EGYPTIAN DENTAL JOURNAL
www.eda-egypt.org

Vol. 71, 619:630, January, 2025

Print ISSN 0070-9484 • Online ISSN 2090-2360

Fixed Prosthodontics and Dental Materials

Submit Date : 11-12-2024 • Accept Date : 20-12-2024 • Available online: 10-01-2025 • DOI : 10.21608/edj.2024.331678.3245

FRACTURE RESISTANCE OF ULTRA TRANSLUCENT ZIRCONIA VERSUS LITHIUM DISILICATE IMPLANT SUPPORTED HYBRID ABUTMENT CROWNS TO TI BASE (AN IN-VITRO STUDY)

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ABSTRACT

Aim of the study: to construct implant supported titanium based hybrid abutment crown from traditional lithium disilicate block/ultratranslucent zirconia disc with the help of five axis milling machine and to compare the fracture resistance of the two material.

Materials and methods: A total number of 24 (implant with titanium base abutment) samples were made and divided into two groups :The first group received ultra translucent zirconia hybrid abutment crown (Z)**,** the second group received lithium disilicate hybrid abutment crown (L). All samples were exposed to a thermocycling and cyclic loading, to measure the strenght of the two materials crown samples were subjected to a static load in universal testing machine parallel to the long axis of the tooth using a metallic rod covered by aluminum foil to distribute the forces evenly till fracture of the specimen. The collected data were arranged in tabular form and statistically analysed.

Results: Implant supported ultratranslucent zirconia hybrid abutment crown showed significant higher fracture resistance (939.72 ± 70.99) than those of lithium disilicate hybrid abutment crown (874.88 ± 40.45) with (65.83 ± 23.59) difference as P=0.01, the results of both crowns showed readings above the clinical acceptable range(300-400N)

Conclusions: Ultratranslucent zirconia showed higher fracture resistance than lithium disilicate hybrid abutment crown.

KEYWORDS: Dental implants, CAD/CAM, five axis milling machine, cyclic load , thermocyclic load.

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INTRODUCTION

Implant-supported restorations have been proven to be a reliable option for replacing a single missing tooth, as indicated by their high success rates. Good osseointegration is not considered the only key for implant success but the ability of the crown to bear the functional load and being biocompatible are considered another keys for implant success[1]. The effectiveness of implant restorations is not solely determined by osseointegration and proper functioning, but also by the ability to achieve a realistic and seamless appearance of the replaced tooth. This, in turn, is heavily affected by the implant abutment and the crown materials [2]. In the past, implant abutments were commonly made from titanium due to its proven ability to be well-tolerated by the body and its strong mechanical features. However, the metal color of titanium abutments often had a negative impact on the appearance of the surrounding gum tissue [1]. Due to zirconia abutment good physical, mechanical and esthetics properties, so it can be used in the anterior esthetic zone, but zirconia abutments have some defects as connection part fracture, wear rapidly and its long-term performance is uncertain. So titanium bases have been used to get the benefits of being connection titanium-to-titanium and also to get a pleasing abutment. Many studies were concluded that using ti base with zirconia abutments offer a higher fracture resistance. Lithium disilicate can be used with titanium bases as hybrid abutments as it has high translucency and also good mechanical properties [3]. To be used with dental implants two possible designs can be used: separate crown can be cemented on the bonded abutment to the titanium base, which is secured onto the implant, or one piece hybrid-abutment-crown, which includs making the abutment and crown as one unit that is cemented to a titanium base and then finally secured onto the implant [3]. Originally mesoblocks made of ceramic are uniquely designed for implant abutments, with a ready made hole specifically created for cementing and fitting onto a customized ti base with the help of using a CAD/CAM system. The connection between the ti base and crown is distinguished by its ability to prevent rotation[4]. Lithium disilicate blocks which were introduced in the market as IPS-Emax CAD mesoblock being precrystallized and have a perforation to get a good fit with the titanium base, so with the chair side cad-cam system, the single layer implant-supported restorations can be fabricated [5]. but unfortunality this mesoblocks not always available for lithium disilicate and not available for zirconia. Fabrication of hybrid abutment crown with customized access hole can be done with help of five axis milling machine through which customized hole can be fabricated especially for zirconia which have no ready made hole blocks.

