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Cervical orthoses

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Abstract

A biomechanical study is presented to compare the effectiveness of three types of off-the-shelf cervical orthoses and one custom-fit collar in restricting cervical spine motion. A group of 10 normal subjects was studied. The measurements of flexion and extension, lateral side flexion and axial rotation were recorded using various measurement techniques. Interface pressures at the chin and occiput were also measured, along with the warming effect of the collars.

The results indicated that all the collars restricted neck movements, for example, the Plastazote collar by 50% of flexion and extension, and that there was no significant difference between off-the-shelf Plastazote and custom-fit collars in restricting movement. Significantly high interface pressures were recorded at the chin, with the subjects wearing the hard and Plastazote orthoses. The warming effect of the soft collar was equal to that of a wool scarf.

The study was aimed at improving prescription and although the subjective observations were not validated, the subjects concluded that the custom-fit collars were more comfortable; an important point with such a high rejection rate.

Introduction

Cervical orthoses are prescribed for a wide spectrum of clinical problems ranging from muscle spasm to serious instability. The main objectives are to rest the neck and give support, to allow muscles to relax and to permit any inflammation to subside. A large number are used as standard treatment in accident and emergency departments for initial immobilization following trauma of soft tissues, as neck injuries result from about 20 per cent of all vehicle accidents (Mealy et al, 1986). These collars are available through the United Kingdom National Health Service as stock items. Almost an equal number are made from sheet material by therapists in outpatient departments for conditions, such as cervical spondylosis and rheumatoid arthritis (Dudgeon, 1984).

There are several categories of cervical orthoses. Johnson (1977), divided them into four groups, namely, the simple collar extending from head to the upper part of the thorax, the "poster brace" with mandibular and occipital supports, the cervicothoracic brace extending over the trunk, and the halo brace involving skeletal fixation. When cervical instability due to trauma or disease is not apparent, then the simple collar is prescribed.

What is the basic rationale of prescription of these simple collars? Lusskin and Berger (1975) stated that collars should act as a reminder to restrict head and neck motions, to mechanically limit flexion, extension, lateral flexion and rotation of the head and cervical spine, and to partially relieve gravitational stress by weight transfer. Since the collar supports a portion of head weight, the cervical spine is partially unloaded. Caillet (1981) stated that whether the problems are acute or chronic, treatment of the painful neck, or of problems related to the neck, employs basic concepts. One such is that a collar, properly made and fitted, and correctly used, should be beneficial. In this context "properly fitted" implies that the collar is made specially for or matched to an individual. Caillet (1981) advocated that the neck should be held in a slightly flexed position so separating the posterior facet joints and opening the foraminae. This position minimizes the need for muscle "splinting", restricts

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excessive motion, and gives sensory cutaneous stimulation and warmth to the neck musculature causing a decrease in pain impulses. Since immobilization is not complete, the neck muscles are allowed to contract isometrically within the collars and atrophy and disuse are thus prevented. However these orthoses may not always match these specifications and Lusskin and Berger (1974) have suggested problems involving,

1. Muscle atrophy and weakness.
2. Tightness and contracture of tissues.
3. Psychological dependence.
4. Symptoms aggravated and undiagnosed disorders progressing.

In this study, the possible effects of the "simple collar" and custom-fit cervical orthoses, were examined in terms of:

1. Limitation of movement.
2. Interface pressures at the occiput and chin.
3. Warming of the skin.

Bearing in mind the prescription specifications and rationale for use.

Materials and methods

The study group comprised ten adults (5 men and 5 women), aged 25–65 years, with no history of neck trauma. The subjects were seated in a geriatric chair with the torso held by diagonal straps to eliminate unnecessary movement of the thoracic and lumbar spines.

The cervical spine movements of each subject were measured when moving freely without an orthosis and repeated when each of the four types of collars were worn. The cervical spine movements measured were flexion/extension, lateral side flexion and axial rotation.

A description of the different cervical orthoses tested is detailed in Table 1 and the orthoses shown in Figure 1.

Table 1. Description of cervical orthoses tested

*Soft Collar:	Made of high density PVC foam, covered in stockinette, fastened by Velcro.
*Hard Collar:	Made of rigid polythene, the contact parts are of foam rubber, covered with soft leatherette, fastened by Velcro.
*Plastazote collar:	A two-piece collar made of Plastazote, strengthened at the front and back, fastened by Velcro.
*Custom fit collar:	Made from a sheet of medium density polythene foam-Plastazote, strengthened at the front by a 2mm thick strip of polythene, fastened by Velcro.

