Tikrit Journal for Dental Sciences 14(1) (2026) 45-55
https://doi.org/10.25130/tjds.14.1.5

Tikrit Journal
for
Dental Sciences
https://tjds.tu.edu.iq
Print ISSN:2073-1213
Online ISSN:3105-9384

Effect of Surface Treatment and Core Material (IPS E.max Press) on the Fracture Resistance of Ceramic Materials

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Keywords:
Fracture resistance, Sand-blast, Potassium hydrogen difluoride, E-max press, Surface treatment.

Article Info.:

Article History:
Received: 7/9/2025
Received in revised form: 20/10/2025.
Accepted: 28/10/2025
Final Proofreading: 28/10/2025
Available Online: 1/6/2026

Citation: Karkosh SHF, Alwan LE,Alwahab ZN, Ali S. Effect of Surface Treatment and Core Material (IPS E.max Press) on the Fracture Resistance of Ceramic Materials. Tikrit Journal for Dental Sciences 2026; 14(1): 45-55
https://doi.org/10.25130/tjds.14.1.5.

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Abstract

Background: Ceramics are biocompatible materials and can simulate the visual character of the tooth substance successfully. Zirconia crowns and lithium disilicate crowns, specifically E-max, are the most highly regarded types of dental crowns.The oral environment is influenced by the all-ceramic restoration system's bond strength. This investigation aimed to determine how surface treatment and core material (Emax- press) affect various ceramic materials' resistance to fracture.

Methods Forty specimens constructed using the heat press method and E-max press material depending on their surface treatment, samples were divided into four groups at random;each group consists of ten samples.Control group:Untreated surface samples.Group sand plast (AL_2O_3) : aluminum oxide particles are used to sandblast samples.Group potassium hydrogen difluoride (KHF_2) : potassium hydrogen difluoride-etched samples.Combination of Group E-max press: samples are etched with potassium hydrogen difluoride and sandblasted with aluminum oxide particles.Using a scanning electron microscope, the morphological change of the E-max press after surface treatment was observed.Every sample has 2mm veneering ceramic applied to it.A universal testing machine was used to measure fracture resistance.

Results: According to data analysis, the (E-max Combination) group had the lowest mean fracture resistance values, while the (E-max sand blast) and (E-max etching) groups had the greatest mean values. **Conclusion:** Within the limitations of this study, the results suggest that, utilizing of various surface treatments with E-max press substructures were more effective on the values of fracture resistance.

Introduction:

The dental community has been researching restorative materials with superior optical qualities that can restore shape and function in recent decades due to the anterior and posterior regions' mechanical needs (1). Utilizing computer-aided design (CAD)/computer-aided manufacturing (CAM) technology led to the development of an entirely new class of zirconium dioxide ceramic substructures(2). In1998,lithium disilicate (SiO_2-Li $_2$O) was added to the glass ceramic industry as a substructure material. It was produced by heat pressing ingots (Empress 2, Ivoclar Vivadent, Lichtenstein) using a process similar to the lost-wax technique (3). Increased use of lithium disilicate all-ceramic restorations is a result of improved methods and materials that enable these ceramics to withstand high stress-bearing applications (4). Lithium disilicate glass ceramic seems the strongest and toughest in all glass ceramic. It is suggested for posterior and anterior single crowns, implanting super structure and bridges anterior to second premolar (5). Glasses and ceramics are fragile, that means that they show a height compressive strength however less tensile strength and probably fractured beneath quite minimum strain(6) One of the most common clinical problems associated with veneering ceramics is chipping. This complication may result from inappropriate veneering techniques, a mismatch between the substructure and veneering material, or inadequate interfacial bonding. (7).Thus, the current study's aims to evaluate how surface treatment and core material (E-max press) affect the fracture resistance of several ceramic materials.

Materials and Methods

Experimental part

1. Preparation of Samples

An in vitro study Forty (40) samples were made from E-max press material fabricated by (heat press technique) each samples thickness was 0.8mm, was done at dental laboratory in the college of health and medical techniques.at Baghdad, the study was performed during October 2024.The core samples' surfaces were veneered using the appropriate veneering ceramic in accordance with the manufacturer's guidelines.The final thickness of veneered ceramic was 2mm according to the design used and the final thickness of core with veneered ceramic was 2.8 mm. scanning electron microscope was used to identify any morphological changes in the E-max press after surface treatment. Fracture resistance of all specimens was measured by using universal testing machine.

2. Sample Grouping

Depending on their surface treatment samples were split randomly for four groups ,each group contains 10 samples .Group EC: specimens with E-max core without surface treatment (control group).Group ESB: samples with E-max core sandblasted with 50µm of Aluminum oxide particles. $EKHF_2$:
samples with E-max core etched with (70 mg) concentration of potassium hydrogen difluoride.Group ECOMB: samples with E-max core sandblasted with 50µm of aluminum-oxide particles and etched with(70 mg)concentration of potassium hydrogen difluoride.

