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CAD/CAM Materials for Endocrown Restorations: Evaluation of Microhardness, Flexural Strength, and Surface Characterization

Materiais CAD/CAM para Restaurações Endocrowns: Avaliação da Microdureza, Resistência à Flexão e Caracterização Superficial

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Abstract

Endocrowns have emerged as a promising option for restoring endodontically treated teeth, offeringa restorable fracture scenario. However, regarding the choice of material and its fracture resistance, there are gaps in the literature regarding the best indication. The objective of this research was to evaluate and compare the effect of restorative materials for CAD-CAM in the manufacture of *endocrown restorations, through an in Vitro study on* hardness and fracture resistance. For the study, CAD-CAM blocks were transformed into discs 12 mm in diameter and 1.2 mm thick (specimens). Three restorative materials were evaluated and distributed into experimental groups (N=12 specimens): Leucita-Reinforced Ceramic/ IPS Empress CAD (MRleu), Lithium Disilicate/ IPS Emax CAD (MRdis) and Nanoceramic Resin /Lava Ultimate (MRres). These restorative materials were evaluated for morphology (N=1) by Scanning Electron Microscopy (SEM) and surface chemistry (N=1) by dispersive energy spectroscopy (EDS). The specimens were evaluated when the Vikers micro hardness (N=1) with a load of 1kg and 10 indentations, as well as the resistance to biaxial flexion (N=10) at a test speed of 0.5 mm/min. After the fracture occurred, the fragments were examined under a stereomicroscope. The results were tabulated and analyzed using the Minitab statistical program. The results showed that the MRdis material demonstrated superior results in relation to hardness (P=0.000) and biaxial bending resistance (P=0.000), followed by MRleu andfinally the MRres. The presence of inorganic particles on an organic matrix and the presence of Zirconium (Zr) stands out in Lava Ultimate. It was concluded that restorative materials for CAD-CAM in the manufacture of *Endocrowns restorations* have a significant effect on hardness and mechanical strength.

Keywords: Ceramics. CAD-CAM. Hardness. Flexural Strength.

Resumo

As endocrowns surgiram como uma alternativa favorável para a restauração de dentes tratados endodonticamente, e se apresentam em um cenário de fratura restaurável. No entanto, em relação ao material de escolha e sua resistência à fratura existem lacunas na literature sobre a melhor indicação. O objetivo dessa pesquisa foi avaliar e comparar o efeito de materiais restauradores para CAD-CAM na confecção de restaurações endocrowns, através de um estudo in vitro sobre dureza e resistência à fratura. Para realização do estudo, blocos para CAD-CAM foram transformados em discos com 12 mm de diâmetro e 1,2 mm de espessura (espécimes). Três materiais restauradores foram avaliados e distribuídos em grupos experimentais (N=12 espécimes): Cerâmica Reforçada por Leucita/ IPS Empress CAD (MRleu), Dissilicato de Lítio/ IPS Emax CAD (MRdis) e Resina Nanocerâmica /Lava Ultimate (MRres). Estes materiais restauradores foram avaliados quanto à morfologia (N=1) através de Microscopia Eletrônica de Varredura (MEV) e química superficial (N=1) pela Espectroscopia de energia dispersiva (EDS). Os espécimes foram avaliados quanto à microdureza Vikers (N=1) com uma carga de 1kg e 10 indentações, como também em relação a resistência à flexão biaxial (N=10) em uma velocidade de ensaio de 0,5 mm/min. Os fragmentos após a fratura foram observados em estereomicroscópio. Os dados obtidos foram tabulados e analisados no programa estatístico Minitab. Os resultados observados mostraram que o material MRdis obteve resultados superiores em relação a dureza (P=0,000) e a resistência à flexão biaxial (P=0,000), seguido pelo MRleu e por fim o MRres. Destaca-se na Lava Ultimate a presença de partículas inorgânicas sobre uma matriz orgânica, além da presença de Zircônio (Zr). Conclui-se que materiais restauradores para CAD-CAM na confecção de restaurações Endocrowns apresentam efeito significativo quanto a dureza e resistência mecânica.

