Wear of dental sealing materials using the replication technique

ABSTRACT

Aim The aim of the present study was an in vivo evaluation of the wear of different sealing materials using the replication technique.

Materials and methods Four different sealing materials were randomly applied on 2 out of 4 caries-free permanent first molars of each patient. Impressions were taken at T0: before the sealing material was applied; T1: right after the application; T2: 6 months after the application, and T3: 1 year after the application. The impressions were then processed for scanning electron microscopy analysis of the wear of the examined materials. Statistical analysis was used to evaluate differences among and within the 4 groups.

Results At T2, the average ratio of residual material in all the groups was 62.37% ± 1.21%, while at T3 it was 49.63% ± 1.11%. At both T2 and T3 there were no statistically significant differences among the 4 groups examined (p=0.76 and p=0.50 respectively). Comparison within the same group at T2 and T3 showed that statistically significant differences were only detected in group D (p=0.015).

Conclusion Sealing materials do not undergo a complete loss after 1 year of application, thus indicating that they are suitable for caries prevention.

Keywords: Dental materials; Dental restoration wear; Pit and fissure sealants; Scanning electron microscopy.

Introduction

Dental decay is the most common chronic childhood disease [Lam, 2008]. In particular, occlusal caries represent approximately 80% of the primary lesions in permanent teeth [Rios et al., 2002]. If not prevented or treated, it can cause difficulty in speech, decreased masticatory efficiency, development of abnormal tongue habits and subsequent malocclusion and psychological problems when also aesthetics is compromised [Usha et al., 2007]. Therefore, prevention is very important to decrease its incidence in the early age.

Proper nutrition, accurate and regular oral hygiene, use of fluoride products, regular check-ups with a dentist as well as sealing pits and fissures of the first permanent molars [Igiç et al., 2008] should be undertaken in order to prevent dental caries. Specifically, sealing of pits and fissures can be effectively used to prevent the initiation and progression of occlusal dental caries [Beauchamp et al., 2008]. It has been reported that 80% of caries affecting children are located in the molars. This is due to the fact that molars show a complex morphology with pits and fissures representing 12% of the total surface. These sites are ideal for the retention of plaque and food remnants and in addition, are difficult to clean, particularly by children [Feldens et al., 1994]; thus, the crucial role of fissure sealing in the prevention of dental caries in childhood.

Fissure sealing is traditionally performed by means of different materials: low-viscosity resins or flowable composites, comomers, and resin-modified glass-ionomer cements. Most types of sealant available in the market are resin-based. These materials present good handling properties due to their low viscosity and fluidity [Droz et al., 2004], which make them more easy to apply in pits and fissures than the highly filled hybrid composites. The preventive effects of this type of sealant are obtained and maintained as long as the material remains completely intact and bonded to the dental surface. Micromechanical retention is provided by the acidic conditioning of enamel prior to the application of sealants [Rios et al., 2002].

Nowadays, sealing materials gained wide acceptance in the scientific community as they show good preventive action and low incidence of caries in the fissure system in sealed teeth [Dukiç and Glavina, 2006]; nevertheless, they still present some disadvantages such as microleakage, fracture toughness and wear. Microleakage and fracture toughness have been improved by using primers and bonding agents, which increased the retention of fissure sealants [Asselin et al., 2008; Mascarenhas et al., 2008].

Concerning the wear of sealant materials, it would be of pivotal importance to know the wear timing in order to schedule recall visits to check the status of restorations and to prevent failure [Qin and Liu, 2005]. Indeed, the wear of these materials can cause an increase in roughness, which might result in faster colonization of the surface and faster maturation of plaque, thereby increasing the risk of caries [Svanberg et al., 1990]. So far, to our best knowledge, the wear of sealing materials has only been tested in vitro by simulating intraoral conditions through thermocycles performed at different temperatures and tooth brushing [Dukiç and Glavina, 2006; Antonson et al., 2006]. However, these methods have some limitations since the intraoral conditions are only grossly mimicked and the real performance of these materials can be very different in vivo.

