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Does the fatigue loading frequency affect the lithium disilicate glass ceramic inlay-dentin bond strength?

Flavia Zardo Trindade[a], Fernanda Campos[b], Caroline Cotes Marinho[b], Marco Antonio Bottino[b], Luiz Felipe Valandro[c,*], Cornelis J. Kleverlaan[d]

[a] Department of Dental Materials and Prosthodontics, Araraquara Dental School, Univ Estadual Paulista (UNESP), 1680 Humaitá Street, 14801-903 Araraquara, SP, Brazil

[b] Department of Dental Materials and Prosthodontics, Univ Estadual Paulista (UNESP), Institute of Science and Technology, São José dos Campos Dental School, 777 Eng. Franscisco José Longo Avenue, 12245-000 São José dos Campos, SP, Brazil

[c] Prosthodontics Unit, Faculty of Odontology, Federal University of Santa Maria, Rio Grande do Sul State, Floriano Peixoto Street, 1184, 97015-372 Santa Maria, RG, Brazil

[d] Department of Dental Materials Science at ACTA, Universiteit van Amsterdam and Vrije Universiteit, Gustav Mahlerlaan 3004, 1081LA Amsterdam, The Netherlands

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ABSTRACT

The aim of this study was to verify the effect of loading frequency during mechanical cycling on the microtensile bond strength between tooth and ceramic inlays. Twenty-four extracted permanent maxillary molars were standardly prepared (3 mm wide × 4 mm deep) to receive lithium disilicate-based ceramic inlays. After the adhesive cementation, the restored teeth were divided into three groups (n = 8), according to different range of mechanical cycling frequency: control group – water storage, 2.0 Hz group – mechanical cycling at frequency of 2.0 Hz (0–100 N, 1.2×10^6 cycles, water 37 °C), and 6.7 Hz group – mechanical cycling at frequency of 6.7 Hz (0–100 N, 1.2×10^6 cycles, water 37 °C). The teeth were then cut into microbars (1 × 1 mm, non-trimming method), which were tested under microtensile (MTBS) loading. The failure mode was classified and the data were analyzed by one-way ANOVA. The mean bond strength value of the control group was the highest and the values of the cycled groups were 15% lower, however the groups were statistically similar ($p = 0.58$). Chi-square test showed no statistical difference among the groups regarding the pre-test failures ($p = 0.17$). For all groups, the most frequent failure type was mode 1 (adhesive at the interface ceramic/cement) and mode 2 (mixed failure). Loading frequencies up to 6.7 Hz had no effect on the lithium disilicate glass ceramic inlay-dentin bond strength.

1. Introduction

Since the 1980s the use of ceramic inlays for posterior restorations have been increasing [1–3]. Among the ceramic systems available, the lithium disilicate-based material is even more indicated due to its properties like translucency [4], good adhesion to tooth substrate [5] and higher strength compared to other glass-based ceramics [6].

The lithium disilicate-based ceramic has a well-defined cementation protocol with hydrofluoric acid etching, silanization, and resin cement [7]. In partial restorations, the adhesive cementation promotes a better bond strength between tooth and ceramic, which leads to enhanced marginal adaptation [8] and lower microleakage [9]. Besides that, a good adhesion between tooth and ceramic would enable less possibility for cusp deflection [9] and increases fracture strength [10]. However, the cusp deflection – which is caused by poor bond strength with the tooth, a smaller amount of remaining tooth structure, among other factors – is the main origin of catastrophic failures of teeth restored with inlays. Therefore, in vitro studies must use some fatigue method to attempt to mimic the physiological cyclic stresses caused by the mastication.

Several in vitro studies using mechanical cycling have been performed to predict the survival rate of the materials and restored teeth. However, the parameters used to execute the mechanical cycling, such as occlusal loading, frequency of mechanical pulses and number of cycles, vary a lot among the studies, and there is no consensus regarding these parameters in the literature. Besides that, the correlation between the in vitro chewing simulation and the clinical situation has been widely discussed [11–16]. According to Boever et al. [17],

* Corresponding author.
E-mail addresses: flaviazardo@hotmail.com (F.Z. Trindade), cd.fernandacampos@gmail.com (F. Campos), caroline_cotes@yahoo.com.br (C.C. Marinho), mmbottino@uol.com.br (M.A. Bottino), lfvalandro@hotmail.com (L.F. Valandro), c.kleverlaan@acta.nl (C.J. Kleverlaan).

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chewing frequency is around about 1 Hz, ranging from 0.5 to 1.3 Hz, while other studies reported frequency rates varying from 1 to 2 Hz [18–20]. Furthermore, these authors states that the frequency rate during chewing can be influenced by the day, the individual, and the type of food, its consistency and viscosity. Additionally, Jemt et al. [21] observed that the length of the masticatory cycle reduces over the cycles and the maximum vertical movement of the mandible decreased throughout the chewing period. These findings shows how the chewing parameters may vary widely, making difficult to reproduce them accurately on in vitro tests.

Since the correlation between in vitro and in vivo situations is difficult to make, the in vitro simulation of the normal and physiological functional chewing parameters is still a challenge. However, researchers have been trying to mimic them on their in vitro tests by using values of occlusal loading and frequency rate as close as possible to the physiological parameters to produce more clinically relevant results [14,22–28]. Studies [23,25,28–30] involving mechanical cycling (aging protocol) and bond strength degradation of adhesive interfaces have used a frequency rate between 1 to 4 Hz.