Palavras-chave: *Cerâmica. CAD-CAM. Dureza. Resistência à Flexão.*

1 Introduction

In the quest to effectivelyrestore endodontically treated teeth in thr oral environment, *endocrowns* have proven favorable for this situation when compared to traditional methods like intraradicular retainer and crowns. *Endocrowns* presented a fracture scenario that is deemed restorable, particularly when compared to crowns due to the fewer number of cracks observed[1]. One study noted that *endocrowns* showed fracture strength values within the range of maximum chewing force in the posterior region[2]. Additionally, an 8 to 19-year follow-up clinical study found that 90.9% of *endocrowns* (10 restorations) were in good function and 9.1% (1 restoration) exhibiting failure[2]. Thus, *Endocrown* have been regarded as a conservative and aesthetic strategy to restoring endodontically treated teeth, showing optimal biomechanical and functional performance with acceptable longevity[3].

Endocrown restorations have higher been shown to possess higher fracture resistance compared to conventional crowns, which are often associated with the use of glass pins[4].

Several materials have been clinically adopted to fabricating *endocrowns*, such as IPS-Empress (feldspathic ceramic), Gradia (hybrid composite resin), Gold Alloy (gold alloy-based) and Isosit-IO (composite resin), Lava Ultimate (nanoceramic resin), IPS Emax CAD (lithium disilicate)[3]. Research efforts have been directed towards identifying the most suitable restorative material that can be milled using CAD-CAM (Computer-aided design - Computer-aided manufacturing) technology for *endocrown* restoration fabrication[1,2,5-9,21.]

Studies showed different resultsregarding fracture strength and indication of restorative materials for making *endocrowns* restorations. This scenario shows the gaps present in the current literature, regarding choice of the material for making this restoration by dental surgeon emphasizing the necessity for further research this area[1,2,8,10].

Based on the above, it was aimed to evaluate the effect of restorative materials for CAD-CAM in the fabrication of *endocrowns* restorations through an *in vitro* study on hardness and fracture resistance. The expected results for this research are: Null Hypothesis (H0) - There will be no statistically significant difference in mechanical strength and hardness among the materials tested; Alternative Hypothesis (H1) - Therewill be statistically significant difference in mechanical strength and hardness amongthe materials tested.

2 Material and Methods

2.1 Making the specimens

Disc-shaped specimens (N=12) were obtained using three indirect CAD-CAM block restorative materials, Leucite Reinforced Ceramics (IPS Empress CAD, Ivoclar Vivadent, Switzerland), Lithium Disilicate (IPS Emax CAD, Ivoclar Vivadent,Switzerland) and Nanoceramic Resin (Lava Ultimate, 3M ESPE, Germany).

The CAD-CAM blocks were cut in a cutting machine (Struers Accutom 100, Ballerup, Denmark) with a diamond disk, operating at a speed of 250 rpm with water cooling. Then, the slices of the materials were rounded, using a truncated cone-shaped diamond tip in a high rotation pen with constant cooling. Thus, discs with approximate dimensions of 12 mm in diameter and 1.3 mm thick were obtained. Subsequently, the samples were then polished using SiC sandpapers with 300, 600 and 1200 grit sizes. According to ISO/CD 6872, the specimens obtained final dimensions of 12 mm in diameter and 1.2 mm thick[11]. The IPS Emax CAD disks were obtained prior to crystallization, a process that was subsequently performed according to the manufacturer’s recommendations regarding the use of the furnace and temperature cycles.

2.2 Experimental groups

The experimental groups are defined by MRleu (Restorative Material - Leucite- reinforced ceramics), MRdis (Restorative Material - Lithium disilicate) and MRres (Restorative Material - Nanoceramic resin) (Table 1). The sample size of this study wascalculated using the statistical program Minitab (version 17 for windows, Pennsylvania USA), based on the standard deviation (0.668) of similar research by Skalskyi[7] for biaxial flexural strength, thus the N=10 presented a sample power of 80.0% in relation to maximum differences. For hardness, testing, a sample size of N=10 indentations on a ceramic disc was recommended, based on a similar study conducted by Lawson[12].

