UNIVERSIDADE DE SÃO PAULO
FACULDADE DE ODONTOLOGIA DE BAURU

EDGAR MASSUNARI MAENOSONO

Influence of thickness and restorative material on the physical-mechanical behavior of CAD/CAM minimally invasive occlusal veneers - in vitro study

Influência da espessura e material restaurador no comportamento físico-mecânico de facetas oclusais minimamente invasivas confeccionadas em CAD/CAM – estudo *in-vitro*

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Dissertação apresentada a Faculdade de Odontologia de Bauru da Universidade de São Paulo para obtenção do título de Mestre em Ciências no Programa de Ciências Odontológicas Aplicadas, na área de concentração Dentística.

Orientador: Prof. Dr. Sérgio Kiyoshi Ishikiriama.

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ABSTRACT

Influence of thickness and restorative material on the physical-mechanical behavior of CAD/CAM minimally invasive occlusal veneers - in vitro study

The occlusal veneers consist in a minimally invasive restorative approach that aims to restore the shape and function of the posterior teeth affected by tooth wear. The aim of this study was to evaluate the behavior of the occlusal veneers when subjected to thermal and mechanical cycling. Sixty specimens were divided into 04 groups (n=15), showing two variation factors divided into two levels: material – lithium dissilicate LD (IPS e.max CAD, Ivoclar Vivadent, Schaan, Liechtenstein) and nano ceramic resins NCR (ESPE Lava Ultimate, 3M, São Paulo, Brazil); thickness - 0.6 and 1.2mm. The occlusal veneers were luted with dual-polymerizing luting agent (Variolink N, Ivoclar Vivadent, Schaan, Liechtenstein) (RelyX Ultimate 3M, São Paulo, Brazil) using the respective adhesive system in self-etch mode. The resin cement was light cured for 40 seconds each face, using a LED light cure equipment that irradiates 1,100 mW/cm^2 (BlueStar II, Microdont, São Paulo, Brazil). A response variable consists of veneer survival rates (crack formation, catastrophic cracks and debonding) when subjected to thermal cycling from 5 ° to 55 ° C for 1,000 cycles and simultaneous mechanical cycling performed at load intensities of 100, 200, 300, 400 and 450N for 20,000 cycles each. Data were submitted to the Kruskall Wallis test and Pairwise Comparison, adopting a significance level of 5%. NCRs presented a lower incidence of failures ($p < 0.05$) when compared to LD. As for thickness, 1.2 mm thick occlusal veneers withstand higher cycling loads. Within the constraints of this study, we can conclude that NCR occlusal veneers with 1.2mm thickness presented superior physical-mechanical behavior and lithium dissilicate occlusal veneers with thickness lower than 1.2mm are more likely to fail.

Key words: Tooth Wear. Dental Veneers. Fatigue. Ceramics. Composite Resins.

RESUMO

Influência da espessura e material restaurador no comportamento físico-mecânico de facetas oclusais minimamente invasivas confeccionadas em CAD/CAM – estudo in-vitro

Facetas oclusais consistem numa abordagem restauradora minimamente invasiva, que tem como objetivo reestabelecer forma e função de dentes posteriores severamente acometidos por desgaste dentário. O objetivo deste trabalho foi avaliar o comportamento das facetas oclusais minimamente invasivas quando submetidas à ciclagem térmica e mecânica. Sessenta espécimes foram divididos em 04 grupos (n=15), apresentando-se dois fatores de variação divididos em dois níveis: material - dissilicato de lítio LD (IPS e.max CAD, Ivoclar Vivadent, Schaan, Liechtenstein) e resinas nano cerâmicas NCR (ESPE Lava Ultimate, 3M, São Paulo, Brasil); espessura - 0,6 e 1,2mm. As facetas oclusais foram cimentadas com cimento resinoso dual (Variolink N, Ivoclar Vivadent, Schaan, Liechtenstein)(RelyX Ultimate 3M, São Paulo, Brasil), utilizando o sistema adesivo de sua respectiva marca no modo autocondicionante. O cimento resinoso foi fotoativado por 40 segundos em cada face utilizando um equipamento fotopolimerizador LED com 1.100 mW/cm^2 (BlueStar II, Microdont, São Paulo, Brasil). A variável de resposta consistiu na taxa de sobrevivência (formação de trincas, trincas catastróficas e deslocamento da restauração) das facetas quando submetidas à ciclagem térmica de 5º a 55ºC por 1000 ciclos e concomitantemente ciclagem mecânica realizada com intensidades de carga de 100, 200, 300, 400 e 450N, por 20.000 ciclos cada. Os dados foram submetidos ao teste Kruskall Wallis e Comparação Pairwise, adotando-se nível de significância de 5%. As NCR apresentaram menor incidência de falhas ($p<0,05$) quando comparadas ao LD. Quanto à espessura, facetas oclusais com 1,2mm de espessura resistiram a cargas maiores de ciclagem. Dentro das limitações deste estudo, pode-se concluir que facetas oclusais confeccionadas com NCR, numa espessura de 1,2mm, apresentam comportamento físico-mecânico superior e facetas oclusais confeccionadas com dissilicato de lítio com espessura menores que 1,2mm estão sujeitas a um maior número de falhas.

Palavras-chave: Desgaste dos Dentes, Facetas Dentárias, Fadiga, Cerâmica, Resinas Compostas

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LIST DE ABBREVIATIONS AND ACRONYMS

CAD	Computer Aided Design
CAM	Computer Aided Manufacturing
DSLR	Digital single-lens reflex
GERD	Gastroesophageal reflux disease
Hz	Hertz
LD	Lithium dissilicate
mm	millimeter
N	Newton
NCR	Nano Ceramic Resin

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1 INTRODUCTION

1 INTRODUCTION

Pathological tooth wear has been recognized as a growing problem in contemporaneous dentistry. Its causes are related to parafunctional habits and acid erosion. According to the systematic review published by Mesko et al., 2017, the prevalence of bruxism reaches 31% of adults. In a study conducted by Mafla et al., 2017, the authors observed a prevalence of dental erosion of around 57.3% in Colombian adolescents. Even more alarmingly, in a study by Gillborg et al., 2019, the authors observed that of a total of 831 individuals in Sweden, almost 80% had some sign of erosion.

