

**YEDITEPE UNIVERSITY INSTITUTE OF HEALTH SCIENCES
DEPARTMENT OF RESTORATIVE DENTISTRY**

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

PHD DOCTORAL THESIS

FARID AHMEDBEYLI, DDS

YEDITEPE UNIVERSITY, ISTANBUL - 2023

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APPROVAL

This thesis has been deemed by the jury in accordance with the relevant articles of Yeditepe University Graduate Education and Examinations Regulation and has been approved by Administrative Board of Institute with decision dated and numbered

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Director of Institute of Health Sciences

DECLARATION

I hereby declare that this thesis is my own work and that, to the best of my knowledge and belief, it contains no material previously published or written by another person nor material which has been accepted for the award of any other degree except where due acknowledgment has been made in the text.

10.10.2023

Farid Ahmedbeyli



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LIST OF SYMBOLS AND ABBREVIATIONS

CAD/CAM - Computer-aided design (CAD) / computer-aided manufacturing (CAM)
Cerec - Chairside Economic Restorations of Esthetic Ceramics or CERamic REConstruction
CCD - Charge coupled device
CS - Cerasmart
DNH - Double network hybrid
3D – 3 dimensional
HF - Hydrofluoric acid
HT – High Translucency
LTD - Low-temperature degradation
LT – Low translucent
 μm – Micrometer
mm – Millimeter
MPa – Megapascal
Ra - Mean roughness / the arithmetic average of the absolute
Rq - root mean square average
 μCT - micro-computed tomography
HT – high translucent
PICN - Polymer-Infiltrated-Ceramic-Network material
PMMA - polymer methacrylate
SEM - Scanning Electron Microscopy
SD – Standart Deviation
TS – Thermocycle
VHN – Vickers hardness test
ZLS - Zirconium oxide and lithium silicate glass ceramics

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ABSTRACT

The Purpose: The aim of this in-vitro study was to evaluate the effect of glaze and thermocycling to the surface roughness and microhardness values of four different ceramic CAD/CAM materials.

Material & Methods: CAD / CAM laminate veneer shaped 80 samples were milled with CAD/CAM system (inLab MC XL Cerec, Sirona) after scan of plastic maxillary first incisor tooth of educational model with Omnicam scanner (Cerec, Sirona). Four different CAD/CAM ceramic materials were tested in this study: Lithium disilicate (IPS E.max CAD, Ivoclar), Leucite reinforced ceramic (IPS Empress CAD), Feldspathic ceramic (Cerec, Sirona) and a Nanoparticle-filled resin ceramic (Cerasmart, GC) (CS). Four groups from 80 samples (20 samples for each group, $n=20$) were allocated to two subgroups (10 samples, $n=10$): Glazed and non-glazed. All specimens were subjected to 10.000 thermo cycles. Surface roughness and Vickers hardness values were obtained in three stages: After milling (Initial), after glazing, after thermocycling. Sem images (100x, 250x, 500x, 1000x magnifications) of each material were obtained from every group (After milling (Initial), after thermocycling).

Results: There is a statistically significant difference between materials in terms of initial surface roughness averages. The initial surface roughness of the Emax group was significantly higher than that of the Empress, CS, and Cerec groups ($p<0.05$). When evaluating the glazed surface, there was a statistically significant difference between the materials in terms of post-glazing microhardness averages ($p<0.05$). The microhardness of the Emax group after glaze was significantly higher than that of the CS, Empress and Cerec groups ($p<0.05$). When evaluating the glazed surface, there is a statistically significant difference between the materials in terms of microhardness averages after the thermo cycle ($p<0.05$)

The post-thermo-cycle microhardness of the Emax group was significantly higher than that of the CS, Empress and Cerec groups ($p<0.05$). When evaluating the surface of CS material; there is a statistically significant difference between the mean microhardness at baseline, after glazing and after thermo cycle ($p1:0.000$; $p2:0.000$; $p<0.05$). Initial surface roughness was found to be statistically significantly higher after glaze and after thermo cycle ($p1:0.000$; $p2:0.000$; $p<0.05$).

When evaluating the surface of Emax material; initial surface roughness was found to be statistically significantly higher after glaze and after thermo cycle ($p<0.05$). Microhardness

level after glazing was statistically significantly higher than after Thermo cycle ($p<0.05$). When evaluating the surface of Empress material; initial surface roughness was found to be statistically significantly higher after glaze and after thermo cycle ($p<0.05$). There was no statistically significant difference between microhardness levels after glazing and after thermo cycle ($p:0.074$; $p>0.05$).

When evaluating the surface of Cerec material; initial surface roughness was found to be statistically significantly higher after glaze and after thermo cycle ($p<0.05$). There was no statistically significant difference between microhardness levels after glazing and after thermo cycle ($p>0.05$).

When glaze is not applied to the surface, the initial microhardness of the Emax group was significantly higher than that of the CS, Empress and Cerec groups ($p<0.05$). When glaze is not applied to the surface, the post-thermo-cycle microhardness of the Emax group was significantly higher than that of the CS, Empress and Cerec groups ($p<0.05$).

When evaluating surface of CS material; microhardness after thermo cycle was found to be statistically significantly lower from baseline ($p:0.000$; $p<0.05$). When evaluating surface of Empress material; microhardness after thermo cycle was found to be statistically significantly lower from baseline ($p<0.05$). When evaluating surface of Emax material; microhardness after thermo cycle was found to be statistically significantly lower from baseline ($p<0.05$).

Conclusion: It was concluded that application of the glazed layer on the surface of the samples significantly affects the surface roughness values of all samples. Reduction of the surface roughness values lead to increase the smoothness of the surfaces. Glazing decreases the surface roughness and microhardness values of CAD/CAM milled laminate veneer samples. Compared to glass ceramics, composite CAD/CAM material is more prone to increase of surface roughness values after aging. Thermocycling has more influence on surface roughness values than microhardness values.

This study was conducted for researchers and clinicians to better understand the surface quality and properties of CAD/CAM materials to be used in clinics. This study was conducted to enable clinicians and researchers to evaluate the surface properties of materials to be used in CAD/CAM systems and to produce better quality, healthier and longer lasting restorations.

Key Words: CAD/CAM; Surface roughness; Microhardness; Glaze; Thermocycling

ABSTRACT (TÜRKÇE)

Amaç: Bu in vitro çalışmanın amacı, glazür ve termosiklüs işlemlerinin dört farklı seramik CAD/CAM materyallerinin yüzey pürüzlülüğü ve mikrosertlik değerleri üzerine etkisini değerlendirmektir.

Gereç ve Yöntemler: Eğitim modelinin plastik maksiller birinci kesici dişi Omnicam tarayıcı (Cerec, Sirona) ile tarandıktan sonra CAD/CAM laminate veneer şekilli 80 tane CAD/CAM sistemi (inLab MC XL Cerec, Sirona) ile üretildi. Bu çalışmada dört farklı CAD/CAM seramik materyalleri değerlendirildi: Lityum disilikat (IPS e.max CAD, Ivoclar), Lösit takviyeli seramik (IPS Empress CAD), Feldspatik seramik (Cerec, Sirona) ve Nanopartikül dolgulu reçine seramik (Cerasmart), GC). 80 numunedan 4 grup (her grupta 20 numune, n=20) iki alt gruba (10 numune, n=10) ayrıldı: Glazürlü ve glazürsüz. Tüm örnekler 10.000 termosiklüs işlemine tabi tutuldu. Yüzey pürüzlülüğü ve mikrosertlik değerleri üç aşamada elde edilmiştir: Frezeleme sonrası (Başlangıç), Glazür sonrası ve termosiklüs sonrası. Her gruptan (Frezeleme sonrası (Başlangıç), termosiklüs sonrası) her materyalin sem görüntüleri (100 × 250 × 500 x 1000 büyütme) elde edilmiştir.

Bulgular: Başlangıç yüzey pürüzlülüğü ortalamaları açısından materyaller arasında istatistiksel olarak anlamlı bir fark vardır. Emax grubunun başlangıçtaki yüzey pürüzlülüğü Empress'inkinden önemli ölçüde daha yüksekti. CS ve Cerec grupları (p<0,05). Glaze'li yüzey değerlendirildiğinde, yaşlandırma sonrası mikrosertlik değerleri ortalamaları açısından materyaller arasında istatistiksel olarak anlamlı bir fark bulunmuştur (p<0,05). Emax grubunun glaze sonrası mikrosertliği CS, Empress ve Cerec gruplarına göre anlamlı derecede yüksekti (p<0,05). Glaze'li yüzey değerlendirildiğinde termosiklüs sonrası mikrosertlik değerlerinin ortalamaları açısından materyaller arasında istatistiksel olarak anlamlı bir fark bulunmuştur (p<0,05)

Emax grubunun termosiklüs sonrası mikrosertlik değerleri CS, Empress ve Cerec gruplarına göre anlamlı derecede yüksekti (p<0,05). CS materyalinin yüzeyini değerlendirirken; başlangıçta, glaze sonrası ve termosiklüs sonrası ortalama mikrosertlik değerleri arasında istatistiksel olarak anlamlı bir fark vardır (p:0,000; p<0,05). Başlangıç yüzey pürüzlülüğünün glaze sonrası ve termosiklüs sonrası istatistiksel olarak anlamlı düzeyde daha yüksek olduğu belirlendi (p1:0.000; p2:0.000; p<0,05).

Emax materyalinin yüzeyini değerlendirirken; başlangıç yüzey pürüzlülüğünün glaze ve

termosikl s sonrası istatistiksel olarak anlamlı d zeyde daha y ksek olduėu belirlendi ($p<0,05$). Glaze sonrası mikrosertlik d zeyi Termosikl s sonrasına g re istatistiksel olarak anlamlı derecede y ksekti ($p<0,05$). Empress materyalinin y zeyini deėerlendirirken; bařlangı  y zey p r zl l ė n n glaze ve termosikl s sonrası istatistiksel olarak anlamlı d zeyde daha y ksek olduėu belirlendi ($p<0,05$). Glaze sonrası ve termosikl s sonrası mikrosertlik d zeyleri arasında istatistiksel olarak anlamlı bir fark bulunmadı ($p:0,074$; $p>0,05$). Cerec materyalinin y zeyini deėerlendirirken; bařlangı  y zey p r zl l ė n n glaze ve termosikl s sonrası istatistiksel olarak anlamlı d zeyde daha y ksek olduėu belirlendi ($p<0,05$). Glaze sonrası ve termosikl s sonrası mikrosertlik seviyeleri arasında istatistiksel olarak anlamlı bir fark yoktu ($p>0,05$).

Y zeye glaze uygulanmadıėında Emax grubunun bařlangı  mikrosertlik deėerleri CS, Empress ve Cerec gruplarına g re anlamlı derecede y ksekti ($p<0,05$). Y zeye glaze uygulanmadıėında Emax grubunun termosikl s sonrası mikrosertlik deėerleri CS, Empress ve Cerec gruplarına g re anlamlı derecede y ksekti ($p<0,05$).

CS materyali y zeyini deėerlendirirken; Termosikl s sonrası mikrosertlik deėerleri istatistiksel olarak bařlangı taki deėerlere g re anlamlı derecede d ř k bulunmuřtur ($p:0,000$; $p<0,05$). Empress materyalinin y zeyini deėerlendirirken; Termosikl s sonrası mikrosertliėin istatistiksel olarak bařlangı taki deėerlere g re anlamlı d zeyde daha d ř k olduėu bulundu ($p<0,05$). Emax materyalinin y zeyini deėerlendirirken; Termosikl s sonrası mikrosertlik deėerlerinin istatistiksel olarak bařlangı taki deėerlere g re anlamlı d zeyde daha d ř k olduėu bulundu ($p<0,05$).

Sonuç:  rneklerin y zeyine glaze uygulamasının t m  rneklerin y zey p r zl l k deėerlerini  nemli  l  de etkilediėi sonucuna varılmıřtır. Y zey p r zl l k deėerlerinin azalması y zeylerin d zg nl ė n n artmasına neden olur. Glaze, CAD/CAM ile  retilen lamineler  rneklerinin y zey p r zl l ė  ve mikrosertlik deėerlerini azaltır. Kompozit i erikli CAD/CAM  rnekleri cam seramiklere g re termosikl s sonrası y zey p r zl l k deėerlerinin artmasına daha yatkındır. Termosikl s n y zey p r zl l k deėerleri  zerinde mikrosertlik deėerlerine g re daha fazla etkisi vardır.

Bu  alıřma, arařtırmacıların ve klinisyenlerin kliniklerde kullanılacak CAD/CAM malzemelerinin y zey kalitesini ve  zelliklerini daha iyi anlamaları amacıyla yapılmıřtır. Bu  alıřma, klinisyen ve arařtırmacıların CAD/CAM sistemlerinde kullanılacak materyallerin y zey  zelliklerini deėerlendirerek daha kaliteli, daha saėlıklı ve daha uzun  m rl  restorasyonlar  retebilmelerini saėlamak amacıyla yapılmıřtır.

Anahtar Kelimeler: CAD/CAM; Y zey p r zl l ė ; Mikro sertlik; Glaze; Termosikl s

1. INTRODUCTION and PURPOSE

Nowadays, aesthetics holds significant importance not only in dentistry but also in various other fields. Due to rising aesthetic standards and advancements in digital dental technology, a range of biocompatible all-ceramic systems with exceptional aesthetic and mechanical characteristics have been effectively integrated into dental practice. These alternatives are replacing traditional metal-supported ceramic restorations (1).

While metal-supported ceramic restorations have long been a favored treatment option in dentistry, they have led to the development of alternative materials and production methods due to several drawbacks. These drawbacks include the reflection of the dark color of the underlying metal structure, issues like allergies, complications such as fractures and cracks in veneer materials, and the inadequacy in replicating optical properties resembling natural dental tissue (2).

The aim of our in vitro study was to evaluate the surface roughness and microhardness values of four different CAD/CAM ceramics Feldspathics ceramics (Cerec), Lithium disilicate ceramics (IPS E.max CAD), Leucite reinforced ceramics (Empress CAD), and Resin-composite nano ceramics (Cerasmart).

The hypothesis of the study was that, there is a statistically significant difference between surface roughness, microhardness values of glazed and not glazed samples.

2. LITERATURE REVIEW

The technology used in computer-aided design (CAD) and computer-aided manufacturing (CAM) is one of the areas of modern restorative dentistry that is developing the fastest. Since Mörmann and Brandestini created the Cerec system in 1985, CAD/CAM technology and chairside dentistry have existed side by side. There are currently more chairside solutions available than ever before (3). With additional built-in design software surfaces, intraoral scanners have gotten smaller, faster, and more accurate. Without using any actual models, different restorations can be created in a virtual environment with on-screen planning and computer-assisted production with rapid prototyping techniques like milling or the expanding use of 3-dimensional printing. Two significant advantages of the digital process over traditional impression techniques in fixed prosthodontics are patient preferences and superior marginal and internal fit (4). The use of homogeneous industrial blanks and blocks reduces the likelihood of material failures during production and clinical application (5). The reliability of CAD/CAM blocks is boosted since they show fewer defects and porosity than hand-built materials do (6).

Currently, a wide variety of materials are accessible for the digital manufacturing process, expanding the spectrum of indications in the fields of sophisticated treatment planning, orthodontics, restorative dentistry, and dental implants. As a result, selecting the appropriate material for each specific indication has become a challenging task. Therefore, the objective of this study is to provide an overview of the development of CAD/CAM ceramic materials, assess their individual properties, and critically examine the recent clinical evidence. (7).

2.1. Digital Dentistry

The recent strides in digital dentistry have brought about new challenges for dental professionals. Computer-aided design/computer-aided manufacture (CAD/CAM) technology, renowned for its speed, ease of use, and clinical effectiveness, has become a cornerstone of everyday dental practice. This technology boasts a wide array of applications, spanning from the creation of indirect restorations such as inlays, onlays, veneers, and crowns to the production of fixed partial dentures, implant abutments, full-mouth reconstructions, and even its role in orthodontics (8,9).

The development of CAD/CAM technology was driven by the desire to enhance the aesthetics of restorations for a more uniform appearance, ensure the strength of tooth restorations, and streamline, expedite, and enhance the overall dental processes (10).

More specifically, digital scans of the denture offer speedier and easier treatment than traditional impressions because casts, wax-ups, investing, casting, and firing are removed. Additionally, the presence of a milling machine on the premises avoids the need for interim restorations, which require additional time for fabrication and fitting, and enables patients to receive their permanent restorations at the initial appointment. CAD/CAM restorations are of a high caliber because to the precise measurements and construction made possible by the use of digital technology (11). The primary constraints associated with CAD/CAM technology include the upfront expenses related to acquiring both the hardware and software, in addition to the investments of time and finances required for adequate training (9).

Dental CAD/CAM technologies are typically recommended for the fabrication of indirect tooth restorations. For such restorations, ceramic or composite materials are commonly chosen. Composite materials used in CAD/CAM have recently seen significant advancements, with enhanced physical and mechanical characteristics compared to ceramics. These improvements have been made possible through modifications in the manufacturing processes, such as huge-pressure and huge-temperature procedures, as well as structural enhancements like the incorporation of glass ceramic networks (12,13).

CAD/CAM composites exhibit lower hardness and stiffness compared to ceramics, resulting in reduced clinical wear on antagonistic tooth tissues and being more compatible with the milling machine. Additionally, composites are less brittle than ceramics and are simple to produce and repair, improving marginal quality and reducing chipping and fracture formation during manufacture (possible thickness up to 0.2 mm) (14,15,16,17).

CAD/CAM composites can be categorized into two main groups based on their microstructural characteristics: a) those with resin diluted fillers, and b) those with polymer-impregnated porcelain networks (PICN) (18). The first class encompasses composite blocks with an organic matrix primarily composed of a basic monomer type (e.g., Bisphenol A diglycidylmethacrylate, or Bis-GMA) and filler particles (such as silica, zirconia, barium glass, etc.) dispersed within the matrix. These composite blocks may also contain other monomers like urethane dimethacrylate (UDMA) and triethylene glycol dimethacrylate (TEGDMA), among others (7).

To enhance fracture resistance and preserve the marginal integrity of restorations, it is essential to strengthen the adhesion between indirect CAD/CAM restorations and resin cement when attaching them to tooth surfaces using resin cements (19,20). In order to achieve satisfactory adhesion to composite CAD/CAM restorative materials, it is necessary to apply pre-treatments to the bonded surfaces, which can be either mechanical or chemical in nature (21,22). There are chemical interactions between resin cement and resin-formed restorative materials (21). Applying primers to watery polymeric resin areas can greatly enhance this adhesive bonding process (23,24).

Additionally, sandblasting with aluminum oxide (Al_2O_3) particles or micromechanical pre-treatments, which primarily employ hydrofluoric acid (HF), can also strengthen the binding between surfaces (25), that generates a micro-retentive surface that let on the resin cement to mechanically interlock (26).

In addition, a tribochemical technique that uses silica-coated particles rather than pure Al_2O_3 for sandblasting has been developed. This results in an extra chemical bonding by increasing the surface's silica (SiO_2) content such that a silane can be applied before the adhesive agent (27,28).

The surface shape and roughness of the two bonding surfaces play a major role in this micromechanical interlocking of the interface (29).

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 (30). The first system was produced in 1971 by Duret and friends, but due in large part to insufficient

digitizing accuracy, insufficient processing power, and other considerations, it was not widely utilized (31). In Zurich, Switzerland, during the next ten years, Mormann and Brandestini developed the CEREC system. Ceramic reconstruction is referred to as CEREC. CEREC is responsible for the CAD/CAM industry's rapid global expansion. The computer-aided design of restorations includes several potentially dangerous steps, including data collection, calculating the margin in the digital model, and restoration design (32).

There are challenges in the manufacturing process as well, such as surface flaws caused by cutting channels and the accuracy of restoration fit, particularly when intricate surfaces need to be recreated (33).

Because of these concerns, the systems have been improved during the previous 20 years. Most modern dental labs now employ CAD/CAM, and some forward-thinking dentists are even using it at the chairside (34). Data gathering, indirect restorative design, and prosthetic creation are the three separate steps that make up the CAD/CAM process (35).

To maximize the outcomes, each phase necessitates specific consideration. It's also crucial to note that each stage is separate, even though the photographs that are taken will affect how the digital model is formed and how the indirect restorations will be built (34).

Throughout the indirect restoration design process, data can be sent to the milling machine while still being preserved and available at any time. At this stage, a computer program details the construction of the indirect restoration. are offered for both internal and external use (36).

Typically, an active triangulation technique is used by the optical scanner to record projected patterns of light and shade using a sensor. The sensor's receptor converts changes in depth into distances to produce the three-dimensional image (37). The accuracy of the digitalized images could be harmed by diffusion, though, as the data is gathered by the light's reflection being captured by a PSD sensor (35). Sprays that must be applied to the duplicated surfaces, especially those inside the mouth, can assist to prevent this. The requirement of performing this task must be considered while choosing the data collection method (38).

For instance, this could be lessened by using sprays on the surfaces that need to be copied, especially inside the oral cavity. It is crucial to consider the importance of this step while choosing a data collection method (31). Plaster models can be used to collect data when it's necessary to duplicate several dental components or insert parts of implants into soft tissues. Although it seems that digital impression has a lot of advantages, not all prosthetic applications can use it (39,36). There is a chance for both intraoral and extraoral usage.

An active triangulation approach is frequently used by the optical scanner to record the patterns of reflected light and shadow using a sensor. In order to construct the three-dimensional image, the sensor's receiver converts changes in depth into distances (37). The accuracy of images that have been digitally enhanced, however, may be impacted by diffusion as data is digitalized by light reflection captured by a PSD sensor (35). Sprays that should be applied to the affected areas, especially the oral cavity, can help to lessen this. Consider the necessity of performing this operation when selecting the data collection method (38).

Despite the fact that there isn't much material to back this up (31), data collection can be done on plaster models when multiple dental components need to be reproduced and implant components need to be put into soft tissues. Although digital impression appears to offer many advantages, it cannot be used in all prosthetic scenarios (39).

