

A comparison of fracture strength among different brands of translucent zirconia crown restorations

Dr. Sattar J. Abdul-Zahra Al Hmedat*
B.D.S, M.Sc. Department of conservative Dentistry, College of Dentistry, University of Kufa, Najaf, Iraq.

Dr. Zuha Ayad Jaber
B.D.S., M.Sc. Department of conservative Dentistry, College of Dentistry, University of Kufa, Najaf, Iraq.

DR. Adel F. Ibraheem
B.D.S, M.Sc. Department of Conservative Dentistry, College of Dentistry, University of Baghdad, Baghdad, Iraq.

Abstract:
Objectives: As the development of translucent zirconia crown using CAD/CAM technology, the usage of full zirconia crown is gradually increased. The purpose of this study was to investigate the highest fracture strength of translucent zirconia full zirconia crowns among different brands of translucent zirconia. **Methods:** Maxillary 1stpremolar resin teeth were prepared the total circumferential axial reduction was about (1 mm), and axial taper of 6°. Three brands of translucent zirconia (Whitepeaks, Imes-icor and Dentaldirect) that was used in three groups, every group contain five full zirconia crowns using CAD/CAM system (CAD/CAM system 250i, Imes-icor, Germany). The samples seated on the resin die using. All specimens were tested with a universal testing machine. Single load-to-fracture was applied on the lingual aspect of the facial cusp at a rate of 1mm/min. The specimens were thoroughly evaluated for bulk fracture with fractography. **Results:** Statistically high significant difference ($p < 0.00$) was found between the groups. The fracture strength of the groups varied Whitepeaks crowns was (2737.5 ± 106) **N**, which was significantly higher than the two overall mean fracture strength measured for the Imes-icor crowns (3620 ± 40) **N** and Dental direct crowns (3830 ± 130) **N**, the Dental direct highest fracture strength than other groups. **Conclusions.** The fracture strength of Dental direct crowns is considerably higher than that of Whitepeaks crown, The fracture strength of all the groups made of monolithic high translucent Y-TZP is exceeded human maximum bite force, sufficient for clinical use for the majority of patients.

1.introdaction:

All-ceramic dental restorations have been widely applied in prosthodontics because of their aesthetic, biocompatible, absence of metal and inert properties.[1]Among the major short comings of brittle ceramics is susceptive to flaws and defects.

In recent decades, dental ceramics with high strength and toughness have been developed to meet the requirements of routine functions similar to the functions of teeth. Despite their general success, some all-ceramic crowns experience failure after years of service. As indicated in a clinical survey, the main cause of failure is fracture of the ceramics.

Because the estimated survival rates of all-ceramic crowns were 97.3% at 5 years, 93.5% at 10 years and 78.5% at 20 years, their long-term success remains a major concern for restorative dentistry. [2]

Zirconium oxide–based materials, especially yttria-tetragonal zirconia polycrystals (Y-TZP), were recently introduced forprosthetic rehabilitations as a core material for single crowns, conventional and resin-bonded fixed partial dentures (FPDs) [3]

The combination of Y-TZP and computer-aided design/computer-aided manufacture (CAD/CAM) systems is a new approach that reduces the number of steps in prosthetic manufacturing and eliminates the variables introduced by the manual procedures of the dental technician. Y-TZP exhibits exceptional physical and mechanical properties, such as high flexural strength, fracture toughness, hardness, wear and corrosion resistance in acidic and basic ambient conditions, translucency [3], colour stability, greater effectiveness of diagnostic radiographs [4] [5], and high biocompatibility. Moreover, the polycrystalline structure, which lacks a glass matrix, makes zirconia ceramic more resistant to hydrofluoridric acid etching and, as a consequence, resistant to chemical roughening [6].

