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Original article

Fatigue failure and success rate of lithium disilicate table-tops as a function of cement thickness

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Abstract

Purpose: Under thin, partial coverage restoration the proper cement thickness to be clinically employed still remains an issue. The aim of this study was to determine the failure and success rates of simplified lithium disilicate occlusal veneers as a function of cement thickness. The null hypothesis was that cement thickness has no effect on the fatigue resistance.
Methods: Sound human molars were severed in a plane parallel to the occlusal surface to create a flat dentin surface surrounded by enamel edges. Forty-five occlusal veneers 1.0 mm thick (IPS e.max CAD LT) were luted to the teeth with Multilink Automix resin cement, creating 3 experimental groups (n=15) with cement thicknesses of 50, 100, and 200 µm. The restorations were fatigue-cycled using a ball mill machine containing zirconia and stainless steel spheres. Twelve 60 min cycles were performed. Survival statistics were applied to "failure" and "success" events, comparing the three groups using a log-rank Mantel–Cox test and a log-rank test for trends (alpha = 0.05).
Results: The failure and success rates were not significantly influenced by cement thickness (P = 0.137 and P = 0.872, respectively); thus, the null hypothesis was accepted. However, when log-rank test for trends was applied to failure events, the tendency to have less failures with increasing thicknesses was found statistically significant (P = 0.047).
Conclusions: The cement thickness within the range adopted here did not have a significant effect on the failure or success rate of lithium disilicate occlusal veneers when exposed to randomized impact stresses generating fatigue phenomena.
Keywords: *All-ceramic restorations, Fatigue resistance, Lithium disilicate, Luting cements, Occlusal veneers*

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1. Introduction

Posterior teeth wear is often associated with a reduction in the vertical dimension of occlusion, which is responsible for occlusal instability, temporo-mandibular joint diseases, increased dental sensitivity, altered intermaxillary relationship, and aesthetic impairments.[1-7] Improved adhesive techniques have pushed clinical practice towards more conservative restoration designs for the treatment of occlusally abraded and worn-out teeth. Ceramic veneers and partial coverage crowns offer the advantage of minimal dental tissue removal,[8] maintaining larger portions of the already compromised dental elements.[9-12] Strong, durable bonding between the ceramic restoration and the dental substrate is a key factor increasing the reliability and functional life of this type of restoration. Several studies have reported encouraging clinical outcomes for thin, adhesively luted glass-ceramic partial crowns, with a survival rate on the order of 92–97% for different ceramic inlay and onlay restorations. Kaytan et al.[13] reported that only the marginal adaptation criteria of ceramic onlay restorations significantly differed over a 24-month observational period. In Fradeani et al.,[14] the estimated survival rate of ceramic inlays was 95.63% after a 4.5-year follow-up period. Other studies have reported rates of 93% for ceramic onlays after a 49-month mean observation time,[15] and 97.5% for pressed-ceramic of inlays/onlays over a mean observational period of 23.4 ± 6.1 months.[16] Van Dijken et al. [17] reported a 9.7% ceramic-coverage (onlay) failure rate in non-vital teeth and 6.6% in vital teeth.

Lithium disilicate glass ceramic, processed using conventional pressing techniques or the latest computer-aided design and manufacturing (CAD-CAM) technology, is considered one of the most suitable materials for this type of occlusal restoration, due to its higher elastic modulus and fracture strength.[18,19]

Relevant factors influencing the long-term outcomes of lithium disilicate restorations are related to the adhesive luting material, in terms of the mechanical resistance, stiffness (elastic modulus), and thickness.[20-22]

Besides providing a stable seal at the interface between the preparation margins and the restoration, the cement should ensure homogeneous transmission of masticatory forces towards the underlying tooth structure. The lack of any potential stress peak at the inner ceramic surface can only be achieved by a strong, uniform interfacial bond and an even thickness of the cement film.[23,24] The correct luting cement layer can provide improved retention and increased fracture resistance to ceramic restorations, compared to non-adhesive conventional cements.[25] Moreover, given today's high standards, CAD-CAM technology allows for true control over some of the most important restoration design parameters,

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including the pre-determination of the cement space width.[26,27]

The optimal resin cement thickness to be employed underneath lithium disilicate occlusal veneers or partial coverage crowns is still debated, as many factors related to the luting material properties and investigation techniques strongly affect experimental results and clinical guidelines.[28,29]

As a golden rule for experimental research, cycling fatigue tests applied to specimens luted to dental substrates are preferable to static load "crunch the crown" study designs, as the former more closely replicates the functional stress patterns of the oral environment.[30,31]

The fatigue stress responsible for weakening of adhesive interfaces and progressive crack growth within the restorative material (including a certain degree of wear) can be simulated with a ball mill machine, introduced by Kasim. et al.[32] as a rapid method for evaluating the bonding resistance of orthodontic brackets to repeated impact stresses. Recently, the concept has been further developed by Baldissara et al. in a similar fatigue machine purposely designed for brittle restorative material testing.[33]

In this study, we investigated the fatigue resistance of lithium disilicate flat-model occlusal veneers as a function of luting cement thickness by means of impact testing with the novel ball mill machine. The null hypothesis was that cement thickness would not influence the restoration survival rates after fatigue cycling tests.

