SAS Journal of Surgery ISSN 2454-5104
SAS J. Surg., Volume-1; Issue-2 (Jul-Aug, 2015); p-40-46
Available online at https://saspublishers.com/journal/sasjs/home

Research Article

Anterior plate fixation of lower cervical spine fractures Comparing two angular stable implants

Florian M. Kovar[1], Florian Kutscha-Lissberg[2]
[1]Department of Trauma Surgery, General Hospital Vienna, Medical University Vienna, Waehringer Guertel- 18-20, 1090 Vienna, Austria.
[2]Department of Orthopedics, Landesklinikum Wr. Neustadt, Corvinusring- 3, 2700, Wr.Neustadt, Austria.

***Corresponding author**
Florian M. Kovar
Email: florian.kovar@meduniwien.ac.at

Abstract: The objective of this study was to analyse the functional and radiographic long term results following anterior plate fixation of lower cervical spine comparing the outcome of two angular stable plating procedures. Prospective collected and retrospective evaluated case series Dep. Trauma Surgery, General Hospital Vienna, Austria, Level I Trauma Centre 65 patients (23 females, 42 males) with an average age of 37.1 (15 – 87) years were enrolled. 30 patients were treated by the Morscher Plate and entered study group A, 35 patients were stabilised with the Cervical Spine Locking Plate (CSLP) and entered group B. All patients were monitored for two years. Anterior plate fixation in fractures of the lower cervical spine with the Morscher Plate or the CSLP. Bone union, implant failure, Webster-Smiley scale. Bony union was achieved in 62 patients (95%). Non-union rate was 7% (n=2) in group A, and 3% (n=1) in group B. The rate of failures of reduction and fixation was 20% (n=6) in group A, and 14% (n=5) in group B respectively. Reoperations were necessary in 3 patients (3%). 58 (89%) patients were fully satisfied with their treatment. 7 patients (11%) complained about occasional or chronic pain and a decrease of motion. The overall functional outcome score was 1.70 in Group A, 1.65 in group B (Smiley Webster Scale).Our data reveal that comparing Morscher´s plate and the CSLP, we found no significant differences in terms of technical failures, complications or outcome in our dataset.
Keywords: cervical spine, trauma surgery, Bone, CSLP

INTRODUCTION

The last 20 years have shown an ongoing discussion whether anterior or posterior surgery is the treatment of choice for most of the cervical spine injuries [1]. Looking at the distribution of acute cervical spine trauma, 55% of the injuries are located at the level of C5/6 and C6/7, and anterior surgery at this level is well established [1]. Occurring instabilities are treated with anterior cervical discectomy and fusion (ACDF), which was first reported by Robinson and Smith, in 1955 and is now considered an established surgical technique [2, 3]. Due to high rates of pseudarthrosis and kyphotic deformity in those procedures, the need for an anterior internal cervical fixation device was recognized[1]. This led to the development of the first anterior cervical plate (ACP) and screw system by Boehler in 1964, followed by the evolution of newer ACP system designs [1,4-6].

Current developments in implant design have facilitated insertion procedures and enhanced biomechanical properties, leading to its increased use in trauma surgery [6-8]. Recently, anterior plating systems have also been used in the hope of improving outcomes following anterior cervical discectomy or corpectomy for degenerative and oncologic disorders [3, 5, 7-11]. The aims of this technique include decompression of neural structures, reduction of deformity, immediate stability, and creation of a conductive environment for osseous fusion to occur. Proponents of plating systems, particularly angular stable plates have cited numerous advantages, including earlier patient mobilization, cost-effectiveness, a decreased need for orthesis, a diminished rate of graft dislodgment and migration, superior fusion rates, immediate stabilization, and the prevention of spinal deformity [12-17]. The goal of any treatment of cervical spine injuries is return to maximum functional ability, minimum of residual pain, decrease of any neurological deficit, minimum of residual deformity and prevention of further disability [13].

The purpose of this study was to analyse the functional and radiographic long term results following anterior plate fixation of lower cervical spine fractures and discoligamentous injuries (C3- C7) at this Level I Trauma centre, with the particular interest in comparing the outcome of two angular stable plating procedures.

METHODS

Patients

In this IRB approved study, the records of 81 patients, over a 12 year inclusion period, which were diagnosed with traumatic fractures and discoligamentous injuries of the lower cervical spine that underwent anterior plate fixation where collected prospectively and evaluated retrospectively. According to our inclusion criteria, patients who underwent anterior plate fixation of lower cervical spine fractures or discoligamentous instability with angular stable implants with complete sets of collected data and a postoperative follow up monitoring of at least two years after surgery were finally enrolled in this study.

