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RESEARCH ARTICLE

THE EFFECT OF GLAZING AND THERMOCYCLING ON THE SURFACE ROUGHNESS OF DIFFERENT CAD/CAM MILLED CERAMIC LAMINATE VENEERS WITH SEM OBSERVATIONS

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Abstract

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CAD/CAM technologies are one of the rapidly developing fields in digital restorative dentistry. The objective of this in vitro study was to evaluate the influence of glazing and thermocycling on the surface roughness values of four different types of milled CAD/CAM ceramic materials.

Aim – This study aimed to evaluate the effects of glazing and thermocycling on the surface roughness values of four different types of CAD/CAM ceramic veneers. It was hypothesized that there would be a statistically significant difference in surface roughness values between glazed and nonglazed CAD/CAM materials across the four tested ceramics.

Materials and Methods - As part of the investigation, 80 CAD/CAM ceramic veneer samples were milled using CAD/CAM system (inLab MC XL CEREC, Dentsply Sirona, Germany). The processing occurred after scanning of the first right typodont incisor of the upper jaw model prepared with the palatal chamfer preparation design without approximal involvement (KaVo, Germany) via an Omnicam scanner (CEREC, Dentsply Sirona, Germany). Four different CAD/CAM ceramic materials were evaluated in this study: lithium disilicate (IPS E.max CAD, Ivoclar, Germany), leucite-reinforced ceramic (IPS Empress CAD, Ivoclar, Germany), feldspathic ceramic (Cerec, CEREC, Dentsply Sirona, Germany), and hybrid ceramic (Cerasmart, GC, Japan). The 80 samples were categorized into four groups (20 in each, n=20), each group was further subdivided into glazed and nonglazed subgroups, with 10 samples in each subgroup (10 samples, n=10). All specimens underwent 10,000 thermal cycles. The surface roughness values were evaluated at three stages: post-milling, post-glazing, and post-thermocycling. Scanning electron microscope images (magnifications of 100x, 250x, 500x, and 1000x) were captured for each material before glazing and after thermocycling.

Results - Significant differences in surface roughness values were observed among materials after glazing and thermocycling. Surface roughness notably decreased following glazing. Significantly higher surface roughness values were observed in the Cerec group compared to Cerasmart, Empress, and E.max groups ($p < 0.05$). Analysis of the glazed surfaces after thermocycling also revealed significant differences among the groups ($p < 0.05$). Tamhane's T2 post-hoc test revealed that the Cerec

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group exhibited significantly higher surface roughness values compared to Cerasmart, Empress, and E.max after thermocycling ($p < 0.05$). For non-glazed samples, thermocycling similarly led to higher surface roughness values in the Cerec group compared to the other three groups ($p < 0.05$). These findings highlight the effects of glazing and thermocycling on the surface roughness of CAD/CAM ceramic materials, reflecting their clinical behavior. Conclusion There were statistically significant differences in surface roughness between glazed and non-glazed CAD/CAM materials. Among the tested materials, the Cerec group consistently showed higher roughness values compared to Cerasmart, Empress, and E.max ($p < 0.05$). Glazing and thermocycling significantly influenced the surface roughness of all groups.