2. Materials and Methods

The request for approval to use extracted teeth for the study was obtained from the ethics committee of our institution (Authorization No. 0059671, approved on 11/05/2018).

2.1. Specimen Preparation

Sixty human molar teeth with no caries lesions that had been extracted for periodontal disease or orthodontic needs were used as experimental specimens. After scaling with ultrasonic instruments, the teeth were immersed in 10 vol H_2O_2 for 30 min and then stored in distilled water and thymol solution (0.02%) at 4°C. All specimens were mounted in 12 mm diameter resin cylinders (Technovit 4071, Heraeus Kulzer GmbH, Hanau, Germany) by embedding the roots 2 mm below the cement–enamel junction. Then the occlusal surface of each tooth was severed with a microtome (Micromet Evolution, Remet, Bologna, Italy) using a rotary diamond blade (Norton, 125 × 0.35 mm) between the most cervical enamel extension and the pulp horns, simulating heavily worn teeth. Teeth showing accidental pulp horn exposure were discarded. (n=15) The intaglio surfaces were slightly abraded using # 320-grit SiC wet sandpaper (Imperial, Italy). Forty-five tablets (14.8 × 12.7 × 1 mm) were obtained by sectioning metasilicate lithium blocks (IPS e.max CAD, Ivoclar-Vivadent AG, Schaan, Liechtenstein) with the microtome under water irrigation; the tablets surface was finished with # 320, 400, 600, and 1200-grit SiC sandpaper. The thicknesses of the slices were checked using a digital caliper (CD-6" ASX, Mitutoyo Co., Kanagawa, Japan).

The mesio-distal and buccal-lingual dimensions of each tooth specimen were measured with a digital caliper to fit in the ball mill receptacles, and the mean values were defined. Fifteen specimens presenting the highest and lowest differences from the mean values were discarded; thus, 45 specimens were available for the study. The selected teeth were divided into three groups using a web-based random generator (www.random.org), according to three cement thickness values: Group A, 50 µm; Group B, 100 µm; and Group C, 200 µm.

Each ceramic tablet was assigned to a tooth, and then the edges were trimmed using a coarse diamond bur (881.314.016 Komet Brasseler, Lemgo, Germany), to roughly create the tooth margin profile. Then the margins of the metasilicate were finished using a fine diamond bur (881EF.314.012, Komet-Brasseler,), steam-cleaned and dried, then thermally-treated in an oven (Programat P500, Ivoclar-Vivadent AG, Schaan, Liechtenstein) to be converted into lithium disilicate. After crystallization, the thicknesses of the ceramics were checked again; a maximum error range of ±0.05 mm from the nominal value was applied. The ceramic specimens were observed under a stereomicroscope at 16× magnification (Wild M3C, Leica Camera, Wetzlar, Germany). Transillumination, performed with a polymerizing lamp (OptiLux 501, Kerr, Danbury, CT, USA), allowed for the exclusion of potentially flawed specimens. The occlusal surfaces of the restorations were polished with rubber points (Ivoclar Optrafine Polishing Kit, Ivoclar-Vivadent AG), and then all restorations were cleaned with water steam and air dried. The internal surface of the restoration was conditioned with an all-in-one etchant/silane gel (Monobond Etch & Prime, Ivoclar-Vivadent AG) for 60 s, gently rubbing the surface with a micro-brush for the first 20 s, as recommended by the manufacturer. Then the restorations were rinsed with distilled water for 5 s and air dried for 10 s. The dentin surfaces were treated with a self-etching primer (Multilink Primer A+B, Ivoclar-Vivadent AG) for 20 s, according to the manufacturer's instructions, and carefully air dried. Each occlusal restoration was glued to a titanium shaft of a parallelometer (Fig. 1 a,b) using adhesive wax (GEO Cera Collante, Renfert, Hilzingen, Switzerland).

