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THE COMPARISON OF MECHANICAL PROPERTIES OF CUSTOM-MADE AND "BOIL AND BITE" TYPE MOUTHGUARDS

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Abstract

Introduction: Most of carried out investigations are concentrated on custom-made and "boil and bite" type mouthguards. Because of the variety of materials and techniques used in their preparation, there is a need for conducting durability tests of ready-to-use occlusal splints. The aim of this study was to determine the properties of different types of mouthguards, their resistance to external force in the form, which is ready to use by competitors, and to determine the research method for their comparison.

Materials and Methods: At first stage, custom-made mouthguards were prepared with the use of Corflex Orthodontic and Impak materials; also "boil and bite" type splints were adapted—perforated (Protech), strengthened (Shock Doctor) and single-layer (Porida). They were tested with the use of MTS Q/Test 10 device on the gypsum class IV cast models. The results were compiled with the use of statistical analysis.

Results: The best result was obtained by Corflex mouthguard (average rank 2,006.060), followed by Impak (1,730.292), Shock Doctor (1,700.456), Protech Dent (1,613.580) and Porida (1,397.113). In multiple comparison test there were statistically important differences between all types of mouthguards, with the exception of the following pairs: Protech-Impak, Shock Doctor®-Impak, Protech-Shock Doctor ($p>0.05$).

Conclusions: Mechanical properties of custom-made mouthguards are better than these of "boil and bite" type guards. Defined research method may be used for preliminary comparison of mouthguards, which are ready to use by competitors.

Key words: *mouthguards; custom mouthguards; "boil and bite" mouthguards; teeth trauma; sport*

Introduction

Usage of mouthguards is recommended in variety of disciplines, especially in extreme sports, team sports and martial arts. It should be also recommended in other disciplines like cycling, rollerskating or skiing. Nowadays, "boil and bite" type guards, available in retail in sports stores, are the most frequently used guards [1]. Proper fitting depends on the user's qualifications, as one adjusts the guard directly in oral cavity, alfter plasticising it using hot water. However, the retention obtained this way is insufficient, which makes it necessary to clench teeth in order to hold the mouthguard in right place [2]. The loss of protection splint's stabilization during the impact may be a possible cause of damage amplification. Owing to this fact, custom-made mouthguards, which ensure the optimal retention and stabilization, should be recommended for competitors as a mean to prevent head and oral cavity injuries [3-5].

The evaluation of resistance of materials used in mouthguards' preparation, the formulation of strict quality standards and the study on adequate thickness of material have been the subject of many investigations [6, 7, 8]. Commercially available "boil and bite" type splints make it difficult to define appropriate research method—their shape makes preparation of samples required for durability tests impossible, while heating and compressing them into flat plates influences final results [9]. In addition, manufacturers often use patented material's composition, which also causes difficulties in comparing with custom-made mouthguards' materials. As of now, researches determining standardization of mouthguards are unavailable. Further analysis concerning the comparison of custom-made and "boil and bite" type splints are essential.

The aim of this study was to compare mechanical properties of different types of mouthguards in the form, which is ready to use by competitors, assessing the durability of material subjected to external force and to create research method, which would provide the possibility of comparing different types of available mouthguards.

Material and Methods

At first, two types of custom-made mouthguards were prepared with the use of the Corflex Orthodontic (Pressing Dental, Italy) material (Fig. 1), and the Impak (CMP Industries, Albany, USA) material individually for the patient. Concurrently, "boil and

Fig. 1. *Custom-made mouthguard made of Corflex Orthodontic material*

Fig. 2. *Perforated Protech Dent "boil and bite" mouthguard*

Fig. 3. *Strengthened Shock Doctor "boil and bite" mouthguard*

Fig. 4. *Mouthguard in MTS Q/Test 10 device*

bite" type mouthguards were—using hot water and under supervision of a dentist—fitted by the athlete. From among standard guards, perforated (Protech Dent, Akervall Technologies, Ann Arbor, MI) (Fig. 2), strengthened (Shock Doctor® INC., Minnetonka, MN) (Fig. 3) and single-layer (Porida, Cobat Gear, Pakistan, India) mouthguards were examined. Additionally, on the basis of fifteen patient's alginate dental impressions, gypsum class IV models were cast. They were used as a non-reusable, custom-made stabilizers for tested guards, which were destroyed during trial. Mouthguards placed on gypsum models were subjected to external dynamic force, impacting labial side of incisors protected by mouthguard. The force was generated using conical element of MTS Q/Test 10 device (Fig 4). The research was conducted on the Division of Materials Design, The Faculty of Materials Science and Engineering at the Warsaw University of Technology. Each mouthguard was exposed to the force three times; maximal value of the force was read in the moment of destruction of gypsum model. Fifteen trials were taken. Due to differences in material characteristics, each mouthguard durability test differed in time span. The results were subjected to statistical analysis. Using Shapiro-Wilk test, the normality of distribution was analyzed—as the results in each group deviated from a normal distribution value ($p<0.05$), further analyses were prepared with the use of nonparametric ANOVA Kruskal-Wallis test. In order to define the differences between mouthguard types, multiple comparison test was carried out.