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Introduction:-

A wide range of materials are nowadays available for the digital milling process, broadening the range of treatment options for CAD/CAM treatment planning. Selecting the most suitable material for each specific clinical indication can be challenging. Therefore, the purpose of this study is to provide an overview of the development of ceramic CAD/CAM materials, evaluate their individual properties and critically analyze recent clinical data. [1]. The CAD/CAM procedure in dentistry refers to an indirect restoration produced by a computer-aided design (CAD) and a computer-assisted machine (CAM) milling process [2]. The first system was developed in 1971 by Duret and colleagues, but due in large part to insufficient digitizing accuracy, insufficient processing power, and other considerations, it was not widely utilized [3]. The development of CAD/CAM technology was driven by the desire to improve the esthetics of restorations, give them a more uniform appearance, ensure the strength of restorations, and simplify, speed up and improve dental procedures. [4]. The reliability of CAD/CAM blocks is boosted since they show fewer defects and porosity than hand-built materials do [5]. Dental CAD/CAM technologies are recommended for the fabrication of indirect restorations using ceramic or hybrid materials. Composites containing ceramic materials used for these purposes have recently been significantly improved due to improved physical and mechanical characteristics compared to ceramic [6,7]. The data acquisition step of a dental scan varies depending on the CAD/CAM system. The scanner interfaces with CAD software that is compatible with many of the CAD/CAM systems of which it is a part [8,9]. The digital scanning method makes the process more comfortable for the patient, reducing the time and resources required for classical impression procedures and the preparation of plaster models [10,11,12]. The users can select a preset template that the CAD software has created or they can develop their own with some alterations. Once the restoration design is complete, the CAD software converts the virtual model into another format, which the CAM system uses to start the milling process [13,14,15]. This study provides new data characterizing the physical properties of various CAD/CAM materials, which will enable a more rational approach to selecting CAD/CAM blocks for different clinical situations.

The purpose of the study –
To evaluate the effect of glazing and thermal cycling on the surface roughness values of four different types of ceramic milled CAD/CAM veneers.

Materials And Methods:-

In this in vitro study, typodont models (Kerr, Germany) were used, each featuring a maxillary central incisor prepared with minimal reduction of the incisal edge and no proximal intervention, following specified guidelines. Four types of ceramic materials in the form of CAD/CAM blocks were used: lithium disilicate-based glass ceramics (IPS E.max CAD, Ivoclar Vivadent, Germany), leucite reinforced glass ceramics (Empress CAD, Ivoclar Vivadent, Germany), feldspathic ceramics (CEREC, Dentsply Sirona, Germany), and hybrid nanoceramics (Cerasmart, GC, Japan). Twenty laminate-shaped samples were milled from each material, with each sample measuring 10 mm in length and 0.8 mm in thickness at the middle 1/3 and incisal 1/3 areas, and 0.7 mm in the cervical areas. All samples were categorized into four groups (n=20 each), which were further subdivided into two subgroups: 10 Samples with glazing (n=10) and without glazing (n=10).

Table 1:- List of materials used in this study.

Material name	Types of materials	Manufacturer	Code
Step Bur 12S	CAD/CAM bur	Dentsply,Sirona, Germany	E72579
Cylinder Pointed Bur 12S	CAD/CAM bur	Dentsply,Sirona, Germany	M71663
IPS Ivocolor Refill	Glaze material-liquid	Ivoclar,Vivadent,Germany	Z005KX
IPS Ivocolor Refill	Glaze material-powder	Ivoclar,Vivadent,Germany	Z003H6
Glaze mixture	Mixture for glaze from liquid and powder	Ivoclar,Vivadent,Germany	
Optiglaze Color	Glaze material	GC, Japan	1909141

Fig. 1:- Drawing the margins of the prepared tooth #11 (CEREC, Dentsply Sirona, Germany).

To design the restoration, three-dimensional modeling was conducted using CEREC SW 4.6.1 software. Initially, margins of the prepared tooth were automatically identified and subsequently manually adjusted (Fig. 1). The software then automatically generated the digital shape of the restoration (Fig. 2).

Fig. 2:- Designing and editing the restoration (CEREC, Dentsply Sirona, Germany).

