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Original Article

Use of Polyolefin as Mouthguard Material as Compared to Ethylene Vinyl Acetate

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Abstract

A new mouthguard material, polyolefin, was recently developed. To date, no studies have compared ethylene vinyl acetate (EVA) and polyolefin mouthguards. The aim of this study was to evaluate the physical properties of polyolefin, relative to those of EVA. Two polyolefin materials, hard and regular, were used, in addition to EVA. Hardness, tensile strength, tear strength, elongation, and water absorption were analyzed, as well as the adhesive strength of the materials in laminated mouthguards. Hard polyolefin (MG-H) and EVA were significantly harder than regular polyolefin (MG-R) ($p<0.01$). Regular polyolefin had significantly lower tensile and tear strengths than MG-H and EVA ($p<0.01$), while MG-H had significantly higher tensile and tear strengths than EVA ($p<0.01$). Both polyolefin materials had significantly lower water absorption and higher adhesive strength than EVA ($p<0.01$). In this study, polyolefin exhibited satisfactory physical properties when compared with EVA. This suggests that polyolefin is suitable for use as a mouthguard material.

Introduction

All sporting activities are associated with risks regarding injury to various parts of the body. In contact sports, such as football, rugby, karate, and boxing, the head and facial areas are more likely to sustain injuries (1). In the case of teeth and oral tissues, the mouthguard is the principal device that protects against injuries, thus reducing the need for expensive therapy and preventing irrecoverable buccal damage (2).

Studies have shown that intraoral mouthguards protect players from injuries to the teeth and lips and reduce the chances of serious injury to the head and neck, such as concussion and jaw fracture (3-7). Athletic mouthguards are designed to protect the lips and intraoral soft tissues from bruises and lacerations, to protect teeth from crown fractures, root fractures, dislocations, and avulsions, to protect jaws from fractures and dislocations, and to provide support for edentulous spaces (8-10). Dentists should therefore make periodic inquiries about the sports activities of their patients and determine who is at risk of orofacial injury (11). Dentists should then offer to fabricate a custom-made mouthguard for these patients as a part of their regular dental visits (12).

In addition to preventing athletic injuries, custom-made mouthguards can also prevent oral trauma to the labia oris, glossa, and buccal mucosa. Mouthguards have been shown to be effective against the involuntary injuries seen in persons with cerebral handicaps, infantile palsy, and comatose state and we have already applied such devices clinically (13).

The quality of materials employed in a good mouthguard is important. Physical properties, such as hardness, tensile strength, water absorption, elongation, and tear strength, must be considered for anatomical adaptation (14, 15). At present, various types of custom-made mouthguards are prepared from ethylene vinyl acetate (EVA), which exhibits satisfactory physical properties as well as good adaptation, fitness, comfort, and durability.

In addition, adhesion strength between mouthguard sheets, in addition to sheet material characteristics, is important when attempting to improve the protective properties of laminate mouthguards for athletes. Polyolefin, which was initially developed as a denture base material, has recently been applied as a mouthguard sheet material. However, no studies have yet compared the physical properties of polyolefin with those of EVA.

The aim of this study was to evaluate the physical properties of polyolefin, including the peel strength of laminate mouthguards, and to compare these properties with those of EVA.

Materials and Methods

Two types of polyolefin (MG21®, Molten Corporation, Tokyo, Japan), hard and regular (MG-H and MG-R, respectively), and EVA (Proform®, Dental Resources Inc., Delano, MN, USA) were used in this study. The thickness of these materials was 2 mm.

Physical properties of polyolefin and EVA materials were analyzed according to the procedures of the International Organization for Standardization (ISO ; numbers 48, 37, 34, 2285, and 1817, respectively).

Hardness was measured based on the gum hardness scale GS-70 (Temrock Co. Ltd.,) according to ISO 48.

Tensile strength, tear strength, and elongation were measured based on AGS-500A (Shimazu Co. Ltd., Japan) at a speed of 500 mm/min according to ISO 37, 34, and 2285. Tensile strength is determined before tear strength makes a cut in one piece of a sample (30×30 mm) and pulls it, and an opposing force tears it further. This value becomes a permanent index.