Mechanical properties of zirconia have been reported to be higher than other ceramics for dental applications. Fracture resistance of 6–10 MPa/m1/2, a flexural strength of 900–1200 MPa and a compression

resistance of 2000 MPa have been reported for it.[19]
Mechanical stress, in this case erosion by hard ceramic particles, induces phase transformation of the metastable tetragonal phase into the monoclinic phase and is associated with an increase in volume (~4%) and shear strain (~7%) [7].
By favouring the development of surface stress–assisted phase transformation (tetragonal→ monoclinic), the stresses induced by this kind of operation cause surface compressive stresses with an increased fracture toughness, low temperature degradation (LTD) [8], and crack formation. This affects the flexural strength of zirconia components, in line with the damage induced [9] [10].
Furthermore, the high kinetic energy of the impacting abrasive particles may chemically contaminate the surface during machining [11] [12]. Microcracks and defects that inherently grow during the thermal and mechanical processes can significantly influence the measurement of resistance.

1.1- OPTICAL QUALITY OF TRANSLUCENCY ZIRCONIA AND ITS IMPACT ON STRENGTH:

The processing techniques mentioned by researchers, which led to increased translucency in the processed zirconia. Adding titanium oxide to yttrium-stabilized zirconia, and it was reported to be effective in densifying yttrium-stabilized zirconia. **(13)**

Tsukuma(14) studied the effect of TiO2 on the transparency of zirconia, instead of translucency. He added 10 mol% TiO2 to 8 mol% yttrium-zirconia powder and sintered it to 1430 °C for 12 hrs and 1630 °C for 7 hrs.**15** The x-ray diffraction showed that TiO2 dissolved in ZrO and formed a solid solution, but the grain size in TiO2-doped zirconia was larger than in TiO2 un-doped. That indicates that TiO2 stimulates grain growth during sintering. It was found that the addition of TiO2 provides a fairly high transmittance to the zirconia. Moreover, the pressure associated with TiO2-adding technique led to pore migration, which is thought to increase the transparency and the strength as well.

1.2- Research Hypotheses:

(1) There is no difference in fracture strength between the three different brands of translucent zirconia crown restorations.
(2) All the different brands of translucent zirconia crown restorations have acceptable fracture strength values.
NH
(1) There is difference in fracture strength between the three different brands of translucent zirconia crown restorations.

2-Materials and Method

2.1- Method:

A dentoform left maxillary first premolar was prepared to receive all ceramic crown using a high speed hand piece with air-water coolant that was adapted to the suspending arm of the modified surveyor in such a way so that the long axis of the bur was paralleled to the long axis of the ivorine tooth, the horizontal arm of the surveyor permitted vertical as well as rotational movement around the tooth.
The die was prepared to receive a complete translucent zirconia crown figure (1), with the following preparation features: a90°radial shoulder finish line all around the tooth with (1 mm) depth, a total circumferential axial reduction was about (1 mm), and axial taper of 6° using a diamond bur No. (G846R). This bur was selected because it provides a shoulder finishing line; occlusal reduction of about 1mm was performed using a diamond disk bur No. (G818) figure (2) **[**Penwadee et al, 2009]**.**
The prepared dentoform tooth was used as a pattern of the master die for completes the construction of translucent zirconia crowns by the CAD CAM imes-icon machine. After complete master die preparation remove it from the jaw base and than construct acrylic base figure (3) to the die to facilitate the procedure of the scanning.
Amount the master die at the scanning table with the gypsum base, the scanning table fixed with the 3D scanner by magnetic and than switch on the scanner and CAM computer to start the scanning as a following:
1-Insert the information of the case as: (patient name, technician name, address, and dentist name) and save the case, and name the type of the crown (full anatomy crown with minimum thickness 0.6mm.
2-Press scanning imes-icons to start the 2Dscanning to determine the position of the crown, and than continue with the 3Dscanning, the 3Dscanner figure. (4) will tack multipicture and then press match icon to get the 3D picture of the master die. Three-dimensional images were displayed on the computer monitor.
3-Desgin of the crown by press the design icon to open the design window and start the designing of full zirconia crown, the first step determined the finishing line, the crown done with the following features a minimum wall thickness of the core (1mm) and cement gap should have 0.05um thickness, the cement space started at 0.25mm

from the finishing line, after complete the design of the crown copy it as a STL file and send it to the CAM computer to amount the design crown in to the translucent zirconia blank, the crown fixed in to the blank by three connector and than calculate the crown to the milling computer.