2.1.1. Cerec CAD/CAM Systems

In the 1970s, Duret and Preston developed the CAD/CAM (Computer Aided Design/Computer Aided Manufacture, or CAD/CAM) approach for dental fixed prosthesis application procedures. The CAD/CAM systems were replaced by the CEREC® (Ceramic Reconstruction) technology, developed by Moermann in the 1980s and utilized by dentists, in many labs and offices (8). CAD/CAM technology offers reasonably priced restorations with excellent function, biocompatibility, and cosmetic quality using new and improved materials (3).

Since the 1980s, various technologies, including the well-known CEREC, have been created. Numerous software and hardware upgrades have caused systems to change (40,41).

The use of various high-quality materials that are delicately compatible with dental abutments or implant abutments is made possible by these systems, which also have the advantages of reducing technician-related steps, minimizing errors, producing restorations with better internal and marginal compatibility in a single session, and delivering the restoration to the patient as soon as possible (7,42).

The three steps of production in the CAD/CAM method are as follows: (36,43)

1. Getting digital data by either directly scanning the prepared support tooth or support implant surface with a digital impression technology or indirectly scanning a plaster model made using a traditional impression technique,
2. The use of software to process digital data and create restoration designs (CAD),
3. Restoration product production (CAM).

Digital Data Acquisition

In the past, a cast model was employed to capture the images and/or measurements of the prepared teeth and related structures. Intra-oral imaging has been applied directly more recently. Both procedures can be carried out using nuclear magnetic resonance (NMR), contact scanner devices, 3D microtomography (MCT), visual scanners (31),(34) CCD digital cameras that make use of lasers or visible light. Smaller scanners can also be used, offering them a variety of uses in dentistry offices and manufacturing facilities for prosthetics (35).

The tooth scanning data capture stage varies amongst CAD/CAM systems. The scanner works with CAD software that is compatible with several CAD/CAM systems as one of its components (44),(3). Data is acquired rapidly and with excellent resolution using optical scanners. Digital intraoral scanners eliminate the need for traditional impression taking and model acquisition techniques. The digital impression method makes the treatment process more comfortable for the patient. The application requires less time and supplies overall. (45,46,47).

In a dental lab, where the final glazed surface is created via an oven firing process, ceramic restorations are routinely constructed. The restoration's surface is thus smudge-free and biocompatible. Using chairside CAD/CAM systems, which demand the dentist to fabricate the restoration there, ceramic restorations can be made in a single appointment. However, a smooth, ready-for-cementation surface is not produced by the milling process. The ceramic material needs to be finished and contoured post-milling in order to be ready for shipping. Two types of ceramic materials are available for chairside CAD/CAM restorations, and they can be either hand-finished and polished or glaze-fired in a porcelain oven. Vita Mark II (Vita, Yorba Linda, CA, USA), Sirona Blocs (Vita), and Empress CAD (Ivoclar, Germany) are three examples of fine-grained feldspathic porcelains. Empress CAD is a leucite-strengthened glass ceramic. Many chairside ceramic CAD/CAM restorations are hand-polished before delivery as an alternative to firing these ceramic materials in an oven to create a glaze (48).

Geometric design information from CAM (Computer Aided Machining) is supplied to a system with a controlled milling mechanism to manufacture the final restorative prosthesis.

The major objective is to create and improve a quicker replica of the exact measurements of the missing tooth structure. With the use of the device the dentist is able to do a ceramic restoration in only one appointment without the need for a separate laboratory. The dentist captures essential details by digitally scanning the cavity within the mouth (such bordering lines and approximal contacts), and the restoration is fabricated from a prepared porcelain block. The accurate fit and fracturing of the edges of the porcelain restoration are both influenced by the type of ceramic material used, the operator's abilities, and the age and quality of the grinding equipment (49).

The most recent technologies can produce distinctive lithium disilicate implant abutments, three-unit bridges, inlays, onlays, veneers, and crowns using a three-dimensional (3-D) design program (50).

Finishing and polishing methods, which create a glossy surface with qualities resembling those of natural teeth in terms of reflection and refraction, also enhance the aesthetic appeal of the milled CAD/CAM restorations. According to multiple laboratory tests, utilizing diamond polishing pastes with rubber polishers results in the flat porcelain surfaces. (51,52,53).

Numerous in vitro studies in the dental literature demonstrate the value of polishing tools and techniques for correcting and repolishing laboratory-fabricated ceramic restorations. Instead of requiring a porcelain oven, chairside CAD/CAM restorations can be completed at a dental office in only one visit. Due to this, the entire repair must be completed before delivery, which will take a lot of time and work. Two new chairside CAD/CAM materials have been developed that are easier to mold and polish without the use of a ceramic furnace and are reportedly more resilient to chipping and fracture than conventional ceramics. In a resin matrix, the Lava Ultimate resin-based ceramic material from 3M ESPE in St. Paul, Minnesota, contains clusters of 4 to 11 nm zirconia and aggregated 20 nm silica. (54). According to the description, Enamic (Vita) is a hybrid porcelain made up of 86% feldspathic porcelain and 14% interpenetrating polymer network (55).

Instruments and methods indicated for contouring and polishing must provide a smooth surface in order to promote biocompatibility by inhibiting bacterial growth on the surface of the restorations (56,57). This will increase the bending strength of the restoration and reduce the risk of crack (58,59,60,59,60,61,62).

The tooth scanning data capture stage varies amongst CAD/CAM systems (63). The scanner works with CAD software that is appropriate for the many CAD/CAM systems of which it is a part (44,3).

Data is acquired rapidly and with excellent resolution using optical scanners. Digital intraoral scanners eliminate the need for traditional impression taking and model acquisition techniques. The digital impression method makes the treatment process more comfortable for the patient. The application requires less time and resources (45,46,47).

On a computer screen, there are many CAD programs that allow for three-dimensional restoration design. The user has the choice of directly using the templates provided by the CAD software or designing his own design and making adjustments. After the restoration's design is complete, the CAD program converts the virtual model to a different format, enabling the CAM unit to begin manufacturing (64,8,65).

The use of several different technologies is required for the development of restorations. The subtractive method and the additive method are the two main strategies employed in the manufacturing phase nowadays (66,67).

2.1.2 History of CAD/CAM

Preston and Duret in 1970s developed the CAD/CAM (Computer Aided Design/Computer Aided Manufacture) method for applying dental fixed prostheses (68). CAD/CAM systems started to take their position in many dental labs and offices after dentists adopted Moermann's CEREC® (CEramic REConstruction) technology in the 1980s (8). CAD/CAM technology enables the fabrication of high quality restorations that are practical, biocompatible, and aesthetically acceptable while also reducing the cost thanks to the use of new and improved materials (69),(3). Benefits of these systems include the ability to produce restorations with better internal and marginal compatibility in a single session, the ability to produce restorations with fewer technician-related steps and reduced errors, the ability to use a variety of high-quality materials sensitive to dental abutments or implant abutments, and the ability to provide the restoration to the patient as soon as possible (7,42).

Along with the methods used by dental technicians, like sintering, pressing, or casting the ceramic material, a number of computer science-based technologies have lately been created. The first and currently most well-known of them was the Cerec unit (Siemens, Bensheim, Germany) based on CAD/CAM (Computer-Aided Design/Computer-Aided Manufacturing). A computer software program called CAD (Computer Aided Design) is used to help with the scanning and optical imprint. The system designs the ultimate virtual restoration after analyzing the data it has collected. Research on connected dental applications was sparked by the rapid growth of digital computer technology in the early 1980s. The objective was to make it possible for private practice dentists to independently design and produce dental ceramic restorations quickly and easily (70).

In the Cerec technology, an optical impression of a tooth preparation is captured using a tiny opto-electronic video camera and kept on a chip. After getting the digital 3D information, the dentist employs computer-aided design to interactively design the restoration on the screen. These data are used to grind an industrially constructed feldspathic ceramic block using a diamond-coated disc integrated into a three-axis milling unit (CAM) (Computer-Aided Manufacturing) (71).

A large dental products manufacturer (Siemens Dental, now Sirona Dental Systems, Bensheim, Germany) continued to develop the technology starting in 1986. A few dental offices conducted field tests in 1987, and by the end of 1988, the Cerec 1 system had been extensively released on the market (72). Since there were no long-term clinical studies for either CAD-CAM ceramic restorations or the adhesive seating of these ceramic restorations at the time, it was decided to conduct a follow-up study on Cerec reconstructions installed in our private practice and to track the treatment outcomes on a regular basis. 200 continuous-production Cerec inlays and onlays were inspected in our office after two years (73), five years (74), and ten years (75).

In 1960s the aerospace and automotive sectors began using computer-assisted design and manufacturing, (76) and 10 years later it was utilized for the first time in dentistry. Prominent individuals in the field of dental CAD/CAM advancement include Drs. Francois Duret from France, Werner Mormann from Switzerland, Dianne Rekow from the United States, and Matts Andersson from Sweden. Dr. Duret pioneered the inaugural dental CAD/CAM system back in 1971, which was designed for crafting crowns through the utilization of a numerically controlled milling apparatus and an optical record of the abutment tooth (77). In November 1985, he exhibited his method at the international conference of the French Dental Association by finishing his wife's posterior crown restoration in under an hour. He had developed the first dental restoration fabricated by CAD/CAM system in 1983 (78,79). Dr. Duret later developed the system named Sopha.

Dr. Mormann pioneered the first CAD/CAM system utilized in industry. In collaboration with engineer Doctor Marco Brandestini, they introduced the concept of optical tooth scanning. In 1985, they successfully produced the inaugural chairside inlay by integrating their optical scanner with a milling machine. This innovation led to the creation of CEREC, an abbreviation signifying "computer-assisted ceramic reconstruction," for their device (70). In the middle of the 1980s, Dr. Rekow and his friends at the Minnesota University worked on CAD/CAM system that was used in dentistry. This technique was created to mill restorations using a 5-axis machine while collecting data information using pictures with a high-resolution scanning device (80). Dr. Andersson introduced the Procera process in 1983, a pioneering method for crafting precise dental crowns. This process has evolved into what we now recognize as Nobel Procera, a significant contribution associated with Nobel Biocare, headquartered in Switzerland (81). Additionally, he was the pioneer of composite veneered restorations using CAD/CAM (82). The development of crowns, onlays, inlays and veneers were made possible by early technology. Fixed partial restorations and implant abutments can now be produced using CAD/CAM technologies. Orthodontics is a field where CAD/CAM is also used. One such treatment is Invisalign (Align Technology, USA), which utilizes a series of transparent, removable aligners created and manufactured using CAD/CAM technology to align teeth. Dental offices are increasingly utilizing CAD/CAM technologies. In the US and Canada, around 10,000 dentists, and worldwide, more than 30,000 dentists, have integrated scanning and milling equipment into their practices. Notably, over 15 million CEREC restorations have been completed globally, highlighting the widespread utilization of this technology in dentistry (82).

2.1.3 Advantages of CAD/CAM

Utilizing CAD/CAM technology for dental restorations offers a multitude of advantages compared to traditional methods. These benefits encompass swiftness, user-friendliness, and quality. Digital scans can be notably faster and more convenient than conventional impressions, as they eliminate the need for molds, wax-ups, investing, casting, or firing processes. Moreover, the use of CAD/CAM expedites both the design and manufacturing phases; a complete crown can be milled in a mere 6 minutes. Thanks to the presence of on-site milling equipment, patients can receive their permanent restoration on the same day as their appointment, obviating the necessity for a subsequent visit. Consequently, patients are no longer required to have temporary restorations, which entail additional time for fabrication and fitting. In instances where anesthesia is needed, it only needs to be administered once (71).

According to a 2005 publication by Christensen et al., it was noted that traditional impressions sent to labs sometimes exhibited the challenge of having more than 50% of the prepared margins not visible. These conventional impressions were prone to issues such as missing teeth, the presence of cords or other debris within the impression material, as well as the occurrence of bubbles in the impression material itself (83). In contrast, CAD/CAM restorations, which can be crafted from ceramic blocks available in various colors and possessing a transparent quality akin to enamel, are esteemed for their natural appearance (83). Remarkably, even when used for posterior teeth, ceramic restorations prove to be long-lasting in the oral cavity and are less abrasive than traditional and hybrid posterior composite resins, thus minimizing wear on neighboring teeth (71).

The assurance of consistent quality is upheld by the inherent defect-free composition of pre-made ceramic blocks and the computer software's proficiency in designing shapes capable of withstanding wear. This prospect of swifter, high-quality restorations is likely to be well-received by patients, who also appreciate the avoidance of uncomfortable impressions that can cause gag reflex, potentially saving both time and labor, and potentially reducing costs. Another advantage lies in the ability to store all scans digitally on a computer, a more efficient alternative to conventional stone models that occupy space and are vulnerable to breakage or chipping if not handled with care (83).

2.1.4. Disadvantages of CAD/CAM

CAD/CAM technologies do come with certain drawbacks. Dental practitioners need to dedicate both time and financial resources to undergo training, and the initial investment in the equipment and software can be quite substantial (71). Dentists who do not do enough restorations will struggle to get a return on their investment. The dentist must take an accurate optical scan of the tooth in need of repair, much like with traditional impressions. The scan must clearly replicate the adjacent and occlusive teeth and emphasize the finish line.

Similar soft-tissue management, retraction, moisture control, and hemostasis techniques are essential for digital scanning, much like they are for traditional impressions. However, it's important to note that digital impression systems may not always result in time savings in their current usage. For instance, dentists using specific scanners often need to send the scanned images for image cleanup before a dental technician can accurately set the margins. After this, the images are sent to the dental laboratory for assessment before being returned for the milling of models. Subsequently, the dentist's dental laboratory will proceed to fabricate the restoration using the models and dies that were initially sent there (84).

The disadvantages of Cad/Cam systems are listed below: (36,85,86,85,85)

- 1) CAD/CAM hardware, components, and software have a high starting cost.
- 2) As the system gained popularity, it was discovered that the monochromatic blocks made for the devices weren't enough to provide aesthetics. As a result, polychromatic (various hue) blocks were created.
- 3) A crucial first step to guaranteeing a suitable restoration in CAD/CAM systems is to get an accurate patient record. Saving the image could have some issues. Recording the restoration may be challenging, particularly in regions with bleeding, gingival recession, and locations where saliva isolation is not possible. Therefore, effective gingival retraction is essential for managing soft tissue.
- 4) Specific training is necessary in order to use the equipment. The training necessary to utilize the CAD/CAM device must be purchased with time and money.

2.2. Dental Ceramics

Porcelain and materials that resemble porcelain but differ from it in composition, manufacturing process, physical and mechanical qualities are referred to as ceramics. Kelly proposes categorizing ceramics as "composite" materials, composed of a matrix (either glass or polycrystalline) into which additional substances, referred to as fillers, are incorporated in varying proportions. These fillers can take the form of particles (either crystalline or glassy with high melting points) or modified atoms, known as "doping" in the context of polycrystalline ceramics. By adding fillers or doping, they can stabilize polycrystalline structures or enhance mechanical qualities. Glassy matrix determines the ceramic's aesthetic qualities. Translucency, which best mimics the characteristics of enamel and dentin, becomes increasingly important as glass rate increases (87). This glassy matrix enables light diffusion for in-depth translucency. Mechanical characteristics rise with filler content while falling with the brittle glass phase. The nature of the filler within the glassy matrix would preclude the emergence of micro-fractures. Dental ceramics have been classified into various categories. They can be broadly categorized into three primary types based on their microstructure: predominantly glassy ceramics, particle-filled glasses, and polycrystalline ceramics (88,89,90).

Although ceramics are fragile and easily fractured, using better adhesive techniques has made it viable to use the material in medical settings (49). Nowadays, the majority of machinable ceramics for direct CAD/CAM are mostly glassy and particle-filled glasses. Recently, zirconia has also been successfully chairside milled to produce monolithic restorations.

2.2.1 History of Dental Ceramics

The word "ceramic" comes from the Greek word "keramikos," which means "made from soil" (91). It has always been a goal of dentistry from the very beginning to use minerals and materials that mimic or seem like genuine teeth. The first ceramics were mentioned in relation to dentistry was by the Frenchman Pierre Fauchard. Alexis Duchateau used ceramics for the first time in prosthetic devices in 1774 (92). Elias Wildman developed vacuum firing in 1838, enhancing the aesthetics of porcelain. Dr. Charles Land's processing of porcelain on a sheet of metal in 1886 marked the beginning of the use of ceramics in fixed prostheses (93). The creation of 40–50% alumina crystals by McLean and Hughes first improved the base of current porcelain systems. Ceramics in their finished state are now acknowledged as the best material for use in dentistry. The 40–50% alumina crystals made by McLean and Hughes were used to enhance the foundation of the porcelain systems that we use today. The final form of ceramics has been acknowledged as the material best suited for usage in dentistry given human nature. It is also the component that best satisfies patients' expectations in terms of preferred materials.

2.2.2. Properties of Dental Ceramics

Below is a list of dental ceramics' general characteristics (94,95):

1. They are more biologically compatible than metals.
2. An allergic reaction is not caused.
3. They are uniform.
4. They are beautiful. Given that it allows light to reach the natural tooth structure, it is a better material. By allowing light to penetrate beneath the gingiva, it avoids shadowing in the gingival region.
5. They closely resemble the normal tooth structure in terms of heat conductivity and thermal expansion coefficient.
6. They resist pressures of compression.
7. Because metal infrastructures don't leave behind any residue while processing, they are healthier and easier to process than metal structures.
8. The oxidation issue brought on by metal is eliminated in ceramic restorations with metal bases, therefore opaque firing steps are not necessary.
9. Metal substances are also forbidden from giving the gingiva a color.
10. In terms of gingival structure, it is healthier.

2.3. CAD/CAM Restorative Materials

Materials initially needed to be both easily machinable and mechanically strong. Small occlusal inlays can be easily accommodated by feldspathic ceramics (CEREC I). The growing demand for expanding the applications of CAD/CAM restorations, such as onlays and crowns, has driven dentists to seek mechanically resilient materials. This led to the development of reinforced ceramics, some of which are available in a pre-crystallized state to facilitate rapid milling. Achieving the final shade and mechanical strength may necessitate post-milling crystallization. Additionally, softer materials that are less susceptible to brittle fracture have been proposed as an alternative to ceramics. While these resin-based materials are significantly less mechanically robust than ceramics, they possess the property of deforming before fracturing (12,14). The next step was to add ceramic particles to these resins to improve their mechanical characteristics.

Currently, producers offer a ceramic network that is permeated with resin polymers in an effort to merge the benefits of these materials of two families. There are also metal blocks available, although their use and availability are currently essentially sporadic. For a chairside use, manufacturers now offer more than 20 blocks. The size, color, and translucence of blocks can vary, and they may also need a post-milling treatment that will vary depending on the type of material. Among this wide variety of material and the linked commercial communication, practitioners may have trouble selecting the appropriate material for the clinical setting (96).

Research has shown that all CAD/CAM block materials, including nanocomposites, composite-based ceramics, hybrid ceramics, demonstrate similar or even superior resistance to wear from tooth brushing compared to natural enamel. However, this observation doesn't apply to acrylic polymer CAD/CAM blocks. This emphasizes the durability of permanent aesthetic CAD/CAM materials in withstanding the effects of routine tooth brushing, a crucial factor for the long-term performance of dental restorations (97).

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2.4. Classification of CAD/CAM Materials

The expectations for the aesthetics and functionality of restorations have increased as a result of the broad availability of CAD/CAM technologies in medical facilities. Monolithic repairs using CAD/CAM are quick and dependable. Materials with various combinations of structural and physical qualities have been created as a result of this rising expectation. The type of restoration to be produced, its location in the mouth, the patient's socioeconomic status, and the doctor's preference all influence the material choice. The types of ceramics that are produced for CAD/CAM system are as follows (98,99): Lithium disilicate ceramics, leucite enhanced ceramics, resin composite-based ceramics, hybrid ceramics, zirconia-based ceramics

2.4.1. Feldspathic CAD/CAM Ceramics:

Feldspathic ceramics have very good light transmittance properties and average flexural strength (100). The blocks of this material have good mechanical properties. This is a glass-containing ceramic that has an outstanding esthetics and are biologically compatible. Material has good strength and rigidity that has low fracture toughness and difficult to machine (101). Feldspar particles of 3–4 microns in size are equally distributed throughout the glass matrix of these blocks used in CAD/CAM systems (98). Feldspathic ceramic materials are recommended for fabrication of onlays, inlays, single anterior/posterior crowns, and veneers (102,103,104,105,106).

Feldspathic porcelains belong to a category of materials referred to as aluminosilicate glasses. They are primarily derived from feldspar minerals and are composed mainly of silicon oxide and aluminum oxide. These glasses, based on feldspar, are known for their high biocompatibility (89). The feldspathic inlay restoration was the first CAD/CAM fabricated material that was milled from Vita Mark I (Vita, Germany) (107). 90.4 % of success rate in clinical performance of 10-year prospective study was accomplished (108). However, up to 36 percent higher fracture rate was noted after 2 years follow up (109).

Vita Mark II (Vita, Germany), was popularized especially for CEREC (Cerec 1 – Siemens, Germany) in 1991, presented superior mechanical characteristics (110) with the revealed bending strength from 100 MPa (111) to 160 MPa after glazing (112). Vita Mark II blocks are manufactured from materials that share similarities with traditional feldspathic ceramics. However, they undergo a distinct production process called extrusion molding. During this process, a ceramic mixture that has been plasticized is compressed and extruded through a nozzle to achieve the desired shape. Subsequently, these blocks are allowed to dry over a span of several days before undergoing sintering (106).

