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The Utility of Postoperative Bracing on Radiographic and Clinical Outcomes Following Cervical Spine Surgery: A Systematic Review

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Abstract

Study Design: Systematic Review

Objectives: To determine the radiographic and clinical utility of postoperative orthoses following cervical spine surgery.

Methods: We performed a search of the PubMed, Cochrane Library, Medline Ovid, and SCOPUS databases from inception until November 2021. Eligible studies included outcomes of postoperative bracing vs no bracing following cervical spine surgery. The primary outcome of interest was fusion rates after cervical surgery in braced vs unbraced patients. Secondary outcomes included patient reported outcomes and complication rates.

Results: A total of 3232 titles were initially screened. After inclusion criteria were applied, 7 studies (550 patients) were included, which compared results of braced vs unbraced patients after cervical spine surgery. These studies showed acceptable reliability for inclusion based on the Methodical Index for Non-Randomized studies and Critical Appraisal Skills Programme assessment tools. There were no significant differences in fusion rates or complications between braced vs unbraced patients identified in any study. Patient reported pain and quality of life measures between braced and unbraced groups varied amongst studies, without any clear overall advantages favoring either method.

Conclusions: This systematic review found that external bracing, though widely used following cervical spine surgery, may not offer any advantages in patient-reported outcomes, as compared to not bracing. In regard to the effect of bracing on fusion rates, no strong consensus can be made as the methods of fusion assessment in the included studies were heterogenous and suboptimal. Future high-quality studies using recommended methods of fusion assessment are needed to adequately address this important question.

Keywords
spine, surgery, cervical, brace, collar, fusion rates, outcomes, complications

Introduction

Cervical spine surgery is commonly performed for cervical pathology such as myelopathy or radiculopathy after failure of conservative treatment. The goal of surgery is often decompression of neurologic elements and stabilization of vertebral segments, accomplished through spinal instrumentation and fusion. Historically, postoperative bracing was considered an adjunct to protect fixation and provide additional stability.

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Advocates of bracing argue that bracing aids in reducing postoperative pain, improves fusion rates and enhances overall outcomes.[1] However, recent studies have questioned the overall utility of postoperative bracing after spinal surgery. In the lumbar spine literature for example, the overall evidence to support bracing is unclear and it has been suggested that postoperative bracing may offer no significant benefit following lumbar degenerative disease surgery.[2] Additionally, postoperative bracing poses numerous risks such as skin breakdown, airway concerns, dysphagia, and hygiene difficulties.[3]

Bracing after spine surgery is controversial and practice patterns often vary from surgeon to surgeon.[4] Bible et al[4] performed a questionnaire study of 98 spine surgeons to assess bracing patterns following cervical and lumbar spine surgery for degenerative pathology. They found that 63% of surgeons routinely utilized postoperative bracing after cervical spine surgeries, as compared to 46% after lumbar procedures. Additionally, they found that 55% of surgeons used bracing after single-level anterior cervical procedures, and this increased to 76% after multi-level anterior-cervical surgery. They reported that most surgeons tended to utilize bracing for 3-8 weeks postoperatively.

The purpose of this systematic review was to comprehensively review the available literature evaluating postoperative bracing following cervical spine surgery. Specifically, we sought to evaluate whether postoperative bracing has any impact on fusion rates as well as clinical outcomes such as pain and function. Our hypothesis was that postoperative bracing does not influence outcomes.

Materials and Methods

Search Strategy

We conducted a systematic review of the literature in accordance with the Cochrane Handbook for Systematic Reviews,[5] and followed the reporting standards set forth by the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines.[6] The PubMed, SCOPUS, Medline OVID and Cochrane databases were searched by two independent reviewers in duplicate, from inception until November 2021. The exact search terms used, and the results produced from each database can be seen in Appendix A.

Study Screening

Two independent reviewers assessed all titles and abstracts, and then conducted a full-text analysis of all relevant articles to determine final study eligibility for inclusion. A disagreement at any stage was resolved with discussion amongst the reviewers, and ultimately resolved by a senior author. A final consensus was reached for all articles.

Assessment of Study Eligibility

The inclusion and exclusion criteria for study eligibility was determined *a priori*. Inclusion criteria were studies (1) in English, (2) in adults (age ≥18), and (3) specifically reported on outcomes in patients who were braced or immobilized postoperatively after cervical spine surgery compared to patients who were not. Any type of cervical bracing method was considered for inclusion. Any nonclinical studies, opinion papers, and reviews of the literature were excluded. The primary outcome of interest was differences in fusion rates between the braced vs unbraced groups. Secondary outcomes of interest included differences in patient reported outcome measures or differences in complications between the two groups.