The milling computer will receive the calculated crown from the CAM computer for crown milling, at the same manner copy (15) STL files for three groups, (5) STL files for every group, at the end result will obtain five translucent zirconia crowns for each group.

Translucent zirconia crowns have a one 3D scanning and one design and then the complete designed crown STL file copied (15) STL files so we have a standardizes in 3D scanning, designing, and thickness of the crowns.

The crowns that were milled separated from the blank by grind the connecter with micro motor machine by using carbide fisher bur.

2.2- Coloring and Sintering:

All the crowns apply color agent (Whitepex Monolith color paint on: Germany) to obtain the natural color to the crown. Sintering was carried out in the (HT-S MV mihmvogt-Germany) high **temperature** furnace the sintering temperature and sintering program according to the manufacture instruction.

2.3. Fracture testing

The 15 crowns were subjected to single load-to-fracture each groups figure (5). For single load-to fracture, the specimens were mounted on the universal testing machine (Laryee, Germany). And load-to-fracture was applied through a 9mm stainless steel indenter on the lingual aspect of the facial cusp at a rate of 1mm/min (Fig. 2). The load was applied until crowns broken.

2.4- Statistical Analysis:

The SPSS software package was used to perform the statistical analysis. Descriptive statistics were computed for fracture strength. Statistical methods were used in order to analyze and assess the results.

1-One-way ANOVA (analysis of variance) Tukey's test was used to see if there were any significant differences among the means of groups.

2-LSD (least significant difference) test was carried out to examine the source of differences.

Statistical significance level to probability value (P) was determined to be as:

1-Non-significant at $P \geq 0.05$.

2-Significant at $P<0.05$.

3- High significant at $P<0.01$.

2.5- Samples grouping: **-**

The (30) copies of STL files were divided into three groups according to the grand zirconia blank (figure 6):

1- Group (1) Imes-icor.
2- Group (2) Whitepeaks.
3- Group (3) Dentaldirect.

3.Results

A total of 15 samples (3 groups, 5 crowns per group) were measured. The results of the measurements, along with the results of the statistical analysis, are summarized in (Table 1) and graphically presented in table (1).

The overall mean fracture strength measurement for the Whitepeaks crowns was (2737.5 ± 106) **N**, which was significantly higher than the two overall fracture strength mean measured for the Imes-icor crowns (3620 ± 40) **N** and Dental direct crowns (3830 ± 130) **N**, the Dental direct crowns which was lowers overall mean fracture strength measurement.

To spot whether the variation in the mean value at three groups, was statistically significant or not, one way (ANOVA) test was functional in table (3).

One (way-ANOVA) for translucent crowns milling machine groups (whitepeaks, Imes-icor and dental direct). HS: P<0.01(highly significant)

In (table 3), it was revealed that the difference in fracture strength mean values among three groups (whitepeaks, Imes-icor and dental direct) was statistically highly significant.

Additional analysis among three groups was performed using LSD test to examine the resource of the difference between the groups (whitepeaks, Imes-icor and dental direct).

This LSD test results show that there is highly significant difference between (whitepeaks) and (Imes-icor), while there is no significant difference between (Imes-icor) and (Dental direct), and between (whitepeaks) and (dental direct) there is highly significant difference as shown in Table (4).

This LSD test showed highly significant differences in the fracture strength values between the Whitepeaks and the (Imes-icor, Dental direct), showed non-significant differences in the fracture strength values between the Imes-icor and Dental direct and this was clearly shown in table (4) and figure (8).

4. Discussion

This study was undertaken to demonstrate the possible change in strength of sintered zirconia crowns by varying the brands of zirconia blanks. This is of interest because questions have arisen whether the brands of milled zirconia crowns can reach higher strength.

