Surface wear of resin composites used for Invisalign® attachments

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ABSTRACT
Orthodontic treatments with Invisalign® require the use of attachments, which are composite resin buttons attached to tooth surfaces. Attachments constitute one of the most powerful tools for improving the efficiency of orthodontic tooth movement. The main purpose of this study was to evaluate surface wear over six months in two resin composites (Filtek Z350 XT, 3M ESPE and Amelogen Plus TW, Ultradent Products Inc.) used for making Invisalign® attachments. These composites were selected for their esthetic and mechanical properties. Forty attachments were bonded to the buccal surface of maxillary teeth. Materials were randomized and assigned in a double blind manner. Impressions were taken of the attachments using a pre-established technique immediately after bonding and following 6 months of clinical use. The impressions were examined by Scanning Electron Microscopy (SEM) at 12-fold magnification to identify changes in surface texture and attachment shape. Data were analyzed using Mann-Whitney's test on the overall ranking of detected changes in those variables.
Statistically significant differences (P< 0.001) were found for surface wear, with greater changes in Amelogen Plus. Attachment shape did not change significantly in either material (P> 0.05).
According to the results of this study, the alteration of the attachment surface during the first six months of treatment depends on the composite used, while attachment shape does not appear to be affected, so the clinical performance of the materials evaluated could be considered acceptable.

Keywords: *Clear aligner; Orthodontics, attachments; Invisalign; composite, surface wear.*

Desgaste superficial de las resinas compuestas utilizadas en los "attachments" de la técnica Invisalign®

RESUMEN
Los tratamientos ortodóncicos con alineadores Invisalign® utilizan aditamentos construidos en resinas compuestas llamados "attachments" adheridos a la superficie dentaria. El "attachment" es una de las herramientas más potentes para mejorar la eficiencia del movimiento dental.
El propósito de este estudio fue evaluar el desgaste superficial de dos resinas compuestas utilizadas para construir los "attachments" en el tratamiento de ortodoncia con la técnica de alineadores Invisalign®.
Se evaluaron 40 "attachments" adheridos a la superficie vestibular de piezas dentarias del maxilar superior en un período de 6 meses. Los "attachments" fueron construidos en forma aleatoria y a doble ciego con dos resinas compuestas (Filtek Z350 XT de 3M ESPE y Amelogen Plus TW Ultradent Products Inc) elegidas de acuerdo con las propiedades estéticas y mecánicas requeridas. Los "attachments" fueron impresionados con una técnica preestablecida inmediatamente luego de ser adheridos y a los 6 meses. Las muestras fueron preparadas para su observación mediante Microscopía Electrónica de Barrido (MEB) a 12 aumentos. Se observaron los cambios producidos en la textura superficial y la forma entre el inicio y los seis meses de tratamiento. Los datos fueron analizados y comparados utilizando la prueba de Mann-Whitney, realizada en función del ordenamiento global, de menor a mayor según el cambio producido en esas variables.
Los materiales analizados mostraron una diferencia estadísticamente significativa (P< 0,001) en el desgaste superficial, siendo el Amelogen Plus el material que evidenció mayor cambio. Las modificaciones en la forma de los "attachments" no fueron estadísticamente significativas en ambos materiales (P> 0,05).
Según los resultados obtenidos en este estudio, la modificación de la superficie de los "attachments" durante los primeros seis meses de tratamiento varía en función del composite empleado, en tanto la forma del "attachment" no parece ser afectada de manera similar, por lo que el desempeño clínico podría ser considerado aceptable cuando se emplean los materiales evaluados.

Palabras clave: *Alineadores invisibles; Ortodoncia, attachments; Invisalign; resina compuesta, desgaste superficial.*

INTRODUCTION

In recent decades there has been a remarkable increase in the available range of orthodontic treatments for adult patients who demand esthetics and comfortable alternatives consistent with their modern social and working lifestyles.[1] To satisfy these demands, in 1999 Align Technology (Santa Clara, CA) introduced orthodontic treatments with clear aligners using sequential application of clear alignment devices made from thermoplastic material.

