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Results of Long-Term Follow-Up in Patients Undergoing Anterior Screw Fixation for Type II and Rostral Type III Odontoid Fractures

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Study Design. Retrospective analysis of the fusion rate of a group of 38 patients having undergone anterior screw fixation for type II and "shallow" type III odontoid fractures.

Objective. To determine primarily the long-term fusion rate after anterior screw fixation and to study the clinical characteristics of patients that have a statistically significant or nonsignificant influence on successful outcome.

Summary of Background Data. Long-term outcome of anterior screw fixation for odontoid fractures has been evaluated in very few studies. This information should be critical for further establishing this technique as a major therapeutic strategy for these cases.

Methods. Thirty-eight patients, 25 males and 13 females (with mean age 48.4 ± 0.4 years), with type II and rostral type III odontoid fractures, underwent anterior cannulated screw fixation during a 62-month period. Radiologic examination of the cervical spine with plain radiographs was performed at 6 weeks, and 2, 6, 12, and 24 months, while computerized tomography of the upper cervical spine (C1–C3) was obtained at 6 months after surgery. Follow-up was available for 31 patients, and the follow-up time ranged from 39 to 87 months (mean 58.4).

Results. Radiographic evaluation of the follow-up group showed satisfactory bony fusion and no evidence of abnormal movement at the fracture site in 27 (87.1%) patients. Pseudarthrosis developed in 4 (12.9%) patients; however, 3 (9.6%) of them without instability and 1 (3.2%) with instability. One (3.2%) patient had an instrumentation failure without instability.

Conclusions. In our series, anterior odontoid screw fixation comprised a safe therapeutic modality with high stability and low mechanical failure rates during short-term and long-term follow-up.

Key words: anterior, fusion, instrumentation failure, odontoid fracture, screw fixation, surgical outcome. **Spine 2005;30:661–669**

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Odontoid fractures comprise up to 18% of cervical spine fractures, and, due to the complex anatomy of the cranio-cervical junction, their treatment can be quite challenging.[1–15] This region is responsible for the majority of the segmental axial rotation in the neck.[16] It is well documented, that this is a unique area from a biomechanical standpoint and is inherently predisposed to traumatic injuries.[17] The treatment of such injuries requires a thorough knowledge of the regional anatomy and mastering of the available surgical stabilizing techniques.[17] In a key article in 1974, Anderson and D'Alonzo[1] proposed a 3-tier classification system that reflects 3 different types of fractures with distinct rates of healing. It is also widely accepted that type II and rostral "shallow" type III odontoid fractures represent highly unstable entities.[17] The nonunion rate for type II fractures has varied from 4.8% to 62.8%,[1,14,18–25] while in the cases of displaced fractures, the nonunion rates have been as high as 67%,[7] 72%,[23] 75%,[9] and even 88%.[2]

A number of approaches have been attempted to address this potentially disabling injury, spanning from conservative treatment with an external orthotic device, to posterior C1–C2 arthrodesis and anterior screw fixation. Various surgical techniques have also been proposed for stabilization of odontoid fractures.[17] Among these, C1–C2 posterior wiring and fusion, C1–C2 posterior transarticular screws, C1 lateral mass and C2 pars articularis screws, posterior clamping techniques, and anterior screw fixation have achieved higher fusion rates compared to conservative treatment.[17,26–47] With appropriate selection of patients and the *lege artis* technique, anterior screw fixation, since its introduction independently by Nakanishi *et al*[47] and Bohler,[32] has become the most widely used procedure for stabilization of type II and "shallow" type III odontoid fractures.[3,48,49] A major advantage of this technique is the provision of immediate stabilization of the spine, with preservation of substantial C1–C2 rotatory motion.[30,35,47] Its indications (*e.g.*, odontoid type II or rostral type III reducible fractures in patients older than 7 years) and contraindications (*e.g.*, disruption of atlantal transverse ligament, patients with short/thick neck and/or barrel chest, age of fracture more than 6 months, odontoid fractures associated with comminution of one or both atlantoaxial joints, atypical type II fractures, and

