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RESEARCH ARTICLE

EFFECT OF UNDER REDUCTION OF THE ABUTMENT ON THE FRACTURE RESISTANCE OF A MONOLITHIC ZIRCONIA BRIDGE- AN IN VITRO STUDY

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ABSTRACT

Purpose: The aim of the study was to investigate the influence of various depths of reduction of the abutment tooth on the fracture resistance of monolithic zirconia bridge in vitro, with the null hypothesis that the depth of tooth preparation of the abutment has no statistical influence on the fracture resistance of the monolithic zirconia bridge

Materials and Methods: Abutment Tooth preparation is done on phantom teeth no 45 and 47 with the below mentioned depths. Casts are made from the impressions and 5 bridges for each group are manufactured using CAD/CAM. All the 15 bridges are cemented on respective metal dies using glass inomer cement and tested on an Instron testing machine for fracture resistance. The results are tabulated and statistically analyzed.

Results: The statistical analysis (ANOVA) of this research showed that there is significant difference between mean resistance scores among the three groups. Furthermore, LSD post hoc test revealed that the mean resistance score for group 3 is significantly higher than both group 1 and 2. There was no statistically significant difference in resistance scores between group 1 and group 2.

Conclusion: Within the limitations of this study, the following conclusions can be drawn:

1.The depth of tooth preparation of the abutment has significant influence on the fracture resistance of monolithic zirconia crowns and bridges, with 2mm occlusal reduction displaying the best possible fracture resistance strengths.

2.The monolithic zirconia bridge made over the tooth preparation of the abutment with 0.5mm of reduction circumferentially, showed a significantly lower fracture resistance and might exhibit fractures during mastication.

3.The monolithic zirconia bridge made over the tooth preparation with 1mm of occlusal reduction of the abutment performed slightly better than that of 0.5mm reduction but is still significantly weaker than that of 2mm occlusal reduction.

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INTRODUCTION

Zirconia (stabilized zirconium dioxide (ZrO2) has become widely used as a dental ceramic material for full coverage crowns and bridges (Vagkopoulou *et al*., 2009).

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All-ceramic constructions initially gained popularity due to both their biological and aesthetic properties. Zirconia is an oxide ceramic and natural compound of the element zirconium that occurs in nature. It has a principal crystalline phase, has high fracture toughness and is considered as biocompatible. It is currently the strongest available dental ceramic (Denry *et al*., 2008; Manicone, 2007). The fracture resistance of zirconia comes from its ability to control crack propagation by means of crystalline phase transformation (I.e. transformation toughening) (Hannink, 2000; Giordano *et al*., 2008). Ceramic crowns made of zirconia can be constructed with an inner core of zirconia and an outer layer with sintered porcelain as for ordinary metal-ceramic (MC) crowns. This will give the crown a good aesthetic appearance together with an assumed high mechanical strength (Long, 2012). The problem, however, has been fractures in the veneering porcelain due to adhesion difficulties between zirconia and the veneering material (Kim, 2013; Zahran *et al*., 2008). During the past few years manufacturers have developed a monolithic zirconia for fixed dental prosthesis (FDP) system utilizing a tooth-colored zirconia. In this system, full ceramic restorations of zirconia without the veneering porcelain are fabricated using a dental CAD/CAM system for the process in total without the adhesion difficulties between the zirconia and the veneering porcelain. The aesthetic properties of monolithic zirconia are however poorer as compared to zirconia cores with veneering porcelain. This may be due to the fact that monolithic zirconia crowns are fabricated as one homogenous color (Long, 2012). Even though zirconia has a high fracture toughness on its own, the preparation of the tooth is still of importance for the stress state within the crown-tooth complex (Sharhbaf, 2013). An adequate preparation will give higher mechanical retention to the zirconia crown & bridge and decrease the risk of breakage, especially in the posterior part where the bite forces are higher. Recommendations are therefore given by the manufacturers concerning preparation and minimal requirements concerning removal of tooth substance. The following are the Tooth Preparation Guidelines for a zirconia crown and bridge by the dental advisor (John).

