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Comparative Study Of Fracture Resistance Between Monolithic Zirconia Crowns And Veneered Zirconia Crowns

Research Article

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Abstract

This study aims to evaluate fracture resistance of monolithic zirconia crowns designed using CAD/CAM technique and veneered zirconia crowns.
Twenty metal orthodontic abutments were designed and fabricated using a metal laser printer. Specimens were then divided into two groups (n=10). All specimens were bonded and attached using glass ionomer cement. Samples were tested for fracture resistance using a general material testing machine (Testometric).
Data were statistically analyzed using Student's t-test. Significant statistic differences were found between the study groups as monolithic zirconia crowns displayed higher fracture resistance in comparison with veneered zirconia crowns, since monolithic zirconia crowns happened to solve the issue of chipping faced with veneers.

Introduction

Many prosthetic materials have been used in dentistry with the objective of achieving the best cosmetic outcomes in terms of producing a color and a shape that resembles the natural teeth while maintaining mechanical properties of dental prosthesis, accordingly, dental porcelain was developed and studies began to focus on developing CAD/CAM.

Veneered zirconia crowns consist of: [1]

A core directly enveloping the tooth which is made of high-mechanical-resistance-porcelain [2]. and a veneer ceramic corresponding with the shape of the final dental restoration composed of materials that are highly aesthetic but are of low mechanical resistance (meaning it consists of porcelain).[3, 4]

Low-strength-porcelain is combined with zirconia cores in order to achieve mechanical strength while maintaining better aesthetic results when used. Since one of the most important mechanical properties of zirconia is its ability to stop the spread of cracks and fractures, known as transformation toughening [5-7], 3Y-TZP zirconia possesses superior mechanical properties surpassing every other available porcelain material [8-10] making this compound suitable for dental applications. [11]

The core framework should be layered with veneering porcelain due to the high opacity of zirconia. However, chipping of veneering porcelain poses as one of the most significant clinical problems regardless of the strength of zirconia crowns [8]. Monolithic zirconia crowns provided a solution to the problems faced with bilayered zirconia restorations.

Therefore, this study was conducted to evaluate and compare load at fracture of monolithic and veneered zirconia crowns.

Purpose:

The purpose of this study was to compare fracture resistance between monolithic zirconia crowns made using CAD/CAM tech-

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nique and veneered zirconia crowns.

Materials and Methods

Fabrication of the experimental model

The testing specimen included 20 zirconia porcelain crowns divided into two groups:

The first group (n=1-10): its crowns were composed of zirconia cores made using CAD/CAM technique and later layered with veneering porcelain using layering technique.

The second group (n=11-20): its crowns were composed of monolithic zirconia made using CAD/CAM technique.

Metal abutments were designed computationally according to the groups mentioned above and based on criteria specific for receiving full ceramic restorations to ensure the ability of comparing the results of the study.[12]

Abutments were designed in a way that resembles the mandibular first molar with a height of 5mm, a finish line width of 1mm and a convergence angle of the axial walls measuring 6°. Metal abutments were then fabricated using a metal laser printer as it is considered to be more accurate than typical methods, besides its ability to reduce time and cost.[13, 14]

Abutments were designed by the same experienced technician that works on designing and making zirconia crowns.

Zirconia crowns are fabricated by scanning metal abutments using a z-scan machine. A 50m space is left for bonding cement.

Fabrication of monolithic zirconia crowns with a full thickness of 1ml:

Monolithic zirconia crowns that haven't been sintered were milled from pre-sintered blocks in a milling machine, and were then sintered in a sintering furnace oven for 7 hours at 1200°C.

Porcelain-veneered zirconia crowns are fabricated by designing all structures with a wall thickness of 0.5mm and with a design that is 20% bigger to compensate for the shrinkage happening while sintering.

The core framework is hand-layered using feldsphatic ceramic according to the guidelines of the manufacturing company with a thickness of 2mm at the occlusal surface and 0.5mm at the axial walls.

Bonding of zirconia crowns onto metal orthodontic abutments: Zirconia crowns were bonded onto the metal brackets that were made using a metal laser printer with glass ionomer cement from 3M Company at room temperature (18-25°C) according to the guidelines of the manufacturing company using a compression force uniformity device weighing 5kgs.

After removing attached appendages, specimens were submerged in distilled water for 24hrs and were ready for mechanical examinations to be performed.

Performing mechanical examinations

A nylon bag was placed on every specimen to prevent dispersal of chipped porcelain while performing the examination. A vertical compression force was applied at the center of the crown using a general mechanical examination machine (Testometric M350-10KN) via a stainless steel pole with a length of 15mm and a round end with a diameter of 1mm at 0.5mm/minute velocity, the force needed to cause a fracture was recorded in newtons.

Statistical analysis

Arithmetic mean and standard deviation were calculated for fracture resistance in every group. A t-test for the independent specimens was used to compare differences in fracture resistance between zirconia-core crowns with veneering porcelain layered over occlusal-surface-abutments and monolithic zirconia crowns. Statistical tests were made using SPSS v. 25 (IBM, USA) with a significance level of 0.05.