3. Tooth Preparation

In the dental model (Nissin Dental Products), the upper left first molar tooth was prepared as follow, 2mm oclussal reduction, 1.5 mm axial reduction and 0.8mm deep chamfer finishing line to construct metal die(8).To replicate the shape of the perfect prepared plastic tooth to accept all ceramic crowns, a metal die was created using a CAD/CAM technology. As shown in Figure (1).

4.Tooth Scanning

Three dimension dental light scanner scanned prepared tooth. The digital model of the die was transmitted to the computer added machine software to begin the metal die's milling process after a three-dimensional picture was captured that clearly showed the plastic die's finishing line and all of its surfaces. Dental stone type IV was used to make the metal die's base.Using special clay, the metal die was set to the scan stage after being positioned within the scanner machine.

After complete the scanning process, the final 3 dimension (3D) virtual model was appeared on the computer monitor, after that the margin line was detected, crown border were checked,undercut was checked,Finally complete design of the samples was constructed (7).

5. **Milling of Metal Die**

To begin the metal die's milling process, the digital model of the die was sent to the CAM program., by using the milling unit which was loaded with cobalt chromium disc (14mm diameter).The metal die was milled with two new carbide burs (2mm, 1mm diameter).Bur 2 mm used for cutting outline of metal die and, bur 1mm for fine details, the burs were changed automatically,(according to the manufacture instruction).

6. Sample Grouping

Group I (E-max control group): specimens with E-max press core without surface treatment (control group).

Group II(E-max sandblasting group): specimens with E-max press core sandblasted with 50µm of aluminum-oxide particles.

Group III (E-max etching group): specimens with E-max press substructure ,70 mg of potassium hydrogen difluoride was used to etch it.

Group V (E-max Combination group): specimens with E-max press core sandblasted with 50µm of aluminum-oxide particles and 70 mg of potassium hydrogen difluoride was used to etch it.

7. Preparation of IPS E-max Press Specimens:

A. Waxing

Forty E-max wax patterns were fabricated by CAD/CAM system by using fusing Harvest Z cad wax press 98.5 mm to get uniform dimension and 0.8mm thickness of IPS E-max wax pattern, as shown in Figure(2 A, B).

B. Spruing

An axial sprue of 3mm in diameter and 3mm in length was fastened at a 45°–60° angle, and was attached at the edge of the Ips muffle(according to manufacturer's instructions) so that smooth flowing of the viscous ceramic during pressing was achieved.

C. Investing and Burn Out

IPS press vest investment material was mixed.Each 100g of powder was mixed with 25 mL of its special liquid according to manufacturer's instruction by placing the liquid into the mixing bowel then the powder was added, both powder and liquid were mixed by using vacuum auto mixing device under vacuum at pressure of 350 rpm for 60 seconds. Then, the mixture was poured to the silicon ring on the vibrator to minimize the chances of air bubbles formation on the wax pattern.Carefully, the investment ring was filled with investment material up to the marking and position of the ring gauge a distance of about 10mm from the position of ring gauge to the end of silicon ring was left to ensure optimum pressing procedure.After placing the ring gauge, the silicon ring was allowed to set for about 60 minute according to manufacturer's instruction **.**After the final setting of investment material, the ring gauge and ring base were removed and pushed carefully from the silicon ring.Then, the investment ring was placed into the preheating furnace; the ring was heated gradually from the room temperature to 850°C for 60 minute according to manufacturer's instruction.

D. Pressing

The press program and Ips E-max press ingot were selected after completing the burn out procedure of the investment ring, They took the investment ring out of the furnace.After placing an ingot for the IPS E-max Press, the Alox plunger was applied. At 1100 °C and 3.5 bar of pressure, the investment ring containing the ingot and the Alox plunger was positioned in the middle of the furnace.As shown in Figure(3). At room temperature for 60 min the investment ring was left to cool (9).

E. Divesting

After cooling of the investment ring to room temperature for 60 minutes, the length of the Alox plunger marked by a pencil and then the investment ring was separated at the predetermined point by the separating disc.The investment ring was broken by using plaster knife.

F. IPS E-max Press Surface Treatment Groups:

1. Control Group (E-max C):

Ten samples of E-max core group were not treated to any surface treatment and were used as controls.

2. Sandblasting with Aluminum Oxide Group (E-max S B):

Ten specimens of E-max core group were sandblast together with 50 µm alumina particles to 10 second for each surface at a 1.5 bar air compression and at a space of 20 mm by using sand blast machine each sample was cleaned using steam jet for 10 s at distance 10 mm.

3. Etching With Potassium Hydrogen Difluoride Acid Group (E-KHF_2):

Ten specimens of E-max core group were powder coated with KHF_2 acid in amount of 70 mg, then heated in a porcelain furnace (Ivoclar vivadent) to temperature of 280 C◦. The core was then cleaned using steam cleaner for 15s followed by compressed air for 15s. After 30 min, all specimens were stored in distilled water at 37C◦ for 24 h (10).