Table 1. Demographic and Operative Data of the Patients

Patient age	Mean	Median	No. (%)
Total	48.4 yrs		
Female	55.15 yrs	31–79 yrs	
Male	44.8 yrs	17–81 yrs	
Patient sex			
Total			38
Female			13 (35)
Male			25 (65)
Patient race			
Black			16 (42.10)
White			22 (57.90)
Anderson and D′ Alonso type of fracture[1]			
Type II dens fractures			36 (94.70)
Type III dens fractures			2 (5.30)
Associated injuries			
None			33 (86.80)
Unilateral C1 arch fracture			4 (10.50)
Avulsion fracture of C5			1 (2.60)
Presentation			
Neck pain			25 (65.80)
Asymptomatic			7 (18.42)
Upper extremity numbness			4 (10.50)
Lhermitte sign			2 (5.26)
Neck tenderness			1 (2.60)
Injury			
Motor vehicle collision			23 (60.50)
Fall			9 (23.90)
Os Odontoideum with minor trauma			2 (5.20)
Diving			2 (5.20)
Motor cycle accident			1 (2.60)
Fight			1 (2.60)
Previous stabilization			
None			31 (81.50)
Halo vest			5 (13.15)
Galllie C1–C2 posterior wiring			2 (5.20)
No. of screws			
1			24 (63.20)
2			14 (36.80)
Duration of operation			
Total	97 min	65–135 min	
1 Screw	94.6 min	65–120 min	
2 Screws	99.3 min	65–135 min	
Blood loss			
Total	89.5 mL	50–250 mL	
1 Screw	89.6 mL	50–150 mL	
2 Screws	89.3 mL	50–250 mL	

pathologic fractures) have been extensively described in the literature.[17,50] In this retrospective study, we examined the long-term outcome and complications of 38 consecutive patients who underwent anterior screw fixation for type II and "shallow" type III odontoid fractures at our institution.

■ Materials and Methods

Patient Data. Our series derives from a retrospective analysis of 38 consecutively treated patients for the period from August 1995 to September 2000 (62 months). Demographic data of the patients, clinical characteristics of their injuries, and mode of presentation, as well as fundamental operative information are presented in Table 1.

All patients were trauma cases who underwent radiologic evaluation via plain cervical spine radiographs, computerized tomography (CT), and magnetic resonance imaging cervical spine studies. There were 31 acute and 7 chronic cases. A single surgeon (K.N.F.) performed all procedures. Operations were performed on an average of 25 hours after admission. The average length of stay was 3.7 ± 0.1 days. In the beginning of our study, patients undergoing anterior screw fixation were subjected to implantation of 2 screws (14 patients), while the rest of them, who consisted of the majority, underwent a single screw implantation (24). After surgery, all patients were placed on Miami-J (Jerome Medical, Moorestown, NJ) cervical collar for 4 weeks.

Surgical Technique. The patient is positioned in a neutral supine position. The procedure is performed with the patient under spontaneous electromyogram and somatosensory evoked potential monitoring. The use of the Jackson radiolucent operating table (OSI, Union City, CA) is advantageous for noninterference with biplanar intraoperative fluoroscopy. Endoscopic endotracheal intubation is used, and, with the patient under general anesthesia, the correct alignment of C2 vertebral body with the odontoid process is achieved with appropriate manipulation of the neck under fluoroscopic guidance. The insertion of "bite blocks" on each side of the endotracheal tube is crucial to maintain adequate visualization of the surgically relevant structures by keeping the mouth of the patient open. At this point, the lateral masses of C1, the vertebral body of C2, and the odontoid process should be visualized under anterior/posterior and lateral fluoroscopy. The skin is prepared and draped in a standard fashion. A transverse neck skin incision extending from the midline to the anterior border of the sternocleidomastoid muscle is placed preferably (for a right handed surgeon) on the right side. Detailed description of the surgical technique can be found in previously published technical reports.[30,37,38,48,51–53] A specially designed instrument kit (SyntheSpine, Paoli, PA) was used in our cases. After insertion of the odontoid screw (Figures 1–3, available for viewing on ArticlePlus), meticulous hemostasis and vigorous antibiotic irrigation are used, and the surgical wound is closed in anatomic layers.