The shaft was connected to a dial caliper (0.01 mm resolution) and zeroed to the occlusal surface of the underlying tooth preparation. The luting cement (Multilink Automix, Ivoclar-Vivadent) was evenly applied to the tooth surface while the restoration, firmly attached to the shaft, was descended until it reached at the distance from the dentin surface corresponding to the chosen cement film thickness (Fig. 1c). Excess cement was removed with a microbrush, and the restoration margins were covered with glycerin (Liquid Strip, Ivoclar-Vivadent AG). The tooth-restoration units were light-cured with a lamp (OptiLux 501) for 20 s on each side (mesial, distal, lingual, buccal); occlusal side was irradiated after the shaft and wax debris have been removed. All specimens were stored at room temperature in distilled water for 24 h; subsequently, the restoration margins were polished with a diamond wheel and rotating rubber tips (Superflex Fine, Edenta, CH-9434 AU/SG, Switzerland).

2.2. Ball mill machine

The ball mill machine used in this study was composed of a stainless-steel drum (diameter, 120 mm; depth, 140 mm), as shown in Fig. 2. Rotation was powered by a continuous duty-cycle electric motor (AD63N4; AEG, Berlin, Germany) fed by an inverter (J1000, Jaskawa-Omron, Japan) to finely control the revolutions per minute (rpm). The ball mill has a diverse basic principle of functioning compared to conventional chewing machines frequently used for dental research.[33] Nevertheless, it demonstrates high efficiency in promoting wear and fracture propagation sustained by fatigue phenomena in brittle materials. In the ball mill approach, cyclic stresses generated by conventional chewing machines, usually limited to a small surface area [34] of the restoration, are extended to much larger areas in the form of randomly distributed impacts of a certain energy. The impacts are generated by zirconia and steel spheres that fall onto a surface target of ~19 mm^2 (diameter, 5 mm). Given that the impact energy is notably lower than the minimum energy necessary for the immediate fracture of the lithium disilicate restoration, the failure is necessarily caused by wear and damage accumulation (crack growth) within the ceramic. The maximum energy, E, generated by the ball mill spheres is given by the formula $E = mgh$, where m is the mass of the sphere, g is the acceleration due to gravity, and h is the maximum falling height; energy values of 0.021 J for 20 mm Y-TZP spheres and 0.056 J for stainless steel spheres have been reported. The impact area can be predetermined by positioning the specimen in the receptacle at a certain depth, thus regulating the impact points using spatial exclusion criteria (Fig. 3).

Five racks, each carrying six specimens, were inserted into the drum and then charged with 10 zirconia and 10 stainless-steel spheres. The hermetic closure of the drum was secured, and 500 mL water was poured through the specific opening at 37 ± 2°C and maintained at this temperature by built-in Ni-Cr resistors. The rotational speed was regulated on the electronic driver control panel. Each run lasted 60 min, corresponding to about 5.500 revolutions (92 rpm). Eight cycles of 60 min each were applied, for a total run time of 480 min. Due to the limited number of receptacles available (n= 30), two testing sessions were performed by splitting the specimens into two groups of 22 and 23 specimens each.

