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The effect on energy absorption of hard inserts in laminated EVA mouthguards

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Abstract

One of the suggestions for using laminated mouthguards is the inclusion of hard inserts to improve mouthguard performance. However, there is a paucity of published material on the use of such inserts and this study was designed to investigate this theory.

Hard layers of ethylene vinyl acetate (EVA) were included in laminated mouthguard sheets which were then subject to repeated impacts with an impact rig. Hard inserts resulted in reduced energy absorption when compared with a control sheet of the same material and approximate thickness but without the hard inserts.

Additionally, the further the hard inserts were located from the impact surface, the least reduction there was on energy absorption.

Key words: Laminated mouthguard, transmitted forces, energy absorption, hard inserts.

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Introduction

Improvements in energy absorption of mouthguard materials obviously lessen the risk of orofacial injuries. The dynamics of an impact to the teeth when a mouthguard is being worn is illustrated in Fig. 1.

It is known that an inverse relationship exists between thickness and energy absorption properties of ethylene vinyl acetate (EVA) mouthguard materials.[1-3] Also, it has recently been shown that the inclusion of air-cells in EVA mouthguard materials further improves energy absorption and reduces transmitted forces by up to 30 per cent.[4]

Claims are made that laminated mouthguards with hard inserts provide improved safety by increased energy absorption and improved distribution of the residual energy over the maxillary arch.[5-7]

The aim of this study was to investigate this concept and determine the changes in energy absorption in EVA laminated mouthguards when hard inserts of EVA were placed at different levels within a laminated mouthguard material during manufacture.

Materials and method

Four test samples of multilaminated (four layer) mouthguard material were made using three layers of a 1 mm thick soft EVA thermoplastic material (Shore A Hardness 80, Dreve Drufosoft; Dentamid GmbH, Unna, Germany) with a hard EVA insert 1.8 mm thick (Shore A Hardness 90, Dreve Kombiplast; Dentamid GmbH, Unna, Germany) positioned at a different level in each test sample. The different layering of the test samples is shown in Fig. 2. The test samples were all 4.8 mm thick. The control was 5 mm thick, being made by laminating five layers of the 1 mm thick soft EVA. The difference in thickness between the test and control samples (0.2 mm) was not considered significant for the purpose of the study.

All of the five samples of the mouthguard material were impacted ten times, the impact zone being different for each impact. Impacts were produced by apparatus similar to an IZOD impact rig, having a striker with a flat circular face of 12.75 mm, a pendulum impact energy of 1.05 joules and an impact velocity of 3 metres per second (Australian Standard 1544, 1989). The force transmitted through each sample was recorded by a force sensor (model 208A15; PCB, Depew, NY, USA) with a signal amplifier, conditioner (model F484B06; PCB, Depew, NY, USA) and analyser (model 2200; Diagnostic Instruments, Livingston, Scotland).

Data and statistical analysis used Microsoft Excel (Microsoft Corporation, Seattle, USA) and Minitab (Minitab Inc., State College, PA, USA). Statistical tests were conducted at the 0.05 level of significance.

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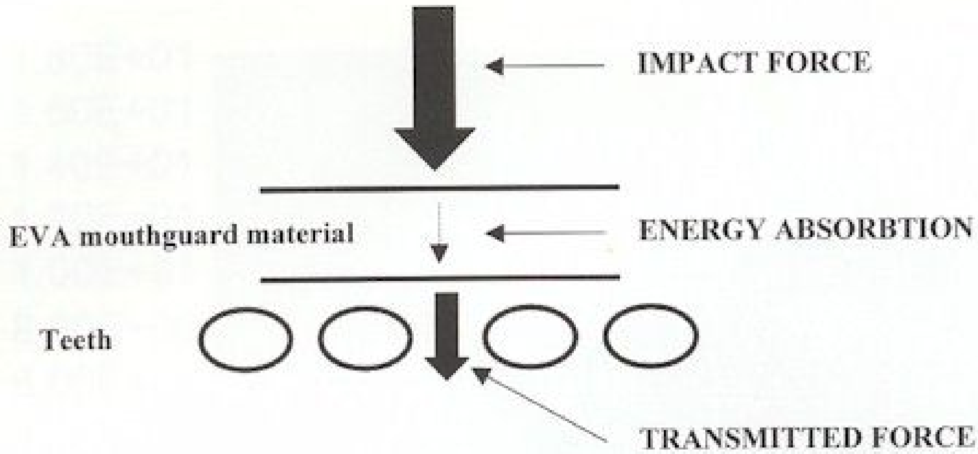

Fig. 1. – Transmitted force and energy absorption through mouthguard materials: outline of testing.