Clinical studies involving Vita Mark II inlays have reported 94.7 percents survival rates of 94.7 percents after 5 years, 90.6 percents after 8 years, and a range of 85.7 to 89 percents after 10 years. These findings indicate the longevity and effectiveness of Vita™ Mark II in clinical applications over extended periods (49,104,105). In an in vitro study involving mandibular crown specimens milled from Vita Mark II blocks using Cerec 3 by Sirona in Germany, it was found that a marginal gap ranging from 53 to 67 μm could be achieved. Vita Mark II is a monochromatic ceramic material but is available in various shades. In contrast, newer blocks like Triluxe Forte, Triluxe, and RealLife from Vita in Germany incorporate multiple shade layers, offering a gradient of colors and translucency for enhanced aesthetics. Similarly, Cerec Blocs by Sirona Dental Systems in Bensheim, Germany, share a similar structure with Vita Mark II but employ a distinct shading system. These Cerec Blocs are also available in aesthetically pleasing multi-shade options, providing additional choices for achieving the desired aesthetic outcomes in dental restorations (113).

These materials incorporate a glass component, enabling them to undergo various processes such as etching with hydrofluoric acid, treatment with a silane coupler, and adhesive bonding to the tooth. The adhesive bonding step is of paramount importance for their long-term success since these materials lack the necessary strength for traditional cementation using resin-modified glass-ionomer or conventional glass-ionomer cements. Adhesive bonding serves two critical purposes: it ensures the restoration's secure retention and enhances its clinical strength, thereby increasing its resistance to fractures over time (100,114).

Attia et al. conducted a study on the fracture load of Paradigm MZ100 crowns in comparison to Vita Mark II crowns and found no significant difference in the fracture load between the crowns when they were adhesively cemented (114). In contrast, the thickness of the resin cement does indeed have an influence on the fatigue failure tests of CAD/CAM feldspathic crowns. The research revealed that crowns with an occlusal cement layer measuring 50 micrometers exhibited greater resistance to fatigue failure compared to those cemented with a thicker layer of 500 μm in feldspathic crowns. This highlights the importance of the cement layer thickness in influencing the durability and resistance to fatigue of these crowns (115). In a study, it was demonstrated that both laser and Al_2O_3 (aluminum oxide) applications resulted in a reduction in the light transmission of 1.5 mm thick feldspathic ceramic material to a level below 400 mW/cm^2 . This threshold of 400 mW/cm^2 is considered a critical limit for achieving adequate polymerization of dental materials.

CEREC Blocs and Vita Mark II are two types of feldspathic ceramics commonly used in dental restorations. Vita Mark II was introduced in 1991 and is available in the 10 common Vita 3D-Master shades. On the other hand, Cerec Blocs, introduced in 2007, are also manufactured by Vita (Germany). These blocks come in six different shades and are categorized into three color saturation levels: opaque (O), medium (M), and translucent (I). It is important to note that both Cerec and Vita Mark II blocks are produced specifically for the CEREC system. These feldspathic ceramic materials provide dental professionals with a range of options to achieve the desired aesthetic and functional outcomes in restorative dentistry (100). Vita Mark II offers a range of multicolored blocks to cater to various dental restoration requirements. For instance, Triluxe blocks incorporate three distinct color bands, enabling the precise reproduction of both the translucency and the shade of a natural tooth, from the cervical (near the gumline) to the incisal (toward the biting edge) region. Triluxe Forte blocks take this a step further by providing a grade of translucency and the color, starting from the cervical area and progressing towards the incisal portion. These blocks exhibit heightened fluorescence and chroma in the cervical region, enhancing their ability to replicate the aesthetics of natural teeth. Cerec Blocs also come in multicolored block form, with the Cerec Bloc PC featuring a three-layered structure. The cervical layer possesses the highest pigmentation and the lowest translucency, while the top layer in the incisal area boasts the highest translucency and lower color intensity. These blocks are available in three different gradient shades, offering flexibility in achieving lifelike dental restorations (100).

Multicolored blocks provide a superior aesthetic outcome when compared to traditional monochromatic blocks. The procedure that benefits the most from a polychromatic block is crown fabrication, as onlays typically have a restricted vertical dimension, making it challenging to fully appreciate the color gradient (100). This material possesses outstanding aesthetic properties and can be customized for color matching with existing teeth by incorporating external stains and utilizing a porcelain add-on kit. (98). A study investigating the color of ultrathin laminate veneers revealed that the color of the underlying tooth substrate primarily dictates the ultimate color of these veneers created from Vita Mark II ceramic blocks. The thickness of the ceramic material significantly affects its ability to conceal the substrate color. Combinations of a lighter substrate shade with a lighter ceramic restoration or a darker substrate shade with a darker ceramic restoration only led to minimal alterations in the final veneer color. Both dental technicians and clinicians should be aware that the interaction between the restoration's color and the shade of the underlying tooth substrate determines the final veneer color. This awareness is crucial for achieving the desired aesthetic results in dental restorations (116).

These blocks are characterized by a microstructure with fine particle sizes, which imparts several advantages. It helps in resisting damage during machining, enhances mechanical properties, reduces the time required for polishing, and promotes wear-friendliness in the resulting dental restoration (98). The surface quality and microstructure of these materials have a substantial impact on enamel wear. Effective polishing or glazing of the surface and the presence of a fine-grained microstructure help reduce tooth enamel wear. In the mentioned test, a value closer to 1 signifies that the material exhibits behavior more akin to natural tooth structure concerning enamel abrasion. This underscores the significance of these attributes in dental materials for safeguarding enamel health (117).

Due to the glass matrix inside, feldspathic ceramics can be acidified and used as an adhesive when bonded to the tooth. A crucial component of a restoration's long-term retention, clinical success, and longevity is its capacity to be cemented to the tooth as an adhesive. These materials are more durable and produce less enamel wear on the opposite tooth than porcelain. The opposite tooth is safeguarded from unwelcome wear thanks to the homogeneous implantation of feldspar particles into the glass matrix. When these blocks are mechanically polished, their resistance is 130 MPa; when they are glazed, it is 160 MPa (99,50).

An airborne particle abrasion technique (50mm Al₂O₃) is used to attach feldspathic ceramics to tooth tissue. Following the etching process with hydrofluoric acid (HF), a silane coupling agent is applied to facilitate the bonding of different components. Materials composed of feldspathic ceramic exhibit excellent aesthetic characteristics. These materials are suitable for producing single anterior and posterior crowns, veneers, inlays, and onlays, making them a profitable choice. However, it's important to note that feldspathic ceramics are generally not considered strong enough for use in posterior load-bearing areas (118,87).

While the use of these blocks with low fracture resistance is contraindicated for the building of bridges and endodontic crown restorations, single crown construction is recommended for the inlay, onlay, veneer, and anterior region (75).

2.4.2. Leucite-reinforced CAD/CAM ceramics:

The biphasic structure observed in leucite-reinforced ceramics is a characteristic shared by other materials like lithium disilicate, zirconium oxide, and lithium silicate reinforced ceramics. However, there is an increase in the percentage of the crystalline phase in these materials. This results in a 30% volume reduction in the glass matrix. The production process involves the growth of filler particles within the glass matrix after the glass object is formed. Subsequently, a specific heat treatment is applied to the machined glass object, leading to the formation and growth of crystallites. Notably, this process, often referred to as "ceraming," also causes a change in the composition of the remaining glass. Overall, these materials are classified as particle-filled composite materials known as glass ceramics (88),(89). Zirconium dioxide, lithium silicate, and lithium disilicate can all be used to fill this sort of ceramic. The flexural strength of these ceramics has been increased, and they also have good visual qualities, a range of translucency, and various hues. Their strength and structure enable a good resistance, preventing the spread of the fracture rather of an initial fracture. In fact, a complete fracture won't occur until a substantially higher load—twice as much as with a traditional ceramic—is applied (119). When they are adhered to enamel, their mechanical resistance increases significantly and reaches 70% of zirconia's resistance (120). Leucite, a crystalline mineral with a potassium alumina silicate structure, is the first particle utilized for filling purposes in dental ceramics (Deany et al., 1996). To ensure that the ceramic can be effectively burned onto the metal, this particle is added to ceramic restorations that are supported by metal.

The term "feldspathic porcelains" should be used to describe these materials even though they are also feldspathic-like glasses in other categories. Leucite not only alters the material's thermal expansion but also lengthens its durability by reducing the rate at which cracks spread. Depending on the type of core and the necessary expansion coefficient, the amount of leucite can be changed. These materials are conventional powders and liquids and are perfect for porcelain veneer and core structures (91).

In comparison to enamel, the material has increased abrasive capabilities because of the size of the particles called leucite, their random dispersion within the glass matrix. In metal-ceramic restorations, these materials are most frequently used as veneer porcelain. Glasses with leucite reinforcement include particles. The inclusion of fillers in the glassy matrix gives these materials different microstructures. Leucite, a crystalline mineral, was one of the earliest fillers to be utilized in dental ceramics (89).

Similar to heat pressed ceramics (Empress™) in terms of fracture load, internal fit, and marginal gap is a leucite reinforced ceramic. The value of this material is the highest in comparison to other complete ceramics. Curiously, at the point of extreme background discoloration, this property may add to the restoration's staining aesthetic look. Empress™ CAD HT, LT and Empress™ CAD Multi offer high and low translucency and polychromatic blocks for CAD-CAM with leucite-reinforced ceramics. Leucite offers two primary advantages when used as a filler in dental ceramics: one that was intentionally chosen and one that likely emerged as a bonus. Initially, leucite was selected because it closely matches the index of refraction of feldspathic glasses, which is crucial for retaining some degree of translucency in the material. Additionally, leucite exhibits a significantly faster etching rate compared to the base glass. It is this phenomenon known as "selective etching" that leads to the creation of numerous microscopic features, enabling resin cements to penetrate and establish a robust micromechanical bond with the ceramic (88).

Leucite-reinforced ceramics are initially formed in a glass state and are subsequently partially crystallized under carefully controlled conditions. This controlled crystallization process yields controlled levels of crystalline content within a chemically uniform glass matrix, resulting in a highly homogeneous and fine-grained structure. This process is commonly referred to as "ceraming" (89). In contrast to other ceramics, feldspathic and leucite-reinforced ceramics contain a substantial proportion of a glassy phase, typically ranging from 55 to 70%. This glassy phase contributes significantly to their translucency (2). Glassy materials are the most common type of dental ceramics that most closely resemble the visual characteristics of enamel and dentin (88). These peculiarities, however, prevent the proper concealment of a metal inlay core or a discolored stump.

In theory, the mechanical strength of these ceramics is inadequate to withstand occlusal loads. Therefore, these ceramic restorations are often reinforced or bonded to enhance their strength. (121). For the creation of prosthetic restorations with a high aesthetic impact, these ceramics are advised since they possess the most significant aesthetic qualities of chairside CAD/CAM blocks. This substance could be used to create cavitary restorations, crowns, and partial crowns.

This material is offered by several producers in a single block color as well as three or four layered hues inside the same block. There is also a 3D building block with a "dentin core" and an "enamel" tint surrounding it. Thanks to CAD software, the restoration was machined in a color gradient with a curved shape. This particular style of block was created especially for attractive anterior restorations. By carefully controlling the crystallization of leucite on a glass matrix, W. Höland et al. produced the first leucite-based glass ceramics. A second fire procedure, which turns the glass particles into single core, double core, and quadruple cores after firing at 720 °C, provides leucite crystallization. In this manner, the development of cracks in the structure is stopped by obtaining a strong barrier. There are 68% quartz and 18% aluminum oxide in these blocks (122). Due to its strong light transmittance and attractive qualities, this material—whose resistance to bending stresses ranges from 120 to 160 MPa—is recommended. However, because of the high light permeability, aesthetic issues could arise if the supporting tooth has a discolouration or core. Three categories—HT (High Translucency), LT (Low Translucency), and MT (Medium Translucency)—are used to categorize the blocks in this group (123).

High translucency (HT) blocks exhibit high light transmittance and low brightness values, whereas low translucency (LT) blocks exhibit low light transmittance and high brightness values. MT, on the other hand, are multiblocks that are polychromatic and feature a variety of color tones. The goal of this coloring is to replicate how the natural tooth changes from being translucent and translucent from the cervical to the incisal (123).

In a study, it was observed that composite inlays maintained their color match from baseline, with no significant change. However, porcelain inlays experienced a decrease in color match at the 6-month mark, and this change persisted afterward. This decrease in color match was attributed to changes in tooth color over time (124). Another study demonstrated a correlation between the percentage change in microhardness and color change in dental restorations. The consumption of coffee, for example, was found to have an adverse effect on both the color and microhardness of Vitablocs Mark II. This could potentially compromise the esthetic appearance of the restoration. Quantitative assessments of ceramic blocks, as performed in these studies, can assist clinicians in predicting the performance of these materials in patients with varying beverage-drinking habits, thus aiding in treatment planning and achieving optimal esthetic outcomes (101).

2.4.3. Lithium disilicate reinforced ceramics

Lithium disilicate ceramic, marketed under the brand name E.max CAD (Ivoclar, Germany), was introduced in 2006 and is notable for its improved flexural strength. This material is offered in nine distinct shades (A-D shades) and is accessible in two translucency variations: HT (high translucency) and LT (low translucency) (99). These blocks consist of lithium metasilicate crystals, ranging in size from 0.2 μm to 1 μm , constituting roughly 40% of the block's volume. They are commonly recognized by their blue-violet hue, often referred to as the "Blue Block." This partially crystallized state allows for easy milling without excessive wear on diamond burs or damage to the material. After milling, the restoration undergoes a two-stage firing process in a porcelain oven under vacuum conditions, lasting approximately 20 to 25 minutes. This process completes the crystallization of the lithium disilicate and transforms the initial blue shade of the pre-crystallized block into the selected tooth color. The end result is a glass-ceramic material featuring a fine grain size of approximately 1.5 μm and a 70% crystal volume embedded within a glass matrix (125).

Lithium disilicate glass-reinforced ceramics made their debut in 1998, under the brand name IPS Empress 2 (Ivocla, Germany). The second generation of heat-pressed ceramics, known as the e.max Press system (Ivoclar, Germany), was introduced in 2006. This newer generation boasts improved mechanical and optical properties compared to the material used in the initial generation. (126). However, since this product's patent just expired, other businesses are now free to manufacture and sell ceramic materials that are identical. Other lithium disilicate-based ceramics are now being made by a number of producers, including AIDITE (Shenzhen, China), IRIS (Tianjin, Mainland China), T-lithium (Talmax, Curitiba, Brazil), and Rosetta (Hass, Gangneung, Korea). Although there are few studies that investigate these materials, the producers claim that these ceramics offer structural, mechanical, and morphological qualities that are comparable to those of the basic e.max system (Ivoclar, Germany) (127).

The mechanical and morphological characteristics of ceramics are influenced by their crystalline structure (128). X-ray diffraction analysis (XRD) is a commonly employed technique for analyzing structural features in ceramics. It helps identify the peaks corresponding to the crystals present in the ceramic, determine the crystalline phase, assess the degree of crystallinity, and measure the size of the formed crystals (128,129,5).

Actually, the only chairside option for lithium disilicate ceramics is e.max CAD (Ivoclar, Germany) (130). In a pre-crystallized metasilicate phase, blocks are machined. Metasilicate crystals will be destroyed during the final crystallization fire, but disilicate crystals will grow in a reticulated pattern to form a kind of mesh that will arm the ceramics. There is a lot of clinical experience in this material (131).

Nowadays, lithium disilicate glass-reinforced ceramic is the most common used material for indirect restorations among ceramic restorations. These ceramic materials are gaining popularity because they offer excellent fracture resistance (380 MPa), satisfactory aesthetics, and acceptable bond strength to resin cements when proper surface preparation is performed (18.00 MPa) (127,132). Another significant benefit that contributes to this ceramic's outstanding clinical approval is the ability to mill it utilizing less complicated fabrication techniques (chairside and laboratory computer-aided design/computer-aided manufacturing (CAD-CAM) systems) (133,134).

2.4.4. Zirconia Based CAD/CAM Ceramics

Zirconia is unique in that it can alter its crystallographic shape while under stress. There is a significant volume rise during the transition phase, enough to cause a catastrophic failure. High toughness results from the transformation's ability to inhibit crack propagation (135).

Zirconia has the highest documented mechanical characteristics of any dental material. As a result, the core thickness may be significantly reduced and posterior FPD (Fixed Partial Denture) may be realized. When strength and beauty are priorities, these qualities are quite appealing (136). This ceramic, however, cannot be bonded using normal methods due to its microstructure. Tetragonal zirconia polycrystals (3Y-TZP) with yttrium cation doping are used as chairside CAD/CAM zirconia blocks. The restorations are either processed by hard machining of completely sintered blocks or by soft machining of presintered blocks followed by sintering at high temperatures (137). However, chairside milling devices, which are less complex than those used in laboratories, can only grind pre-sintered blocks. Restorations made using soft machining are afterwards sintered; this method eliminates the stress-induced transformation from tetragonal to monoclinic and results in a final surface that is almost entirely free of the monoclinic phase, excluding the need for grinding adjustments or sandblasting (136).

Complete zirconia restorations that are machined chairside are relatively new. This type of repair has little clinical history. The realization of crowns or small bridges (up to three elements) appears feasible. This material's microstructure prevents the use of a traditional bonding process. The ideal bonding procedure for zirconia used in dentistry is still up for debate. MDP-based resin cements frequently exhibit better results than other cements do (138).

To reduce the danger of fractures, manufacturers must provide a support with no sharp corners. Studies conducted in vitro reveal that the surface's state is the primary cause of antagonist abrasion. It would not be more abrasive to polish zirconia than other dental ceramics. However, this material's low translucency due to its microstructure and the lack of a glassy matrix and the likelihood of the dental support breaking because of its extremely high mechanical qualities limit its aesthetic appeal (139).

Some monolithic zirconia, however, could exhibit a tolerable level of translucency (140). The number of grain boundaries affects translucency through the mean grain size. Reduced translucency is a result of smaller grain sizes and a greater number of grain boundaries. Therefore, a higher grain size improves mechanical characteristics but reduces the resistance to low-temperature deterioration (LTD). The amount of cubic phase and the distribution of yttrium, which have been proven to directly influence LTD resistance, are dependent on grain size, which is also dependent on sintering temperature (141).

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2.4.4.1. Zirconia-Based Lithium Silicate CAD/CAM Ceramics

Pre-crystallized (easier to process but with an intermediate hue) and fully crystallized (more difficult to machine but with the final shade) zirconium oxide and lithium silicate glass ceramics (ZLS) are both available. They have very small crystals of lithium metasilicate and lithium disilicate (average size: 0.5–0.7 μm) as well as 10% zirconium dioxide that has been dissolved in the ceramic's glassy phase. When compared to lithium disilicate crystallites, the produced crystals are 4 to 8 times smaller (143). It takes two steps to create this dual microstructure. Only lithium metasilicate crystals are present in the pre-crystallized form that the material is given in. The substance is machinable when it is pre-crystallized. Following the completion of the restoration and the water-cooled milling process, an 8-minute firing process at 840°C results in the final dual lithium silicate microstructure (140).

The firing procedure is not required for the completely crystalline state. Although ZLS are newer, they are akin to the clinically successful lithium disilicate glass ceramics (130,143).

2.4.5. Resin CAD/CAM materials

In conjunction with the widespread adoption of ceramic blocks utilized in CAD/CAM systems, there have been notable advancements in composite resin technology, particularly with the emergence of nanofill and nanohybrid composite resins. Consequently, CAD/CAM resin composite blocks have gained widespread acceptance. Composites are composed of a minimum of two materials, each possessing its own distinct properties. The production of resin composite blocks involves a heat polymerization process, where the filler is integrated into a monomer mixture to create these blocks (144).

The production of composite blocks using this method significantly enhances the monomer conversion rate and minimizes polymerization shrinkage when compared to light-cured composites. As a result, it yields more uniform restorative materials, effectively reducing irregularities and the occurrence of pores within the material's structure (145). Furthermore, composite blocks offer the advantage of being able to accommodate a higher proportion of inorganic filler content compared to indirect composites (146). Composite blocks are also suitable for creating long-term temporary restorations. These materials impose less wear on the opposing teeth and can effectively absorb the forces associated with mastication, making them ideal for implant-supported restorations and patients with bruxism. Repairing them is straightforward as they can be directly restored in the mouth using composite materials. Unlike ceramic materials, they don't require a sintering process and can be applied in a single dental session (147).

There are materials that contain an inorganic filler and a matrix resin made of monomers. Fillers help resins perform better. The rise in charge % has a positive impact on mechanical and physical qualities. Outlet shrinkage is also decreased. Reduced load size enhances wear resistance, aesthetics, and surface polish (148).

Composite resins are never completely polymerized. Certain monomers are free or only loosely connected to the chain. The percentage of monomers that react to the total number of monomers at the beginning is known as the conversion rate. Thermal polymerization and industrial manufacturing (polymerization under pressure up to several thousand bars) are both used to create machinable composite blocks (12,18).

Thereafter, the conversion rate is greater than 90% or even 95%. In contrast, the conversion rate for a chairside composite approach is between 50 and 60% (149). The rate would be boosted to 70 to 80% in a dental laboratory (150,151). The microstructure of resin composite and nanoceramics is identical, however their ratios differ. They contain a polymeric matrix and around 80% weight in ceramic nanoparticle filler. In addition, fillers are less than 100 nm. These fillers could be made of traditional ceramic, polycrystalline ceramic (zirconia), or both. In terms of flexure (often close to 200 MPa), compression (380 MPa), and abrasion (between 2 and 10 microns per year), nanoceramics are similar to real teeth. About 15 GPa of elasticity is present. These qualities suggest using these materials for tiny bridges or single-tooth restorations, preferably in the back. A potential use for makeup in the frontal lobe. The matrix, which is a polymer, will, however, wear out more quickly than the ceramic, making it more abrasive than its competitors when compared to conventional ceramics. With their soft matrix, resin-containing materials are simple to machine, and work pieces only potentially need photopolymerization for their make-up. For this kind of material, a standard bonding process is feasible. However, due to the potential leakage of monomers like bisphenol-A, the biocompatibility of materials containing resins is in doubt (152).

