journal of dentistry 37 (2009) 984–993

available at www.sciencedirect.com

journal homepage: www.intl.elsevierhealth.com/journals/jden

In vitro wear gap formation of self-adhesive resin cements: A CLSM evaluation

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ARTICLE INFO

Article history:
Received 23 June 2009
Received in revised form
10 August 2009
Accepted 12 August 2009

Keywords:
Self-adhesive
Cement
Wear
Gap
Toothbrush
ACTA

ABSTRACT

Objectives: To evaluate the depth of wear gaps of new self-adhesive cements after toothbrush abrasion and ACTA wear test.

Methods: Luting spaces ($325 \pm 25\ \mu m$ width, 2 mm depth) were produced in Empress 2 ceramic blocks with a diamond saw to obtain flat substrate segments for toothbrush abrasion ($n = 24$) and ACTA wear ($n = 27$). After etching and silanization, the slits were filled with 8 self-adhesive cements, 2 conventional resin cements and 1 flowable composite, stored for 2 weeks in distilled water at 37 °C and planished to the cement level. Toothbrush abrasion was carried out in a toothbrush simulator (Willytec, Germany) for 20,000 cycles (load 1 N) using an abrasive slurry based on a commercial toothpaste (Elmex, Gaba, Germany, RDA = 77). The ACTA wear experiment was performed following the ACTA protocol in millet seed slurry for 400,000 cycles (Willytec). The gap replicas were measured for vertical wear loss under a confocal laser scanning microscope (CLSM). The data were analyzed using one-way ANOVA and a mod-LSD test at $p < 0.05$.

Results: Toothbrush wear values were lower than the ones obtained for the ACTA wear test for all cements. In the toothbrush test Bifix SE, Clearfil SA, SmartCem 2, G-Cem and Maxcem Elite obtained the highest values together with Grandio Flow. Grandio Flow and AllCem showed to be the most resistant to the ACTA wear test, while SpeedCem the least resistant. No correlation was found between the two wear test experiments.

Conclusion: Self-adhesive cements have good wear resistance to toothbrush abrasion but most of them wear more rapidly under higher loads in the ACTA test than conventional resin cements and flowable composites.

1. Introduction

Resin cements are low viscous composite resins used to retain indirect restorations and to promote an adequate seal between restoration and tooth substrates. Independently of the marginal adaptation, i.e., how close the restoration margin is from the substrate margin, a proportional thickness of cement will invariably be exposed at the tooth/restoration interface after cementation. As any other resin material exposed to the oral environment, the resin cement surface along the margins of indirect restorations will be subjected to water sorption,[1] subsurface degradation[2] and wear processes that may result in marginal ditching over time.[3] Longitudinal studies evaluating the clinical behavior of inlays and onlays luted with resin cements often report the occurrence of cement wear gap formation and marginal discoloration after only a few years of clinical service.[4–6]

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doi:10.1016/j.jdent.2009.08.006

Worn cement margins may raise not only esthetic concerns due to marginal pigmentation but attain biological significance as when they act as a niche for plaque,[7] which could expedite the development of secondary caries in the event of bonding failure, and by retaining periodontal pathogens responsible for gingival inflammation.[8]

However, decrease of marginal integrity rates in long-term clinical evaluations is hardly related to clinical failure of indirect restorations[4–6,9–12] and the survival rates seem not to be directly influenced by the marginal wear of resin cements.[3] Even so, a comprehensive eight-year clinical evaluation of adhesively luted ceramic inlays was able to draw a connection, by means of successive scanning electron microscope (SEM) analysis[13] and 3D morphological measurements,[14] between the wear of the cement line and the development of catastrophic bulk failures of ceramic inlays. Exposed ceramic cavo-surface margins fracture due to persistent wear of the luting space and concomitant occlusal loading, leading to crack formation and its propagation towards the body of the restoration. Indeed cracks of enamel and ceramic margins are recurrently reported as main causes of marginal integrity rates decrease in prospective clinical trials.[9,12]

Wear of the luting cement is likely to occur mainly via three-body abrasion processes, where abrasive mediums, like the food bolus and toothpastes, are constantly being sheared against the cement surface, both in contact areas and contact-free areas. Comparisons of different three-body wear processes on the cement wear gap formation, however, has not yet been systematically evaluated.