However, there is still limited information in the literature regarding the effect of frequency rate on the results of in vitro studies involving mechanical cycling or fatigue tests and bond strength degradation, especially concerning the influence of a higher and non-physiological frequency. Therefore, since there is no consensus in the literature about the frequency rate that should be used in mechanical cycling methodology and there is a great variety on the frequency rate protocol, the present study aimed to evaluate the effect of different loading frequencies - 2 Hz compared to a higher one (6.7 Hz) – of mechanical cycling, on the microtensile bond strength between tooth and lithium disilicate glass ceramic inlays cemented to molars. The null hypothesis was that the loading frequency would not affect the bond strengths results.

2. Materials and methods

The materials (brand, and chemical composition) used are summarized in Table 1.

2.1. Experimental design

Maxillary molars and respective inlay restorations were assigned into 3 groups according to the frequency used for mechanical cycling of the assembly: a control group without applying repeated loading; frequency of 2.0 or 6.7 Hz. After the microtensile test, the 'tooth' was considered as the experimental unit.

2.2. Cavity preparations and ceramic inlay production

Twenty-four permanent maxillary molars, without visible cracks, were selected and randomly divided into three groups (n = 8). The roots of each specimen were embedded in a plastic cylinder filled with chemically cured acrylic resin (Dencrilay, Dencril, Caieiras, SP, Brazil) up to 2 mm from the cervical line in the apical direction. A surveyor was used to place the root perpendicularly to the y-axis. Standardized inlay preparations (3.0 mm wide × 4.0 mm deep), with a rectangular shape and a non-proximal box, were created in all teeth (Fig. 1). A high-speed hand piece with a conical trunk diamond bur with rounded angles (KG Sorensen 3131, Barueri, Brazil) fixed to a modified optic microscope was used for optimal standardization of preparations (Fig. 1). This device (modified optical microscope), limited the movements of the high-speed hand piece, which prevented differences in buccal-palatal width and cusp thickness of the teeth, and all cavities could be created on a standardized and reproducible manner. Impressions of the prepared teeth were made using polyvinyl siloxane (Elite, Zhermack, Badia Polesine, Italy) and stone master dies were created. Ceramic inlays were made of IPS e-max Press (Ivoclar Vivadent, Schaan, Liechtenstein).

2.3. Inlays cementation

Firstly, the inner surfaces of the inlays were etched with 10% hydrofluoric acid (Dentsply, Petrópolis, RJ, Brazil) for 20 s, while teeth preparations were etched with 35% phosphoric acid (Adper Scothbond, 3M/ESPE, St Paul, MN, USA) for 15 s. The treated surfaces were rinsed with water, dried and a silane coupling agent (RelyX Ceramic Primer, 3M/ESPE) was applied on the ceramic surfaces and two layers of an adhesive system (Adapter™ Single Bond, 3M/ESPE) on the dentin surface. The resin cement (Rely X ARC, 3M/ESPE) was mixed and applied to the inner surfaces of the inlays and seated using finger pressure. Excess cement was removed and each specimen was light cured (Elipar FreeLight 2, 3M/ESPE) at the buccal, lingual and occlusal surfaces (3 × 40 s). All procedures were carried out according to manufacturers instructions.

2.4. Mechanical cycling

The specimens were stored for 24 h in distilled water at 37 °C and then subjected to mechanical cycling using a chewing simulator (Fatigue Tester, ACTA, University of Amsterdam, Netherland). The specimens were placed inside this machine, which is composed by a tub bath containing distillated water at 37 °C and 10 metallic cylinder pistons with a 6 mm round shape tip. The load was applied vertically on the specimens, specifically positioning on both cusps, at the area between the top of the cusp and the restoration margin, without direct contact to the ceramic restoration (Fig. 2). A load of 10 to 100 N was applied at a frequency of 2.0 or 6.7 Hz for 1,200,000 cycles (167 h or 50 h). All groups were kept stored in water at 37 °C for the same period (a total of 167 h) before cutting them into microbars.

Table 1
Type, brand, and main chemical composition of the materials used.

Material type	Name/Brand	Chemical composition[a]
Ceramic blocks	e.Max Press (Ivoclar Vivadent, Schaan, Liechtenstein)	Lithium-disilicate based glass ceramic
Hydrofluoric acid	10% Hydrofluoric acid (Dentsply, Petrópolis, Brazil)	10% Hydrofluoric acid by weight, water, stabilizers
Phosphoric acid	Adper Scotchbond 35% (3 M/ESPE, St. Paul, MN, USA)	35% Phosphoric acid by weight, water, stabilizers
Adhesive resin	Adper™ Single Bond (3 M/ESPE, St. Paul, MN, USA)	bis-GMA, polyalkenoic acid, copolymer, dimethacrylates, HEMA, photoinitiators, ethanol, water
Silane coupling agent	RelyX Ceramic Primer (3 M/ESPE, St. Paul, MN, USA)	hydrolyzed y-methacryloxypropyltrimetoxy-silane
Resin cement	RelyX ARC (3 M/ESPE, St. Paul, MN, USA)	Bis-GMA, TEGDMA, dimethacrylate polymer, zirconia/silica glass (67.5 wt%), chemical, and photoinitiators.

[a] Data from manufacturer.