In the event, that the first prosthetic component fractures, these materials can be restored immediately. To create a direct composite, all that is necessary is to create a surface treatment regimen (alumina air abrasion, mechanical abrasion, etc.). This property has a lot of potential, especially for short-term renovations. These materials are recent, and there is little proof that they have been used. After numerous dental professionals reported problems, some manufacturers decided to withdraw the information they had initially provided (3M, Lava Ultimate) or even pull the product off the market (3M, Paradigm MZ100) (153).

Paradigm MZ100, developed by 3M ESPE and introduced in 2000, is a polymer composite block. It utilizes the Z100 composite chemistry as its foundation and employs a specific processing technique to optimize the degree of cross-linking within the material (154). Paradigm MZ100 incorporates zirconia-silica filler particles and is composed of approximately 85% filler by weight. The average size of these filler particles is 0.6 micrometers. This material is radiopaque and is offered in six different shades, including a more translucent enamel color option. Paradigm MZ100 stands out from the more commonly used ceramic materials. Compared to ceramics, composites like MZ100 can be more conveniently adjusted and polished within the oral cavity. This feature is particularly crucial for chairside clinical procedures, as there is typically no working model available, and fine-tuning of occlusion often happens directly within the mouth. Intraoral repair of porcelain restorations has not demonstrated significant long-term effectiveness and is generally considered a temporary solution at best (155,156).

Brilliant Crios, produced by Coltene AG in Switzerland, is a reinforced composite CAD/CAM block designed for the fabrication of permanent indirect dental restorations. It is composed of barium glass particles (less than 1.0 μm), amorphous silica (less than 20nm), a crosslinked methacrylate resin matrix, and pigments. Its mechanical properties are achieved through heat polymerization. With a modulus of elasticity measuring 10 GPa, it closely matches dental tissues, reducing stress formation and the risk of fractures, making it suitable for implant-supported restorations. This material minimizes wear on opposing teeth and exhibits high wear resistance. It is used in the production of crowns, inlays, onlays, veneers, and implant-supported crowns in both anterior and posterior regions. Brilliant Crios is available in block and disc forms, with fifteen shades and three translucency options. Unlike some materials, it doesn't require sintering and can be easily adjusted and repaired. Precise milling and fine margins can be achieved, and it can be polished either intraorally or extraorally using composite polishing agents or polishing paste (157).

Grandio Blocks, developed by VOCO GmbH in Germany, is a nano-hybrid composite CAD/CAM restorative material with a substantial filler content of 86%. It possesses a coefficient of thermal expansion akin to that of dentin and enamel. With a flexural strength ranging from 250 to 290 MPa and a modulus of elasticity at 15.5 GPa, it proves to be a versatile material well-suited for diverse dental applications, encompassing inlay, onlay, veneer, crown, and implant-supported crown restorations. Grandio is accessible in both block (12 and 14L) and disc (H15) formats, with HT and LT blocks offering four and seven shades, respectively. Unlike certain materials, Grandio doesn't necessitate sintering and allows for precise margin achievement. Its polishability is excellent with composite polishes, whether applied intraorally or extraorally (157).

Sarahneh et al.'s study unveiled that Grandio block demonstrated some of the highest bond strength values when compared to other resin matrix ceramic materials. Interestingly, the application of a silane agent alone didn't yield a substantial enhancement in bond strength, but significant improvements were observed when universal adhesives were applied to the resin matrix ceramic materials (158).

LuxaCam Composite, produced by DMG in Hamburg, Germany, is composed of a polymer matrix that incorporates silicate glass fillers. The balance between organic and inorganic components has been finely tuned to closely mimic the mechanical properties of natural teeth. LuxaCam exhibits a modulus of elasticity at 10.1 GPa and a flexural strength of 164 MPa, both of which closely resemble the characteristics of dentin (159). LuxaCam Composite is designed to minimize excessive wear and potential damage to opposing teeth, making it an excellent choice for patients with bruxism. It finds applications in various dental procedures, including veneers, inlays, onlays, partial crowns, full crowns, and bridges (up to three units). This versatile material is offered in both block and disc forms for different clinical requirements (8).

These LuxaCam Composite blocks and discs are offered in a range of seven shades, providing options to match various aesthetic needs. One of its advantages is that it doesn't require sintering, simplifying the fabrication process. LuxaCam Composite is known for its pleasing aesthetics, good polishing characteristics, and its ability to create stable edges and smooth surfaces in restorations. To ensure optimal bonding, the manufacturer recommends surface pre-treatment with primers and adhesive cementation using a dual-cure or self-cure adhesive resin (157).

Tetric CAD/CAM Block, produced by Ivoclar Vivadent AG in Schaan, Liechtenstein, is a composite block designed for creating single-tooth restorations. Its composition includes a blend of crosslinked dimethacrylate and inorganic fillers. The organic matrix contains Bis-GMA, Bis-EMA, TEGDMA, and UDMA. The composite material primarily comprises barium aluminum silicate glass (71.1 wt%) with an average particle size of less than 1 μm , as well as silicon dioxide with an average particle size of less than 20 nm. These fillers reinforce the resin matrix, contribute to translucency, and help manage polymerization shrinkage. The glass fillers offer durability and a high-gloss finish. Tetric CAD/CAM Block boasts a reported flexural strength of 273.8 MPa and a modulus of elasticity measuring 10.2 GPa (159).

Tetric CAD/CAM Block is an industrially produced material that undergoes milling before use. Following milling, it can be polished intraorally and securely cemented using adhesive resins. This versatile material is suitable for a range of applications, including veneers, inlays, onlays, and crown restorations, both in the anterior and posterior regions of the mouth. Tetric CAD/CAM Block is available in two sizes, I12 and C14, and offers two translucency options, MT and HT. The MT and HT blocks are available in five and four shades, respectively. It is important to note that this material is not suitable for self-adhesive resins or conventional cementation. Thanks to its chameleon effect, it seamlessly blends with adjacent teeth. The material's stability allows for minimal wall thickness and minimally invasive preparation techniques. Furthermore, it can be conveniently repaired intraorally using composite resin materials (157).

There is a CAD/CAM composite available in four shades, and it also comes in a multicolor version featuring four shade layers, catering to more esthetically demanding cases. Additionally, Telio® CAD, developed by Ivoclar, has been recently introduced. Telio CAD is a millable block made of cross-linked polymethyl methacrylate designed for temporary crowns and extended temporary partial dentures (EPDs). This block is part of the Telio system, which encompasses a self-curing composite, desensitizers, and cement. Telio CAD is offered in five different shades to accommodate various clinical needs (160).

2.4.6. Hybrid CAD/CAM Ceramics

While advancements in dental ceramics and composite resins have led to a wide range of materials, each group has its own set of advantages and disadvantages. Ceramics offer benefits like impressive flexural strength and color stability, but they also come with drawbacks such as wear on the opposing tooth and a requirement for a minimum preparation thickness of 1.5-2 mm. Conversely, composite materials have certain advantages, including less impact on the opposing dentition and the ability to use minimal preparation. However, they tend to wear more when in contact with natural teeth. Consequently, the ongoing quest is for materials that strike a balance and demonstrate wear characteristics similar to natural dental structures. There is a temporary restorative substance that can be used for up to three years in a therapeutic setting. However, charges added to the PMMA matrix enable better mechanical resistance than "classic PMMA" despite its milling being as simple and quick as for PMMA. This material can be used to create anterior and posterior bridges, anterior and posterior single crowns, inlays/onlays, and veneers. 80 MPa is the flexural strength. Without the use of fillers, PMMA is made of methyl methacrylate polymers. Transparent thermoplastic polymer is used. Incorporated pigments are used in dental technology (161).

They have a low mechanical strength due to the absence of fillers. For a duration of six months to a year, PMMA are recommended to produce interim repairs. Due to its malleable nature, milling is simple and quick with minimal burr wear. PMMA can be used to create any sort of temporary prosthesis (veneers, inlay/onlay, crown, bridge), depending on the manufacturer. Because PICN materials are constructed from a three-dimensional ceramic network that is permeated with a monomer mixture, they have a greater Weibull modulus and are less brittle than glass ceramics (162,163).

The PICN material combines ceramic and polymer characteristics. It is made up of a hybrid structure known as a "double network hybrid" (DNH), which has two interconnecting ceramic and polymer networks (164). This material is made in two steps: first, a coupling agent creates and conditions a porous pre-sintered ceramic network; then, a polymer is infiltrated into this network by capillary action (55,16). This material resembles dentin in terms of abrasion resistance, high flexural strength, and near elasticity thanks to the thin structure of feldspar ceramic and the acrylate polymer network (164). PICN is more resistant to wear than composite resins (164,55). This material's microstructure contributes to its strong bonding properties. The interpenetration of the phase's limits crack development in the material, allowing for thin work pieces and restorations without burst. Long-term in vivo investigations are currently being conducted because this information is recent. There is no information on the endurance of cervical regions or discolorations, and the shade range is constrained. Nevertheless, innovative PICN materials show promise, and further study needs to be done (164).

Composite ceramics are a highly versatile choice for dental restorations, boasting a range of exceptional qualities. They contain ultra-fine, evenly dispersed fillers that provide a durable polish while minimizing wear on opposing teeth. These ceramics exhibit high radiopacity, simplifying the tracking of restorations over time. Their efficient milling results in sharp margins, even under magnification, without visible chipping. Composite blocks allow for the creation of aesthetic restorations that seamlessly blend with natural teeth, thanks to an optimal balance of fluorescence and opalescence. Furthermore, they offer impressive flexural strength and essential flexibility, ensuring they can withstand the rigors of masticatory pressure, even in challenging clinical scenarios. Cerasmart, being a composite based ceramic, boasts high flexural strength and a notable flexibility that makes it particularly suitable for clinical cases where the ability to absorb masticatory pressure is required. This is especially relevant for applications like implant crowns or restorations in patients with conditions such as bruxism and generalized tooth wear. Additionally, Cerasmart offers the advantage of quick and precise milling, resulting in exceptionally accurate marginal adaptation. In terms of material properties, Cerasmart demonstrates impressive flexural strength (216.5 ± 28 MPa), which is significantly higher than some other materials like Lava Ultimate or Vita Enamic. Furthermore, it exhibits a substantial flexural modulus, with IPS e.max CAD leading the way in this regard. IPS e.max CAD also stands out with the highest Vickers hardness values, indicating its hardness compared to the other materials tested (145).

When it comes to fracture toughness, both IPS e.max CAD and Lava Ultimate display significantly higher mean values than Vita Enamic or Cerasmart, emphasizing their resilience and resistance to fracture. These material properties contribute to the suitability of Cerasmart and other materials in various clinical scenarios and dental applications. CERASMART is manufactured through a distinctive high-pressure production process and is composed of ultra-fine, uniformly distributed fillers. These characteristics are designed to ensure the longevity of its shine and minimize wear on the opposing dentition. This makes CERASMART a promising choice for dental restorations that require durability and compatibility with natural teeth. In another study, after 1,200,000 chewing cycles, materials such as Lava Ultimate, Shofu and Cerasmart exhibited significantly higher material loss compared to IPS Empress CAD and VITA Enamic. It is worth noting that both glass-ceramics and VITA Enamic showed significantly greater antagonist (opposing tooth) wear compared to all tested CAD/CAM resin composites (97). These findings provide insights into the wear characteristics of different dental materials, which can inform clinical decisions regarding material selection for dental restorations.

2.5. Glazing and Polishing of CAD / CAM Materials

The milled ceramic restorations can be finished using a variety of techniques.

When compared to glazing and natural teeth, the polished surface is the smoothest. Instead of glazing, polishing can provide a surface that is smooth and more aesthetically comparable to natural enamel (89).

Glaze enables the addition of a natural gloss, sometimes better than a straightforward mechanical polishing. The workpiece's mechanical qualities are improved by the heat treatment and glazing processes by potentially eradicating microcracks brought on during machining (138).

Porcelain has flat surfaces, and glazing creates the ultimate surface finish (56). Smoothing and glazing are used to give porcelain surfaces their ultimate finish (165,166,167). However, when the restoration adaption is imperfect, an occlusal correction may be required. It is important in this case to refinish the modified ceramic surfaces intraorally (168,169,170,171).

Even though it is commonly accepted that plaque accumulates less on ceramic or porcelain restorations, a rough surface encourages plaque buildup. Because of the rough surface of ceramic restorations, increased plaque not only has a caries-causing virulence but also adversely affects periodontal tissue. With a full-coverage restoration, the likelihood of developing cavities would be quite low, but the gingival tissues would require a lot of attention. Poor polishing results in rougher surfaces, which increase plaque collection and irritate the periodontal tissues. The reliability of the methods frequently used for polishing ceramic dental restorations hasn't, however, been sufficiently investigated. Plaque has apparently been demonstrated to build up less on ceramics than on metals or resin composites, two common dental materials (172,173). Surface roughness has been suggested to have a substantial impact on how much plaque accumulates. As a result, the quantity of adhering plaque may serve as a good gauge of the restoration's surface roughness (174).

2.5.1. Surface finishing and gloss retention of feldspathic ceramics

In a study comparing veneering ceramic, pressed ceramic, and Vitablocs Mark II in terms of their structures, all samples were subjected to the same polishing process using diamond-coated rubber polishers. In the veneer ceramic, the presence of porosity was observed, which is often a result of air pockets or excess water remaining in the material prior to the firing process. Similarly, in the pressed ceramic, similar defects were detected, likely stemming from incomplete flow or inadequate pressure during the pressing procedure. However, in the case of Vitablocs Mark II, no such defects were identified, suggesting that the fabrication procedures for this material were successful in producing a structure without these common issues. Ceramics are known for exhibiting superior gloss retention when compared to hybrid ceramics, composites, and acrylic polymers. This characteristic makes ceramics an attractive choice for dental restorations as they maintain their glossy appearance over time, contributing to the longevity and aesthetics of the restoration (97). The manual, dry, three-step system IL (Identoflex Lucent) and the furnace-based glazing method SPL (Shading Paste and Liquid) produced the best results in terms of roughness. The two furnace-based techniques, AGS (Akzent Glaze Spray) and SPL, produced the best results in terms of gloss. The significance of choosing the right glazing system for achieving the desired surface characteristics in dental restorations is highlighted by the fact that only two manual systems and one furnace-based system were capable of delivering clinically acceptable smoothness and gloss on a CEREC surface after milling (145).

A practically pore-free ceramic with fine crystals is produced when fine-grained powders are used to make Vitablocs Mark II ceramics. This unique composition results in several advantages, including enhanced polishability, reduced enamel wear, and increased strength. When the material is polished, its strength is approximately 130 megapascals (MPa). However, when glazed, the strength of Vitablocs Mark II can increase to around 160 MPa or even higher. This level of strength is approximately twice as strong as conventional feldspathic porcelains and exceeds the strength of many pressable materials used in dental restorations. This increased strength makes Vitablocs Mark II a robust and versatile option for dental applications (98).

2.6. Laminate Veneers

Restorations with laminate veneers are one of the less invasive procedures used to satisfy aesthetic demands. For many years, anterior teeth with wear, stains, breaks, or damage have been treated with laminate veneers (175). Laminate veneers were created using translucent ceramics for the first time in 1862. Between 1920 and 1940, this usage increased in frequency (176,177). By 1938, Pincus attempted to employ an adhesive technique to make sure that laminate veneers and dental tissue adhered to one another (178). The failure was brought on by the brittleness of the laminate veneer material and the frailty of the glue (179). Modern treatment methods have been made possible by improvements in adhesive systems and full ceramic systems (180).

Numerous materials and application procedures have been discovered and are currently being produced as laminate veneer signals rise day by day. The major goal of the research is to provide restorations that are more successful in terms of appearance, usability, durability, and longevity. Veneers are restorations that are put in the same color and as a thin layer over dental tissues with the goal of restoring small or large-scale flaws as well as internal stains. Laminate veneers can be manufactured as a thin layer of ceramic or composite resin covering the labial and buccal sides of the tooth. They can be applied directly or indirectly. Veneers are typically recommended for teeth with deformed or discolored facial surfaces (181). A pretreatment with a depth of 0.3-0.8mm can be used to give the lamina material the proper color and shape (182,183).

By using measurements taken from the prepared teeth, experts in the lab can create indirect laminate veneer restorations. The doctor requires at least two appointments for this method. Modern adhesive techniques are used to attach indirect laminate veneers to teeth (184).

Ceramic veneers have the longest history of any laminate veneer type, having been used for the first time in the film business in 1937 for cosmetic purposes (185). Since it was not then possible to permanently adhere them to those tissues, they were only momentarily linked to tooth tissues. When it was conceivable to condition the cementation surfaces of ceramics using hydrofluoric acid followed by silanization and phosphoric acid, respectively, to etch the enamel (186). Ceramic laminates might be adhered to teeth indefinitely. Since 1983, the four-year survival rates of ceramic laminate veneers have ranged from 100 percent (187), after ten years to 53 percent (188). In a meta-analysis that was published in 1997, the survival rate of ceramic laminate veneers was found to be 92 percent after three years of use (189).

Because they have superior fracture toughness and color stability than resin composites, ceramics are typically referred to as the preferred material. Despite the fact that clinical trials have indicated issues such debonding, fracture, chipping, marginal flaws, or microleakage at the margins (190,191,192).

Patient satisfaction might be more accurate than clinical observers' calibrated assessments, who are trained to see even tiny changes in restorations. Patients reported similar levels of satisfaction with ceramic and composite laminates in earlier retrospective and clinical trials ($p > 0.05$) (193,194). However, a noticeable change was seen after two years, with ceramic restorations showing the best results (193).

Feldspar, a naturally occurring glass containing silicon oxide, aluminum oxide, potassium oxide, and sodium oxide, is the primary component of feldspathic porcelain (Walton & Layton 2012) (195). Feldspathic porcelain has various benefits, including the ability to be practically translucent due to the material's extreme thinness, which produces a restoration that seems completely natural. Furthermore, just minor dental preparation is needed. As a result, enamel can be protected. In addition, hydrofluoric acid can be used to etch feldspathic porcelain, giving the surviving enamel a strong bond (196,197,195,187,198,211). Feldspathic porcelain does, however, have significant drawbacks. There are two ways to make feldspathic porcelain: using a refractory die and using platinum foil (199,200,201,202,203). These procedures demand precise expertise, and the manufactured veneer needs to be handled carefully before bonding (204). Additionally, because the porcelain is so thin, it might be challenging to conceal heavily discolored teeth. It was also mentioned that etching porcelain's surface can cause microcracks, which gradually reduce the material's flexural strength and crack the veneer (205).

There are a number of signs that a laminate veneer restoration has been done: Discolored teeth, diastema closure, enamel hypoplasia, masking of enamel defects, rotational teeth, in order to give canine teeth a lateral form, fractures in the coronal part of the tooth, congenital or acquired malformations, colored restorations, in congenital or acquired malformations, teeth whose clinical crown length is insufficient, It can be used to treat class V defects that occur as a result of atresia and abrasion, hypocalcified teeth, wedge laterals, lingually inclined teeth, lingualized teeth, lateral incisor deficiencies, teeth with advanced enamel loss as a result of erosion and wear, teeth with discoloration as a result of cracked enamel, and wedge defects as a result of toothbrush wear (206).

Laminated veneers are not recommended in the following situations: Teeth with insufficient enamel support, parafunctional habits, a high incidence of caries, Class III malocclusion and head-to-head closure, excessive crowding and rotation, sports players who are vulnerable to impacts, partially erupted teeth, and milk teeth can all be listed as having teeth with excessive fluorosis (206,203,207).

2.6.1. Preparation of Laminate Veneers

Within the confines of the enamel, laminated veneer preparation should be carried out using specialized cutting burs. This method allows for the use of four alternative cutting techniques, which can be chosen based on the circumstances (208).

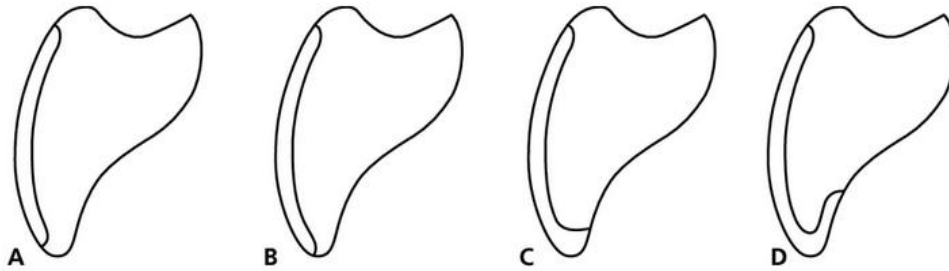


Figure 1.1. Preparation types of laminate veneers (209).

According to the literature, there are four primary designs for tooth preparation (Figure 1.1.):

- A) The window preparation: preservation of the tooth's incisal edge through window preparation.
- B) Feathered edge preparation: These preparations leave the length of the incisor unchanged while incisal edges are made bucco-palatable.
- C) Palatal chamfer preparation: This technique involves making the tooth's incisal edge bucco-palatable and shortening it (by 0.5–1 mm).
- D) Butt joint/Incisal Overlap Preparation: In this procedure, the tooth's incisal edge is made bucco-palatable and its length is decreased (by about 2 mm), allowing the veneer to stretch to the tooth's palatal surface (210,203,211,212).

Although studies that look at how prepared designs affect how long a restoration lasts have yielded a variety of outcomes and points of view. The incisal overlap preparation, which also spreads occlusal stresses over a larger surface area, seems to provide the optimum support for the restoration. During the window preparation, the incisal third is subjected to a large quantity of occlusal stress, which could result in the restoration breaking. Additionally, incisal translucency can be achieved more successfully by lowering the incisal edge. (210,211,213). It is arguable, though, whether a shoulder finish line (butt joint) or the addition of a chamfer finish line is desirable. (Troedson and Dérand 1999) (214) and (Zarone et al., 2005) (215) reported that for the restoration to tolerate the occlusal stress, it is necessary to have a chamfer finish line.