SUBJECTS AND METHODS

Specimens' preparation

24 titanium dummy implants (Neo CMI implant, NeoBiotech,korea) with 4 mm diameter and 10 mm length, A specially constructed split copper cylindrical mold of dimension (20×20mm) was used for placement of implant in resin block, The implants were held during fabrication of the models and was centrally inserted in by the help of a specifically made parallelometer to be side by side with the outer surface of the tube.

An epoxy resin material (Kemapoxy 150, CMB International, Egypt) was balanced and blended according to the producer instructions then placed in the copper tube around the implant till reaching to the first thread to mimic the vertical resorption of bone accured around the implant[6]. For 24 hours, the specimen was left till the polymerization process of the epoxy resin completed then it was removed from the copper tube.

The 24 implant specimens were haphazardly splitted into two groups (n=12 each) based on the material of the hybrid abutment crown used, Group I: Yttria -stabilized tetragonal zirconia polycrystalline (Y-TZP) (Katana zirconia), Group II: Lithium-disilicate glass ceramic (IPS e.max CAD). All the hybrid abutment crowns were CAD/CAM manufactured in the form of single layered upper right first premolar.

A plastic implant level intraoral scan body (Neobitech, korea) corresponding to implant company was screwed to the implant then the assembly was scanned by using an extra oral scanner (Medit T310 scanner,korea), after checking the scan clarity, the data produced by the manufacturers were stored by the help of the computer software.

A 3D virtual cast was formed on the computer screen, and the design was done using software (Exocad software, Germany). The margins and finish line of titanium base were detected and the insertion path was detected. The cement space was set to be (30 μm) [5]. On design window adjusting the bucca, lingual, mesial and distal dimensions and cusp height of the crown outline were performed. An outline of a upper first premolar was formed; height: 8.5 mm, buccal/lingual width: 9 mm, mesio-distal width: 7 mm[7]. **(Figure 1)**

Each finished form was then sent as an STL file to CAM (Computer-Aided Manufacturing) software .Each form was used to produce one hybrid abutment crown from IPS e.max CAD block (LT A3 C 14) and one hybrid abutment crown from Ultra translucent multilayered pre-sintered zirconia disc (A3 T14 Collar) using a high accurate five axis milling device (Roland milling machine, Japan) (Coreitec 350 milling machine, Germany), resulting in 24 hybrid abutment crowns, for each group ($n=12$). IPS e.max CAD hybrid abutment crowns (Group L) were manufactured under wet condition according to the fabricator's instructions, while Ultra translucent multilayered zirconia hybrid abutment crowns (Group Z) were milled dry to be 25% bigger than the required final size for the samples based on the fabricator's recommendations as during the process of sintering some shrinkage accur to the restoration so it must be compensated[8]. **Figure(2)**

Zirconia restorations were sintered in zirconia sintering furnace (Tabeo-1/M/Zirkon-100, Blankenloch, Germany) and lithium disilicate restorations were exposed to crystallization firing in porcelain furnace (P310 Programat, Ivoclar Vivadent, Zurich, Switzerland) based on fabricator's recommendations.

The sintered crowns were finally checked on their corresponding titanium base before cementation.

A permanent marker was used to place a mark on the mid labial surface to check that crown seated in its original position during cementation.