Luting agents were not used in this study because of the limited number of metal dies available for testing. Clinically, restorations are subjected to dynamic complex loading in saliva, which contains both organic and inorganic components. These conditions are quite different from the conditions used in this study; thus, further investigation should be carried out using stress corrosion or corrosion fatigue methodology so that the long-term performance of restorations can be predicted.[22]

The result agree with **CAMILLA J. et al[16]**

Attempts have been made to estimate the human maximum bite force, but estimates vary greatly and the literature presents a wide range of suggestions on the requirements for fracture strength of a dental restoration [17,18–19]. The average maximum bite force varies from one patient to another and intra-individually over time [17–18]. Moreover, the range varies markedly from one area in the mouth to another, increasing from the incisors to the third molar, being ~ 90–340 N in the anterior region, 220–450 N in the premolar region and 400–900 Nin the molar region [20–18].

All groups tested in the present study presented results that exceeded human maximum bite force, the lowest fracture strength mean in the Whitepeaks group (2737.5 N), the highest fracture strength mean the Dentaldirect group (3830 N), and the imes-icor group (3620 N) highly significant different with the Whitepeaks group and non significant different with the Dentaldirect group.

Beuer et al. [20] concluded that monolithic Y-TZP crowns have a higher load-bearing capacity than veneered Y-TZP crown cores. In summary, monolithic high translucent Y-TZP crowns seem to be a promising treatment alternative, especially for patients with a history of fractured restorations.

The Dentaldirect group and the imes-icor group have highly marginal fitness compare to Whitepeaks group this may affected the fracture strength this may because when increase unfitness result in un equal distribution of load then this reduce fracture strength.

Also the difference in bending strength between the groups may play a role in difference between the groups in fracture strength, that the Dentaldirect has high bending strength 1200+-200 Mpa while Whitepeaks has lower bending strength which is 1108-1100 Mpa.

5.Conclusion:

Within the limitations of this in-vitro study, the following can be concluded:

All the different brands of translucent zirconia crown restorations groups tested in the present study presented results that have acceptable fracture strength values and exceeded human maximum bite force

. The fracture strength of Dentaldirect crowns is considerably higher than Fracture strength of Whitepeaks crowns.

. The null-hypothesis is thereby accepted.

. The hypothesis (1) is rejected

. The hypothesis (2) is accepted. There is difference in fracture strength between the three different brands of translucent zirconia crown restorations.

References:

1. Studart AR, Filser F, Kocher P et al. Mechanical and fracture behavior of veneer framework composites for all-ceramic dental bridges. Dent Mater 2007; 23(1): 115–123.

2. Beier US, Kapferer I, Dumfahrt H. Clinical long-term evaluation and failure characteristics of 1,335 all-ceramic restorations. Int. J Prosthodont 2012; 25(1): 70–78.

3. Vagkopoulou T, Koutayas SO, Koidis P, Strub JR. Zirconia in dentistry: part 1. Discovering the nature of an upcoming bioceramic. European Journal of Esthetic Dentistry 2009; 4: 2 - 23.

4. Blatz MB. Long-term clinical success of all-ceramic posterior restorations. Quintessence International 2002; 33: 415 - 426.

5. Raigrodski AJ. Contemporary materials and technologies for all- ceramic fixed partial dentures: a review of the literature. Journal of Prosthetic Dentistry 2004; 92: 557 - 62.