- Uniform, circumferential, toothreduction of1.0-1.5mm
- circumferential chamfer
- occlusal reduction of 2 mm

Rounded line angles

Under clinical circumstances, it can be challenging for a dentist to achieve an adequate tooth preparation, which is essential for the long-term success of fixed dental restorations. Winkelmeyer C, *et al* in their research stated that 92.5% of the tooth preparation done by the general dentist did not meet the clinical requirements for adequate zirconia-based tooth preparations [(11)]. Under reduction of the occlusal surface of the tooth being prepared for a fixed partial denture is one of the most common mistake seen in general practice. It is generally considered that a zirconia crown needs less occlusal reduction than metal ceramic crowns. The reason behind this belief is that zirconia is stronger than cobalt chromium and we don't need an opaque layer over the zirconia (Winkelmeyer *et al*., 2016).

The Aim of the Study

Was to investigate the influence of various depths of reduction of the abutment tooth on the fracture resistance of monolithic zirconia bridge in vitro with the null hypothesis that the depth of tooth preparation of the abutment has no statistical influence on the fracture strength of the monolithic zirconia bridge tested.

MATERIAL AND METHODS

Tooth Preparation

- 3 putty indexes of the phantom jaw in the 4th quadrant are made with Express STD Putty Impression Material 3m Espe polyvinyl siloxane. Two putty indices are sectioned mesiodistally and labioligually in certain areas and used later, to measure the depth of preparation by means of a Vanier calliper,
- Tooth preparation is done with tapered diamond rounded end burs 0.5 , 1 and 1.5 mm diameter and metal round cutting carbide burs for initial grooves in preparation in 0.5 , 1 and 2 mm diameter on phantom teeth (A5A-500, NISSIN, Kyoto, Japan) no 45 and 47 with the following depths
- After the tooth preparation is done, the third putty index is used to prepare a temporary crown with Success CD temporary crown and bridge material in cartridges and the thickness of each temporary crown is verified with a metal calliper "Iwanson Spring Caliper" to comply with the proposed depths. The measurements and fine adjustments of the abutment teeth were repeated until the defined reductions were obtained.
- The final models ware impressioned with 3M ESPE Empress light body and putty and used as master models.

Table 1.

Group	Occlusal reduction	Axial reduction	Margins (chamfer)
1	0.5mm	0.5mm	0.5mm
2	1mm	1mm	1mm
3	2mm	1.5mm	1mm

Manufacturing of The Monolithic Zirconia Bridges

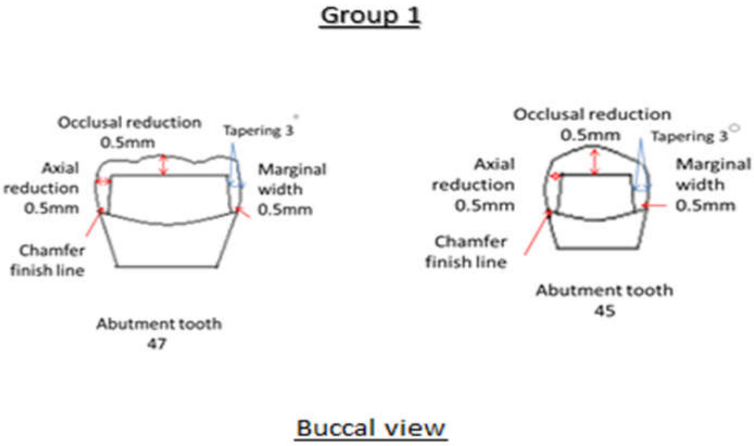
- For the production of the monolithic zirconia crowns, the models ware scanned using a 3d scanner (D-800, 3SHAPE). The occlusal surface and other surface design of the crown was determined by scanning of a non-prepared tooth model. This procedure enabled to fabricate the monolithic zirconia crowns with the same outer surface design and to get the accurate maximum intercuspation.
- The monolithic bridges have been designed using FPD prosthetic option in the CAD/CAM software (dental system 2016, 3shape) following the basic principle of FPD designing. The cement space was fixed at 70 µm for all samples according to the default setting of the CAD software. The data of the bridge design was exported and milled with 4-axix milling machine (Cynoprod, Canada) with the shade of B1. The thickness of the retainers is tested with a metal caliper to match with the proposed thickness. 5 such bridges are made for each group.