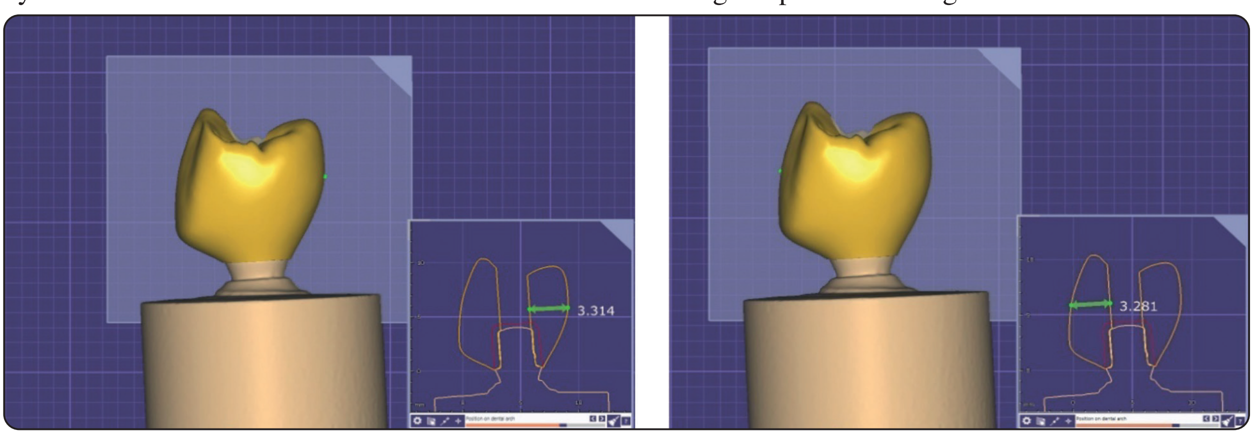

Fig. (1) Hybrid abutment crown design

Fig. (2) The customized milled hole

Cementation

1. Surface treatment of zirconia

The sintered zirconia hybrid abutment crowns were prepared for cementation by sanblasting the inner fitting surface of the crown with 50 μm $Al_2 O_3$ particles at 1 bar pressure , the outer surface of the ceramic crown should be covered by modelling wax to be saved during sandblasting process, then the wax was removed and the restoration was cleaned in distilled water ultrasonically [9] The abraded bonding area was conditioned with a universal primer containing MDP(Z-Prime, Bisco, USA) which was left to react for 60 seconds then air dispersed.

2. Surface treatment of IPS emax CAD

The IPS e max CAD hybrid abutment crowns fitting surfaces were exposed to hydrofluoric acid 9.5% acid etching (Porcelain etchant, Bisco, USA) for 20 seconds, then it was removed with water and air dispersed.

A ceramic silane (Bisco Porcelain Primer, USA) was placed on the treated fitting surfaces of IPS e max CAD crowns and then left to react for 60 seconds then air dispersed.

3. Surface treatment of ti base

The titanium bases were sandblasted using 50 µm aluminum oxide at 2.0 bar and then air washed[10] . The ti base hole was sealed with a teflon and temporary filling material. Universal primer (Z prime, Bisco, USA) was placed to the ti base outer surface and left to react for 60 seconds and smoothly air dry [10].

An auto-mix dual cure self adhesive resin cement (Nova, IMICRYL, turkiye) was placed to the pretreated bonding inner surfaces of all crowns.

At the cement margin line and at the screw hole the excess cement was removed by using of microbrush and Glycerin gel was used to be placed at the cement joint and was left till complete polymerization, it was used to avoid the oxygen inhibited layer formation and left till complete polymerization. Excess cement that was formed at the cement joint was light cured by LED curing unit (Woodpecker RTA,china) for two seconds then it was removed by using dental explorer. Finally, the screw access hole of the hybrid abutment crown was filled utilizing composite resin[11]

Then the samples were exposed to thermocyclic loading. Based on ISO standards 13356:2015, hydrothermal aging was accured in an autoclave at 134ºC, 2 bar steam pressure for 5 hours [12].

Hybrid abutment crown samples were subjected to cyclic load. Mechanical aging was done using a programmable logic controlled device, the newly designed four stations multimodal ROBOTA masicatory simulator (Model ACH-

09075DC-T, AD-TECH TECHNOLOGY CO., LTD., GERMANY) blended with thermal and cyclic protocol worked on servomotor. The samples were placed in teflon housing in the lower sample then a mass of 10 kg which is close to a force of mastication of 98 N was introduced. The study was duplicated 75,000 times to mimic the 6 months intra oral masticatory cycle [13]