4. A combination of Sandblasting with Aluminum Oxide and Etching with Potassium Hydrogen Difluoride Acid Group (E-max COMB):

Ten specimens of E- max core group were treated by a combination of sand blast particles 50 µm AL_2O_3 for 10 second at a 1.5 bar air pressure at a distance of 20 mm by using sand blast machine. The etched was then cleaned using steam jet, then the specimens were powder coated with KHF_2 acid. After that, 70 mg were heated to 280 C◦ in a porcelain furnace.

G. Cleaning of IPS E-max Press Specimens:

All specimens were cleaned completely from any remnants of sandblast particles dust and acid etching before veneering, by steam jet for 10 second and running water. Then all the specimens of IPS E-max press were ready for SEM exam .

H. Scanning Electronic Microscope (SEM) :

Firstly, the specimens were attached to the aluminum holder in compact plasma sputtering coater device for painting their surface with pure gold . At varying magnifications, each painted surface was inspected under a scanning electron microscope to identify any morphological changes in the E-max press after surface treatment (11). As shown in Figure (4 A, B ,C ,D) .

I. Application of Veneering Ceramic on E-max Press Specimens:

In this procedure, the silicon mold was used for application of veneering porcelain for application of E-max ceram veneering porcelain with E-max press specimens.

For standardization,(1.5mg) of E-max ceram dentin powder was mixed with 3 drops of their special liquid (E-max ceram build up liquid) to produce the desired consistency of ceramic The first dentin layer was applied incrementally on the entire specimen, vibrated, dried and fired according to manufacturer's instructions. Second dentin then was mixed to compensate shrinkage of dentin after firing , adjustment of specimens should be accomplished if necessary by using a straight hand piece to obtain the desirable dimensions of E-max specimen 0.8 mm, as shown in Figure (5).

Fracture Resistance Test

Fracture resistance of all specimens was measured by using universal testing machine. A500 Kg of load was applied vertically at the center of the occlusal surface of all specimens of IPS E-max press by small round stainless steel ball with 5.7 mm diameter at cross head speed of (0.5 mm\ min) (12). As shown in Figure(6).Then kg was converted to newton by multiplying the kg by ground acceleration of 9.8.

Statistical Analyses:

The collected data were tabulated and statistically analysed using appropriate descriptive and inferential statistical methods. Descriptive statistics, including the minimum, maximum, mean, standard deviation (SD), and standard error (SE), were calculated for each E-max Press ceramic subgroup, as presented in Table (1).

To determine whether there were statistically significant differences in fracture resistance among the E-max Press

subgroups, a one-way analysis of variance (ANOVA) test was performed. The level of significance was set at $p < 0.05$, with $p < 0.001$ considered highly significant.
Following the ANOVA test, the Least Significant Difference (LSD) post hoc test was applied to identify the specific sources of significant differences between the subgroups, as shown in Table (3). The LSD test allowed pairwise comparisons to determine which groups differed significantly in terms of fracture resistance.

Results and Discussion

According to Table (1), the E-max control group had the lowest mean fracture resistance values, whereas the E-max sandblasting group had the highest mean as shown in Figure (7).
According to Table (2), One-way ANOVA test manifested that there was statically highly significant difference in fracture resistance among all E-max press subgroups at level p<0.001.

Least Significant Difference test (LSD)

The result of LSD test showed there is highly significant difference among (EC) group with (ESB) and ($EKHF_2$) but significant different was showed between (EC) group with (E COMB) group and (ESB) group with (E COMB). Also, LSD test result showed there is non-significant difference between ($EKHF_2$) group with both (ESB) group and (E COMB) group. According to the result the highest mean of fracture resistance was for E-max sandblasting group ,E-max etching group, E-max combination, while the lowest mean of fracture resistance was for E-max control. Nowadays, ceramics are widely employed in prosthetic dentistry because of their mechanical qualities, which are linked to improved microstructures and novel processing techniques.The extended lifespan of such dental restorations is a result of these materials' sufficient mechanical qualities (13). One of the most clinical complication of E-max press based restoration is chipping and fracture ,which mostly reported by various studies(14) .The most major disadvantages of using all ceramic restorations in the posterior location is the risk of fracture related to occlusal and lateral forces (15). Several causes have been associated with chipping and fracture of veneering ceramics, like irregular preparation, inadequate design of the substructure, mismatch between the thermal expansion coefficient of veneering ceramic and substructure(16) .Various techniques are available for applying the veneering layer to the ceramic substrate (17). In this study, layering technique have been used for E-max press samples with their corresponding veneering ceramic (IPS E-max ceram)according to manufacturer's instructions to ensure the compatibility of coefficient of thermal expansion between substructure and veneering ceramic to avoid tensile stress occurred over the core-veneer interface and lead to crack initiation and propagation(18) . Fracture resistance test was utilized in order to enable evaluation of fracture test properties and calculation fracture resistance of all ceramic samples (19). E-max press groups showed significant differences at ($p < 0.05$) in the fracture resistance when fracture resistance outcomes appeared. In current study, three types of surface treatment was used, 50µm Airborne particle abrasion with aluminum oxide(AL_2O_3) technique, 70mg of potassium hydrogen difluoride(KHF_2) 70mg technique and combination technique sandblasting with 50µm (Al_2O_3) and etching with potassium hydrogen difluoride. Airborne particle abrasion with aluminum oxide is important method of surface roughening (20).The highest fracture resistance values obtained with air abrasion with E-max press may be attributed to the ability of AL_2O_3 particles with high pressure to produce irregularities on the surface of lithium disilicate ceramic by attacking the glass content which led to surface roughness and increase micromechanical retention(21). In the present investigation, 50 µm aluminum oxide particles were subjected to sandblast particle abrasion for 10 seconds at a pressure of 1.5 psi. By creating more pits per unit area than the control group, this treatment altered the surface.As shown in Figure (4 A,B,C,D). While potassium hydrogen difluoride (

