

Original Article

Evaluation of the efficiency of cervical orthoses on cervical fracture: A review of literature

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Abstract

Background: Various methods have been used to stabilize the vertebra in cervical fractures, including the use of various orthoses and surgery. However, it is not cleared which type of orthosis is more suitable for the subjects with cervical fractures to best immobilize the vertebra and to decrease the associated side effects. Therefore, the aim of this study was to evaluate the efficiency of various orthoses based on the available literature. **Materials and Methods:** A search was done in some databases include PubMed, ISI Web of Knowledge, EBSCO, Embasco, and Google Scholar. The search was done with some key words such as: Cervical spine injuries; odontoid fractures; hangman’s fractures; axis fracture; axis, atlas, cervical fractures; trauma; neck fracture; neck injury in combination with cervical orthoses. The quality of the studies was evaluated by use of Downs and Black assessment and Assessment of Multiple Systematic Reviews (AMSTAR) for original research and review articles, respectively. **Results:** Based on the aforementioned key words, 25 papers were selected. The quality of the studies varies 10-24. Most of the studies were on the use of the halo vest orthosis, its side effects and also on complications associated with various orthoses. **Discussion:** Halo orthoses provide a high degree of restriction and immobilization; however, there are some side effects associated with this orthosis, including swallowing, pin loosening, and infection. It should be emphasized that other types of orthoses fewer complications, with reasonable outputs on motion restrictions.

Key words: Cervical, cervical fracture, fracture, motion restriction, orthosis, side effects

INTRODUCTION

The performance of the cervical spine is influenced by various diseases and also injuries.^[1] There is no doubt that the motions and integrity of the cervical spine influence the performance of subjects.^[2] Various treatment approaches have been used to manage the problems associated with cervical spine, including

physical therapy, the use of various assistive devices, and surgery.^[3-5]

Various kinds of assistive devices have been prescribed for the cervical spine to control the motions of unstable vertebra, and to

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decrease the loads on cervical spine including halo vest, cervical orthosis, Philadelphia collars, Minerva collars, Aspen, stiff-neck Miami collar, and NecLoc orthoses.^[3-9] Some types of orthoses, such as halo vest collar and noninvasive collar, have been used especially for fractures of C1 and C2.^[7] Although several studies support the effectiveness of these orthoses to immobilize the fracture sites, there are some side effects that influence the use of these orthoses including^[4] pin loosening, infection of pin sites, penetrating skull bone, and uncosmetic of this device are some problems associated with the halo orthosis.^[3] Other orthoses such as Minerva and Aspen collars have been designed and used to solve the problems associated with the use of halo vest collars.

However, the main question posed here is, is there any difference between the performance and compliance of Minerva and Aspen orthoses compared to the halo vest brace? Unfortunately, it is a matter of controversy which type of cervical orthosis is more suitable based on the type of injury, required immobilization, and associated side effects. Therefore, the aim of this review was to collect the evidences regarding the efficiency of various cervical orthoses based on the type of injury.

MATERIALS AND METHODS

Two reviewers independently identified the studies published in English on some databases such as CINAHL, EBSCO, Medline, Google Scholar, PubMed, and ISI Web of Knowledge between 1960 and 2014. Some key words such as cervical spine injuries;

odontoid fractures; hangman's fractures; axis fracture; axis, atlas, cervical fractures; trauma; neck fracture; neck injury have been used with cervical orthoses.

The main criteria to select the papers were those published in English and focused on the use of orthoses. The first selection of the papers was based on their titles and abstracts. If the title and abstract addressed the research questions of interest, the paper was selected for final analysis.

All articles related to the topic were selected and their bibliographies were searched for further references in this context. The second selection of the papers was done based on the inclusion of orthosis and/or cervical orthosis. This means that all papers related to the use of other rehabilitation methods (exercise, physical therapy) and surgery were removed.