Follow-Up. Follow-up data were available for 31 (81.5%) patients (6 were lost to follow-up, and 1 died from reasons unrelated to the procedure). Mean follow-up duration was 58.4 ± 0.4 months (range 39–87). Follow-up studies included dynamic lateral cervical spine radiographs (flexion/extension films) at 6 weeks, and then at 2, 6, 12, and 24 months after surgery, and CT of the upper cervical spine (C_1–C_3) at 6 months after surgery were obtained (Figures 4–9; figures 7 and 9 are available for viewing on ArticlePlus). Strict radiographic criteria (*i.e.*, the presence of bony trabeculation and existence of bony bridges) were used to define solid bony fusion.[54] The radiographic studies were evaluated by an independent neuroradiologist (EZK) not involved in the treatment of the patient.

Clinical evaluation included a thorough neurologic examination, as well as the testing of neck flexion, extension, and lateral bending. Finally, a satisfaction survey was completed by all of our patients at 1 and 3 years after surgery. This survey included questions such as whether the patients thought that there was improvement of symptoms after surgery, if they were symptom-free at the time of the survey, if the patients had smooth postoperative recovery after surgery, if the patients were satisfied with surgery, and if they would recommend this procedure to another person.

Figure 4. Preoperative lateral C-spine radiograph showing type II odontoid fracture in an elderly patient.

Figure 5. Odontoid view showing type II odontoid fracture in same patient.

Results

Successful positioning of the odontoid screw(s) and immediate spinal stabilization were achieved in all patients (31 of 31), as evidenced radiographically by proper fracture alignment and correction of abnormal translatory motion at the C1–C2 junction, since preoperative displacement was evident in all of our cases (average displacement 1.8 mm, range 0.6–3.4).

Bony fusion was radiographically evident in 27 (87.1%) patients at the 18-month follow-up. Analytically, fusion was achieved in 6 (19.4%) patients within 6 months, 11 (35.5%) at 12 months, and 10 (32.2%) within 18 months after surgery. These results were based on the radiographic findings of the postoperative plain radiographs and CT. In 4 (12.9%) cases, no solid fusion was documented after 2 years. In 3 of these patients, no degree of motion was revealed in the dynamic radiographs; there was evidence of fibrous pseudarthrosis at the fracture site. Based on clinical and radiographic findings, no further surgical intervention was used. Abnormal motion was radiographically detected in the remaining patient, therefore he underwent posterior C1–C2 transarticular screw fixation and wiring fusion stabilization.

Regarding the fusion rate in relation to the number of the implanted anterior cannulated screws, our results showed no significant difference between the 2 groups, although the number of patients in our series cannot allow the extraction of any statistically powerful conclusion. Patients with 2 screws had a fusion rate of 72.7% (8 of 11 patients), while the corresponding rate for those with a single screw was 95% (19 of 20). Also, estimated operative blood loss (EBL) and operating time (OP) did not seem to vary depending on the number of screws