Preparation of Metal Dies and Testing Tool Attachment

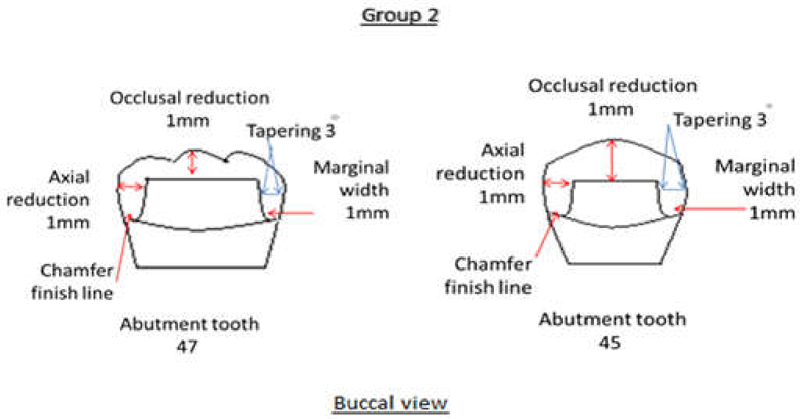
- Putty wash impressions of the three prepared models and the opposing arch are used to make wax patterns.
- The wax pattern of the opposing dentition is modified to fit into the testing tool receiver of the Instron testing machine, and then casted into a metal die.
- The wax patterns of the prepared models along with the zirconia bridge are placed over the Instron testing machine, aligning the wax pattern to obtain a good intercupation of the opposing arch metal die. These wax patterns are casted into Metal dies.

Testing the Bridges for Fracture Resistance

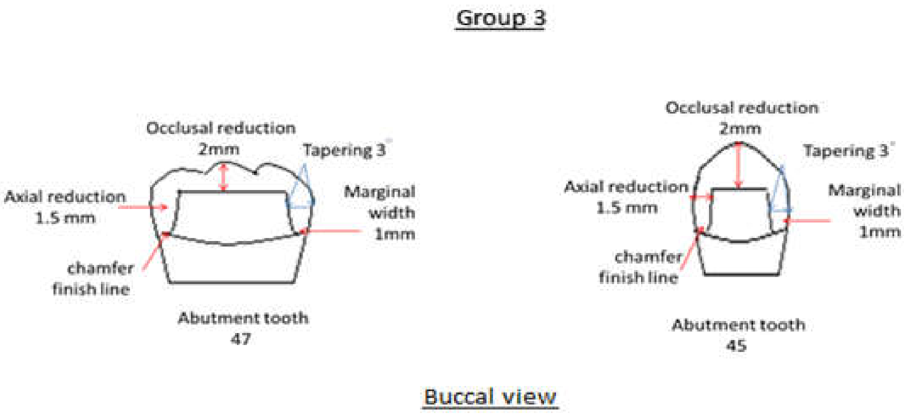
Each zirconia bridge is cemented to the metal die with glass-inomer cement and fixed on the Instron testing machine



Diagrams 1.



Diagrams 2.



Diagrams 3.

Diagram 4.

Diagram 5.

Diagram 6.