*Details of suppliers are given in the Appendix.

Measurements of cervical spine movements

The movements were measured using the vector stereograph, an instrument with three extensible strings mounted on bobbins in one plane and joined at an attachment point, as described by Grew and Harris (1979). In the present study the vector stereograph strings were arranged to intersect at a central anterior position on the head with an attachment to a headband, thus allowing for positioning with or without an orthosis (Gant, 1985). For the first combined movement of flexion and extension the subjects were instructed to look forwards and follow a taped line marked on the wall, from the ceiling down to the floor. When completing the second movement of combined lateral side flexion the subjects were instructed to look forwards to a mirror, and bring their ear down to their shoulder, following an arcshaped wall marker. The movement was reversed so that the opposite ear was brought down to the contralateral shoulder. This method with straps pulling downwards over the shoulders helped to limit rotation and involvement of the shoulder and thorax. The stereograph outputs were fed into a minicomputer for subsequent analysis of movement patterns. A goniometer or builders inclinometer, as described by Pearcy (1986), was also used to measure cervical movements of flexion, extension and lateral side flexion. The subjects wore a headband with the inclinometer attached, while strapped into the geriatric chair. All the movements of flexion, extension and lateral side flexion to the right and to the left, were measured in degrees and taken as separate motions. Axial rotation could not be measured satisfactorily using the vector stereograph, and this was measured using two different goniometers. One inclinometer-type goniometer was attached to the top of the subject's head by a headband with the subject in the supine position, while the other horizontal goniometer, the mortar board type, measured head rotation about a vertical axis with the subject seated in the test position (Fig. 2). All movements were repeated on six occasions for each subject.

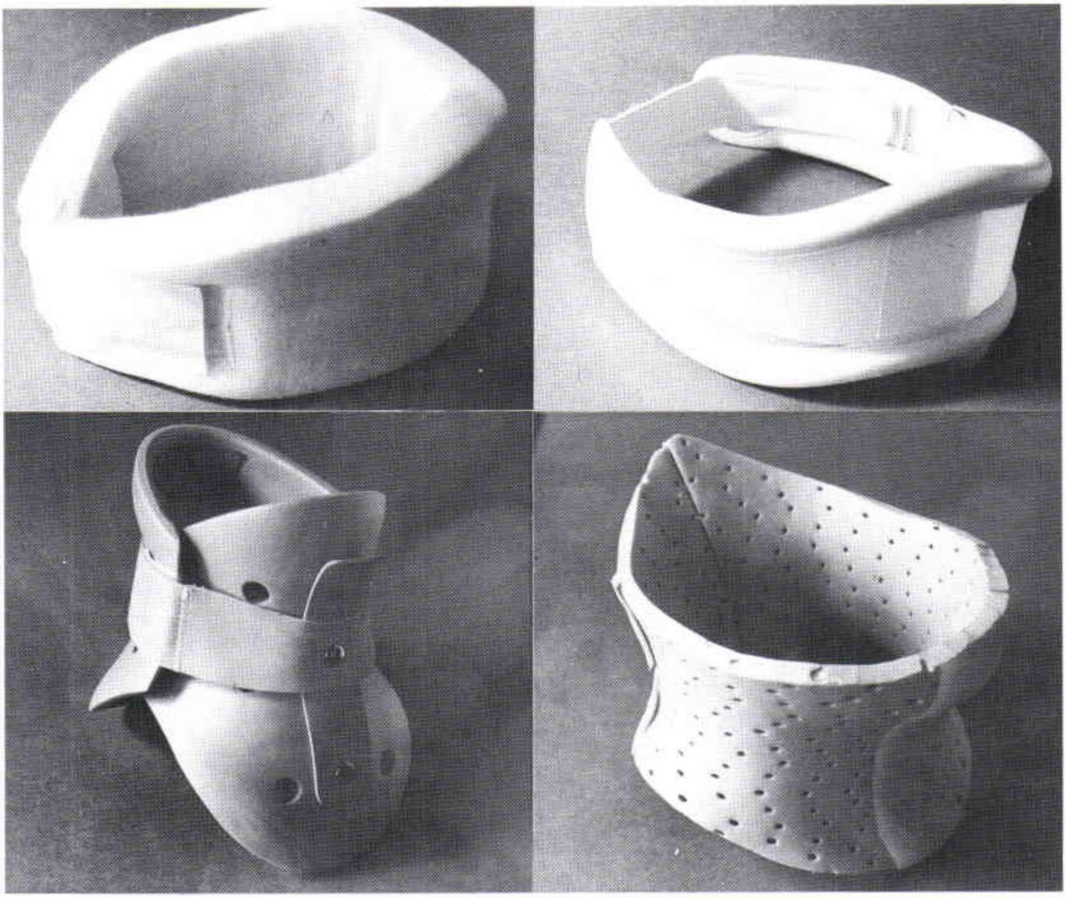


Fig. 1. Types of cervical orthoses used in the trial. Top left, soft collar; top right, hard collar; bottom left, Plastazote collar; bottom right, custom-fit collar.