Assessment of Study Quality

All studies that were included in the final analysis were independently assessed by two reviewers to determine overall quality and risk for bias. Non-randomized controlled studies were assessed using the Methodical Index for Non-Randomized Studies (MINORS)[7] tool. This validated instrument uses 12 measures to grade comparative studies, and 8 measures to grade non-comparative studies. Each measure is given a response of not reported (0 points), reported but inadequate (1 point), or reported adequately (2 points). All randomized controlled trials were graded using the Critical Appraisal Skills Programme (CASP)[8,9] checklist. This instrument does not give a numeric score, but rather gives an overall assessment of study quality. Studies which met the majority of this tools criteria were considered acceptable.

Data Abstraction and Statistical Analyses

The demographic information of each included study was recorded including authors, year of publication, study type, number of participants, pathology, surgery type, and collar type. Results that compared outcomes on healing or fusion rates between the braced compared to unbraced groups was recorded, as well as the results of patient reported outcomes and any complications that were identified. When available, data on how and when fusion status was assessed, who assessed the fusions in each study, and how and when patients were randomized was also collected.

To ensure adequate inter-observer agreement between reviewers at each stage of the systematic review, a Kohen's kappa (κ) coefficient[10] was utilized. The overall strength of agreement between the two reviewers was stratified using κ = .01-.20 indicating slight agreement; κ = .21-.4 indicating fair agreement; κ = .41-.6 indicating moderate agreement; κ = .61-.8 indicating substantial agreement and κ >.8=indicating almost perfect agreement.

Results

Study Identification

An initial search of all 4 databases yielded 3232 studies, of which, 605 duplicates were identified and removed, which left 2627 unique records to be analyzed. After a review of all titles and abstracts, 2574 records were eliminated, leaving 53 articles. These 53 articles were thoroughly assessed via full-text review, and 45 were subsequently excluded as they did not meet all inclusion criteria. This left 7 studies[11–17] (total 550 patients) which met all inclusion criteria and were used in this analysis (Figure 1). There was a Cohen's kappa (k) coefficient > .8 between reviewers on final study eligibility. All studies were deemed appropriate for inclusion after risk of bias assessments, also with a Cohen's kappa (k) coefficient > .8 between reviewers. Table 1 provides a comprehensive review of the demographics of the included studies. Please see Table 2 for a detailed review of the fusion techniques and assessment methods of included studies. Table 3 documents treatment and diagnosis modalities, as well as outcome assessments used in each study. Finally, Table 4 provides the pertinent results of included studies regarding braced vs unbraced patients after cervical spine surgery.

Anterior cervical discectomy and fusion

A total of four articles[12–15] reported on the utility of post-operative bracing following ACDF. Overley et al[12] analyzed outcomes in 44 patients who underwent single or two-level ACDF for degenerative cervical myelopathy or radiculopathy. All patients were fused with corticocancellous allograft and anterior plating. The average age of unbraced patients was 50 (±9.79) years, and the average age of braced patients was 55 (±11.72) years. Half of the patients in the study were not