Finally, load till fracture test was performed. These tests were achieved utilizing Bluehill Lite Software from Instron. Fracture study was made by applying a compressive load from occlusal direction by using a metallic bar with spherical tip (3.6 mm diameter) connected to the upper movable part of testing machine moving at a speed of 1mm per one minute with a sheet made of tin of thickness 1 mm between the specimen and the metallic bar to get even force distribution and decrease the transmission force peaks locally[14]. The force at which fracture accured is detected by a detectable fissure and can be checked by a large fall at load/ deflection arc recorded by using computer software. The force needed till failure was recorded in Newton. **(figure 3)**

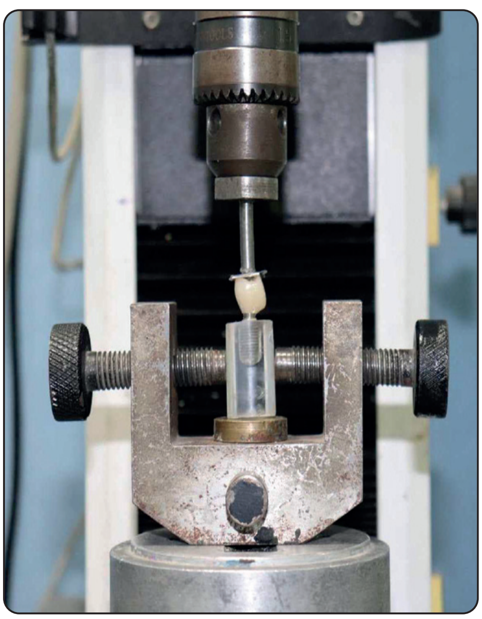

Fig. (3): Universal testing machine

Each failured specimens was detected visually and the way of failure for each specimen was detected. Furthermore, the abutment mobility and any plastic distortion accurs at the implant cervix were detected. The crowns in our study failured with catastrophic cohesive failures in the ceramic, mesiodistally splitting the crown into buccal and palatal parts, eventhough the ti base still undamaged. Regularly one part still attached to the ti base.

RESULTS

The results were analyzed using SPSS 20®, Graph Pad Prism® and Microsoft Excel 2016. All quantitative data were explored for normality by using Shapiro Wilk Normality test. Exploration of the given data was performed using Shapiro-Wilk test and KolmogorovSmirnov test for normality which revealed that the significant level (P-value) was shown to be insignificant as P-value > 0.05, which indicated that alternative hypothesis was rejected, and the concluded data originated from normal distribution. (Mean±SD) for both groups were summarized in **table (1,2)** and **figure (4,5)**

TABLE (1) Descriptive results of Group 1 (Ultra translucent zirconia abutment hybrid crown) fracture resistance:

Group 1 Ultra translucent zirconia abutment hybrid crown		
Mean		939.72
95% Confidence Interval for Mean	Lower Bound	894.61
	Upper Bound	984.82
Median		960.26
Std. Deviation		70.99
Std. Error		20.49
Minimum		830.00
Maximum		1023.10
Range		193.10
Interquartile Range		117.76

TABLE (2) Descriptive results of Group 2 (Ultra Lithium disilicate hybrid abutment crown) fracture resistance

Group 2 Lithium disilicate hybrid abutment crown		
Mean		874.8867
95% Confidence Interval for Mean	Lower Bound	849.1846
	Upper Bound	900.5887
Median		880.1150
Std. Deviation		40.45212
Std. Error		11.67752
Minimum		821.40
Maximum		928.18
Range		106.78
Interquartile Range		79.21

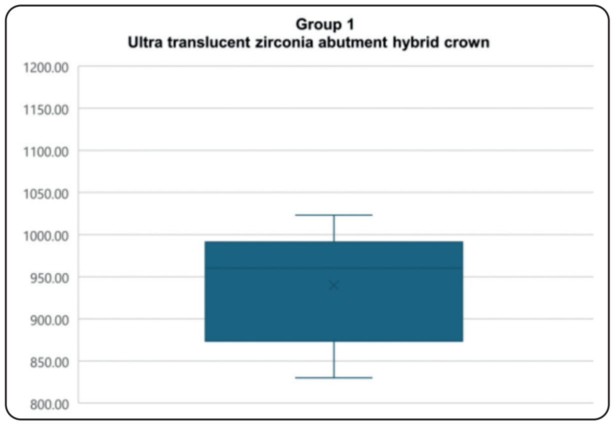

Fig. (4): Boxplot representing fracture resistance of Group 1 (Ultra translucent zirconia abutment hybrid crown)