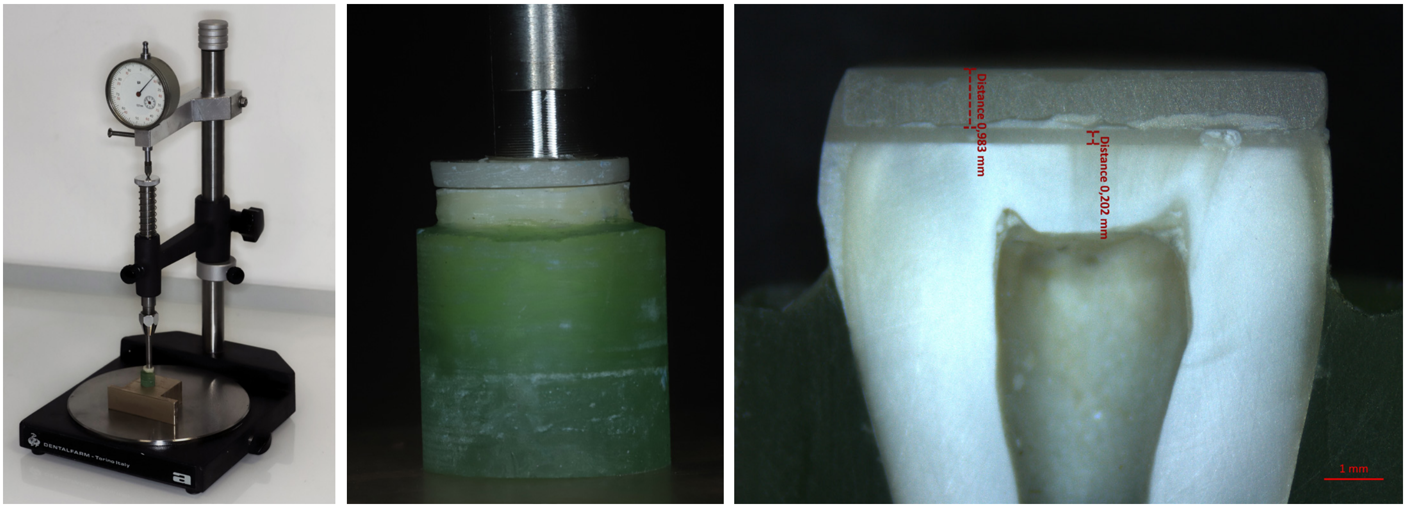

Fig. 1a, 1b, 1c. Cement application. a) Parallelometer coupled with a dial caliper for occlusal veneer accurate positioning; b) 200 µm cement space as checked before cement application; c) Section of a specimen belonging to 200micron cement thickness group showing the uniform thickness of both ceramic and cement layer. Fracturing of the lithium disilicate intaglio surface is an artifact. (X10).

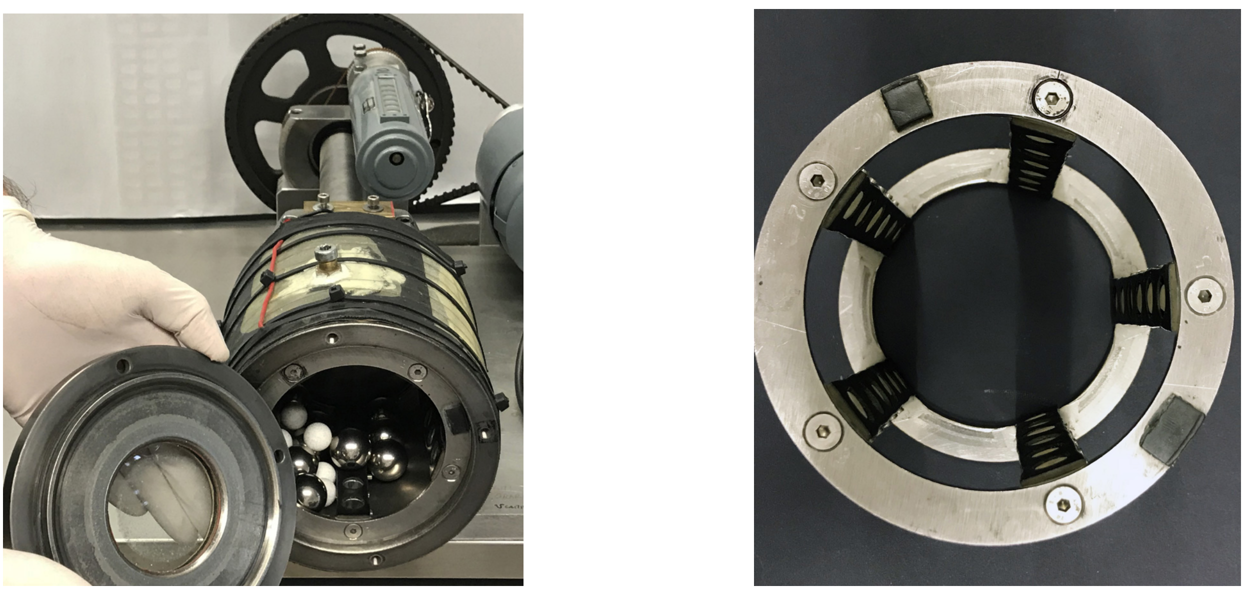

Fig. 2a and 2b. The ball mill. a) the ball mill machine used in this study just after spheres loading; b): rubber-lined steel racks with specimens already positioned in their receptacles.

2.3. Specimen analyses

After each cycle series of 60 min, the specimens were separated from the carrying racks, washed, and air-dried. Wear, cracks, and damage in the restorations were searched and evaluated under a stereomicroscope (Wild M3C, Zeebrugge, Switzerland) at different magnifications (X10 to X40) using transillumination. The specimens subjected to the ball mill effect were categorized as a "success," "survival," or a "failure".

The term "success" was assigned when the restoration was still functional and stable, as indicated by the absence of cracks under optical microscopy and transillumination observations (Fig. 4). A restoration was categorized as "survival" if one or more cracks were revealed by stereomicroscopy observation and transillumination, which makes the restoration potentially unstable although still functional. Notably, the crack formation could be in the form of parting and/or radial crack lines that did not extend to the restoration margins (Fig. 5).