Milling of the samples was carried out using a milling device (CEREC MC XL, Dentsply Sirona, Germany). After the appropriate block was fitted into the milling device (CEREC MC XL, Dentsply Sirona, Germany), it was fixed using a special diameter screwdriver. Three-dimensional modeling for the restoration design was carried out using the CEREC SW 4.6.1 software. Cylindrical burs (Cylinder Pointed Bur 12S, Dentsply Sirona, Germany) and step burs (Step Bur 12S, Dentsply Sirona, Germany) were used for the milling process (see Table 1). Before milling, separate burs were dedicated for each group of materials. After milling, the samples were carefully taken and placed into a designated box with identification numbers to prevent mixing. Due to the higher hardness of the E.max block, the milling process took longer compared to the Empress, CEREC, and Cerasmart groups. To achieve final strength, the partially crystallized samples from the IPS E.max CAD group were fully crystallized in an Ivoclar Programat P500 oven (Ivoclar Vivadent, Germany) at 850°C, with an initial temperature of 550°C for 20 minutes. Ten samples each from the IPS Empress CAD and IPS E.max CAD groups were glazed using IPS Ivocolor Glaze Paste (Ivoclar Vivadent, Germany) (refer to Table 1). These glazed samples were fired for 20 minutes at a temperature of 840°C, with an initial temperature of 550°C, in a Programat P500 oven (Ivoclar Vivadent, Germany). CEREC samples underwent the glazing process in a Focus 2010 oven (Shenpaz, Israel) (see Fig. 26), at a temperature of 820°C, with an initial temperature of 550°C. Cerasmart samples were finished with Optiglaze Color glaze (GC, Japan) (Table 1). The external surface of Cerasmart samples (GC Corp, Japan) was treated with a steam cleaner for 5 seconds and subsequently sandblasted with aluminum oxide particles sized at 25 microns (0.15 MPa/2.5 bar). After cleaning and drying, Multi Primer (GC, Japan) was applied to the surface of 10 samples from the Cerasmart group. The samples were then stored in a closed box for 60 seconds. Glaze (Opticolor, GC) was applied to the surface of the Cerasmart samples. Polymerization was carried out using a polymerization lamp (Bluephase, Ivoclar Vivadent, Germany) for 40 seconds. Surface roughness measurements were conducted on both sides of each sample using a profilometer. The average surface roughness values from each sample were measured three times at three different points using a profilometer (Perthometer M1, Mahr, Germany) in the hard tissue laboratory (Faculty of Dentistry, Yeditepe University, Istanbul, Turkey). Measurements were taken at the incisal edge, in the middle, and cervical areas of the samples. These measurements were performed after milling, after glazing, and after thermocycling. The samples underwent the thermocycling process in distilled water at temperatures of 5°C and 55°C (±2°C) using 10,000 cycles (thermal cycler, Delta, Salibrus, Turkey). It has been noted that 10,000 cycles approximately correspond to one year [14]. The dwell time was set to 10 seconds, and the holding time at each temperature was set to 20 seconds. Surface roughness measurements were performed at three stages: after milling, after glazing, and after thermocycling. Scanning electron microscopy images (at magnifications of 100x, 250x, 500x, and 1000x) were obtained from each material both after milling (see Fig. 7, 9, 11, 13) and after thermocycling (see Fig. 6, 8, 10, 12).

Statistical analysis of the study's findings was performed using IBM SPSS Statistics 22 (IBM SPSS, Turkey). The Kolmogorov-Smirnov and Shapiro-Wilk tests were used to assess the normality of the data distributions and confirm their suitability. When group variances were homogeneous, the Tukey HDS and Tamhane's T2 tests were applied; otherwise, the Oneway ANOVA test was used to compare parameters between material groups. Within-group comparisons before and after thermocycling were conducted using paired sample t-tests. For repeated measurements, analysis of variance (ANOVA) was employed, followed by post hoc Bonferroni tests to compare values across milling, glazing, and thermocycling periods. The significance level for all analyses was set at $p < 0.05$.

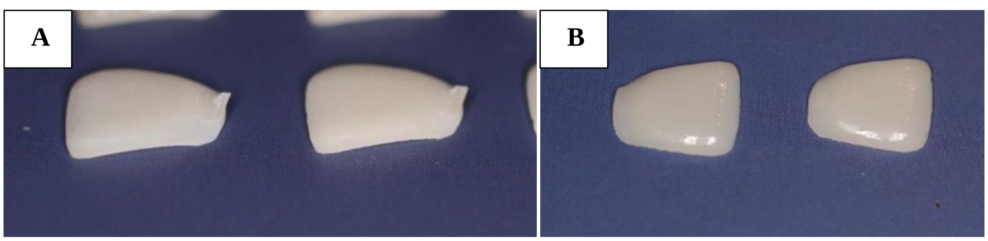

Fig. 3:- Samples without (A) and with (B) the application of the glaze layer.

