHN, M., DELLING, G.: Structural heterogenity within the axis: the main cause in the etiology of dens fractures. J. Neurosurg., 83:330–335, 1995.
2. AMLING, M., WENING, V., POESL, M., GROTE, H.: Die Struktur des Axis-Schlüssel zur Ätiologie der Densfraktur. Chirurg, 65:964–969, 1994.
3. ARAND, M., LEMKE, M., KINZL, L., HARTWIG, E.: Inzidenz von Komplikationen der Schraubenosteosynthese von Frakturen des Dens axis. Zbl. Chir., 126:610–615, 2001.
4. ASKINS, V. EISMONT, F.: Efficacy of five cervical orthoses in restricting cervical motion. A comparison study. Spine, 22:1193–1198, 1997.
5. BENZEL, E., HADDEN, T., SAULSBERY, C.: A comparison of the Minerva and halo jackets for stabilization of the cervical spine. J., Neurosurg., 70:411–414, 1989.
6. BERLEMANN, U. SCHWARZENBACH, O.: Dens fractures in elderly. Results of anterior screw fixation in 19 elderly patients. Acta orthop. scand., 68:319–324, 1997.
7. BLAUTH, M., LANGE, U., KNOP, C., BASTIAN, L.: Wirbelsäulenfrakturen im Alter und ihre Behandlung. Orthopäde, 29:302–317, 2000.
8. BLAUTH, M., RICHTER, M., KIESEWETTER, B., LANGE, U.: Operative oder konservative Behandlung der Pseudarthrose des Dens axis. Chirurg, 70:1225–1238, 1999.
9. BÜHREN, V., HOFMEISTER, M., MILITZ, M., POTULSKI, M.: Indikationsstellung für die operative Behandlung bei Verletzungen der Halswirbelsäule. Zbl. Chir., 123:907–913, 1998.
10. CHUTKAN, N., KING, A., HARRIS, M.: Odontoid fractures: Evaluation and management. J. Amer. Acad. Orthop. Surg., 5:199–204, 1997.
11. DORMANS, J., CRISCITELLO, A., DRUMMOND, D., DAVIDSON, R.: Complications in children managed with immobilization in a halo vest. J. Bone Jt Surg., 77-A:1370–1373, 1995.
12. ESSES, S. BEDNAR, D.: Screw fixation of odontoid fractures and non-unions. Spine, 16 (Suppl):483–485, 1991.
13. GOVENDER, S., MAHARAJ, J., HAFFAJEE, M.: Fractures of the odontoid process. J. Bone Jt Surg., 82-B:1143–1147, 2000.
14. GREENE, K., DICKMAN, C., MARCIANO, F., DRABIER, J., HADLEY, M., SONNTAG, V.: Acute axis fractures. Analysis of management and outcome in 340 consecutive cases. Spine, 22:1843–1852, 1997.
15. HART, R., SATERBAK, A., RAPP, T., CLARK, C.: Nonoperative management of dens fracture nonunion in elderly patients without myelopathy. Spine, 25:1339–1343, 2000.
16. HOSSSAIN, M., McLEAN, A., FRASER, M. H.: Outcome of halo immobilisation of 104 cases of cervical spine injury. Scott. Med. J., 49:90–92, 2004.
17. JOHNSON, R., HART, D., SIMMONS, E., RAMSBY, G., SOUTHWICK, W.: Cervical orthoses: a study comparing their effectiveness in restricting cervical motion in normal subjects. J. Bone Jt Surg., 59-A:332–339, 1977.
18. KNÖRINGER, P.: Die Osteosynthese der Densfraktur mit Doppelgewindeschraube. Operat. Orthop. Traum., 2:178–192, 1990.
19. LENNARSON, P., MOSTAFAVI, H., TRAYNELIS, V., WALTERS, B.: Management of type II odontoid fractures: a case control study. Spine, 25:1234–1237, 2000.
