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IN VITRO WEAR RESISTANCE OF THREE TYPES OF POLYMETHYL METHACRYLATE DENTURE TEETH

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ABSTRACT

The wear resistance of denture teeth is important to the longevity of removable prostheses of edentulous patients. The ability of denture teeth to maintain a stable occlusal relationship over time may be influenced by this property. The purpose of this *in vitro* study was to evaluate the wear resistance of polymethyl methacrylate (PMMA) denture teeth based on their chemical composition when opposed by a ceramic antagonist. The maxillary canines (n=10) of 3 PMMA denture teeth (Trubyte Biotone, cross-linked PMMA; Trilux, highly cross-linked IPN (interpenetrating polymer network)-PMMA; and Vivodent, highly cross-linked PMMA) were secured in an *in vitro* 2-body wear-testing apparatus that produced sliding contact of the specimens (4.5 cycles/s, sliding distance of 20 mm, under 37°C running water) against glazed or airborne particle abraded ceramic. Wear resistance was measured as height loss (mm) under 300 g (sliding force) after 100,000 cycles, using a digital measuring microscope. Mean values were analyzed by 2-way ANOVA and Tukey's test (α=0.05). The wear of Trubyte Biotone (0.93 ± 0.14 mm) was significantly higher than that of both other types of teeth tested against abraded ceramic ($p<0.05$). The Vivodent tooth (0.64 ± 0.17 mm) exhibited the best wear resistance among the denture teeth tested against airborne particle abraded ceramic. There were no statistically significant differences ($p>0.05$) in wear among the 3 denture teeth evaluated against glazed ceramic. Trilux and Vivodent teeth tested against either glazed or airborne particle abraded ceramic did not differ significantly from each other ($p<0.05$). All teeth showed significantly more wear against airborne particle abraded ceramic than against glazed ceramic ($p<0.05$). In conclusion, the three types of PMMA denture teeth presented significantly different wear resistance against the abraded ceramic. The high-strength PMMA denture teeth were more wear-resistant than the conventional PMMA denture tooth.

Key words: Denture teeth. Polymethyl methacrylate. Acrylic resin. Wear resistance.

INTRODUCTION

Wear resistance of denture teeth has been considered as one of the most important requirements for oral rehabilitation of edentulous patients with removable dentures, in order to maintain a stable occlusal support over time[13]. Wear of the occlusal surfaces may result in insufficient posterior tooth support[25], loss of chewing efficiency[1,21] and nonfunctional activities[1,2]. Although wear of acrylic resin teeth has also been related to the loss of vertical dimension of occlusion with complete dentures, the major factor affecting it is the reduction of residual ridges by resorption[22].

Initially, denture teeth were made of ceramic material. With the advent of polymethyl methacrylate (PMMA) in the 1940s, a new material was introduced for the fabrication of denture teeth[8]. Denture teeth are currently made of either methacrylate-based resins (acrylic resin) or ceramics, although resin teeth have almost eliminated ceramic teeth from the market[25] due to a number of advantages, such as the chemical bond to denture base[5,6,16], lower susceptibility to fracture[6] and decrease of clicking[4,24]. Nonetheless, the wear resistance of acrylic resin teeth has been questioned for being lower than that of ceramic teeth[10-12,18,20,22,28]. Manufacturers have then tried to develop acrylic resins designed to offer improved wear resistance for resin denture teeth[25].

PMMA has been reported to have advanced with the advent of cross-linked agents[27], which are bifunctional monomeric molecules that are added to the polymeric material to allow crossing between linear polymeric chains[11]. The

cross-linked polymer was later modified by increasing the quantity of cross-linked agents to ensure a higher degree of cross-linking between the polymers[22], or by blending special polymers and co-polymers.[3] Other modification of cross-linked polymer was the appearance of resins with interpenetrating polymer network (IPN) [22,28]. IPN resin is formed when a polymer network is crossed inside another network occupied by a second crossed polymer. The crossed networks coexist in the same volume of the space (one being physically retained within the other) and cannot be separated without chemical bond rupture[22,29]. These factors may influence the final quality for the acrylic resin and produce denture teeth with better mechanical and physical properties[26].

The search for a more wear-resistant denture tooth material resulted in the development of modified resin teeth that display acceptable wear resistance[21]. In present days, acrylic resin denture teeth can be classified into two main categories: conventional (with crossed-linked polymeric chains) and high-strength (with various polymer technologies that provide different chemical compositions). Some studies[22,27,28] have found a higher wear resistance for the high-strength acrylic resin denture teeth with modified polymers in comparison to conventional PMMA, while others[14,15,17,19,29] have found no advantages of such materials with regard to wear properties.