Results

Table 1 shows the transmitted forces for the five different mouthguard sheets, as well as the differences in forces transmitted and the percentage differences of the four test samples compared with the control. Figure 3 summarizes these results.

All test sheets exhibited increased levels of transmitted forces compared with the control sheet. The maximum transmitted force was 15.6 N in sample 2 where the hard layer was the second layer from the impact surface. Energy absorption, that is impact force less transmitted force, was greatest in the control material (sample 5) where the transmitted force was the lowest at 10.4 N.

The most efficient energy absorption using a hard insert was observed when the hard insert had the thickest covering of softer EVA thermoplastic and was the deepest layer. The mean transmitted force through this sample was 12.1 N.

Statistical analysis showed that the control material without a hard insert transmitted significantly lower forces than all of the test samples. Although a one-way analysis of variance showed that the transmitted forces through samples 1 and 2 were not significantly different, it is not clear why the transmitted forces in sample 2 were slightly greater than in sample 1 and against the trend shown in the other results. However, the transmitted forces in sample 3 were significantly less than in samples 1 and 2. There was also a significant difference in the transmitted forces in samples 3 and 4 and also between sample 4 and the control.

Table 1. Transmitted forces (N): means, differences and percentage differences from control

	Mean (SD)	Difference	% difference
Sample 1	15.1 (0.30)	4.7	44.9
Sample 2	15.6 (0.28)	5.2	50.0
Sample 3	13.8 (0.30)	3.4	32.6
Sample 4	12.1 (0.18)	1.7	16.7
Sample 5 (control)	10.4 (0.13)	0	0

Discussion

When impacted, the energy absorption of a mouthguard material is produced by the distortion and recovery of the mouthguard material with subsequent energy absorption. The elasticity of the material determines the energy absorption. The current results show that the inclusion of hard inserts with higher Shore A values (90), and consequently less elasticity, reduces the ability of the mouthguard to absorb energy.

In practice, the use of harder material to fabricate mouthguards may affect wearer confort while retention may also be reduced due to the difficulty of insertion into undercut areas. This latter aspect is recognized by some laminated mouthguard manufacturers who include an initial deep layer of

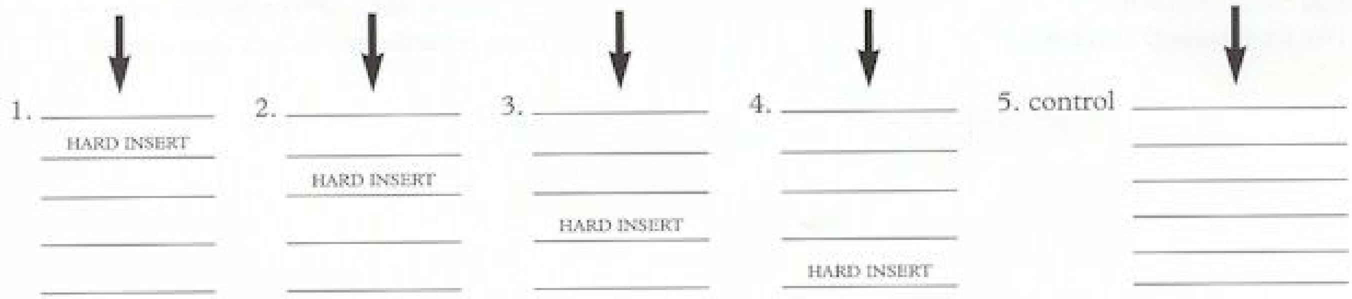

Fig. 2. – Laminate samples: combinations and impact direction.