Collected data included variables such as age, gender, mechanism and type of injury, presence of neurological deficits, associated injuries, pre-existing systemic disease and surgical risk factors, method of operative treatment as well as clinical and radiographic outcome after surgery. Exclusion criteria of this study contain patients who were stabilised with non-angular stable plating systems, patients with incomplete datasets as well as penetrating mechanism of injury or congenital cervical spine anomalies.

Patients were divided into two study groups: Group A included patients treated by the AO internal fixator (Morscher Plate, Synthes Inc., Paoli, PA), representing the first eight years of inclusion time. Group B contained patients stabilised by its successor, the Cervical Spine Locking Plate (CSLP; Synthes Inc., Paoli, PA).

Follow up monitoring included accurate clinical and radiographic examination of the patients, before discharge and then at six, twelve and 24 weeks after trauma. Further regular examinations were performed at 12 and 24 months after injury. All patients were at least monitored for a period of two years (Table-1).

SURGICAL PROCEDURES

For the technique of anterior plate fixation of lower cervical spine fractures or instabilities, the patients were placed in supine position with the head slightly extended and secured by a temporarily fixed Halo Ring. After closed reduction in cases of displacement using biplanar (ap and lateral) fluoroscopic guidance, an anterior cervical approach was performed. After incision of the skin and platysma at the level of the injury the anterior cervical spine was approached by dissecting through the cervical fascia. The level of the fracture was identified and the fixation points of the plate constructing systems were determined. Anterior plate fixation was either performed by the Morscher Plate (n=30) or the CSLP (n=38) (Figure-1 and 2).

According to the institution´s treatment protocol, anterior plate fixation was performed in all patients with unstable fracture types, discoligamentous instability and/ or patients with neurological deficits.

Radiographic assessment consisted of a standard cervical spine series (ap and lateral) at each follow up visit. Additional flexion/ extension views were performed between six weeks to 12 months after trauma. Fine cut CT- Scans with helical reconstruction were routinely obtained during primary assessment of the patients and between three to 12 months after trauma, if the adequacy of bony fusion could not be determined on the standard radiographs.

For clinical examination, range of motion, local pain and activities of daily living were routinely assessed. To quantify the clinical results, the patients were asked to grade their functional outcome according to the Webster-Smiley Scale as excellent, good, fair or poor [18]. For evaluation of neurological function patients were additionally assessed by a neurological consultant. ASIA Grades were provided to quantify the severity of neurological deficits (Table-1 and 2).

STATISTICAL ANALYSIS

For statistical analyses we used the SPSS 16.0 software package (SPSS, Chicago, Ill., USA). Mean values and standard error of the mean were given unless otherwise indicated for continuous variables. Clinical and radiographic results were compared between the two study groups using student's t-test. Statistical significance was defined as $p< 0.05$.

RESULTS

A total of 65 patients, 23 female and 42 male with an average age of 37.1 (15 – 87) years at the time of surgery, were included in the analysis. Thirty patients were treated by the AO internal fixator (Morscher Plate) and entered into study group A, 35 patients were treated with the CSLP and were included into study group B. The average age in study group A was 33.6 (15 – 86) years, the average age in study group B was 40.5 (18 – 87) years.

Injuries resulted from motor-vehicle accidents in 41.5% (n=27), sports-related injuries (climbing, diving) in 30.8% (n=20), falls from a considerable height or downstairs in 16.9% (n=11), falls that were of low energy in 7.7% (n=5), and from other causes in 3.1% (n=2).

Types of injury included fractures of the cervical spine in 18 cases, fractures with dislocation in 26 cases, dislocations of the lower cervical spine in 6 cases, discoligamentous injuries in 4 cases, as well as combined types of injury in 7 cases. Injuries were classified based on the Magerl Classification System. 23 patients had sustained an injury of type A, 34 of type B and 8 of type C. In study group A we had 11 patients

with a type A injury, 15 patients with a type B lesion and 4 patients suffering from a type C injury. In study group B 12 patients showed an injury of type A, 19 patients of type B and 4 patients showed an injury of type C. Initial displacement was measured on cervical CT-scan, which was obtained routinely before surgery.