Interface pressures measurements at the chin and occiput

The interface pressures were recorded using the Oxford Pressure Monitor (Bader and Hawken, 1986) as the subjects were seated in the test position wearing the different collars. Two pressure matrices, each incorporating a row of six pneumatic cells, were employed at the interfaces between the chin and collar and the occiput and the collar. The pressures in millimetres Hg were recorded at rest and at the extremes of the movements of flexion and extension, as recommended by Fisher (1977).

The subject was required to flex the neck to a position which could enable normal reading at lap level. Then an extended neck position was attained with no extreme level of force or movement.

Skin temperature

To assess the warming effect of each collar, skin temperatures were measured at two sites, one in the mid-cervical spine area under the collar, and a second in the mid-thoracic T7 area. This latter site was at a distance from the area of influence of the collar and therefore used as a control, Grew and Deane (1982). The three thermistors (Technoterm 1100) were taped to the skin with porous tape (Micropore 3M) and the electronic thermometer recorded the three temperatures, namely,

1. Skin temperature under the collar
2. Skin temperature at the thoracic spine under normal clothing
3. The ambient temperature

A pilot study indicated that the thermometer registered the change of skin temperature

Fig. 2. Subject seated in test position for head rotation measurement using a horizontal goniometer.

under the collars and clothing to within 0.2° of the final temperature within 1 minute 40 seconds.

The subjects had the thermistors taped to their skin in the appropriate areas and recordings made with and without the collars, and with and without a wool neck scarf. Also the subjects skin temperatures were registered indoors and outdoors, in different weather conditions, specifically on a cold January day and a damp May day.

Results

Cervical spine movements

The mean results of movement using the vector stereograph and the inclinometer goniometer are detailed in Tables 2 and 3, respectively. The percentage limitation of movements, as assessed by the vector stereograph and the goniometer, can also be represented in histogram form (Fig. 3). The differences between the two measuring techniques, namely the vector stereograph and the goniometer (inclinometer), for both types of movements were not found to be statistically significant. The results of the rotation measurements by the two different goniometers are indicated in Table 4.

There was no significant difference between using the goniometer (inclinometer) and horizontal goniometer (mortar board type) for measuring rotation in the supine or sitting positions.

A specific comparison was also performed between two Plastazote collars. The restriction with all three types of movement is shown in histogram form (Fig. 4).

Table 2. The mean distance of motion measured by the vector stereograph and percentage reduction of motion from unrestrained normal movement.

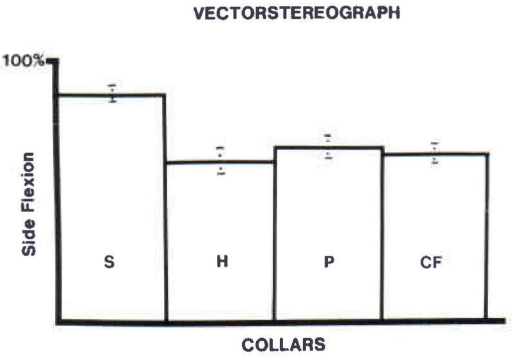
	Flexion/ extension	%	Lateral side flexion	%
No collar	362±7	—	299±5	—
Soft collar	310±7	14	261±6	13
Hard collar	206±6	43	186±6	38
Plastazote collar	179±8	51	194±7	35
Custom-fit collar	197±8	46	185±6	38

All values are in millimetres

Table 3. The mean degrees of motion measured by the inclinometer goniometer, and percentage reduction of motion from unrestrained normal movement.