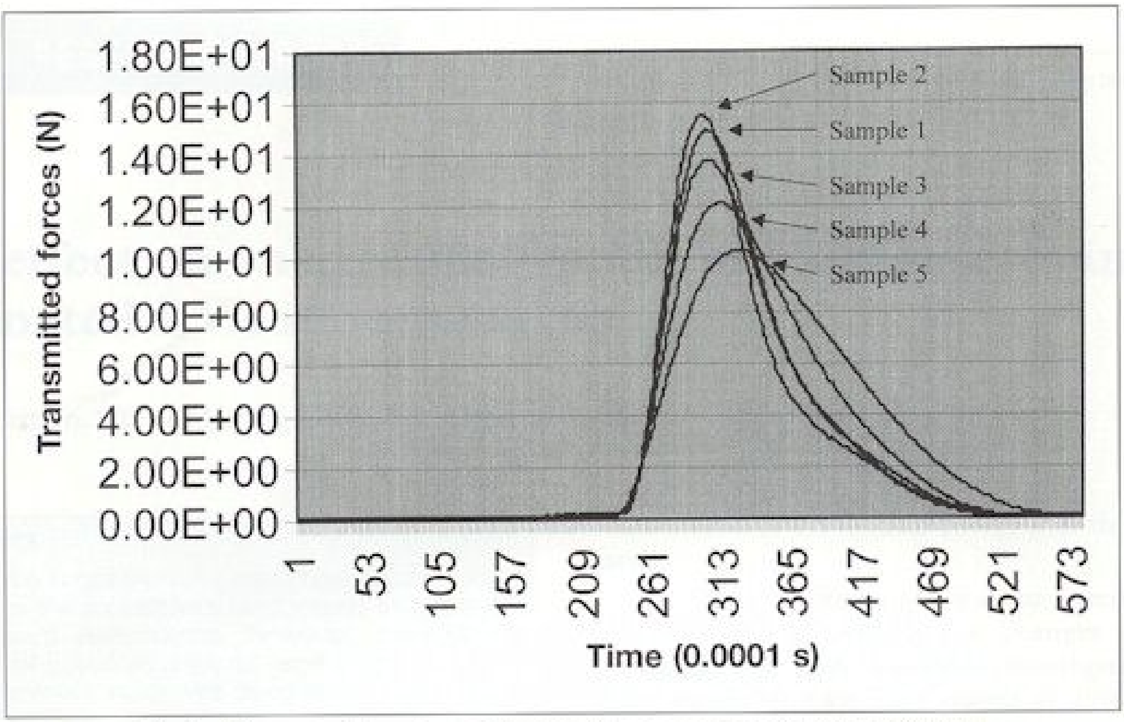

Fig. 3. – Transmitted forces through laminated mouthguard materials with hard inserts.

soft material which directly contacts teeth and gingival surfaces.

The impaired energy absorption of multilaminate mouthguard materials with hard inserts must be balanced with unpublished claims that harder inserts may spread the impact force to other parts of the maxillary arch in a form of energy dissipation. This study identifies the transmitted forces through the mouthguard materials at the point of impact. These forces represent the maximum transmitted forces and therefore the most likely to damage underlying tissues.

This study suggests that the use of hard inserts in laminated mouthguards does not improve energy absorption but, in fact, actually increases the risk of injury to the mouthguard wearer. A mouthguard material with high elasticity, and therefore maximum energy absorption properties, provides maximum protection for reducing dental and dento-alveolar trauma.

Conclusion

The inclusion of a hard layer of EVA plastic in laminated mouthguards reduces the energy absorption properties of a mouthguard. This would lead to a greater risk of dental and dento-alveolar injury.

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References

1. de Wijn JR, Vrijhoef MMA, Versteegh PA, Stassen HP, Linn EW. A mechanical investigation to the functioning of mouthguards. Biomedics: Principles and applications. The Hague: Martinus Nijhoff Publishers, 1982.
2. Park JB, Shaull KL, Overton B, Donly KJ. Improving mouthguards. J Prosthet Dent 1994;72:373-380.
3. Westerman B, Stringfellow PM, Eccleston JA. Forces transmitted through EVA mouthguard materials of different types and thickness. Aust Dent J 1995;40:389-391.
4. Westerman B, Stringfellow PM, Eccleston JA. An improved mouthguard material. Aust Dent J 1997;42:189-191.
5. Hunter K. Sports mouthguards. Sydney: Dental Health Foundation, 1998.
6. Kopp HP. All mouthguards are not created equal. Laboratory Digest 1996;Fall:1.
7. Hunter K. Pressure formed mouthguards. Australasian Dental Practice 1998;9(2):30-32.

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