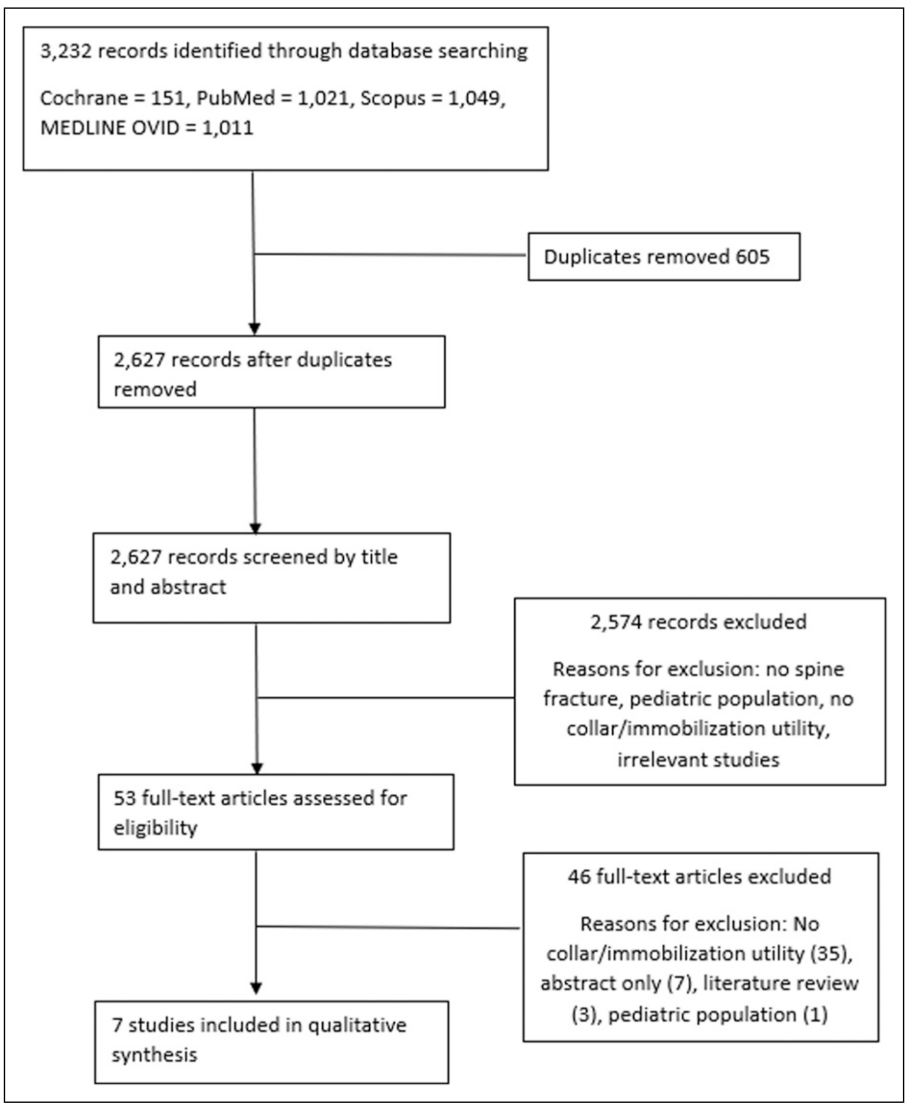

Figure 1. Flowchart of selected studies.

Table 1. Demographics of Included Studies.

Author	Year	Study Type	N (Braced)	N (Unbraced)	Average Age (Years ± SD)	Bias Quality Tool	Bias Conclusion
Overley et al	2016	Prospective RCT (preoperative randomization)	22	22	Braced = 55.21 ± 11.72 Unbraced = 40.15 ± 9.79	CASP	Acceptable
Scerrati et al	2019	Retrospective Comparative Study	36	36	Braced = 48 ± unreported Unbraced = 48 ± unreported	MINORS	(24/24) Acceptable
Abbott et al	2013	Prospective RCT (preoperative randomization)	17	16	Braced = 53.4±13 Unbraced = 47.4±11	CASP	Acceptable
Campbell et al	2009	Randomized Controlled Pilot Trial (bracing not randomized)	149	108	Braced = 44.3 ± 8.8 Unbraced = 43.3 ± 9.0	CASP	Acceptable
Cheung et al	2019	Randomized Clinical Trial (preoperative randomization)	16	19	Braced = 61.7 ± 14.3 Unbraced = 67.2 ± 11.4	CASP	Acceptable
Hida et al	2017	RCT (preoperative randomization)	39	35	Braced = 72.0 ± 8.7 Unbraced = 71.6 ± 9.6	CASP	Acceptable
Duetzmann et al	2015	Single-blinded Randomized Controlled Trial (pre and postoperative randomization)	15	15	Braced = 57 ± unreported Unbraced = 55 ± unreported	CASP	Acceptable

Abbreviations: RCT, Randomized Control Trial; CASP, Critical Appraisal Skills Programme; MINORS, Methodological Index for Non-Randomized Studies.

Table 2. Anterior Cervical Discectomy and Fusion Fusion Technique and Assessment in Included Studies.

Author	Surgeon Criteria	Surgery Technique	Fusion Assessment	Fusion Assessor	Time Points Assessed
Overley et al	Not reported	Corticocancellous allograft+anterior plating	CT scan to assess marginal trabecular bone	Blinded independent neuroradiologist	1 year postoperatively
Scerrati et al	Senior author performed all surgeries	PEEK interbody	AP, lateral, flexion/extension radiographs. Assessing bridging trabecular bone	Not reported	1, 6, 12 months postoperatively
Abbott et al	Not reported	Interbody cage	Lateral radiographs with flexion/ extension. Assessing qualitative interbody motion	Radiologist and neurosurgeon (unclear if operative surgeon)	3 months postoperatively
Campbell et al	Not reported	Allograft and anterior plating	AP, lateral, flexion/extension radiographs. Assessing bridging trabecula, lack of lucency around graft, angulation less than 4 degrees dynamically	2 independent blinded radiologists, 3rd was used if needed	6, 12, 24 months postoperatively

Abbreviations: ACDF, anterior cervical discectomy and fusion; CT, computerized tomography; PEEK, polyetheretherketone.

braced postoperatively, and the other half of the patients were braced postoperatively with a semi-rigid cervical brace (Miami-J) for 6 weeks. Patients were preoperatively randomized to the braced vs unbraced groups. It is not reported whether one or multiple surgeons performed the operations. In regards to assessing fusion status, computed tomography (CT) scans were performed 1 year postoperatively in all patients, with no statistically significant differences found in fusion rates between the two groups (P = .37). The authors defined fusion as the presence of marginal trabecular bone from endplate to endplate at the operative level/s. Fusion was assessed by a blinded and independent neuroradiologist. The unbraced group had a 97% fusion rate, while the braced group had an 89% fusion rate. When analyzing patient reported outcomes with the Neck Disability Index (NDI), the unbraced group had better scores two weeks postoperatively (17.14 ±11.52) compared to the braced group (26.23±11.05, P = .0285). The minimum clinically important difference (MCID) in NDI scores amongst cervical fusion patients is often accepted at 7.5.[18] However, there were no differences at long-term follow up. Additionally, the authors reported no difference in complications or reoperation rates between braced and