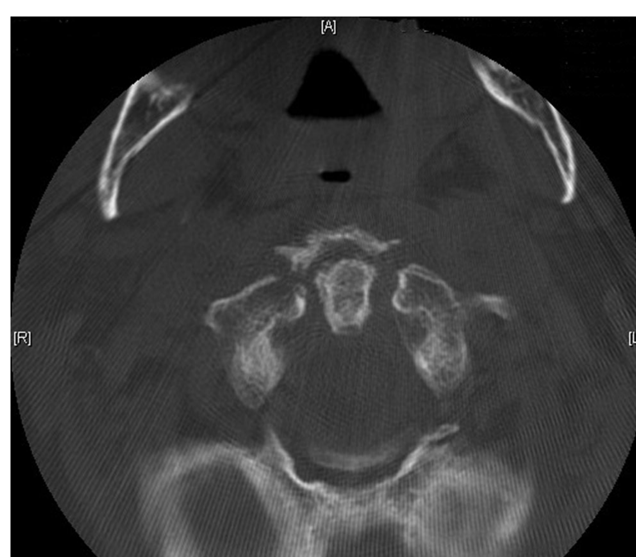

Figure 6. Preoperative axial computerized tomography of C-spine in the same patient.

Figure 8. Postoperative lateral C-spine showing the implanted cannulated screw.

inserted (EBL total: 89.5 mL, EBL-1 screw/2 screws: 89.6/89.3 mL; OP total: 97 minutes, OP 1 screw/2 screws: 94.6/99.3 minutes)

Patient age and sex were not correlated to the fusion rate in a statistically significant fashion by using analysis of variance methodology. The *P* value for age and fusion rate was 0.384, and the one for the patient sex and fusion rate was 0.437. All of our patients presented without initial neurologic deficit, and remained neurologically well after surgery and during follow-up.

Regarding intraoperative complications, we had no unfortunate accidents except in one case in which the fracture of an implanted K-wire occurred. The broken K-wire fragment was left in the vertebral body of C2, and a cannulated screw was positioned without any further problems (Figures 10–17; figures 12 and 14 are available for viewing on ArticlePlus).

There were no complications such as postoperative hematomas, dysphagia, hoarseness, or vascular or neural structure injuries. Postoperative instrumentation related complications occurred in only one patient in whom a cannulated screw fracture was documented. A stable fibrous union had developed in the patient, and no further surgery was required. One patient had a superficial wound infection, which was treated with a course of oral antibiotics without instrumentation removal. Pulmonary atelectasis developed in another patient, which resolved after the first postoperative week.

Figure 10. Preoperative lateral C-spine showing a type II odontoid fracture.

Regarding the development of adjacent level degenerative pathology, no anterior osteophyte formation was documented at the anteroinferior border of the C2 vertebral body in our patients during follow-up,. There was also no evidence of hypermobility of the C2–C3 segment in the follow-up flexion/extension radiographic studies. Characteristically, no new degenerative changes at the C2–C3 or C3–C4 levels developed in any of our patients postoperatively. Four patients in our series had lower cervical spine degenerative disease, for which they underwent single level anterior cervical diskectomy and fusion (3 patients at C5–C6 and 1 at C6–C7 level). It needs to be emphasized that these patients had documented degenerative changes in the preoperative (anterior screw fixation) radiographic studies.

Patient range of motion during the postoperative dynamic (flexion/extension) radiographic studies was preserved in our cases. The average range of motion in flexion/extension was 25.8° (range 10° to 35°). Unfortunately, no preoperative dynamic studies were available in these patients, so comparison was not feasible. Based only on the postoperative dynamic radiographs, it is difficult to determine if the preserved range of motion is due to the preservation of the C1–C2 segment mobility or compensatory increased lower cervical mobility.[1,55] No lateral bending radiographs were obtained in our series,

Figure 11. Preoperative 3-dimensional formatted C-spine computerized tomography showing a type II odontoid fracture in the same patient.

so the extraction of any conclusion regarding preservation of lateral motion was not possible.

Regarding the patient clinical examination, none of our patients had any symptomatology related to the anterior odontoid fixation procedure 6 months after the procedure. In addition, none of our patients were on any kind of pain medication, and all of them had returned to a preoperative style of life. Regarding the clinical gross examination of the mobility of our patients during flexion, extension, and lateral bending, we found that this had remained quite functional.