Results:-

A statistically significant difference in terms of surface roughness values among different types of ceramic materials was observed. Application of glaze layer resulted in a significant decrease in surface roughness values. Specifically, the surface roughness of the CEREC group after glazing was significantly higher compared to that of the Cerasmart, IPS E.max, and IPS Empress CAD groups ($p < 0.05$) (see Fig. 4).

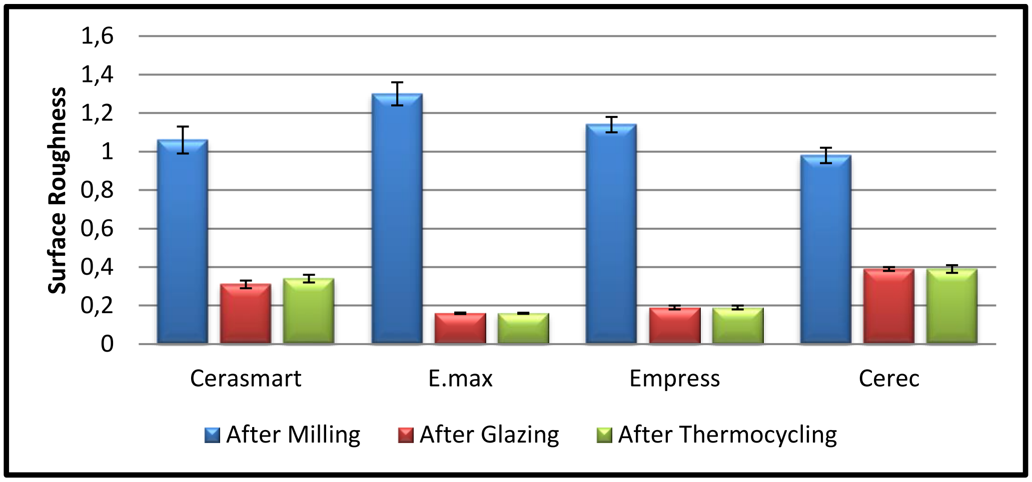

Fig. 4:- Subsequent evaluation of materials based on surface roughness values.

Table 2:- Evaluation of the surface roughness (μm) values in the presence of the glaze layer on the surface.

Materials	After milling	After glazing	After thermocycling	²p
	Mean±SD	Mean±SD	Mean±SD	
Cerasmart	1,06±0,07	0,31±0,02	0,34±0,02	<0,001*
E.max	1,30±0,06	0,16±0,004	0,16±0,003	<0,001*
Empress	1,14±0,04	0,19±0,01	0,19±0,01	<0,001*
Cerec	0,98±0,04	0,39±0,01	0,39±0,02	<0,001*
¹p	<0,001*	<0,001*	<0,001*	

[1]Oneway ANOVA Test [2]Repeated measures ANOVA *p<0.05

When assessing the values of the glazed surface, a statistically significant difference was revealed between the surface roughness values of the materials after thermocycling (p<0.05). When applying glaze to the surface, a statistically significant difference was observed between the materials in terms of average surface roughness values after milling (p<0.05). The surface roughness values after milling of the E.max group were significantly higher than those of the Empress, Cerasmart, and Cerec groups (p<0.05) (Table 2). When analyzing subgroups without applying glaze layer to the surface of the samples, a statistically significant difference was revealed between the materials in terms of surface roughness after milling (p<0.05) (Table 3, Fig. 5). It was found that the surface roughness values after milling of the E.max group were significantly higher than those of the Empress, Cerasmart, and Cerec groups (p<0.05). In the absence of glaze layer on the surface of the samples, there was a significant difference in the average surface roughness values between the materials after thermocycling (p<0.05) (Table 3). It was found that surface roughness after thermocycling were higher in the E.max group compared to the Cerasmart, Cerec, and Empress groups (p<0.05). The surface roughness values of materials after thermocycling was found to be statistically significantly lower than the values after milling (p<0.05) (Table 3).