Table 3. Disease Diagnosis, Treatment Modalities and Outcome Assessments of Included Studies

Author	Pathology / Diagnosis	Treatment	Outcome Assessment	Type of Immobilization	Complications
Overley et al	Radiculopathy or myelopathy	Single and two-level ACDF	NDI; fusion rates, subsidence rates	Cervical brace	No difference in complication rates (one symptomatic nonunion in each group requiring revision)
Scerrati et al	Radiculopathy, myelopathy, or cord compression	Single and two-level ACDF	NDI; fusion rates	Cervical collar	No reported complications
Abbott et al	Cervical spondylosis; disc herniations; degenerative disc disease	Single and two-level ACDF	Fusion rates; pain intensity; sitting CROM; unipedal standing balance test; NDI; SF-36	Rigid cervical collar	Not reported
Campbell et al	Single-level radiculopathy or myelopathy	Single level ACDF	Fusion rates; SF-36; NDI; numeric pain scores	Hard or soft cervical collar	Not reported
Cheung et al	Cervical myelopathy	Single door laminoplasty	CROM; VAS; NDI; SF-36; MJOA score	Rigid cervical collar	No reported complications
Hida et al	Cervical myelopathy	Double-door laminoplasty	VAS; JOA score; SF-36; CROM; lordotic angle	Philadelphia Collar	No difference in complication rates
Duetzmann et al	Degenerative conditions of the cervical spine	Posterior single and multi-level cervical fusions with or without decompression	VAS; Number of pain pills taken during 30-day postoperative period	Clavicle brace	One braced patient developed fascial dehiscence

Abbreviations: ACDF, Anterior Cervical Discectomy and Fusion; CT, Computed Tomography; CROM, Cervical Range of Motion; VAS, Visual Analog Scale; SF-36, Short Form Health Survey; NDI, Neck Disability Index; JOA, Japanese Orthopaedic Association; MJOA, Modified Japanese Orthopaedic Association.

unbraced patients following ACDF. The authors ultimately conclude that cervical bracing offers no advantage at long-term follow up after 1 or 2-level ACDF.

Scerrati et al[13] reported on a case series 72 patients who underwent single or two-level ACDF for degenerative cervical radiculopathy, myelopathy or cord compression. Half of their patients were braced using a cervical collar (Schanz) postoperatively, and the other half of patients were not braced postoperatively. Notably, this was not a prospective study, and no randomization was performed. All patients underwent surgery by the same senior author, and all received the same polyetheretherketone (PEEK) interbody fusion construct. Those who were in the collar group were instructed to wear the collar for 4 weeks. In regards to fusion status, patients were assessed postoperatively with upright radiographs at 1, 6 and 12 months after surgery, including AP, lateral and flexion/extension films. The authors defined fusion as having bridging trabecular bone connecting the adjacent vertebral bodies, either anterior/posterior, lateral, or through the interbody device. Notably, it is not reported on who assessed fusions in this study. No statistically significant differences in fusion rates between the two groups was found at any time interval. The braced group had 5 patients (13.9%) with incomplete fusions, while the unbraced group had 8 (22.2%) patients with incomplete fusions (P = .54) at final follow up. Of note, the authors state they are likely underpowered to detect small differences between groups. Additionally, no significant differences existed between the two groups with respect to the NDI at any time point after surgery. The authors reported that none of their patients had postoperative complications. Ultimately, they recommended against routinely using cervical bracing after 1 or 2-level ACDF.

Abbott et al[14] examined 33 patients who underwent 1 or 2-level ACDF with interbody cage in the treatment of degenerative cervical spondylosis, disc herniations, or degenerative disc disease in this randomized control pilot study. Their study included an unbraced group of 16 patients, as well as a group of 17 patients who were instructed to wear a rigid cervical collar (Philadelphia) for 6 weeks during the daytime postoperatively. Patients were randomized to the collar or unbraced groups prior to surgery. It is not reported whether one or multiple surgeons performed the operations. During the first 3 weeks, collars were worn in both indoor and outdoor settings. In the subsequent 3 weeks, the collar could be removed in an indoor setting with neck support. In regard to assessing fusions, the authors state that all patients had standing lateral

Table 4. Significant Outcomes and Utility of Included Studies.