Table 1 - Description of the restorative materials in the study

Experimental Group	RestorativeMaterial (CommercialName)	Ceramic Families /Ceramic Type Materials	Chemical Composition
MRres	Nanoceramic Resin (Lava Ultimate)	Ceramics with Resinous Matrix	Resin-ceramic, Restorative dental polymerization, composed of silica nanomers (20 nm), zirconia nanomers (4-11 nm), nanomer-derived nanocluster particles (0.6-10 µm), silane coupling agent, resin matrix.
MRleu	Leucite Reinforced Ceramics (IPS Empress CAD)	Vitrocerami c	SiO2 (60-65%), Al O23 (16-20%), K2 O (10-14%), Na2 O (3.5-6.5%), other oxides (0.5-7%), Pigments (0.2-1%).
MRdis	Lithium Disilicate (IPS Emax CAD)	Vitrocerami c	SiO2 (57-80%), Li2 O (11-19%), K2 O (0-13%), P O25 (0-11%), ZrO2 (0-8%), ZnO (0-8%), Al O23 (0-5%), MgO (0-5%) and colored oxides (0-8%).

Source: research data.

2.3 Surface analysis

One specimen from each experimental group was used for the chemical analysis and surface morphology. The surface morphology of the restorative materials was analyzed by scanning electron microscopy (SEM) (HITACHI, TM300 model), using magnifications of 1,000X, 3,000X and 5,000X.

For the chemical analysis of the surface, the identification of elements of the CAD-CAM materials was performed by means of Energy Dispersive X-ray Spectroscopy (EDS) (Bruker). As well as, the elaboration of the map when selected the point of the specimen that would be analyzed by the software (Quantax), which provides data related to the percentage for each prominent chemical element on the surface.

2.4 Hardness

The specimens were positioned facing a Vicker micro hardness indenter (DuraScan, Emcotest). Ten indentations were made on each specimen, arranged near the center and space at least 0.5 mm from each other. The test occurred with a load of 1 kg and a dwell time of 15 s based on the recommendations of ASTM C1327. The main Vicker indentation diameters (d1 and d2) were measured with an optical micrometer and the hardness was calculated with Formula 1 as per the study by Lawson[12]

$$\text{Hardness} = \frac{1850\ x\ Carga}{(d1\ x\ d2)}$$

Formula 1: Calculation of Hardness.

2.5 Biaxial Flexural Strength

The specimens were positioned in a circular metal base with three 3.2 mm diameter spheres, equidistant from each other, forming a plane, according to ISO 6872. A 1.6 mm diameter blunt tip was attached to a testing machine (Emic DL-1000, Emic, São José dos Pinhais, PR, Brazil), and load applied. The test was conducted with a speed of 0.5 mm/min and a load cell of 100 Kgf. During the test, the specimen was covered with an adhesive tape on the compression side maintain thethe fragments in position[11].

The calculation of biaxial flexural strength (σ) (MPa) of the discs was obtained according to the description of the ISO 6872 standard (Formula 2): where P is the load in kgf, X and Y are parameters related to the elastic properties of the material (Poisson's Ratio in Elastic Modulus) and b is the specimen thickness at the origin of fracture in mm[11].The reference values X and Y were obtained from the study by Wendler[13].

$$\sigma = -0{,}2387P\,\frac{(X-Y)}{b^2}$$

Formula 2: Calculation of the biaxial bending strength.

2.6 Fracture analysis

The fractured specimens were analyzed under a stereomicroscope (Discovery V20, CarlZeiss, Germany) to determine the fracture characteristics and observe the number of fragments after mechanical testing.

2.7 Analysis of results

The results were tabulated and analyzed in Minitab (version 17 for windows, Pennsylvania, USA), with a significance level of 5%. The data of biaxial flexural strength, hardness and number of fragments after fracture were submitted to the statistical test 1 Factor Anova ($p < 0.05$), to evaluate the effect of the material. When statistically significant difference was observed between the data, Tukey's Test was applied to identify the difference between experimental groups. Previously, the Komolgorov Smirnov Normality Test was applied to the data and experimental groups, which presented a significance level greater than 1%.

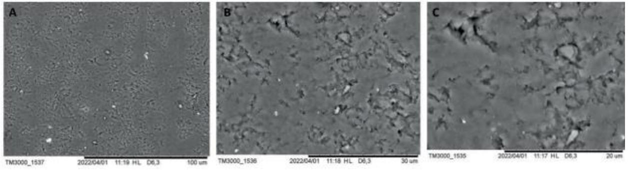
3 Results and Discussion

The results of the research are presented according to the analyses performed.

