AL-AZHAR
Dental Journal
For Girls

The Official Publication of The Faculty of Dental Medicine For Girls, Al-Azhar University Cairo, Egypt.

Print ISSN 2537-0308 • Online ISSN 2537-0316

ADJ-for Girls, Vol. 9, No. 4, October (2022) — PP. 555:561

The Influence of Different Implant Abutment Sizes on Fracture Resistance of Two Monolithic Ceramic Crown Systems

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Codex : 01/22.10

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http://adjg.journals.ekb.eg

DOI: 10.21608/adjg.2022.74968.1360

Restorative Dentistry
(Removable Prosthodontics, Fixed Prosthodontics, Endodontics, Dental Biomaterials, Operative Dentistry)

ABSTRACT

Purpose: to study the effect of different implant abutment sizes on fracture resistance of two ceramic monolithic crown systems. **Material and Methods:** Research Ethics committee approval of faculty of Dental Medicine for Girls was obtained (REC18-065). Forty (40) Titanium implant supported abutments were fabricated and divided into2 groups (n=20 each) according to abutment diameter; Group (1): implant abutment diameter 4mm and Group (2): implant supported abutment diameter 4.5mm. Samples of each group were divided into 2 sub-groups (n=10 each) according to type of monolithic ceramic crowns. Subgroup(A): zirconia ceramic crowns, Subgroup(B): vita suprinity crowns. All crowns were cemented to implant abutments by Rely X resin cement, then subjected to thermal cycling and seated on a universal testing machine and subjected to fracture resistance test. Data were statistically analyzed**. Results:** It was found that the highest mean ± SD values of fracture resistance were recorded for large diameter Zirconia subgroup (1032.2±174.78 N) followed by large diameter Vita suprinity subgroup mean ± SD values (935.7±83.71 N) then small diameter Zirconia subgroup (930.3±69.53 N), meanwhile the lowest mean ± SD values were recorded with small diameter Vita suprinity (815.9±101.52 N). **Conclusion:** The mean fracture values of zirconia were higher than that of vita suprinity crowns, while the crowns were supported on large implant abutment diameter had higher fracture resistance than that supported on smaller implant abutment diameter.

KEYWORDS

Fracture Resistance, Implant Abutment Diameter, Monolithic Ceramic Crowns

INTRODUCTION

Its biocompatibility and mechanical properties are well-documented, implant abutments are always made of commercially pure titanium[(1)]. The dental implant market offers a wide range of abutment materials

- Paper extracted from thesis titled " Fracture resistance of implant supported all ceramic zirconia-lithium disilicate crowns "

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and designs, but the biggest challenge for clinicians is understanding the mechanical and biological responses of each material, as well as the best indications for using each type to achieve harmonious crown integration in the dental arch[2].

The implant design (material, structure, and dimensions) has a big impact on the implant's stability and the stresses generated in its surrounding bone[3]. In the instance of two-stage implantation, implant diameter was found to be more relevant than implant length in transferring stresses to the surrounding bone[4]. Wider implants may allow more surrounding bone to be engaged, which enhances both structure stability and the pattern of induced stress distribution[5]. The implant abutment's fracture strength is said to rise as the implant diameter increases[6].

With the CAD/CAM process, zirconia was introduced for restoration manufacturing in prosthetic dentistry[7-10]. Different methods for fabricating all-ceramic restorations were used, but with the integration of engineering technology in the dental field, a new window of accuracy has opened with the use of CAD/CAM systems to obtain a natural-looking restoration that can harmonies with adjacent natural teeth[11].

Monolithic zirconia restorations, which are only made using CAD/CAM technology, have several advantages: they have high flexural strength, require more conservative dental preparation, minimize antagonist wear, have acceptable aesthetics, require less laboratory time and fewer dental sessions, and because they are monolithic, they do not have the unwanted complication of chipping. opaque and translucent zirconia are the two forms of monolithic zirconia materials. Translucent zirconia provides more natural aesthetic properties, giving scientists a wide range of coloring and characterization options[12].

Over the last ten years, zirconia and high-strength glass-ceramics (e.g., lithium disilicate) have been well-established and clinically used in prosthodontics and restorative dentistry.