Table 3:- Evaluation of the surface roughness (μm) values without a glaze layer on the surface.

	After milling	After thermocycling	²p
Materials	Mean±SD	Mean±SD	
Cerasmart	1,04±0,06	1,29±0,04	<0,001*
E.max	1,30±0,03	1,39±0,02	<0,000*
Empress	1,14±0,02	1,10±0,21	0,543
Cerec	0,96±0,06	1,24±0,04	<0,001*
¹p	<0,001*	<0,001*	

[1]Oneway ANOVA Test [2]Paired samples t test *p<0.05

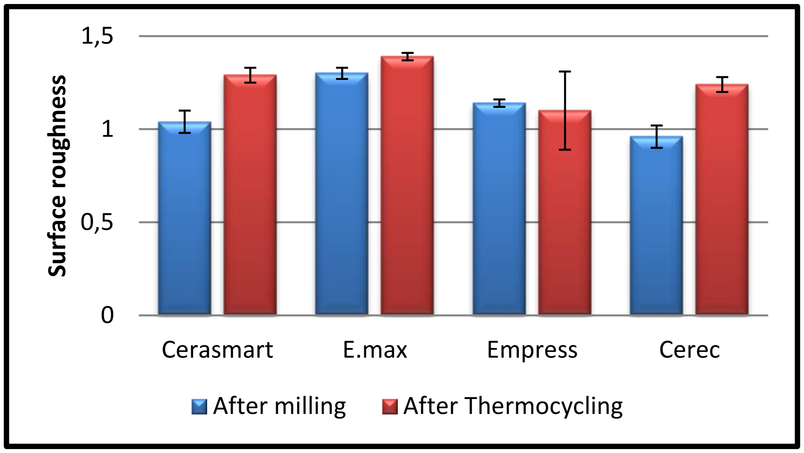

Fig 5:- Surface roughness values after milling and after thermocycling.