For water absorption, a specimen of 50φ×1.5 mm was produced according to ISO 1817 and was soaked in distilled water at 37 °C for 24 hours. Weight change was then measured using an electronic balance (AE166 ; Meratoe Co., Ltd.).

The adhesive strength of the materials in laminated mouthguards was also tested. Mouthguard materials of the same thickness were mounted in an Erkopress device (Erkodent Inc., Germany). The upper material was heated and then glued with compression to the lower material without using organic solvents. During this latter step, a fluoro-ethylene-vinyl sheet (Molten Corporation, Tokyo, Japan) was partially inserted between the upper and lower materials. After cooling, the heated and glued material was cut to a size of 10 mm×30 mm with an adhesion area of 10 mm×10 mm and a non-adhesion area of 10 mm×20 mm ; this was used as a test specimen for peel strength (Fig. 1). In addition, Soft Retainer Bond EX® (Rocky Mountain Morita Corp., Japan) was used for adhesion of EVA in accordance with the manufacturer's instructions. This specimen was mounted in an AGS-500A (Shimadzu Co., Osaka, Japan) and was tested at an abrasion speed of 30 mm/min. The ISO test for adhesive peeling resistance of rubber was utilized (ISO 813).

Mean values and standard deviation (SD) of physical properties were calculated for each material. Analysis of variance (ANOVA) was performed to detect significant differences in mean values between the materials and post-hoc comparisons were performed using the Bonferroni method.

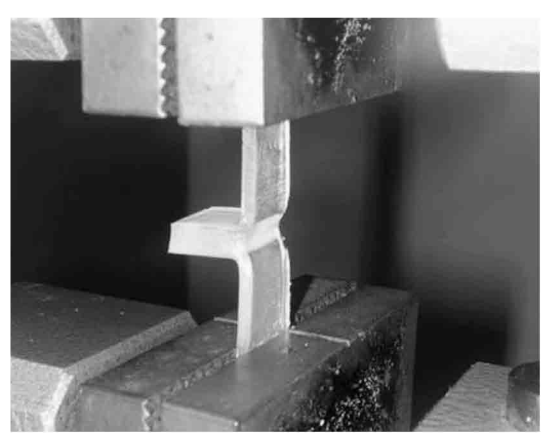

Fig. 1. System and specimen for measuring adhesive peeling strength of laminated mouthguard materials.

Results

Figure 2 shows : hardness (A), tensile strength (B), tear strength (C), elongation (D), water absorption (E), and adhesive strength (F) data for each material.

With regard to hardness, MG-R (75.7±0.6) was significantly softer when compared to MG-H and EVA (82.0±1.0 and 80.7±0.6, respectively) ($p<0.01$, ANOVA). However, there were no significant differences between MG-H and EVA.

MG-R had significantly lower tensile strength (1236.3±56.7 N/m²) and tear strength (44.1±0.94 N/mm) when compared to MG-H and EVA ($p<0.01$, ANOVA). In addition, MG-H had significantly higher tensile strength and tear strength (2120.8±121.3 N/m² and 60.4±0.8 N/mm, respectively) when compared to EVA (1757.5±86.6 N/m² and 48.1±1.5 N/mm, respectively) ($p<0.01$, ANOVA).

There were no significant differences among the three materials on the elongation test.

MG-H and MG-R had significantly lower water absorption (0.012±0.0009%, 0.015±0.0006%, respectively) and higher adhesive strength (14.4±0.01 N/mm, 12.7±0.06 N/mm, respectively) when compared to EVA (0.222±0.0096% : water absorption, 7.4±0.25 N/mm : adhesive strength) ($p<0.01$, ANOVA).

