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Material properties of Velcro fastenings

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Abstract
An assessment of the material properties of three types of touch and close fasteners (Velcro) in general orthopaedic usage is presented.

The materials were tested under various loading regimes using an Instron testing machine. The force-extension curves were analyzed and values determined for both the stiffness and strength of the various attachments. Particular reference was made to the alteration in attachment strength after cyclic loading.

The strength of the standard Velcro was found to be least affected after cyclic loading to simulate continuous usage. A recommendation is made on the specific application of each type of Velcro based on their material properties.

Introduction

Touch and close fasteners, known synonymously as Velcro*, are used widely as fastening devices. They are particularly appropriate for the attachment of orthotic devices such as splints and cervical collars, as patients who require these often have difficulty in fastening buttons due to loss of hand and finger dexterity. Their use as an aid in surgical procedures has also been reported (Roberts 1967, Nelson 1976).

An interest in the material was initiated by an enquiry into the relative strengths of the various Velcro materials for use in the support of soft orthotic shoes. A review of the literature failed to produce any assessment of Velcro in terms of standard engineering parameters.

Materials

A request made to the stores of a large orthopaedic centre and to the manufacturers of Velcro in the United Kingdom yielded three basic types of Velcro-like materials. Their known characteristics are summarized in Table 1.

Methods

The mechanical strength of the attachment of the different materials was investigated using three different modes of force application i.e. axial shear, lateral shear and peel (Fig. 1). For each test, the two strips of material were placed in the appropriate configuration and overlapped by a specific distance (x in Fig. 1). The overlap

Table 1. Characteristics of Velcro types studied

	Attachment mechanism	*No. of attachments/cm^2	Widths mm	Composition Polyurethane: Nylon
A—standard	hooks/loops	40–48	20, 30, 50	55:45
B—elasticated	hooks/loops	40	30, 50	55:45
C—"Kric Krac"	bobble-ends/loops	48	50	11:89

*The density was measured using a stereo microscope.

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*Velcro is a Registered Trade Mark of Selectus Limited, Biddulph, Stoke-on-Trent.

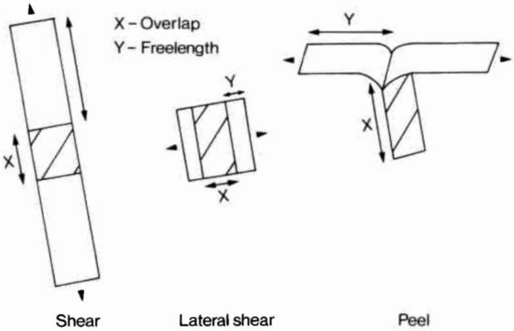

Fig. 1. Velcro strips subjected to three modes of force application.

region was then compressed between two blocks of wood by applying weights to a lever system. Initial tests showed that a closing pressure of 8·3 kPa on the overlap region was sufficient such that no greater strength of attachment could be achieved by subsequent pressing with the fingers. This standard procedure for pressing the two components together enabled a comparison to be made between the various materials. The free ends of the specimens were fixed into standard grips and they were strained at a slow rate of 0·167mms^{-1} using an Instron 1122 testing machine. Both deformation and load were recorded automatically during the tests.

In use, Velcro is subjected to continuous wear and its performance as a result of such conditions was tested using two load cycling programmes;

(a) 100 continuous cycles up to 50% of the original attachment strength for each of the three modes of force application.
(b) 100 cycles of pulling the specimens apart in peel mode.

Results

The experimental results for attachment strength are summarized in Table 2 and for the effect of cyclic loading programme (b) in Table 3. The cyclic programme (a) produced no alteration in attachment strength. Repeatability tests gave a coefficient of variation of ±5% for attachment strength and typical behaviour of the three types of Velcro is illustrated in Figure 2.

The only similarity in their behaviour was in respect of their small peel attachment strength (< 5N). The other findings are most easily described with reference to the individual materials.