KHF_2) in this study was selected because the process of melt etch technique with KHF_2 can produce in fluoridated surface which has attached hydroxyl groups following water cleaning resulting a positive effect on the adhesion(22) .In addition, other researchers reported that mechanical and chemical etching methods can be used together (23) ·Combination technique was selected to increase fracture resistance of ceramic substructure by improve bond strength between samples and veneering ceramic. According to the outcomes of the current study, there was a highly significant effect of the sandblast particles on the mean of fracture resistance of E-max press ceramic when compared with control group (EC) which was without any surface treatment. The outcomes of current study comes in agreement with Alashal *et al*.,2016, (24). A study stated that ability of 50µm AL_2O_3 particles with high pressure to produce irregularities on the surface of lithium disilicate ceramic by attacking the glass content which led to surface roughness and increase micromechanical retention.

The outcomes of current study come in agreement with those of Yoshihara *et al*., 2017 (25). A study manifested that 50µm of aluminum-oxide with lithium-disilicate created a microstructure that induced mechanical retention to lithium-disilicate. The outcomes of current study disagreed with Tarib *et al*., 2016, (26). A study claimed that 50µm of aluminum-oxide have a lowest mean of bond strength when compared with untreated group due to the microcracks that can initiates bigger cracks and reduce their strength. The SEM evaluation showed that, AL_2O_3 sandblasted surface yielded a rougher microstructure with deep and uniform size porosities on the E-max press. In the current study, KHF_2 was used instead of HF to improve bond strength between E-max press substructure and veneering ceramic, 70 mg of KHF_2 powder was coated with distilled water, then powder was spread on the E-max press specimen and then inserted in the ceramic furnace at temperature 280C°. During the heating process and after water evaporation, the fluoride compounds appeared melted. The specimens removed and allowed to cooled, each specimen was steam cleaned and stored in distilled water for 24 h.Their outcomes manifested that KHF_2 acid is able to etch E-max press ceramics by creating micro –morphological changes on its surface. According to the knowledge of the authors there were no previous studies on the effect of KHF_2 on the fracture resistance of IPS E-max press, so the outcomes of the current study, could be explained that there was a significant effect of KHF_2 acid on the fracture resistance of E-max press when compared with control group (EC). The KHF_2 etchant with melting point of 280 C° was effective on the lithium disiicate surface. The SEM evaluation showed that etching with KHF_2 produced a visible irregularities and porosities on the E-max press specimens due to dissolution of glassy phase and exposing of lithium disilicate crystals. As far as the authors were aware, no prior research had examined the impact of AL_2O_3 and KHF_2 combination treatment on the fracture resistance of IPS E-max press. Therefore, the results of this study showed that the combination treatment (ECOMB) group differed significantly from the control group (EC).

The SEM evaluation showed that E-max press specimens treated with the combined of etching with KHF_2 and subsequent 50µm AL_2O_3 sandblasting particles surface roughness and porosities when compared with control group.

Conclusion

Within the limitations of the current study, the following conclusions are drawn:

1- The values of fracture resistance were improved by using various surface treatments with lithium disilicate substructures.

2-Airborne particles of 50µm manifested appositive effect for conditioning of the lithium disilicate surfaces.

Funding:

This research was self-funded.

Conflicts of interest:

The authors claim to have no conflicting interests.