Despite the higher prevalence, the treatment of tooth wear is still quite complex. It may involve restoration of all posterior teeth, which requires time and consequently high costs, and it often requires wear of the dental structure for onlay, overlay and crown preparations. In order to make more conservative preparations, the occlusal veneers, also known as "table tops" shown up. This restorative approach consists of a thin layer of restorative material positioned on the occlusal surface of the posterior teeth. Its purpose is to restore shape and function to teeth that have worn out and also to prevent the progression of tooth wear in an ultra-conservative way, and may also be used in clinical cases that need to increase vertical dimension of occlusion is necessary (GROTEN, 2007; BAHILLO et al., 2014).

The use of ultra-conservative restorative materials can be considered to be well established in the anterior teeth. Ultrathin occlusal veneers have shown very satisfactory clinical results (GROTEN 2007; BAHILLO, et al. 2014). However, it is important to note that the bite force that occurs in the posterior teeth are much higher, in the order of 300 to 600N (CALDERON et al. 2006; KOGAWA et al. 2006; TAKAKI P., VIEIRA M., BOMMARITO S. 2014). There is no consensus in the literature regarding the thickness and type of material that can withstand the chewing forces involved in the posterior region.

Dental ceramics have interesting properties for this type of restoration such as high wear resistance, higher acid resistance commonly associated with dental erosion and adhesion to the dental structure. Some studies indicate that dental ceramics have better properties when compared to composite resin restorations (FRON CHABOUIS H, SMAIL FAUGERON V, ATTAL JP 2013).

Another viable material option to make occlusal veneers is indirect composite resins. A higher degree of conversion, better mechanical properties were achieved due to the laboratory processing, mainly for indirect resins block for CAD/CAM, as their manufacture allows a higher amount of filler, less diluent, and are polymerized at high pressure and high temperature (MAINJOT et al. 2016).

However, not much is known about the clinical longevity of this treatment, because the thickness of the material associated with parafunctional habits may reduce the survival of these occlusal veneers. Magne et al. (2010) performed isometric mechanical cycling of occlusal veneers made of leucite-reinforced ceramics, lithium dissilicate ceramics (IPS Empress CAD and IPS e.max CAD) and composite resin (Paradigm MZ100), each with 1.2mm thick. These specimens were mechanically cycled at various load intensities (400, 600, 800, 1,000, 1,200, and 1,400N). After mechanical cycling the specimens were evaluated by translumination, microscopy and photography, looking for cracks larger than 2mm in the surface that would indicate failure. Composite resin specimens had 100% survival, lithium dissilicate ceramics 30% and leucite-reinforced ceramics an 0% survival rate.

Schlichting et al. (2011) also performed isometric mechanical cycling of occlusal veneers made of leucite-reinforced ceramics, lithium dissilicate ceramics (IPS Empress CAD and IPS e.max CAD) and composite resin (Paradigm MZ100 and experimental resin) each with 0.6 mm thick. These specimens were mechanically cycled at various load intensities (400, 600, 800, 1,000, 1,200, and 1,400N). The specimens were evaluated by translumination, microscopy and photography, looking for cracks larger than 2mm in the surface which would determine the failure of the restoration. Experimental composite resin specimens had 100% survival, commercial composite resin 60%, lithium dissilicate ceramics 0% and leucite-reinforced ceramics 0% survival.

Sasse et al. (2015) compared different thicknesses of minimally invasive occlusal veneers and luted on different substrates (strictly enamel; enamel and dentin; enamel, dentin and composite resin). Strictly enamel luted restorations had significantly lower fracture resistance than the other groups. The work suggests that the minimally invasive ceramic occlusal veneer is a good restorative procedure for worn or misplaced teeth, but the study also suggests that it should be used at least a thickness of 0.7 to 1.0mm.

Heck et al. (2019) evaluated occlusal veneers made of different materials: IPS Empress CAD, IPS e.max CAD and LAVA Ultimate. The restorations had a thickness of 0.3mm in the region of pits and fissures, and 0.5mm in the region of the cusps. 64 teeth were prepared so that there was only enamel at the edge of the preparation, and only dentin on the occlusal surface. The specimens were mechanically cycled 1,000,000 cycles at a 50N load, and another 1,000,000 cycles at 100N were performed on lithium dissilicate specimens. All lithium dissilicate restorations survived mechanical cycling, 10 leucite-reinforced glass ceramic restorations fractured, 8 in the 10,000 cycle range and 2 in the 100,000 cycle range, and only one nano ceramic resin restoration fractured in the 100,000 cycle range. Based on these results the group concludes that IPS Empress CAD occlusal veneers have a higher probability to fracture compared to LAVA Ultimate and IPS e.max CAD occlusal veneers.

Maeder et al. (2019) evaluated the loading-bearing of 0.5 and 1.0mm occlusal veneers with various materials: zirconia (Vita YZ HT (ZIR)); lithium dissilicate (IPS e.max Press (LDC)); nano ceramic resin (Vita Enamic (E), Lava Ultimate (LU)). The average force required to start cracking was 1,350N for 0.5-ZIR, 850N for 0.5-LDC, 1,100N for 0.5-E, 1,950N for 0.5-LU, 2,100N for 1.0-ZIR, 1,750N for 1.0 -LDC, 2,000N for 1.0-E and 2,300N for 1.0-LU. And the average load required for the restoration fracture was 2,493N for 0.5-ZIR, 1,165N for 0.5-LDC, 2,275N for 0.5-E, 2,265N for 0.5-LU, 2,489N for 1.0-ZIR, 1,864N to 1.0-LDC, 2.485N to 1.0-E and 2.479N to 1.0-LU. Based on these results, it was concluded that these materials have the properties necessary to be used as occlusal veneers.