Buttons made of composite resin, known as "attachments", are placed on tooth surfaces as retentive elements and to improve the efficiency of complex tooth movements. Since they are one of the most powerful tools for moving teeth efficiently, it is important that their integrity and shape should remain constant throughout the treatment. [2-5]

An aligner attachment needs esthetic and mechanical properties. In addition to being resistant to stain, it should be the same shade as the tooth or translucent enough to blend with the underlying tooth.[6] It should also be resistant to wear, and it is on this property that the current study focuses.

Composite resin materials are made of an organic phase (matrix) and a ceramic phase (filler) consisting of admixtures of particles of different sizes, which determine the material's properties. According to the clinical requirements, fillers may make up 50% to 70% of the volume, and particle size may range from 20 nanometers to 5 micrometers. [7-9] Higher filler content results in better mechanical properties, while smaller average particle size provides better esthetic properties.[10] Composite resin surface wear has been remarkably reduced through the recent development of nanoparticle resin. [11-14]This study compares two composites of high esthetic and mechanical characteristics with the goal of finding an ideal material for attachments.

The aim of this study was to use Scanning Electron Microscopy (SEM) to determine whether attachment surfaces remain unaltered during the first six months of treatment.

MATERIALS AND METHODS

This study was approved by "Sociedad Argentina de Ortodoncia" Research Ethics Committee resolution number 6-0108/2015.

Ten subjects were selected, male or female, aged 15 to 50 years, who required orthodontic treatment, with full upper dentition and mild or moderate crowding. Patients with mixed dentition, maxillary crown restorations, active periodontal disease and/or edentulous spaces in upper maxillary were excluded. All subjects were treated with Invisalign® aligners. Patients were instructed to brush their teeth with a soft toothbrush (Colgate® Slim Soft) and low abrasive dentifrice (Sensodyne® Pro Enamel).

The attachments were prepared from one of two light-cured resin composite types: Filtek Z350 XT, 3M ESPE orAmelogen Plus TW, Ultradent Products Inc., which have different mechanical and esthetic properties. Materials with high ceramic filler content (72% - 76% by weight) were selected for their translucency and physical properties (Table 1).

Forty (40) attachments were made with Invisalign® Templates on upper maxillary teeth. Materials were randomized for each attachment.

Before attachment preparation, dental enamel was treated following total acid etching protocol with 37% phosphoric acid (Scotchbond™ Etchant, 3M),15-second application. Acid was removed with water spray for 30 seconds and the enamel surface was dried for bonding agent application. A layer of bonding agent (Single Bond 2, 3M ESPE) was applied with a micro-brush and any excess removed by blowing with compressed air. Each attachment was light-cured for 10 seconds (Bluephase G2 Curing Light, Ivoclar Vivadent®) following manufacturer's instructions. The attachment surface was not polished after template removal (Fig 1).

A customized device was designed to use as a tray for attachment impressions. It was prepared from a 6 mm x 6 mm x 6 mm cubic plastic block (Blocky®) customized in an improved stone cast with acrylic (DuraLay, Reliance) for each tooth on which an attachment was placed, in order to provide a consistent insertion pathway for the first and subsequent impressions (Fig. 2 a).

Table 1: Materials tested.

Material	Type	Shade	Filler Content (by weight)	Monomer	Manufacturer	Batch
Filtek Z350 XT	Nanofilled	Amber Translucent	72.5%	Bis-GMA, UDMA, Bis-EMA, TEGDMA	3M ESPE	N593705
Amelogen Plus TW	Micro-hybrid	Translucent White	76%	Bis-GMA	Ultradent products, Inc.	D00B9

Bis-GMA: Bisphenol-A diglycidlethermethacrylate; UDMA: urethane – dimethacrylate; Bis-EMA: Ethoxylatedbisphenol-A dimethacrylate; TEGDMA: triethylene glycol dimethacrylate.

Fig. 1: Attachment preparation. a- Loading the composite into the template. b- Bonding process. c- Attachments on tooth surfaces.