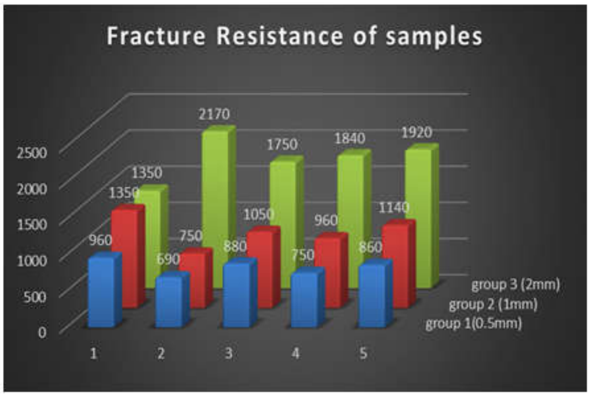
Diagram 7

against the opposing teeth metal die attached to the upper component of the machine. The upper and lower teeth are aligned in maximum intercuspation and a compressive force is applied by the testing machine. The load is slowly and continuously increased until the zirconia bridge fractures. The reading of the load just before the fracture is noted. This procedure is repeated with all the samples performed to compare the groups in pairs. The raw data of all the three groups are entered on an excel sheet and the mean and standard deviation calculated. The test of significance is done using ANOVA test. The level of significance was set to 5%. Further, LSD post hoc test is

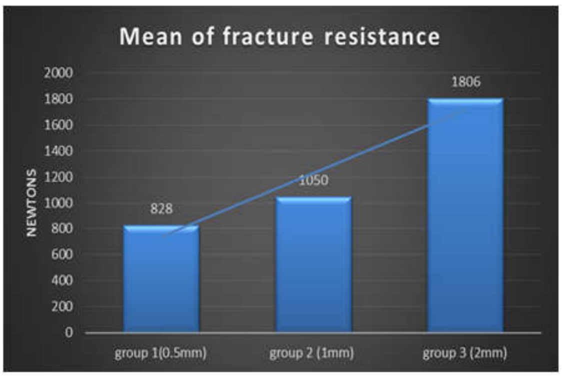
RESULTS

Table R1 shows that there issignificant differences between mean resistance scores among the three groups [F (2, 12) =26.280, p=0.0000]. Furthermore, LSD post hoc test revealed that the mean resistance score for group 3 is significantly higher than both group 1 and 2. There was no statistically significant difference in resistance scores between group 1 and group 2. (Table R 2)

Diagram 8



Graph 1



Graph 2

Table 2.

Groups	Group 1	Group 2	Group 3
Occlusal reduction	0.5mm	1mm	2mm
Axial reduction	0.5mm	1mm	1.5mm
Margins (chamfer)	0.5mm	1mm	1mm

Table R1

Groups	Number	Mean	SD	df	F	F-crit	P=Value
Group 1	5	828	107.563	2	26.280	3.8852	0.0000*
Group 2	5	1050	221.472				
Group 3	5	1806	299.048				

**Significant at 5% level of significance*

Table R 2

Post Hoc Comparison	P=Value
Group1 to Group2	0.1425
Group1 to Group3	0.0000*
Group 2 to Group 3	0.0000*

**Significant at 5% level of significance*

DISCUSSION

The null hypothesis of the present study was that the depth of tooth preparation of the abutment has no statistical influence on the fracture strength of a monolithic zirconia bridge. The results from this study showed that the hypothesis was rejected; there was statistical evidence showing influence of the depth of the abutment tooth preparation on the fracture resistance. According to a research done in the university of leads, The occlusal thickness of CAD-CAM monolithic zirconia crowns did not influence either the fracture resistance and the mode of failure of the restorations; the occlusal thickness of CAD-CAM monolithic zirconia crowns can be reduced up to a lower bound of 0.5 mm keeping a sufficient strength to withstand occlusal loads; CAD-CAM monolithic zirconia crowns showed sufficient fracture resistance to be used in molar regions, even in a thin configuration (0.5 mm) (12). Contrarily, our research showed that the zirconia bridge made over 0.5mm thick circumferential preparation was inferior in strength in comparison to 1mm and 2mm thickness. The force generated during routine mastication of food like carrots or meat is about 70 to 150 Newton (16 to 34 lbf). The maximum masticatory force in some people may reach up to 500 to 700 Newton (110 to 160 lbf). [13] Some of the fracture resistance values recorded in group 1 (circumferential 0.5mm reduction) are close to the maximum masticatory forces. This finding indicates that there are chances of fracture of the zirconia bridge during mastication. There have been a lot of contradictory recommendations in relation to the tooth preparation designs for zirconia crowns and bridges.