Results

During testing of five types of mouthguards, there have been statistically significant differences between the load (N) at 0.05 level of significance. The average rank in Kruskal-Wallis test was the highest for custom-made Corflex Orthodontic material mouthguard: 1,738.295. Further, the average rank for Shock Doctor amounted to 1.932 635, for Porida—1.759 725, for Impak—1.626 530 and for Protech Dent—1.237 211 (Table 1). The highest median load (N) was obtained by Corflex mouthguard: 651.017 N, and it was followed by Impak with 602.994 N, Shock Doctor with 359.562 N, Porida with 93.293 N and finally Protech with 0.098 N (Table 2). In multiple comparison test statistically significant differences between different types of mouthguards were obtained for variable load, except

Table 1. *Ranks assigned to the load*

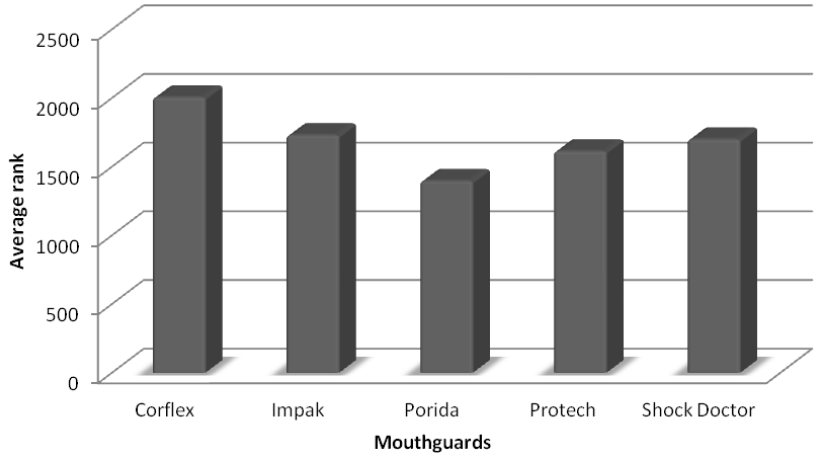

Table 2. *Median load*

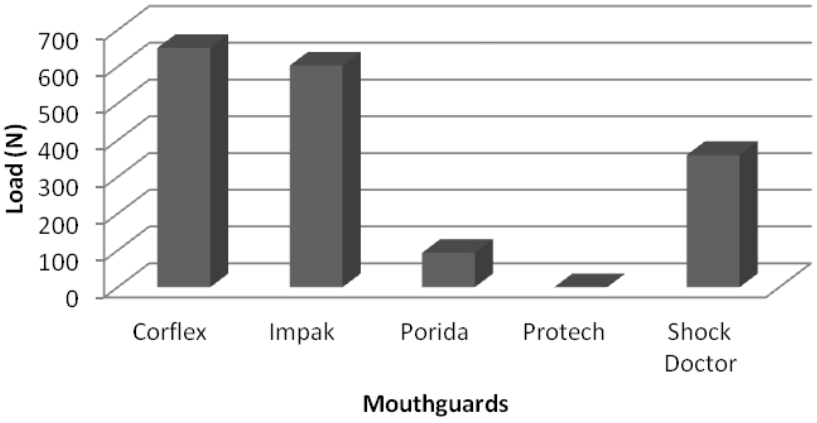

Table 3. *Multiple comparison test, statistically significant differences (p>0,05)*

Multiple comparison test (load)	Corflex	Impak	Porida	Protech	Shock Doctor
Corflex		0,000	0,000	0,000	0,000
Impak	0,000		0,000	0,604	1,000
Porida	0,000	0,000		0,010	0,000
Protech	0,000	0,604	0,010		1,000
Shock Doctor	0,000	1,000	0,000	1,000	

for the following pairs: Protech-Impak, Shock Doctor--Impak, Protech-Shock Doctor (p>0.05) (Table 3).

Discussion with conclusions

Usage of mouthguards plays an important role in prevention of head and mouth injuries. Presented research method, based on gypsum class IV models, despite obvious simplifications can be used in preliminary comparison of different mouthguards in form of ready-to-use splint. In order to obtain permission for sale and trading and to ensure sufficient protection for the users, comparable for each available construction, further investigation, concentrated on providing standards for testing of custom-made and "boil and bite" type guards, is necessary. Additional research, evaluating Protech Dent mouthguard, made from thin, perforated, and rigid material is recommended. In this study, it achieved the lowest median load and rank in Kruskal-Wallis test. The time of breakage was short and measured force was low probably because of the fact, that it did not absorb and dissipate the impact force. Considering the limitations of presented study, it is essential to conduct another research to properly estimate the *in vivo* protective function.

