Research Article

Misaligned Versus Straight Placement of Anterior Cervical Plates: A Clinical and Radiologic Outcomes Study

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Abstract

Background: In anterior cervical diskectomy and fusion (ACDF), misaligned plates are concerning because of the risk of screw-and-plate failure; however, these plates also hypothetically have the potential for asymmetric micromotion on the facet and uncovertebral joint. The aim of this study was to determine whether misaligned plate placement during ACDF had clinical benefits compared with straight plate placement.

Methods: Postoperative AP radiographs of 128 consecutive patients who underwent ACDF with anterior cervical plate (ACP) fixation were reviewed, and plate alignment was assessed. Patients were separated into control group 1 (straight plates) or group 2 (misaligned plates).

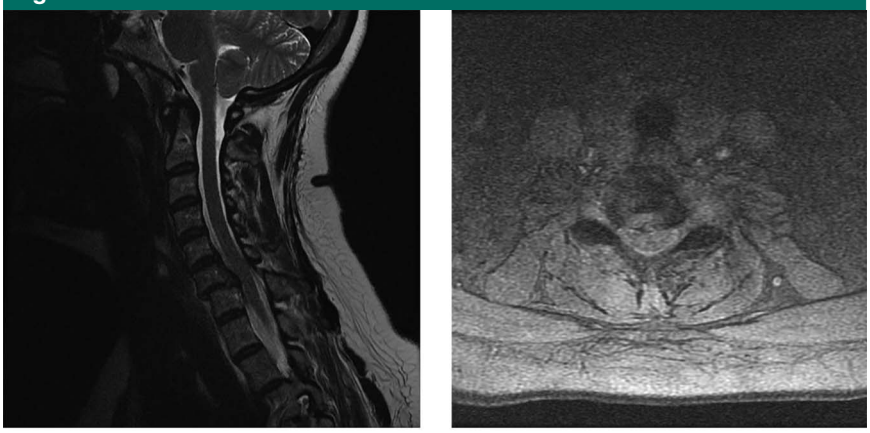
Results: The mean age of patients was 51.5 ± 0.9 years, and women represented 51% of the total population. There was no significant difference between groups with regard to the preoperative visual analog scale (VAS) and Neck Disability Index (NDI) scores (P = 0.744 and P = 0.943, respectively). At 6 weeks postoperatively, the VAS scores for group 1 decreased from 7.6 ± 0.2 to 4.0 ± 0.2 compared with the scores in group 2, which decreased from 7.7 ± 0.2 to 2.1 ± 0.1, which demonstrated statistical significance (P = 0.019). At 2-year follow-up, no significant difference was demonstrated between the groups' VAS and NDI scores (P = 0.670 and P = 0.266).

Conclusion: Misaligned plates have increased torsional strength and are associated with better clinical outcomes compared with those of straight plates in the early postoperative period. After fusion, no significant difference in clinical outcomes between the groups was noted, which may reduce the concerns regarding misaligned plates.

Level of Evidence: Retrospective comparative study

Anterior cervical diskectomy and fusion (ACDF) with anterior cervical plate (ACP) fixation is valuable in the management of disk herniation and cervical spondylosis.[1-6] The use of ACPs has been shown to improve the overall rate of fusion after ACDF because of the additional stability that the plates provide.[3,7,8] Ball et al[9] described proper plate placement, including plate size and screw placement and position, with the use of Kirschner wires and lateral radiographs. Biomechanical studies

Figure 1



A B

Sagittal (**A**) and axial (**B**) magnetic resonance images demonstrating disk herniation at C6-7 and retrolisthesis at C7.

have demonstrated equivalent and better strength with misaligned plate placement compared with neutral (ie, straight) plate placement.[10,11]

Although studies have validated the use of ACP fixation[3,12] along with their modes of failure, few studies have addressed the effect that plate alignment has on complications, fusion rates, and patient-reported outcomes. Surgeons are motivated to align plates in a straight position to satisfy patients who may feel concerned when they see misaligned plates on their postoperative radiographs.[13]

To our knowledge, there has been one clinical study demonstrating an effort to centralize plates in the coronal plane.[13] A recent biomechanical study showed evidence that angulation provides cervical plates with the capability to withstand more torsional load.[11] We measured the degree of angulation and offset distance from the midline in relation to adjacent pedicles and spinous process using the cervical plates as the midline. Our aim was to determine the correlation between plate alignment and postoperative outcomes on the basis of these measurements, with the purpose of determining whether the concerns about misaligned ACPs were clinically justified.