Composite resin denture teeth were developed in the 1980s as an effort to achieve greater wear resistance and bond strength to denture bases[30]. Tooth materials made with microparticle inorganic fillers immersed in a BIS-GMA (bisphenol a glycidyl methacrylate) matrix[1,28], or nanometric inorganic fillers immersed in a PMMA matrix[26] have been used for fabrication of composite denture teeth. It has been reported that composite denture teeth show a higher wear resistance than acrylic resin denture teeth[3,26], although data vary depending on the experimental design[3]. Moreover, some authors found denture teeth with inorganic fillers to be 40-50% more abrasion-resistant than IPN teeth[27].

Despite the evolution of the mechanical properties of PMMA, wear of this material continues to occur with clinical use[10,12]. The wear resistance of acrylic resin denture teeth has been investigated[22,27,28]; however, the constant appearance of resins with modified polymers used for fabrication of denture teeth manufacturing, impose the need for further studies in this context. Furthermore, the results are not clear because the wide variety of wear-testing devices have hindered the comparison of the results[19,26], which reflect the lack of a standardized and reproducible methodology for testing the wear resistance of acrylic resin denture teeth[28].

This *in vitro* study tested the null hypotheses that there is no difference among the wear resistance of one conventional (Trubyte Biotone) and two high-strength PMMA denture teeth (Trilux and Vivodent) when opposed to glazed or airborne particle abraded ceramic. The two different antagonist ceramic surfaces were used to allow the test to be carried out under conditions that would cause minimal and maximal wear of the denture teeth.

MATERIAL AND METHODS

Both right and left maxillary canines (n=10) of 3 types of PMMA denture teeth were purchased: Trubyte Biotone (a conventional denture tooth composed by cross-linked PMMA); Trilux (a high-strength tooth composed by highly cross-linked IPN-PMMA); and Vivodent (a high-strength tooth composed by highly cross-linked PMMA) (Table 1). These products were selected on the basis of their chemical composition. All teeth were stored in distilled water at 37°C for 24 h before wear testing to allow water absorption.

The *in vitro* two-body wear-testing apparatus used in this study was a simulated brushing machine. The denture tooth was fixed on the top of a tooth brush using a screw and composite resin to allow the tooth be fixed on the wear-testing apparatus. The tooth was securely mounted on the upper stainless steel holder of the apparatus (movable part), whereas the antagonist plate was mounted on the fixed bottom part so that they contact tightly on each surface (Figure 1). Glazed or airborne particle abraded metalloceramic plates (2.5 X 1.2 X 0.15 cm) were used as antagonist surfaces and replaced after each change of denture tooth. The opposing plates were cast in Ni-Cr alloy (Durabond® Universal, Odonto Comercial Importadora Ltda) and trimmed with aluminum oxide abrasive burs at low rotation. Thereafter the surface was sandblasted with 100 μm aluminum oxide particles (Trijato Odonto Larcon, Maringá, PR, Brazil) and the conventional application of porcelain was made, including the glaze final process (Duceram® Plus, DeguDent Ind. Com. Ltda, Catanduva, SP). For the airborne particle

TABLE 1- Tested polymethyl methacrylate denture teeth

Material	Manufacturer	Composition (as *per* manufacturer information)
Trubyte Biotone	Dentsply Ind. e Com., Rio de Janeiro, RJ, Brazil	cross-linked PMMA
Trilux	Dental Vipi, Pirassununga, SP, Brazil	highly cross-linked IPN-PMMA
Vivodent	Ivoclar-Vivadent, Liechtenstein	highly cross-linked PMMA

*PMMA: Polymethyl methacrylate; IPN: interpenetrating polymer network.

