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GABRIEL MARINI

Análise do desempenho em fadiga de zircônia transluzente de terceira geração usada como prótese parcial monolítica implantossuportada

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Dissertação apresentada ao Programa de pós-graduação em Odontologia da Faculdade IMED, como requisito parcial à obtenção do título de Mestre em Odontologia.

Professor orientador: Dr. Ataís Bacchi

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Banca examinadora

____
Prof. Dr. Atais Bacchi – Presidente
Professor Doutor, Programa de Pós-Graduação em Odontologia da Faculdade Meridional – IMED, Passo Fundo, RS, Brasil

____
Prof. Dr. Gabriel Kalil Rocha Pereira – Membro efetivo
Professor Doutor, Programa de Pós-Graduação em Ciências Odontológicas da Faculdade Federal de Santa Maria – Santa Maria, RS, Brasil

____
Prof. Dr. Rodrigo Alessandretti – Membro efetivo
Professor Doutor, Graduação Odontologia da Faculdade Meridional – IMED, Passo Fundo, RS, Brasil

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RESUMO

O objetivo deste estudo foi avaliar o comportamento de fadiga de prótese parciais fixas implanto-suportadas confeccionadas em (I) zircônia monolítica transluzente multicamada de terceira geração e, como grupo controle, (II) infraestrutura de zircônia de segunda geração recoberta com porcelana. Foram confeccionadas estruturas CAD-CAM de próteses fixas de 3 elementos e sinterizadas. As próteses (n = 22) foram parafusadas em implantes dentários (ø= 4,3×10 mm, (Flexcone, DSP Biomedical) embebidos em bases de suporte de resina epóxi. Para definir os parâmetros do teste de fadiga um teste monotônico foi obtido em uma máquina de ensaio universal com uma velocidade de 0,5 mm / min, e uma carga de 1000kgf incremental até a falha da amostra. As amostras foram testadas quanto ao desempenho em fadiga (carga inicial de 100N em 5.000 ciclos, com posterior aumento de 200N a cada 20.000 ciclos sobrevividos pela amostra até a observância da falha). Para análise dos dados, foi considerada a carga da falha em fadiga, o número de ciclos necessários até a falha, e as taxas de sobrevivência em cada ciclo, bem como análises de confiabilidade mecânica pelo módulo de Weibull, e análises fractográficas para observar regiões de início e propagação de fratura. Estruturas monolíticas apresentaram superior carga de fratura em fadiga, número de ciclos até a fratura e probabilidade de sobrevivência que a estrutura bicamada. O módulo de Weibull não diferiu entre grupos. Análise fractográfica revelou falhas catastróficas na estrutura monolítica e fratura de porcelana nas próteses bicamadas. Zircônia monolítica apresentou resultados promissores para uso como prótese parcial fixa implanto suportada.

Palavras-chave: Zircônia, prótese dentária fixa, fratura de fadiga.

ABSTRACT

The aim of this study was to evaluate the fatigue behavior of implant-supported fixed partial prostheses made of (I) third generation monolithic multilayer zirconia and, as a control group, (II) second generation zirconia infrastructure veneered with porcelain. CAD-CAM structures were made of fixed prostheses with 3 elements and sintered. The prostheses (n= 22) were screwed into dental implants (ø4.3 × 10 mm, (Flexcone, DSP Biomedical) embedded in epoxy resin support bases. To define the parameters of the fatigue test, a monotonic test was obtained on a universal testing machine with a speed of 0.5 mm / min, and a load of 1000kgf incrementally until the sample failed. The samples were tested for fatigue performance (200N initial load in 5,000 cycles, with a subsequent increase of 200N for every 10,000 cycles survived by the sample, until failure is observed. For data analysis, the fatigue failure load, the number of cycles required until failure, and the survival rates in each cycle were considered, as well as mechanical reliability analyzes using the Weibull module, and fractographic analyzes to observe regions of fracture onset and propagation. Monolithic structures showed higher fracture load in fatigue, number of cycles to fracture and probability of survival. Fractographic analysis revealed catastrophic flaws in the monolithic structure and porcelain fracture in bilayer prostheses. Monolithic zirconia showed results promising for use as fixed implant supported partial dentures.

Key words: zirconia; fixed partial prosthesis; fatigue failure.

SUMÁRIO

1 INTRODUÇÃO

Durante décadas as próteses metalocerâmicas tem sido a principal escolha para a confecção de próteses fixas múltiplas ou unitárias sobre dentes e implantes [1]. Uma restauração suportada por implante é uma boa alternativa de tratamento para edentulismo com sucesso comprovado a longo prazo. Fornecer condições biomecânicas ideais é de suma importância para obter e manter essas altas taxas de sucesso [2]. As opções de tratamento para restaurações fixas suportadas por implantes incluem coroas unitárias ou pontes fixas (FDPs), podendo ser elas parafusadas ou cimentadas. [3].

O desenvolvimento de novos processos de fabricação permitiu o uso de diferentes materiais para tal indicação, dentre eles os sistemas cerâmicos livres de metal. Porém os materiais cerâmicos são friáveis por natureza. Apresentam usualmente resistência à fratura, aliada a resistência a flexão, inferiores as apresentadas por estruturas metálicas, diferenças que podem ser relevantes principalmente quando consideramos seu uso em regiões posteriores de boca onde existe uma força de mastigação muito maior [4].