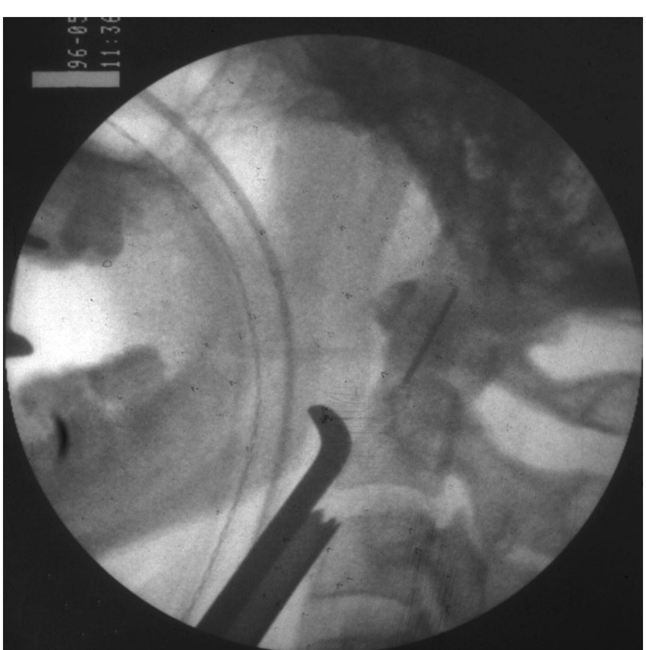

Figure 13. Intraoperative fluoroscopic image showing the broken fragment of the inserted K-wire (lateral view).

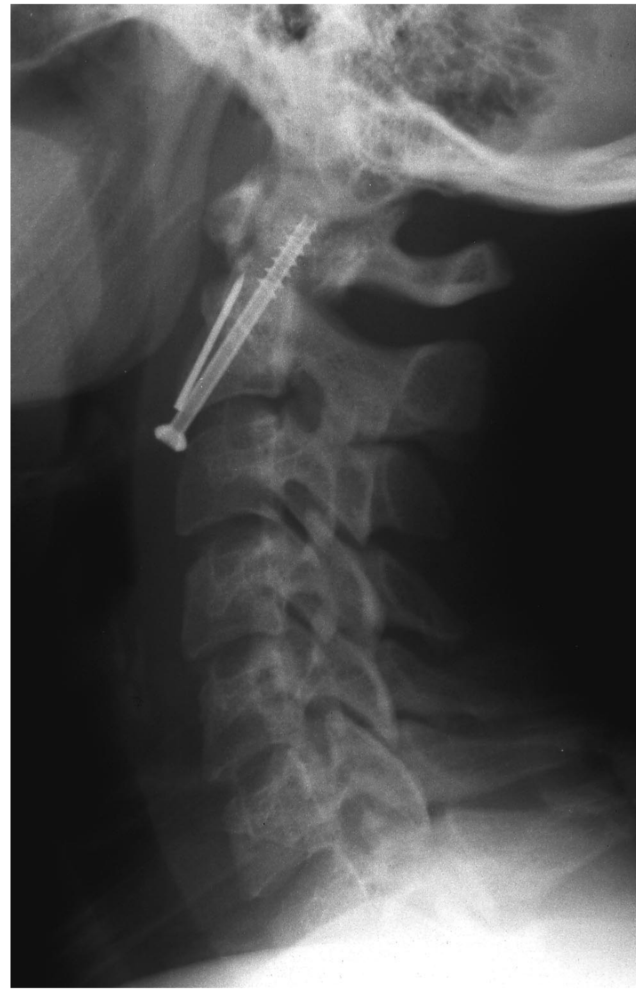

Figure 15. Postoperative lateral C-spine radiograph showing the implanted screw and the broken K-wire fragment.