In contrast, (216,210) advised that the restoration's lifetime isn't increased by adding a chamfer finish line. In addition, they stated that veneers with butt-joint finish lines might be able to provide different insertion pathways (Figure 1.2.). Having only one line of insertion, however, can be useful since it prevents the veneer from slipping during cementation. The investigation came to the conclusion that the treatment's durability and predictability are unaffected by an overlap preparation with a chamfer finish line.

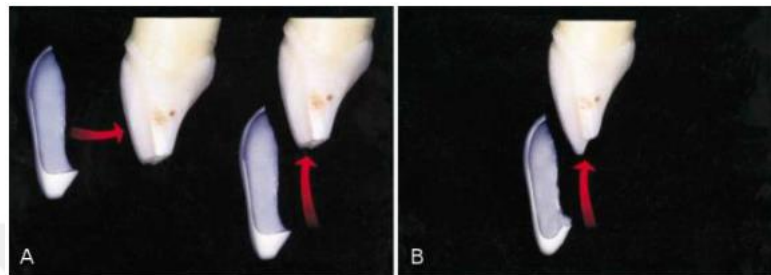


Figure 1.2. Incisal overlap with shoulder finish line (A) provide more than one path of insertion while incisal overlap with chamfer finish line (B) provides only one path of insertion (216,210).

The final assessment of the anterior teeth's biting force (100–200 N) is that it is low (233). Furthermore, because there isn't a strong, well-executed clinical study, the choice of preparation design is mostly determined by the preferences of the physician; nonetheless, incisal overlap can always be made to restore anterior guidance (217,195,218,217).

A conservative option to crowns that has a lengthy track record of efficacy in improving anterior aesthetics is porcelain laminate veneers (PLVs). The PLV preparation should be based on the finalized grin design, taking into account the color and positioning of the restorations' margins. The final wax-up or intended outcome, not the initial tooth, must serve as the foundation for any tooth reduction that may be required. If you don't, you risk needlessly and unnecessarily removing enamel from your teeth (219).

To ensure a trustworthy and robust adhesion between the restoration and the remaining tooth tissue, every effort should be made to keep the preparation inside the enamel. Due to the less stable bond to dentine and the disparity in elastic modulus and flexibility between dentine and porcelain, preparation into dentine should be avoided. Porcelain is hence susceptible to breaking when subjected to tensile stress. Of the 583 veneers Gurel evaluated during a 12-year period, 42 veneers, or 7.2%, failed (220). A nearly tenfold greater failure rate was seen for veneers bonded to dentin and for teeth with dentin preparation margins than for veneers affixed to enamel.

Before placing porcelain laminate veneers, careful tooth preparation is necessary. A few objectives of tooth preparation include: Create a distinct border so the ceramicist can see the completion line and ensure the veneer emerges from the gingival margin properly. This will give the porcelain enough thickness to withstand fracture and prevent the finished restoration from becoming too curved. If at all possible, keep the preparation inside the enamel. Deliver a finished product that is polished and free of any acute internal line angles. To assist customers on effectively sitting the veneer, create recognizable seating landmarks (219).

Preparation for Labials

The labial contour of anterior teeth (Figure 1.3.) must be prepared using three planes: the incisal, middle third, and cervical. The labial contour's surface has a convex shape.

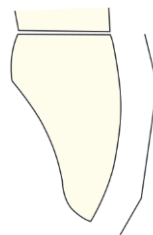


Figure 1.3. Labial surface of the maxillary anterior tooth's three-plane contour (221).

The tooth structures are carefully decreased in depth to provide a minimum of 0.3 mm (for feldspathic porcelain) or 0.6 mm (for Empress, E.max) preparation. The gingival third of the enamel is between 0.3 and 0.5 mm thick, the middle third is between 0.6 and 1 mm thick, and the incisal third is between 1.0 and 2.1 mm thick (222). A minimum amount of tooth structure should be removed from the enamel in order to prepare it for long-term adherence. Veneers can be used to conceal discoloration. In order to improve the shade of a porcelain veneer that is discolored, the veneer must be at least 0.2–0.3 mm thick; otherwise, an opaquer porcelain can be utilized. Simply said, the degree of desired shade change and the final tooth placement, which is dictated by both practical and esthetic criteria, determine the thickness of porcelain veneers. Since common items make it possible to accurately judge depth, the use of depth cutters or grooves and dimples has been recommended to control tooth preparation. Then, cuts made with burs that are precisely engineered to give graduated depth cuts are reduced using chamfer burs (7.2.2.1 and 7.2.2.2).



Figure 1.4. Using a depth cutting bur to initiate the necessary depth of reduction required.

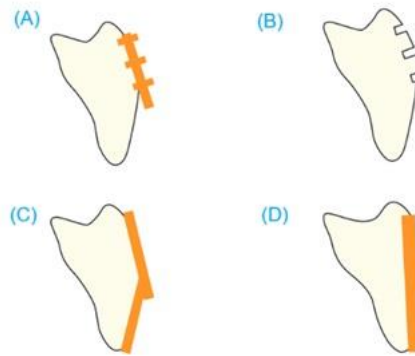


Figure 1.5. (A) an illustration of a depth cut made with a depth cutting bur in cross-section. (b) The cross-sectional depth cuts. (c) The connection between burs and depth cuts; pay attention to the required convex shape. (d) Improper preparation with a single plane reduction may expand into the pulp's immediate vicinity and result in permanent damage (221).

As an alternative, depth grooves or dimples can be used. The tooth's surface is given a dimpled appearance by sinking a spherical bur with a diameter of 1 mm down to a depth of 0.5 mm. Keep in mind that the position of the teeth in respect to the arch's shape will also affect how much tooth tissue needs to be removed.



Figure 1.7. Arch form of the teeth

Another option is to use depth grooves or dimples. On the occlusal view, dimples are depth pits that show how much reduction is required to form the orange-lined arch shape. Before starting any preparation, it is essential to determine whether eliminating tooth structure is indeed required to accomplish the desired tooth position and contour. It should be noted that only one tooth would require preparation; the proper arch form could be attained by simply adding surfaces to the tooth using a round bur with a 1 mm diameter that has been sunk to half its diameter to obtain 0.5 mm depth. Keep in mind that the position of the teeth in respect to the form of the arch will also have an impact on how much dental tissue needs to be removed. (Figure 1.7.)

Feather preparation. The preparation is added to or feathered to the incisal edge; it is not diminished. This preparation has the disadvantage of potentially exposing the margins to shear stresses in protrusion.

Window preparation. This can be achieved by preparing the veneer up to the incisal edge while leaving the enamel on top. An issue in this scenario is the inability to conceal the margin.

Bevel preparation. A bevel is carried along the incisal edge from buccal to palatal by 1-2 mm of incisal reduction. Incisional overlap in tooth preparation is good, according to Calamia, because it strengthens the veneer and guarantees a stable seat during cementation (177). This preparation design has the benefit of simple tooth preparation and simpler aesthetic construction with the ceramist because it can provide incisal translucency. The veneer can be properly seated with the helpful seat that is provided. The margin should not be in a place where it will be subject to protrusive forces during excursive motions in order to reduce stress inside the veneer and disperse the occlusal load across a greater surface area.

Incisal overlap. Incisional edges are trimmed during preparation, and they are then extended onto the palatal aspect. This preparation provides a comfortable seat, but it's crucial to thoroughly inspect the insertion path to make sure there are no undercuts.

The ideal incisal preparation has not been determined. An overlap or bevel design is widely utilized due to the advantages of a good seat during cementation. Because of the aesthetic potential of this method, ceramists can add more features to the restoration. Furthermore, it is the preferred style when lengthening the teeth (219).

Proximal Preparation

Close proximity preparation can be accomplished by halting shortly before breaking the contact or by preparing at the point of contact. It is preferable to leave contact points with a margin that extends 0.25 mm or more labially from the contact region when leaving them intact. The tooth-porcelain interproximal interface is apparent from different viewing angles, but it can be hidden by employing an L-shaped preparation or elbow preparation to cover the interproximal borders (219).

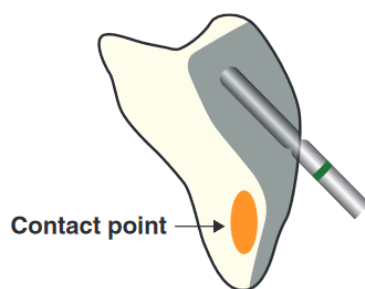


Figure 1.8. Use an L-shaped proximal preparation to hide proximal borders (221),(221).

Breaking the contact is frequently required when changing the position or shape of teeth. The additional interproximal space allows the ceramist the flexibility to alter the shape, alignment, and breadth variations of the teeth. Additional proximal preparations may be necessary depending on the level of caries and any existing restorations (219).

Cervical Margin

It is suggested that chamfers have a maximum depth of 0.4 mm. Because of this, the veneer can imitate the forms of real teeth without being overly molded. Additionally, it simplifies veneer sitting and lessens stresses, enhancing the veneer's eventual resistance to fracture. When the edges blend together without a clear dividing line, the use of thin, translucent porcelain frequently results in a "contact lens" effect. Margin type so has two options: supragingival or equigingival. A supragingival margin has various advantages because there is less likelihood of exposing dentine and less chance of damaging the soft tissues during preparation. Since the margin is more likely to be in enamel during enamel bonding, the likelihood of micro-leakage is lower. Subgingival borders may be required when cavities or prior restorations spread subgingivally. The edge is positioned deeper, frequently onto dentine, increasing the likelihood of micro-leakage and discolouration. Additionally, it is more difficult for the patient to clean after cementation and for the dentist to finish the restoration (219).

Existing Restorations

When veneers are adhered to composite restorations, especially when the preparation margin is on an existing filling, the risk of failure rises (223,224). It is advised to incorporate the repair within the veneer if it is possible to do so and allows for complete removal.

Finishing the Preparation

It is important to carefully inspect the preparation in its finished state, ideally under magnification. The intersection of the preparation's lingual, labial, and proximal reduction planes should not have any sharp angles and should instead be rounded. Sufficient reduction and smoothed internal line angles are also necessary. These regions could lead to a buildup of tension inside the ceramic, increasing the likelihood that it would crack. No margins should exist at wear facets or in occlusion zones; they should be well defined and smoothed (219).

2.7. Evaluation of materials

2.7.1. Hardness Tests

The ability of a substance to resist repeated deformation in the presence of a hard object is known as hardness (225). Hardness guarantees that a material maintains its original shape in the face of forces while also enhancing the material's mechanical strength, scratch, fracture, and abrasion resistance (226,227). Depending on the applied force and the changes that are seen, the hardness measurement can be classified as macro, micro, or nano grade (228). By exerting pressure on the material surface of the micro diamond tip under load for a predetermined amount of time, micro hardness tests are conducted (226). Once the load has been removed, a microscope is used to measure the length of the traces that have been produced as a result of this operation (229). In contrast to macrohardness testing, the weights utilized in these tests and the traces that are produced are very small and restricted to a depth of less than 19 m (228). There are four ways to assess microhardness: Rockwell, Vickers, Knoop, and Brinell (230). The dwell time, test force, and VHN number should all be included. The resistance of the specimen to indentation can be used to describe surface hardness. One indicator of the degree of conversion is surface hardness assessment, which also reveals how well restorative materials operate clinically (231). To determine how tough brittle materials are, the Vickers indentation test method is frequently employed (232,233,234).

The method's basic idea is to press the indenter onto the indentation's pyramidal contact area (A) while applying a known force (F). The formula used to determine hardness was $H=1.854 F/d^2$, where F stands for the test force that was applied and d for the diagonal length that the indenter left behind (16). When measuring the hardness of a material, a trace is made by applying a force of 1 to 100 kg with a diamond tip that has a square bottom and a pyramidal shape with an apex angle of 136°. Following the removal of the applied load, the diagonals of the rectangular shape are measured (235).

Vickers hardness value is calculated by dividing the test load in kg by the trace area in mm² ($HV=1.854 \times \text{force} / \text{base diagonal}$). The formula is used to calculate it. The Vickers hardness value increased as the imprint area shrunk, and this finding suggests that the material is harder. Vickers hardness test results provide benefits including a very small margin of error, a diamond tip that does not deform quickly and readily, and the ability to be applied to all types of materials and surfaces. Additionally, the top surface, center, and bottom surfaces of a sample can all be measured using the Vickers hardness test (236).

2.7.2 Thermocycling

The thermocycle approach is among the most popular leaching techniques. Other rationale techniques include soaking in water, mechanical loading, enzyme breakdown, and application of different chemicals (237). Methods including in vitro applied thermocycling, soaking, and aging are widely employed to assess a material's compatibility for in vivo application.

3. MATERIAL AND METHODS

3.1. Research Plan and Method

As a result of the Power analysis using the G power program, the surface effect size d for roughness: 0.631 standard deviation 11, Power: 0.80 and the number of samples determined for $\alpha:0.05$ is minimum $n=7$ samples for each group detected.

3.2. Tooth Preparation

Upper and lower educational jaws were used in the study (Figure 2.1.). A pilot study was conducted at the beginning of the study. Butt joint preparation was applied to the maxillary left central tooth. The incisal edge was shortened by 2 mm. Since the surface of the laminate was not flat, in the hard tissue laboratory the profilometer device could not identify the surface. Therefore, it was decided that the preparation in the study would be made flatter. Maxillary right first typodont tooth was prepared for a digital scanning. Tooth preparation was made with incisal reduction without approximal involvement. Tooth preparations were done according to the descriptions (181). The prepared cavity designs were evaluated by one senior faculty member for quality (Figure 2.2.). The rating scale: “Rating System for Quality Evaluation of Prepared Cavities” was followed for the evaluation of the cavity designs (238). Prepared surfaces of the tooth were polished with different aluminum-oxide impregnated disks varying from coarse to fine depending on the grain size of the polishing discs. Optidisc (Kerr).

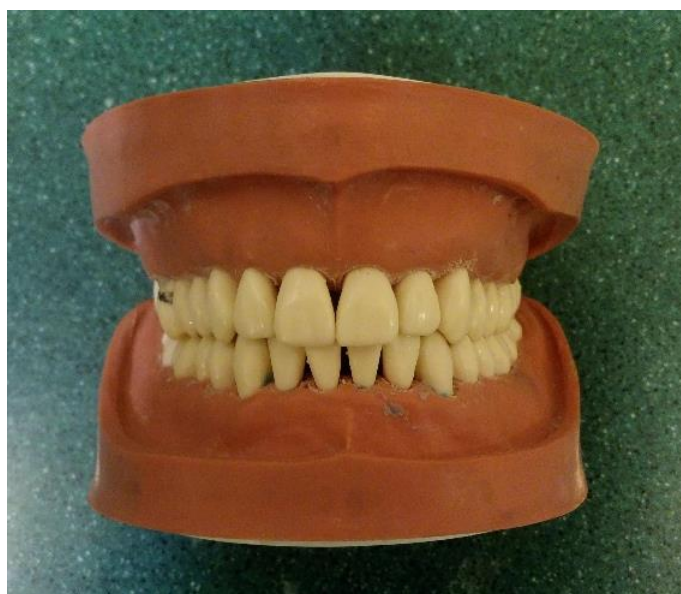


Figure 2.1. Educational model jaw.



Figure 2.1.1 Preparation for the pilot study.



Figure 2.2. Preparation of typodont tooth.



Figure 2.3. Prepared tooth.

3.3 Material Selection

Four types of CAD/CAM materials: the lithium disilicate glass ceramic (IPS E.max CAD; Ivoclar Vivadent, Schaan, Liechtenstein), Empress CAD (Leucite re-enforced glass-ceramic), Cerec (Feldspathic ceramic, Sirona, Dentsply, Germany) and Cerasmart (Force Absorbing, Flexible Nano Ceramic CAD/CAM Block) were used in this study. Twenty laminate shaped specimens from each material (10 mm in length and 1 mm in thickness) were fabricated. The details of the materials used in the study are described in Table 2.1.

Table 2.1. List of all ceramic materials used in this study

Material name	Material type	Brand and place of production	Code
Cerec	Feldspathic ceramic	Sirona	54660
IPS Empress CAD/CAM	Leucite re-enforced glass-ceramic	Vita	W73302
IPS E.max CAD	Lithium disilicate glass ceramic	Ivoclar	Y38634
Cerasmart	Composit-based Hybrid Ceramics	GC	1909021

Glass ceramic blocks reinforced with lithium disilicate; samples obtained from IPS Emax (LOT no: Y38634) blocks (Figure 2.5.) were divided into two groups, unglazed (n:10) and glazed (n:10).



Figure 2.4. Cerec ceramic blocks.



Figure 2.5. E.max CAD ceramic blocks.

Samples obtained from leucite reinforced glass ceramic blocks and IPS Empress (LOT no: W73302) blocks (Figure 2.6.) were divided into two groups, unglazed (n:10) and glazed (n:10).



Figure 2.6. Empress CAD ceramic blocks.

The force absorbing hybrid ceramic CAD/CAM block.; Samples obtained from Cerasmart HT 270 (Figure 2.7.) (LOT no:1909021) blocks were divided into two groups: unglazed (n:10) and glazed (n:10).



Figure 2.7. Cerasmart blocks.

Feldspathic blocks; Samples obtained from Cerec feldspathic (LOT no: 54660) ceramic blocks (Figure 2.4.) were divided into two groups as glazed (n: 10), unglazed (n: 10).

Table 2.2. List of other materials used in this study.

Material name	Material type	Brand and place of production	Code
Step Bur 12S	CAD/CAM bur	Sirona	E72579
Cylinder Pointed Bur 12S	CAD/CAM bur	Sirona	M71663
IPS Ivocolor Refill	Glaze material liquid	Ivoclar Vivadent	Z005KX
IPS IvocolorRefill	Glaze material powder	Ivoclar Vivadent	Z003H6
Optiglaze Color	Glaze material	GC	1909141

3.4. Digital Scanning

After the preparation was done, the digital impression was obtained with intraoral scanner (Cerec, Omnicam, Sirona Dental Systems, Bensheim, Germany). The Cerec Cad/Cam intraoral scanner device (Omnicam, Sirona Dental, Bensheim, Germany) was used for digital impression.

Material selection at the “Administration” tab on the CAD/CAM device (Figure 2.8.) is an important step before the scanned images are saved. The brand of each group was selected and scanned in separate tabs on the device. In the “Materials” section, “Vita-Empress” and “Vita-E.max” for E.max and Empress, “GC-Cerasmart” for Cerasmart, “Sirona-Cerec” for Cerec. (Figure 2.8.). According to the mouth model, the tooth number to be restored was selected and the "Scanning" tab was opened to scan with the intraoral camera. Omnicam digital camera was kept as close to the tooth as possible and angled measurements were taken on the buccal, occlusal lingual, mesial and distal regions, respectively (Figure 2.9.). When necessary, the measurement process was stopped by pressing the pedal of the device once, and the quality and accuracy of the measurement was examined, the measurement of the missing parts was taken again and the digital measurement of that region was made by removing it from the beginning. For scanning to continue, it is important that the device coincides with where the image stopped. (Figure 2.10.) After the scanning of the image is complete, you can remove unwanted faulty images from the toolbars with the "Cut" method.

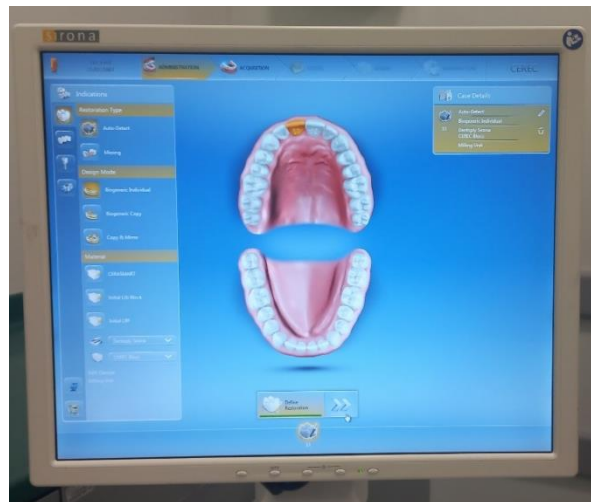


Figure 2.8. Administration and material selection.

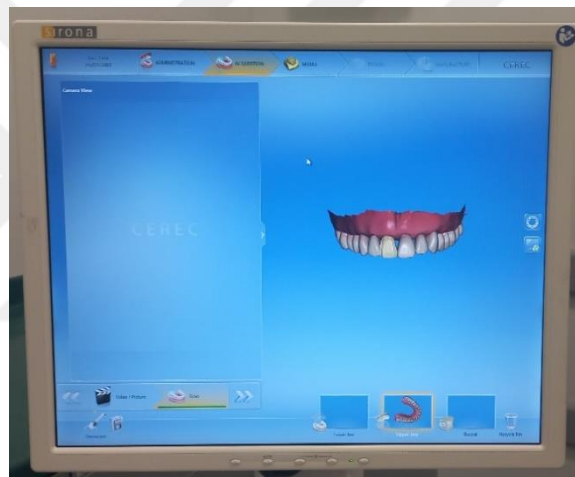


Figure 2.9. Scanning of the upper jaw.

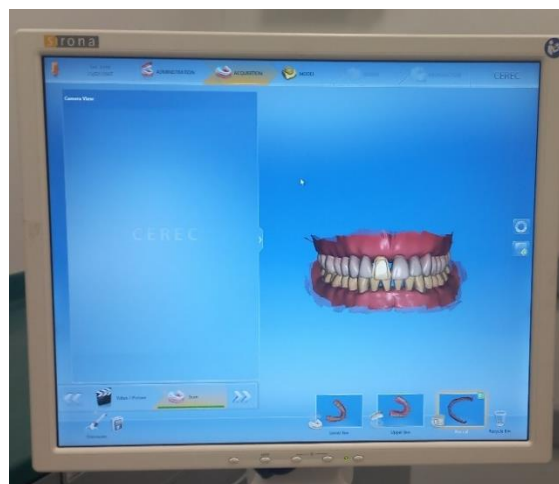


Figure 2.10. Scanning of the upper and lower jaw in occlusion.