Recentemente materiais cerâmicos a base de óxido de zircônio tem sido propostos como alternativa para substituir as estruturas metálicas para próteses em regiões mais críticas da cavidade bucal. A zircônia demonstra grandes qualidades de biocompatibilidade, dureza e resistência [5]. Suas propriedades mecânicas são muito semelhantes com os materiais metálicos, e apresentam como benefício uma coloração esbranquiçada que é mais favorável esteticamente na mimetização das características das dentições naturais [6].

Como matéria prima, o óxido de zircônio (ZrO_2) existe em 3 fases cristalográficas, sendo elas monoclínica, tetragonal e cúbica. A transformação da fase tetragonal para monoclínica (t-m) aumenta o volume em aproximadamente 4%, esse aumento abrupto resulta em uma fratura na estrutura da cerâmica [7]. Contudo a introdução de estabilizantes, como o ítrio (Y_2O_3), o mais utilizado em Odontologia, a composição da zircônia auxilia o controle desta transformação, evitando a fratura, e promovendo a obtenção de um material denso e apto para confecção de restaurações dentárias [8]. A zircônia policristalina estabilizada por ítrio constitui então um material de alta tenacidade, e de altíssima resistência a flexão, embora de alta opacidade [9].

Mesmo de forma estabilizada quando a Y-TZP é submetida a estímulos externos, pode passar por transformação de fase voltando a configuração monoclínica, essa característica faz com que a Y-TZP seja considerada um material metaestável [10]. Este fator resulta no aumento da resistência e tenacidade estrutural, pois com a expansão volumétrica é provocada uma força de compressão contra as superfícies onde há trincas, assim, inibindo sua propagação. Forças de tensão superiores seriam necessárias para que a trinca seja formada [11].

O mesmo mecanismo de transformação também é responsável pelo processo de degradação a baixa temperatura (LTD) quando o Y-TZP é submetido a um ambiente úmido com temperaturas entre 150 e 400 ° C [12]. O mecanismo de transformação se espalha (nucleação e crescimento) para o núcleo do material, levando a soltura do grão superficial, aumentando sua rugosidade [13]. A água é incorporada aos grãos de zircônia e as consequências desse processo de envelhecimento são múltiplas incluindo a degradação da resistência, tenacidade a fratura e densidade das estruturas Y-TZP [14,15]. Este problema envolve principalmente estruturas que não são submetidos a revestimento de porcelana e estruturas de zircônia sobre implante que são expostas ao ambiente oral.

A baixa fase vítrea das zircônias odontológicas faz com que sua translucidez seja baixa. Por isso suas propriedades são indicadas como material de infraestrutura e então recoberta com uma cerâmica vítrea para poder obter características ópticas e colorações compatíveis com a de estruturas dentais [16]. Estudos mostraram interesse na interface na camada de revestimento e relatam que a principal complicação da técnica é a fratura coesiva do material de revestimento, conhecida como lascamento (chipping) [17]. Devido a fraca ligação entre infraestrutura de zircônia e porcelana de cobertura e incompatibilidade no coeficiente de expansão térmica, tensões internas são geradas no momento de resfriamento [18].

Com intuito de melhorar e diminuir as falhas foram desenvolvidas as zircônias (monolíticas), que dispensam uma camada de cobertura por cerâmicas vítreas, podendo assim serem utilizadas em próteses totalmente feitas de zircônia (corpo único) [19]. Outra vantagem que a zircônia monolítica apresenta é o processo de fabricação acelerado, pois dispensam o processo de aplicação de várias camadas de porcelana e detalhes anatômicos que também eram necessários [20].

Com a ideia de estabilizar totalmente o material e aprimorar as propriedades ópticas a zircônia recebeu mudanças que resultaram em 3 diferentes gerações. A primeira geração apresentou alta opacidade, resistência, tenacidade e propriedades mecânicas aprimoradas). Devido à falta de características estéticas esse material foi recomendado principalmente para restaurações convencionais que recebem aplicação de cobertura com cerâmica (vítrea). Mudanças foram feitas alterando o nível molecular na segunda geração de zircônia onde o óxido de alumínio teve sua estrutura e quantidade diminuída e realocada na estrutura. Efeitos de transmissão de maior quantidade luz, estabilidade e alta resistência foram atingidos mantendo o mecanismo de tenacificação do material, a partir dessa segunda geração teve início a fabricação de restaurações monolíticas. A terceira geração resultou em um material totalmente estabilizado, onde até 53% da fase cúbica pode ser observada na estrutura além da fase tetragonal nas gerações anteriores. O aumento da porcentagem do estabilizante de óxido de ítrio (com aproximadamente 5mol%) melhorou as propriedades de translucidez e transmitância de luz, mas também compromete as propriedades mecânicas pela diminuição da fase t-m. [20].