Ioannidis et al. (2019) evaluated the loading-bearing of 0.5 and 1.0mm occlusal veneers made of various materials: zirconia (Vita YZ HT (ZIR)); lithium dissilicate (IPS e.max Press (LDC)); nano ceramic resin (Vita Enamic (E), Lava Ultimate (LU)) The average load required for the restoration fracture was 1,692N for 0.5-LDC, 2,390N for 0.5-E, 2,200N for 0.5-LU, 2,299N for 1.0 -ZIR, 1,537N for 1.0-LDC, 2,124N for 1.0-E and 2,489N for 1.0-LU The group did not get results for

0.5mm zirconia because of the difficulty of milling ultrathin specimen restorations. Based on these results, it was concluded that these materials have properties necessary for use as occlusal veneers.

Considering that further studies are still needed to better understand the physical-mechanical behavior of restorative materials indicated for occlusal veneers, as the materials are constantly evolving to improve their properties, especially those used in CAD/CAM systems, the aim of this work was to evaluate the physical-mechanical properties and survival rate of occlusal veneers made of nano ceramic resin and lithium dissilicate ceramic, milled in CAD/CAM at 1.2mm and 0.6mm thickness when submitted to thermomechanical cycling with different load intensities.

2 ARTICLE

2 ARTICLE

The article presented in this Dissertation was written according to the Operative Dentistry instructions and guidelines for article submission

Influence of thickness and restorative material on the physical-mechanical behavior of CAD/CAM minimally invasive occlusal veneers - in vitro study

Maenosono EM[1], Maenosono RM[2], Queiroz CT[1], Lauris JRP[3], Borges AFS[1], Ishikiriama SK[1]

Running title:
Edgar Massunari Manenosono[1]
edgar.maenosono@usp.br
Alameda Octávio Pinheiro Brisolla, 9-75, Bauru, SP, Brazil/Zip Code:17012-901
DDS, MS Student
[1]Department of Operative Dentistry, Endodontics and Dental Materials, Bauru School of Dentistry, University of São Paulo

Rafael Massunari Manenosono[1]
rafamaenosono@hotmail.com
Rua José Augusto de Carvalho, 734, Andradina, SP, Brazil/Zip Code:16900-013
PhD, Ms, DDS, Professor
[2]Department of Operative Dentistry and Dental Materials, UNIFUNEC

Camila Thais Queiroz[1]
camilatq@hotmail.com
Alameda Octávio Pinheiro Brisolla, 9-75, Bauru, SP, Brazil/17012-901
DDS, MS student
[1]Department of Operative Dentistry, Endodontics and Dental Materials, Bauru School of Dentistry, University of São Paulo.

José Roberto Pereira Lauris[1]
jrlauris@usp.br
Alameda Octávio Pinheiro Brisolla, 9-75, Bauru, SP, Brazil/Zip Code:17012-901
MS, PhD, Associate Professor
[3]Department of Pediatric Dentistry, Orthodontics and Community Health, Bauru School of Dentistry, University of São Paulo.

Ana Flávia Sanches Borges[1]
afborges@fob.usp.br
Alameda Octávio Pinheiro Brisolla, 9-75, Bauru, SP, Brazil/Zip Code:17012-901
DDS, MS, PhD, Associate Professor
[1]Department of Operative Dentistry, Endodontics and Dental Materials, Bauru School of Dentistry, University of São Paulo.

Sérgio Kiyoshi Ishikiriama[1]
serginho@usp.br
Alameda Octávio Pinheiro Brisolla, 9-75, Bauru, SP, Brazil/Zip Code:17012-901
DDS, MS, PhD, Associate Professor
[1]Department of Operative Dentistry, Endodontics and Dental Materials, Bauru School of Dentistry, University of São Paulo.

Key words: occlusal veneer, fatigue, nano ceramic resin, lithium dissilicate.

Corresponding author: Prof. Dr. Sérgio Kiyoshi Ishikiriama
Department of Operative Dentistry, Endodontics and Dental Materials
Bauru School of Dentistry-FOB-USP
Alameda Octávio Pinheiro Brisolla, 9-75, Bauru, SP, Brazil/17012-901
Phone: +55-14-3235-8323/ 8480
Fax: +55-14-3235-8323
E-mail: serginho@usp.br

SUMMARY

The occlusal veneers consist in a minimally invasive restorative approach that aims to restore the shape and function of the posterior teeth affected by tooth wear. The aim of this study was to evaluate the behavior of the occlusal veneers when subjected to thermal and mechanical cycling. Sixty specimens were divided into 04 groups (n=15), showing two variation factors divided into two levels: material – lithium dissilicate LD (IPS e.max CAD, Ivoclar Vivadent, Schaan, Liechtenstein) and nano ceramic resins NCR (ESPE Lava Ultimate, 3M, São Paulo, Brazil); thickness - 0.6 and 1.2mm. The occlusal veneers were luted with dual-polymerizing luting agent (Variolink N, Ivoclar Vivadent, Schaan, Liechtenstein) (RelyX Ultimate 3M, São Paulo, Brazil) using the respective adhesive system in self-etch mode. The resin cement was light cured for 40 seconds each face, using a LED light cure equipment that irradiates 1100 mW/cm2 (BlueStar II, Microdont, São Paulo, Brazil). A response variable consists of veneer survival rates (crack formation, catastrophic cracks and debonding) when subjected to thermal cycling from 5° to 55° C for 1,000 cycles and simultaneous mechanical cycling performed at load intensities of 100, 200, 300, 400 and 450N for 20,000 cycles each. Data were submitted to the Kruskall Wallis test and Pairwise Comparison, adopting a significance level of 5%. NCRs presented a lower incidence of failures ($p<0.05$) when compared to LD. As for thickness, 1.2mm thick occlusal veneers withstand higher cycling loads. Within the constraints of this study, we can conclude that NCR occlusal veneers with 1.2mm thickness presented superior physical-mechanical behavior and lithium dissilicate occlusal veneers with thickness lower than 1.2mm are more likely to fail.