3.1 Superficial analysis

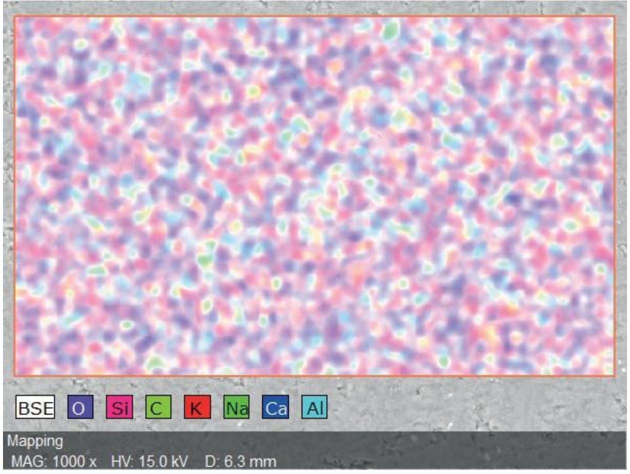
The Leucite Reinforced Ceramic (IPS Empress CAD) presented in the morphological surface analysis the presence of the inorganic matrix representative of the glass-ceramics (Figure 1). As for the chemical surface analysis, the chemical elements Carbon (C), Oxygen (O), Silicon (Si), Aluminum (Al), Potassium (K), Sodium (Na), and Calcium (Ca) were identified, highlighting the highest percentage of Silicon (Si) (Figures 2, 3) (Graph 1).

Figure 1 - SEM surface image of the Leucite Reinforced Ceramics (A) 1,000X; (B) 3,000X, the inorganic matrix of the material can be seen; (C) 5,000X



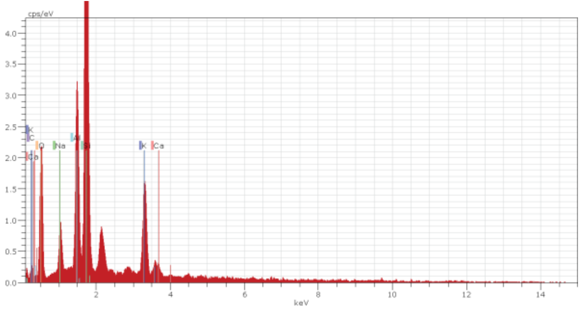
Source: the authors.

Figure 2 - Surface image of the EDS map of the Leucite Reinforced Ceramics, predominance of Silicon (Si) in pink color, magnification 1,000X



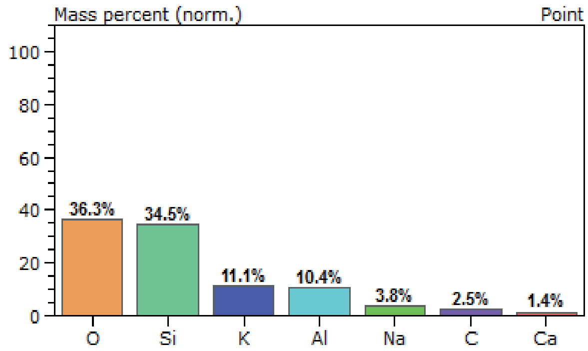
Source: the authors.

Figure 3 - EDS of the Leucite Reinforced Ceramics, chemical elements C, Ca, K, Na, Al, O, Si



Source: research data.

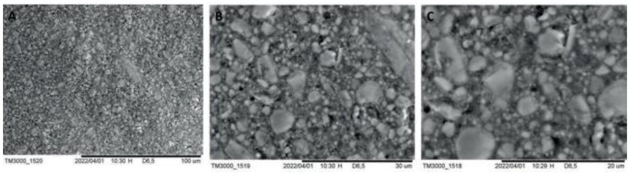
Graph 1 - Percentage of each chemical element present in the EDS analysis ofthe Leucite Reinforced Ceramics



Source: research data.