Significant associated injuries were noted in 23 patients, whereas 42 patients had isolated injuries of the cervical spine. Four patients showed evidence of a severe head injury, five patients had signs of a severe thoracic, abdominal or pelvic trauma, eight patients had significant injuries of the limbs and six patients sustained a combination of multiple severe injuries.

Pre-operative neurological deficits related to the fracture of the lower cervical spine were found in 47 patients. Four patients showed motor deficits, eight patients incurred sensory deficits and 21 patients had motor and sensory deficits. Fourteen patients showed complete para- or tetraplegia. Providing ASIA grades to quantify the severity of the spinal cord injury and the impairment of neurological function, the deficits were graded as ASIA D in twelve patients and as ASIA C in eighteen patients, ASIA B in three patients.

Relating to pre-existing systemic disease and risk factors for surgery, 19 patients admitted regular tobacco use and/ or alcohol consumption, three patients suffered from a chronic obstructive lung disease (COLD), another three patients showed a severe Bechterew´s disease, two had significant cardiac disease and four patients of them received anticoagulant therapy. Chronic renal dysfunction and diabetes mellitus were found in one case each. The average ASA (= American society of anaesthesiologists) score, which was determined preoperatively as a measure of anaesthesiological risk, was 1.56 in Study group A and 1.57 in Study group B.

Surgical treatment was obtained within 24 hours of the injury in 31 patients, within 72 hours in 17 patients and within a week in 17 patients. Comparing between the two study groups we had 14 patients treated within 24 hours in group A and 17 patients in study group B respectively. Within 72 hours eight patients were treated in study group A and 9 patients in study group B. Another eight patients underwent surgery within a week in study group A, whereat group B showed nine patients in this interval. The mean interval between fracture and surgery was three days and did not significantly differ in the study groups.

In 27 patients out of group A and 23 patients out of group B bone grafting was carried out.Nine patients were initially treated by a halo fixator another six patients were additionally stabilised postoperatively by a halo thoracic vest.

Solid bony union was achieved in 62 patients (95%). In 3 patients adequate bony fusion could not be determined on the standard radiographs and incomplete bony healing was diagnosed by cervical CT-scan between six to twelve months after surgery. Comparing between the study groups, we had a non-union rate of 7% (n=2) in Group A and 3% (n=1) in study group B. No significant difference was found between the two groups ($p > 0.05$). The three patients with incomplete bony healing (Bridwell Classification Grade 3) [19] underwent no further surgical interventions, as the patients were free of symptoms and did not show any relevant residual instability at the cervical spine.

Failures of reduction and fixation were noted in eleven patients (17%). In four cases we failed to achieve correct anatomical reduction, in one patient we found a mal-positioning of the implants and in six cases we noted secondary loss of reduction (Table- 3). Comparing the study groups, we had a failure rate of 20% (n=6) in group A, and a rate of 14% (n=5) in the CSLP Group. No significant difference was found between the two groups ($p > 0.05$). Reoperations due to failures of reduction or fixation were finally necessary in three patients (4.4%).

An analysis of clinical follow-up monitoring showed that 58 (89%) patients had returned to their pre-injury activity level one year after surgery and were fully satisfied with their treatment. Seven patients (11%) complained about certain limitations in daily living, occasional or chronic pain symptoms and a decrease of cervical spine motion. Using the Webster-Smiley scale to quantify the clinical outcome of the patients by grading their results from excellent (=1) to poor (=4), we had an overall functional outcome score of 1.70 in the Morscher Group A, and 1.65 in the CSLP Group B ($p > 0.05$).

Neurological deficits after surgery were evaluated in 17 patients (26.2%). Five patients showed tetraplegia, two out of group A, three out of group B. One patient showed motor deficits, four patients had sensory deficits and seven patients incurred motor and sensory deficits. In three patients (4.4%) recurrent laryngeal nerve injury was found after surgical stabilization which had completely recovered at the time of being discharged. All other patients with preoperative neurological deficits recovered fully after surgery. General and specific complications were showed in Table 3.