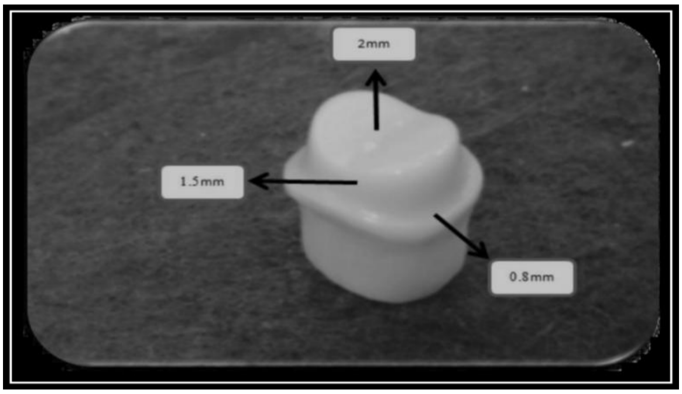


Figure 1 : Final dimensions of plastic die

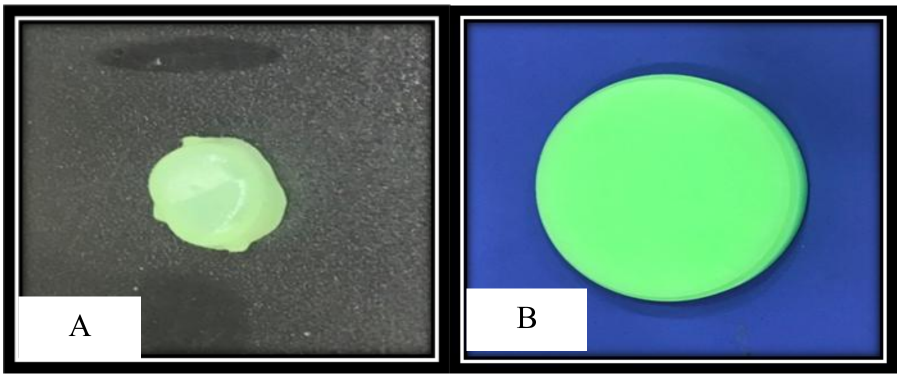


Figure 2:

(A) Z cad wax press (B) E-max press wax pattern

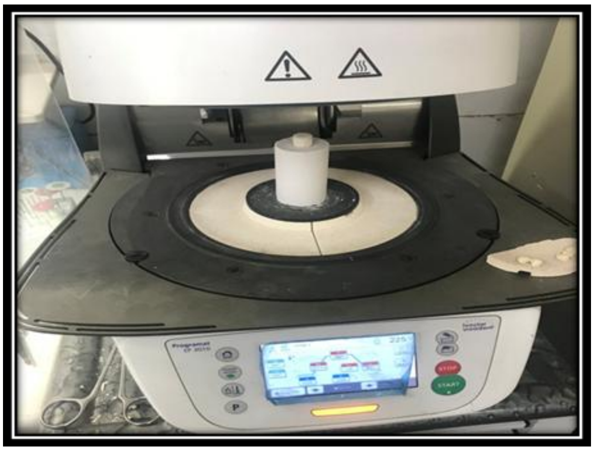
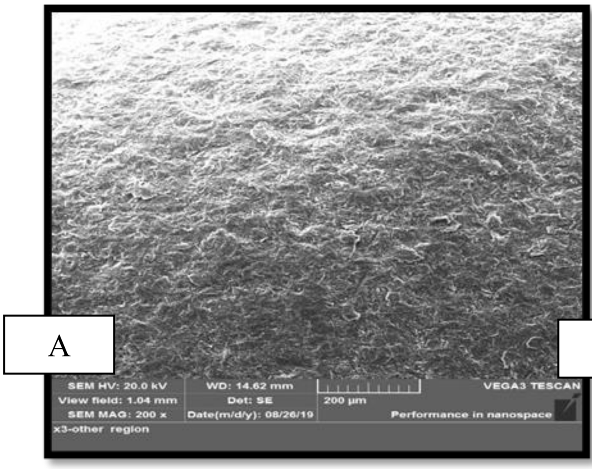


Figure 3: Pressing process



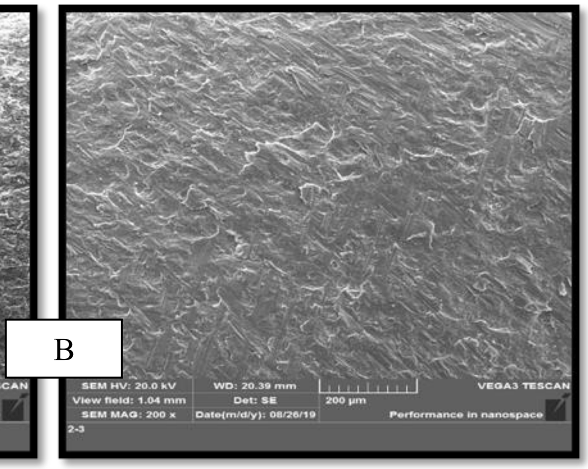
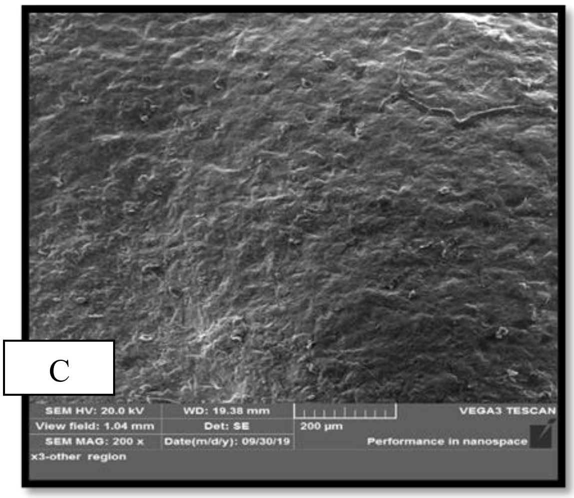
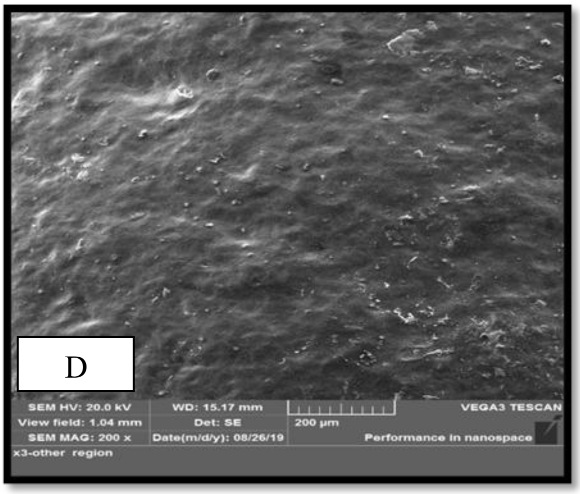