Key words: occlusal veneer, fatigue, nano ceramic resin, lithium dissilicate.

INTRODUCTION

The occlusal veneer seems to be an excellent restorative approach to a problem that is emerging in Dentistry: tooth wear. The research for effective treatments to non-carious lesions, as abrasion, abfraction, attrition and erosion has grown up mainly by two reasons: systemic complications from mental stress as bruxism and gastroesophageal reflux disease (GERD), and simultaneous decrease of carious lesions[1]. The current restorative approach to posterior teeth with occlusal dental wear due to non-carious lesions are onlays or thin crown[2], although those need a tooth preparation of a structure that is already worn, coming against the current tooth maximum preservation philosophy. On the other side, the occlusal veneers, also known as “table top”, do not need an invasive tooth preparation because of the material adhesive properties, so it is pointed as an excellent restorative approach to this type of non-carious lesions[3,4,5,6,7].

The severe attrition due to bruxism, associated or not with dental erosion due to GERD and hypo salivation are the main cause of posterior dental wear, forming an occlusal wear facet, flattening this surface[8,9]. This pathologic dental loss may cause dentinal hypersensibility and may affect the vertical occlusal dimension, affecting not only the aesthetical pattern but also can spoil the occlusion relation[10].

The occlusal veneer is an interesting restorative approach to occlusal dental wear, as it follows minimal intervention and maximum preservation of the dental tissue philosophy. It is an excellent option because the dental preparation for this type of restoration only requires the removal of possible retention at pits and fissures[3,4,5,6,7,11,12]. Improvement of dental ceramics[13,14], especially in terms of the material intrinsic strength, restoration manufacture and adhesion, has allowed ceramic restorations to be smaller in thickness, providing minimal intervention treatment and allowing resin cementation with the benefit of adhesion[16], not requiring frictional retention to the tooth. Dental ceramics have excellent characteristics for this type of restoration such as high wear resistance, higher acid resistance commonly associated with dental erosion, and satisfactory adhesion to the dental structure.

Another viable material option for minimally invasive occlusal veneer is the indirect resin, which with its technological enhancement now has higher flexural strength and wear resistance due to the higher degree of conversion of monomers to polymers. This properties improvement occurs mainly in indirect resin blocks for

CAD/CAM systems, as their manufacture allows a higher incorporation of filler, less amount of diluent monomer, and are polymerized at better conditions[17].

As very thin occlusal veneers have been reported in the literature, with different emerging materials, the aim of this study was to evaluate the survival rate after thermomechanical cycling of minimally invasive occlusal veneers made of nano-ceramic resin and lithium dissilicate ceramic, milled by CAD/CAM system at 1.2mm and 0.6mm thicknesses.

Material and Methods

This research was approved by Local Institutional Ethics Committee (protocol CAAE nº: 86784418.0.0000.5417). Sixty sound third molars freshly extracted were stored in 0.1% thymol solution. The teeth were inserted in acrylic resin (JET, Clássico, Campo Limpo Paulista, Brazil), using a PVC tube as a matrix, centralized and with the occlusal surface parallel to the ground.

This in vitro study presented two variation factors: CAD/CAM restorative material (lithium dissilicate, nano ceramic resin); and occlusal veneer thickness (0.6mm, 1.2mm). The variable response through thermomechanical cycling applied at different load stages were initial cracks, catastrophic cracks and debonding.

Specimen preparation

Specimens were randomly sorted in four groups (n=15): NCR12 – 1.2 mm thickness nanoceramic resin occlusal veneer; NCR06 – 0.6 mm thickness nanoceramic resin occlusal veneer; LDC12 - 1.2 mm thickness ceramic occlusal veneer; LDC06 - 0.6 mm thickness ceramic occlusal veneer. The tooth preparation must simulate an advanced occlusal wear by attrition/dental erosion (Figure 1), creating a flat occlusal surface by removing the cusps with a Isomet saw (METS-DCUT-W04-H012, Erios, São Paulo, Brazil). The specimens were standardized with 5mm crown high and with no enamel at occlusal surface.

The occlusal veneers were milled with CAD/CAM system (CEREC MC XL, Sironal, New York, US)(Figure 1). First of all, the flattened specimens were scanned with an intraoral digital scanner (Trios Cart, 3 Shape, Copenhagen, Denmark), then the restorations were designed with the software InLab, using the telescope crown design to create a flat occlusal veneer with 0.6mm and 1.2mm thickness. The restorations were milled from nanoceramic resin blocks (ESPE Lava Ultimate, 3M, São Paulo, Brazil) and lithium dissilicate blocks (IPS e.max CAD, Ivoclar Vivadent, Schaan, Liechtenstein).