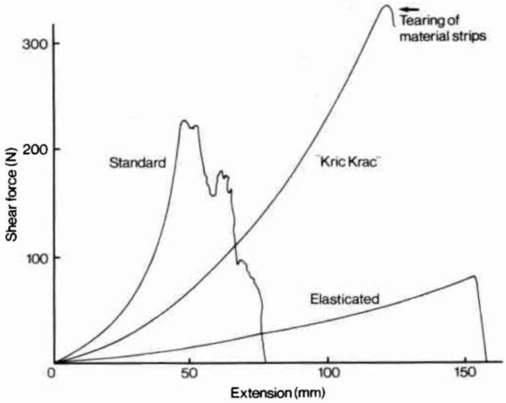

Fig. 2. Typical force-extension curve for three types of Velcro.

(a) Standard

Provided a relatively constant stiffness bond (estimated from the gradient of the force-extension curves) and a large attachment strength. Beyond the value for maximum strength, the attachment remained with a

Table 2. Attachment strength of Velcro subjected to slow rate extension

Material	Width (mm)	Attachment strength (N)				
		Shear		Lateral shear		Peel
attachment overlap (mm) x (Fig. 1)		20	72	10	30	72
A—standard	20	35	87	32	—	4·6
A—standard	30	35	98	30	—	4·8
B—elasticated	30	25	36	22	—	2·0
A—standard	50	74	195	48	72	5·0
B—elasticated	50	40	60	21	54	3·4
C—"Kric Krac"	50	>365*	>335*	284	>390*	4·8

*Tearing of material rather than pulling apart of attachment reduced strength as the two material elements slipped relative to each other. The cyclic loading programme did not significantly alter its mechanical properties.

(b) Elasticated

The magnitude of force required to break the attachment was relatively low for this material although the maximum extension was considerable (i.e. twice the overlap length). No slipping of the material attachment was observed before sudden separation of the two elements occurred. The bond strength was reduced by up to 50% following load cycling.

(c) "Kric Krac"

This material provided a low stiffness attachment, whose ultimate strength exceeded that of the material strips. This resulted in the strips tearing rather than pulling apart. Cyclic loading reduced the mechanical strength of its attachment significantly.

Discussion

By using specimens of the same dimensions from the different materials comparisons between them can be made, although the true stiffness of the overlap section was not measured with these tests because of the freelengths of the material. The material "Kric Krac" differs from the other two materials studied in the form of its active attachment components. These "bobble-ended" structures produce a high strength attachment resistant to both shear and lateral shear forces. However, microscopic examination of the cycled material revealed that about 15% of these active components had pulled out from the woven backing material. This reduces the strength of the "Kric Krac" attachment. When the load cycling programme (b) was extended to 500 cycles, the resulting strength of "Kric Krac" was found to be less than the corresponding value for standard Velcro (Table 3).

The properties of the elasticated material closely followed the elastic characteristics of the separate material strips indicating that the stiffness of the specimens is not dependent on the entanglement of the active elements.

The low value for peel strength is generally an advantage enabling easy release of a fastener. However, in certain applications of rigid orthoses, such as the Boston brace, which intimately supports the body for long periods, any release of the fastening will reduce its effectiveness. This release may be initiated either by the patient himself or by relative movement in the direction of peel between two rigid sections of the orthosis, and so a conventional webbing strap and buckle is generally used for such orthoses.

Conclusion

A comparative study of the material properties of three types of Velcro was undertaken. The conclusions from the tests were—

1. The standard Velcro was shown to be the best of the three when an attachment is required, whose strength is not significantly reduced as a result of continuous usage, e.g. hand splints and prosthetic lower limb support bands.
2. The elasticated Velcro, with its inherent capacity to accommodate large extensions, could be used when large movements about the attachment is anticipated, e.g. lower limb orthoses, where joint movement and muscle bulk alterations must be accommodated.

Table 3. Effect of cyclic loading on the attachment strength of Velcro

Material	Width (mm)	Attachment strength (N) after load cycling programme (b)			
		Shear		Lateral shear	
attachment overlap (mm) x (Fig. 1)		20	72	10	30
A—standard	30	40	89	33	—
A—standard	50	80	182 (137)	47	75
B—elasticated	50	27	47	11	42
C—"Kric Krac"	50	111	295 (86)	75	184

( ) values of strength after 500 cycles

3. The material "Kric Krac" was shown to be unsuitable for applications requiring continual unfastening and would be most suitable for special one-off applications when an extremely strong attachment is required, e.g. at surgical operation.

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