Figure 4: Scanning electron microscope

(A) E-max untreated

(B) E-max treated with 50 µm **of Al_2O_3**





(C)) E-max treated with 70mg KHF_2

(D) E-max treated with a combination of 50µ of Al_2O_3 and 70mg KHF_2

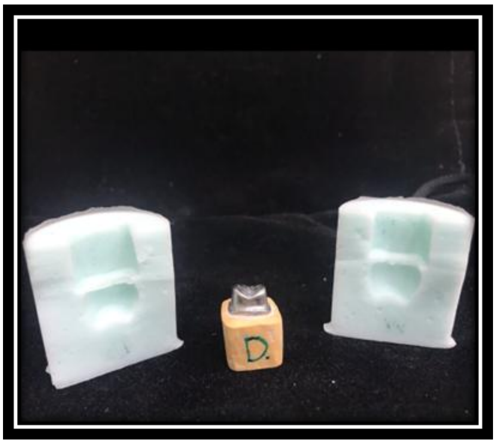


Figure 5: Silicon mold used as veneering Build up reference

Figure 6: The core with base placed
on the base of the universal

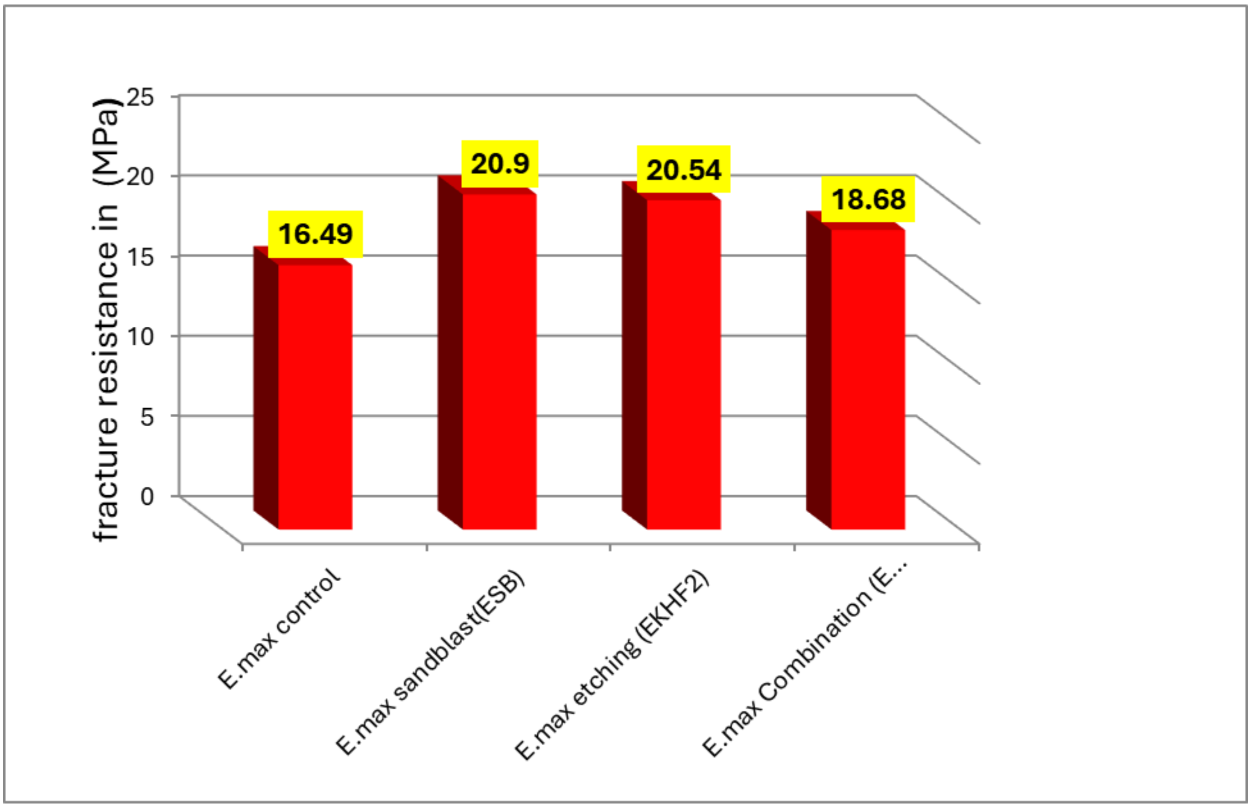


Figure 7: Average fracture resistance of IPS E.max press groups in (MPa)and experimental groups.