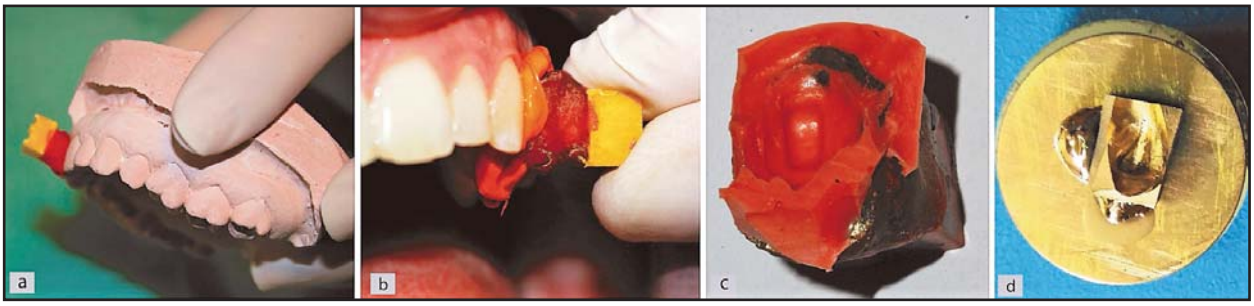

Fig. 2: a- Customized tray for attachment impression. b and c- Impression of an attachment with polyvinylsiloxane. d- Specimen preparation for display in SEM.

Before the attachment impression procedure, an adhesive for silicone impression material was applied over the inner surface of the tray (Universal Tray Adhesive, Zhermack®) and dried with compressed air. Impressions of all attachments were made on the placement day with polyvinylsiloxane (Elite Light Body, Elite P&P Fast Set, Zhermack®, Reorder N.REF C206011) using the manufacturer's syringe and mixing tips (Fig. 2 b,c).

The impressions were inspected under 4.5X magnification to identify any imperfections, cracks in the silicone, pores, etc. Once approved, they were sputter coated (Fig. 2d) and analyzed by SEM (Philips 505). Micrographs were taken at 12- and 100-fold magnifications. The template with which the attachments were prepared was also observed under SEM showing curved lines attributable to the imprint left on the template during the stereolithography manufacturing process (Fig. 3).

The impressions and SEM analyses were repeated at 6 months using the same procedure, for comparative purposes. Images with 12X magnification were the most suitable for evaluating attachment shape and surface texture. They were printed on 13 mm X 18 mm dull photographic paper. Thus, pre- and post-images of each attachment were obtained.

Evaluation

Initial and final photographs for each attachment were numbered on the back. Three observers agreed on a visual order according to changes in surface (texture) and shape. The surface of the attachments showed the stereolithography lines of the template, which were taken as reference for this evaluation. For descriptive purposes, degrees of change were classified according to the following criteria:

Grade 1. Slight or unnoticeable change

Grade 2. Moderate change

Grade 3. Noticeable change (may include cracks or fracture).

Data were analyzed and compared with Mann-Whitney test, performed according to global order from small to large changes in surface and shape (Fig. 4-6).

RESULTS

Comparison of initial and final images showed that all samples underwent some degree of modification of the surface texture, but there was never total destruction of the attachment.

Statistically significant differences ($P<0.001$) were found for surface wear, with greater changes in

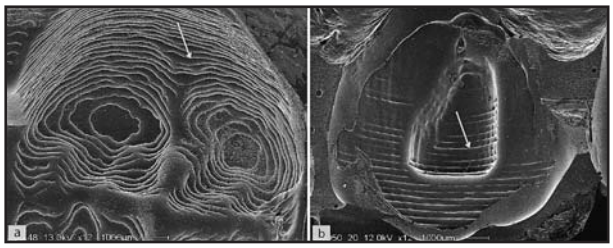

Fig. 3: a- Attachment Template image. 12X magnification. b- Stereolithography lines of the template can be seen on attachment surface.

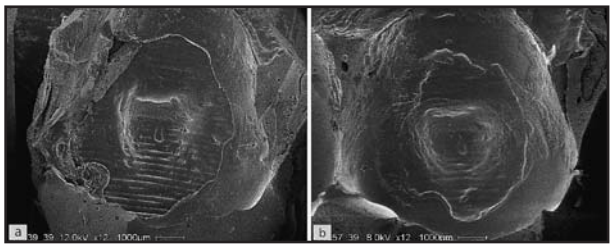

Fig. 4: SEM images (12X) of an attachment showing slight change; baseline (a) and at 6 months (b). Filtek Z350 composite.