Estudos futuros são necessários para investigar as variáveis que afetam o tempo de duração clinica nas próteses fixas implantossuportadas de 3 elementos, como estrutura, desenho da infraestrutura, procedimentos de revestimento e tratamentos de superfície, métodos de aplicação de porcelana, temperaturas de aquecimento e resfriamento, perfis de queima, todos esses fatores podem levar a uma função mecânica diferenciada [21]. Dados ainda são limitados para o entendimento da confiabilidade de zircônia para próteses fixas implanto suportadas de 3 elementos [5].

2. OBJETIVO

O objetivo deste estudo foi avaliar a carga de falha por fadiga, número de ciclos até a falha e sobrevivência em fadiga de materiais cerâmicos de zircônia (segunda geração) com cobertura de porcelana e zircônia monolítica (terceira geração) para próteses fixas implanto suportadas.

3. HIPÓTESE

A hipótese testada era que a estrutura monolítica apresentaria comportamento mecânico superior ao da bicamada.

4. ARTIGO

Fatigue performance analysis of a third-generation translucent zirconia as implant-supported fixed-partial prosthesis

ABSTRACT

The aim of this study was to evaluate the fatigue behavior of implant-supported fixed partial prostheses made of (I) third generation monolithic multilayer zirconia and, as a control group, (II) second generation zirconia infrastructure veneered with porcelain. CAD-CAM structures were made of fixed prostheses with 3 elements and sintered. The prostheses (n= 22) were screwed into dental implants (ø4.3 × 10 mm, (Flexcone, DSP Biomedical) embedded in epoxy resin support bases. To define the parameters of the fatigue test, a monotonic test was obtained on a universal testing machine with a speed of 0.5 mm / min, and a load of 1000kgf incrementally until the sample failed. The samples were tested for fatigue performance (200N initial load in 5,000 cycles, with a subsequent increase of 200N for every 10,000 cycles survived by the sample, until failure is observed. For data analysis, the fatigue failure load, the number of cycles required until failure, and the survival rates in each cycle were considered, as well as mechanical reliability analyzes using the Weibull module, and fractographic analyzes to observe regions of fracture onset and propagation. Monolithic structures showed higher fracture load in fatigue, number of cycles to fracture and probability of survival. Fractographic analysis revealed catastrophic flaws in the monolithic structure and porcelain fracture in bilayer prostheses. Monolithic zirconia showed results promising for use as fixed implant supported partial dentures.

Key words: zirconia; fixed partial prosthesis; fatigue failure.

1 Introduction

Ceramic materials based on zirconium oxide have been proposed as an alternative to replace metal structures for dental prostheses. Zirconia demonstrates great qualities of biocompatibility, hardness and resistance [1]. Its mechanical properties are very similar with metallic materials, and have the benefit of a whitish color, that is more aesthetically favorable to mimic the characteristics of natural dentition [2].

Zirconium oxide (ZrO_2) exists in 3 crystallographic phases, which are monoclinic, tetragonal and cubic. The transformation of the tetragonal to monoclinic phase (t-m) increases the volume by approximately 4%, this abrupt increase results in a fracture in the ceramic structure [3]. However, the introduction of stabilizers, such as yttrium (Y_2O_3), the most used in dentistry, to the composition of zirconia, helps control this transformation, preventing fracture, and promoting a dense and adequate material for making dental restorations [4]. Yttrium-stabilized polycrystalline zirconia, thus, constitutes a material of high tenacity, and of very high flexural strength, although of high opacity [5].

The low glassy phase of dental zirconia makes their translucency very low. Therefore, it is indicated as infrastructure material, to be covered with a glass ceramic, to obtain translucency and color similar to the dental structures [6]. Studies have shown that the main complication of the technique is the cohesive fracture of the coating material, known as chipping [7]. Due to the weak connection between zirconia infrastructure and veneer ceramic and incompatibility in the thermal expansion coefficient, internal stresses are generated at the time of cooling [8].

In order to improve and minimize the failures, full contour zirconia (monolithic structures) was developed [9]. Another advantage that monolithic zirconia presents is the accelerated manufacturing process, since it eliminates the process of several layers of porcelain and anatomical details [10].

With the idea of totally stabilizing the material and improving the optical properties, zirconia received changes that resulted in 3 different generations. The first generation showed high opacity, resistance, toughness and improved mechanical properties (intelligent biomaterial, already mentioned). Due to the lack of aesthetic characteristics, this material was recommended mainly for conventional restorations that receive a ceramic (vitreous) coating application. Changes were made to the molecular level in the second generation of zirconia where the aluminum oxide had its structure and quantity decreased. Effects such as higher light transmission, stability and high resistance were achieved. From this second generation, the manufacture of monolithic restorations began. The third generation resulted in a fully stabilized material, where up to 53% of the cubic phase can be seen in the structure, besides the tetragonal phase present in previous generations. The increase in the percentage of the yttrium oxide stabilizer (with approximately 5 mol%) improved the translucency and light transmittance properties but also compromises the mechanical properties by decreasing the t-m phase [10]. Studies have shown adequate mechanical performance of monolithic zirconia when compared to other monolithic [11]; and also bilayer unitary structures [12]. However, data are still scarce for understanding the reliability of monolithic zirconia for implant-supported fixed prostheses of 3 units [2].