The fundamental motivation for the creation of zirconia-reinforced lithium silicate (ZLS) is that zirconia has a high strength of around 1000 MPa and a high strength glass ceramic in the range of 360 MPa–400 MPa, allowing it to be used safely in a variety of applications. The full potential of these materials is covered by CAD/CAM technology. ZLS's exceptional qualities are due to its distinct microstructure. The presence of 10% zirconia in the glass phase in atomically dissolved form ensures that restorations are strong, safe, and long-lasting. The zirconia is primarily responsible for the crystal phase nucleation[13].

The use of 10% zirconium oxide ensures a very high level of strength. The crystallites generated are 4–8 times smaller than standard lithium disilicate crystals. The outcome is an ultra-fine microstructure with a high glass content and high average flexural strength. This has a significant impact on the material's optical and mechanical properties. For a satisfactory clinical prognosis of all-ceramic, fracture resistance within a safety range should be necessary. The ceramics' fracture behaviour should be assessed for lifetime and to estimate the likelihood of failure[14].

The study's goal was to see the effect of different sizes of implant abutment on fracture strength of two monolithic ceramic crown systems.

MATERIAL AND METHODS

Forty titanium implants with 4.3 mm diameter and 11.5 mm length (J Dental Care s.r.l. Italy) were used in the current study. Titanium abutments (J Dental Care s.r.l. Italy) representing maxillary first premolar were tightened to their corresponding implants according to their manufacturer's recommendations. Thereafter, all implants with their respective abutments were embedded in upright position inside special specimen holders filled with epoxy resin (CMB. International, Egypt) using dental surveyor, (Fig.1). Epoxy resin had a modulus of elasticity of approximately 12 GPa, which approximates that of human bone 18 GPa[15].

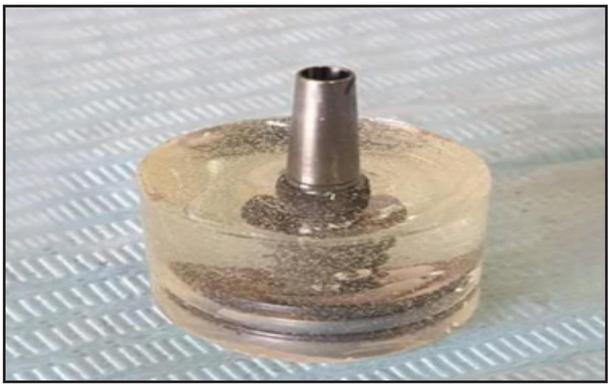

Figure (1) Implant and implant abutment embedded in epoxy resin

All samples were divided in to 2 groups (n=20) according to abutment diameters. Group 1: 20 samples of implant supported abutments with diameter 4mm. Group 2:20 samples of implant supported abutments with diameter 4.5mm. Samples of each group were divided into two sub groups (n=10) according to type of monolithic ceramic crowns superastructure: Subgroup (a):10 monolithic Katana zirconia ceramic crowns. Subgroup (b):10 Vita Suprinity crowns. In subgroup (a), Roland machine "DWX-510" was used to mill the Zirconia disc after the abutment scanning was completed. The zirconia disc was cut and milled, and then the milled crowns were finally sintered. In subgroup (b), Serona MCXL machine was used to mill Vita Suprinity disc, then the milled crowns were sintered in programate p310 furnace(Fig.2). The crowns were then finished and glazed.

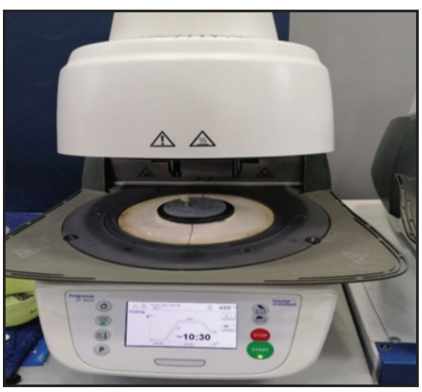

Figure (2) Programmat (p310) furnace showing crystallization s of Vita suprinity crown

Cementation procedure

Self-curing resin cement (Rely X Unicem resin cement) was used to bond the restorative crowns to their abutments after the following:

1. Sandblasting the fitting surface of the abutments
2. Sandblasting the fitting surface of zirconia crowns and application of zirconia primer.
3. Etching of the fitting surface of vita suprinity crowns by hydrofluoric acid and application of porcelain silane primer. Each sample was subjected to 3 kg weight in a load applicator then adhesive resin was light cured for 20 seconds for each crown surface.

All samples were treated to 5,000 heat cycles of 5˚C and 55oC after 24 hours of cementation, with a 30 second dwell time at each temperature. After that, each sample was placed in the Universal testing machine's lowest fixed compartment (Model 3345; Instron Industrial Products, Norwood, USA).