Author	Significant Outcomes	Suggested Utility
Overley et al	No significantly different fusion or subsidence rates in braced (89%) vs unbraced (97%) groups (P = .37) NDI significantly lower at 2 weeks postoperative in unbraced group, but no difference at long term follow up	No significant advantage of postoperative bracing following 1 or 2-level ACDF
Scerrati et al	No significant difference in complete fusion between braced (86.1%) and unbraced (77.8%) groups No significant difference in NDI scores between groups	The authors advise against the routine use of cervical collars following 1- or 2-level ACDF
Abbott et al	No significant difference in fusion rates Significantly lower levels of NDI and prospective neck pain in the braced group at 6 weeks post-operatively	Postoperative bracing may offer advantages in reducing short term neck pain and disability following 1 and 2-level ACDF
Campbell et al	No significant difference in fusion rates between braced (96.1%) and unbraced (100%) groups at 24 months Significantly better NDI scores 6 weeks postoperatively in unbraced group. No difference after 6 weeks	No advantage of postoperative bracing following single level ACDF
Cheung et al	Significantly lower mean VAS scores in braced group at week 1 (P = .038) week 2 (P = .028) and week 3 (P = .031) than the unbraced group No difference in range of motion, complications, or quality of life between groups	Article suggests postoperative bracing after laminoplasty should be considered, not enforced, in patients where postoperative pain may be an issue. No difference in function or complications between groups.
Hida et al	No significant difference in any outcomes (pain, range of motion, quality of life, complications) between groups	The authors suggest that post-operative bracing does not result in significantly improved patient outcomes following double-door laminoplasty
Duetzmann et al	Mean VAS for pain was significantly lower from POD 4-13 in braced group Braced group took significantly less pain medications from POD 4-12	Article suggests postoperative bracing has advantages in the immediate postoperative period (first two weeks) in providing significant pain relief following posterior cervical surgery

Abbreviations: ACDF, Anterior Cervical Discectomy and Fusion; NDI, Neck Disability Index; VAS, Visual Analog Scale; SF-36, Short Form Health Survey; POD, Postoperative day.

radiographs at 3 months post-operatively including flexion/extension views. These radiographs were qualitatively reviewed by both a radiologist and a neurosurgeon. Whether or not this was the same surgeon as who performed the surgery was not specified. Fusion was defined as a lack of qualitative motion of the interbody cage on flexion/extension radiographs and an overall assessment of any sagittal malalignment. No objective measures of fusion determination are reported. There was no difference in fusion rates between the groups, with a reported 100% fusion rate in both braced and unbraced patients. Although both groups had 100% fusion rate, they do note that they are underpowered to detect small differences in fusion in this pilot study. Significantly lower levels of NDI scores 6 weeks after surgery, (mean difference 4.4 between groups, P = .042), and prospective neck pain scores, (mean difference between groups 1.4, P = .038), were found in the braced group. Using MCID of 7.5 for the NDI and 2.5 for pain rating scales,[18] these may not be clinically significant differences. The authors suggest that patients undergoing single or 2-level ACDF may benefit from a rigid cervical collar in the immediate postoperative period in regard to pain and disability relief. Given their small sample size in this pilot study, their results beyond this initial post-operative period would be underpowered and the author notes additional studies with more power are needed. The authors did not report on study complication rates.

Campbell et al[15] reported on 257 patients who underwent a single-level ACDF with allograft and anterior plating for symptomatic degenerative radiculopathy or myelopathy. Of the 257 patients, 108 were not braced postoperatively, while 149 patients were braced. Patients were not randomized into braced vs unbraced groups; this decision was made post-operatively based on surgeon discretion. It is not stated whether one or multiple surgeons performed the operations. The braced cohort wore hard or soft collars based on treating surgeons' preference. Patients were evaluated after surgery at 1.5, 3, 6, 12, and 24 months by radiographs, outcome instruments, and neurologic examination. In regard to fusion assessment, radiographs were obtained at 6, 12, and 24 months postoperatively. These included upright AP, lateral and flexion/extension views. All radiographs were reviewed by 2 blinded independent radiologists, with a 3rd being used as needed. The authors defined fusion as having bridging trabecula across vertebrae either anterior/posterior, lateral or through the graft, angulation less than or equal to 4 degrees on flexion/extension views, and the absence of radiolucency around the graft (less than 50% radiolucency along the endplates around graft). There was no difference in fusion rates between the groups, with a 96.1% fusion rate in the braced group and a 100% fusion rate in the unbraced group at 2 years postoperatively (P = .552). There was also no difference in fusion rates between groups at any time point of the study. The only statistically significant finding occurred at 6 weeks after surgery, when the unbraced group had greater improvement in NDI scores (28.4) than the braced group (21.6) (P = .008), although this is likely not clinically significant based on an MCID of 7.5.[18] After 6 weeks, there were no significant differences between groups. The authors suggest that bracing is not necessary after single level ACDF. The authors did not report on their complication rates.