The quality of the original research articles was evaluated by use of the Downs and Black questionnaire, which evaluates the internal validity, external validity, and bias of various research studies. The reliability and validity of the Downs and Black tool in evaluation of quality of research papers have been proved.^[10] The quality of review article was evaluated by the Assessment of Multiple Systematic Reviews (AMSTAR) tool, which is a reliable tool to assess the quality of review articles. It consists of 11 questions.^[11]

Some information, such as the method of evaluation, number of studies, type of studies, number of subjects, follow-up period, type of orthosis used, and brief review of outcomes, were provided in tables [Tables 1-6].

Table 1: The comparison of efficiency of various cervical orthoses

Reference	Method	Results
[8]	Five cadavers were utilized for this study. Motion analysis system was used to capture motion relative to the C5-C6 vertebral bodies. The range of motion of flexion/extension, lateral bending, and rotation were evaluated following three conditions: (1) One-piece extraction collar (2) Two-piece collar (3) No collar	Although using a cervical collar is better than no immobilization, collars do not effectively reduce motion in an unstable cervical spine cadaver model
[14]	The halo vest orthosis was compared with soft collar, Minerva brace, and Miami J collar. The control effect for the segments of C1-2, C2-4 was tested for all devices for fracture of type II odontoid process	All four devices produced motion control at both C1-2 and C2-3. The soft collar did not provide stabilization to the unstable spine. Miami J and Minerva produced moderate control on the sagittal plane. Halo restricted motion significantly. Thus it would be the first choice for conservative treatment of unstable injury of the upper cervical spine
[15]	Twenty normal subjects participated in this study. The efficiency of some cervical collars (Philadelphia, Aspen, stiff-neck, Miami J, and NecLoc) in controlling the motion of flexion/extension, lateral bending, and rotation was evaluated	NecLoc cervical orthosis produced superior restriction of cervical motion in flexion, extension, rotation, and lateral tilt. The Miami J was the next best and was superior to Philadelphia and Aspen orthoses
[16]	The effectiveness of Newport/Aspen collar in restricting the motion of cervical was evaluated on 15 normal volunteers	The orthosis allowed flexion/extension by 31%, lateral bending by 51.1%, and rotation by 41% of the normal. The orthosis had no ability to control snaking
[17]	Two orthoses (Aspen, Miami J collar) and 2 CTOs (Aspen 2 post, Aspen 4 post) were tested on 20 normal subjects. An optoelectronic motion measuring system was used	No statistically significant difference was found between Miami J and Aspen collars in controlling gross motion. CTO produced more motion control (gross and intervertebral motion) compared to the two others. Aspen 2 post CTO and Aspen 4 post produced the same restriction of flexion but Aspen 4 produced more motion restriction of extension motion

Table 2: The complications associated with the use of various cervical orthoses

Reference	Method	Results
[21]	23 patients with upper cervical injury including C1 fracture, C2 dens fracture, C2 hangman's fracture, C1, C2-associated fractures were recruited in this study. The patients' satisfaction, clinical outcome, and complications were evaluated in this study	Generally, external immobilization can be used for upper cervical spine fracture by use of halo brace. Operative intervention is preferred in the following cases: Type 3 hangman fracture, type 2 odontoid fracture with dislocation of more than 5 mm. The postoperative outcome with regard to pain is poor. The healing rate for upper cervical fracture using Halo vest immobilization (HVI) was 80.9%. Bony healing occurred within 16 weeks, failure was 39.1%; 80.9% of patients experienced complications including pin loosening (34.8%) and pin site infection (17.4%)
[22]	15 patients used the halo fixation device for cervical immobilization	13% of subjects had ring dislodgment. Complication with new assessment form was satisfactory. Reuse of titanium skull pins should be avoided
[23]	83 patients with unstable cervical fracture were treated with halo vest stabilization during a period of 10 years; 6 patients were followed up. The age range of subjects varied 13-89 years. Flexion/extension and side bending were measured by x-ray. The halo vest was used for 10-12 weeks	First-year healing rate was 90%. Complications were minor; however, the main complication was pin loosening (60%); 80% of the patients had complications of local neck symptoms. Pain at extremes of motion was also obvious. The restriction of motion in flexion/extension was less than that of rotation compared to normal subjects
[24]	42 patients with cervical spine injury. The intervertebral motion was determined by lateral radiograph taken in supine and upright positions	At the injured levels, the sagittal plane angulations averaged 7 degrees and translation averaged 1.7 mm. The injured level and type of fracture did not influence the fracture site motion. Nearly 77% of the subjects had fracture site motion greater than 3 degrees of angulations or 1 mm of translation. It is better to use other methods of immobilization for excessive motion restriction