The failure classification was given to specimens that experienced catastrophic, unrecoverable damage preventing clinical function, as in the case of dentin exposure, restoration debonding, or fractures that propagated to the margins (Fig. 6,7). Micro-cleavage and/or associated surface wear aspects were not classified as damages.

2.4. Statistical Analyses

Two separate survival analyses were performed for failure and success events using the following tests (GraphPad, Prism 8.0, www.graphpad.com).

- The log-rank Mantell–Cox test was used to determine if a statistically significant difference existed among the three survival curves with respect to failure and success events.
- The log-rank test for trends was employed to establish the linear trend of the tendency progression of an event (failure or success) as the cement thickness values increased from 50 to 200 µm.

The alpha level was set at 0.05.

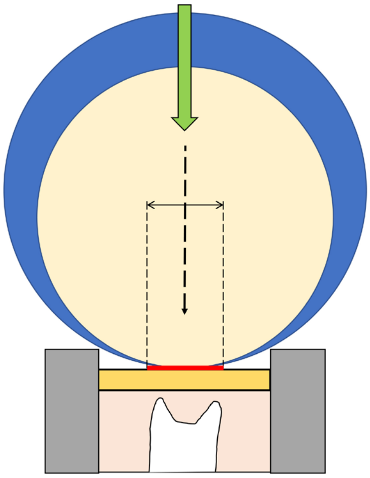

Fig. 3. Impact scheme of the position of the disilicate on the inner area of the steel racks. The restoration position was programmed to determine an area of limited diameter (~6 mm) for loading impacts, excluding the restoration edges.

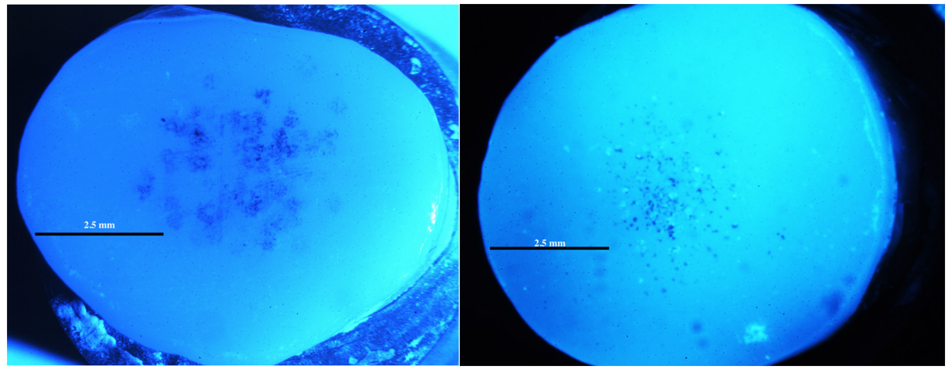

Fig. 4a and 4b. specimen showing success events. a) At the early stages, only dark spots related to the metal left by the steel spheres are observable; b): after 180–240 min of cycling time, impact areas probably related to quasi-plastic microcracking were detectable as very tiny white spots. X10.

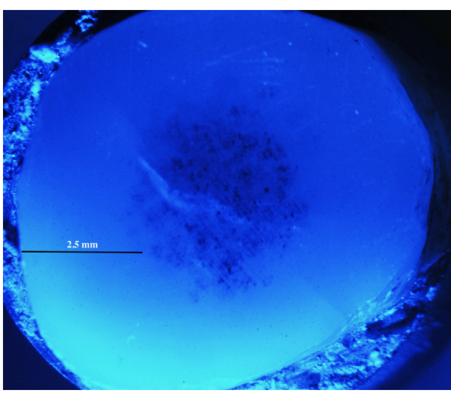

Fig. 5. an early radial crack not extending to the restoration margins appears under transillumination in a survived specimen after 180 min of fatigue cycling. The fracture is located at the center of the occlusal surface. The stainless steel spheres left some metal on the ceramic surface at the impact stressed area, creating a dark pitted circle about 6mm in diameter. X10.

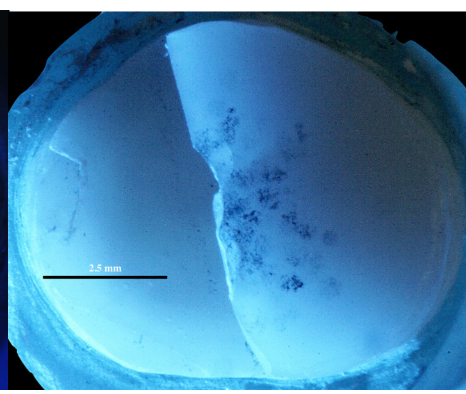

Fig. 6. A failed specimen with half of the dentin surface exposed. X10.