Standard deviations

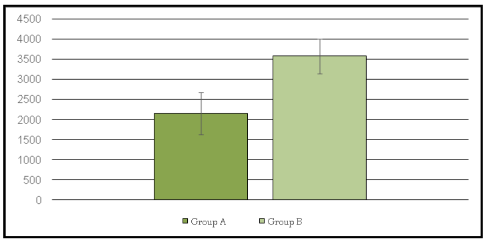
Table 1. Descriptive statistics for fracture resistance in study groups.

Group	Arithmetic Mean	Standard Deviation	Min	Max	95% Confidence Interval for Mean	
					Lower Bound	Upper Bound
First Group	2146.8	521.7	1520	3252	1773.6	2520
Second Group	3578.9	434.6	2975	4266	3268	3889.8

Table 2. Study of difference for fracture resistance in study groups.

	First Group	Second Group	Mean Difference	p	95% Confidence Interval for Difference	
	Mean ± SI	Mean ± SI			Lower Bound	Upper Bound
Fracture Force Resistance	2146.8 ± 521.7	3578.9 ± 434.6	1432.1	0	-1883.2	-981

Chart 1. Arithmetic mean and standard deviation for fracture resistance in study groups.



Results and Discussion

Fracture resistance recorded in zirconia-core crowns with veneering porcelain layered over anatomical occlusal-surface-abutments group measured 521.7 ± 2146.8 newtons. Statistically significantly less than the resistance recorded in monolithic zirconia crowns placed over occlusal-surface-abutments group measuring 434.6 ± 3578.9 newtons with a difference of 1432.1 newtons ($p < 0.001$).

In the first group containing veneering porcelain, the veneering porcelain was chipping initially and the fracture would then reach the core framework.

The study aims to compare fracture resistance between zirconia-core crowns with veneering porcelain layered over anatomical occlusal-surface-abutments and monolithic zirconia crowns.

Monolithic zirconia displayed higher resistance to fractures in comparison to bilayered-ceramic crowns.

The minimum value of fracture load in both groups was greater than 1000 newtons, greater than the maximum value of bite force in humans, estimated at about 700 newtons.

Many factors affecting fracture resistance in CAD/CAM zirconia crowns include microscopic structure, temperature, bonding, etc..

Metal abutments were made using a metal laser printer, alternatively to using natural teeth, as monolithic zirconia crowns have a resistance to fractures at an occlusal thickness of 1.5mm of up to 10kN, despite that a fracture happened using natural teeth as brackets, as seen in Strub'sstudy.[15]

It is preferable to use metal abutments due to their high durability against fracture force applied on crowns in comparison to acrylic brackets made from PMMA, causing elimination of specimens due to fracturing of the brackets before crowns began to fracture as seen in Jang's study. [16]

Zirconia porcelain was used due to its superior mechanical properties, good chromatic stability, low heat conductivity and good radiological opacity.

Veneering porcelain is made for application on zirconia cores in a way that accommodates with thermal expansion coefficient of zirconia, stated in the manufacturing company guide.

Veneering porcelain was applied on the crowns of the first group in a consistent thickness to negate the effect of veneering porcelain thickness on fracture resistance, as increased veneering porcelain thickness increases fracture resistance of full porcelain crowns, veneering porcelain is also deemed cosmetically essential for full porcelain crowns. [17]

All zirconia crowns were bonded using glass ionomer cement as it possesses superior mechanical properties especially when used with zirconia crowns since there's no effect of the type of the cement used on zirconia-crown-fracture-resistance.

Where we notice that fracture resistance of crowns in the first group was less than that of the crowns of the second group, after conducting statistical studies, it was found that there are statistically significant differences and therefore the fracture resistance of monolithic zirconia crowns was found to be higher than the fracture resistance of porcelain-veneered zirconia-core crowns.

Within the limits of this study, we happened to disagree with Tsuyuki, et al. (2018) study on the effects of occlusal form preparation on fracture resistance of monolithic zirconia crowns; they found that addition of medial and lateral groove to occlusal forms of abutments reduced their resistance to fractures whilst we found no evidence of effect, this discrepancy is possibly due to the difference in zirconia-crown-thickness at occlusal surfaces where fracture force was applied, while we standardized crown thickness at occlusal surfaces. [18]

The result of this study was similar to that of Sorrentino, et al. in that CAD/CAM monolithic zirconia crowns withstood occlusal forces at low surface thickness, as he examined fracture resistance of zirconia crowns at low thicknesses that do not exceed (0.5 - 1 - 1.5 - 2) and concluded that a thickness of 0.5mm was enough to withstand occlusal forces, he didn't find an effect of crown thickness on fracture resistance. [19]

Conclusion

Within the limits of this study, crowns of both groups displayed clinically acceptable resistance to fractures, and monolithic zirconia solved the issue of porcelain chipping.

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