Added to critical access, lighting and moisture conditions, clinical evaluation of cement margins wear rates render fairly inaccurate information as it is based on qualitative score measurements rather than on quantitative values. For that matter, many studies on long-term evaluation of marginal integrity of inlays and onlays use the replica technique and more accurate measuring methods, from profilometry[15] to computer-based mechanical scanning systems[16,17] and optical scanners.[14,16,18] This allowed for more scientific-based evaluations and a closer insight on wear degradation processes occurring on surfaces of dental materials subjected to different wear phenomena. Different methods, however, vary in the ability to detect the true position of a given point in a bidimentional plane (i.e., low accuracy). When testing the reliability of three different wear measuring methods, Heintze et al. was able to show a slightly higher variability and lower vertical wear measuring accuracy for a mechanical sensor in comparison to two other optical sensors, although a high correlation coefficient was found for all three methods.[16] High accuracy attains even critical importance as for the assessment of reduced geometries where mild wear processes tend to hinder the discriminatory power among materials.

Despite of the wear of composites resins has been recently stated as ‘‘not an essential issue’’[19] and ‘‘no longer considered to be a major concern’’[20] due to the current optimized mechanical properties of composite resins, new material formulations not yet prospectively evaluated *in vivo* and lacking extensive *in vitro* evidences may be understood as rationale for further investigations on this matter. Therefore, this study intended to investigate the wear resistance of novel self-adhesive cements using two different three-body wear experimental set-ups by means of confocal laser scanning microscopy, a novel method not yet introduced for dental materials wear evaluation.

Two null hypothesis to be tested were that (1) there is no difference on three-body wear gap resistance between self-adhesive cements vs. conventional resin cements and light-cured composite resins and (2) both toothbrush abrasion and ACTA wear simulation produce similar wear on resin cement margins.

2. Materials and methods

For the simulation of marginal cement slit abrasion two different experimental methods were used – tooth brushing abrasion and three-body ACTA abrasion. Eight self-adhesive cements, two conventional resin cements and one flowable micro-hybrid composite (Table 1) were tested for absolute vertical loss after the experimental set-ups described below. The lithium-disilicate based IPS Empress 2 (Ivoclar Vivadent, Liechtenstein) ceramic was used as substrate material in both methods due to its neglectful abrasion rate. The ceramic blanks for both experiments were fabricated using the lost-wax hot-pressing technique according to the manufacturer's instructions.

2.1. *Tooth brushing abrasion*

For each tested material three Empress 2 blanks (15 mm length × 10 mm width × 5 mm depth) were fabricated, embedded in a special epoxy resin (Technovit, Heraeus, Germany) and polished flat through #1200 grit SiC paper. On the surface of each ceramic blank four slits (two parallel in the x-axis 5 mm apart, and two parallel in the y-axis 10 mm apart) of 2 mm in depth and 325 ± 25 μm in width were cut with a low-speed diamond saw (Buehler Ltd., Lake Bluff, IL, USA) under water lubrication. The slits were etched with hydrofluoric acid (Ceramics Etch, Vita, Germany) for 20 s, rinsed for 60 s and silanated (Monobond S, Ivoclar Vivadent, Liechtenstein). The materials were mixed according to the manufacturers instructions, applied into the slits, covered with a polyester strip with slight pressure and cured with a halogen curing unit (Elipar Trilight, 3MESPE, Germany) at 750 mW/cm^2 for 60 s. For Variolink II only the Base paste (without the catalyst paste) was used in order to avoid air incorporation into the cement during manual mixing. After two weeks of storage in distilled water, the specimens were polished through #2500 grit SiC paper under constant lubrication until a complete flat surface could be achieved. After polishing the specimens were stored for more 24 h in water at 37 °C prior to testing.

The slurry used as the abrasive medium was produced by mixing the commercial toothpaste Elmex (Gaba, Germany), which has a high abrasive potential (RDA 77), with Tragacanth solution ((E413, Merck, Germany), 246.88 g glycerine, 246.88 g deionised water, 6.24 g Tragacanth) in a 1:1 ratio by weight. This was accomplished by slowly adding the Tragacanth into a beaker containing the glycerine under constant agitation using a magnetic mixer until a homogeneous mixture could be achieved. Afterwards deionised water was added and homogenized for 6 h under constant agitation. Tragacanth, a complex