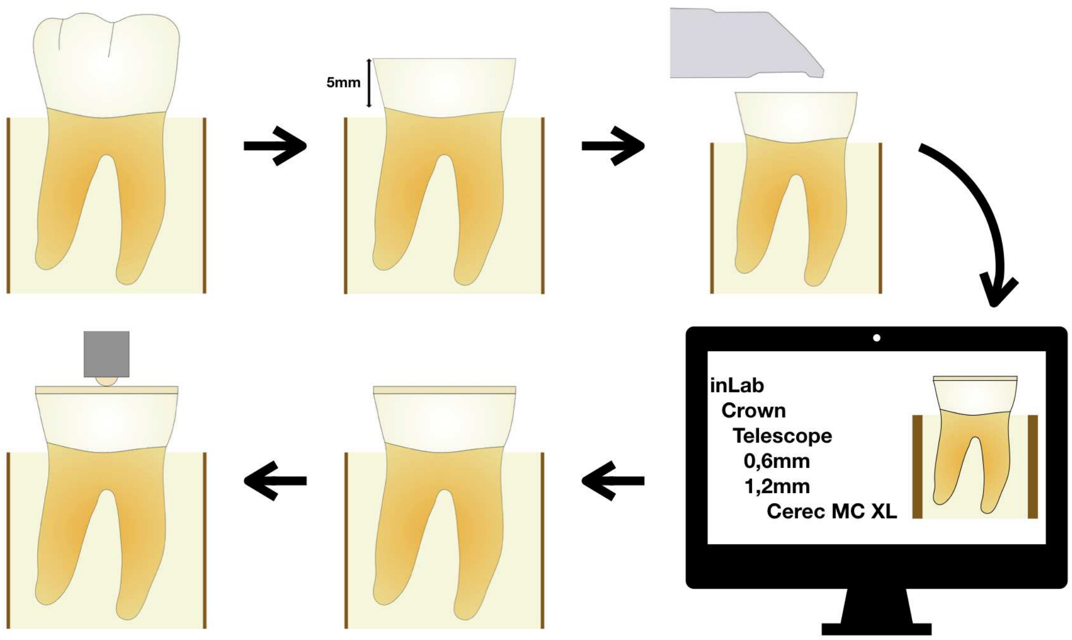

Figure 1 - Tooth inserted in acrylic resin; Creating a flat occlusal surface; Scanning specimen with intraoral digital scanner; Obtaining the restoration with the aid of CAD/CAM system; Occlusal veneer placed in specimen; Indenter positioned in the center of the occlusal surface

Bonding procedure

After finishing and polishing, the ceramic restorations inner surface was etched with 10% hydrofluoric acid (Condac porcelana, FGM, Joinville, Brazil) for 20 seconds, water rinsed and air dried, followed by application of silane (Monobond N, Ivoclar Vivadent, Schaan, Liechtenstein), waiting 60 seconds to apply the adhesive system (Tetric N-Bond Universal, Ivoclar Vivadent, Schaan, Liechtenstein). The specimen enamel was etched for 30 seconds with 37% phosphoric acid, water rinsed and air dried, followed by application of universal adhesive system (Tetric N-Bond Universal), in self-etch mode in dentin. Then the restoration was adhesively luted with dual-polymerizing luting agent (Variolink N, Ivoclar Vivadent, Schaan, Liechtenstein) and light cured for 40 seconds at each side.

At inner surface of nano ceramic composite restorations was only applied the adhesive system (Singlebond Universal, 3M, São Paulo, Brazil). The specimen enamel was etched for 30 seconds with 37% phosphoric acid, water rinsed and air dried, followed by application of adhesive system (Singlebond Universal), in self-etch mode in dentin. Then the restoration was adhesively luted with dual-polymerizing luting agent (Relyx Ultimate, 3M, São Paulo, Brazil) and light cured for 40 seconds at each side.

In order to standardize the cementation line, a force of 6N was applied by gently placing a weight over the veneer for 60 seconds before light curing. The LED equipment (BlueStar II, Microdont, São Paulo, Brazil) used for light curing irradiates 1100 mW/cm^2. After light curing, the specimens were stored in water at 37°C for 24 hours before finishing and polishing the restorations and cementation line.

Fatigue testing

The specimens were submitted to a thermomechanic cycling test (Cicladora Termomecânica, Biopdi, São Carlos, Brazil), using a 6mm-diameter ceramic sphere (e.max press, Ivoclar Vivadent, Schaan, Liechtenstein) as an indenter. The indenter was placed in the center of the occlusal surface and it was always in contact with the specimen (Figure 1). Different load stages were applied (100, 200, 300, 400 and 450N) at a frequency of 2 Hz. In each stage 20,000 cycles were performed, totalizing 100,000 cycles. While the dynamic mechanic cycling was performed, the specimens were also submitted to a simultaneous thermocycling, in the way that the specimens were submerged in water, varying the temperature from 5ºC to 55ºC (20 seconds at each temperature), totalizing 1,000 cycles.

Crack formation

The specimens were photographed with a DSLR camera (D3200, Nikon, Tokyo, Japan) after each 20,000 cycles in order to evaluate the crack formation. Also, a light curing device (VALO, Ultradent, South Jordan, USA) was used to optimize the tracking of initial cracks that were not visible to unaided eye, positioning the point cure around the specimen. The cracks were sorted in two groups: initial cracks and catastrophic cracks. Even when initial cracks were found, the specimen proceed to the thermomechanical cycling until catastrophic cracks occur.

Results

The survival rate of each group at every load cycling are shown at table 1. In group NCR12, all the specimens survived all the thermomechanical cycling without any fracture or subsurface crack (100% survival). However, all the specimens had an early wear spot where the indenter was placed to apply the cyclic load. The specimens from group NCR06 had an 86,66% rate of survival, and the specimens had the same early wear spot due to the indenter. One veneer was debonded and other specimen was shattered both the occlusal veneer and the tooth during the 400N load cycles (80.000 cycles).

For the group NCR12, an 26,66% rate survived to all the thermomechanical cycling, among these, two specimens presented visible cracks for unaided eye. At 300N load cycle, 53,33% of the specimen presented visible cracks and only one specimen presented subsurface crack that was able to see only with the aid of light curing equipment, but no fracture was found at this stage. Most of the fractures happened at the 400N load cycle, leading to fracture 46,67% of the specimens. For LDC06, only a 14,28% rate survived to all the thermomechanical cycling, among these, one specimen presented subsurface cracks and the other presented visible cracks. This group presented early fractures, with an 85,71% survival rate at the 100N load cycle, decreasing to 64,28% at 200N load cycle. At this point all the specimens were compromised, presenting subsurface cracks, visible cracks or fractures of the occlusal veneer. Only two of them had subsurface cracks and maintained this characteristic at 300N load cycle, which led to a 50% survival rate. At 400N load cycle, the survival rate decrease to 42,85%, occurring the first shattered occlusal veneer and the debonding of the fragment, and 4 out 14 specimens presents visible cracks.