Laminoplasty

Cheung et al[16] looked at 35 patients who were diagnosed with degenerative cervical myelopathy and underwent single-door laminoplasty with mini-plates at one or more levels. Their study cohort consisted of 19 patients who were not braced postoperatively and 16 patients who were braced with a rigid cervical collar (Philadelphia) for 3 weeks following surgery. Patients were preoperatively randomized to the braced or unbraced groups and underwent surgery by 4 different surgeons from the same institution. Statistically significant lower mean Visual Analogue Scale (VAS) scores were observed at weeks 1 (3.5 vs 5.4), 2 (1.5 vs 3.5), and 3 (1.3 vs 3.8) postoperatively for the braced group (P = .038, .028, and .031) respectively. There were no differences in range of motion, quality of life, or complications between the cohorts. The authors concluded that a rigid cervical collar may be beneficial in the immediate postoperative period for pain relief, but prolonged bracing does not lead to statistically significant reduction in pain relief compared to unbraced patients. The authors report that none of their patients had postoperative complications.

Hida et al[17] studied 74 patients who underwent a double-door laminoplasty for cervical degenerative myelopathy between the C2/C3 and/or C7/T1 disc levels. In total, there were 35 patients assigned to the unbraced group, while 39 patients were assigned to the braced group and wore a Philadelphia collar for 2 weeks postoperatively. All patients were randomized prior to surgery. It is not reported whether one or multiple surgeons performed surgery. Using the VAS, Japanese Orthopedics Association (JOA) score, Short Form-36 score (SF-36), cervical range of motion, lordotic angle, and radiographs to compare the two groups at 1 year after surgery, the study found no significant differences between the two groups. The authors found no statistically significant difference in complication incidence between braced and unbraced patients (P = .53). The authors suggest that postoperative immobilization results in similar outcomes after cervical laminoplasty when compared to no postoperative immobilization, and therefore, strict collar use may not be needed.

Posterior Fusion Surgery

Duetzmann et al[11] looked at degenerative conditions of the cervical spine that required posterior cervical single or multilevel decompressions, with or without fusions, as well as posterior cervicothoracic decompressions and fusions. A total of 30 patients were included in the study; 15 patients, whose average age was 55 years, were not placed in clavicle brace in the postoperative period, and 15 patients, whose average age was 57 years, were braced postoperatively with a clavicle brace for 30 days. All patients wore a hard cervical collar during the study period. Patients were randomized either prior to surgery or the day after surgery into the clavicle vs no clavicle brace groups. All surgeries for both groups were performed by 2 surgeons at the same institution. Significantly lower mean VAS scores were recorded in the braced group during the 4th through 13th day following surgery. The braced group also took used significantly less pain medications postoperatively compared to the unbraced group, from postoperative day four to twelve. The authors report that 1 patient in the braced group developed the complication of fascial dehiscence. The authors suggested that a clavicle brace after posterior cervical surgery may reduce pain and medication requirement in the early postoperative period.

Discussion

This systematic review identified 7 studies investigating the utility of postoperative cervical spine bracing. Four of these studies assessed the utility of bracing following single and/or two-level ACDF, 2 studies examined bracing after laminoplasty, and 1 reported on single and multilevel posterior cervical fusion and decompressions.

In regard to cervical bracing after single or two-level ACDF, this review found 4 studies which attempted to assess differences in fusion rates between braced and unbraced groups. Of note, the quality of the included studies must be considered when interpreting these fusion results. The methods of assessing fusion in the included studies was heterogenous and consisted of various radiographic and CT interpretations at different time points and with various surgeon/radiologist reviewers. In order to determine whether or not fusion has been achieved after ACDF, a widely accepted method is that which was reported by Song et al[19]. The authors found that using dynamic flexion/extension radiographs magnified to at least 150%, and assessing whether or not there was 1 or more mm of interspinous movement at the fusion level was the most reliable and reproducible method to assess fusion, with comparable accuracy to CT. Notably, they found that there must also be at least 4mm or more of interspinous movement at the adjacent levels, in order to ensure that enough flexion/extension had been performed. This was further demonstrated by Riew et al[20] in 2019 who showed that extragraft bridging bone seen on CT had the highest inter and intraobserver reliability, as well as being the most correlated to intraoperative exploration of fusion. They also found that interspinous motion using the described technique above was just as effective as the traditional bridging bone assessment using CT. The authors therefore recommend using interspinous motion of <1mm on flexion/extension radiographs as the initial assessment tool for fusion given cost benefits over CT, and make note that this is also the recommendation on the Cervical Spine Research Society. Similarly, a 2018 systematic review assessed the reliability of all the methods in the literature described to assess fusion after ACDF.[21] The authors found that the four most common methods included: assessing bridging trabecular bone, assessing for radiolucency between the implants and adjacent endplates, assessing motion between adjacent vertebral bodies on dynamic radiographs, and assessing interspinous motion on dynamic radiographs. The authors concluded that the most reliable and objective measure was using <1mm of interspinous motion on dynamic radiographs, and they recommend using this to assess fusion after ACDF. While one study included in this review,[12] assessed their fusion rates after ACDF with the use of CT scan, which has been shown to be reliable,[22] the remainder of the 3 studies[13–15] assessed ACDF fusion rates using radiographs. However, these studies did not report on imaging magnification rates used for their assessments or if these were standardized across studies. Additionally, these studies did not use interspinous movement of less than 1mm on dynamic films as their assessment tool for fusion determination, although this has been shown and recommended as above as the ideal method. Of note, 2 studies[13,15] did use the presence of bridging trabecular bone as part of their fusion criteria, and this is a fairly widely accepted method.[21] Given the heterogenous and suboptimal methods of fusion assessment used in the majority of the included studies in this review, it is not possible to make any reliable conclusion on the effects of postoperative cervical bracing on fusion rates.