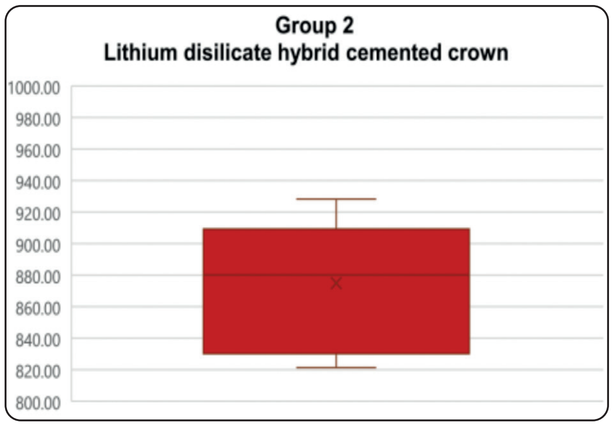

Fig. (5): Boxplot representing fracture resistance of Group 2 (Lithium disilicate hybrid abutment crown).

Analytical results:

Mean and standard deviation of fracture resistance of group 1 and 2 and comparison between them using Independent t test were presented in **table (3)** and **figure (6).** Comparison between them demonstrated that group 1 (939.72 ± 70.99)_ was significantly higher than group 2 (874.88 ± 40.45) with (65.83 ± 23.59) difference as P=0.01.

TABLE (3) Fracture resistance of group 1 and 2 and comparison between them using Independent t-test:

	Mean	St. Deviation	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference		P value
					Lower	Upper	
Group 1	939.72	70.99	64.83	23.59	15.91	113.75	0.01”
Group 2	874.88	40.45					

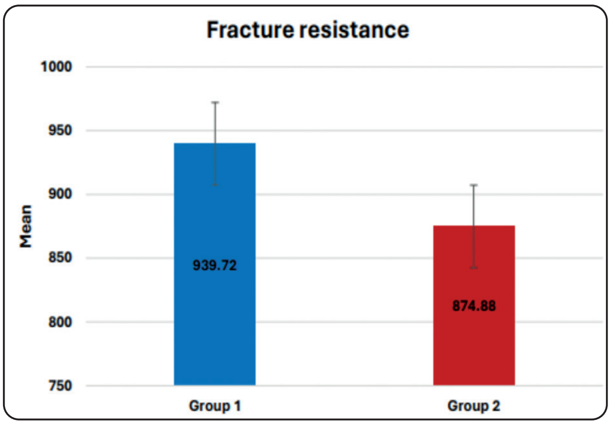

Fig. (4) Boxplot representing fracture resistance of Group 1 (Ultra translucent zirconia abutment hybrid crown)

DISCUSSION

Implant-supported crowns are mostly considered as a good option to replace missing teeth. It acts as an important factor in fixed prosthodontics treatment to achieve high rate of survival clinically and patient acceptance for long period of time. [15] Implant abutments are considered the key to the functional and esthetic aspects of implant treatment. They have a direct effect on the long-time prognosis of implant supported prosthesis, as by creating an appropriate emergence profile the harmony between the implant, soft tissue and the final crown could be found. [16]

Titanium abutments are considered the basic abutment used responsible for long term survival of the implant supported prosthesis treatment modility in all regions of the jaw, as they have high mechanical properties, but they may affect the esthetic result of implant restorations especially with thin gingival biotype [17] Ceramic abutments made out of the ceramics of high strength such as zirconia could replace titanium abutment [18]

Zirconia which is used for abutments is polycrystalline ceramics which is considered a strong and very tough material that makes crack propagation is not easy in comparison to glass ceramics with its non regular network. Compared with the grayish color of titanium abutments, the zirconia abutments white color provides good esthetics result. However, zirconia is more opaque, making natural translucency achievement of tooth is difficult. So, lithium-disilicate abutment has been used instead of using zirconia abutment as lithium-disilicate abutment have proven to be more esthetic than the whitish colour of zirconia abutment. IPS e.max CAD showed good results in laboratory studies. [19]