Therefore, the aim of this study was to evaluate the mechanical fatigue performance of a third-generation translucent multilayer zirconia used as monolithic implant-supported fixed partial prosthesis; a veneered zirconia-porcelain group was used as comparison. The tested hypothesis was that the monolithic structure would present superior mechanical behavior than the bilayer one.

2. Materials and Methods

2.1. Laboratorial Analysis

The study design was: groups of implant-supported fixed partial prosthesis made of (I) third-generation multilayer translucent zirconia in the monolithic form or (II) porcelain-veneered second-generation zirconia frameworks. Fatigue testes were applied to compare the fatigue failure load, number of cycles until failure and survival probabilities. Weibull and fractographic analysis were also performed.

Epoxy resin support bases (N = 22) were confectioned containing two parallel implants (Flexcone, ø4.3x10mm, DSP Biomedical) separated by 14 mm. A master model with two analogs and an index with two splinted transfers were confectioned to standardize the implant insertion into the bases.

Scan bodies were used to transfer the position of the implants with a digital scanner (DS-6000; Tecnodrill). CAD structure projects of three-unit fixed partial prostheses were designed and confectioned (n = 11) as:

GROUP 1 (control) – Second-generation zirconia framework stabilized by 4% yttrium (4Y-PSZ) (Zenostar T) to be covered with porcelain.

GROUP 2 – Third-generation multilayer translucent zirconia stabilized with 5% yttrium (5Y-PSZ) (IPS e.maxZirCAD Multi) in the monolithic form.

Details about the materials used in the study are presented in Table 1. For the monolithic structure, the premolar had a mesial-distal width of 5 mm and 9 mm for the molars. The buccal-lingual dimension of the teeth was 8 mm. Simple occlusal surface and a minimum wall thickness of 1.0 mm were adopted.

In the bilayer group, the space for porcelain application was ensured at dimensions of 1.5 mm at occlusal and 1mm for the other surfaces.

The connectors' cross-sectional area was 12 mm^2 for zirconia used in bilayer restoration and 16 mm^2 for monolithic zirconia, as the manufacturers' recommendation.

The zirconia structures were milled (DM-5; Tecnodrill) and then sintered (ME1600 / 1; Fortelab Indústria de Fornos Elétricos Ltda). The frameworks (zenostar T) were sintered at temperature of 1450 °C during 2h, with heating/cooling rate of 5 °C /min. The monolithic structures (IPS e.max ZirCAD Multi) were sintered at 1500 °C during 2h, with heating/cooling rate of 10 °C /min, both following the manufacturer's recommendation.

For porcelain application, a silicone matrix was built over one of the monolithic specimens to serve as dimension reference. To improve bonding stability with a zirconium oxide structure used by ZirLiner (IPS e.max Ceram). Porcelain powder (IPS e.max Ceram) was mixed with the modeling liquid to produce a thick slurry, which was applied over the copings and sintered (Programat EP 5000-G2, Ivoclar vivadent, Schaan, Liechtenstein) at 750 °C. The external surface of porcelain was glazed after finishing and polishing.

2.2 Fatigue testing

First, to define the fatigue test parameters for the groups, a load-to-fracture test was executed in a universal testing machine (n= 2; EMIC DL 2000, São José dos Pinhais, SP, Brazil) with a crosshead speed of 0.5 mm/min, a loading cell of 1000kgf, and an incremental load until specimen failure.

Second, the specimens (n= 9) were submitted to a fatigue test until failure using specific equipment (Instron ElectroPuls E3000, Instron Corporation, Norwood, USA) through the step-stress methodology according to previous studies [13,14]. Cyclic loads were applied by a stainless-steel piston with a 6 mm diameter rounded active portion, being the specimens immersed in water. Before testing, an adhesive tape (110 μm) was placed on the occlusal surface to enhance stress distribution by improving the contact between piston and specimen [15]. The load frequency was defined in 20 Hz and then 5,000 cycles were initially run on 100 N aiming to set the specimen and adjust the piston/specimen contact. Next, 20,000 cycles were performed at progressive stress levels of 200 N, starting at 200 N until failure occurrence. The fatigue failure load (FFL) and the number of cycles for fatigue failure (CFF) of each specimen were recorded with statistical purposes.

2.3 Fractographic analysis

After the tests, the specimens were inspected in a stereomicroscope (Discovery V20, Carl Zeiss, Gottingen, Germany) with a Achromat S 0.5× FWD 151mm lens (Carl Zeiss, Gottingen, Germany) with 9x and 25x magnification to access the failure pattern.

2.4 Data analysis

Descriptive analysis was executed with FFL and CFF data to obtain mean and standard deviation values. After guarantee homoscedastic and parametric distribution (Levene and Kolmogorov-Smirnov tests) of such data, a survival analysis (Kaplan-Meier followed by log-rank Mantel-Cox post-hoc test) was performed, for both FFL and CFF, with a significance level of 5% in a statistical software (SPSS version 21, IBM, Chicago, US). Additionally, Weibull's analysis of such data was performed in the Super SMITH

Weibull 4.0k-32 software (Wes Fulton, Torrance, United States) to obtain the characteristic measurement and the Weibull modulus of each outcome, whereas the characteristic parameter represents the value in which 63.2% of the tested specimens present a probability of failure, and the Weibull modulus is used as a measure for the distribution of the FFL and CFF values, expressing the mechanical structural reliability of each condition.