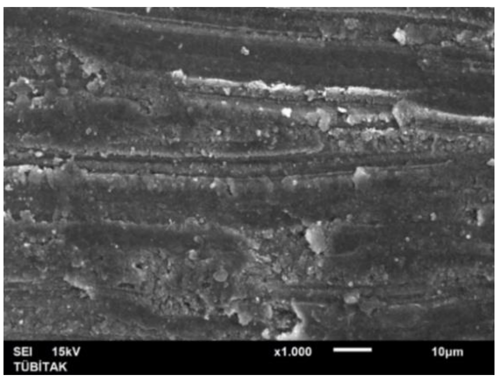

Fig. 6:- SEM images of Cerasmart

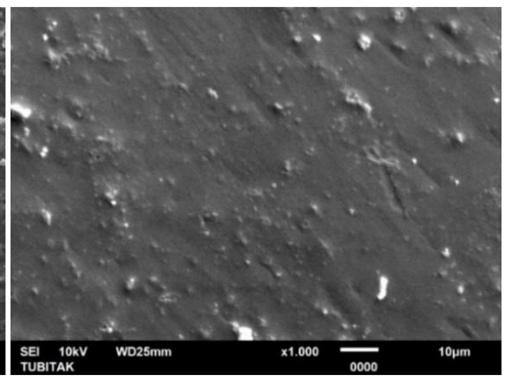

Fig. 7:- SEM image of Cerasmart after glazing and thermocycling

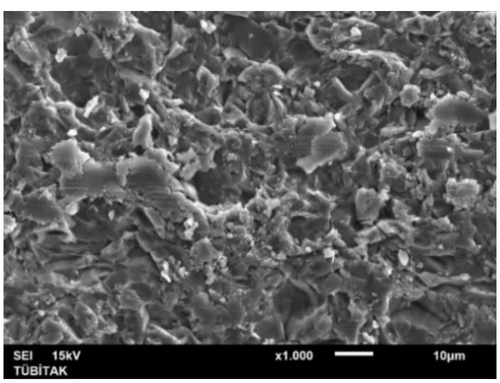

Fig. 8:- SEM images of Cerec

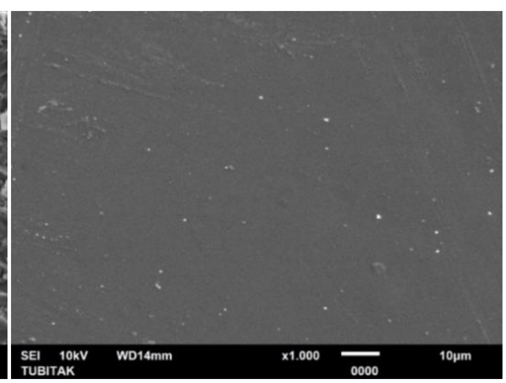

Fig. 9:- SEM image of Cerec after glazing and thermocycling

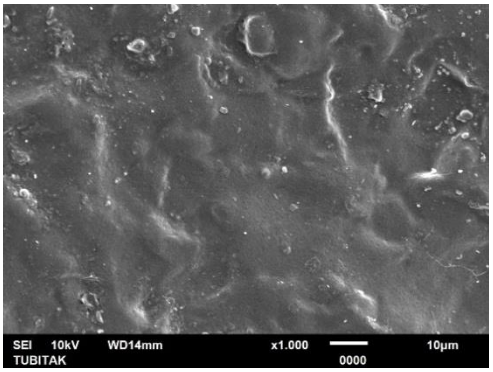

Fig. 10:- SEM images of E.max

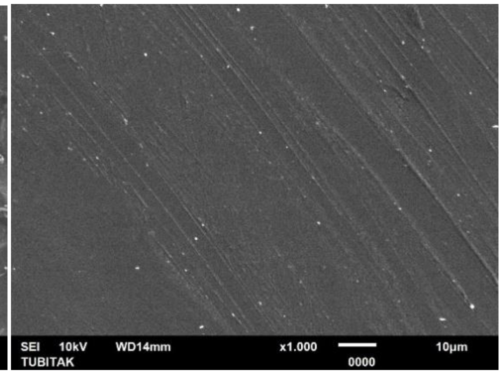

Fig. 11:- SEM image of E.max after glazing and after thermocycling

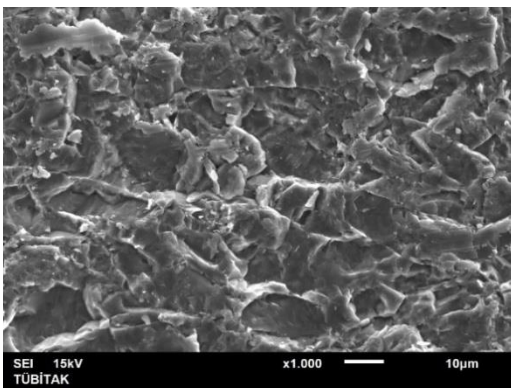

Fig. 12:- SEM images of Empress.

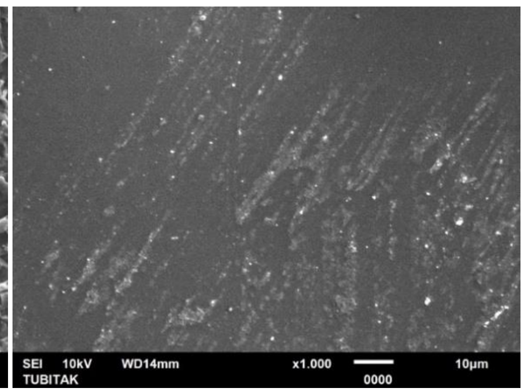

Fig. 13:- SEM image of Empress after glazing and thermocycling.