Table-1: Characteristics of study population

	n	%
Total	65	*100*
Male	23	*35.4*
Female	42	*64.6*
Age (*y*)	37.1 (*15-87*)	
Group A	30	*46.2*
Group B	35	*53.8*
Mechanism of injury		
MVA	27	*41.5*
Sport	20	*30.8*
Falls from hight	11	*16.9*
Falls low energy	5	*7.7*
Other	2	*3.1*
Magerl Class.		
Type A	23	*35.38*
Type B	34	*52.30*
Type C	8	*12.30*

Table-2: Details according to group division

Group	A		B	
	n	%	n	%
Total	30	*100*	35	*100*
Age	33.6 (*15-86*)		40.5 (*18-87*)	
Magerl Class.				
Type A	11	*36.7*	12	*34.3*
Type B	15	*50*	19	*54.3*
Type C	4	*13.3*	4	*11.4*
ASA* score	1.56		1.57	
Time till surgery				
<24h	14	*46.6*	17	*48.5*
<72 h	8	*26.6*	9	*25.7*
< 7 days	8	*26.6*	9	*25.7*
Mean intervall (d) Fx till surgery	3		3	
Bone grafting	27		23	
Webster Smiley scale	1.70		1.65	

Table-3: General and specific complications following anterior fixation

Group	A	B
	n	n
Specific complications		
Non-union	2	1
Incorrect reduction	2	2
Secondary lose of reduction	3	3
Mal-positioning of implants	1	0
Severe infection	0	0
General complications		
Cardiac failure	1	2
Respiratory failure	2	2
Pneumonia	1	0
Severe infections	2	1
Thromboembolism	1	0
Deaths	2	1

DISCUSSION

The anterior cervical spine surgery approach at the level of C3 to T1 has been introduced in 1952 [1, 20]. This concept has been modified in very different ways, leading to a myriad of anterior plate systems [1]. Since the late seventies, the anterior plate fixation can be considered as standard procedure, independently from type of lesion (A to C) [1, 13, 21-24]. Most of the results in the current literature show that anterior surgery and proper application of a plate-bone construct lead to stable results in most instances and associated with a complication rate below 5% [1,25,26].

Bombart et al. have compared patients with posterior and anterior fixation techniques [27]. Anterior surgery with or without plates and posterior surgery with plates or wiring were included. The overall results showed that the infection rate of the posterior approach was twice as high as that of the anterior approach, similar results have also been demonstrated by Aebi et al. [28]. However, there were some cases of dysphonia and dysphagia in the anterior surgery group, which resolved spontaneously. Oesophageal tear or perforation was neither observed in Bombart´s study nor in Aebi´s

series. The number of spinal cord complications was significantly higher in the posterior surgery group [27-30].

To our opinion the lower cervical spine should be approached based on the type and location of the dominant lesion. Predominantly anterior lesions such as disruption of the ventral ligaments, or vertebral body fractures that need anterior realignment or decompression and fusion, should be operated by an anterior approach, which provides atraumatic preparation and preserves the biomechanically important paravertebral muscles [31, 32] Recently, anterior cervical plate fixation of the cervical spine has evolved tremendously, as most of the injuries affect anterior structures. Many clinical studies have reported higher fusion rates with anterior cervical plates [30, 33,34]. Previous plate systems, such as the Caspar plate required bicortical screw purchase within the vertebral body increasing the risk for neurological damage [12-17, 35-38]. In recent years screw locking systems have been developed as standard feature and found widespread acceptance in orthopaedic, neurosurgical and traumatological anterior cervical reconstruction. Biomechanical advantages of angular stable implants are still controversially discussed and are finally determined by the clinical and radiographic outcome [39-42].

Several clinical trials have reported on fusion rates of angular stable implants for single level procedures from 90-100% and from 70-95% respectively for two- or multilevel procedures. Cheng et al. for example showed a fusion rate of 100% in 17 patients, whereat the authors reported on orthopaedic and trauma patients [43]. Covering exclusively patients following acute cervical spine trauma, Ripa et al. as well as Aebi et al. also revealed a bony union rate of nearly 100% in their series [28, 32]. In contrast, Johnson et al. reported on 87 patients showing a lower fusion rate of 93% and delayed or incomplete fusion in another 27% of their patients [44]. In our series we had an overall solid fusion rate of 95% without any significant difference between the Morscher plate (93%) and the CSLP (97%). In the remaining five percent we saw incomplete or delayed fracture healing leading to clinically stable and fibrous unions requiring no further surgical interventions.