Importantly, time to fusion is also an important variable to consider. Of the four ACDF studied included which discussed fusion rates, 2 studies[13,15] specifically assessed fusion rates at variable time points throughout the study duration, and both studies found no difference at any time point between the braced and unbraced groups. When considering study design, it is also important to ensure that surgeon factors do not affect results. In their study, Scerrati et al[13] report that one surgeon performed all surgeries, thus eliminating any surgeon factors from fusion rates amongst the braced vs unbraced groups. The remaining 3 ACDF studies do not discuss whether one or multiple surgeons performed the surgeries and in which groups, so this must also be considered. These study designs must therefore be carefully considered when interpreting their results on fusion rates. Next, we found that there does not appear to be any difference in complication rates between braced and unbraced groups after ACDF. Lastly, the current literature identified in this review offered heterogenous results in regards to patient reported pain and outcomes, again suggesting that routine use of cervical bracing is likely not advantageous after 1 or 2-level ACDF.

When looking at the two studies identified by this review which discussed bracing after cervical laminoplasty, the results were heterogenous, with one study[16] suggesting bracing may help with pain in the early postoperative period, and the other study[17] suggesting no difference in pain or outcomes between braced and unbraced groups. Given the limited and conflicted current evidence, no strong recommendation for or against bracing after cervical laminoplasty can be made.

Lastly, one study discussed the use of clavicle bracing after posterior cervical or cervicothoracic decompressions and/or decompressions with fusions.[11] This study suggested that clavicle bracing may reduce acute postoperative pain and medication requirements, but the impact of cervical bracing was not assessed. This study did not assess fusion rates.

Historically, cervical orthoses have been used postoperatively due to the potential benefit they offer in immobilizing a specific segment of the spine, accelerate healing, and reduce pain.[23] However, recent trends have suggested a decline in prescribed orthoses by attending U.S. surgeons. A survey conducted by Pathak et al[24] found that only a quarter of responding surgeons braced following lumbar surgery, suggesting a statistically significant drop compared to a similar questionnaire study conducted 10 years ago. This may be attributed to the growing literature which has critically evaluated the biomechanical and postoperative usage of spinal orthoses. While cervical collars had been generally seen as a benign post-operative device, recent studies have shown that this device has been associated with muscle atrophy, pain, pressure skin ulceration, breathing and swallowing discomfort, and difficulty in driving.[25,26] Furthermore, Nasi et al[2] performed a study which assessed the utility of postoperative lumbar braces following surgery in lumbar degenerative diseases. They found that individuals who were braced did not improve in pain, quality of life, fusion rate, reoperation rate, and disability metrics compared to unbraced controls. They had also implicated that there may actually be no medical evidence to support the use of bracing following surgery in these patients. Our study emphasizes the growing evidence against routine bracing following ACDF. This is by and large similar to the systematic report conducted by Karikari et al[27] which concluded that there was a lack of strong evidence to support the use of cervical bracing following a 1 or 2-level ACDF procedure on degenerative spine pathologies. Overley et al[12] and Scerrati et al[13] both suggest a lack of advantage when routinely bracing due to the statistical correlations between braced and unbraced groups. Campbell et al[15] has emphasized that the recent growth and advancements in surgical implants nullifies the need for postoperative bracing. An important note should also be made that all included studies in this review assessed the outcomes of braced vs unbraced patients with degenerative cervical spine conditions. No included study assessed patients with traumatic indications for cervical surgery. When considering unstable cervical spine injuries, the surgeon may be more inclined to brace the patient postoperatively for additional stability, as compared to a routine degenerative case. When assessing 59 German Spine Centers, a 2021 survey[28] found that 51% of respondent's routinely braced patients postoperatively after subaxial cervical injuries, with 16% using a rigid brace. There is limited evidence to guide the spine surgeon in regards to postoperative bracing in cases of cervical trauma, and these situations should be independently assessed from the results of this review, which did not identify any included cases of trauma.