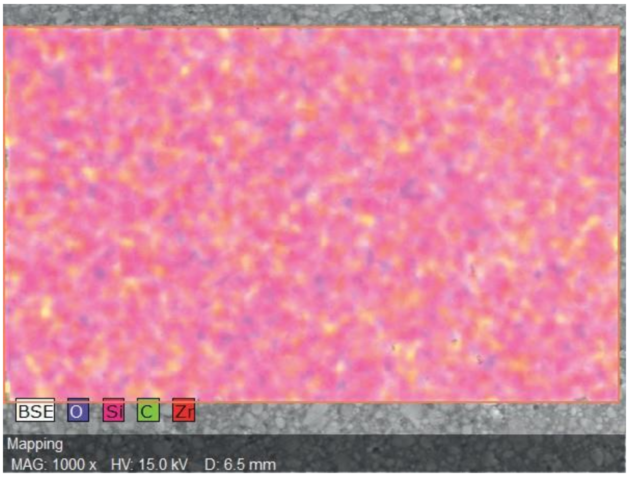
For the Nanoceramic Resin (Lava Ultimate), the surface morphological analysis in SEM shows the presence of organic matrix and inorganic particles on it (Figure 4).As well, pores and defects were observed on the surface (Figure 4C). As for the chemical surface analysis, the chemical elements Carbon (C), Oxygen (O), Silicon (Si) and Zirconia (Zr) were identified, highlighting the highest percentage of Silicon (Si) as an inorganic component (Figures 5, 6) (Graph 2).

Figure 4 - SEM surface image of the Nanoceramic Resin (A) 1,000X;, (B) 3,000X, inorganic particles are observed over the organic matrix; (C) 5,000X, highlighting the presence of defects and pores



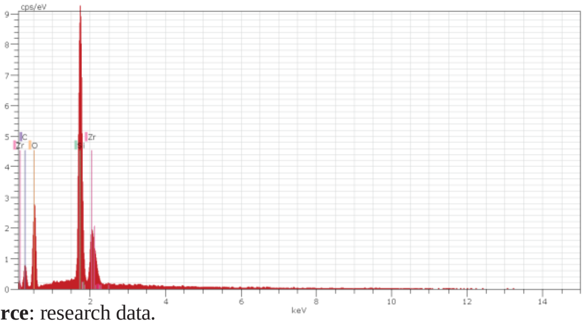
Source: the authors.

Figure 5 - Surface image of the EDS Map of the Nanoceramic Resin, predominance of Silicon (Si) in pink color and scattered red pointson the surface representing Zirconium (Zr), magnification 1,000X



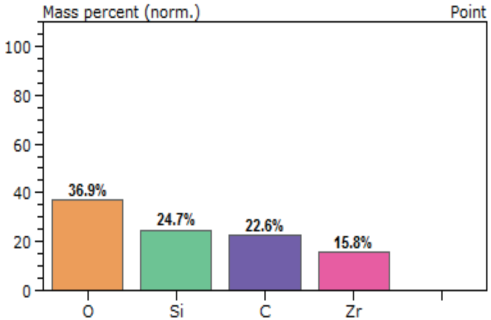
Source: the authors.

Figure 6 - EDS of the Nanoceramic Resin, chemical elements C, O, Si, Zr.



Source: research data.

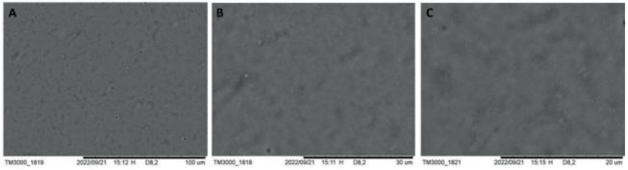
Graph 2 - Percentage of each chemical element present in the EDS analysis of the Nanoceramic Resin



Source: research data.

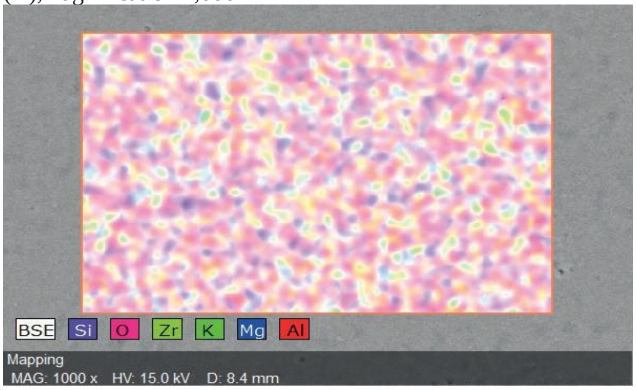
In the morphological surface analysis of Lithium Disilicate (IPS Emax CAD), the characteristic inorganic surface of this ceramic was observed (Figure 7). As for the chemical surface analysis, the chemical elements Oxygen (O), Silicon (Si) and Zirconia (Zr), Potassium (K), Magnesium (Mg) and Aluminum (Al) were identified, with Silicon (Si) showing the highest percentage (Figures 8, 9) (Graph 3).