3. Results

Survival analysis (Kaplan-Meier and Mantel-cox post-hoc test) of FFL and CFF data shows that monolithic restorations present a significantly enhanced ability to withstand higher loads (FFL) and number of cycles (CFF) in comparison to bilayer restorations upon failure occurrence (Table 2). It is also important to notice that in comparison to monotonic static tests, the loads necessary to promote specimen failure is much higher than the ones observed during fatigue tests, for both monolithic (49% decrease) and bilayer (17% decrease) assemblies, which corroborates the occurrence of fatigue during the adopted testing setup/method (Table 2).

Table 3 and Figure 2 shows the survival probability for each group during the progression of the fatigue test. It is clear that bilayer assemblies start to fail in much lower loads than monolithic assemblies, whereas under 600N/65,000 cycles bilayer specimens present 67% of probability of survival whereas the monolithic specimens only present failure at 1000N/105,000 cycles. Besides, at 1200N/125,000 cycles all bilayer specimens present failure, and monolithic specimens still present 33% of survival probability on such step.

The characteristic parameter for FFL data, obtained via Weibull analysis (Table 2, Figure 3), corroborates the observations of survival analysis (Kaplan-Meier and Mantel-cox post-hoc test) of higher performance of monolithic restorations. Despite that, the characteristic parameter for CFF data was statistically similar between monolithic and bilayer (Table 2, Figure 3). Such statistical similarity is a result of a discrete overlap of 95% confidence intervals, which by guidance of maximum likelihood estimations indicates a similarity between groups for such outcome (Table 2, Figure 3), being possible that a higher sample size would allow a narrower distribution of the 95%

confidence intervals and by that would allow a clearer distinction between conditions on such analysis. In regards of Weibull moduli, it was not noticed any difference between monolithic and bilayer restorations, which indicates similar variability for each outcome considered herein (FFL and CFF).

As pattern of failure, it was observed 100% of chipping on bilayer specimens that failed during fatigue test, and 100% of catastrophic fracture at mesial connector region on monolithic assemblies. Figure 4 illustrates the fractographic analysis made on a representative specimen of each group. It is clear that at bilayer assemblies the failure starts at occlusal surface (where it concentrates compression stresses) and spreads into the porcelain veneer material, without zirconia framework exposition. On the other hand, at monolithic assemblies the fracture started at the mesial connector at gingival level, where it concentrates tensile stresses during the test, and then spreads into the restoration core directed to the occlusal surface where it concentrates compression stress (compression curl is clearly noticed from a lateral view).

4. Discussion

The tested hypothesis of this study was accepted, as the implant-supported fixed partial prosthesis made of third-generation multilayer translucent zirconia in the monolithic form presented superior fatigue performance than the bilayer zirconia-porcelain veneered structure considering FFL, CFF, and survival probabilities. The bilayer structure was composed by a second-generation zirconia, which presents flexural strength ~900 MPa, covered with porcelain that presents ~80 MPa; on the other hand, the multilayer translucent zirconia presents ~600 MPa for flexural strength [16]. Therefore, the study showed the greatest importance to have higher resistance in the structure that contacts the loading surface than the internal structure.

This is proved also by the fractographic analysis, as the images showed 100% of fracture only in porcelain in the bilayer group. The monolithic structure had fractures evolving the connector basis and the occlusal surface in contact with the load application. This might be attributed to the tensile forces acting on the connector basis associated to the contact damage in the load application on the occlusal surface [17]. This pattern is in agreement with some previous studies [18,19] and points out for the relevance of the connector characteristic in this kind of restoration.

This is the first study to evaluate these materials in the present configuration, however, a previous study by Alessandretti [12] also found higher values of cyclic contact fatigue resistance for monolithic zirconia in comparison to the bilayer. It is worth to mention that, in their study, disc-shaped specimens were used and the monolithic zirconia adopted was a second-generation one.

The monotonic screening test showed equivalent results between the groups, with bilayer (zirconia-porcelain) group presenting fracture strength of 1654 N, value comparable of that obtained in a previous study of Mallmann [20] (1446 N), even though the specimens were aged 10^6 cycles of 100 N. This might represent the importance of the fatigue testing as the step-stress adopted in the present analysis to induce subcritical crack growth in the ceramic structures [15].

The survival probabilities have presented encouraging results for the monolithic group. No specimen failure was observed in this group with loads up to 800 N. This is also clinically relevant as literature reports maximum bite forces up to this value in bruxer patients [21] for the bilayer group, 1/3 of the specimens failed at 600 N load; besides, the 100% survival at 400 N might prove the zirconia-porcelain adequate for non-parafunctional patients, as mean chewing forces range between 285.0 - 462.3 N for men, and 253.9 - 445.8 N for women [22].

Most of the former studies evaluating monolithic zirconia in prosthetic structures used materials of second generation, which means, materials of improved strength by having 3-5 %mol yttria and less than 15% of cubic phase, which also provides high opacity to the material. The present study is, by the authors knowledge, the first to test the more translucent third-generation zirconia (those with greater yttria content and >25% cubic phase) in such configuration.