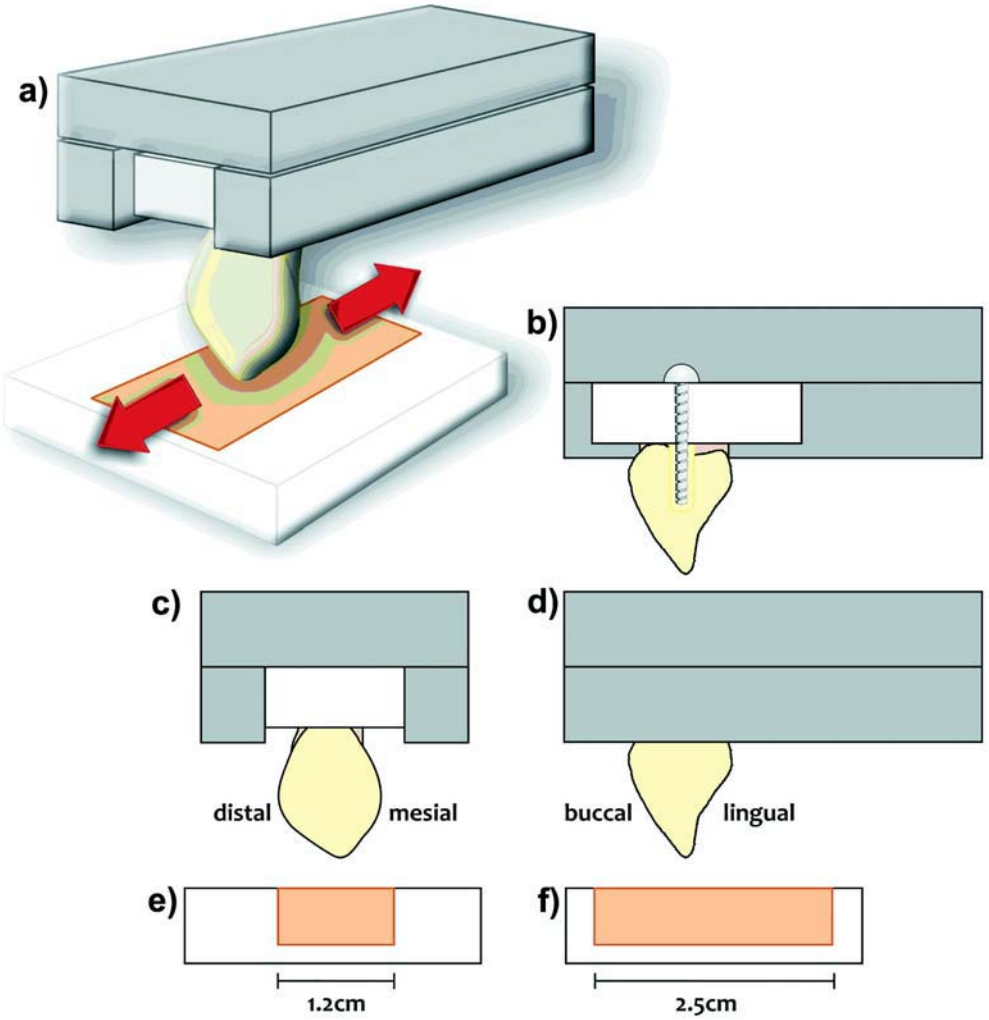

FIGURE 1- a) The canine tooth specimen mounted on the upper stainless steel holder of the apparatus (movable part) and the antagonist plate mounted on the fixed bottom part. b) The canine specimen fixed on the top of a tooth brush using a screw and composite resin (internal aspect). c,d) The shape of the canine specimen (frontal and lateral aspect). e, f) The shape of the antagonist specimen (frontal and lateral aspect)

abraded group, the antagonist ceramic was planed and polished using silicon carbide paper up to 600 (Extec Corp., Enfield, USA) and then sandblasted with 100 µm aluminum oxide particles. At each change of paper, the metalloceramic plates were cleaned in an ultrasonic cleaner at 40 Hz for 2 min.

Wear testing was performed by repeated sliding contact at 4.5 cycles/s with 20 mm sliding distance *per* cycle in the buccolingual direction with a load of 300 g. During the wear test, continuous rinsing with demineralized water (37°C) was used to remove abraded particles from the sample surface and to simulate the wet environment of the oral cavity. The height (mm) of each tooth was measured using a digital measuring microscope accurate to 0.001 mm (TM-505, Mitutoyo Corporation, Japan) before and after the wear test. The wear resistance assessed as height loss (mm) was calculated as the decrease in height after 100,000 cycles. The mean of 4 measurements taken by a single examiner was recorded. The mean wear values were analyzed individually by two-way analysis of variance (ANOVA) and the differences between the denture teeth were determined by the Tukey's test (α=0.05).

RESULTS

The mean wear values obtained after 100,000 cycles of all denture teeth tested against the glazed or airborne particle abraded ceramic plates are summarized in Table 2. There were no statistically significant differences ($p>0.05$) in wear among the 3 denture teeth evaluated against glazed ceramic. There were significant differences among the teeth tested against abraded ceramic, with Trubyte Biotone presenting significantly more wear compared to the high-strength denture teeth ($p<0.0001$), which, in turn, did not differ significantly from each other ($p>0.05$) when tested against either glazed or airborne particle abraded ceramic. All teeth showed significantly more wear against airborne particle abraded than against glazed ceramic ($p<0.05$).

TABLE 2- Wear (mm) after 100,000 cycles

Material	Antagonist ceramic	Wear (mm)
Trilux	Glazed	0.14 (0.04) [a]
Vivodent	Glazed	0.16 (0.08) [a]
Biotone	Glazed	0.17 (0.17) [a]
Trilux	Airborne particle abraded	0.66 (0.16) [b]
Vivodent	Airborne particle abraded	0.64 (0.17) [b]
Biotone	Airborne particle abraded	0.93 (0.14) [c]

*Data with the same letters are not statistically different within the same antagonist ceramic at 5% significance level. Results are expressed as mean(SD).