The results were subjected to statistical analysis by the Kruskal Wallis Test, which showed a statistical difference between the groups in every load stage. Performing the Pairwise Comparison, it could demonstrate in which stage and which group the differences happened. At 100N and 200N load stage, only the LDC06 presented statistical difference, indicating a lower survival rate at this stage. At 300N, 400N and 450N stage, the Pairwise Comparison demonstrated a statistical difference between the groups NCR12-LDC12, NCR12-LDC06, NCR06-LDC12 and NCR06-LDC06, indicating a higher survival rate to the nano ceramic resin veneer groups.

Table 1 – Survival rate after each load stage and statistical analysis

	100N	**200N**	**300N**	**400N**	**450N**
NCR12	100% a	100% a	100% a	100% a	100% a
NCR06	100% a	100% a	100% a	86,66% a	86,66% a
LDC12	100% a	100% a	100% b	53,33% b	26,66% b
LDC06	85,71% b	64,28% b	50% b	42,85% b	14,28% b

* different letters represent statistical difference between lines in the same column

Discussion

The occlusal loads evaluated vary among some studies. According to Kogawa et al. 2006, the mean maximum occlusal load was 338N, which is very close to the value found by Palinkas et al. 2010 who assessed the maximum masticatory force in a group of adolescents and young adults and found a mean of 339N and 280N respectively. Calderon et al. 2006 found a mean maximum occlusal load of 587.2N for men and 424.9N for women. This group also evaluated the maximum masticatory force of bruxists patients, and found a mean of 490.1N, which when compared to non-bruxists patients (522.1N) there was no statistical difference. Based on these studies, the compressive loads used during the mechanical cycling of the present study (100N, 200N, 300N, 400N and 450N) were selected to simulate the forces exerted during chewing. It is noteworthy that no larger loads were applied due to the limitation of thermomechanical cycling equipment (Thermomechanical Cycler, Biopdi, São Carlos, Brazil), but the load applied was sufficient to demonstrate that the mechanical behavior of the occlusal venners, causing a large number of failures.

In the present study, a 6mm diameter spherical ceramic indenter (IPS e.max Press, Ivoclar Vivadent, Schaan, Liechtenstein) was used, which was positioned in the center of the occlusal surface where mechanical cycling forces were applied. This indenter was positioned in contact with the restoration to simulate non-impact load; if the indenter was not in contact with the restoration, the impact caused by the machine would lead to earlier veneer fractures, as detected in a pilot test. The occlusal veneer made of nano ceramic resin presented a lower failure rate, which may be associated with their greater resilience and distribution of the applied forces, avoiding the formation of cracks due to the concentration of forces. Despite their higher survival rate and the indenter constant contact with the restoration surface, punctual wear was found where the indenter was positioned, which can lead to premature restoration failure in a very thin thickness, which may have been responsible for the small drop in survival rate of the NCR06 group. This wear also occurred in the NCR12 group, however, due to the greater thickness of the occlusal veneer in this group, the wear did not influence the survival rate (Table 1). This wear can be evidenced only in the NCR groups regardless of the applied load intensity, but can also be associated with the fact that the indenter was made of lithium dissilicate, which is a harder material than composite resin.

According to Kern et al. (1999), to simulate 5 years of clinical use, 1,200,000 cycles should be performed on a mechanical cycling equipment. In the present study, a total of 100,000 cycles were performed, which is equivalent to approximately 6 months of clinical life, but one way to expand the clinical simulation time is to apply different loads during mechanical cycling (Borba et al., 2013), as was accomplished. It is noteworthy that the number of cycles is important, however, a correlation with the magnitude of the load must be thoroughly analyzed. In the study by Heck et al. (2019) high survival rates in 0.5mm occlusal veneers were reported for both NCR and LD, differing from the results of the present study. However, it is important to note that although the number of cycles was much larger, the loads applied were much smaller (50N and 100N), which may have masked the difference between the materials as seen in the results. It is noteworthy that the largest differences between materials occurred at higher loads.

In the studies by Maeder et al. 2019 and Ioannidis et al. 2019, the load-bearing supported by the tested materials (zirconia, lithium dissilicate and indirect resins) was evaluated, and the high loads supported by all materials were considered adequate for the use for occlusal veneers, differing from the present study. This type of test can evaluate the maximum loads that a material can withstand before starting cracks and its total fracture. However, this type of test does not simulate a clinical situation, only evaluates the material's load-bearing. Further studies with different tests are interesting because the sum of these knowledge may provide greater predictability of the clinical behavior of the occlusal veneer.

As already noted, due to all the evolution of resin and ceramic materials, the use of very thin thicknesses has been reported in the literature (GROTEN, 2007; BAHILLO et al., 2014). According to the data obtained, 1.2mm occlusal veneers had a higher survival rate when compared to 0.6mm groups, which would counter indicate the use of thinner occlusal veneers. Based on the results, there was no statistical difference between the 1.2mm and 0.6mm groups made with NCR, a result similar to that obtained by MAGNE et al. and SCHLICHTING et al. in their studies. However, when assessing groups made with LD, a low survival rate can be observed even at 1.2mm thickness, because after the appearance of initial cracks in the occlusal veneers of lithium dissilicate, catastrophic cracks were more likely to occur due to concentration of forces in the crack region, and also due to the chemical action of water according to Kelly (1999). In the 1.2mm occlusal veneers, these initial cracks began to appear after 300N cycling, most of which were visible to the unaided eye. At 0.6mm thickness, these initial cracks were already present after 100N load cycling, leading to an early failure of the restorations. This difference may have been due to the difference in force distribution across the restoration, because when there is a greater thickness of restorative material, it is possible to better dissipate the applied forces. Regarding the type of material, NCR had a significantly higher survival rate than LD. These results can be explained by the greater resilience that composite resins have when compared to dental ceramics. MAGNE et al, and SCHLICHTING et al, observed similar results comparing occlusal veneers made of leucite-reinforced ceramics, lithium dissilicate ceramics and composite resin by mechanical cycling, where they observed a significantly higher survival rate for the composite resin group. These results may be related to the slow crack growth that occurs in ceramic restorations, which may turn initial cracks into catastrophic cracks.