Methods

Institutional Review Board approval was obtained for the study as part of a cohort population at our institution. In our prospective study, we reviewed the medical records of 128 patients who underwent instrumented ACDF (Arena-C, SpineFrontier) in the outpatient setting; fusion was reinforced with an ACP (Inset, SpineFrontier) placed at one or two levels. Fusion was aided by the use of demineralized bone matrix (DBMPure MICRO, SpineFrontier). Surgery was considered only after a failed 6-week course of nonsurgical management. Indications for surgery included chronic neck pain with or without radiculopathy, cervical spondylosis, degenerative disk disease, or herniated nucleus pulposus (Figure 1).

All procedures were performed by a single surgeon (K.R.C.) from 2010 to 2014, with a 2-year follow-up. The total number of levels operated on was 160; 96 one-level and 32 two-level procedures were performed. Two cohort groups were created based on measurements made on AP radiographs; a control group of 64 patients with straight plate alignment (group 1) and 64 patients with misaligned ACPs (group 2). Plates had variable angles (range, 5° to 19°) that were designed to allow consistent placement of 12- to 14-mm long screws through the cortical end plate.

Technique for Measuring Anterior Cervical Plate Alignment

A horizontal line was drawn connecting the superior surface of each pedicle above or below the ACP, depending on which pedicle was more clearly visible on the radiograph (Figure 2). To confirm that the radiograph was a true AP view, a vertical line was drawn through the uncovertebral joints at 90° ± 1° to the horizontal line (ie, angle function). A line that was drawn through the vertical axis of the spinous processes above and below the ACP was labeled the midline. A vertical line bisecting the long axis of the ACP was then drawn (ie, Cobb angle function). The degree of angulation of the ACP vertical axis line from the midline was measured using Cobb angles with the RadiAnt Dicom software V1.9.4 (Medixant). The distance of translation of the center of the ACP from the midline was then measured. ACP position parameters were defined as misaligned when they were (1) offset or shifted from the midline by ≥5 mm, (2) angulated away from the midline by >20°, or (3) a combination of both (Figure 3).

We assessed intragroup and intergroup outcomes preoperatively and postoperatively. We also conducted a subgroup analysis of patients who had evidence of fusion on AP and lateral views at 6-month and 2-year follow-ups to determine the effect of

plate alignment on fusion and outcomes. Exclusion criteria included acute severe trauma, fracture, malignancy, infection, unstable chronic medical illnesses, prior anterior cervical fusion or total disk arthroplasty, posterior cervical procedures, and a body mass index (BMI) >42 kg/m^2.[14] Patient-reported outcomes included preoperative and postoperative visual analog scale (VAS) and Neck Disability Index (NDI) scores. Instrumentation-related complications, such as screw back out or broken screws, were considered implant failure.

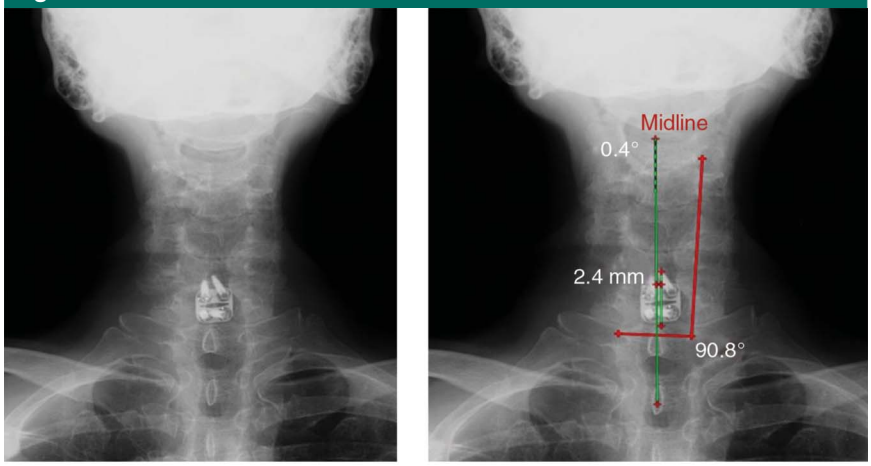
Statistical Analysis

A power analysis performed on the primary outcome of VAS scores demonstrated that a total sample size of 102 patients was required to verify statistical difference, with a power of 0.8 and $\alpha = 0.05$.[11,15] Values are expressed as mean ± standard error. Quantitative comparisons were made using the Student *t*-test. Data were analyzed using the SPSS statistical software version 22 (IBM). Tests were considered significant when $P < 0.05$. Correlational analysis was conducted using linear regression and analysis of variance (ANOVA) to assess for the dependence and significance of plate alignment and how it affects the overall outcome.