Fatigue tests have been adopted and considered an adequate in vitro analysis to correlate with clinical situations [23]; however, the tested protocol lacks control of other factors such as temperature changes, PH variations and most importantly the complex direction of forces resulting from jaw movements during mastication, which might be considered one limitation of the present study when dealing with clinical extrapolation.

5. Conclusion

Third-generation multilayer translucent zirconia presented promising results under mechanical fatigue analysis as monolithic three-unit implant-supported fixed prostheses, with superior results in comparison to bilayer zirconia-porcelain in regards to fatigue failure load, cycles until failure and survival probabilities.

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TABLES

Table 1 – Description of materials used in this study.

Material	Manufacturer (Composition)
Flexcone Implant	DSP Industrial Eireli EPP, Campo Largo, PR, Brasil
Prosthetic screw (ref number 7.7050)	DSP Industrial Eireli EPP, Campo Largo, PR, Brasil
Zenostar T, Framework material	Wieland Dental, Ivoclar Vivadent; Schaan, Liechtenstein (ZrO_2 (≥99%), Y_2O_3(> 4.5 - ≤6.0 wt %), HfO_2 (≤5.0%), Al_2O_3 (<1.0%); Other oxides (<1.0%))
IPS e.max Ceram, Veneering material	Ivoclar Vivadent, Schann, Liechtenstein (SiO_2, Al_2O_3, Na_2O, K_2O, KnO, CaO, P_2O_5, F, other oxides and pigments)
IPS e.max ZirCAD MT Multi, monolithic zirconia	Ivoclar Vivadent, Schann, Liechtenstein (ZrO_2 (86.0–93.5%); Y_2O_3 (> 6.5 - ≤8.0 wt %); HfO_2 (≤5.0%); Al_2O_3 (<1.0%); Other oxides (<1.0%))
IPS e.max Ceram ZirLiner	Ivoclair Vivadent, Schann, Liechtenstein (SiO_2, Al_2O_3, ZnO_2, Na_2O, K_2O, ZrO, CaO, P_2O_5, fluoride and pigments.

Table 2 – Results of monotonic test depicting mean and standard deviation of load-to-fracture, and results of fatigue test depicting mean, standard deviation (SD), 95% confidence interval (CI), characteristic parameter (probability value where 63.2% of specimens present failure), and Weibull Modulus (measurement of dispersion of the characteristic parameter) for each outcome (fatigue failure load – FFL in Newtons, and cycles for fatigue failure – CFF in count).

FFL (N)

Groups	***Monotonic (n= 2)***	***Kaplan-Meier* (n= 9)***		***Weibull Analysis** (n= 9)***			
	Mean (SD)	***Mean (SD)***	***Confidence interval***	***Characteristic Parameter***	***Confidence Interval***	***Modulus***	***Confidence Interval***
Bilayer	1654 (397)	844 (219)^{B}	676 – 1012	926^{B}	777 – 1090	4.59^{A}	2.56 – 7.29
Monolithic	1436 (210)	1200 (265)^{A}	997 – 1403	1305^{A}	1114 - 1512	5.06^{A}	2.87 – 7.93

CFF (Count)

Groups	***Kaplan-Meier****		***Weibull Analysis*****			
	Mean (SD)	***Confidence interval***	***Characteristic Parameter***	***Confidence Interval***	***Modulus***	***Confidence Interval***
Bilayer	74,827 (24,769)^{B}	55,788 – 93,866	83,324^{A}	66,662 – 102,569	3.63^{A}	2.00 – 5.83
Monolithic	109,935 (24,992)^{A}	90,725 – 129,145	119,739^{A}	101,657 – 139,480	4.88^{A}	2.78 – 7.63

*Different letters indicate statistical differences depicted by survival analysis of Kaplan-Meier and post-hoc Mantel-cox.

**Different letters indicate statistical differences depicted by survival analysis of Weibull using the maximum likelihood method (overlap of 95% confidence intervals).

Table 3 – Survival table obtained by Kaplan-Meier analysis depicting the probability of survival in each testing step and its respective standard error considering each outcome of the test (FFL – fatigue failure load in Newtons, and CFF – cycles for fatigue failure in count).

FFL/CFF

Groups	***100/5,000***	***200/25,000***	***400/45,000***	***600/65,000***	***800/85,000***	***1000/105,000***	***1200/125,000***	***1400/145,000***	***1600/165,0000***
Bilayer	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	0.67 (0.16)	0.44 (0.17)	0.11 (0.11)	0.0	-	-
Monolithic	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	0.44 (0.17)	0.33 (0.16)	0.22 (0.14)	0.0

The sign “-” indicates absence of specimen being tested on this respective step.

FIGURES

Figure 1 – Illustrative figure of specimen geometry, relation between load applicator and specimen during mechanical tests and the adopted occlusal contact.

	Bilayer	**Monolithic**
Specimen		
Load		
Occlusal contact		

Figure 2 – Kaplan-Meier graph depicting the cumulative probability of survival through the progression of the fatigue test for both outcomes considered (FFL – fatigue failure load, CFF – cycles for fatigue failure).