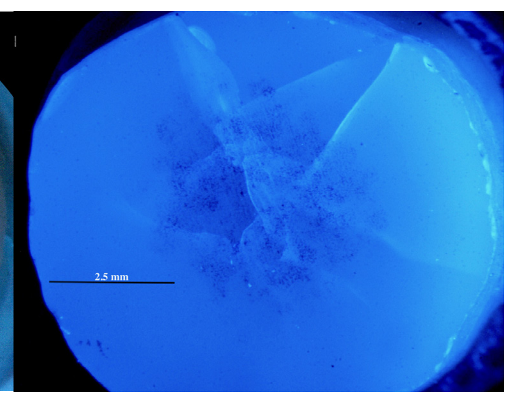

Fig. 7. Failure by multiple fracturing extending to the restoration margins after 480 min of fatigue cycling. The crack lines started from the dark pitted impact area at the centre of the restoration and propagated towards the ceramic edges. X10.

3. Results

Survival curve for failure and success events are shown in Fig. 8. Group A (50 μm) had only successes (n = 8) and failures (n = 7), without any survival events. Group B had four failures, two survivals, and nine successes, whereas Group C had two failures, five survivals, and eight successes. In B and C (100 and 200 μm, respectively), the survival events were registered at the end of the 480 min cycling time). Failure events showed no significant differences ($p = 0.137$) among the three cement thicknesses when the groups were compared using the log-rank Mantel–Cox test. However, when the log-rank test was used to evaluate whether failure rates changed as a function of increasing cement thickness, the trend appeared to be statistically significant ($p = 0.047$).

Success rates were not statistically different among the three groups when tested with the log-rank Mantel–Cox test ($p = 0.872$). In contrast to the failure analyses, the log-rank test did not reveal any significant tendency of change in the success rate as a function of increasing cement thickness ($p = 0.626$).

The damage progression showed the following phases: formation of very tiny white spots, probably due to quasi-plastic ceramic deformations at the points with the highest energy impact (Fig. 4); development of subsurface radial cracks and parting-type fractures that, in the earlier stages, did not extend to the restoration margins (Fig. 5); and restoration detachments or catastrophic failures with at least one crack extending to the restoration margin. (Fig. 6,7)

4. Discussion

The survival statistics applied to the collected data did not reject the null hypothesis that the cement thickness has no influence on the failure and success rates of lithium disilicate restorations, confirming the results obtained in other studies.[24,35-37]

However, when the failure, or “unrecoverable damage” event, was considered alone, the log-rank test for trends indicated that increasing the cement thickness (from Group A to Group C) tended to reduce the number of failures ($p = 0.047$), suggesting that a cement thickness of 200 μm is

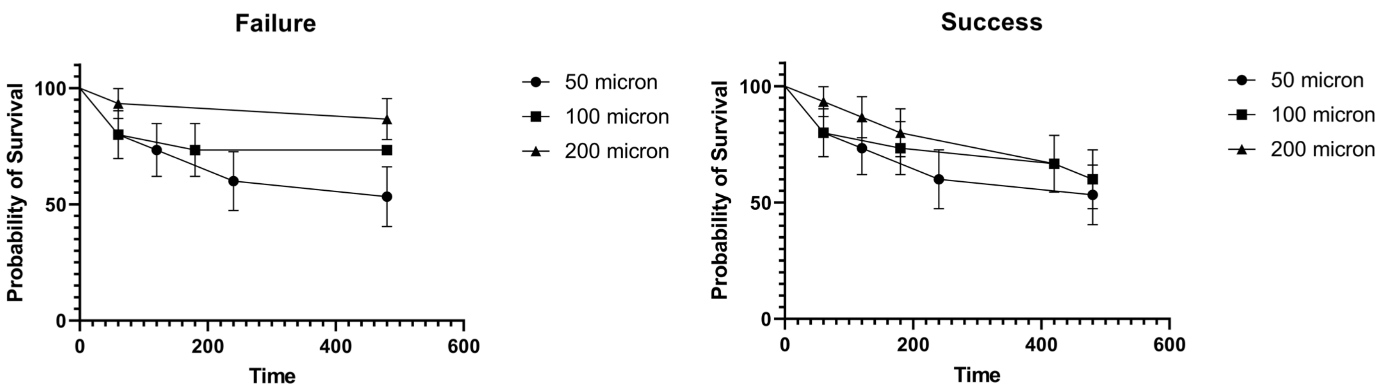

Fig. 8. Probability of survival over time: (a) failure and (b) success curves for cement thicknesses of 50, 100, and 200 μm.