Table 3: The complications associated with the use of various cervical orthoses

Reference	Method	Results
[25]	Of the 3702 patients, 369 (10%) had cervical spine fracture from blunt trauma and finally 56 met the inclusion criteria	34% had no evidence of swallowing dysfunction, and 66% had evidence of dysphasia. Patients with cervical fracture treated with halo orthosis had a high incidence of dysphasia and aspiration
[26]	12 subjects with cervical fracture treated with halo vest were selected. They were followed up for a period of 5 months to check the effects of orthosis on swallowing	All patients achieved satisfactory results regarding postoperative head position. Only one patient experienced transcript dysphasia
[27]	6 healthy subjects aged 24-33 years were recruited in this study. Swallowing thin liquids at neutral position without halo vest, with halo vest, and hyper extension with halo vest was evaluated	The results of this study confirmed that cervical hyperextension with halo vest caused mechanical changes in swallowing in normal healthy adult volunteers
[28]	An 83-year-old woman with C1, C3, and odontoid fractures participated in this study. A Minerva brace was used to immobilize the fractured site. Then it was replaced with a halo vest	It has been recognized that some conditions such as low-grade fever, transient hoarseness, and stiffness of facial muscles are related to the use of Minerva. Use of halo vest decreased the symptoms
[6]	17 normal subjects were recruited in this study. Subjects were radiologically observed swallowing thin liquids and solid food without collar and with Philadelphia Sterno-Occipital Mandibular Immobilizer (SOMI) and halo vest	82% of the subjects demonstrated radiographic change with brace. 47% had problems with swallowing. 59% demonstrated increased pharyngeal residue and 23.5% demonstrated changes with bolts flow. It can be confirmed that cervical bracing does change swallowing physiologically in normal healthy adults

RESULTS

Based on the key words mentioned above, 1800 papers were found. After screening the papers based on titles and abstracts, 25 were selected for final analysis. The quality of original studies varied 10-24. Nearly 7 studies were found on comparison between the efficiency of various orthoses with quality varied 16-20. Fifteen studies focused

on complications of orthosis. Three papers also focused on outputs of treatment by orthoses based on type of fractures.

DISCUSSION

The performance of the cervical spine is influenced by various musculoskeletal disorders and injury. Various treatment