Results

The overall mean age of the study participants was 51.5 ± 0.9 years, and women represented 51% of the total patient population. A total of 160 spinal levels were treated; 96 one-level and 32 two-level procedures were performed. Group 1 consisted of 44 single-level procedures and 18 two-level procedures, whereas group 2 consisted of 52 single-level procedures and 14 two-level procedures ($P = 0.371$). There was no intergroup significance demonstrated between age and BMI ($P = 0.388$ and $P = 0.526$, respectively). Patient demographics are presented in Table 1.

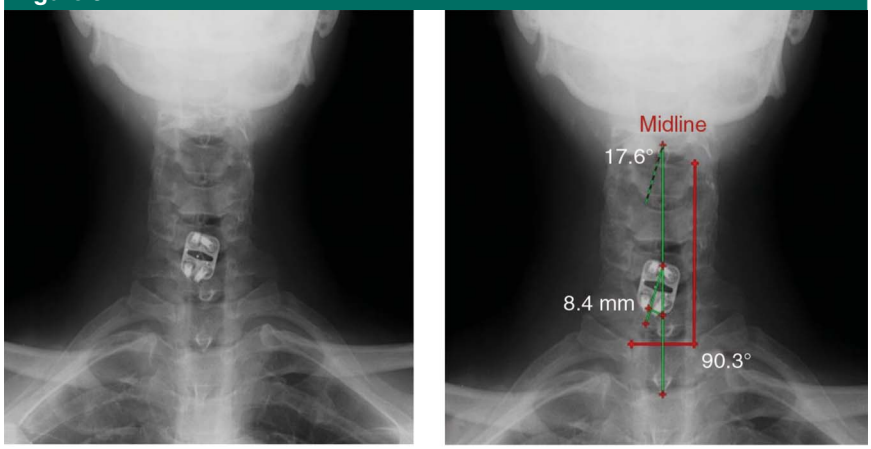
Figure 2



A B

AP radiograph of the cervical spine demonstrating straight placement of the anterior cervical plate (ACP) before (**A**) and after (**B**) plate alignment was measured. The red lines demonstrate confirmation of a true AP view via a vertical line drawn through the uncovertebral joints at 90° ± 1° to the horizontal line (angle function). The green line with black dashes demonstrates the vertical axis through the spinous processes above and below the ACP. The green vertical line demonstrates bisection of the long axis of the ACP (Cobb angle function).

Figure 3



A B

A, AP radiograph of the cervical spine demonstrating the placement of a misaligned anterior cervical plate. **B**, AP radiograph of the cervical spine demonstrating measurements used to assess plate alignment. The red lines demonstrate confirmation of a true AP view via a vertical line drawn through the uncovertebral joints at 90° ± 1° to the horizontal line (angle function). The green line with black dashes demonstrates the vertical axis through the spinous processes above and below the ACP. The green vertical line demonstrates bisection of the long axis of the ACP (Cobb angle function).

Table 1

Patient Demographics

Variable	Group 1	Group 2
Age (yr)	51 ± 1	52 ± 1
BMI (kg/m^2)	26.2 ± 0.9	26.9 ± 0.6
Female	38	27
Male	26	37
Pathological level		
C3-C4	4	5
C4-C5	17	18
C5-C6	29	31
C6-C7	30	24
C7-T1	0	2
Diagnosis		
Herniated disk	17	13
Degenerative disk disease	15	18
Spondylosis (chronic pain)	22	19
Myelopathy	3	5
Radiculopathy	7	9

BMI = body mass index

Table 2

Outcomes in Patients With Straight Versus Misaligned Plates

Outcomes	Group 1	Group 2	Intergroup *P* Value
VAS			
Preoperative	7.6 ± 0.2	7.7 ± 0.2	0.744
6 wk postoperative	4.0 ± 0.2	2.1 ± 0.1	0.019
6 mo postoperative	4.4 ± 0.2	4.1 ± 0.1	0.255
2 year postoperative	4.0 ± 0.2	3.9 ± 0.2	0.670
NDI			
Preoperative	47.7 ± 3.1	45.4 ± 2.6	0.943
6 wk postoperative	36.7 ± 0.8	31.9 ± 0.7	0.071
6 mo postoperative	27.9 ± 0.3	26.4 ± 0.4	0.798
2 year postoperative	20.8 ± 0.3	19.4 ± 0.3	0.266