Table 1: Descriptive Statistics of Fracture Resistance of E.max press Ceramic Groups(EC, EKHF$_2$, ESB and ECOMB)in newton.

Groups	N	Minimum	Maximum	Mean	Std. Error	SD
E.max control	10	13.70	18.90	16.4900	.65565	2.07335
E.max Sandblast	10	18.20	23.80	20.9000		1.61727
E.max Etching	10	17.60	23.90	20.5400	.58788	1.85903
E.max Combination	10	16.70	20.70	18.6800	.41009	1.29683

Table 2: One- way ANOVA test for fracture resistance among E-max press ceramic subgroups.

E-max press Groups	F	P-value	Sig
Among Groups	13.598	.000	HS

****P<0.001 (High significant) .**

Table 3: LSD test among E-max press groups of fracture resistance.

Groups			Mean Difference	P-value	Sig
LSD	E.max control	E.max (EKHF2)	-4.05000-*	.000	HS
		E.max (ESB)	-4.41000-*	.000	HS
		E.max (E Comb)	-2.19000-*	.037	S
	E.max(EKHF2)	E.max (E SB)	-.36000	.966	NS
		E.max (E Comb)	1.86000	.096	NS
	E.max (E SB)	E.max (E comb)	2.22000*	.034	S

*P<0.001 High significant
**P<0.05 Significant
***P>0.05 Non Significant

References

1. Ricci WA, Fahl Jr N. Nature-mimicking layering with composite resins through a bio-inspired analysis: 25 years of the polychromatic technique. Journal of Esthetic and Restorative Dentistry. 2023 Jan;35(1):7-18. DOI: 10.1111/jerd.13021

2. ElGendy MA, ElSharkawi NM. A Review on the Evolution of CAD-CAM Materials in Fixed Prosthodontics Regarding Mechanical Properties, Aesthetic Outcomes, and Clinical Indications. ERU Research Journal. 2025 Apr 1;4(2):2595-629. DOI: 10.21608/ERURJ.2025.331419.1196

3. Zarone F, Ferrari M, Mangano FG, Leone R, Sorrentino R. "Digitally oriented materials": focus on lithium disilicate ceramics. International journal of dentistry.2016;(1):9840594. DOI: .org/10.1155/2016/9840594

4. Yan J, Kaizer MR, Zhang Y. Load-bearing capacity of lithium disilicate and ultra-translucent zirconias. Journal of the mechanical behavior of biomedical materials. 2018 Dec 1;88:170-5. DOI: org/10.1016/j.jmbbm.2018.08.023

5. Karkosh SF, Alwan LE, Alwahab ZN. Comparative Estimation the Influence of Core Material (Zircon) and Surface Treatment on The Fracture Resistance of Some Ceramic Material. Tikrit Journal for Dental Sciences. 2024 Dec 1;12(2):280-9.

