Research Article

Effect of Artificial Aging Test on PEEK CAD/CAM Fabricated Orthodontic Fixed Lingual Retainer

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Abstract: Background: The purpose of this study was to evaluate the effect of in vitro long-term simulation of oral conditions on the bond strength of PEEK CAD/CAM lingual retainers. Material and methods: The sample consisted of 12 PEEK CAD/CAM retainers each composed of 2 centrally perforated 3x4mm pads joined by a connector. They were treated by 98% sulfuric acid for 1 minute and then conditioned with Single Bond Universal and bonded to the lingual surface of premolar teeth by 3M Transbond TM System. Half of the retainers were artificially aged using a 30-day water storage and 5000 thermocycling protocol before bond strength testing to compare with the non-aged specimens. Results: The artificially aged retainers showed a marginally lower bond strength than the non-aged retainers. However, independent sample t-test indicated that this difference was statistically not significant. Conclusion: The durability of the PEEK lingual retainer adhesive system has been confirmed using the well-known oral simulating artificial aging protocol of water storage and thermocycling.

Keywords: PEEK, fixed lingual retainer, Single Bond Universal, artificial aging

Introduction

After orthodontic appliance removal, a significant amount of work is yet to be done (1). The retention phase is a vital part after active orthodontic treatments and in most cases, long-term retention is recommended (2).

Since fixed retainers have better esthetics and patient acceptance, they are highly recommended by orthodontists (3). However, poor adaptation and weak durability play an important role in failure of conventional fixed retainers (4).

Depending on the wire materials and manufacturing processes, various types of fixed retainers have been described (5). In recent years, CAD–CAM systems has been used for providing of fixed retainers. However, the studies in this area are limited. When compared to the traditional method, the CAD/CAM technology is more efficient in producing fixed retainers (6). Two recent articles reported the fabrication of a round CAD–CAM nickel-titanium and rigid zirconium bar as a bonded fixed retainer (7,8).

Alternatively, advanced PEEK (poly-ether-ether-ketone) CAD CAM retainer can be anatomically adapted onto teeth to create a strong, durable, tooth-colored, biocompatible retainer; and its flexibility provides physiological teeth movement (9).

This organic thermopressed PEEK polymer is a unique material and now widely used in engineering, medical and dental applications [10]. PEEK has excellent chemical and mechanical resistance even at higher temperatures [11].

The optimal design of a PEEK CAD/CAM lingual retainer had centrally perforated pads to allow the escape of excess composite and allow efficient light cure penetration. These pads are joined by a connector with occlusal support for better adaption. [12] One minute of 98% sulfuric acid etching before conditioning with single bond universal was shown to be the strongest adhesive protocol for bonding of PEEK retainers [13].

The objective of this study was to investigate the effect of artificial aging of PEEK retainers using long-term water storage and thermocycling as an alternative to oral conditions.

Materials and Methods

The proximal surfaces of premolar teeth were reduced to reach a tooth width of 6mm to approximate the width of a lower incisor. Each two teeth were paired in intimate contact and fixed in the plastic mold so that the long axis of the teeth was perpendicular to the mold's base. Then cold cure acrylic was poured into the mold.

The teeth model was scanned and transferred to the lab using the Smart Optic Digital Scanner. The file was opened in Exocad software to create a virtual PEEK retainer with a thickness of 0.8mm [9]. The final design had two pads (3mm wide and 4mm high) joined by connector (2mm in height) with occlusal supports for simpler seating and better precision [12].

The virtual design was then transferred to the CORITEC 250i CAD/CAM system milling engine (Imes-Icore GmbH, Leibozgraben, Germany) which was loaded with a blank of dental PEEK (JUVORA™ Dental Disc; JUVORA Ltd, Wyre, Lancashire, UK) to produce a smooth and passive PEEK retainer.