more effective for reducing catastrophic failures than a thinner layer. This contrasts with the findings of several other studies that have reported a general reduction in ceramic bonding and restoration strength as cement thickness increases.[24,38] However, the significance level of this trend was weak, and the specimens per group (n = 15) in the present study were too few to strongly support this hypothesis, and others have observed a significant weakening effect due to an excessively thick cement layer; one reported that the effect began at 300 μm,[24] while another study saw weakening as the cement layer thickness approached 500 μm.[38]

The success rate analysis is clinically more representative since for a dental practitioner, cracked ceramic restoration, often unperceived by both the patient and the clinician, should be considered a true failure, even if it is still functional. In this respect, the success analyses that excluded sub-clinically damaged restorations showed that the cement thicknesses considered in this study had no significant effect on the restoration success.

By looking at the general theory of adhesive luting cements applied to thin ceramic veneers,[39] it should be noted that a homogeneous and evenly distributed cement layer may function as a protective cushion,[36] preserving the brittle ceramic from direct contact with the substrate, eliminating any potential stress peak that could initiate a crack at the intaglio, tensile-stressed side.[37] The stiffness of adhesive-resin luting cements is reportedly low[38] when compared to many restorative materials, with elastic moduli ranging from 3–8 GPa;[40] thus, these luting cements can be considered relatively flexible, compared to both ceramics and dental tissue substrates. The cement used in this study, Multilink Automix luting cement, is a dual-curing material that when correctly light-polymerized can reach an elastic modulus of 6.0 ± 0.4 MPa; this value is representative of many luting cements purposely designed for glass-ceramic restorations.[37,41]

As the elastic modulus of the luting cement decreases, the film thickness becomes an important parameter for the survival of the rigid, brittle restoration overlay, such as those made of glass ceramics and lithium disilicate.[36,42] The strain of the cement layer after loading is proportional to its stiffness and is inversely proportional to its thickness.[43]

Thus, cement layers greater than 200–300 μm with a low elastic modulus may allow for greater deformation of the ceramic material, with a consequent increase in the tensile stresses located at the ceramic intaglio surface.[28] This, in turn, could trigger the formation of sub-surface radial cracks, fracture growth, and at a later stage, macroscopic failure of the restoration.[35]

It is generally accepted that at a given film thickness, stiffer cements may better sustain and protect the ceramic veneer restorations from occlusal stresses than more flexible, low elastic modulus cements.[36,43] This is why many laminated veneer restorations are cemented using warmed dental restorative composites with higher mechanical properties, rather than conventional adhesive resin cements.[44]

Another variable involved in the clinical success of ceramic restorations is the mechanical properties of the ceramic, like the lithium disilicate used in the present study. Ceramics are brittle materials and may fail under cyclic loading. The fracture can occur under a single overload event; however, it is more likely to occur over a long period of repetitive loading under the fracture threshold limit. Mechanical failure of dental ceramics has been described in previous studies that have used in vitro models that simplify the number of variables involved in the process of ceramic failure. However, the masticatory cycle, the mechanical properties, and the residual structure of the tooth with different substrate types (e.g., dentin, enamel, and composite), as well as the amount of supporting tissue and food type, are variables that are difficult to reproduce, giving only partial evidence of the natural complex mechanism involved in the process of fracture resistance. Moreover, during fatigue testing of ceramic restorations, usually only a small portion of the occlusal areas are involved, whereas during mastication, the occlusal loading occurs to larger areas of the restoration, not only at the ones chosen for load application.

Several studies have reported a significant effect of cement thickness on the strength, fatigue resistance, and bonding of a ceramic restoration to the substrate. Cekic-Nagas et al.[45] showed that augmenting the resin cement film thickness from 50 to 100 μm resulted in decreased bond strength at the interface between resin core materials and lithium disilicate pressed ceramics. A similar relationship between restoration resistance and cement thickness was confirmed by Gressler May et al. on CAD-CAM feldspathic ceramic crowns cemented to a dentin analogue blocks with a 50 μm-thick resin cement layer; the specimens were more resistant to fatigue cycling than those having a cement layer increased to 500 μm.[46]