Referring to the clinical outcome of the patients following anterior cervical plate fixation after injuries to the lower cervical spine, many authors have shown satisfactory functional results [1,5,7,8,11,15,17,28,31, 33-40,43,45-49]. Most of the surgically treated patients were able to return to their pre injury activity level without any notable impairment in their activities of daily living. Cheng et al. revealed excellent to good results in more than 80% of their patients according to the Kurokawa Score for clinical measurement of the cervical spine [43]. Yue et al. also reported that more than 90% of their patients were widely free of pain symptoms and had no neurological deficits or gait problems at a final follow up examination after seven years [45]. Blauth et al. reported on a series of 57 patients following traumatic anterior cervical spine fusion and found after ten years, that 86% of the patients did not take any medication due to pain or other symptoms in their cervical spine, whereat 7% of their patients complained about persistent pain. They did not find any significant correlation between symptoms and radiological findings or number of fused levels. In our series 89% of the patients were satisfied with their treatment and recovered fully after rehabilitation [32]. Using the Webster-Smiley Scale to quantify the clinical outcome, we also had an excellent to good outcome underscoring the reports in literature [50]. With regards to the neurological outcome, we had a neurological improvement after decompression and surgical stabilisation in more than one third of our patients.

In previous decades a long standing concern was the safety of using anterior plate fixation regarding treatment related complications. Fears regarding incorrect primary reduction, malpositioning of the implants or secondary loss of reduction due to screw loosening or plate breakage have been widely dispelled in articles on anterior fixation. Most authors reported on extremely low complication rates of less than two or three percents [1, 32, 46, 51, 52]. Only Yue et al. showed a rate of implant related complications in seven of 71 patients leading to a failure rate of nearly ten percents [45]. However, none of these patients required revision surgery. In our series, we had a rate of treatment related complications of 17%, which was in contrast to current data and literature. More than 50% of the patients with technical failures showed secondary loss of reduction due to slight screw migration and increasing kyphosis. Reoperations following failures of reduction and fixation were finally necessary in three patients (4.4%) which are concordant to recent articles. Further specific complications referring to the surgical approach, such as recurrent laryngeal nerve injury or dysphagia, were also seen in 3 of our patients, whereat all these patients fully recovered until the time of being discharged.

Our data reveal that angular stable anterior plating of the lower cervical spine is a suitable treatment option for fractures and/or instabilities of the lower cervical spine. Comparing Morscher´s plate and the CSLP, we found no significant differences in terms of technical failures, complications or outcome in our dataset.

REFERENCES

1. Aebi M; Surgical treatment of upper, middle and lower cervical injuries and non-unions by anterior procedures. Eur Spine J, 2010; 19(1): 33-39.