Table 4: Comparisons of various methods of cervical spine fracture treatment

Reference	Method	Results
[31]	20 patients with extremely unstable cervical spines with excellent results regarding healing and stability participated in this study	A new invasive halo orthosis was presented. It controlled motion properly and was used successfully for immobilization of the cervical spine following cervical spine surgery
[7]	14 subjects with unstable fractures of cervical spine were treated with skull traction and then with halo thoracic brace. The follow-up duration varied between 8 and 18 months	Immediate mobilization with less time in the hospital and less nursing; stable conditions were achieved in all subjects
[5]	The performance of NIH orthosis was tested on 19 patients. The time spent in NIH orthosis ranged from 36 days to 150 days (79 days). Mean follow-up was 6 months	All fractures healed successfully in acceptance alignment with no additional loss of neurological function. Most patients reported a secure and comfortable healing once the orthosis was properly donned Complication: Occipital ulceration (1 subject), strap loosening (2 subject), and subluxation (1 subject)
[12]	70 patients (34 female, 36 male), mean age 47 years, with injury at upper cervical spine. 65 were followed for a mean duration of 18 months. Stability was evaluated using flexion/extension radiography. Pain levels and neurological outcome were assessed	29 patients were treated conservatively and for 41 patients, surgery was the primary treatment. 17% of the subjects had instability and infection. Isolated odontoid fracture: Mean follow-up=12 months. Type I was unproblematic, no complications were observed. Isolated hangman's fracture: 13 months follow-up. None of the patients complained of pain. Ligamentous injury: 54 months, no complication occurred during treatment C2 fracture: 15 months with no complications Combined C1/C2 fracture: 10 months, all healed, and radiologically stable
[13]	Minerva orthosis was evaluated on 16 healthy subjects. Maximum active cervical flexion, extension, and lateral bending were recorded and measured radiographically. Rotation control measured from overhead photographs	Improvement in control of flexion/extension of the upper cervical spine and in rotation was found. Occiput to C1 level, however, remained poorly controlled
[32]	The effectiveness of Yale cervical orthosis was tested on 17 normal subjects in three dimensions based on radiograph and overhead photographs	Yale orthosis was most successful in controlling motion in lower cervical and middle part, especially in extension. Least efficiency for control of motion in upper cervical (atlantoaxial articulation). Use of this orthosis is recommended for postsurgery for the middle and lower parts but not for the upper part
[18]	A new type of thermoplastic orthosis named as thermoplastic Minerva body brace (TMBB) was introduced and tested on 4 patients with various diagnostics of cervical injury and 1 normal subject. The range of flexion extension was tested	The efficiency of TMBB is appropriate for patients with varying degrees of neurologic deficiency. Adequate cervical spine stabilization, superior properties of the material, and opportunity for early rehabilitation are the most common advantages of this material. However, most of the mentioned advantages are based on the points of view of the authors
[33]	A new type of cervical orthosis was introduced and tested on 7 cases. This orthosis was mainly prescribed for kyphosis	No evaluation was done to test comfort and effectiveness of the orthosis in stabilizing the head. The orthosis seem to be lightweight, inexpensive, and effective

methods have been recommended for the treatment of cervical spine including surgery, rehabilitation, and the use of cervical orthoses. Cervical orthoses are being used for the immobilization of the spine following injuries. Although various orthoses have been used for fracture of the cervical spine, it is controversial which orthosis is more suitable to be used depends on the type of injury. Moreover, it was not cleared which orthoses have more ability to restrict the motions and have fewer complications. Therefore, the aim of

this study was to compare the efficiency of various cervical orthoses depending on the type of injury.

Efficiency of cervical orthosis

There were only five studies on the efficiency of the cervical orthosis for the treatment of cervical injuries which most of them focus on cervical fracture. In the research done by Vieweg *et al.* with 70 patients with upper cervical injury (with ligament injury, C1, C2, C1, and C2 fractures) it was shown that the

Table 5: The results of the reviews done on efficiency of cervical orthoses in treatment of cervical fractures

Reference	Method	Results
[4]	A search was done on various databases. Some key words such as axis fracture and axis and atlas fractures were used with halo fixation	A total of 47 papers were found that cover the results of treatment of 1078 patients with C1-C2 fracture treated with halo fixation. Halo fixation has a defined place in the management of fractures of the cervical spine. Management of cervical spine with halo is safe and effective
[29]	The outcomes of treatment of cervical fracture with halo vest orthosis were evaluated based on 35 studies	In 35 studies, 682 patients were treated with 709 different injuries. The results of treatment with halo were unsatisfactory with regard to combined injury of odontoid type 2 fracture. The healing rate was 86%. This treatment is a good alternative to operations on injuries of the upper cervical spine
[30]	This is a critical review	Halo vest may be more effective in controlling and effective in mobilization injuries above C2, but Minerva is safer, more comfortable, freer of compliance from patients, and more reliable for injuries below C2. The skills to maintain both devices are also important