Conclusion

Based on the results, it can be concluded that the survival rate of minimally invasive occlusal veneers made of nano ceramic resin was higher when compared to lithium dissilicate veneer. It can also be concluded that the thicker restoration, the higher survival rate, regardless of material. The nano ceramic resin presented adequate survival rate against the thermomechanical cycling applied, in both thicknesses tested. On the other hand, lithium dissilicate showed unsatisfactory behavior against thermomechanical cycling, even at lower loads at both thicknesses. It is noteworthy that although the indirect resin has presented more satisfactory results, other aspects should still be analyzed such as wear resistance, pH cycling and marginal adaptation, which are important factors that can also directly influence the clinical behavior of the occlusal veneer. In addition, clinical studies are also needed in order to provide a higher level of scientific evidence, since in the oral cavity all factors act at the same time.

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3 Discussion

3 DISCUSSION

The industry has invested in research to improve the physical and mechanical properties of previously existing restorative materials, aiming to expand indications and find a solution to restorative challenges, and the focus has always been on restorative aesthetic materials. Major advances in the physical and mechanical properties of these materials, whether resinous or ceramic, have achieved higher strengths even in thin material thickness. Therefore, minimal invasive restorative approaches are found in the literature, which were only possible due to the considerable improvement in material properties. (GRESNIGT et al. 2019)

Due to all this evolution, restorative materials have been used in challenging situations that put them in situations of great mechanical stress and low retention. These situations include the occlusal veneers that have been indicated for restoration of worn posterior teeth by situations involving processes of attrition/erosion. In these situations where the teeth are already present marked occlusal wear, very thin veneers have been indicated in the literature, with very controversial results. Thus, the aim of this study was to evaluate some physical-mechanical properties involved in the survival of minimally invasive veneers made of nano ceramic resin and lithium dissilicate ceramic, obtained with the aid of CAD/CAM system, after thermomechanical cycling fatigue.

The occlusal loads evaluated vary among some studies. According to Kogawa et al. 2006, the mean maximum occlusal load was 338N, which is very close to the value found by Palinkas et al. 2010 who assessed the maximum masticatory force in a group of adolescents and young adults and found a mean of 339N and 280N respectively. Calderon et al. 2006 found a mean maximum occlusal load of 587.2N for men and 424.9N for women. This group also evaluated the maximum masticatory force of bruxists patients, and found a mean of 490.1N, which when compared to non-bruxists patients (522.1N) there was no statistical difference. Based on these studies, the compressive loads used during the mechanical cycling of the present study (100N, 200N, 300N, 400N and 450N) were selected to simulate the forces exerted during chewing. It is noteworthy that no larger loads were applied due to the limitation of thermomechanical cycling equipment (Thermomechanical Cycler, Biopdi, São Carlos, Brazil), but the load applied was sufficient to demonstrate that the mechanical behavior of the occlusal venners, causing a large number of failures.

In the present study, a 6mm diameter spherical ceramic indenter (IPS e.max Press, Ivoclar Vivadent, Schaan, Liechtenstein) was used, which was positioned in the center of the occlusal surface where mechanical cycling forces were applied. According to Kelly (1999), metallic indenters do not adequately represent a tooth-tooth contact, for this reason a ceramic indenter was chosen looking for a better clinical simulation, because ceramics have a structural similarity with dental enamel. This indenter was positioned in contact with the restoration to simulate non-impact load; if the indenter was not in contact with the restoration, the impact caused by the machine would lead to earlier veneer fractures, as detected in a pilot test. The occlusal veneer made of nano ceramic resin presented a lower failure rate, which may be associated with their greater resilience and distribution of the applied forces, avoiding the formation of cracks due to the concentration of forces. Despite their higher survival rate and the indenter constant contact with the restoration surface, punctual wear was found where the indenter was positioned, which can lead to premature restoration failure in a very thin thickness, which may have been responsible for the small drop in survival rate of the NCR06 group. This wear also occurred in the NCR12 group, however, due to the greater thickness of the occlusal veneer in this group, the wear did not influence the survival rate (Table 1). This wear can be evidenced only in the NCR groups regardless of the applied load intensity, but can also be associated with the fact that the indenter was made of lithium dissilicate, which is a harder material than composite resin.

According to Kern et al. (1999), to simulate 5 years of clinical use, 1,200,000 cycles should be performed on a mechanical cycling equipment. In the present study, a total of 100,000 cycles were performed, which is equivalent to approximately 6 months of clinical life, but one way to expand the clinical simulation time is to apply different loads during mechanical cycling (Borba et al., 2013), as was accomplished. It is noteworthy that the number of cycles is important, however, a correlation with the magnitude of the load must be thoroughly analyzed. In the study by Heck et al. (2019) high survival rates in 0.5mm occlusal veneers were reported for both NCR and LD, differing from the results of the present study. However, it is important to note that although the number of cycles was much larger, the loads applied were much smaller (50N and 100N), which may have masked the difference between the materials as seen in the results. It is noteworthy that the largest differences between materials occurred at higher loads.

In the studies by Maeder et al. 2019 and Ioannidis et al. 2019, the load-bearing supported by the tested materials (zirconia, lithium dissilicate and indirect resins) was evaluated, and the high loads supported by all materials were considered adequate for the use for occlusal veneers, differing from the present study. This type of test can evaluate the maximum loads that a material can withstand before starting cracks and its total fracture. However, this type of test does not simulate a clinical situation, only evaluates the material's load-bearing. Further studies with different tests are interesting because the sum of these knowledge may provide greater predictability of the clinical behavior of the occlusal veneer.

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SCHLICHTING et al, observed similar results comparing occlusal veneers made of leucite-reinforced ceramics, lithium dissilicate ceramics and composite resin by mechanical cycling, where they observed a significantly higher survival rate for the composite resin group. These results may be related to the slow crack growth that occurs in ceramic restorations, which may turn initial cracks into catastrophic cracks.