Finally, the patient subjective opinion regarding the success of the surgical procedure is well reflected on the satisfaction surveys. At 1 year after surgery, 24 of 31 (80.6%) patients were completely satisfied with this procedure, while 7 (19.4%) were satisfied. The respective percentages remain almost unchanged at the 2-year follow-up; 23 of 31 (74.2%) patients had remained completely satisfied with the procedure, while 8 (25.8%) were still satisfied. Regarding the recommendation of this procedure to another person, 30 of 31 (96.8%) patients would definitely recommend this procedure to another person, while 1 (3.2%) would not. These percentages remained exactly the same at the 2-year follow-up.

■ Discussion

Numerous clinical studies have been published in the literature, documenting the efficacy of the anterior screw fixation technique in stabilizing acute type II and "shallow" type III odontoid fractures.[30–38,43,45,47–49,52,53,56–58]. The superiority of this surgical procedure has been extensively evaluated in a series of clinical studies and the

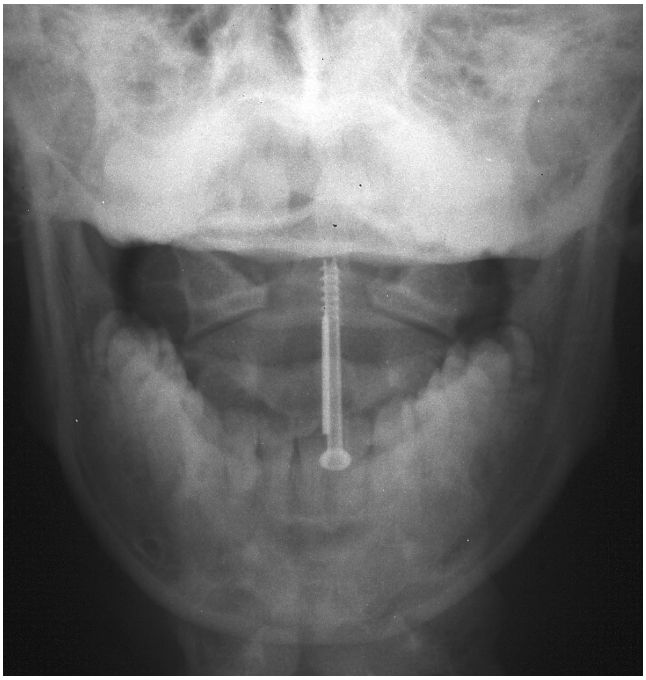

Figure 16. Postoperative anterior/posterior C-spine radiograph showing the implanted screw and the broken K-wire fragment.

significantly higher fusion rate of this approach, *versus* the posterior wiring or clamping techniques, have been adequately addressed in the literature.[17,52,53,56–59] A number of biomechanical advantages of the anterior screw fixation technique, a major one being the preservation of a substantial degree of the rotatory motion of the C1–C2 complex,[30,35,47] have also been adequately explored and emphasized in previous clinical series.[40,60] Our relatively large, retrospective, clinical study focused on the long-term outcome of patients undergoing anterior screw fixation and attempted to address 2 quite puzzling issues: the long-term fusion rate accomplished by this methodology and the potential time-related instrumentation "worn-out," or even failure, associated with this surgical procedure.