The evaluation of mouthguards in the form of ready-to-use splint and attempt to define research

procedure had been the object of study before. Despite *Greasley*, et al. have developed standard test procedure for guards' assessment, it has not been commonly used yet [10]. They were using standard jaw model, constructed of an arch of rubber (94 in Shore's Hardness Scale) containing idealized teeth. Purposefully created model of head—modified Xybrid III mannequin—was used by *Viano*, et al. [11] in assessing the possibility of reducing the likelihood of concussion and estimating the reduction of the impact force concentrated on upper arch or temporomandibular joint structures. The modification used in the research had simulated temporomandibular joint and teeth. The comparison of custom-made and "boil and bite" type mouthguards have also been performed by *Hoffman*, et al. [12]. In the research, the Top Ten (Berlin, Germany) and Macho (Sebastian, CA, USA) "boil and bite" type splints were compared with similarly shaped custom-made guards prepared with the use of Playsafe Light/Medium/Heavy/Heavy Pro (Erkodent, Pfalzgrafenweiler, Germany) material. They were introduced onto resin jaw model with set metal teeth and exposed to force created by pendulum impact. Similar results were presented by *Greasley*, et al., who were using standard jaw model in order to compare *in vitro* the effectiveness of different types of mouthguards. All tested custom-made intraoral guards evidenced favourable protective functions in comparison with "boil and bite" type ones [13].

The highest load, before damaging gypsum models serving as stabilizers for mouthguards, was observed during testing of mouthguard custom-made of Corflex Orthodontic material. On the basis of this analysis, it can be concluded that guards made of this material deliver the best protective function. The mechanical properties of custom-made mouthguards proved to be better than these of "boil and bite" type mouthguards. The lowest median of the load and the lowest rank was assigned to Protech Dent mouthguard. The usage of this product is not recommended in head and oral cavity trauma prevention.

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PORÓWNANIE WŁAŚCIWOŚCI MECHANICZNYCH WEWNĄTRZUSTNYCH OCHRANIACZY INDYWIDUALNYCH I TYPU „BOIL AND BITE”

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Streszczenie

Wprowadzenie: Większość prowadzonych badań, które dążą do wskazania najbardziej korzystnych pod względem funkcji ochraniaczy, koncentruje się na ochraniaczach indywidualnych i typu „boil and bite”. Ze względu na różnorodność materiałów i technik stosowanych w wykonawstwie ochraniaczy, niezbędne jest przeprowadzenie ich testów wytrzymałościowych w postaci gotowej do użytkowania szyny nazębnej, w oparciu o prostą procedurę o charakterze porównawczym.

Cel pracy: Celem badania było określenie właściwości różnych rodzajów ochraniaczy i ich odporności na działanie siły zewnętrznej w formie przygotowanej do użytkowania przez zawodnika oraz opracowanie wstępnej metody badawczej pozwalającej na ich porównanie.

Materiał i metody: W pierwszym etapie wykonano ochraniacze indywidualne z materiałów Corflex Orthodontic i Impak oraz dostosowano ochraniacze typu „boil and bite” – perforowany (Protech), wzmocniony (Shock Doctor) i standardowy (Porida). Ochraniacze zostały następnie poddane próbie ściskania za pomocą urządzenia MTS Q/Test 10 na modelach z gipsu klasy IV. Siłę przyłożono za pomocą elementu stożkowego do powierzchni zębów siecznych zabezpieczonych ochraniaczem. Otrzymane wyniki poddano analizie statystycznej.

Wyniki: Na poziomie istotności 0,05 występuje statystycznie istotna różnica między wartościami obciążenia (N) osiąganymi dla pięciu powyższych rodzajów ochraniaczy. Najwyższe obciążenie przed uszkodzeniem badanej próby uzyskał ochraniacz Corflex (średnia ranga 2006,060) następnie kolejno: Impak (1730,292), Shock Doctor (1700,456), Protech (1613,580) oraz Porida (1397,113). W teście porównań wielokrotnych występuje statystycznie istotna różnica (p=0,000) dla wartości zmiennej obciążenie między wszystkimi rodzajami ochraniaczy, z wyjątkiem par (p>0,05) Protech - Impak, Shock Doctor - Impak, Protech - Shock Doctor.

Wnioski: Właściwości mechaniczne ochraniaczy indywidualnych są lepsze niż ochraniaczy typu „boil and bite”. Opracowana metoda badawcza pozwala na wstępne porównanie ochraniaczy w postaci gotowej do użytkowania przez zawodnika.

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