It has been reported that the moderate flexural strength of lithium disilicate (360 to 440MPa) [20], fracture strenght (2.5 to 3 MPa`m0.5) [21]. Tooth colored lithium-disilicate for excellent translucency and shade matching could be especially in esthetically challenging cases to provide more natural and better esthetic result than white zirconia abutments. IPS e.max cad abutments may be used as a suitable as esthetic alternative to zirconia. It can be used in combination to titanium base to form hybrid abutments. [22]

After investigation in many studies the flexure strenght of hybrid abutment crowns as a single unit and hybrid-abutments with a separate crown sit was found that the single unit hybrid abutment crowns showed the highest flexure strenght, a sit has been concluded that the separation between the abutment and crown showed a weaker mechanical properties than making a single unit hybrid abutment crown design [23] Cement-retained prosthesis was developed to overcome the issue of restoring an angled impalnt, providing the esthetic and mechanical results that not provided by using screw-retained implant restorations. However, a systematic analysis of clinical studies reported that 1.9% to 75% of cement retained implant restorations having periimplantitis and/or mucositis with the excess cement occurred in with 33% to 100% [24]. The difficulty of excess cement removal of cement-retained restoration affect the resulting, endless success of the implant itself. The screw-retainted prosthesis requires screw placement and removal and need of radiograph to verify the seating of restoration making delivery more time-consuming. The "screwmentation" or the "combination implant crown" technique was introduced to get the benifits of each approach [25] The crown can be corrected inside patient mouth donnot need to remove or exchange the screw during the step of adjustment, also the crown extraorally can be bonded by using an implant analog on the abutment, so the removal of excess cement will be much easier. The final restoration is placed and screwed as the screw-retained crown, which is then covered by composite resin [26]. The hybrid-abutment-crown form use can provide the benefits of both screw-retained and cement-retained prosthesis. also, avoiding some of their issues. [10, 27]

Development in computer-aided designing and computer-aided manufacturing (CAD/CAM) innovation improved laboratory and clinical steps especially for reconstruction patients cases with dental implants. By using this technology, professionals can improve the quality and decrease the defects in the design, produce customized esthetic abutments and all-ceramic crowns in short time and decrease personal errors. [28]

The aim of the current study was construct implant supported titanium based hybrid abutment crown from traditional lithium disilicate block/ultra translucent zirconia disc with the help of five axis milling machine and to compare the flexure strenght of the two material. Also, elimination of other possible factors affecting the flexure resistance, only the abutment material and crown was changed, while all other factors such as cement materials were not changed.

For the aim of standardization of all the samples and to simulate an osseointegrated implant an epoxy resin material was used because its modulus of elasticity is similar to that of the bone [6][29][30], according to the manufacturer instructions an epoxy resin material was proportioned and mixed then placed in the copper tube around the implant to mimic the vertical bone resorption occured around the implant, the epoxy resin placed till the first thread of the implant. [6]

To prepare the sintered zirconia design and the titanium base for adhesive cementation, the ceramic structure outer aspect, the screw access channel and the titanium base emergence profile were covered by modelling wax to be protected during the sandblasting step. The inner surface of the titanium base and the zirconia outline were covered by a thin film of automix self adhesive resin cement and the crown was gently placed onto the titanium base. Micro brush was used to remove undue cement at the bond line and at the screw hole and glycerin gel was placed on the bond line to avoid the oxygen inhibited layer production then it was left for seven minutes untill the polymerization process of the cement ended according the fabricator's recommendations [31].

After storage period for 24 hours, in an autoclave samples were exposed to thermocycling step at 134ºC, two bar water vapour pressure for five hours based on ISO standards 13356:2015[12] , to be equivalent to one year of intra oral situations based on ISO standards 13356[32] .

Subjecting all specimens in this study to thermocycling to mimic the clinical conditions as studied by many authors [1][33][34]

Fracture test was made by using a rod made of metal with spherical tip of diameter 3.6 mm to apply a compressive load occlusally, this metallic rod connected to the upper part of the device of the test, this part is not fixed it moves at speed of 1mm per min, while putting a sheet of tin foil of one mm thickness between the specimen and the metallic rod to distribute all the load evenly, also to decrease the transmission of load peaks locally. The forces needed till fracture was recorded in Newton.