6. Piconi C, Maccauro G. Zirconia as a ceramic biomaterial. Biomaterials 1999; 20: 1 - 25.

7. Swain MV. Limitation of maximum strength of zirconia-toughened ceramics by transformation toughening

increment. Journal of American Ceramic Society 1985; 68: C97 -C99.
8. Bonfante EA, Coelho PG, Guess PC, Thompson VP, Silva NR. Fatigue and damage accumulation of veneer porcelain pressed on Y-TZP. Journal of Dentistry 2010; 38: 318-324.
9. Guazzato M, Quach L, Albakry M, Swain MV. Influence of surface and heat treatments on the flexural strength of Y-TZP dental ceramic Journal of Dentistry 2005; 33: 9 - 18.
10. Guazzato M, Albakry M, Ringer SP, Swain MV. Strength, fracture toughness and microstructure of a selection of all-ceramic materials. Part II. Zirconia-based dental ceramics. Dental Materials 2004; 20: 449 - 56.
11. Rateick RG Jr, Karasek KR, Cunningham AJ, Goretta KC, Routbort JL. Solid-particleerosion of tungsten carbide/cobalt cement and hardened 440C stainless steel-A comparison. Wear 2006; 7: 773 - 78.
12. De Arellano-Lopez AR, Martınez-Fernandez J, Varela-Feria FM, Orlova TS, Goretta KC, Gutierrez-Mora F, Chen N, RoutbortJL. Erosion and strength degradation of biomorphic SiC. Journal of the European Ceramic Society 2004; 24: 861 - 70.
13. **Noguchi T.** Advance in high temperature chemistry 2. New York: Academic Press; 1967:274. 2010;31(9):682-4, 86, 88 passim; quiz 98, 700.
14.**Tsukuma K.** Transparent titania-yttria-zirconia ceramics. J Materials Sci. Letter 1986(5): 1143-4.
15. **McLean JW.** Polycarboxylate cements. Five years' experience in general practice. Br Dent J 1972; 132:9-15.
16. CAMILLA J, GRATIELA K, JOHNNY R, CHRISTEL L &PER VULT VON STEYERN Fracture strength of monolithic all-ceramic crowns made of high translucent yttrium oxide-stabilized zirconium dioxide compared to porcelain-veneered crowns and lithium di-silicate crowns Acta Odontologica Scandinavica. Early Online, 2013; 1–9
17. Larsson C, El Madhoun S, Wennerberg A, Vult von Steyern P. Fracture strength of yttria-stabilized tetragonal zirconia polycrystals crowns with different design: an in vitro study. Clin Oral Implants Res 2012; 23:820–6.
18. Koc D, Dogan A, Bek B. Bite force and influential factors on bite force measurements: a literature review. Eur J Dent 2010; 4:223–32.
19. Helkimo E, Carlsson GE, Helkimo M. Bite force and state of dentition. Acta Odontol Scand 1977; 35:297–303.
20. Lassila V, Holmlund I, Koivumaa KK. Bite force and itscorrelations in different denture types. Acta Odontol Scand1985; 43:127–32.
21. Beuer F, Stimmelmayr M, Gueth JF, Edelhoff D. Naumann M. In vitro performance of full-contour zirconiasingle crowns. Dent Mater 2012; 28:449–56.
22. Potiket N, Chiche G, Finger IM. In vitro fracture strength of teeth restored with different all-ceramic crown systems. J Prosthet Dent 2004; 92:491-5.

Figures:

Figure (1) prepared tooth

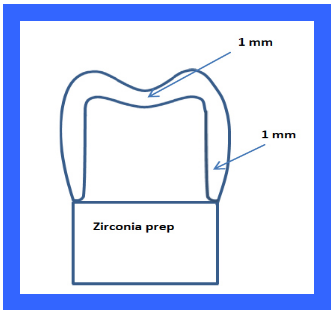

Figure (2)Zirconia preparation[18].

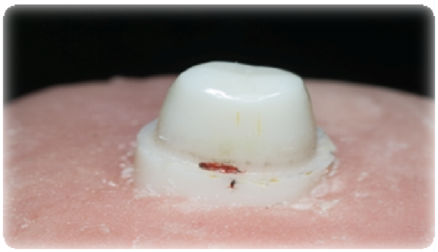

Figure (3) Master die

Figure (4) 3Dscan of imes-icor system.

***Figure (5)* prepared dentoform tooth**

Figure (6) Master die with 15 crowns of three groups.