Although the definition of fusion has remained controversial, fusion has become a meritorious term in spinal surgery literature. With inherent difficulties in defining fusion and also documenting it (absence of universal radiographic criteria, significant interobservational variation[54]), fusion represents one of the most commonly used parameters for assessing the efficacy of spinal surgical techniques. With these limitations in mind, we used strict radiographic criteria for defining fusion because this had been done in previously reported clinical series of anterior odontoid screw fixation.[30,37,38,45,48,53,56,57] In our series, the long-term fusion rate (87%) was comparable with the reported ones from other large but short-term clinical series. Aebi *et al*,[30] using rigid radiographic fusion criteria similar to ours, reported an 88% fusion rate in a large series of type II and "shallow" type III odontoid fractures; the same fusion rate was accomplished by Apfelbaum *et al*[48] in their recent large clinical series. Montesano *et al*[45] similarly reported an 84% fusion rate in a limited series. In their study, Etter *et al*[37] documented radiographic fusion in 92.3%, although the demographic data of the included patients were lacking. In a large clinical series, Henry *et al*[57] reported a 92% radiographically proven fusion rate; although it is noteworthy that in their series, patients with only acute type II and type III odontoid fractures were included. In a retrospective study, Subach *et al*[53] reported a 96% fusion rate in treating acute only, type II odontoid fractures. Similarly, in a limited series, Geisler *et al*,[38] and, in a short-term follow-up study, ElSaghir *et al*[56] reported a 100% fusion rate.

Reviewing the data regarding the timing of the fusion, the evidence is significantly less detailed. In our study, a radiographically proved fusion was accomplished at a mean time of 11.2 months (range 6–18) after the procedure. The respective average time of fusion achievement was 8 months (range 3–24) in series studied by Aebi *et al*,[30] while Etter *et al*[37] reported 5.5 months. In their study, Montesano *et al*[45] reported 4 months (range 3–5),

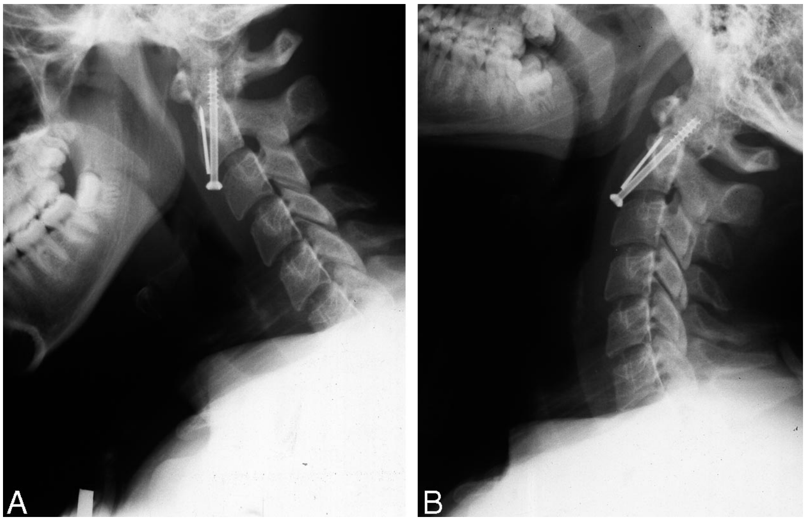

Figure 17. **A** and **B,** Flexion/extension C-spine radiographs obtained 24 months postoperatively.

while Henry *et al*[57] reported 14.1 week (8–50) as mean time required for bony fusion.

Analysis of our data regarding the effect of age and sex showed no statistically significant correlation between any of these factors and the observed fusion rate. Our findings confirmed the observations of Apfelbaum *et al*,[48] who concluded that these 2 parameters had no statistically significant impact on the surgical outcome of the patient. Berleman and Schwarzenbach[61] have reported higher fusion rates among elderly patients (older than 65 years); in their series, the advanced age of the patient did not compromise postoperative fusion, which was 84.2%. Börm *et al*[62] arrived at the same conclusion after performing a case-control study of 27 patients with type II odontoid fracture; there was no statistically significant difference regarding the fusion rate among patients younger and older than 70 years. On the contrary, in a retrospective study, Anderson *et al*[63] concluded that the fusion rate was significantly worse among patients older than 65 years. Additionally, their complication rate was unusually high in their reported series; their explanation for this high failure rate was osteoporosis and comminution of the fracture site.[63] It needs to be emphasized though, that a comminuted fracture consists of one of the contraindications of the anterior screw fixation technique, as these have been outlined in several previously published articles.[50]

The issue of a single *versus* dual screw fixation has been adequately addressed by other groups.[48,60,64] Our results agree with the findings of previously published studies in which there was no statistically significant difference in the observed fusion rate among the patients with one and two screws.[48,60,64] Interestingly in our study, this rate was higher among the patients with a single screw compared to the one in patients with 2 screws (95% *versus* 72.7%, respectively), although this difference did not reach the level of statistical significance.