20. LIEBERMANN, I. WEBB, J.: Cervical spine injuries in the elderly. J. Bone Jt Surg., 76-B:877–881, 1994.
21. LIND, B., NORDWALL, A., SIHLBOM, H.: Odontoid fractures treated with halo-vest. Spine, 12:173–177, 1987.
22. LIND, B., SIHLBOM, H., NORDWALL, A.: Halo-vest treatment of unstable traumatic cervical spine injuries. Spine, 13:425–432, 1988.
23. MAGERL, F., SEEMANN, P.: Stable posterior fusion of the atlas and axis by transarticular screw fixation. In: Kehr, P., Weidner, A., eds.: Cervical spine. Berlin, Heidelberg, New York, Springer 1976, 322–327.
24. MARCHESI, D.: Management of odontoid fractures. Orthopedics, 20:911–916, 1997.
25. McBRIDE, A., MUKHERJEE, D., KRUSE, R., ALBRIGHT, J.: Anterior screw fixation of type II odontoid fractures. A biomechanical study. Spine, 20:1855–1860, 1995.
26. MÜLLER, E., WICK, M., RUSSE, O., MUHR, G.: Unfallbedingte Pseudarthrosen des Dens axis. Unfallchirurg, 101:750–754, 1998.
27. OBENAUER, S., HEROLD, T., FISCHER, U. et al.: Evaluation experimentell erzeugter Verletzungen der oberen Halswirbelsäule mit digitaler Röntgentechnik, Computertomographie und Magnetresonanztomographie. Fortschr. Röntgenstr., 171:473–479, 1999.
28. POLIN, R., SZABO, T., BOGAEV, C., REPLOGLE, R., JANE, J.: Nonoperative management of types II and III odontoid fractures: the philadelphia collar versus the halo vest. Neurosurgery, 38:450–456, 1996.
29. RICHTER, D., LATTA, L., MILNE, E. et al.: The stabilizing effects of different orthosis in the intact and unstable upper cervical spine: a cadaver study. J. Trauma, 50:848–854, 2001.
30. ROTH, R. WÖRSDÖRFER, O.: Die operative Therapie der Dens-Fraktur. Zbl. Chir., 123:914–918, 1998.
31. SASSO, R., DOHERTY, B., CRAWFORD, M., HEGGENESS, M.: Biomechanics of odontoid fracture fixation. Spine, 18:1950–1953, 1993.
32. SCHULZE, W., ESENWEIN, S., MÜLLER, E., RUSSE, O., MUHR, G.: Komplikationen beim Halo-Fixateur. Zbl. Neurochir., 62:2–9, 2001.
33. SCHWARZ, N.: Anmerkungen zum Beitrag von C. Gerstenkorn et al. „Verögerte Diagnose einer Odontoidfraktur nach Schleudertrauma der Halswirbelsäule“. Unfallchirurg, 104:672–674, 2001.
34. SEYBOLD, E. BAYLEY, J.: Functional outcome of surgically and conservatively managed dens fractures. Spine, 23:1845–1846, 1998.
35. STONEY, J., O'BRIEN, J., WILDE, P.: Treatment of type-two odontoid fractures in halothoracic vests. J. Bone Jt Surg., 80-B:452–425, 1998.
36. TANNOURY, T. Y., ZMURKO, M. G., TANNOURY, C. A., ANDERSON, D. G., CHAN, D. P.: Multiple unstable cervical fractures with cord compromise treated nonoperatively: a case report. Spine, 29:E234–E238, 2004.
37. TRAYNELIS, V.: Evidence-based management of type II odontoid fractures. Clin. Neurosurg., 44:41–49, 1997.
38. WEISSKOPF, M., REINDL, R., SCHRÖDER, R., HOPFENMÜLLER, P., MITTLMEIER, T.: CT scans versus conventional tomography in acute fractures of the odontoid process. Europ. Spine J. 10:250–256, 2001.

Dr. Peter C. Strohm,
Department of Orthopaedic and Trauma Surgery,
University of Freiburg Medical Center,
Hugstetterstr. 55,
79106 Freiburg im Breisgau
GERMANY
Tel: +49-761-270-2401
Fax: +49-761-270-2520
E-mail:strohm@ch11.ukl.uni-freiburg.de

Práce byla přijata 20. 3. 2006.