Collar	Flexion	%	Extension	%	Lateral side flexion			
					Left	%	Right	%
None	49±2	—	62±2	—	37±1	—	41±1	—
Soft	30±2	39	45±2	27	32±2	14	32±2	22
Hard	15±1	69	41±2	34	29±1	22	27±1	34
Plastazote	13±1	73	26±3	58	25±2	32	25±1	39
Custom-fit	17±1	65	26±2	58	23±1	38	25±1	39

All values are in degrees



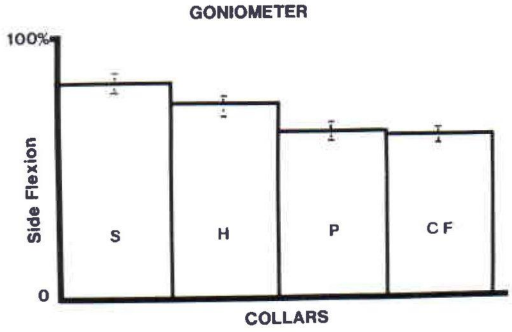


Fig. 3. Top, restriction of movement with different orthoses using the vector stereograph. Bottom, restriction of movement with different orthoses using the goniometer.

Interface pressures

Table 5 gives the mean values of the maximum pressures recorded at the two interface areas. Even at rest, the hard, Plastazote and custom-fit collars produced considerable maximum pressures, which increased by greater than 100 per cent when the subject went into flexion. The occipital pressures were negligible at rest but increased to significant interface pressures during full extension of the cervical spine.

Skin temperatures

In both Winter and Spring climatic conditions the thoracic sensors recorded a constant skin temperature of 35.3°C, and this was taken as the control sensor, as recommended by Grew and Deane (1982). As the subjects moved from indoors with an ambient temperature of 20°C, to outside at an ambient temperature of −1°C, on a January day, the skin in the uncovered cervical area decreased by 8.1°C from 34.1°C to 26°C. However, when either the soft collar or a wool neck scarf was worn on the same day a decrease of only 1.5°C in skin temperature was recorded in the cervical area.

Repeating the same measurement on a May day, when the ambient temperature inside was 27.5°C and outside was 10.5°C, and the control thoracic skin temperature was 35.1°C, the skin temperature in the uncovered cervical area decreased 5°C from 35°C to 30°C. However when either the soft collar or a wool neck scarf was worn a decrease of only 1°C in skin temperature was recorded in the cervical area.

It thus appeared that both the soft cervical orthosis and the wool scarf were equally effective in maintaining neck skin temperature at a comfortable level.

Discussion

The anatomy and movements of the cervical spine are complex, but normally there is a gradual intersegmental flow of movement, which is greatest in the upper part of the neck. There is also a gliding motion at the facet joints, while the discs deform. The amount of anterior shift depends on the obliquity of the articular processes (Fielding, 1964). So in this study, the combined anterior posterior movement measured in the sagittal plane by the vector stereograph was not 'true' flexion/extension of the cervical spine, Kaufman et al (1986). Again,

Table 4. The mean rotation measured by the goniometer inclinometer and the horizontal goniometer, showing percentage restriction of movement from unrestrained rotation.

	INCLINOMETER				HORIZONTAL			
	Left	%	Right	%	Left	%	Right	%
No collar	62±3	—	64±3	—	69±3	—	66±3	—
Soft collar	44±3	30	46±3	28	51±3	27	48±4	12
Hard collar	31±3	50	33±3	48	37±3	46	41±4	38
Plastazote collar	23±3	63	22±3	69	27±3	61	31±3	53
Custom-fit	22±2	65	24±2	62	25±2	64	28±3	58

All values are in degrees

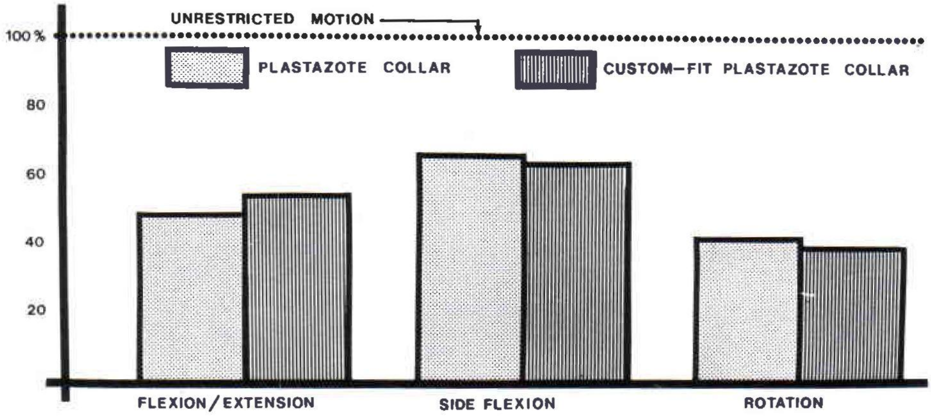


Fig. 4. Restriction of movement of off-the-shelf and custom fitted Plasatzote collars in all three types of movement.

lateral side flexion is not a 'true' movement of side bending, as it is always associated with rotation (Caillet, 1981). However, for the purpose of the present study, each subject was instructed to exert a conscious effort to eliminate unwanted movements, as recommended by other researchers (Hartman et al, 1975; Kaufman et al, 1986).