Discussion:-

Observations using a scanning electron microscope (SEM) revealed that groups with glazed surfaces exhibited smoother surfaces compared to those without glaze layer. In the Cerasmart group (Fig. 7), glazed surfaces showed minor irregularities. The glazed layer of the E.max group (Fig. 11) displayed uneven surfaces with some irregularities. The glazed surface of the Cerec group (Fig. 9) appeared more uniform, while the Empress group (Fig. 13) exhibited fuzzy scratches and some deep, wide irregularities on the glazed layer.

The effects of various surface treatments on the surface roughness of CAD/CAM materials have been extensively studied. Our findings regarding surface roughness were compared with those from previous research, highlighting both similarities and differences.

In a study by Kara et al. (2020) [16], the effects of the glazing and polishing processes on the surface roughness of CAD/CAM composite-based blocks were evaluated. In their study, the surface roughness (Ra) values for Cerasmart, Lava Ultimate, and Shofu Block after glazing with Optiglaze Color were reported as follows: Cerasmart (0.170 ± 0.06 µm), Lava Ultimate (0.164 ± 0.03 µm), and Shofu Block HC (0.226 ± 0.08 µm). Similarly, our study found a higher surface roughness value for Cerasmart (0.31 ± 0.02 µm), which could be attributed to differences in the preparation methods, as our specimens were milled with a CAD/CAM Cylinder Pointed bur and Step Bur, leading to rougher surfaces before glazing.

In another study by Tekçe et al. (2018) [17], the effects of accelerated aging on the surface characteristics of glazed CAD/CAM composite blocks were investigated. They found that glazed surfaces, particularly those treated with Optiglaze Color, showed significant resistance to wear after 5000 heat cycles. Our findings align with theirs, indicating that glazing with Optiglaze Color helps smooth the surface of CAD/CAM resin materials. However, the surface roughness values we observed were slightly higher (0.31 µm) compared to those reported in their study (0.164 µm for

Lava Ultimate). This discrepancy may stem from differences in material composition, glazing procedures, and measurement techniques.

Zanoboni et al. (2022) [18] studied the effects of different glaze firing techniques on the surface roughness of CAD/CAM ceramics, such as E.max CAD and IPS Empress CAD. Their results showed a significant increase in surface roughness after the glazing process, with values ranging from 0.306 µm to 0.433 µm depending on the technique used. In comparison, our study found that the surface roughness (Ra) values of IPS Empress CAD were 0.189 µm, which was lower than those reported by Zanoboni et al. This difference may be attributed to variations in the glaze material used, as our study applied IPS Ivocolor (Ivoclar) as a glaze material, which might result in smoother surfaces.

Flury et al. (2010) [19] also investigated surface roughness after the application of glazes and polishing systems. Their study reported that glazed surfaces had higher roughness values (Ra = 0.306 µm for Vita Mark II and Ra = 0.433 µm for IPS Empress CAD) compared to those polished with systems like Sof-Lex. In contrast, our study found that the surface roughness of IPS Empress CAD after glazing was lower (Ra = 0.189 µm). The difference in values could be explained using different glaze materials and the specific experimental setup, as surface treatments can significantly affect roughness outcomes.

In conclusion, our study provides valuable insights into the surface roughness of various CAD/CAM materials after glazing. While the results of our study align with those of some previous studies, the observed differences emphasize the importance of factors such as material composition, surface preparation methods, and glaze application techniques in determining the final surface roughness. Future studies should continue to investigate these variables to optimize the longevity and clinical performance of CAD/CAM materials in dental application

Conclusion:-

The research hypothesis was confirmed through this in vitro study, which demonstrated significant differences in surface roughness between glazed and non-glazed samples. Significant variations in surface roughness values were observed among the tested materials based on their group affiliations. Specifically, the Cerec group exhibited higher surface roughness values compared to the Cerasmart, Empress, and IPS E.max groups ($p < 0.05$). Both glazing and thermocycling processes significantly influenced surface roughness among various samples. In conclusion, there is a statistically significant difference in surface roughness between glazed and non-glazed CAD/CAM materials.

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