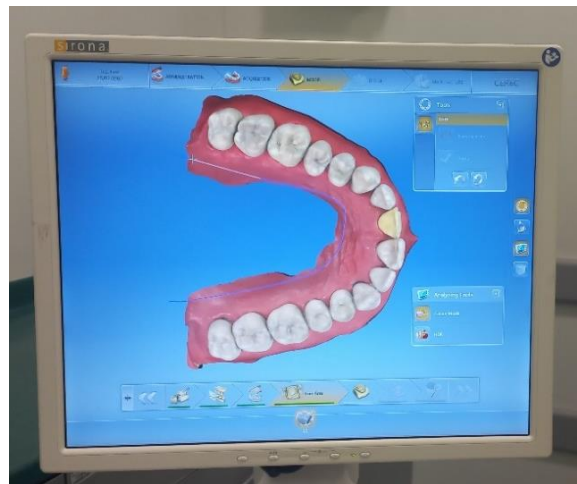


Figure 2.11. Trimming of excessive parts of the image.

3.4.1 Design of the Samples

After the margin drawing phase was completed (Figure 2.13.), the design part of the restoration was started. Restoration parameters suitable for laminate restoration were reviewed before the design was made. In the restoration parameters suggested by the software (SW 4.6), the manufacturer's settings of 120 μm cement spacing and +50 μm margin thickness were checked.



Figure 2.12. Setting model axis of the upper jaw.



Figure 2.13. Drawing margins of the restoration.

There three-dimensional design of the restoration on CEREC SW 4.6 software was used for the design of the restoration. The margins of the restoration were applied automatically and corrected manually. The shape of the digital restoration was created automatically by Cerec software. Corrections were applied manually to obtain the final digital shape of the restoration before production (Figure 2.14.).

The design of the specimens was done using integrated software (Sirona Cad-Cam system, Dentsply). Specimen production was carried out using a milling unit (MCXL, Sirona Dental, Germany) (Figure 2.17.). CEREC SW in the CEREC AC device 4.4.4. software is opened. A separate patient record was opened for each sample tooth to avoid any future confusion. After creating the identity information of the samples, proceeding to the application part (Figure 3.7.), firstly, "Crown" as the restoration type and "Biogeneric Individual" as the "Design Shape" were selected from the "Indication" tab.

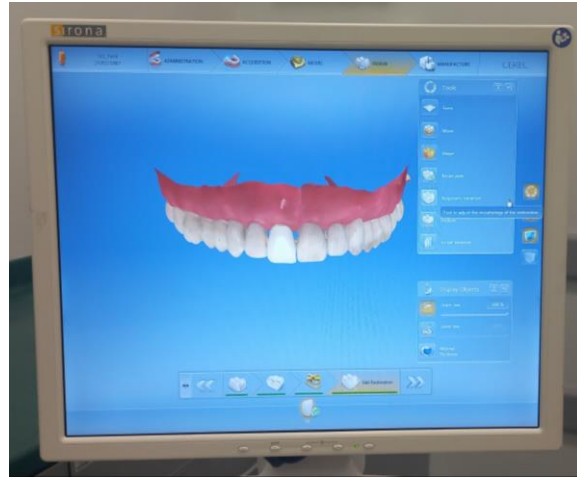


Figure 2.14. Editing the restoration (Cerec, Sirona).

In the Design tab, the "Bio Jaw" option is checked. Considering the standard laminate lengths of the mandibular and maxillary permanent 1st incisors, the standardization of the laminate lengths from the enamel-cementum border to the highest tubercle apex of the restorations was achieved. For this, the restoration height from the cervical band part of the laminates to the highest tubercle apex was designed as 10mm mm for the laminate restorations to be applied. While making this measurement, a section parallel to the long axis of the teeth was taken on the software and necessary adjustments were made on this section.

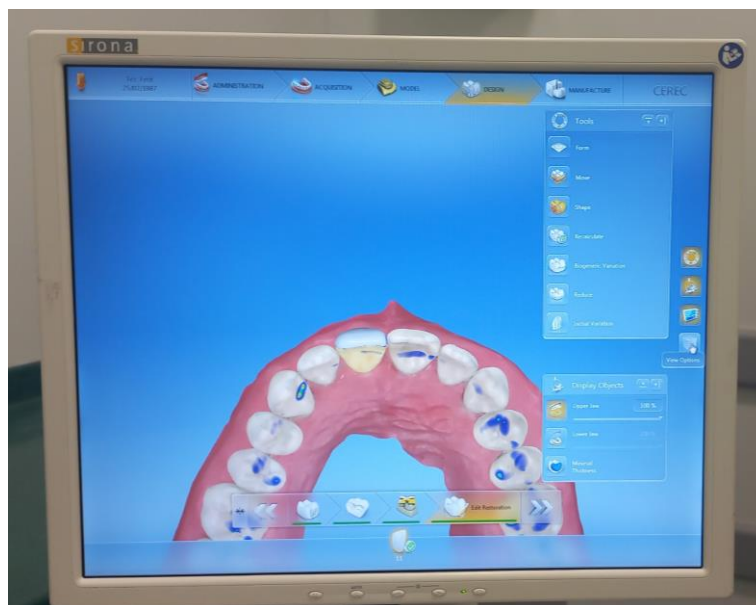


Figure 2.15. Editing the restoration from the different angle.

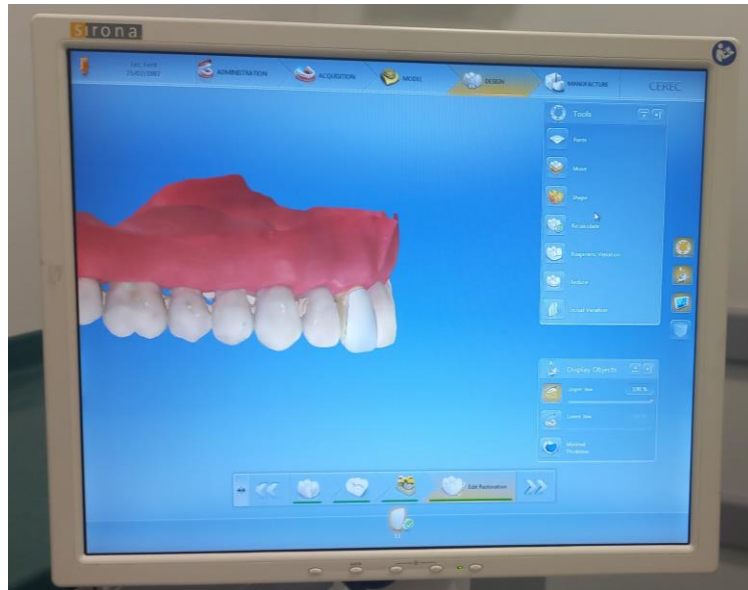


Figure 2.16. Editing the restoration from the different angle.

3.5. Fabrication of the Samples

The production of the samples was obtained by CAD/CAM (CEREC MC XL, Sirona, Germany) device (Figure 2.17.)



Figure 2.17. CAD/CAM milling device (CEREC MC XL, Sirona, Germany).



Figure 2.17.1. CAD/CAM burs (Sirona, Germany).

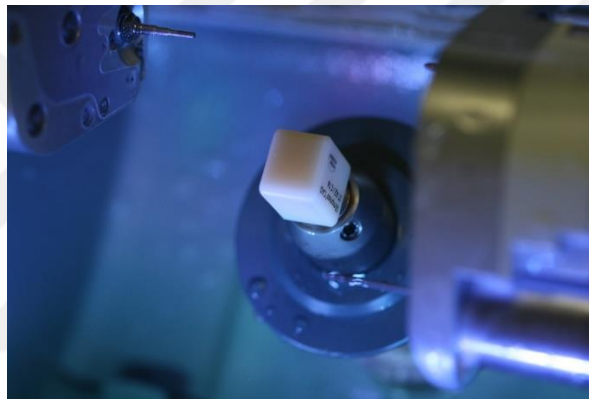


Figure 2.18. Fitted IPS Empress CAD ceramic block in the milling device.



Figure 2.19. Selection of the burs before placing of the burs.



Figure 2.20. Milling process of the sample.

Position in the block (Figure 2.18.) and the block size were determined. After placing the CEREC block in the size required by the software into the Cerec milling device (Cerec MC XL, Sirona Dental Systems, Bensheim, Germany), it was tightened with a special torque screwdriver. Special burs (Cylinder Pointed Bur 12S-Step Bur 12, Sirona Dental Systems, Bensheim, Germany) were used for block milling operations. Burs were fitted before the milling process. After making sure the block size and the accuracy of the burs, according to the instructions on the engraving device, the engraving process started. After the scraping process was finished, the laminate restoration that fell into the chamber of the device was taken and kept in a separate container with the specific tooth with the identification number. Each scraping took an average of 12-16 minutes while milling of E.max restorations and these processes were repeated for 20 teeth. Because of the high hardness of E.max materials, it took more time for milling of these materials in comparison with the Empress, Cerec and Cerasmart groups.

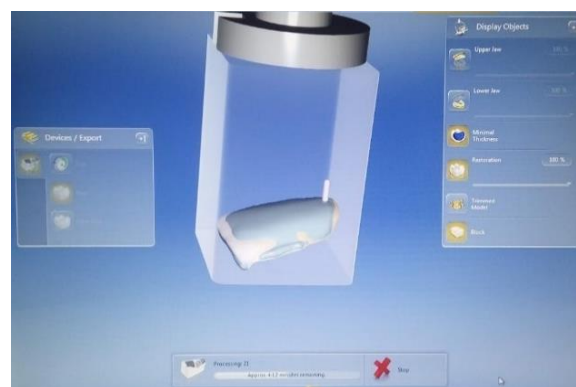


Figure 2.21. Production of the sample.

The specimens were carefully separated from the milled block after the milling process was completed. All the specimens from all groups were milled with cad cam burs (Step bur 12S (LOT: E72579) and cylinder pointed bur 12S (LOT:M71663)). The thickness of all samples

was 0.7 mm in incisal 1/3, 0.8 mm in middle 1/3 and 0.8 mm in cervical 1/3.

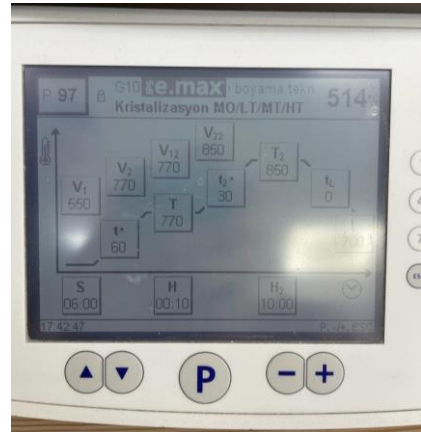


Figure 2.21. Furnace (Programat500, Ivoclar) **Figure 2.22.** Crystallization of E.max material

3.6. Glaze

To achieve final strength 20 samples of partially crystallized IPS E.max CAD specimens were fully crystallized in an Ivoclar Programat P500 furnace (Ivoclar, Germany) for 20 min at a start temperature of 550°C and a maximum temperature of 850°C.

The glaze process was applied to 10 samples of every group in accordance by manufacturer's instructions. For this process, a mixture of glaze powder and liquid was applied with a brush in a very thin layer on the restoration (Figure 2.23.).



Figure 2.23. The glazed sample.

The glaze material (IPS Ivocolor Glaze Paste, Ivoclar Vivadent, Germany) (Lot: Z005KX, Lot:

Z003H6) (Figure 2.24.) was used for Cerec, IPS Empress CAD and IPS E.max CAD. Specimens were fired as recommended by the manufacturer. E.max and Empress samples were glazed in Ivoclar oven (Programat P500, Ivoclar, Germany).



Figure 2.24. Ivocolor Glaze Powder and The liquid.

Cerec specimens were glazed in a furnace (Focus 2010, Israel) (Figure 2.25.) with a start temperature 550° C.



Figure 2.25. Furnice (Focus 2010, Israel).



Figure 2.26. The milled and glazed sample.

3.6.1. Glaze For Cerasmart Samples

Cerasmart specimens were glazed with GC glaze (Optiglaze Color, GC) (Lot:1909141) (Figure 2.29.). The external surface of Cerasmart (Cerasmart® 270, GC Corp, USA) was cleaned with steam cleaner for 5 seconds (Figure 2.27.). The dust was removed and the surface was made smooth. The surface was sandblasted with 25µm alumina (0,15 MP/2.5bar.) (Figure 2.27.), cleaned and dried. G-Multi Primer (Figure 2.29.) was applied on the external surface of the first 10 samples of Cerasmart group. The samples were kept in a closed box for 60 sec. Optiglaze color bottle was shaken well (Figure 2.29.). A few drops of optiglaze color were dispensed in a dispensing dish. A thin layer of glaze was applied with the clean brush on the external surface of Cerasmart samples. Polymerization was applied by Ivoclar Vivadent Bluephase (Figure 2.31.) for 40 sec.



Figure 2.27. Steam for cleaning the surface



Figure 2.28. Sandblast (Renfert Basic Master)



Figure 2.29. Optiglaze color and multi primer for Cerasmart glaze procedure



Figure 2.30. Steam for cleaning the surface



Figure 2.31. Polimerization unit for cerasmart samples (Ivoclar Vivadent Bluephase).



Figure 2.32.: Glazed Cerec specimen.



Figure 2.33. Glazed Cerec specimen mesial view.



Figure 2.34. Glazed Cerec specimen distal view

3.7. Evaluation of the samples

Evaluation of the samples were done in hard tissue laboratory in Yeditepe University Faculty of Dentistry. Microhardness tester, Profilometer and Thermocycler were used for evaluation of the samples.

3.7.1. Evaluation of microhardness values

A hardness tester (Buehler, Illinois USA) (Figure 2.36.) was used to evaluate surface microhardness values. For the microhardness test three indentations were made in each specimen using a Vickers diamond indenter under 150 gr load and a 10-seconds dwell time. The resulting indentations were reported in Vickers hardness (VH) units by the machine. Values were obtained after milling, after glazing and after thermocycling.



Figure 2.35. Microhardness tester, Buehler.



Figure 2.36. Microhardness tester (Buehler, Illinois USA).

3.7.2. Evaluation of Surface Roughness Values

Surface roughness measurement was done for two sides of every sample using profilometer. For the average surface roughness (R_a) measurements, three measurements were made from each sample, from three different points, with a profilometer (Perthometer M1, Mahr, Germany) (Figure 2.37.). The average R_a value was obtained.

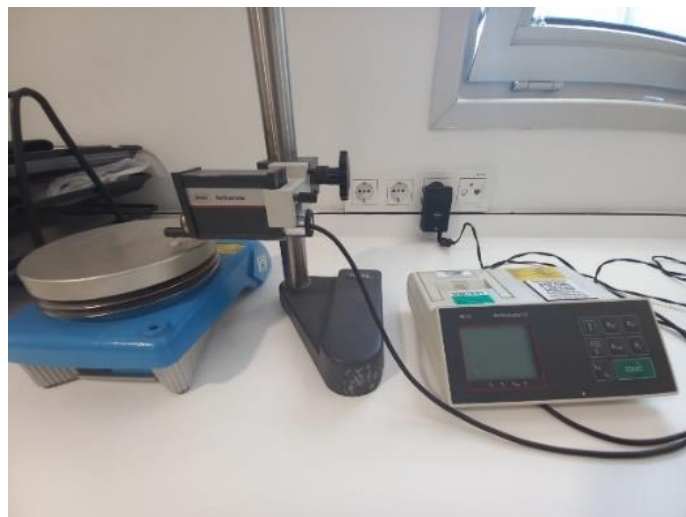


Figure 2.37. Surface roughness tester, Profilometer, Perthometer M1, Mahr.

The profilometer device (Perthometer M1, Mahr, Gottingen, Germany) that was placed in the Hard Tissue Research Laboratory in Yeditepe University Faculty of Dentistry, was used to measure the surface roughness of the samples (Figure 2.38.). Parameters of the device, measuring length (Lt); 1.75 mm, cut off value (λ_c); 0.25, number of measurements (n); It was set to be 5. The surface roughness value was calculated by taking the average of the Ra values (μm) obtained from 3 different points of each sample surface, including the center and periphery. In order to obtain more reliable results during the measurement, the samples were fixed on a holding apparatus. In addition, the device was calibrated every 10 measurements using a reference block with a Ra value of $2.4 \mu\text{m}$.

The samples' average surface roughness both before and following the correction and glazing process (Figure 2.38.). A diamond stylus with a tip radius of $12.5 \mu\text{m}$ and a length of 2 mm was used to measure the roughness value in m over the course of 15 seconds with a measurement range of $524 \mu\text{m}$.



Figure 2.38. Measurement of surface of nonglazed Empress sample with profilometer device (Perthometer M1, Mahr)

Surface roughness (Ra) of all samples was measured with a profilometer (Perthometer M1, Mahr, Gottingen, Germany, Mahr, Göttingen, Germany, Lt=1.750 mm, 0.250*5, stylus PHT 6-350/2 μm). The profilometer device was calibrated before the measurement of each group. A total of 3 measurements were taken from the surface of each sample in 3 different directions, one measurement from each direction and the averages were taken. For standardization of the study the measurements were done in a “Z” shaped form.

Profilometer device measurement of each group calibrated before the measurement of every group from the surface of each sample to be 3 measurements in different directions. First measurement was done horizontally at 1/3 incisal region. The second measurement was done at the 1/3 middle area diagonally and the last measurement was done horizontally. A total of 3 measurements were made and the averages were calculated.

3.7.3. Aging with Thermocycling Process

The specimens were processed with thermocycling procedure in a distilled water with 5/55 °C (± 2 °C) temperature for 10.000 cycles (Thermocycler, Delta, Salibrus, Turkey) (Figure 2.39.). The 10.000 cycles have been reported to represent approximately 1 year (239). The transfer time was set at 10 seconds, and the dwell time for both temperatures was set at 20 seconds.



Figure 2.39. Thermocycler (Delta, Salibrus).

3.8. Scanning Electron Microscopy Evaluation

SEM images of each group's representative samples indicate microhardness and surface roughness values that are comparable to the average values of the related groups. The samples were exposed to a scanning electron microscope (JSM 6335-F; JEOL Ltd, Tokyo, Japan) after being dried and coated with gold.

One sample from each ceramic group was taken for sem analysis, which provide a gualified analysis of the surface characteristics. Surface roughness was visualized by SEM analysis. The differences between the surface topography have been investigated. For scanning electron microscopy (SEM) analysis, samples were attached to an aluminum metal platform with a double-sided adhesive tape. Samples were gold-plated and carefully observed under a SEM (JSM 6335-F; JEOL Ltd, Tokyo, Japan) with magnifications of 100×, 250×, 500×, 1000. Representative micrographs of the surface roughness of the samples were recorded and descriptive analyzes were made. The samples with different surface treatments were investigated before and after termocycling.

3.9. Methods Of Statistical Analysis

IBM SPSS Statistics 22 (IBM SPSS, Turkey) application was utilized for statistical analysis when analyzing the study's findings. Using the Kolmogorov-Smirnov and Shapiro-Wilks tests to assess the parameters' suitability for the normal distribution, it was found that the parameters were appropriate. The Tukey HDS test and Tamhane's T2 test were applied if the variances of the groups were homogeneous and the Oneway Anova test was applied to compare the parameters between material groups if they were not. Comparisons of the internal and external surfaces were made using the student t test. The parameters within the group were compared before and after the thermocycling using a paired sample t-test. For repeated measurements, analysis of variance was employed, and the Bonferroni test was utilized for post hoc analyses to compare the initial, post-glazing, and post-thermocycling periods. The level of significance used for evaluation was $p < 0.05$.

4. RESULTS

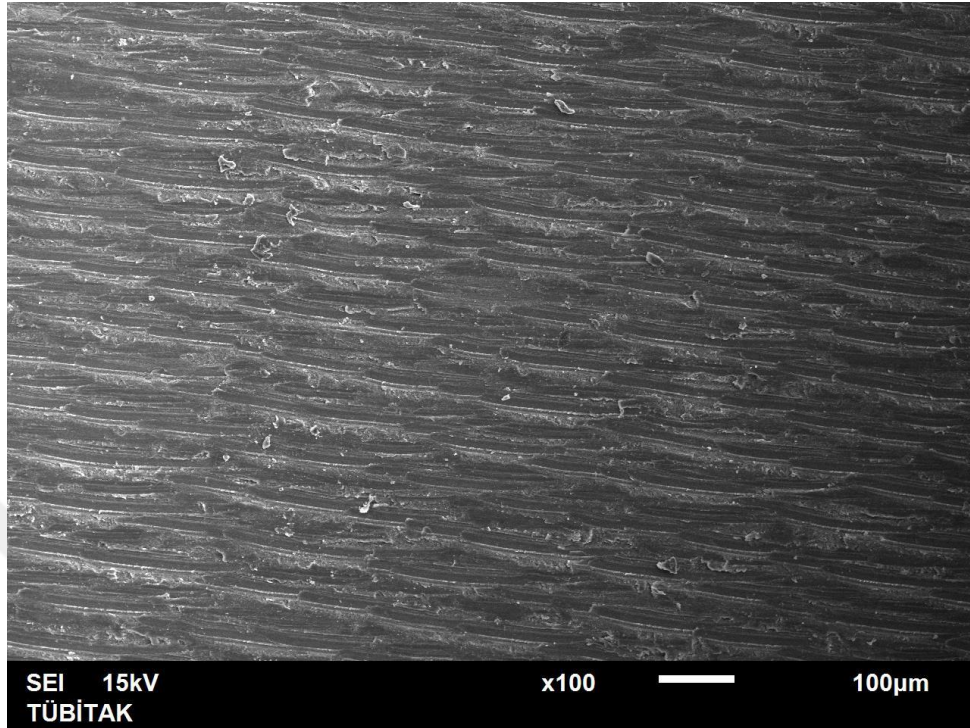


Figure 2.40. The initial 100x SEM image of the Cerasmart sample.