Figure 7 - SEM surface image of Lithium Disilicate (A) 1,000X; (B) 3,000X; (C) 5,000X



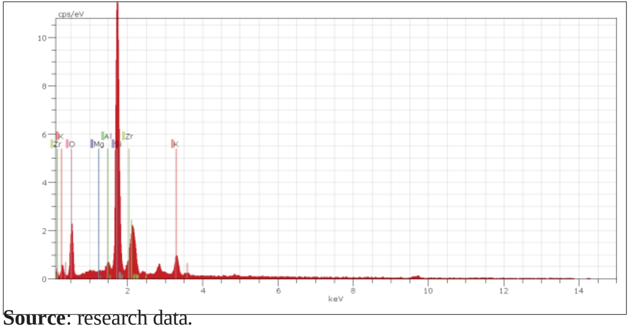
Source: the authors.

Figure 8 - Surface image of the EDS map of Lithium Disilicate, predominance of Silicon (Si) in purple color and scattered green points on the surface representing Zirconium (Zr) and Potassium (K),magnification 1,000X



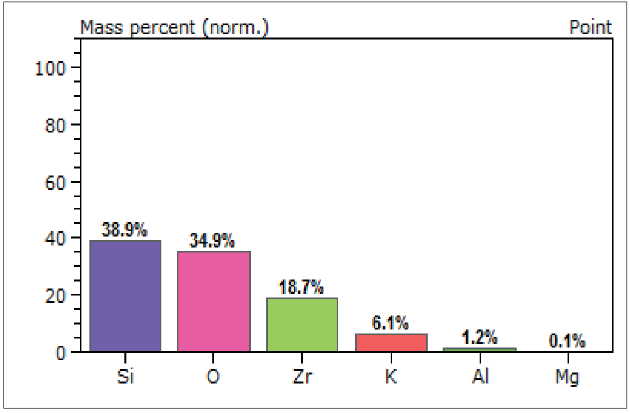
Source: the authors.

Figure 9 - EDS of Lithium Disilicate, chemical elements Si, O, Zr, K, Mg and Al



Source: research data.

Graph 3 - Percentage of each chemical element present in the EDS analysis ofLithium Disilicate



Source: research data.

3.2 Hardness analysis

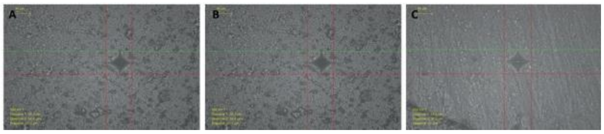
The hardness findings show Lithium Disilicate, Leucite Reinforced Ceramic and Nanoceramic Resin in decreasing order of hardness, with statistically significant mean values observed between these materials (Table 2). Figure 10 show the Vickers indentation among the restorative materials.

Table 2 - Hardness Data*

Experimental Group	Average Hardness	Standard Deviation	Maximum Hardness Value	Minimum Hardnesss Value	P-value
MRleu	517,4^{B}	61,2	592	425	
MRdis	614,2^{A}	61,9	721	535	0,000
MRres	103,97^{C}	4,59	113	99,1	

*Distinguished letters show the difference between experimental groups.
Source: research data.

Figure 10 - Vicker indentation 20X magnification (A) Leucite Reinforced Ceramics, (B) Nanoceramic Resin, (C) Lithium Disilicate



Source: the authors.

3.3 Biaxial flexural strength

The results of the mechanical strength test showed statistically significant mean fracture strength among the materials under study (P=0.000). Lithium disilicate obtained the highest average fracture strength, with its minimum value was higher thanthe maximum value of the Nanoceramic Resin group. Leucite-reinforced ceramics showed intermediate values compared to the other experimental groups. The restorative materials under study are statistically different from each other (Table 3).

Table 3 - Biaxial Bending Strength Data*

Experimental Group	Average Fracture Strength (Mpa)	Standard Deviation	Maximum Fracture Strength value (Mpa)	Minimum value of Fracture Strength (Mpa)	P-value
MRleu	242,779^{A}	60,91	388,3	196,0	
MRdis	476,215^{B}	143,9	721,8	267,2	0,000
MRres	54,313^{C}	10,59	67,57	30,78	

*Distinguished letters show the difference between experimental groups.
Source: research data.