One of the manufacturers of zirconia, (Bruxzir) recommended the following Preparation requirements for its Crowns & Bridges (14):

- *Shoulder preparation not needed, feather edge is OK.*
- *It is a conservative preparation similar to full-cast gold, so any preparation with at least 0.5 mm of occlusal space is accepted.*
- *Minimum occlusal reduction of 0.5 mm; 1 mm is ideal.*

“The Dental Advisor” recommended the following technical guidelines for zirconia crowns and bridges:

- Uniform, circumferential, tooth reduction of 1.0-1.5 mm
- Circumferential chamfer
- occlusal reduction of 2 mm
- Rounded line angles (John *et al*.,).

Findings in our research support the recommendations of "The Dental Advisor".

Based on the results of study by Beuer F, a shoulder preparation is highly recommended by virtue of fracture resistance whenever possible (Beuer *et al*., 2008).
In contrary, According to Aboushelib MN, The finish line design did not influence the fatigue or the fracture resistance of veneered zirconia crowns. Selection of any of the finish line designs should be based on the clinical condition of the restored tooth [16]. However in our research, a circumferential chamfer was used for all the groups. Contradictory recommendations such as mentioned above by various researcher suggests that there is a need to extensively evaluate further into the subject. One of the limitations with this type of study was, it is difficult to reproduce a clinical situation in an in-vitro study (Nakamura *et al*., 2014; Kelly, 1999). According to Kelly, traditional failure tests of single unit all-ceramic prostheses are inappropriate because they do not mimic the clinical situation to a satisfactory degree. In a clinical situation, the cyclic load over time (fatigue) will result in fracture of the crown (Kelly, 1999). The direction of forces over the teeth is oblique as well as vertical. It has also been proposed that the presence of saliva will be of importance in crack propagation over time leading to fatigue failure. In the present study the crowns were not subjected to such environment and will not properly reflect a clinical situation [19, 20]. Moreover, the aim of the present study was not to test the aging of the bridge but to test the importance of depth of tooth preparation for fracture resistance of monolithic zirconia bridge under standardized conditions. Another limitation of our research is that the sample size is small and continuation of the research with increased sample size is indicated.

One of the strengths of the present study was that equal conditions were ensured for all the crowns in the test, thus eliminating bias. There have been a lot of in-vitro studies in relation to a single crown; our research is focused on similar parameters in a posterior bridge. This is particularly important because of present day increase in the usage of zirconia for posterior bridges.It is difficult to achieve high clinical relevance in an in vitro study. A lot of factors will be of importance in deciding whether a study has clinical relevance or not. Some of these factors have been discussed above. Even though not all of them have high relevance compared to a clinical situation, the present study may have indicated how the tooth-crown complex will react in a clinical situation.

Conclusion

Within the limitations of this study, the following conclusions can be drawn

- The depth of tooth preparation of the abutment has significant influence on the fracture resistance of monolithic zirconia crowns and bridges, with 2mm occlusal reduction displaying the best possible fracture resistance strengths.
- The monolithic zirconia bridge made over the tooth preparation of the abutment with 0.5mm of circumferential reduction showed a significantly lower fracture resistance and might exhibit fractures during mastication.
- The monolithic zirconia bridge made over the tooth preparation with 1mm of occlusal reduction of the abutment performed slightly better than that of 0.5mm reduction but is still significantly weaker than that of 2mm occlusal reduction.

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