NDI = Neck Disability Index, VAS = visual analog scale

Functional Outcomes

Each group had 64 patients, and the outcomes were assessed preoperatively and at 6 weeks, 6 months, and 2 years postoperatively. Preoperatively, group 1 had a mean VAS score of 7.6 ± 0.2 and a mean NDI score of 47.7 ± 3.1, whereas group 2 had a mean VAS score of 7.7 ± 0.2 and a mean NDI score of 45.4 ± 2.6, demonstrating no significant difference in these scores between the two groups (P = 0.744 and P = 0.943, respectively).

We compared the postoperative VAS and NDI scores at 6 weeks, 6 months, and 2 years. In group 1, the VAS scores decreased from a mean of 7.6 ± 0.2 preoperatively to a mean of 4.0 ± 0.2 at 6 weeks postoperatively. In group 2, the mean preoperative VAS score decreased at 6 weeks postoperatively (7.7 ± 0.2 preoperatively to 2.1 ± 0.1 at 6 weeks; P = 0.019). The mean NDI scores for group 1 decreased from 47.7 ± 3.1 preoperatively to 36.7 ± 0.8 at 6 weeks postoperatively, and in group 2, the mean NDI scores decreased from 45.4 ± 2.6 preoperatively to 31.9 ± 0.7 at 6 weeks postoperatively (P = 0.071; Table 2). The decrease in mean VAS scores at 6 weeks postoperatively shows that there was significant improvement from the preoperative VAS scores in the patients with misaligned plates. The difference in NDI scores at 6 weeks postoperatively between the groups approached statistical significance.

At 6-month follow-up, 123 of 128 patients (96%) had postoperative radiographs. Of these 123 patients, all showed radiographic evidence of fusion. A total of 62 patients in group 1 and 61 patients in group 2 achieved fusion. There was no significant difference between the groups with regard to mean VAS and NDI scores at 6 months postoperatively. In group 1, the mean VAS and NDI scores were 4.4 ± 0.2 and 27.9 ± 0.3, respectively, compared with the mean VAS and NDI scores in group 2, which were 4.1 ± 0.1 and 26.4 ± 0.4, respectively (VAS, P = 0.255; NDI, P = 0.798; Table 2).

At final 2-year follow-up, radiographs for 120 patients were available for evaluation. All of these patients had radiographic evidence of fusion (60 patients in group 1 and 60 patients in group 2). In group 1, the mean VAS score decreased from 7.6 ± 0.2 preoperatively to 4.0 ± 0.2 at 2 years postoperatively ($P < 0.001$). The mean NDI score decreased from 47.7 ± 3.1 preoperatively to 20.8 ± 0.3 at 2 years postoperatively ($P < 0.001$). In group 2, the mean VAS

score decreased from 7.7 ± 0.2 preoperatively to 3.9 ± 0.2 at 2 years postoperatively ($P < 0.001$), and the mean preoperative NDI score decreased from 45.4 ± 2.6 preoperatively to 19.4 ± 0.3 at 2 years postoperatively ($P < 0.001$). Results demonstrate that improvement in outcome scores was significant in both groups. No intergroup significance between VAS and NDI scores was noted at 2-year follow-up ($P = 0.670$ and $P = 0.266$, respectively; Table 2). The intergroup results demonstrate that patients with misaligned plates had better clinical improvement than did patients with straight plates in the early postoperative period, but there was no significant difference in clinical improvement between the two groups after fusion was achieved.

We determined plate alignment by using the previously described technique, which was initially outlined in an earlier biomechanical study.[11] To investigate and statistically confirm whether plate alignment was dependent on the variables of angle and translation, we performed a correlation analysis using linear regression. Results showed a correlation coefficient of $r = 0.827$ and ANOVA significance of $P < 0.001$, which demonstrates that alignment was highly dependent on plate angle and translation and was statistically significant. After verifying the method used to determine plate alignment, we then performed an analysis to establish whether functional outcomes were dependent on plate alignment ($r = 0.522$; ANOVA significance, $P = 0.001$). This confirms functional outcomes are determined by alignment.