The issue regarding instrumentation failure due to metal fatigue has remained an unresolved one because evidence from long-term, follow-up studies was lacking. In our series, with mean follow-up longer than 4 years, only one case of mechanical instrumentation failure was documented. Similarly, Aebi *et al*[30] reported one case of screw fracture in their series. Our long-term follow-up enforces the general impression that mechanical instrumentation failure will most probably not constitute a potential, long- term problem in patients undergoing anterior screw fixation.

The good functional outcome of our patients, as was reflected by the absence of any postoperative symptomatology and also the observed high satisfaction rate among our patients, was in agreement with the findings of previously published series.[35,65] Our relatively long follow-up documented the maintenance of the high level of satisfaction among the patients undergoing anterior odontoid screw fixation. Our findings (clinical and radiographic) appear to support the postoperative preservation of range of motion, previously reported in the literature.[30,65] Although the absence of any preoperative dynamic radiographic studies in our series made any comparisons impossible, the range of motion (radiographically and clinically evaluated) was quite satisfactory. The fact that all of our patients returned to a preoperative style of life is exactly indicative of a good functional outcome.

Regarding other procedure related complications, our series showed only one case of a K-wire fracture, which was our only intraoperative complication. Our low postoperative complication rate confirms the rates reported by other groups in the past.[30,48,53] The importance of early ambulation of these patients and its clinical impact, especially in elderly patients, cannot be overemphasized. The short OP and minimal blood loss are 2 other contributory factors in the good clinical outcome of patients with acute odontoid fractures, who occasionally have multisystem injuries. Moreover, the lack of need for bone graft harvesting (compared to the posterior surgical stabilization techniques) is another important factor in the decreased complication rate associated with the anterior screw fixation technique.

Finally, a few technical issues that can affect significantly the overall outcome of these patients need to be briefly addressed. The importance of applying strict preoperative criteria in selecting the ideal candidates for this procedure is apparent. We strongly believe that reducibility (either preoperative or intraoperative) of the odontoid fracture, intact transverse ligament (as acute ligamentous injury can be excluded by a preoperative magnetic resonance imaging study), and body habitus of the patient are the most important factors for selecting the appropriate surgical approach for type II or "shallow" type III odontoid fracture stabilization. Biplanar fluoroscopy is also of paramount importance because it significantly decreases the OP and increases the confidence of the surgeon regarding optimally positioning the odontoid screw.

Our long-term follow-up study attempted to address some of the puzzling questions related to the use of the anterior screw fixation in treating type II and rostral type III odontoid fractures. However, there are still specific issues related to this surgical approach and its associated clinical outcome that deserve further consideration. Of these considerations, the application of this procedure in pediatric patients and its role in the treatment of nonhealed type II or rostral type III odontoid fractures deserve special consideration. A large, prospective, multi-institutional clinical study could potentially address these issues in the future.

Conclusion

Our long-term outcome study further strengthens the idea that anterior screw fixation represents a highly effective and safe surgical treatment option in the care of patients with type II and "shallow" type III odontoid fractures. Meticulous selection of patients, early surgical intervention, and avoidance of technical pitfalls can increase the likelihood of a satisfactory long-term outcome.

Key Points:

- Anterior screw fixation is a safe and effective surgical treatment option for type II and rostral type III odontoid fractures.
- Radiographically proved fusion rate has been 87% in our clinical series.
- Long-term follow-up confirms excellent results.
- Instrumentation mechanical failure did not increase with time.

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