A metallic rod with round tip (3.6 mm diameter) attached to the upper movable compartment of the machine was applied at the middle of the occlusal surface of the crowns, with tin foil sheet in-between to achieve homogenous stress distribution and minimize transmission of local force peaks. The samples were subjected to a slowly increasing load (1mm/ min). When the crown fractured, the maximum load was recorded. And failure modes of all samples were investigated.

RESULTS

Descriptive statistics showing mean values and standard deviation of fracture resistance test results measured in Newton (N) as function of material groups and thermal aging are summarized in table (1) and graphically drawn in (Fig.3).

The highest mean values (±SD) of fracture resistance were recorded for large diameter Z_ subgroup (1032.2±174.78 N) followed by large diameter S_ subgroup mean ± SD values (935.7±83.71 N) then small diameter Z_ subgroup

(930.3±69.53 N) meanwhile the lowest mean ± SD values with small diameter S_ subgroup (815.9±101.52 N) was recorded.

Table (1) *Fracture resistance test results (Mean±SD) as function of material groups and thermal aging*

Variables			Descriptive statistics			t-test
			Mean±SD	95% confidence intervals		P value
				Lower	Upper	
Material group	S_group	Large	**935.7^{B}**±83.71	886.1	985.3	0.019*
		Small	**815.9^{B}**±101.52	732.3	899.5	
	Z_ group	Large	**1032.2^{A}**±174.78	959.7	1104.6	0.013*
		Small	**930.3^{B}**±69.53	893.3	967.4	
ANOVA test		P value		0.0007*		

Different superscript large letter in the same column indicating statistically significant difference (p < 0.05)
; significant (p < 0.05) ns; non-significant (p>0.05)

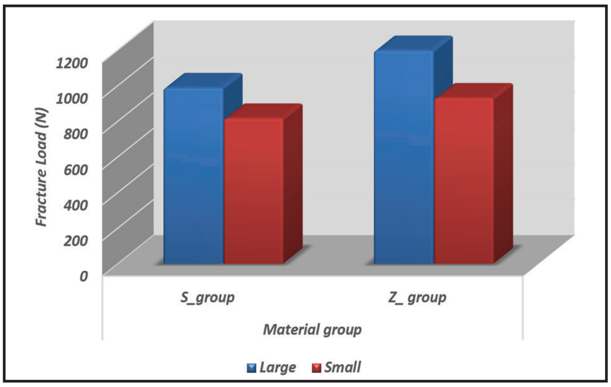

Figure (3) Column chart showing the mean values of fracture resistance for all groups after thermal aging protocols

Analysis of fracture failure mode:

Samples were examined after fracture to determine the failure type occurred in this study using magnification lens(x=15). The type of failure was assigned according to the following tables (2,3) and (Fig.4).

Table (2) *Classification of failure modes*

Repairable	Fracture restoration only
Catastrophic	Fracture restoration and abutment

Table (3) *Frequent distribution of failure modes recorded for both **groups***

Material subgroups		Groups			
		Small diameter		Large dimeter	
		Repairable %	Catastrophic %	Repairable %	Catastrophic%
KATANA Zirconia		100	0	80	20
VITA SUPRINITY		100	0	100	0
Chi square test	X^2		22.22		
	P value		<0.0001*		

**; significant (p < 0.05) ns; non-significant (p>0.05)*

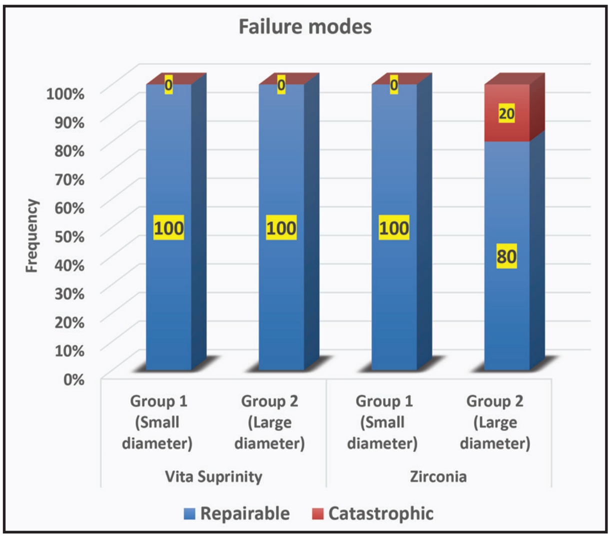

Figure (4) Bar chart illustrating frequency distribution of failure modes recorded for both groups

DISCUSSION

Dental implants have demonstrated a great capacity for restoring the appearance and function of missing teeth. They also have a strong track record of success and longevity. Implant survival and success rates have been demonstrated over time[16].