The null hypothesis of this research which stated that the fracture resistance of ultra translucent zirconia and lithium disilicate hybrid abutment crown was denied. The outcome revealed that ultra translucent zirconia crowns showed higher significant fracture strenght than IPs e.max CAD crowns.

The outcome of our research were similar to the result of a study made by [35] who investigated the mechanical properties of posterior crowns used on implant and it was concluded that monolithic zirconia crowns showed the highest fracture strenght, then IPS e max CAD then Vita Enamic. Also the outcome was similar to the results of another study made by [36] who concluded that monolithic zirconia crowns in comparison to IPS emax CAD crowns showed higher fracture strenght.

In the composition of the UHT zirconia crown the content of the yttria stabilizer content is around 9.42 wt%, which produces the UHT zirconia that have cubic phase lead to decrease the alumina content. Because at temperature of room zirconia grains still in the cubic satge and can not be converted into the monoclinic phase, so the higher amount of the cubic stage makes the UHT monolithic zirconia crown more stable hydrothermally. The decrease in conversion in the zirconia from the tetragonal stage to the monoclinic stage will decrease the strenght of UHT monolithic zirconia as this conversion enhances the mechanical properties of the zirconia. So, the more content of cubic stage in UHT monolithic zirconia this will decrease the final strenght of zirconia [37].

When the fracture strenght of both ultra translucent monolithic zirconia (UTZ) and super translucency monolith zirconia (STZ) was compared, both showed higher fracture strenght when compared to IPS e.max. This result was predicted as the zirconia characterized by having higher mechanical properties than the IPSe.max. There are many factors may affect the ceramic restoration flexure strength as the components, technique of manufacturing, design of preparation and bonding technique [38].

IPS e max CAD crowns are considered as a second best choice this may be due to its chemical components and its procedure of manufacturing as IPS e.max CAD block first come in an intermediate stage, containing lithium metasilicate particles. during this stage, the block has blue color and it is less durable chemically. After exposure to a crystallization cycle thermally at temperature 850 C, the lithium metasilicate is converted into a lithium disilicate, this crystal gives the lithium disilicate its strenght and esthetic properties **Ritter (2010)** [39].

With further crystallization cycle, the fracture strength enhances and cracks induction are decreased, this may lead to a higher fracture strenght [40]. The fracture strenght results of lithium disilicate and ultra translucent zirconia hybrid abutment crown in the current research were higher than the chewing load normally act on premolar tooth, corresponding to 300-400 N. This indicates the suitability of the lithium disilicate and ultra translucent zirconia hybrid abutment crown for the implant supported monolithic posterior crowns. [45]

The universal testing device steel ball that was placed to the inclines of the buccal and palatal cusp of the restoration structure to cause this type of failure. The applied load caused the seperation of the buccal and palatal cusps externally, line of fracture is located in mesiodistal direction as the concentration of tensile force at the occlusal side of the crown. [1,42]

The restrictions of this research, it is an in vitro study which cannot replicate the intraoral condition accurately, so it settle a base for additional studies to be conducted clinically, so as to check the material reaction intraorally and ensure its appropriate to be used as a restoration for posterior implant.Also, further studies must be conducted to check the variables that may accur as hybrid abutment crowns loss of torque values.

CONCLUSION

1. Titanium based hybrid abutment crowns could be produced from lithium disilicate block/ ultratranslucent zirconia disc
2. From traditional block/disc with the help of five axis milling machine custom made hole of hybrid abutment crown could be fabricated
3. Although zirconia hybrid abutment crowns have shown better results. However, both zirconia and lithium disilicate hybrid abutment crowns could withstand oral forces in premolar area (300 to 400 N)

Conflict of Interest

The authors state no conflict of interest.

Funding

This research received no special gift from any funding agency in the public, commercial, or not for financial gain zones.

Ethics

This study protocol was accepted by the ethical committee of the faculty of dentistry- Cairo university on: 28/9/2021, approval number:10.9.21

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