Table 6: The results of quality assessments

Studies	Reporting (10)	External validity (3)	Internal validity — Bias (7)	Internal validity — Confounding (7)	Total score (27)
Original article quality assessment by Downs and Black tool					
[8]	7	3	3	7	20
[7]	5	3	1	2	11
[21]	6	3	1	0	10
[5]	5	3	1	11	20
[31]	5	2	2	3	12
[27]	5	3	1	3	12
[6]	7	3	2	3	15
[25]	6	3	2	3	14
[20]	7	3	2	4	16
[23]	7	3	2	4	16
[28]	5	2	1	3	11
[34]	7	3	1	4	15
[9]	8	3	3	10	24
[35]	8	3	3	10	24
[17]	5	3	2	6	16
[15]	7	3	2	8	20
[36]	6	3	1	7	17
[14]	6	3	1	7	17
[18]	7	3	2	7	19
[13]	5	3	2	6	16
[16]	6	3	2	7	18
[12]	6	3	3	7	19
Review article quality assessment by AMSTAR tool (total score out of 11)					
[4]			10		
[29]			4		
[30]			3		

use of halo orthosis is a good choice with no complications.^[12] Moreover, the use of halo orthosis decreases hospital time and stabilizes the injured spines successfully.^[5] The outputs of the study done by Sewers *et al.* also showed that the noninvasive halo (NIH) orthosis successfully immobilized the fractured sites with acceptable alignment and with no additional loss of neurological dysfunction.^[5] As can be seen from the studies mentioned above, most of the studies focused on the use of the

halo orthosis for immobilization of the fractured cervical spine. It can be concluded that the halo orthosis is a good alternative to surgery to stabilize the fractures of the cervical spine.

Comparison between orthoses

There were five studies comparing the efficiency of orthoses. It should be noted that the efficiency of an orthosis is determined based on restricted motions, which mostly was evaluated by the

x-ray in extremes of flexion and extension.^[13] In the research done by Horodyski *et al.* on the comparison of two different orthoses (one-piece extraction collar and two-piece), it was shown that although using a cervical collar is better than no immobilization, the mentioned collars do not efficiently reduce the motion in unstable vertebra at C5/C6.^[8] The efficiency of the soft collar, Minerva brace, and Miami collar for fracture of the odontoid process (type 2) was evaluated by Richter *et al.*^[14] Based on the results of this study, halo restricts the motions of C1-C2-, C2-C3 more than other, mentioned orthoses. Thus, it would be the first choice for conservative treatment of unstable injuries of the upper cervical spine.^[14]

In another research done on normal subjects, the efficiency of the NecLoc cervical orthosis on motion restriction was evaluated. It has been shown that this orthosis was superior in controlling flexion/extension, rotation, and lateral rotation to the Philadelphia and Aspen collars.^[15]

The results of other studies showed that Newport/Aspen controlled flexion/extension/rotation and lateral bending in daily activities but had no ability to control snaking.^[16] The efficiency of cervical orthosis to control the upper and lower parts was also evaluated. It was found that the cervicothoracic orthosis (CTO) produced more motion control (gross and intervertebral) compared to Miami and Aspen collars.^[16, 17]

There are also some studies that compared Minerva and halo and other cervical orthoses.^[13,14,18-20] In the research done by Benzel *et al.*, the intervertebral motions were evaluated on 18 patients. They showed that the unstable fractures in the upper part of cervical vertebra should be treated with a halo orthosis. In contrast, the injuries between the mid- and low cervical vertebra can be treated with a Minerva orthosis.^[20] The intervertebral motions of 20 healthy subjects were also evaluated by Maiman *et al.* The results of their research confirmed that the immobilization provided by the Minerva orthosis was the same as that of halo. However, it seems that the Minerva provided more immobilization at C3-C4 and C6-C7.^[19] Most of these studies were done on normal subjects or cadavers. Based on these studies, the Minerva orthosis was as effective as the halo in controlling the cervical motions, especially in the lower part of the cervical spine.