Of relevance, different forms/variations of cervical spine braces exist and can have different goals or benefits. For example, this review included a study by Duetzmann et al[11], who assessed the effectiveness of the clavicular brace following posterior cervical fusions and noted that patients reported statistically significant reduction in pain during the early postoperative period. The authors attribute this to the possible biomechanical advantages the brace provides as it reduces fascial pain brought about by the nature of the operation. During the procedure, the surgeon must pass through 2 different layers of fascia which are later sewn back together.[11] The tension which is generated can cause pain. Hence, the clavicular brace works by reducing this tension, which effectively reduces pain. Similarly, different types of soft and hard cervical collars exist, and various biomechanical studies have attempted to assess their comparative function and utility in regards to immobilizing the spine. For example, a study by Miller et al[29] sought to determine if there were any differences in cervical motion prevention between soft collars and a rigid Vista collar. The authors found that the hard collar prevented significantly more motion in the sagittal and axial planes, however, no difference in motion in the lateral bending plane was identified. More importantly, they found that when analyzing 15 common activities of daily living such as walking or putting on socks, there was no difference in motion prevention between the two collars. This is likely attributed to the fact that having any type of collar on creates caution and self-regulation amongst patients. The only significant difference in motion was found going from sitting to standing and backing up a car, with less motion being identified in the hard collar group. Similarly, Holla et al[30] performed a systematic review assessing the biomechanical functionality of various cervical immobilization devices. They concluded that soft collars had poor ability to restrict cervical range of motion in all directions, and that cervico-high thoracic braces such as the Miami J or Aspen braces afforded moderate restriction in the flexion/extension plane and poor-moderate for control of lateral bending or rotation.

Cervical laminoplasty is a non-fusion procedure used to help decompress patients suffering from cervical spondylotic myelopathy. Hida et al[17] demonstrated that postoperative bracing did not lead to inferior outcomes with braced and unbraced patients performing similarly on pain, range of motion and complication metrics. It should be noted that this study only assessed fixation within a 2-week period. Thus, as the authors have noted, a study with a longer follow-up period should be conducted to assess the true utility of postoperative bracing following laminoplasty. Although a single-blind 12-month prospective study by Cheung et al[16] did note that the use of a rigid collar did reduce overall pain, this was only significant over the course of the first two weeks postoperatively. No additional benefits were noted alongside this.

Complication rates between braced and unbraced cohorts is another factor to be considered when evaluating the utility of spine bracing. Five out of our 7 studies (Overley et al,[12] Scerrati et al,[13] Cheung et al,[16] Hida et al,[17] Duetzmann et al[11]) found that there was no statistical difference between braced and unbraced groups, with both displaying overall low complication rates. These findings are similar to that of Nasi et al[2] with regards to the lumbar spine. They indicated that bracing following lumbar degenerative disease did not lead to changes in complication rates.

Strengths and Limitations

The major strength of this study is that it is the first to our knowledge which systematically reviews the utility of bracing amongst all cervical spine procedures. The present study has several limitations as well. First, only English literature was assessed. There may be potentially other, non-English studies of interest which could have contributed to this study. In addition, the heterogeneity among the included studies with regards to types of pathology diagnosed, treatment, healing assessment, and type of immobilization may have hindered our ability to perform a comprehensive meta-analysis. For example, the exact surgical techniques and implants for each ACDF study included are not well described, and this can potentially confound results. Two of the included studies only describe performing an ADCF with interbody cage, but do not specify what type of cage or implant is used, and do not specify if anterior plating was also used. Additionally, no trauma cases were included in any of the identified studies, so any insight on the value of bracing postoperatively in this patient population cannot be ascertained. Trauma patients may represent unique situations of increased instability as compared to routine degenerative patients, and therefore bracing may have different advantages in this group. Further studies looking at this specifically would be justified. Lastly, the overall quality of the included studies with low sample sizes with questionable power and the suboptimal methods of assessing fusion must also be heavily considered when interpreting these findings.

Conclusion

This systematic review found that generally, routine bracing following ACDF for degenerative cervical pathologies offers no significant advantages patient reported outcomes. The literature on bracing after cervical laminoplasty is limited and heterogenous, making any type of recommendation not possible. Clavicle bracing after posterior cervical decompression and fusions may offer limited short-term pain relief. Finally, in regards to the effects of bracing on fusion rates, no strong consensus can be made as the methods of fusion assessment in the included studies were heterogenous and suboptimal. Future high-quality studies using recommended methods of fusion assessment are needed to adequately address this important question.

Appendix

A. Search terms used

(cervical OR "cervical spine") AND (surgery OR procedure OR operation OR "operative intervention") AND (collar OR "cervical collar" OR bracing OR "cervical bracing" OR "postoperative bracing" OR brace OR orthosis) AND (outcome OR results)

Pubmed produced 1,021 results, Cochrane produced 151 results, OVID Medline produced 1,011 results and SCOPUS produced 1049 results on 11/13/2021

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Ethical Statement

The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

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