In the center of each pad, a 1mm hole was drilled. The retainers were then treated for 60 seconds with 98% sulfuric acid, washed with distilled water, and dried using oil-free compressed air. The pads were then conditioned with Single Bond Universal (3M ESPE, Deutschland GmbH, Germany) by rubbing for 20 seconds, moderate air blowing for 10 seconds, and LED light curing for 10 seconds with 1700 MW/cm2 intensity in intimated contact.

The lingual surfaces of the premolars were polished with pumice, washed with water, air dried, etched with 35% phosphoric acid, washed with water, and dried for 20 seconds. Transbond XT primer was then applied carefully, air-blown, and light cured for 20 seconds. Following that, Transbond™ LR adhesive was applied to the PEEK pad and adhered to the enamel with occlusal support guide for better fitness.

After removing the extra adhesive, the teeth were light-cured for a total of 40 seconds, 20 seconds each on the mesial and distal sides. Then the occlusal rests were separated with a turbine and removed. Before the bond strength test, the specimens were kept in distilled water for 24 hours at 37°C [13].

Half of the specimens were artificially aged for 30 days in distilled water before being exposed to 5000 heat cycles between 5°C and 55°C with a 15-second dwell duration on a customized automated digital thermocycling system [21]. Then bond strength was measured with a Universal Testing Machine (Instron 5965, Instron, Pfungstadt, Germany) at a crosshead speed of 1 mm/min. The specimens were held in place using a specific fixture, and the applied force was directed along the occlusо-apical axis of teeth to simulate the initial bite force. The edge of the shearing rod was positioned in the middle of the connector. The load on the wire was raised until debonding occurred and bond strength was recorded in Newton (N) (Figure 1).

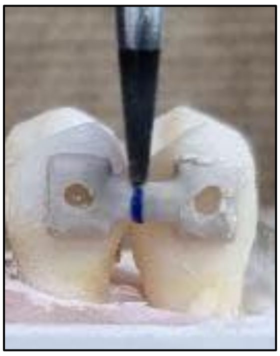

Figure 1: Bond strength test of PEEK retainer.

Statistical analysis

The SPSS statistical software (SPSS version 22, IBM, Armonk, NY, USA) was used. Bond strength results were statistically analyzed with independent sample t-test with a significance level of 5%.

Results

The artificially aged retainers gave slightly less bond strength (265.8 N) than the non-aged samples (270 N) as shown in figure 2. However, independent sample t-test indicated that this difference was statistically not significant as shown in table 1.

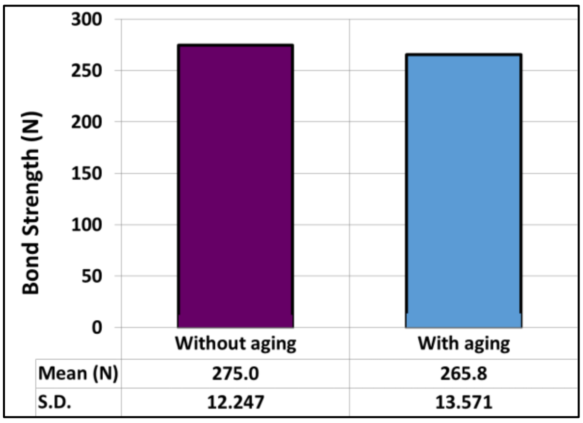

Figure 2: Bond strength of PEEK retainer with and without aging.

Table 1: T-test of the SBS of PEEK retainer with and without aging.

Groups	Group difference		
	t-test	d.f.	p value
With aging Without aging	-1.228	11	0.247

Discussion

After confirming of the optimal design and adhesive system (12-13), the in vitro bond strength of retainer after long-term simulation of oral conditions seems necessary before clinical uses in accordance with Kern *et al.* (14).

Since the bonded PEEK retainer is exposed to the salivary fluid and thermal changes of oral environment at the same time, water storage and thermal cycling were explored in this study as artificial aging protocol for in vitro testing of bond strength as previously recommended (15).

According to the ISO standard, artificial aging was 500 cycles at 5 and 55°C. However, for efficient aging, this number of cycles is very low (16). Because oral temperature is difficult to estimate, 5000 thermal cycles resemble oral conditions from 6 months (17) to 4-5 years of service (18).