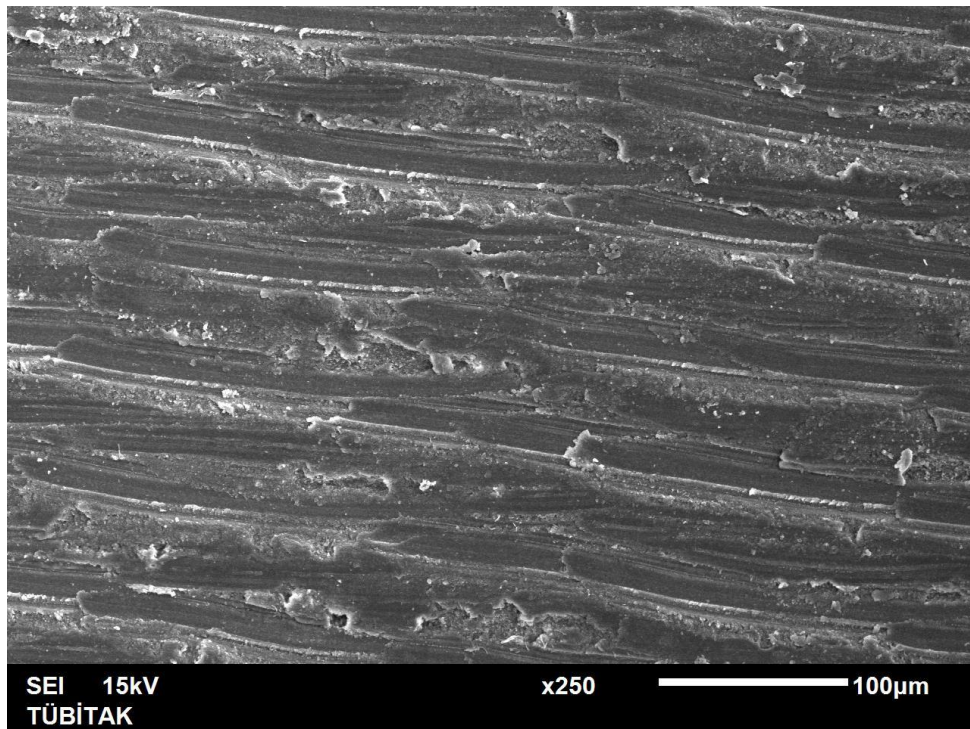


Figure 2.41. The initial 250x SEM image of the Cerasmart sample.

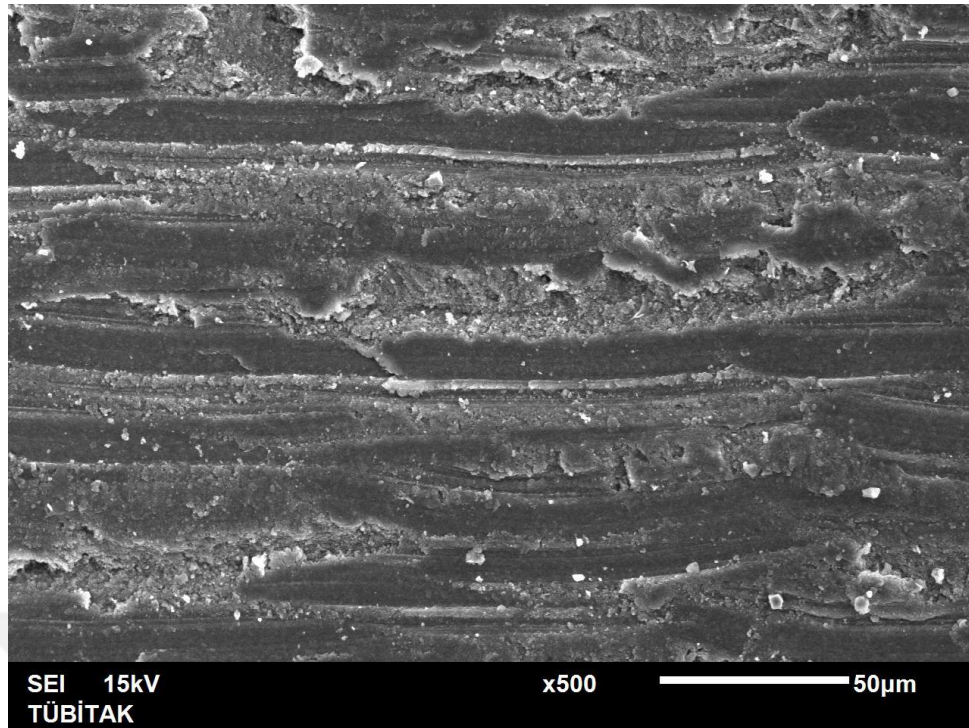


Figure 2.42. The initial 500x SEM image of the Cerasmart sample.

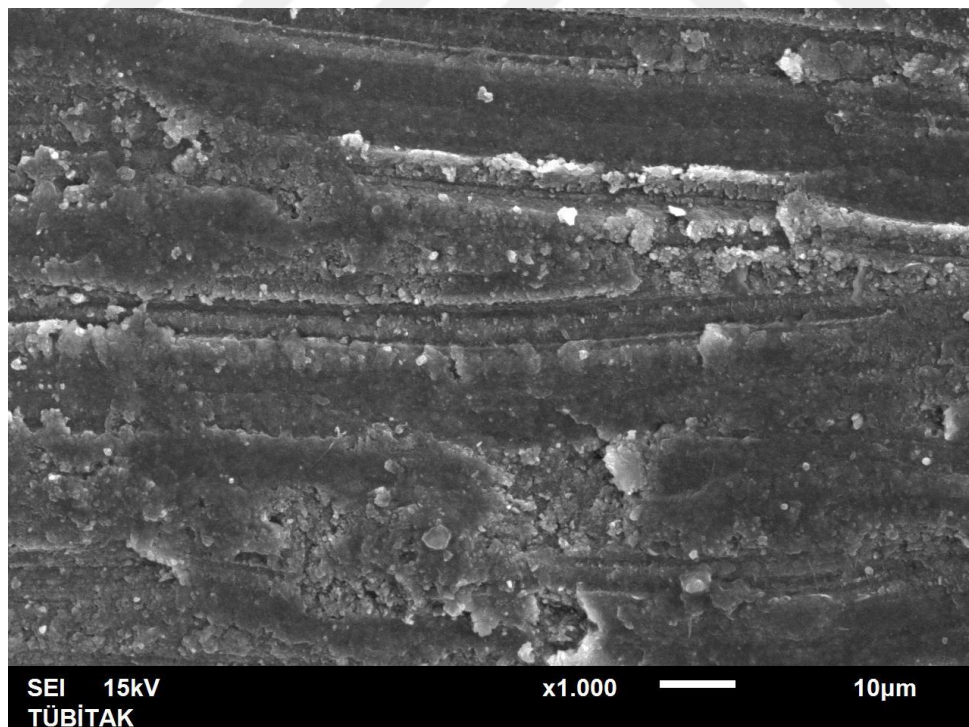


Figure 2.43. The initial 1000x SEM image of the Cerasmart sample.

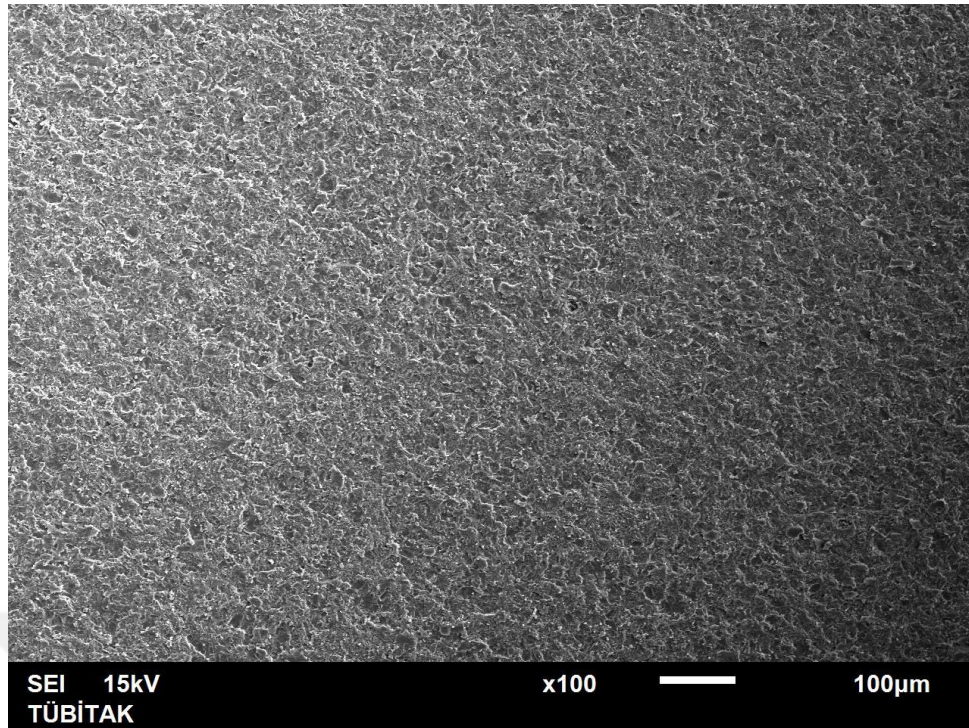


Figure 2.44. The initial 100x SEM image of the Cerec sample.

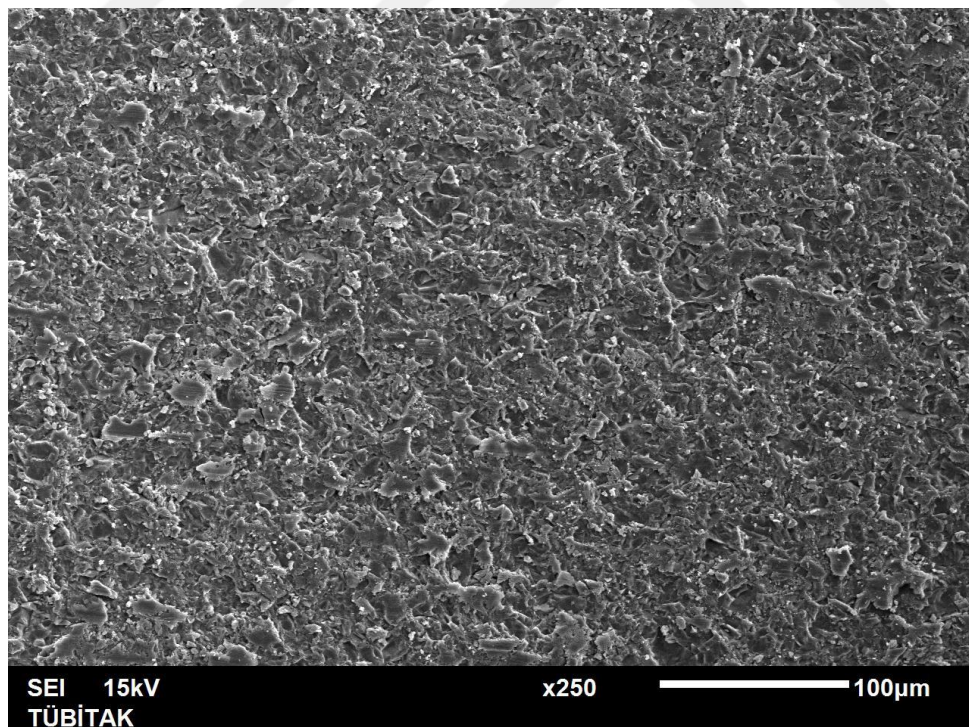


Figure 2.45. The initial 250x SEM image of the Cerec sample.

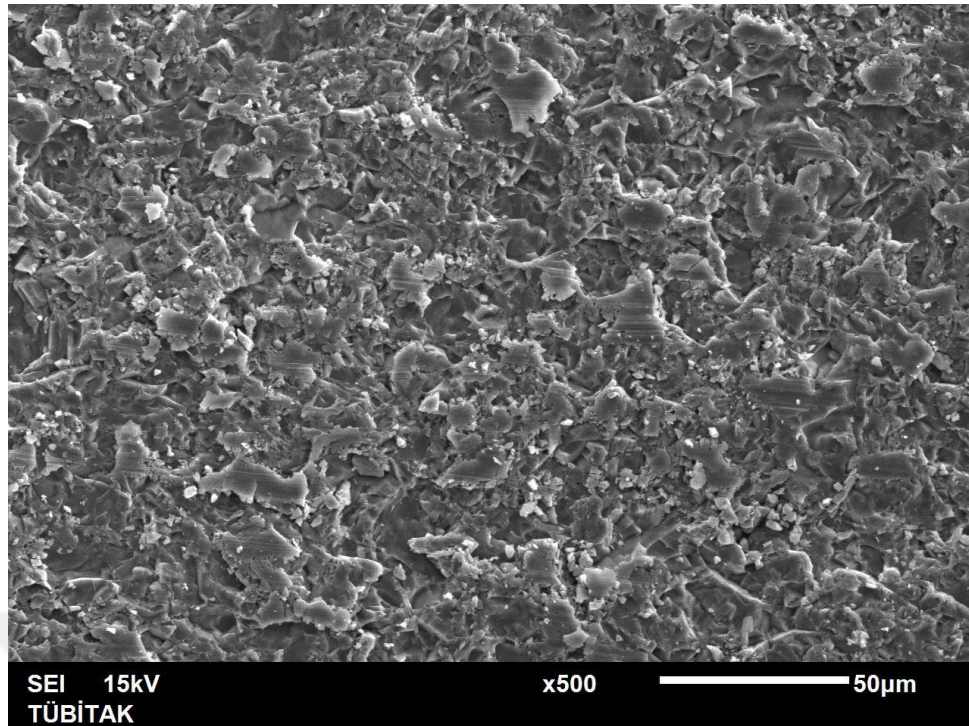


Figure 2.46 The initial 500x SEM image of the Cerec sample.

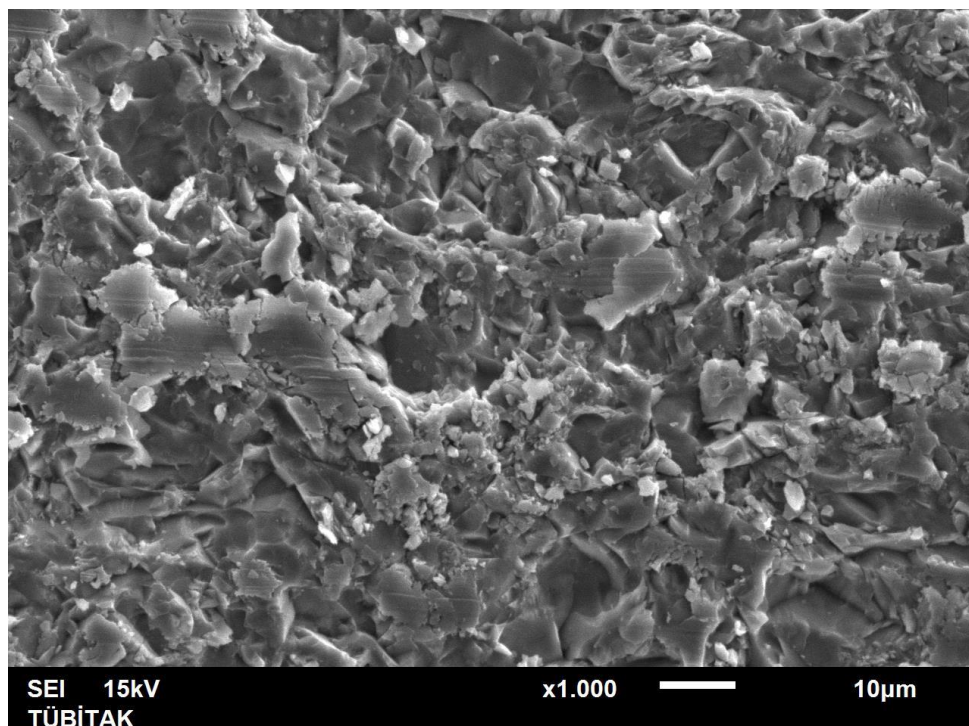


Figure 2.47. The initial 1000x SEM image of the Cerec sample.

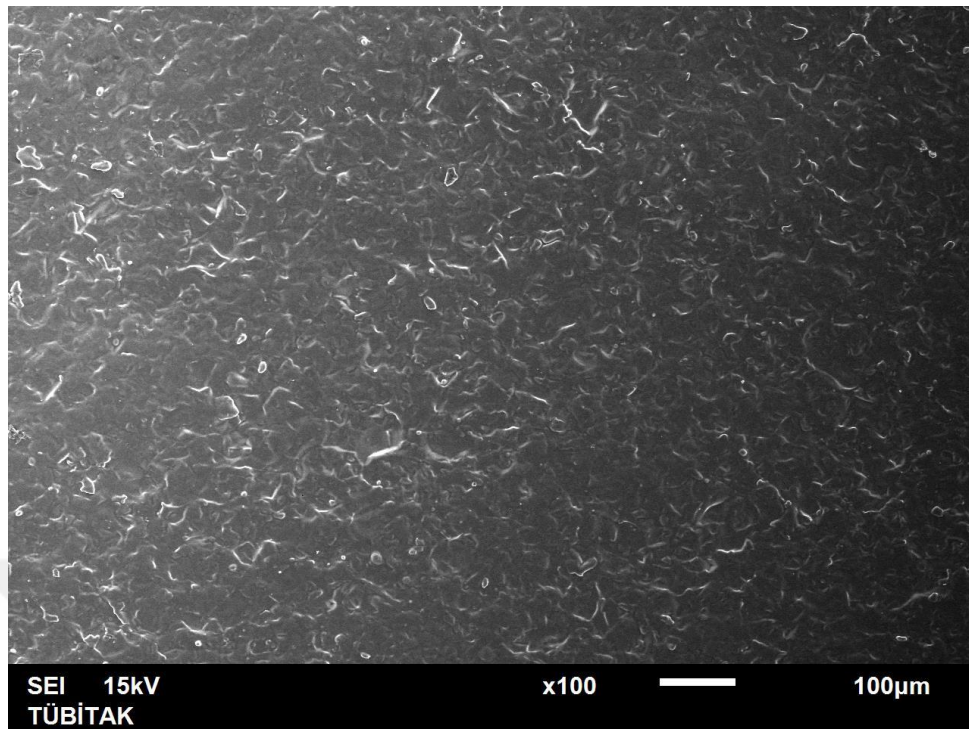


Figure 2.48. The initial x100 SEM image of the E.max sample.

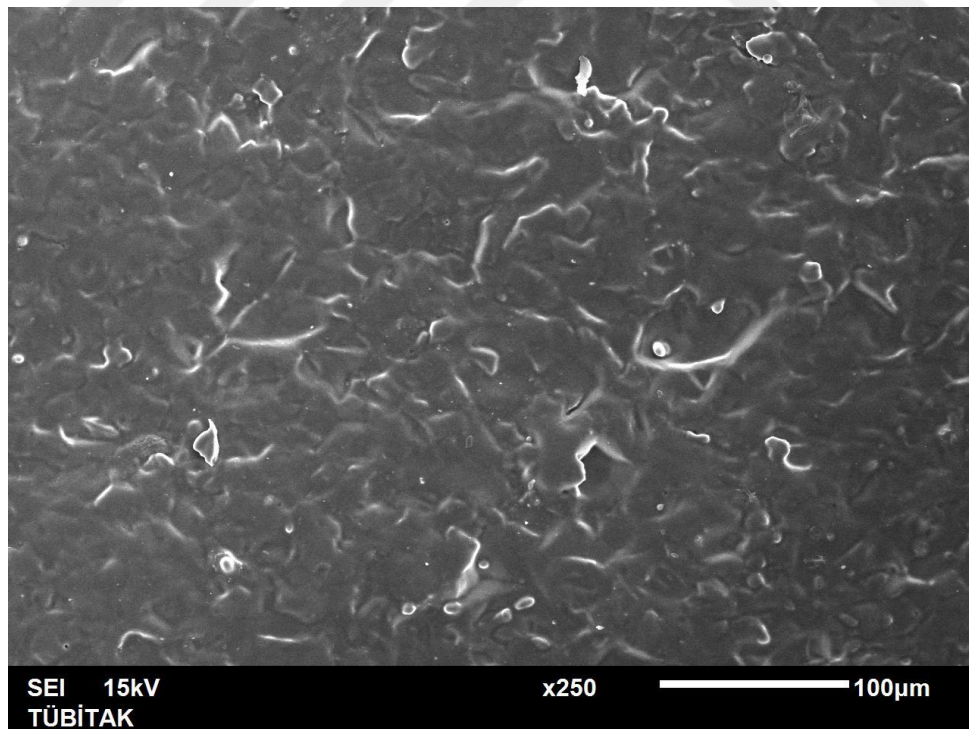


Figure 2.49. The initial 250x SEM image of the E.max sample.

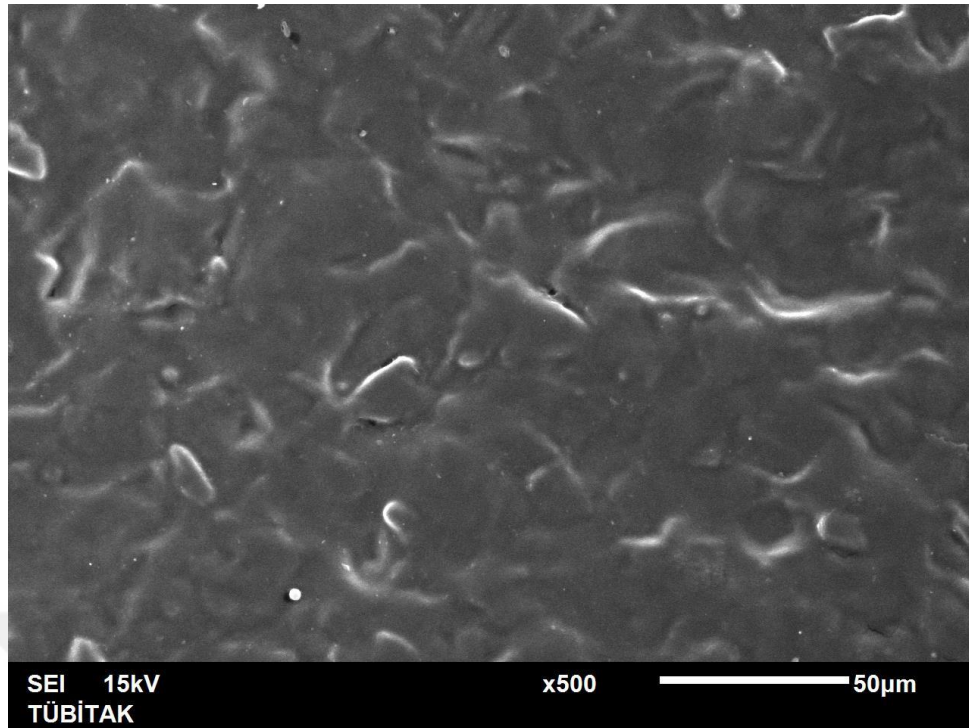


Figure 2.50. The initial 500x SEM image of the E.max sample.