Conversely, another study by Scherrer reported that below a film thickness of 100 μm, the influence on the survival of glass-ceramic plates (Macor, Corning Glass Works, NY) on fracture resistance is negligible;[24] our data are in line with those findings. May et al.[38] suggested that, when the cement layer is thick enough, shrinkage phenomena may lead to cement detachment, reducing the ceramic adhesion to the substrate. Our results are in accord with other studies that support the hypothesis that if the cement thickness is representative of the range used in clinical practice (50–200 μm),[37,47] this variable plays a secondary role in preserving a thin ceramic restoration.[36]

Accordingly, our data suggest that the cement layer has no significant effect on the clinical outcome of lithium disilicate occlusal veneers. Rather, the mechanical properties of the cement and ceramic material, the restoration thickness, the intaglio surface roughness, and the achievable interfacial adhesion strengths are the most important factors determining the clinical success of adhesively luted occlusal veneers.[36,46]

4.1. Failure analyses

Due to the high impact randomization and symmetrical positioning of the specimens in the ball mill supporting racks, it is unlikely that the specimens received different stressing patterns, thus it is assumed that the different failure types are generated by the intrinsic variables of the restorations. Cement thickness did not affect the failure distributions in the three groups. In accord with Baldissara et al.,[33] the damage progression followed two main patterns in our study: detachment and fracturing. The former is due to a weakening process at the adhesive interface when the ceramic is defect-free and/or particularly strong. In the case of lithium disilicate, this event is more likely to occur when the restoration thickness is at least 1.0 mm.[33,43] Conversely, initial fracturing may result from defects in the ceramic (particularly at the intaglio surface),[48] uneven adhesion strength, and voids within the cement layer[38] that might facilitate undetectable sub-surface cracking in the early stages of cycling. Due to repeated impact energy transfer, low restoration thickness, and water-induced stress corrosion phenomena, cracks propagate towards the surface and ceramic edges until catastrophic failure occurs; this damage progression is closely in accord with the model described by Thompson et al.[43] In the present study, the lithium disilicate occlusal veneers were polished without applying any glazing ceramic and thus wear and roughening due to the fracture of glaze[33] were not observed. Instead, stereomicroscope observations of the specimens that successfully reached 720 min of fatigue cycling revealed only small, whitish impact areas that were ascribed to quasi-plastic micro-fracturing, lacking the conchoidal fracture aspect widely observed in glazed restorations. The sporadic and tiny quasi-plastic wear pattern, in absence of other detectable cracks (parting or radial fracture), is the result of the optimal and well-balanced properties of lithium disilicate ceramic, i.e., medium flexural strength and modulus (in comparison to zirconia), coupled with a high adhesion to resin luting cements. The findings here suggest that the mechanical polishing of monolithic lithium disilicate is preferable to preserve the surface finish of the restorations.

4.2. Ball mill discussion

To test fatigue resistance, an updated version of the ball mill machine has been adopted; this approach is described in detail in Baldissara et al.[33] The main feature of this testing machine is the capacity to randomize the impacts over a larger area of the restoration. Once a certain sphere diameter is chosen, the impact area extension can be set by accurate positioning of the specimen inside the receptacle: since the sphere cannot impact geometrically hindered areas, the margins of the occlusal veneers can be efficiently preserved from the applied stresses, excluding edge-chipping phenomena that could restrain the survival evaluation of the ceramics.

The advantage of a larger stressed area is to have a greater probability to include the effects of local variables (porosities, ceramic defects, air bubbles entrapped in the cement layer, and so forth) in the experimental results obtained from fatigue testing. Another characteristic of this ball mill is the ability to set the energy transferred to the restorations by the falling spheres. The mass of the spheres is chosen to generate a maximum impact energy that is well below the threshold required to immediately fracture the restoration, developing a true crack-growth effect with damage accumulation as a function of testing time.

In this study, the simplified flat geometry of the occlusal veneers was adopted to standardize their thickness and exclude morphological variables (cusps and occlusal grooves) to better determine the effects of the cement. Furthermore, the limited thickness of occlusal veneers - 1.0 mm, a commonly used value in similar studies [30,49] usually does not permit the modeling of complex anatomies, that would have also required an unsustainable number of specimens to overcome the effect of the shape variables.

5. Conclusion

- Cement film thicknesses in the range of 50–200 µm did not affect the failure and the success rate of lithium disilicate occlusal veneers subjected to fatigue stress ($P=0.137$; $P=0.872$, respectively).
- The tendency to reduce the failures occurrence (unrecoverable damages) by increasing the cement film thickness was found to be weakly statistically significant ($P=0.047$), suggesting that further studies are needed to confirm a positive effect produced by a thicker cement film.

Declarations of interest

None

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