3.4 Fracture analysis

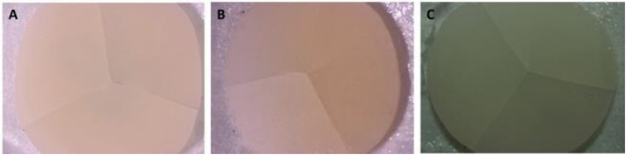
For the Leucite Reinforced Ceramics, the highest number of fragments after fracture was identified, while the other experimental groups showed the same mean value. However, there was no statistically significant difference observed among the experimental groups (P=0.128) (Table 4). Figure 11 depicts the distribution of fragments after fracture.

Table 4 - Number of Fragments after Fracture

Experimental Group	Average Number of Fragments after Fracture	Standard Deviation	Maximum Number ofFragments after Fracture	Minimum Number of Fragments after Fracture	P-value
MRleu	4,7	0,8	6	3	
MRdis	3,9	0,9	5	2	0,128
MRres	3,9	1,1	5	2	

Source: research data.

Figure 11 - A: Sample 8 with 03 fragments of the Nanoceramic Resin. B: Sample 7 with 04 fragments of Leucite Reinforced Ceramics. C: Sample 2 with 3 Lithium Disilicate fragments



Source: the authors.

From the results found in this research, the Alternative Hypothesis (H1) was accepted and the Null Hypothesis (H0) was rejected. There was a statistically significant difference ($p<0.05$) observed for mechanical strength and hardness among the tested restorative materials. Thus, IPS Emax CAD showed superior performance, across all analyses investigated in the research. This finding corroborates with other research on fracture strength[14;15] and hardness[16,17]. As also, it aligns with studies by Foad[2], Skalskyi[7], Kanat-ertürk[8]; Sedrez-porto[9] ; Elashmawy[10]on fracture toughness.

The study by Tribst[15] presents *Endocrowns* fabricated with

IPS Emax CAD with a higher load to fracture IPS Empress CAD after mechanical fatigue. Theselithium disilicate-based ceramics have aesthetic and mechanical qualities proven by the literature. Furthermore, leucite-reinforced ceramic can be considered as an alternative to lithium disilicate for *Endocrown* restorations due to its favorable dentin bond strength, despite having lower mechanical strength. Another literature finding on flexural strength of materials for CAD-CAM, reinforces the mechanical superiority, in the absence of aging,of IPS Emax CAD compared to Lava Ultimate, Vita Enamic and IPS Empress CAD[14].

Contrary research shows that although lithium disilicate showed high fracture toughness values, these are not statistically superior to the mechanical performance of Zirconia[7,8,10], Poly-Infiltrated Ceramics (Vita Enamic)[2] and Direct Resinous Materials[9] for *Endocrowns* restorations. Polycrystalline ceramics by their predominantly crystalline nature, explains the mechanical characteristics superior to vitroceramics[18]. The dentin-like modulus of elasticity and higher resilience of Vita Enamic, makes this material show better mechanical results before and after aging of the tooth/restoration set[2]. As well, the reduced elastic modulus of direct resin materials reflects Sedrez's[9] findings in his study.

As for the results of IPS Empress CAD and Lava Ultimate, the literature shows that the fracture strength values of LAVA Ultimate were statistically superior to IPS Empress CAD for *Endocrowns* restorations before and after mechanical aging[1,19]. As also, the same mechanical performance was observed for such restorative materials regarding flexural strength in the absence of aging[14,20]. Disagreeing with the findings of this research, perhaps this result can be explained by the mechanical strength test adopted in the study of Stawarczyk[14], the three-point bending test, or by the greater resilience of Lava Ultimate in absorbing energy during tension[20].

For research that produced the *Endocrown* restoration and evaluated the fracture of the *tooth/endocrown* assembly[1,8,9,10], IPS Emax CAD showed both repairable[8] and non-restorable[9,10] fracture patterns. Lava Ultimate and IPS Empress CAD, on the other hand, demonstrate repairable fracture patterns[1,8,15]. Tribst[15] showed that Lithium Disilicate demonstrates higher stresses than Leucite Reinforced Ceramics in the *endocrown* and tooth structure, while Leucite Reinforced Ceramics shows better stress distribution in the tooth/restoration assembly. Additionally, Lava Ultimate's modulus of elasticity closer to that of dentin, facilitates stress distribution in the tooth/restoration assembly[20].However, the research at hand represented *endocrowns* restorations through geometric disk specimens, a condition that limits the discussion of fracture results with studies with anatomical specimens.