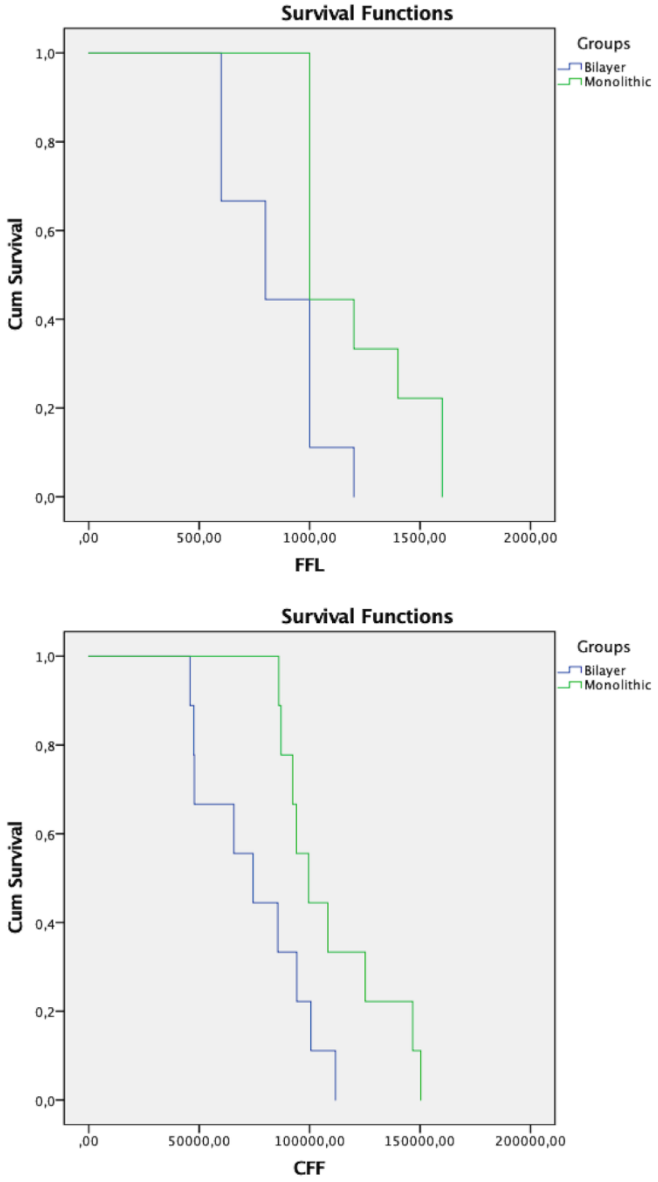


Figure 3 – Weibull survival graph, depicting the probability of failure in respect to the fatigue failure load (FFL, on left) and cycles for fatigue failure (CFF, on right).

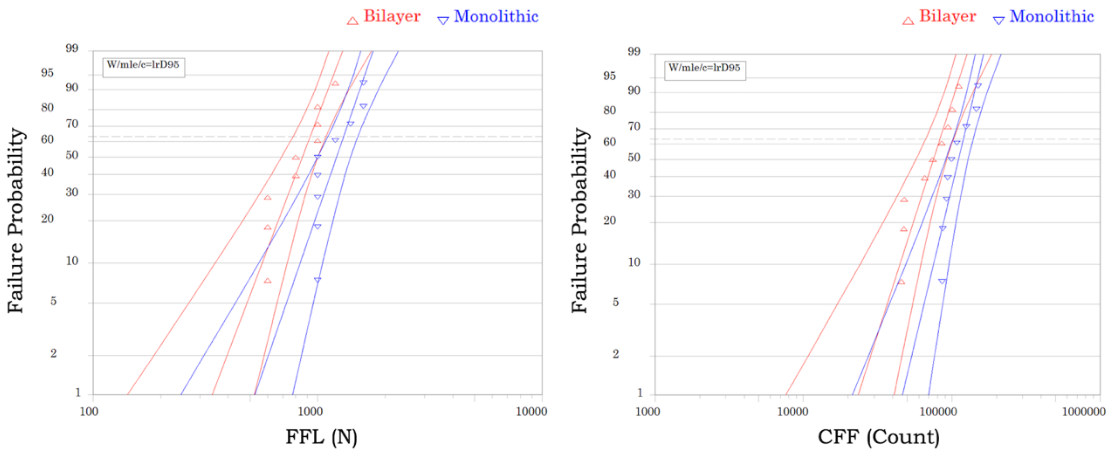
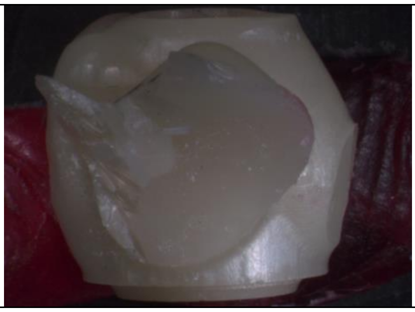


Figure 4 – Stereomicroscope figure illustrating the fractographic analysis of a failed representative specimen of each group.

