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The effect of chewing simulation on surface roughness of resin composite when opposed by zirconia ceramic and lithium disilicate ceramic

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ABSTRACT

Objective. To assess the change in surface roughness of nanohybrid resin composite (Tetric EvoCeram) after antagonist wear against monolithic zirconia and lithium disilicate ceramics through a simulated chewing test using a three-dimensional (3D) profilometer.
Methods. A total of 40 Tetric EvoCeram™ resin composite specimens against either a Lava™ Plus zirconia antagonist ($n = 20$) or IPS e.max Press lithium disilicate antagonist ($n = 20$) were prepared for the study. The surface roughness profiles of each resin composite before and after an in-vitro simulated chewing test were analysed using a 3D profilometer and Talymap software. After the simulated chewing, the surface profiles of representative Tetric EvoCeram specimens from each group were analysed using scanning electron microscopy. Independent t-test and paired t-test were used for statistical analysis.
Results. For both lithium disilicate and zirconia groups, all surface roughness parameters (Ra, Rt, Sa, Sq,) of Tetric EvoCeram were significantly higher post-chewing compared to pre-chewing ($p < 0.05$); the post-chewing surface roughness parameters of Tetric EvoCeram for the lithium disilicate group were significantly higher ($p < 0.05$) than in the zirconia group.
Significance. This chewing simulation test showed that Tetric EvoCeram composites exhibited a rougher surface when opposing lithium disilicate ceramic compared to opposing zirconia ceramic.

1. Introduction

Dental restorative materials are used in restoring form and function of teeth with carious lesions or non-carious tooth surface loss [1,2]. Ideal restorative materials are expected to behave as close as possible to natural tooth structure in terms of their strength, appearance, biocompatibility and resistance to wear by opposing teeth or restorations [3,4].

Full ceramic crowns are widely used as indirect restorations due to excellent aesthetics, which can avoid the 'greying' effect at gingival margins associated with porcelain fused to metal crowns. Crystalline reinforced ceramics, for example aluminium oxide, leucite, lithium disilicate and zirconia oxide,

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Table 1 – List of materials used.

Trade name	Type	Composition	Batch number	Manufacturer
Tetric EvoCeram direct resin composite	Nano-hybrid	Resin Matrix: Bis-GMA, UDMA, Ethoxylated Bis-EMA (16.8 wt%) Filler: Barium glass, ytterbium trifluoride, PPF mixed oxide (82.5 wt%) Mean particle size of filler: <550 nm	R24643 P02083 Shade A2	Ivoclar Vivadent, Schaan, Liechtenstein
Lava^{TM} Plus High Translucent Zirconia	Yttria tetragonal zirconia polycrystals (Y-TZP)	The zirconia ceramic is a tetragonal polycrystalline zirconia partially stabilized with approx.3 mol% yttria.	357797 Shade A3	3M ESPE, St Paul, MN, USA
IPS e.max Press Low Translucent Lithium Disilicate	Lithium disilicate glass ceramic	The lithium disilicate ceramic contained 57-80% wt% SiO_2, 11–19 wt% Li_2O and other oxides such as K_2O, MgO, ZnO, Al_2O_3, P_2O_5	Bleach shade	Ivoclar Vivadent, Schaan, Liechtenstein

were developed to improve the mechanical strength so that all ceramic crowns can be used not only to restore anterior teeth but also to restore posterior teeth [5].

Lithium disilicate is one of the more widely known and widely used types of glass ceramic; it is a partially filled ceramic, formed by adding lithium oxide to alumina-silicate glass to enhance the mechanical properties. Lithium disilicate crowns are processed using either lost-wax hot pressing techniques or Computer-Aided Design/Computer-Aided Machining (CAD-CAM) procedures [5]. Lithium disilicate ceramic crowns have been used successfully as single crown restorations and fixed partial dentures with higher survival rates when compared with feldspathic porcelain crowns and alumina-oxide crowns [6]. The mechanical properties of lithium disilicate (e.g. IPS emax Press) are considered superior when compared to feldspathic porcelain crowns and alumina-oxide crowns with a flexural strength of 0.28 GPa and fracture toughness of KIC = 2.75 MN/$m^{3/2}$ [7].

In recent decades, zirconium dioxide (zirconia, ZrO_2) ceramics have gained popularity for use in dental restorations. Zirconia is produced by calcining zirconium compounds, exploiting its high thermal stability forming it into a monoclinic crystalline structure [8]. During the heating process, it has been shown that crack formation occurs due to the stresses induced during the phase transformations. This phase transformation of zirconium oxide can be inhibited by the addition of a small percentage of yttria. Yttrium-stabilised zirconia exhibits transformation toughening and the atoms are densely packed into a regular crystalline arrangement making it tougher and less susceptible to crack propagation [5]. This transformation toughening mechanism significantly extends the mechanical properties, which is three times the fracture toughness of lithium disilicate (KIC = 9–10 MN/$m^{3/2}$) [9].

With modern bonding systems and resin composites, a high clinical success rate has been demonstrated [10,11], for example a recent retrospective study showed that the mean survival time of resin composites that remained functional was 11 years and 7 months [12]. Resin composite is conservative and economical, especially in restoring tooth surface loss cases where tooth structure has already been worn down due to erosion or attrition, whereas the tooth preparation to receive a full coverage crown is very destructive and can lead to pulpal complications [11,13]. With regards to resin composites, they are susceptible to wear and the surface will become rough [14–17], which in turn is then more susceptible to staining and bacterial adhesion [18,19].

There is a positive relationship between the hardness of ceramics and the abrasiveness against teeth [20,21]. Due to the hardness of zirconia, there has been debate regarding increased wear rates and surface roughness on the opposing antagonists as compared to other ceramic systems. However in a recent study, it was shown that zirconia and lithium disilicate ceramics cause less wear on opposing enamel compared to traditional feldspathic porcelain [22–25].

Ideally, clinical trials are the best methods to test the wear characteristics of materials. However, such in-vivo wear measurements are complex and present confounding variables that could complicate the interpretation of result [26]. To overcome the difficulties in in-vivo methods, wear simulators and methods have been developed to study the wear behaviour of dental restorative materials in-vitro [27]. Established wear tests include using a tooth-brushing machine and the use of two-body wear simulators such as abrasion single-pass sliding, two-body wear rotating countersample, and Taber abraser [28]. Advances in current technology have enabled simulation of the human chewing cycle in a laboratory using specific loads and frictional forces exerted by a chewing simulator [29], where the surface profile of worn materials can be determined by using a 3D profilometer [30]. A combination of qualitative and quantitative wear measurements was advocated by Altaie et al. [31] to provide more useful information on the wear of resin composite.