Based on the studies mentioned above, it can be concluded that the use of the cervical orthosis is a good and effective alternative to surgery to stabilize the injured spine. It seems that the efficiency of the halo orthosis is more than other available orthoses, especially to immobilize the upper cervical spine.

Complication of cervical orthoses

Regarding the complication of available orthoses, 15 papers were found.^[6,21-28] The quality of the papers varies 10-16. The main complications associated with the use of cervical orthoses include: Pin losing, pin site infection, misalignment, local neck symptoms, pressure sores from plastic vests, nerve injury, dual penetration, pain, change in swallowing function, stiffness of facial muscles, change in bolus flow, and occipital ulceration.

However, most of the problems mentioned are related to the use of the halo cervical orthosis.

In the research done by Shin *et al.* on 23 patients with upper cervical injuries (C1 fracture, C2 dens fracture, C2 hangman's fracture), 34.8% and 17.4% of the subjects had complications from pin loosening and pin site infection, respectively.^[21] In contrast, Morishima *et al.* (CNM *et al.*) showed that of 179 subjects treated with halo-external device, 36 had complications from pin loosening, 20% from pin site infection, 11% pressure sores from pelvic vest, 2% from nerve injury, 1% from dural penetration, 2% from dysphasia, 9% from scar, and 18% from severe pain/discomfort.

Swallowing was the other complication mentioned following the use of cervical orthoses.^[6,25,27] In the review article published by Branco, it was concluded that cervical orthoses change swallowing functions. Bradley *et al.* also showed that 66% of the subjects had dysphasia and aspiration^[25] and this was counter to the finding of Bagley *et al.*, which showed a low percentage of dysphasia.^[26]

From the studies mentioned above, it can be concluded that many complications mentioned with regard to cervical orthoses relate to the use of halo vest orthosis. There is not enough evidence regarding the complications associated with other types of cervical orthoses. However, the interesting point is that the complications vary across different studies, which may be due to methods of use of orthoses, types of orthoses, available facilities to control infections, etc. Based on the results of the study done by Ho *et al.*, most of the complications, such as infection and pin loss following the use of halo orthosis, are related to the reuse of titanium skull pins.^[22] They concluded that reuse of titanium skull pins should be avoided. Regarding swallowing, it can be concluded that most total-contact orthoses restrict the normal swallowing performance of subjects.

From the reviewed studies, it can be determined that most studies were done on halo vest orthoses and in subjects with cervical fractures. The use of the halo orthosis has a high healing rate but also has some complications. Halo orthosis may be more effective in the immobilization of injuries above C2 but the Minerva is safer, more comfortable, has more patient compliance, and more reliable.^[4,29,30]

There is no doubt that the immobilization provided by the halo orthosis is greater than that provided by other available orthoses and this is the main reason to use this orthosis. However, the mentioned complications restrict the usability of this orthosis. Therefore, new orthoses should be designed to decrease the complications of the halo vest orthosis but maintain the same performance. The Wilson orthosis is one of the orthoses designed especially to overcome the problems mentioned above.^[31] This new orthosis was tested on 20 patients with unstable cervical spines. The results confirmed that this orthosis can control appropriate motions properly and can be used successfully for the immobilization of the cervical spine.

CONCLUSION

The results of this review study showed that most studies done on the efficiency of cervical orthoses were based on halo vest orthoses. Although the halo orthosis provides a high degree of restriction and immobilization, it has lots of complications. Swallowing problems and pin loosening infections are the most important complications associated with the use of the halo. There is not enough evidence regarding the efficiency of other types of cervical orthoses. Therefore, it is recommended that available cervical orthoses be studied regarding motion restriction and complications.

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Conflicts of interest

There are no conflicts of interest.

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