Based on the results, it can be concluded that the survival rate of minimally invasive occlusal veneers made of nano ceramic resin and lithium dissilicate differ from each other. The nano ceramic resin presented adequate survival rate against the thermomechanical cycling applied, in both thicknesses tested. On the other hand, lithium dissilicate showed unsatisfactory behavior against thermomechanical cycling, even at lower loads at both thicknesses. It is noteworthy that although the indirect resin has presented more satisfactory results, other aspects should still be analyzed such as wear resistance, pH cycling and marginal adaptation, which are important factors that can also directly influence the clinical behavior of the occlusal veneer. In addition, clinical studies are also needed in order to provide a higher level of scientific evidence, since in the oral cavity all factors act at the same time.

4 FINAL CONSIDERATIONS

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The NCR occlusal veneers presented satisfactory properties to endure the thermomechanical cycling and show a higher survival rate when compared to LDC occlusal veneers even in thin thickness. Further studies are needed to support the use of occlusal veneers as restorative approach to patients that presents parafunctional habits.

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APPENDIXES

APPENDIXES

APÊNCIDE A - DECLARAÇÃO DE USO EXCLUSIVO DE ARTIGO EM DISSERTAÇÃO/TESE

DECLARATION OF EXCLUSIVE USE OF THE ARTICLE IN DISSERTATION/THESIS

We hereby declare that we are aware of the article (Influence of thickness and restorative material on the physical-mechanical behavior of CAD/CAM minimally invasive occlusal veneers - in vitro study) will be included in (Dissertation/Thesis) of the student (Edgar Massunari Maenosono) and may not be used in other works of Graduate Programs at the Bauru School of Dentistry, University of São Paulo.

Bauru, November 1st, 2019.

Edgar Massunari Maenosono Author	________________________ Signature
Sérgio Kiyoshi Ishikiriama Author	________________________ Signature

Título da Pesquisa: Influência da espessura e material restaurador no comportamento físico-mecânico de facetas oclusais minimamente invasivas - estudo in-vitro
Pesquisador Responsável: EDGAR MASSUNARI MAENOSONO
Área Temática:
Versão: 2
CAAE: 86784418.0.0000.5417
Submetido em: 19/04/2018
Instituição Proponente: Universidade de Sao Paulo
Situação da Versão do Projeto: Aprovado
Localização atual da Versão do Projeto: Pesquisador Responsável
Patrocinador Principal: FUND COORD DE APERFEICOAMENTO DE PESSOAL DE NIVEL SUP

Comprovante de Recepção: PB_COMPROVANTE_RECEPCAO_1074360

Survival rate of specimens in different load stages

Material	100N	200N	300N	400N	450N
NCR 1.2mm	1	1	1	1	1
NCR 1.2mm	1	1	1	1	1
NCR 1.2mm	1	1	1	1	1
NCR 1.2mm	1	1	1	1	1
NCR 1.2mm	1	1	1	1	1
NCR 1.2mm	1	1	1	1	1
NCR 1.2mm	1	1	1	1	1
NCR 1.2mm	1	1	1	1	1
NCR 1.2mm	1	1	1	1	1
NCR 1.2mm	1	1	1	1	1
NCR 1.2mm	1	1	1	1	1
NCR 1.2mm	-	-	-	-	-
NCR 1.2mm	1	1	1	1	1
NCR 1.2mm	1	1	1	1	1
NCR 1.2mm	1	1	1	1	1
	100%	100%	100%	100%	100%
NCR 0.6mm	1	1	1	1	1
NCR 0.6mm	1	1	1	1	1
NCR 0.6mm	1	1	1	1	1
NCR 0.6mm	1	1	1	1	1
NCR 0.6mm	1	1	1	1	1
NCR 0.6mm	1	1	1	1	1
NCR 0.6mm	1	1	1	1	1
NCR 0.6mm	1	1	1	1	1
NCR 0.6mm	1	1	1	1	1
NCR 0.6mm	1	1	1	1	1
NCR 0.6mm	1	1	1	1	1
NCR 0.6mm	1	1	1	1	1
NCR 0.6mm	1	1	1	7	-
NCR 0.6mm	1	1	1	6	-
NCR 0.6mm	1	1	1	1	1

	100%	100%	100%	86,66%	86,66%
LDC 1.2mm	1	1	1	1	1
LDC 1.2mm	1	1	1	2	3
LDC 1.2mm	1	1	3	3	3
LDC 1.2mm	1	1	1	1	4
LDC 1.2mm	1	2	3	3	4
LDC 1.2mm	1	1	3	4	4
LDC 1.2mm	1	1	3	4	4
LDC 1.2mm	1	1	1	3	4
LDC 1.2mm	1	1	2	2	2
LDC 1.2mm	1	1	1	4	4
LDC 1.2mm	1	1	3	3	4
LDC 1.2mm	1	1	3	4	4
LDC 1.2mm	1	1	3	4	4
LDC 1.2mm	1	1	3	4	4
LDC 1.2mm	1	1	3	4	5
	100%	100%	100%	53,33%	26,66%
LDC 0.6mm	1	2	2	2	2
LDC 0.6mm	1	2	2	2	5
LDC 0.6mm	3	4	4	4	4
LDC 0.6mm	2	3	4	4	4
LDC 0.6mm	2	3	3	3	4
LDC 0.6mm	3	4	4	4	4
LDC 0.6mm	-	-	-	-	-
LDC 0.6mm	2	3	3	3	4
LDC 0.6mm	2	3	3	3	4
LDC 0.6mm	2	2	2	3	3
LDC 0.6mm	2	3	4	4	4
LDC 0.6mm	3	4	4	4	4
LDC 0.6mm	2	3	3	4	4
LDC 0.6mm	4	4	4	5	-
LDC 0.6mm	4	4	4	4	4
	85,71%	64,28%	50%	42,85%	14,28%

1 – no crack; 2 – subsurface crack; 3 – visible crack; 4 – fracture; 5 – fracture + debonding; 6 – debonding; 7 – tooth fracture