Two other clinical factors make bracing the neck with a 'simple' type collar even more complicated. Firstly, Caillet (1981) found clinically that 'nodding' first will result in a greater degree of total flexion, so the sequence of acts alters the degree of movement. If the neck is fully flexed first and then the chin is brought into flexion as a second phase, total neck movement is less than if the chin is flexed first ('nod') and then followed by bending the rest of the neck. In addition, when the subjects were restricted by a chin-piece and attempted to flex against it the upper part of the cervical spine extended while the lower part flexed. Fisher (1978) an Colachis et al, (1973) also found that the chin-piece on the collar produced straightening of the upper cervical spine. Caillet (1981) also stated that fitting the collar to an individual is of paramount importance. The 'nodding' and 'chin poking' movements must be considered, as the cervical spine movements of flexion and extension occur about many axes (Kaufman et al, 1980).

In spite of movement complexities, the ten subjects fitted with the different collars showed limitation of movement in all ranges. The soft collar limited flexion/extension and lateral side flexion by approximately 14 per cent, whilst the hard, Plastazote, and custom-fit collars limited the movements of flexion/extension and lateral side flexion by between 43 and 51 per cent.

In the rotation of the cervical spine, 50 per cent takes place at the atlanto-axial joint (Fielding 1964). However, it may be surprising that the soft collar restricted axial rotation by as much as between 13 and 20 per cent and the three other collars restricted rotation by between 42 and 66 per cent.

Bearing in mind the biomechanics of the neck, the study found, using the analysis of variance, three subjects which stood out as having higher than normal variance in their range of movements. One female subject had a long slender neck and the other two male

Table 5. Maximum interface pressures during flexion extension.

	Soft collar	Hard collar	Plastazote collar	Custom fit
Chin-rest	7±1	82±3	65±4	62±4
Occiput-rest	0	0	0	0
Chin-flexion	47±.8	150±3	143±6	172±7
Occiput-extension	14±.5	55±3	40±1	53±3

All values in mmHg

subjects were of a short stocky build. These anomalies did not alter the overall readings in the study, but as already noted the clinical factor of sequence of movement the 'nod' factor and the 'poking chin' factor, i.e. gliding motions of the facet joints may play a part in the anomalous findings with regard to these three subjects in the study.

There was no significant difference between the methods of measuring the movements of the cervical spine, using either the vector stereograph or the different goniometers.

The interface pressures recorded at the chin area were high, especially on flexion, but did not cause discomfort to the subjects. This increase of pressure could act as a reminder to restrict movements to a subject's injured neck. The pressures recorded, especially at rest, do indicate that the collars partially relieve gravitational stress to the neck muscles (Lusskin and Berger, 1975).

All collars had a satisfactory result in keeping the neck warm, but interestingly a wool scarf had an equal warming effect.

All the subjects stated that their custom-made Plastazote collars were very comfortable immediately on donning, and all subjects were convinced that the limitation of movement was greater and the pressures at the chin and occiput were less with these than with the off-the-shelf type of Plastozote collar. However, these subjective observations were not validated. Nevertheless, since the custom-made collars are more comfortable, and the rejection rate of orthoses is always high, subjective feeling of comfort should not be disregarded.

In conclusion, all the cervical collars in the study both off-the-shelf and custom-made, limited the movements of flexion/extension, lateral side flexion and rotation, and the goniometer proved to be a reliable non-invasive clinical tool.

Acknowledgements

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Appendix

*Soft Collar:	Manufactured by Camp Ltd. Northgate House Staple Gardens Winchester SO23 8ST UK
Hard Collar:	Supplied by OEC Orthopaedic Ltd Waterton Industrial Estate Bridgend South Glamorgan CF31 3YN Wales
Plastazote Collar:	Manufactured by Camp Ltd.
Custom-fit collar:	BXL Plastics ERP Division Mitcham Road Croydon Surrey
Velcro:	UK Manufacturer Selectus Ltd.

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