2. Robinson R, Smith G; Anterolateral cervical disk removing and interbody fusion for cervical disk syndrome. Bull Johns Hopkins Hosp, 1955; 96: 223-224.
3. Herman JM, Sonntag VK; Cervical corpectomy and plate fixation for postlaminectomy kyphosis. J Neurosurg, 1994; 80(6): 963-970.
4. Haid RW, Foley KT, Rodts GE, Barnes B; The cervical spine study group anterior cervical plate nomenclature. Neurosurgical focus, 2002; 12(1): 1-6.
5. Scholz M, Reyes PM, Schleicher P, Sawa AG, Baek S, Kandziora F, Crawford NR, et al.; A new stand-alone cervical anterior interbody fusion device: biomechanical comparison with established anterior cervical fixation devices. Spine, 2009; 34(2):156-160.
6. Boehler J, Gaudernak T; Anterior plate stabilization for fracture-dislocations of the lower cervical spine. J Trauma, 1980; 20(3): 203-205.
7. Pazdernyik S, Sándor L, Elek P, Barzó P; Anterior cervical fusion on the lower cervical spine: own clinical experience. Ideggyogyaszati szemle, 2010; 63(1-2): 25-37.
8. Rehman L, Akbar H, Das G, Hashim ASM; Anterior Cervical Decompression and Fusion with Caspar Plate Fixation. Journal of the College of Physicians and Surgeons--Pakistan: JCPSP, 2013; 23(4); 257-260.
9. Dietze DD, Fessler RG Jr., Jacob RP; Primary reconstruction for spinal infections. J Neurosurg, 1997; 86(6):981-989.
10. Troyanovich SJ, Stroink AR, Kattner KA, Dornan WA, Gubina I; Does anterior plating maintain cervical lordosis versus conventional fusion techniques? A retrospective analysis of patients receiving single-level fusions. J Spinal Disord Tech, 2002;15(1):69-74.
11. Palepu V, Kiapour A, Goel VK, Moran JM; A unique modular implant system enhances load sharing in anterior cervical interbody fusion: a finite element study. Mio Medical Engineering online, 2014; 13(1):26.
12. Caspar W, Barbier DD, Klara PM; Anterior cervical fusion and Caspar plate stabilization for cervical trauma. Neurosurgery, 1989; 25(4): 491-502.
13. Caspar W, Geisler FH, Pitzen T, Johnson TA; Anterior cervical plate stabilization in one- and two-level degenerative disease: overtreatment or benefit? J Spinal Disord, 1998; 11(1): 1-11.
14. Caspar W, Pitzen T, Papavero L, Geisler FH, Johnson TA ; Anterior cervical plating for the treatment of neoplasms in the cervical vertebrae. J Neurosurg, 1999; 90(1): 27-34.
15. Connolly PJ, Esses SI, Kostuik JP; Anterior cervical fusion: outcome analysis of patients fused with and without anterior cervical plates. J Spinal Disord, 1996; 9(3): 202-206.
16. Kirkpatrick JS, Levy JA, Carillo J, Moeini SR; Reconstruction after multilevel corpectomy in the cervical spine: A sagittal plane biomechanical study. Spine, 1999; 24(12): 1186-1191.
17. Kaiser MG, Haid Jr.RW, Subach BR, Barnes B, Rodts Jr.GE; Anterior cervical plating enhances arthrodesis after discectomy and fusion with cortical allograft. Neurosurgery, 2002; 50(2): 229-238.
18. Ko SB, Lee SW; Result of posterior instrumentation without fusion in the management of thoracolumbar and lumbar unstable burst fracture. J Spinal Disord Tech, 2014; 27(4):189-195.
19. Bridwell KH, Lenke LG, McEnery KW, Baldus C, Blanke K; Anterior fresh frozen structural allografts in the thoracic and lumbar spine. Do they work if combined with posterior fusion and instrumentation in adult patients with kyphosis or anterior column defects? Spine, 1995; 20(12):1410-1418.
20. Bailey RW, Badgley GE; Stabilization of the cervical spine by anterior fusion. J Bone Joint Surg A, 1960; 42: 565-594.
21. Balabhadra RS, Kim DH, Zhang HY; Anterior cervical fusion using dense cancellous allografts and dynamic plating. Neurosurgery, 2004; 54: 1405-1411.
22. Heidecke V, Rainov NG, Burkert W; Anterior cervical fusion with the Orion locking plate system. Spine, 1998; 23: 1796-1802.
23. Lim TH, Kwon H, Jeon CH, Kim JG, Sokolowski M, Natarajan R, Andersson GB, et al; Effect of endplate conditions and bone mineral density on the compressive strength of the graft–endplate interface in anterior cervical spine fusion. Spine, 2001; 26(8): 951-956.
24. Mobbs RJ, Rao P, Chandran NK; Anterior cervical discectomy and fusion: analysis of surgical outcome with and without plating. J Clin Neurosci, 2007; 14: 639-642.
25. Aebi M, Mohler J, Zaech G; Indication, surgical technique, and results of 100 surgically-treated fractures and fracture-dislocations of the cervical spine. Clin Orthop Relat Res, 1986; 203: 244-257.
26. Reindl R, Quellet J, Harvey E; Anterior reduction for cervical spine dislocation. Spine, 2006; 12(6):648-652.
27. Bombart M, Deckart CD. Comparaision sur l´ensemble de la série des resultats de la chirurgie par voie antérieure et postérieure. Rev Chir Orthop, 1984; 70: 533-536.
28. Aebi M, Zuber K, Marchesi D; Treatment of cervical spine injuries with anterior plating. Indications, techniques, and results. Spine, 1991; 16(3): 38-45.
29. Beutler WJ, Sweeney CA, Connolly PJ; Recurrent laryngeal nerve injury with anterior