The aim of the present study was an in vivo evaluation of the wear of 4 different sealing materials by using an
impression-based technique, called the replication technique.

Materials and methods

A total of 10 patients (6 males, 4 females; mean age 8 years, range 7-9 years) participated to this study. The protocol was approved by the Ethics Committee of the University “G. D’Annunzio” Chieti-Pescara and all patients signed a written informed consent form.

All the patients, who were enrolled at the Paediatric Dentistry division of the Dental School, University “G. D’Annunzio” Chieti-Pescara, presented a good level of oral hygiene, all 4 permanent molars erupted and caries-free after clinical and radiographic inspections.

Clinical procedure

In each patient an upper and a lower one-stage teeth impression was taken using dental putty and light silicone (Elite HD ZHERMACK, Badia Polesine, Italy), in order to precisely and reliably impress pits and fissures (T0). On the same day, sealants were randomly applied on 2 out of 4 permanent first molars, after isolating the selected teeth by a rubber dam. The teeth were always selected in the same dental arch in order to be in occlusion with not treated teeth. A total of 20 teeth (10 maxillary and 10 mandibular) were examined. The teeth were divided into 4 groups (N = 5 per group) according to the sealing material used, as follows.

- **Group A**: a low-viscosity light-cured fluoride-releasing sealant (Saremco Microseal, Saremco AG, St. Gallen, Switzerland) available in two shades. It contains Bis-GMA, Bis-EMA, TEGDMA, silanised silica dioxide, polymerisation initiators and stabilisers.
- **Group B**: a low-viscosity light-cured fluoride-releasing resin sealant (Clinpro Sealant 3M- ESPE, St.Paul, USA). It has a pink colour for an easy-to-see application, and changes to white when cured. It contains: Bis-GMA, TEGDMA, EDMAB, components of the photo-initiator system, silane treated with amorphous silica, tetrabutylammonium-tetra-fluoroborate, titanium dioxide, rose bengal sodium.
- **Group C**: a sealing material that contains low-viscosity monomers (Delton FS + Dentsply, York, PA), 55% glass fillers, triethylene glycol dimethacrylate, BisGMA, barium alumino fluoroboro silicate glass, titanium dioxide (opaque only), sodium fluoride, polymerisation initiators and stabilisers.
- **Group D**: a low-viscosity light-cured flowable resin composite (Filtek Supreme XT 3M Unitek, St.Paul, USA) that contains methacrylate resin monomers, Bis-GMA, TEGDMA, Bis-EMA, dimethacrylate polymer.

The instructions provided by manufacturers were followed for the handling of the materials. Once sealed, early contacts were eliminated and a second impression, by means of dental putty and light silicone, was taken (T1). Then, in order to check the wear of the sealing materials, a third (T2) and a fourth (T3) impressions were taken after 6 months and 1 year, respectively (Fig.1). Furthermore, clinical evaluation of the sealants was carried out to assess retention at 6 and 12 months after initial treatment.

Sample processing

The impressions were processed. First, the impression of the permanent first molars was separated by the impression of the remaining teeth. Secondly, parallel
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consecutive 1 mm thick sections were made along the vestibular-buccal/lingual axis of permanent first molars. Only the section including the central groove was used for the measurements. The samples were then processed for scanning electron microscopy (SEM) analysis. They were mounted on aluminum stubs, gold coated (Emitech K 550, Emitech Ltd, Ashford, Kent, UK) and observed using a LEO 435 VP SEM (LEO Electron Microscopy Ltd, Cambridge, UK). Images of the central groove were analysed with a software with image capturing capabilities (Image J 1.41x NHI, USA); measurements of the depth of the central groove were carried out by calculating the area between the most external margins (A and B) of the section and the total perimeter of the groove (Fig. 2).

Statistical analysis
The Kruskal-Wallis test was used to evaluate the presence of statistically significant differences among the 4 groups at T2 and at T3; while comparison within the same group at T2 and T3 was carried out using the non parametric Mann-Whitney U-test, for independent samples. Results are presented as means ± standard errors (SE), and differences at p≤0.05 were considered statistically significant.