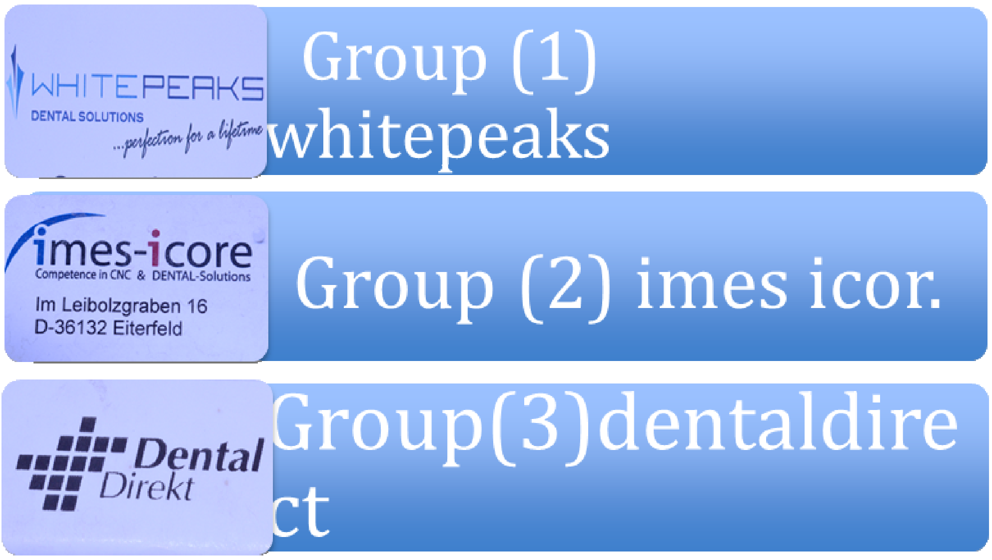

Figure (7) Groups distribution of translucent zirconia blanks.

Whitepeaks	Imes-icor	Dental direct
--------------------------Highly significant---		
*---Highly significant-- *		
*	*--------------------------------Non significant------------------------------- *	

Figure (8) LSD test between (Whitepex, Imes icor and Dental direct)

Tables:

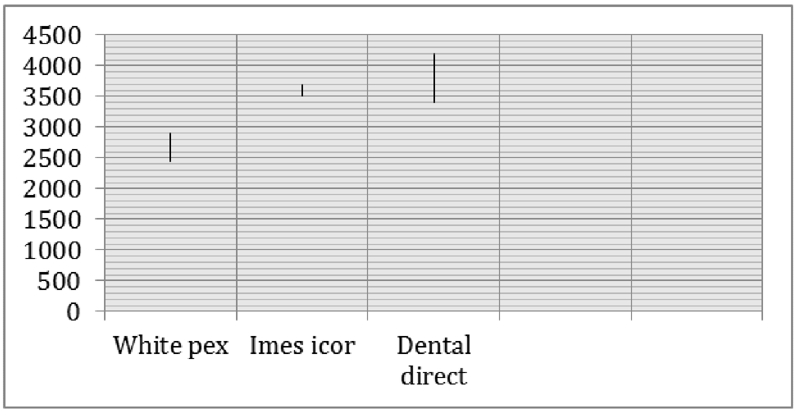

Table (1) Charts of the results of mean; high and low value fracture strength.

Table 2 - Results of fracture strength measurements (Mean ± SD; in **N**) and statistical analysis.

	N	Mean(N)	Std. Deviation	Std. Error	Minimum	Maximum
White peaks	5	2737.5000	213.60009	106.80005	2450.00	2900.00
Imes icor	5	3620.0000	90.82951	40.62019	3500.00	3700.00
Dental direct	5	3830.0000	292.83101	130.95801	3400.00	4200.00
Total	15	3442.8571	512.10619	136.86614	2450.00	4200.00

Table (3): One way- ANOVA for translucent crowns milling machine groups (Whitepeaks, Imes icor and Dental direct).

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	2896410.714	2	1448205.357	31.061	.000
Within Groups	512875.000	11	46625.000		
Total	3409285.714	13			

Table (4): LSD test between the three groups (Whitepeaks, Imes icor and Dental direct)

(I) VAR00001	(J) VAR00001	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
Whitepeaks	Imes icor	-882.50000-*	144.84906	.000	-1201.3106-	-563.6894-
	Dental direct	-1092.50000-*	144.84906	.000	-1411.3106-	-773.6894-
Imes icor	Whitepeaks	882.50000*	144.84906	.000	563.6894	1201.3106
	Dental direct	-210.00000-	136.56500	.152	-510.5775-	90.5775
Dental direct	Whitepeaks	1092.50000*	144.84906	.000	773.6894	1411.3106
	Imes icor	210.00000	136.56500	.152	-90.5775-	510.5775

*. The mean difference is significant at the 0.05 level.