cervical spine surgery risk with laterality of surgical approach. Spine, 2001; 26(12):1337-1342.
30. Bazaz R, Lee MJ, Yoo JU; Incidence of dysphagia after anterior cervical spine surgery: a prospective study. Spine, 2002; 27(22): 2453-2458.
31. Blauth M, Schmidt U, Dienst M, Knop C, Lobenhoffer P, Tscherne H; Langzeitergebnisse von 57 Patienten nach ventraler interkorporeller Spondylodese der unteren Halswirbelsäule. Der Unfallchirurg, 1996; 99(12): 925-939.
32. RIPA DR, Kowall MG, MEYER Jr. PR, Rusin JJ; Series of ninety-two traumatic cervical spine injuries stabilized with anterior ASIF plate fusion technique. Spine, 1991; 16(3): 46-55.
33. Wang JC, McDonough PW, Endow K, Kanim LE, Delamarter RB, The effect of cervical plating on single-level anterior cervical discectomy and fusion. J Spinal Disord, 1999; 12(6): 467-471.
34. Wang JC, McDonough PW, Endow KK, Delamarter RB; Increased fusion rates with cervical plating for two-level anterior cervical discectomy and fusion. Spine, 2000; 25(1): 41.
35. Schulte K, Clark CR, Goel VK; Kinematics of the cervical spine following discectomy and stabilization. Spine, 1989; 14(10):1116-1121.
36. Vaccaro AR, Balderston RA; Anterior plate instrumentation for disorders of the subaxial cervical spine. Clin Orthop Relat Res, 1997; (335): 112-121.
37. Vaccaro AR, Sahni D, Pahl MA, Harrop JS, Sharan AD, Venger BH, Albert TJ, et al.; Long-term magnetic resonance imaging evaluation of bioresorbable anterior cervical plate resorption following fusion for degenerative and traumatic disk disruption. Spine, 2006; 31(18): 2091-2094.
38. Brodke DS, Klimo P, Bachus KN, Braun JT, Dailey AT; Anterior cervical fixation: analysis of load-sharing and stability with use of static and dynamic plates. J Bone Joint Surg Am, 2006; 88(7): 1566-1573.
39. Bose B; Anterior cervical fusion using Caspar plating: analysis of results and review of the literature. Surg Neurol, 1998; 49(1): 25-31.
40. Bose B; Anterior cervical instrumentation enhances fusion rates in multilevel reconstruction in smokers. J Spinal Disord, 2001; 14(1): 3-9.
41. Omeis I, DeMattia JA, Hillard VH, Murali R, Das K; History of instrumentation for stabilization of the subaxial cervical spine. Neurosurgical focus, 2004; 16(1): 1-6.
42. Lehmann W, Briem D, Blauth M, Schmidt U; Biomechanical comparison of anterior cervical spine locked and unlocked plate-fixation systems. European Spine Journal, 2005; 14(3): 243-249.
43. Cheng NS, Lau PY, Sun LK, Wong NM; Fusion rate of anterior cervical plating after corpectomy. Journal of Orthopaedic Surgery, 2005: 13(3).
44. Johnson MG, Fisher CG, Boyd M, Pitzen T, Oxland TR, Dvorak MF; The radiographic failure of single segment anterior cervical plate fixation in traumatic cervical flexion distraction injuries. Spine, 2004; 29(24): 2815-2820.
45. Yue WM, Brodner W, Highland TR; Long-term results after anterior cervical discectomy and fusion with allograft and plating: a 5- to 11-year radiologic and clinical follow-up study. Spine, 2005; 30(19): 2138-2144.
46. Cabanela ME, Ebersold MJ; Anterior plate stabilization for bursting teardrop fractures of the cervical spine. Spine, 1988; 13(8):888-891.
47. Goldberg G, Albert TJ, Vaccaro AR, Hilibrand AS, Anderson DG, Wharton N; Short-term comparison of cervical fusion with static and dynamic plating using computerized motion analysis. Spine, 2007; 32(13): E371-E375.
48. Morscher EFHS, Sutter F, Jenny H, Olerud S; Anterior plating of the cervical spine with the hollow screw-plate system of titanium]. Der Chirurg; Zeitschrift fur alle Gebiete der operativen Medizen, 1986; 57(11): 702-707.
49. Bolesta MJ, Rechtine GR 2nd, Chrin AM; One- and two-level anterior cervical discectomy and fusion: the effect of plate fixation. Spine J, 2002; 2(3): 197-203.
50. Webster FS, Smiley DP; End result study of a series of operations for herniated intervertebral lumbar discs. Am J Surg, 1960; 99: 27- 32.
51. Van Peteghem PK, Schweigel JF; The fractured cervical spine rendered unstable by anterior cervical fusion. J Trauma, 1979; 19(2):110-114.
52. Hollowell JP, Reinartz J, Pintar FA, Morgese V, Maiman DJ; Failure of synthes anterior cervical fixation device by fracture of Morscher screws: a biomechanical study. Journal of Spinal Disorders & Techniques, 1994; 7(2): 120-125.