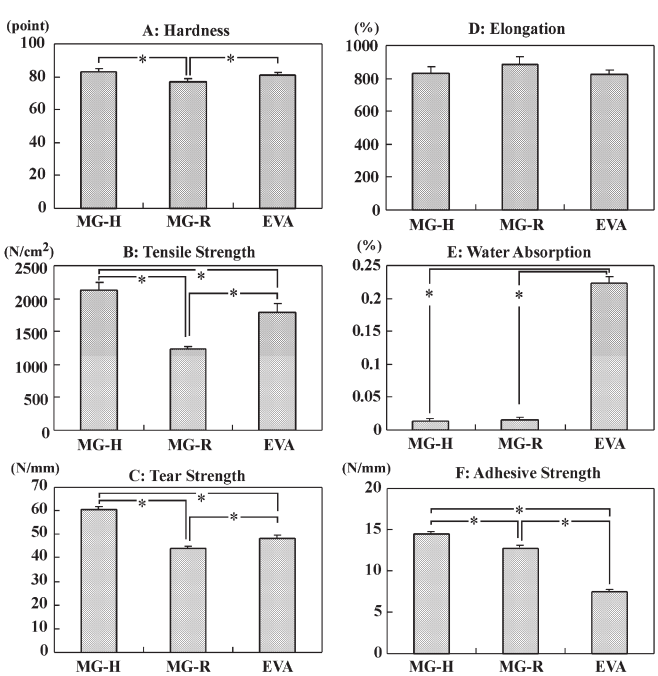

Fig. 2. Physical data for hardness (A), tensile strength (B), tear strength (C), elongation (D), water absorption (E), and adhesive strength (F) for each material ; hard polyolefin (MG-H), regular polyolefin (MG-R), and ethylene vinyl acetate (EVA). *$p<0.01$

Discussion

The purpose of mouthguards is to protect the teeth and oral tissues from impact injuries during sporting activities. However, sporting activities differ substantially, and various impacts are possible, such as frontal, lateral, and downward impacts (16). The buccal region is easily damaged during sporting activities (17). Material thickness in critical areas is believed to enhance protection and allows for maxillary articulation during impact.

The most common material employed in the fabrication of mouthguards is EVA (18). The physical qualities and the potential for multiple layers of EVA to meet the thickness requirements of individual athletes are widely well known (19-21).

On the other hand, polyolefin is already used in sports mouthguards (22), but its physical properties have not been reported. This study reports the pathognomonic physical properties of polyolefin. MG21, which was used in this study, is a polyolefin copolymer and this compound can be used to produce sheet materials of varying consistency by changing the average molecular weight of the polyolefin copolymer. Thus, polyolefin is available in hard (MG-H) and regular (MG-R) hardness in sheets with the same thickness.

With regard to hardness, tensile strength, and tear strength, MG-R has lower values than EVA, while MG-H has higher values than EVA. Craig *et al*. reported that EVA possesses good physical properties for use in mouthguards (23). However, polyolefin material has similar or better physical properties when compared with EVA. These results suggest that polyolefin material is a suitable material for use in mouthguards.

Surprisingly, MG-H and MG-R had markedly lower water absorption when compared with EVA. This suggests greater stability than EVA, particularly with regard to problems commonly associated with water absorption, such as expansion, pigmentation, and bacterial contamination.

Furthermore, adhesive peeling tests revealed that MG-H and MG-R possess significantly higher adhesion strength when compared with EVA. Ideally, reinforcing materials should bond chemically to the matrix material, to prevent deterioration during molding and use (24). However, when the mouthguard begins to peel or exhibit failures, it is difficult to repair these areas by adding new pieces of EVA.

Polyolefin allows adhesion between pieces without bonding agents. Utilizing only the heat pressure laminating technique, it is possible to prepare mouthguards of various thicknesses, depending on the at-risk areas. Partial customization by heating, which was previously difficult using EVA, is now possible using polyolefin, and thus the demands of athletes can be met by using polyolefin as a conventional mouthguard material. Polyolefin was shown to have better adhesive strength than EVA, which is achieved without chemical adhesives, and thus the potential risks from residual solvent are minimized.

In this study, polyolefin material exhibited satisfactory physical properties when compared with EVA. In particular, the polyolefin compounds studied here were easily layered and repaired using heat alone and do not require organic solvents. This suggests that polyolefin is a suitable material for mouthguards. Further clinical trials of polyolefin mouthguards are required to ensure quality and safety during actual use.

Conclusions

A new mouthguard material, polyolefin exhibited satisfactory physical properties when compared with EVA. This suggests that polyolefin is suitable for use as a mouthguard material.

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