Bilayer	**Monolithic**
	
Occlusal view 9x mag – illustrates the chipping occurrence from top view	Occlusal view 9x mag – illustrates the fracture occurrence from top view
	
Lingual view 9x mag – chipping restricted to the lingual region of the pontic from mesial to distal regions	Lingual view 9x mag – compression curl propagating from the fracture origin at gingival level into the occlusal surface

	
Lingual view 25x mag – higher magnification of chipping region	Lateral view 25x mag – higher magnification of mesial connector region from where the fracture originated at gingival level and propagated into the occlusal surface
	
Internal view 25x mag – detached fragment	Lateral view 25x mag – higher magnification of pontic region into distal connector from where the fracture originated at gingival level and propagated into the occlusal surface

5. Considerações Finais

A zircônia translúcida multicamada de terceira geração apresentou resultados promissores na análise de fadiga mecânica como próteses fixas implantossuportadas monolíticas de três unidades, com resultados superiores em comparação à zircônia bicamada relacionado à carga de falha por fadiga, ciclos até a falha e probabilidades de sobrevivência.

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ANEXOS/APÊNDICES

Figura 1 – index para padronização do paralelismo entre os implantes.

Figura 2 – Base de suporte com 2 implantes paralelos.

Figura 3- pistão de aço inoxidável com uma parte ativa 6 mm de diâmetro para os testes de carga cíclica.

A

Figura 4- (A) estrutura de zircônia de segunda geração (Zenostar T); (B) zircônia transulucida multicamadas de terceira geração monolítica (IPS e.maxZirCAD multi)

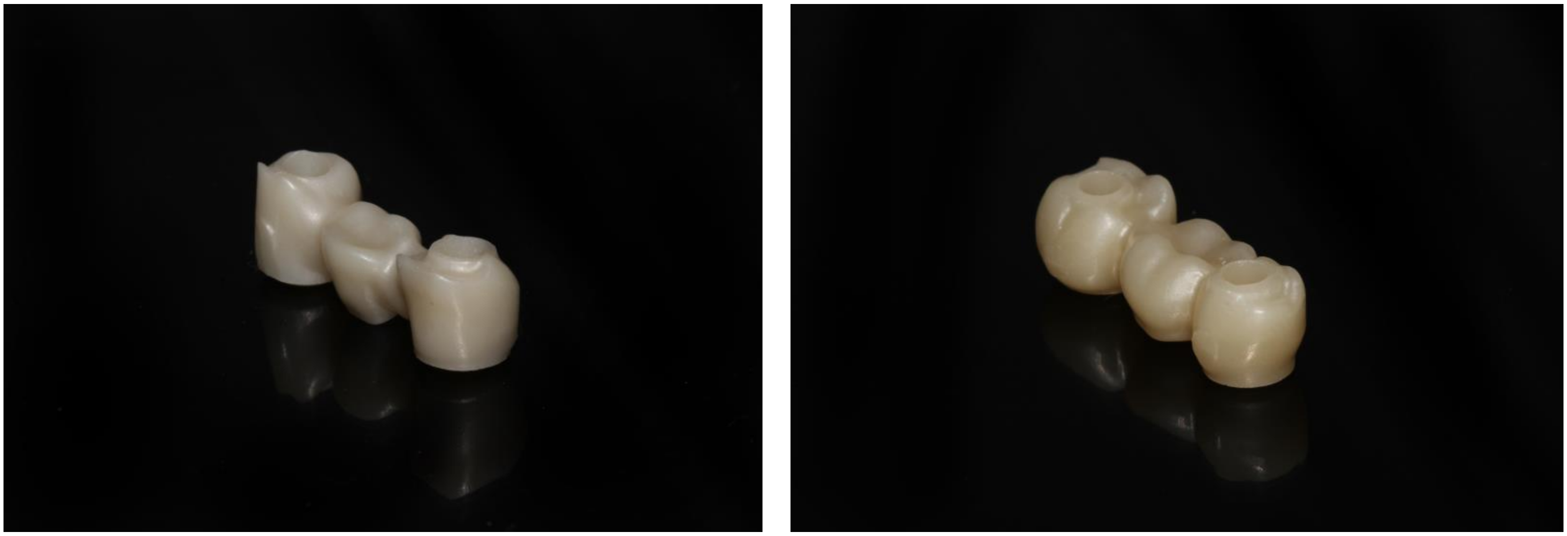

Figura 5- aplicação de porcelana de cobertura (IPS e.max Ceram) sobre os copings.

Figura 6. sinterização (Programat EP 5000-G2, Ivoclar vivadent, Schaan, Liechtenstein) a 750 ° C.

Figura 7- projetos de estruturas CAD-CAM

Autor/a: Gabriel Marini

Título: Análise do desempenho em fadiga de zircônia transluzente de terceira geração usada como prótese parcial monolítica implantossuportada.

Dissertação apresentada ao Programa de Pós-Graduação *Stricto Sensu* – Mestrado em Odontologia – da IMED, como requisito para a obtenção do grau de Mestre em Odontologia.

Passo Fundo, RS, 01/04/2021

Prof. Dr. Atais Bacchi – Presidente

Gabriel KR Pereira

Prof. Dr. Gabriel Kalil Rocha Pereira – Membro

Prof. Dr. Rodrigo Alessandretti – Membro