In the present study, no statistically significant difference was found between thenumber of fragments of the restorative materials after fracture, even though there were different fracture strength values among the experimental groups. That is, the number of fragments to fracture of a restorative material may not be related to the mechanicalstrength, being in disagreement with reports by Ramos[11].Fractographic study is extremely important to investigate the behavior of restorative materials, although absent in research with geometric specimens.[7,14,20] Thus, perhaps this finding is due to the specimens not aging, as thermomechanical loading can alter the mechanical properties of Lava Ultimate[21].

IPS Emax CAD and IPS Empress CAD show higher hardness values compared to Lava Ultimate, being in agreement with the researched literature[17,21]. This result can atributed to differences in matrix composition,glass-ceramics containing an inorganic matrix and Lava Ultimate containing an organic matrix[18]. Besides the chemical composition and morphological arrangement, for example, the arrangement of the disilicate crystals hinders thepropagation of cracks and failures compared to other restorative materials[12,15]. Whereas, the morphological arrangement of Lava Ultimate presents inorganic particles randomly arranged on the organic matrix, as observed in the SEM images of this research. Therefore, this restorative material cannot resist the high loads until fracture, resulting from the lower hardness values.

The surface analysis findings corroborate with other research by Lawson[11], Sonmez[17], Hampe[21]. The identified chemical elements are in agreement with the manufacturers' composition, except for Lithium (Li) which was not identified in IPS Emax CAD, stemming from the sensitivity of EDS in not picking up chemical elements with low atomic number. Lava Ultimate stands out in relation to the distribution of a large number of inorganic particles on the resin matrix and even with the presence of Zirconium (Zr) in the chemical composition did not guarantee higher hardness values and mechanical strength than IPS Empress CAD[12,17]. Perhaps because IPS Empress CAD is a glass-ceramic and presents other oxides (Al2O3, K2O, Na2O), which favor mechanical performance[12]. And Lava Ultimate, even though it has a quantity of silicon (Si) that is close to the quantity of IPS Empress CAD, has an organic matrix, and the EDS is limited in promoting a more complex chemical analysis because it performs a superficial analysis.

The data from this research are limited in their applicability to clinical practice, as it is an *in vitro* study and with geometric specimens not associated with a dental structure. However, the glass-ceramics in this study showed no statistical difference in the number of fragments after fracture compared to the nanoceramic resin. Consequently, the choice for a glass-ceramic material to fabricate an *Endocrown* restoration seems more favorable, as it presents values of resistance to fracture and hardness superior to nanoceramic resin. That is, there may be greater durability of the restoration and are clinically acceptable, as observed in some research with the confection of *Endocrown restorations*[8,15].

However, in relation to the biomimetic view of restorative materials, these materials should present mechanical properties that approximate human dentin and dental enamel.

Lava Ultimate presents flexural modulus that corresponds to the desirable biomimetic conditions for restoring a single dental element, however, its low stiffness property may be considered a disadvantage due to the potential for flexing at the restoration margin and generate the decimentation of the same[20].

Finally, the limitations of this study were the use of a geometric specimen to represent the *Endocrown*, difficulty in making disc specimens from blocks for CAD- CAM, not having performed the aging of the specimens, which hinders the discussionof the results mainly in relation to the biomimetic view. New *in vitro* studies should be proposed from the confection of the *Endocrown* restoration cemented on a dental element, in order to represent more faithfully the oral condition. Thus, observe wear ofthe restorative material, antagonist wear and tooth fracture after accelerated aging. Then, randomized and controlled clinical trials should be performed, so that the long- term performance of restorative materials can be known.

4 Conclusion

Within the limitations of this study, the following conclusions were presented:

1. Restorative materials for CAD-CAM in the fabrication of *Endocrowns* restorations show significant effect regarding hardness and mechanical strength;
2. IPS Emax CAD and IPS Empress CAD showed better mechanical performance than Lava Ultimate;
3. The number of fragments after fracture is not influenced by the restorativematerial

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Data Availability

All data are available in the Federal University of Pernambuco (UFPE) repository.

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