Complications

Complications are listed in Table 3. Postoperative dysphagia, which was defined as discomfort or difficulty with swallowing that was not present before surgery, was the main complication experienced in both groups. Severity was assessed over the initial 3-month postoperative period using the Bazaz-Yoo dysphagia severity scale[16] (Table 4). Mild, transient dysphagia occurred in both groups (five patients in group 1, six patients in group 2), with the longest period lasting 6 weeks and with no intergroup significance ($P = 0.753$). Patients with intractable pain had no additional major surgical procedures and were treated with steroid injections.

Table 3

Complications Associated With Anterior Cervical Plate Alignment

Complication	Group 1	Group 2
Dysphagia	5	6
Pain not relieved by TTH medications	3	1
Dressing completely soaked	1	2
Intractable pain	1	2

TTH = to take home

Table 4

Bazaz-Yoo Dysphagia Severity Scale[16]

Severity	Difficulty Swallowing Liquids	Difficulty Swallowing Solids
None	None	None
Mild	None	Rare
Moderate	None or rare	Occasionally (only with specific food)
Severe	None or rare	Frequent (most solids)

Follow-up

Neutral and flexion-extension spinal radiographs were evaluated by the authors (K.R.C., F.J.R.P., E.A.H.) for graft subsidence, implant failure, and the status of fusion at 6-month and 2-year follow-up. Fusion was defined as <1 mm of motion on plain radiographs, including flexion and extension views[17] (Figure 4). No evidence of implant failure or signs of nonunion in the groups was noted during the early and 2-year follow-up period.

Discussion

Since the introduction of ACPs in the 1980s,[18,19] the use of these plates with ACDF has become popular. Instinctively, surgeons strive to achieve straight and centered plate placement during implantation;[13] however, in reality, substantial variability in alignment exists. Perfectly centered or straight alignment of plates is sometimes sacrificed because of the poor quality of bone at the preferred site for screw drilling, but the tendency to sacrifice plate alignment for plate stability is less acceptable when it causes the plate to infringe on the adjacent nonfused disk space.[2]

In addition to the effect of poor bone quality on straight plate positioning, local anatomy commonly used as intraoperative landmarks,

Figure 4

A B C

Postoperative neutral (**A**), flexion (**B**), and extension (**C**) plain radiographs of the cervical spine obtained at 2-year follow-up demonstrating stability at C6-7.

such as the orientation of the uncovertebral joints, is frequently disrupted because of the spondylotic process.[2] The effect of plate alignment on implant failure rates and patient-reported outcomes has not been extensively reported in the literature to date. Ipsen et al[2] found that there was a minimal relationship between plate angulations or lateralization and postoperative outcomes. Although these results are reassuring, the authors based their conclusions on the assessment of final outcomes at an average follow-up period. We chose to look at a cohort of patients with straight and misaligned ACPs, and examined radiographs and compared the outcomes (ie, VAS and NDI scores) at 6 weeks, 6 months, and 2 years with the same parameters documented at the preoperative visit.

A recent biomechanical study was conducted to assess patterns of device failure between straightly aligned and misaligned ACPs (both straight and aligned plates shifted by 5 mm and were angulated at 20° from the midline).[11] The results suggested that shorter plates and misaligned plates had more torsional strength at the screw-bone interface than did longer plates with straight alignment. Our study focused on the effect of plate alignment on clinical and functional outcomes in single-level and two-level cervical fusions. We found that plate misalignment did not have a negative effect on implant stability (eg, no screw back-out or implant failure) or patient-reported outcomes. In the early postoperative period, patients with a misaligned plate showed a statistically significant decrease in neck VAS scores compared with the scores of patients with an aligned plate. This study clinically confirms the results of a previous biomechanical study that showed that misaligned plates gave additional torsional strength, which may contribute to less micromotion and decreased pain in the early postoperative period while the vertebrae are undergoing the fusion process.[11] Fusion rates were not affected by plate alignment.

The main strength of this study is the adequate sample size. The outcomes assessed include patient factors (eg, age, sex, BMI) and surgeon factors (ie, a single surgeon performed the procedures, decreasing the variability of the technique of placement), which were independently analyzed. Limitations of this study include the fact that it was a single-surgeon investigation. This study was also a retrospective review of prospectively collected data from two cohort populations. We acknowledge the variations of diagnosis in each group; however, each cohort had a similar number of patients with each diagnosis. Because the data were collected prospectively, the number of patients required in each group to achieve statistical significance was determined based on power analysis.