DOI:org/10.25130/tjds.12.2.4

6. Abdulsattar MH, Turki SA, Alwahab ZN. Effect of Polishing Systems on Mechanical Properties of Emax Press Restorations. Tikrit Journal for Dental Sciences. 2023 Dec 10;11(2):208-15. DOI:org/10.25130/tjds.11.2.7
7. Hussain SA, Hamid MA. Assessment of marginal accuracy of CAD CAM Interim material by two different types of dental scanners. World J Pharmaceutical Res. 2019;8(2):1750-61. DOI: 10.20959/wjpr20192-14046
8. Nawafleh NA, Hatamleh MM, Öchsner A, Mack F. Fracture load and survival of anatomically representative monolithic lithium disilicate crowns with reduced tooth preparation and ceramic thickness. The journal of advanced prosthodontics. 2017 Dec 1;9(6):416-22. DOI: org/10.4047/jap.2017.9.6.416
9. Riad MH, Younis JF, Zaghloul HH, Cam CA. Effect of processing technique and coping thickness on fracture resistance of lithium disilicate copings. Stomatological Dis Sci 2017. Mar 31;1: 14-21. DOI:10.20517/2573-0002.2016.13
10. Akazawa N, Koizumi H, Nogawa H, Kodaira A, Burrow MF, Matsumura H. Effect of etching with potassium hydrogen difluoride and ammonium hydrogen difluoride on bonding of a tri-n-butylborane initiated resin to zirconia. Dental materials journal. 2019 Jul 26;38(4):540-6. DOI: https://doi.org/10.4012/dmj.2018-152
11. El-Shrkawy ZR, El-Hosary MM, Saleh O, Mandour MH. Effect of different surface treatments on bond strength, surface and microscopic structure of zirconia ceramic. Future Dental Journal. 2016 Jun 1; 2(1):41-53. DOI: https://doi.org/10.1016/j.fdj.2016.04.005
12. Ali SM, Manoharan PS, SheKhAwAt KS, Deb S, Chidambaram S, Konchada J, et al. Influence of Full Veneer Restoration on Fracture Resistance of Three Different Core Materials: An Invitro Study. Journal of Clinical and Diagnostic Research: JCDR. 2015 Sep 1;9(9):12. DOI: 10.7860/JCDR/2015/12891.6440
13. Montazerian M, Baino F, Fiume E, Migneco C, Alaghmandfard A,et al. Glass-ceramics in dentistry: Fundamentals, technologies, experimental techniques, applications, and open issues. Progress in Materials Science. 2023 Feb 1;132:101023. DOI: org/10.1016/j.pmatsci.2022.101023
14. Brandt S, Winter A, Lauer HC, Kollmar F, Portscher-Kim SJ, Romanos GE. IPS e. max for all-ceramic restorations: clinical survival and success rates of full-coverage crowns and fixed partial dentures. Materials. 2019 Feb 2;12(3):462. DOI: **org/10.3390/ma12030462**
15. Harb EJ, Kanaan SM. Comparing and Evaluating the Effect of Different Thickness of Two Metal-Free Restoration on Fracture Resistance in Molar Implant Prosthesis. Tikrit Journal for Dental Sciences. 2021 Dec 30;9(2):97-103. DOI: org/10.25130/tjds.9.2.5
16. Alsarani M, De Souza G, Rizkalla A, El-Mowafy O. Influence of crown design and material on chipping-resistance of all-ceramic molar crowns: An in vitro study. Dental and medical problems. 2018;55(1):35 DOI: 10.17219/dmp/85000
17. Silva LH, Lima ED, Miranda RB, Favero SS, Lohbauer U, Cesar PF. Dental ceramics: a review of new materials and processing methods. Brazilian oral research. 2017 Aug 28;31. DOI: org/10.1590/1807-3107BOR-2017.vol31.0058
18. Jalali H, Bahrani Z, Zeighami S. Effect of Repeated Firings on Microtensile Bond Strength of Bi-layered Lithium Disilicate Ceramics (e. max CAD and e. max Press). The journal of contemporary dental practice. 2016 Jul 1;17(7):530. DOI: 10.5005/jp-journals-10024-1884
19. El Sayed SM, Emam ZN. Marginal Gap Distance and Fracture Resistance of Lithium Disilicate and Zirconia-Reinforced Lithium Disilicate All-Ceramic Crowns Constructed With Two Different Processing TechniquesWith Two Different Processing Techniques. Egyptian Dental Journal. 2019 Oct 1;65(4-October (Fixed Prosthodontics, Dental Materials, Conservative Dentistry & Endodontics)):3871-81. DOI:10.21608/edj.2019.76035
20. Borges GA, Sophr AM, De Goes MF, Sobrinho LC, Chan DC. Effect of etching and airborne particle abrasion on the microstructure of different dental ceramics. The Journal of prosthetic dentistry. 2003 May 1;89(5):479-88. DOI: org/10.1016/S0022-3913(02)52704-9
21. Helal MA, Al-Gazzar AE, Abas M, Akhtar S, Gad MM, Al-Thobity AM. Comparative effect of different surface treatments on the shear bond strength of two types of artificial teeth bonded to two types of denture base resins. Journal of Prosthodontics. 2022 Jun;31(5):427-33. DOI: org/10.1111/jopr.13425
22. Kvam K, Irkayek A, Vangaeva E, El-Homsi F. Comparison of sandblasted, ground and melt-etched zirconia crowns regarding adhesion strength to resin cement. Biomaterial Investigations in Dentistry. 2019 Dec 20;6(1):1-5. DOI: org/10.1080/23337931.2019.1621179
23. Kutsuma R, Koizumi H, Nogawa H, Burrow MF, Yoneyama T, Matsumura H. Effect of surface treatment with potassium hydrogen difluoride and ammonium hydrogen difluoride on bond strength between layered veneering porcelain and zirconia. International Journal of Adhesion and Adhesives. 2021 Mar 1;105:102777. DOI: org/10.1016/j.ijadhadh.2020.102777
24. Alashal IB, Ghazy MH, Lamia EL. Effect of different surface treatments on the shear bond strength of two types of ceramic materials. EDJ. 2016;62:1-8. DOI: org/10.1016/j.dental.2016.12.003
25. Yoshihara K, Nagaoka N, Maruo Y, Nishigawa G, Irie M, Yoshida Y, Van Meerbeek B. Sandblasting may damage the surface of composite CAD–CAM blocks. Dental Materials. 2017 Mar 1;33(3):e124-35. DOI: org/10.1016/j.dental.2016.12.003
26. Tarib NA, Anuar N, Ahmad M. Shear bond strength of veneering ceramic to coping materials with different pre-surface treatments. The journal of advanced prosthodontics. 2016 Oct;8(5):339-44. DOI: org/10.4047/jap.2016.8.5.339