DISCUSSION

A large number of chewing simulators serving to determine the *in vitro* wear of acrylic resin denture teeth have been described[8,24,30]. *In vitro* methods are classified as two-body test or three-body tests[1]. Three-body wear tests are frequently used to measure wear characteristics. In these tests, in addition to the antagonists, various factors are taken into consideration, namely the abrasive properties of the intermediate medium or pH-related dissolution processes. On the other hand, in two-body wear tests, all substance losses result from a direct interaction between the specimen surface and the antagonist surface[31]. Clinically, this situation arises, for example, during swallowing, empty mastication, parafunctional habits and dynamic occlusion movements. Especially in the case of full dentures with bilaterally balanced occlusion, these direct occlusal contacts are a factor that contributes to the wear of denture teeth. Therefore, a two-body wear simulation was performed in the present this study[25].

The wear-testing apparatus used in this study was developed to evaluate two-body wear of the PMMA teeth abraded directly against glazed or airbone particle abraded opposing ceramic without an intermediate abrasive medium. The obtained data showed that the wear of resin denture teeth was influenced considerably by the texture of the opposing material. The least wear indicated as the total height loss was observed with Trilux tooth opposing the glazed ceramic. However, a very small amount of wear occurred in all denture teeth tested against glazed ceramic, which suggests that the difference on wear among the teeth could not have been detected in this way. Indeed, no significant differences were observed on the wear of the teeth tested against the glazed ceramic ($p>0.05$). Nonetheless, with regard to the data obtained from the airborne particle abraded ceramic, Trubyte Biotone (a conventional denture tooth made of cross-linked PMMA) showed significantly more wear than Trilux (a high-strength denture tooth made of highly cross-linked IPN-PMMA) and Vivodent (a high-strength denture tooth made of highly cross-linked PMMA). Since higher mean wear values were found against the abraded ceramic compared to the glazed ceramic, these results appear to be more consistent in this current wear test series. It is thus assumed that a connection between the chemical composition and the wear resistance of these denture teeth may rather exist. These data are consistent with those other studies that have also found a lower wear resistance for conventional PMMA denture teeth evaluated in comparison to high-strength denture teeth[8,21,24,28,27,26]. However, regarding the high-strength teeth evaluated in the present study (Trilux and Vivodent), no significant differences were found in wear for either of the opposing ceramics. This finding was in accordance with some authors[15,19,21] and had previously been reported by other study[3]. In spite of that, differences in the wear of high-strength denture teeth formulations have been reported[27].

Therefore, the results of previous *in vitro* studies on wear resistance of acrylic resin denture teeth seem to be rather inconsistent[25]. The findings of Whitman, et al.[28], Hirano, et al.[13], and Suzuki[26] have suggested that denture teeth made of IPN resin, highly cross-linked polymers or composite resin are more wear-resistant than the conventional acrylic resin denture teeth made of cross-linked PMMA. Stober, et al. [25], on the other hand, did not find any connection between the chemical composition and the wear resistance of the tested denture teeth. Other investigations also failed to show differences among denture teeth made of polymers with a high degree of cross-linking or polymers with inorganic fillers and teeth made of conventional PMMA[3,14,15,19,22,28,29]. These evidences put in question the superiority of high-strength denture teeth and raises doubts about the advantageous clinical use of these products over time. Indeed, recent clinical investigations have not revealed any statistically proven difference in wear behavior between polymers with a high degree of cross-linking or with inorganic fillers and conventional polymethyl methacrylate[15,19,22]. These conflicting data may be due to the large variety of experimental designs, measuring instruments and wear-testing methods used in these investigations. The large number of denture tooth brands with different chemical compositions has created additional difficulties to the analysis of these data.

In spite of the controversy, the manufacturers frequently launch on the market denture teeth made of new materials. These teeth are advertised as products with improved mechanical properties. The results of this study may assist dentists in selecting PMMA denture teeth from the standpoint of wear resistance. Nonetheless, it is important to consider that

there is not a determinant factor for predicting the wear of PMMA denture teeth. On the contrary, besides the chemical composition of the acrylic resin, several other factors should be taken into account on the abrasive process to allow the scientific understanding of the complex phenomenon of wear, namely the chewing pattern[10,18], chewing frequency[14], occlusion force, food abrasion[10,18], non-functional tooth-grinding habits[11], abrasive cleansers[3], materials' mechanical properties[1,5,20] and dusty atmosphere[12].

CONCLUSIONS

Under the experimental conditions and within limitations of this study, the null hypothesis was rejected, since the wear resistance of the three types of polymethyl methacrylate denture teeth was different against glazed or airborne particle abraded ceramic.

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