Results
At 6 months (T2), the average ratio of residual material in all the groups was 62.37% ± 1.21%; there were no statistically significant differences among the 4 groups examined (p=0.7626); group A showed the highest percentage of residual material, followed by group C, B and D (Fig. 3).

At 1 year (T3), the average ratio of residual material in all the groups was 49.63% ± 1.11%. There were no statistically significant differences among the 4 groups examined (p=0.50); group A showed the highest percentage of residual material, followed by group C, B and D (Fig. 3). These results are in agreement with the ones obtained at 6 months.

Comparison within the same group at T2 and T3 showed that statistically significant differences were only detected in group D (p=0.015), while within the remaining groups there were no differences between the two time points examined (Fig. 3).

Furthermore, the ranking of the percentage of residual materials remained unchanged at T2 and T3, with group A showing the highest values, followed by C, B and D. In addition, no clinical signs of partial loss were observed.

Discussion and conclusion
Wear is a complex process that can hardly be simulated while controlling all the variables. Especially the extrapolation of the in vitro wear results to the in vivo situation is complicated because there is an interplay with biological factors that are difficult to mimic [Lambrechts et al., 2006]. The rate of abrasion depends on several factors such as the type of dentifrice, the water/dentifrice ratio, the type of brush, and the speed and pressure employed during brushing [Rios et al., 2002].

Furthermore, wear simulation devices should simulate processes that occur in the oral cavity during mastication, namely force, force profile, contact time, sliding movement, and clearance of worn material. Different devices that use different force actuator principles are available. Those with the highest citation frequency in the literature are - in descending order - the Alabama, ACTA, OHSU, Zurich and MTS wear simulators. When following the FDA guidelines on good laboratory practice only the...
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expensive MTS wear simulator is a qualified machine to test wear in vitro; the force exerted by the hydraulic actuator is controlled and regulated during all movements of the stylus. All the other simulators lack control and regulation of force development during dynamic loading of the flat specimens. This may be an explanation for the high coefficient of variation of the results in some wear simulators (28-40%) and the poor reproducibility of wear results if dental databases are searched for wear outcomes of specific dental materials (difference of 22-72% for the same material) [Heintze, 2006].

The replication technique not only allows to evaluate the actual wear of the sealing materials in vivo, but also provides quantitative data, and therefore extensive and detailed information about the occlusal wear [Peters et al., 1999]. Moreover, the replication technique was used to simulate crown gap space after cementation and was found to be accurate and reliable [Rahme et al., 2008] for any measurement location (cervical, axial or occlusal) [Laurent et al., 2008]. In the present study regardless of the material applied, the grade of wear was the greatest at 6 months (T2). On the contrary, at 1 year there was a reduction of the wear with not statistically significant differences among the 4 groups. These results are in agreement with previous studies, which showed that the wear of fissure sealants is equal to the one of flowable composites used as sealing materials [Dukiç et al., 2007]. Furthermore, the decrease of the grade of wear between 6 months (T2) and 1 year of application (T3) can be attributed to the fact that the area of the sealant that undergoes occlusal forces is decreased. Evidence shows that wear may be of minimal importance for restorations of small to moderate size. However, the literature does suggest that failure rates are higher for larger restorations of small to moderate size. However, the literature does suggest that failure rates are higher for larger restorations. The replication technique not only allows to evaluate the actual wear of the sealing materials in vivo, but also provides quantitative data, and therefore extensive and detailed information about the occlusal wear [Peters et al., 1999].

In conclusion, the replication technique proved suitable for evaluating sealing materials’ wear. Moreover, a complete loss of the sealing materials was not detected after 1 year of application, thus indicating that the use of pit and fissure sealants is appropriate for caries prevention. Therefore, recall visits to check the wear should be scheduled 1 year after the application of the materials analysed in the present study.

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References