Conclusion

This study has demonstrated that early (6-week) patient outcomes are statistically dependent on plate alignment. We have also confirmed the findings of a recent biomechanical study[11] by demonstrating that misaligned ACPs resulted in significantly improved clinical outcomes in the early postoperative period with no change noted after fusion is achieved. After fusion was achieved, the outcomes in patients

with straight or misaligned plates were equivalent.

References

Evidence-based Medicine: Levels of evidence are described in the table of contents. In this article, references 12, 14, 16, and 17 are level III studies. References 1, 2, 4-7, 9, 13, 18, and 19 are level IV studies. Reference 3 is level V expert opinion.

References printed in **bold type** are those published within the past 5 years.

1. Smith GW, Robinson RA: The treatment of certain cervical-spine disorders by anterior removal of the intervertebral disc and interbody fusion. *J Bone Joint Surg Am* 1958;40(3):607-624.
2. Ipsen BJ, Kim DH, Jenis LG, Tromanhauser SG, Banco RJ: Effect of plate position on clinical outcome after anterior cervical spine surgery. *Spine J* 2007;7(6):637-642.
3. Scherping SC Jr: Anterior cervical discectomy and fusion: Role of anterior plate fixation in degenerative cervical disorders. *Semin Spine Surg* 2004;16:35-41.
4. Goldberg G, Hilibrand A: Anterior cervical discectomy and fusion. *Oper Tech Orthop* 2003;13:188-194.
5. Cloward RB: The treatment of ruptured lumbar intervertebral discs by vertebral body fusion: I. Indications, operative technique, after care. *J Neurosurg* 1953;10 (2):154-168.
6. Bailey RW, Badgley CE: Stabilization of the cervical spine by anterior fusion. *J Bone Joint Surg Am* 1960;42:565-594.
7. Wang JC, McDonough PW, Endow KK, Delamarter RB: Increased fusion rates with cervical plating for two-level anterior cervical discectomy and fusion. *Spine (Phila Pa 1976)* 2000;25(1):41-45.
8. Wang JC, McDonough PW, Kanim LE, Endow KK, Delamarter RB: Increased fusion rates with cervical plating for three-level anterior cervical discectomy and fusion. *Spine (Phila Pa 1976)* 2001;26(6): 643-647.
9. Ball PA, Benzel EC, Baldwin NG: A simple method to ensure proper screw position and plate size selection using the Morscher cervical spine locking plate: Technical note. *J Neurosurg* 1994;80(4):748-749.
10. **Lawrence BD, Patel AA, Guss A, Ryan Spiker W, Brodke DS: Malaligned dynamic anterior cervical plate: A biomechanical analysis of effectiveness. *Spine (Phila Pa 1976)* 2014;39(25):2057-2061.**
11. **Chin KR, Cumming VB, Henson M, Murrell B, Chan FW: Effects of misalignment on static torsional strength of anterior cervical plate systems. *Spine J* 2013;13(11):1544-1548.**
12. Samartzis D, Shen FH, Lyon C, Phillips M, Goldberg EJ, An HS: Does rigid instrumentation increase the fusion rate in one-level anterior cervical discectomy and fusion? *Spine J* 2004;4(6):636-643.
13. Chin KR, Stieber JR, Mehta S, Cohen JD, Auerbach JD: The manubrium as an external guide for centralizing anterior cervical plates: Technique tips and initial experience. *Spine (Phila Pa 1976)* 2010;35 (7):E244-E247.
14. **Chin KR, Pencle FJ, Coombs AV, Packer CF, Hothem EA, Seale JA: Eligibility of outpatient spine surgery candidates in a single private practice. *Clin Spine Surg* 2016; March 17 [Epub ahead of print].**
15. Carneiro AV: Estimating sample size in clinical studies: Basic methodological principles. *Rev Port Cardiol* 2003;22(12): 1513-1521.
16. Bazaz R, Lee MJ, Yoo JU: Incidence of dysphagia after anterior cervical spine surgery: A prospective study. *Spine (Phila Pa 1976)* 2002;27(22):2453-2458.
17. **Rhee JM, Chapman JR, Norvell DC, Smith J, Sherry NA, Riew KD: Radiological determination of postoperative cervical fusion: A systematic review. *Spine (Phila Pa 1976)* 2015;40(13):974-991.**
18. Böhler J, Gaudernak T: Anterior plate stabilization for fracture-dislocations of the lower cervical spine. *J Trauma* 1980;20(3): 203-205.
19. Caspar W, Barbier DD, Klara PM: Anterior cervical fusion and Caspar plate stabilization for cervical trauma. *Neurosurgery* 1989;25(4):491-502.