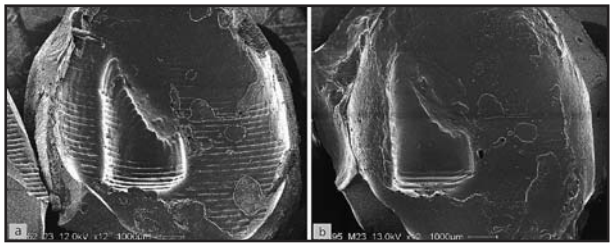

Fig. 5: SEM images (12X) of an attachment showing moderate change; baseline (a) and at 6 months (b). Filtek Z350 composite.

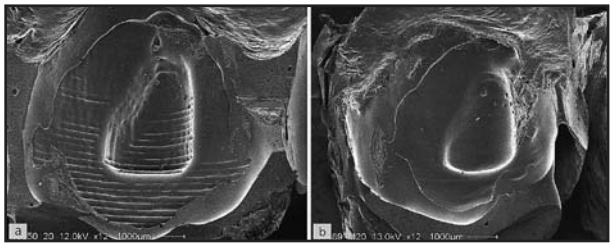

Fig. 6: SEM images (12X) of an attachment showing noticeable change; baseline (a) and at 6 months (b). Amelogen Plus composite.

Table 2: Texture change frequency category according to material.

	Texture			
Material	**Slight change**	**Moderate change**	**Noticeable change**	**Total**
Filtek Z350 XT (3M ESPE)	8	6	4	18
Amelogen Plus TW (Ultradent Products Inc)	1	3	18	22
Total	9	9	22	40

The difference between materials is statistically significant ($p<0.001$)

Table 3: Shape changes frequency category according to material.

	Shape			
Material	**Slight change**	**Moderate change**	**Noticeable change**	**Total**
Filtek Z350 XT (3M ESPE)	13	5	1	19
Amelogen Plus TW (Ultradent Products Inc)	15	4	2	21
Total	28	9	3	40

The difference between materials is not statistically significant ($P>0.05$).

Amelogen Plus. Attachment shape showed no significant change ($P>0.05$). Results for changes in texture and shape are provided in Tables 2 and 3, respectively.

DISCUSSION

In addition to the aligners themselves, treatments using invisible aligners require auxiliary "attachments" to help retain and move teeth.[3,4,15]

In a systematic review, Rossini et al. concluded that transparent aligner treatments require the use of attachments to improve the predictability of orthodontic movement.[2] Another study by the same authors compared complex orthodontic movements with and without attachments, showing the relevance of using attachments to improve the efficiency of the appliance.[16] The composite selected must therefore have adequate mechanical properties. There is currently no published study establishing minimal integrity for proper attachment performance.[6]

Studies *in vitro* and *in vivo* have referred to wear of composite resins in contact with the tooth structure antagonist in occlusal restorations and/or mechanical action of brushing, diet and salivary pH.[17-19]We did not find any analyses of abrasive wear against an antagonist such as the aligner material.

In our study, all final SEM images showed surface differences such as reduction and/or total absence of lines related with the template stereo-lithography impression. The observed changes in the surfaces of the attachments may be produced by the friction generated when placing and removing the aligner, among other causes. Filtek Z350 revealed less surface wear than Amelogen Plus TW after the first six months' use, in agreement with Feinberg et al.[6]Attachment shape did not change significantly for either of the study materials, suggesting that tooth movement related to the attachment would still be effective after six months.

Further research using a larger number of resin materials and longer time periods is needed to quantify the observed changes and their relation to the efficiency of orthodontic tooth movement.

We believe that the results of this study provide a useful contribution to be considered when materials are being selected for making attachments.

CONCLUSION

Attachments used in the Invisalign® orthodontic technique contribute to orthodontic tooth movement. According to the results of this study, the alteration of the surface of the attachments during the first six months of treatment varies depending on the composite used, while the shape of the attachment does not appear to be affected, so the clinical performance of the materials evaluated can be considered acceptable.

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