In orthodontic researches, a variety of thermocycles have been used; 6000 cycles at 5–55°C (19), 10000 thermocycles (20). Our specimens were thermally cycled for 5000 cycles at 5 to 55°C after 30 days of water storage (21).

The impact of oral thermal changes on the orthodontic adhesives should be determined (17). This thermal fluctuation can reduce the bond due to the hydrolytic effect on the interface components (22); or following aging, increase in bonding as result of post polymerization process (23). However, PEEK retainer showed non-significant differences of bond strength after aging test.

An optimal degree of curing (DC) required sufficient light power and curing time. Incomplete DC means increase unreacted monomers resulting in increased water input and softening of the adhesive matrix (24). The small surface area and thin adhesive layer PEEK retainer may enhance the pre- and post-polymerization process. The central hole allows the curing light to penetrate deeper in the resin resulting in increasing the DC. Furthermore, the bonded PEEK pads cover nearly all the resin and act as protective barrier from the oral environment. This may enhance the durability of the PEEK retainer.

In this study, artificial aging slightly decreased bond strength than the non-aged samples. Stawarczyk *et al.* (16) attributed the decreased bond strength to rupture of the covalent bonds by water molecules following artificial aging.

The comparison of PEEK adhesion with other studies should be done with caution and the following factors should be considered; type of PEEK, surface treatment, adhesive, number of thermocycles, duration of water storage, adhesion to dentin or enamel, and the type of test used (24). For example, Caglar *et al.* [25] used 5000 thermocycles with no water storage, Çulhaoğlu et al. [20] used 10000 thermocycles with different adhesive systems.

Finally, the findings of this experiment revealed that after using long duration water storage and thermal cycling as a method of artificial aging, there were no significant variations in bond strength of PEEK retainer to enamel.

Conflict of interest: None.

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العنوان: تأثير اختبار الشيخوخة الاصطناعية على التجنيب اللغوي الثابت لتقويم الأسنان المصنوع من PEEK CAD / CAM

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المستخلص:
الهدف: تقييم تأثير المحاكاة طويلة المدى للظروف الفموية في المختبر على قوة رابطة مثبت الاسنان اللساني المصنوع من مادة البولي اثير اثير كيتون المصمم والمصنع بمساعدة الحاسوب.
المواد والطرق: تتكون العينة من 12 مثبت اسنان لساني المصنوع من مادة البولي اثير اثير كيتون المصمم والمصنع بمساعدة الحاسوب. يتكون كل مثبت من وسادتين مثقبتين مركزيًا مقاس 3 × 4 ملم متصلتين بموصل تمت معالجتها بحمض الكبريتيك بنسبة 98٪ لمدة دقيقة واحدة ثم تم ترطيبها باستخدام اللاصق(**Single Bond (Universal** ولصقها بالسطح اللساني لأسنان الضواحك بواسطة نظام **(3M Transbond TM).** نصف العينه قد تم شيخوختها اصطناعيا باستخدام تخزين المياه لمدة 30 يومًا وبروتوكول التدوير الحراري 5000 قبل اختبار القوة الرابطة ومقارنتها مع العينات غير االمشيخه.
النتائج: أظهرت العينه المشيخه اصطناعيا قوة رابطة أقل بشكل هامشي من الخدم غير المشيخ. ومع ذلك ، أشار اختبار **t** المستقل للعينة إلى أن هذا الاختلاف لم يكن مهمًا من الناحية الإحصائية.
الخلاصة: تم تأكيد متانة مثبت الاسنان اللساني المصنوع من مادة البولي اثير اثير كيتون المصمم والمصنع بمساعدة الحاسوب باستخدام بروتوكول محاكاة الشيخوخة الاصطناعية عن طريق التخزين بالمياه والتدوير الحراري.
الكلمات الرئيسية: البولي اثير اثير كيتون ، مثبت الاسنان اللساني ، الشيخوخة الاصطناعية