Titanium implants and abutments were used in this investigation. Titanium is a metal with a number of appealing properties, including excellent corrosion resistance (nearly as good as platinum) and mechanical resilience[17].

All-ceramic materials have grown in favour as an alternative for metal-ceramic restorations because of their better aesthetics, with dental ceramics providing the most natural-looking replacement material for missing tooth substance. They are available in a variety of colours and translucencies for a realistic appearance, chemical stability, and biocompatibility[18] .

Because of its great flexural strength (1,000 MPa), complete contour zirconia crowns have become popular in recent years. These values exceed the maximum occlusal loads during normal chewing. Materials with a fracture resistance of more than 2,000 N are also possible[10]. Monolithic yttria-stabilized tetragonal zirconia has the advantages of tooth colour, minimum wear on opposing teeth, conservative tooth preparation, and the promise for outstanding long-term clinical performance[19]. Clinical performance has been great without layering porcelain, as long as tooth preparation is appropriate and the dental laboratory and clinical materials are treated correctly[19,20].

The innovative zirconia-reinforced lithium silicate glass-ceramics have excellent mechanical properties and a high aesthetic quality, making them a viable alternative to lithium disilicate ceramics for high-aesthetic prosthetic rehabilitations. The better polishability of the lithium silicate ceramic over the lithium disilicate variant is attributed to the smaller crystal sizes[21].

CAD/CAM systems have the ability to reduce method errors and infectious cross contamination risks. They enable the use of modern high-strength materials with good biocompatibility and mechanical strength, as well as provisions for aesthetic designs, excellent fit precision, and long-term durability. However, these benefits must be balanced against the high cost of CAD/CAM systems and the need for additional training[22].

In this study, full anatomical restorations were used because it has been reported that these may allow the restoration to behave in a manner that potentially represents the clinical situations[23].

In the current study, fracture resistance of zirconia crowns cemented on large implant abutment diameters ranged from 1032.2 N to 1206 N. While those cemented on small implant abutment diameters ranged from 930.3 N to 999.83 N. Meanwhile, fracture resistance of Vita Suprinity crowns cemented on large implant abutment diameters ranged from 935.7 N to 1019.41 N. While those cemented on small implant abutment diameters ranged from 815.9 N to 917.42 N. These findings are consistent with a previous study[24], which reported significant differences of fracture resistance with different sizes of abutment where largest abutment diameter had a fracture resistance higher than the smallest diameter of abutment. Also these findings are consistent with Jassim et al, (2018)[24] The fracture strength of monolithic crowns made from five different all-ceramic CAD/CAM materials was compared (lithium disilicate, zirconia, reinforced composite, hybrid dental ceramic, and zirconia-reinforced lithium silicate). Monolithic zirconia was shown to have the highest fracture resistance.

On examination of the fracture mode of different studied subgroups, it was found that the fracture was almost repairable in all samples except four samples from zirconia crowns with large implant abutments(catastrophic failure).

In this study, it was found that there were significant differences of fracture resistance among the 2 types of materials. Similarly, a previous study reported higher value of fracture resistance with monolithic zirconia[25].

The current study was not free of limitations; only diameter of implant abutment was considered, while the length of abutments was not considered which may have affected the final result.

CONCLUSIONS

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

1. All obtained fracture resistance values lie within the clinically accepted ranges.
2. Zirconia monolithic crowns have fracture resistance qualities superior to Vita Suprinity crowns when supported on implant abutments with similar diameter.
3. The larger implant abutment diameter improves fracture resistance qualities compared to smaller implant abutment diameter.

ACKNOWLEDGMENTS

I'd like to thank from the bottom of my heart. Dr. Mona Hossam El Din, Professor of crowns and bridges, faculty of Dental Medicine Al- Azhar University for Girls for the continuous support of my study and research .

RECOMMENDATIONS

It is recommended to perform further study on the effect of implant abutment length on fracture resistance of zirconia and suprinity crowns.

Declaration Statement

No fund was received for this study, and there was no conflict of interest during the course of the study.

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