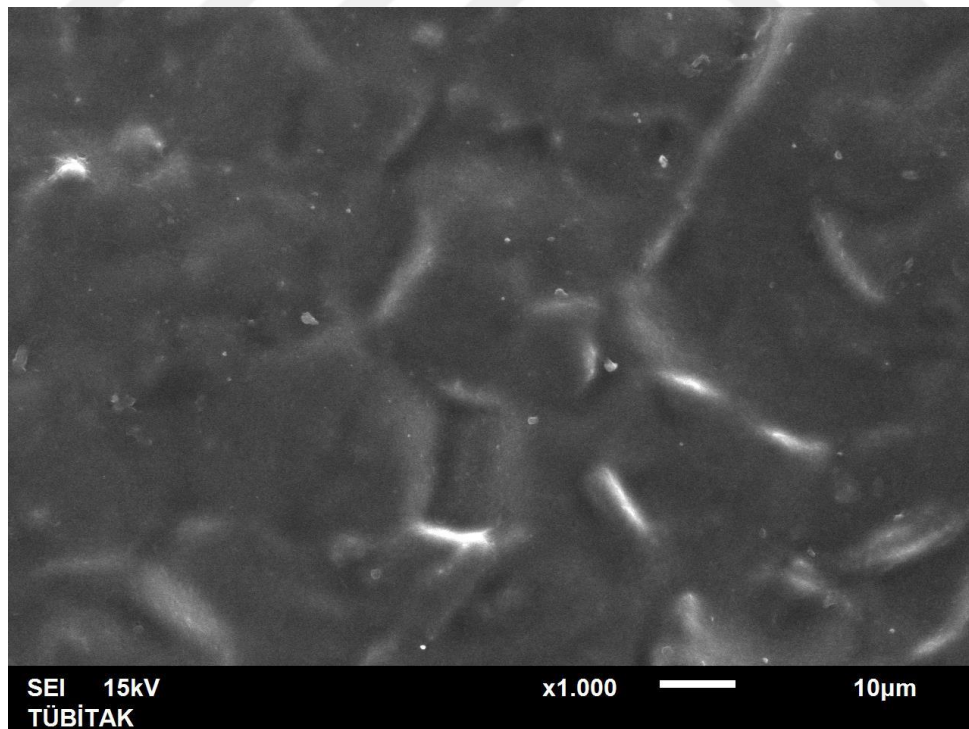


Figure 2.51. The initial 1000x SEM image of the E.max sample.

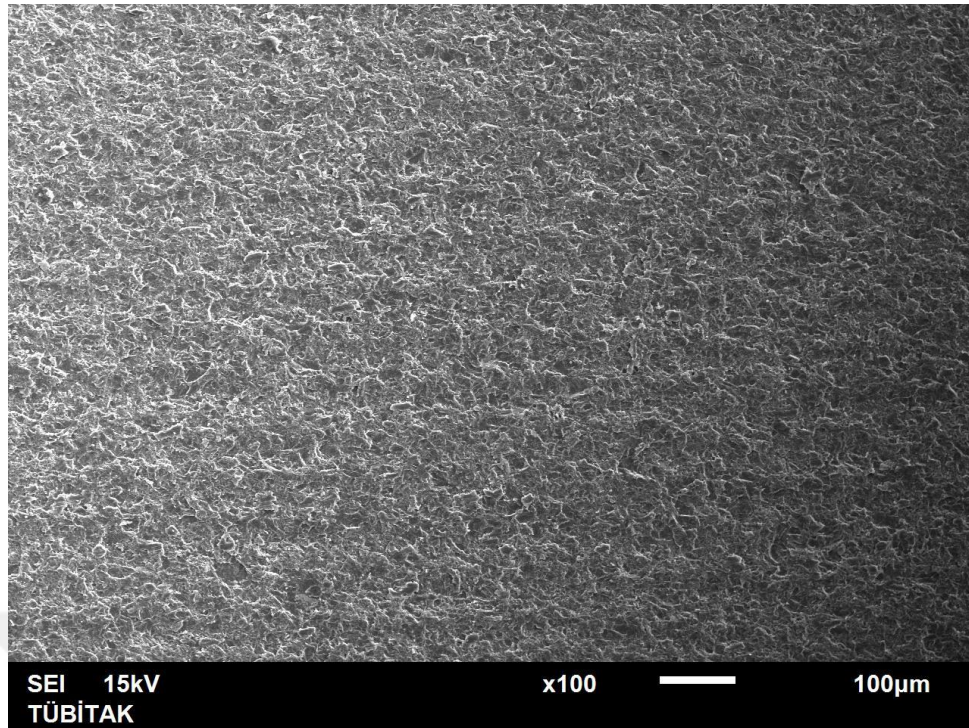


Figure 2.52. The initial 100x SEM image of the Empress sample.

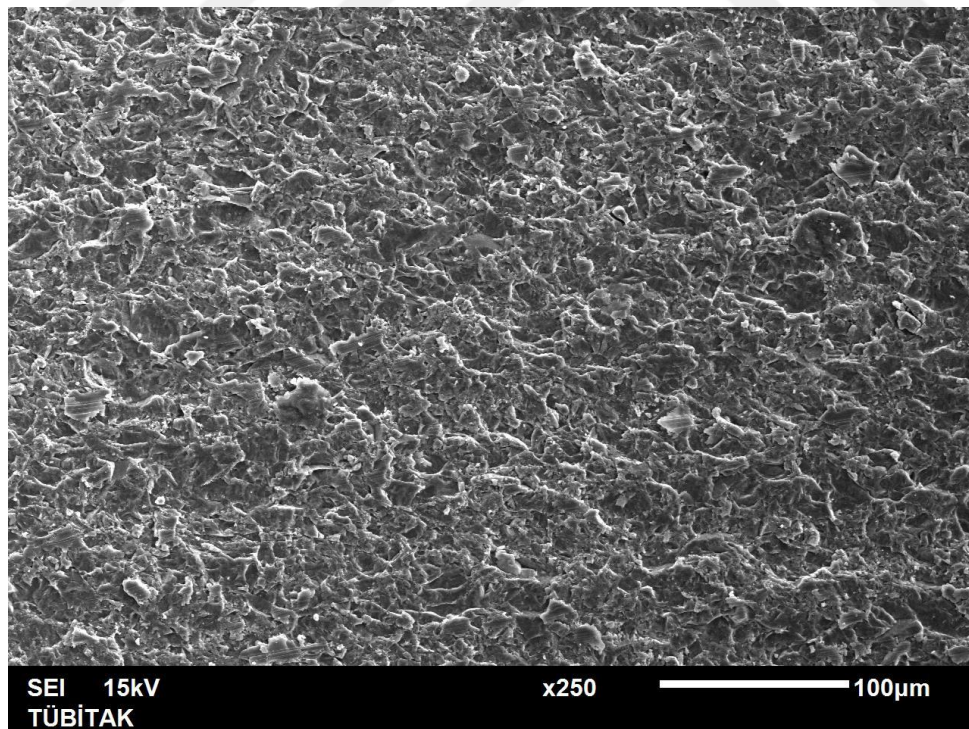


Figure 2.53. The initial 250x SEM image of the Empress sample.

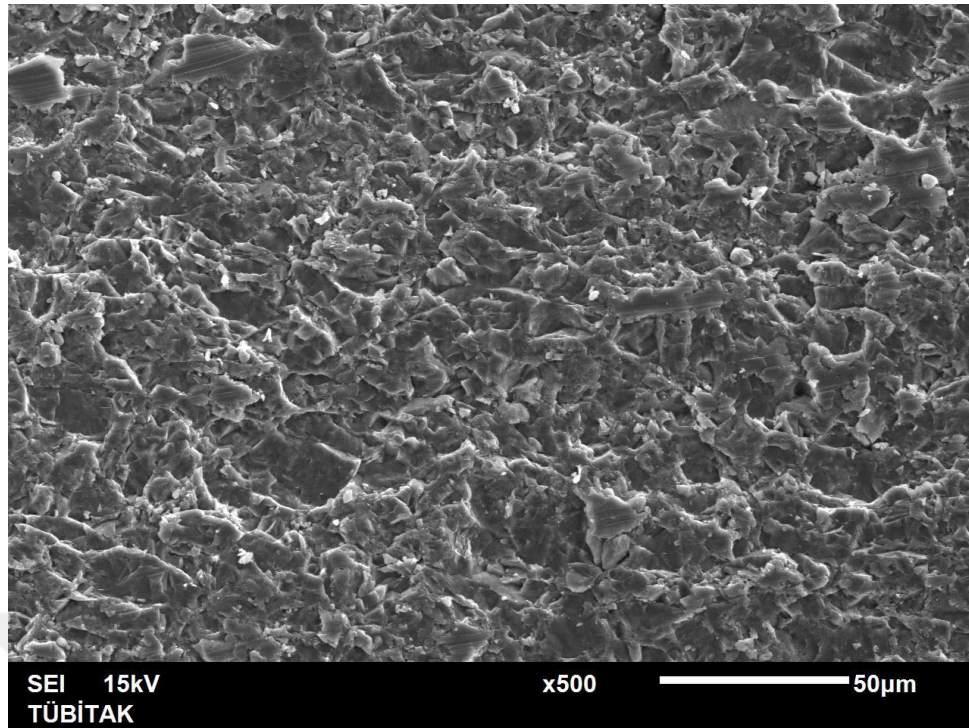


Figure 2.54. The initial 500x SEM image of the Empress sample.

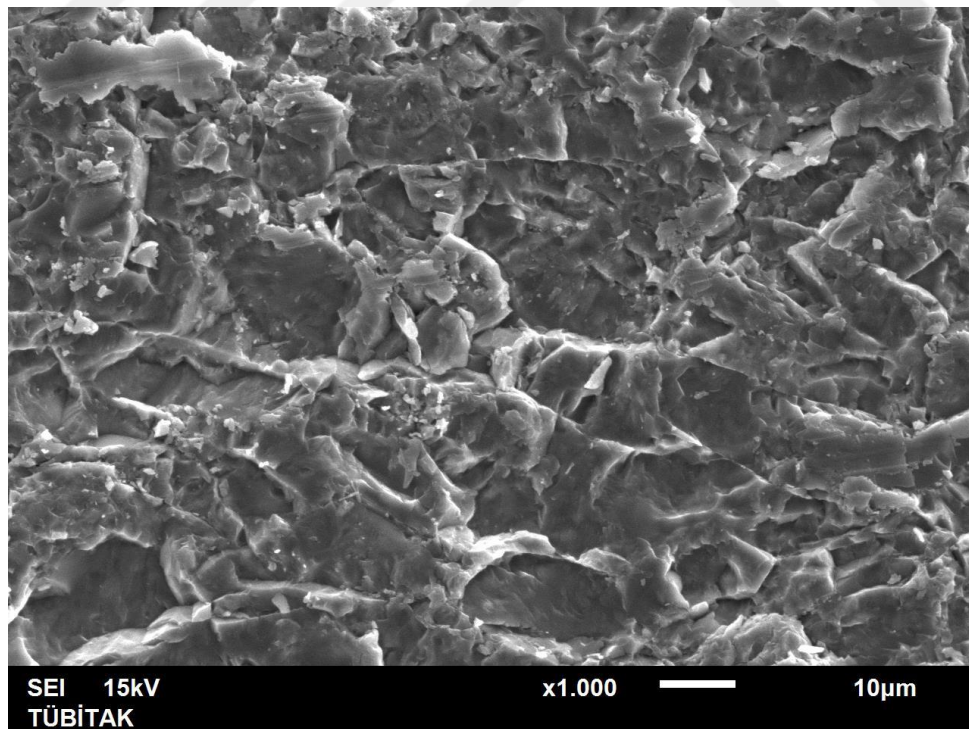


Figure 2.55. The initial 1000x SEM image of the Empress sample.

Table 2.3. Initial surface roughness (μm) values of the Cerasmart group.

Cerasmart Surface roughness Initial	1.Measure	2.Measure	3.Measure	Average $\pm$ SD
1	0.98	1.15	1.05	1.06 $\pm$ 0.90
2	1.15	0.99	0.98	1.04 $\pm$ 0.09
3	1.15	1.17	1.17	1.16 $\pm$ 0.01
4	1.04	1.00	1.01	1.02 $\pm$ 0.02
5	1.18	1.17	1.16	1.17 $\pm$ 0.01
6	1.13	1.09	1.05	1.09 $\pm$ 0.04
7	0.97	0.99	0.98	0.98 $\pm$ 0.01
8	1.12	1.09	1.10	1.11 $\pm$ 0.01
9	1.01	0.94	0.99	0.98 $\pm$ 0.04
10	0.97	0.98	1.01	0.98 $\pm$ 0.03
11	1.12	1.12	1.11	1.12 $\pm$ 0.01
12	1.06	1.05	1.06	1.06 $\pm$ 0.01
13	0.97	0.99	0.97	0.99 $\pm$ 0.01
14	1.01	0.99	0.98	0.99 $\pm$ 0.02
15	0.98	0.99	1.06	1.01 $\pm$ 0.04
16	1.04	1.11	1.12	1.09 $\pm$ 0.04
17	1.07	1.04	1.05	1.05 $\pm$ 0.01
18	1.12	1.12	1.11	1.12 $\pm$ 0.01
19	0.97	0.97	0.95	0.96 $\pm$ 0.01
20	0.98	0.99	0.99	0.99 $\pm$ 0.01
Ave $\pm$ SD	1.05	1.05	1.05	1.05 $\pm$ 0.03

Table 2.4. Initial surface roughness (μm) values of the IPS E.max CAD group.

E.max Surface roughness Initial	1.Measure	2.Measure	3.Measure	Average $\pm$ SD
1	1.27	1.34	1.30	1.30 $\pm$ 0.03
2	1.31	1.34	1.34	1.33 $\pm$ 0.02
3	1.13	1.14	1.17	1.15 $\pm$ 0.02
4	1.36	1.29	1.28	1.31 $\pm$ 0.04
5	1.34	1.33	1.34	1.34 $\pm$ 0.01
6	1.37	1.24	1.28	1.29 $\pm$ 0.07
7	1.29	1.32	1.36	1.33 $\pm$ 0.03
8	1.32	1.35	1.37	1.35 $\pm$ 0.03
9	1.27	1.25	1.28	1.27 $\pm$ 0.01
10	1.28	1.34	1.32	1.31 $\pm$ 0.03
11	1.22	1.28	1.25	1.25 $\pm$ 0.03
12	1.30	1.29	1.28	1.29 $\pm$ 0.01
13	1.31	1.34	1.37	1.34 $\pm$ 0.03
14	1.27	1.24	1.28	1.26 $\pm$ 0.02
15	1.37	1.39	1.29	1.36 $\pm$ 0.05
16	1.29	1.27	1.34	1.30 $\pm$ 0.03
17	1.27	1.28	1.31	1.29 $\pm$ 0.02
18	1.30	1.32	1.35	1.32 $\pm$ 0.02
19	1.32	1.27	1.28	1.29 $\pm$ 0.02
20	1.24	1.30	1.24	1.26 $\pm$ 0.04
Ave $\pm$ SD	1.29	1.29	1.30	1.29 $\pm$ 0.03

Table 2.5. Initial surface roughness (μm) values of the IPS Empress CAD group.

Empress Surface roughness Initial	1. Measure	2. Measure	3. Measure	Average $\pm$ SD
1	1.19	1.29	1.12	1.20 $\pm$ 0.09
2	1.19	1.12	1.17	1.16 $\pm$ 0.04
3	1.19	1.14	1.17	1.17 $\pm$ 0.03
4	1.10	1.10	1.05	1.09 $\pm$ 0.03
5	1.00	1.09	1.28	1.12 $\pm$ 0.14
6	1.11	1.12	1.20	1.14 $\pm$ 0.05
7	1.11	1.10	1.12	1.11 $\pm$ 0.01
8	1.16	1.15	1.10	1.14 $\pm$ 0.03
9	1.17	1.14	1.13	1.15 $\pm$ 0.02
10	1.10	1.11	1.05	1.09 $\pm$ 0.03
11	1.18	1.13	1.13	1.14 $\pm$ 0.03
12	1.16	1.12	1.15	1.14 $\pm$ 0.02
13	1.11	1.11	1.20	1.14 $\pm$ 0.05
14	1.12	1.12	1.16	1.14 $\pm$ 0.02
15	1.19	1.12	1.17	1.16 $\pm$ 0.04
16	1.11	1.11	1.11	1.11 $\pm$ 0.00
17	1.11	1.11	1.14	1.12 $\pm$ 0.01
18	1.11	1.12	1.13	1.12 $\pm$ 0.01
19	1.19	1.19	1.18	1.19 $\pm$ 0.01
20	1.12	1.12	1.14	1.13 $\pm$ 0.01
Ave $\pm$ SD	1.14	1.13	1.14	1.14 $\pm$ 0.03

Table 2.6. Initial surface roughness (μm) values of the Cerec group.

Cerec Surface roughness Initial	1. Measure	2. Measure	3. Measure	Average $\pm$ SD
1	0.94	0.97	0.97	0.96 $\pm$ 0,02
2	0.89	0.96	0.94	0.93 $\pm$ 0,03
3	0.90	1.00	1.00	0.97 $\pm$ 0,06
4	1.07	1.08	1.05	1.07 $\pm$ 0,01
5	0.97	0.97	0.98	0.97 $\pm$ 0,01
6	0.97	0.98	0.99	0.98 $\pm$ 0,01
7	0.97	0.95	0.96	0.96 $\pm$ 0,01
8	0.94	1.00	1.01	0.98 $\pm$ 0,04
9	0.96	0.97	0.99	0.97 $\pm$ 0,02
10	1.00	1.00	1.01	1.00 $\pm$ 0,01
11	0.96	0.97	0.97	0.97 $\pm$ 0,01
12	0.98	0.97	0.97	0.97 $\pm$ 0,01
13	0.93	0.99	1.00	0.98 $\pm$ 0,03
14	0.89	0.91	0.94	0.91 $\pm$ 0,02
15	0.99	0.84	0.84	0.89 $\pm$ 0,09
16	0.96	0.83	0.84	0.88 $\pm$ 0,07
17	0.99	1.10	1.09	1.06 $\pm$ 0,06
18	0.89	0.94	0.99	0.94 $\pm$ 0,05
19	0.94	0.98	1.02	0.98 $\pm$ 0,04
20	0.96	0.97	0.99	0.97 $\pm$ 0,02
Ave $\pm$ SD	0.95	0.97	0.96	0.97 $\pm$ 0.3

Table 2.7. Initial microhardness values of the Cerec group.

Cerec Microhardness Initial	1. Measure	2. Measure	3. Measure	Average
1	475	524	456	485±35
2	488	487	507	494±11
3	500	503	480	494±13
4	475	508	509	498±19
5	492	500	494	495±4.3
6	502	504	505	504±1.3
7	493	492	502	496±5.7
8	503	512	514	510±5.8
9	507	500	501	503±3.5
10	519	500	498	505±12
11	503	510	513	509±4.8
12	476	479	509	488±18
13	516	575	610	567±47
14	517	519	526	520±4.7
15	489	492	503	495±7.6
16	481	492	500	491±9.5
17	500	503	506	503±2.9
18	512	512	519	514±3.7
19	522	523	518	521±2.5
20	500	512	512	508±7.2
Ave±SD	498	507	509	505±11

Table 2.8. Initial microhardness values of IPS Empress CAD group.

Empress Microhardness Initial	1. Measure	2. Measure	3.Measure	Ave±SD
1	594	591	592	592±1.9
2	477	576	573	542±57
3	550	611	522	561±46
4	643	642	580	621±36
5	632	639	586	619±29
6	632	593	599	608±21
7	612	619	622	618±4.8
8	591	599	603	598±5.9
9	608	620	639	622±16
10	632	631	630	631±1.2
11	617	591	597	602±14
12	630	644	617	630±13
13	593	598	591	594±3.7
14	612	632	632	625±11
15	622	593	588	601±18
16	604	617	640	620±19
17	610	618	619	615±5.1
18	630	629	640	633±6.0
19	611	619	623	618±6.4
20	631	622	599	617±16
Ave±SD	606	614	605	616±16

Table 2.9. Initial microhardness values of the IPS E.max CAD group.

E.max Microhardness Initial	1. Measure	2. Measure	3. Measure	Ave±SD
1	602	653	630	628±25
2	624	632	638	631±7.1
3	655	667	644	655±11
4	629	628	636	631±4.5
5	614	632	632	626±10
6	639	655	644	646±8.6
7	642	650	644	645±4.2
8	672	655	667	665±8.7
9	672	655	667	665±8.7
10	637	641	644	641±3.7
11	655	636	643	645±9.9
12	653	658	648	653±5.0
13	646	643	647	645±2.0
14	632	636	638	635±3.2
15	646	648	643	645±2.3
16	661	658	658	659±1.7
17	648	651	653	651±2.7
18	645	659	655	653±7.1
19	652	655	637	648±9.9
20	644	648	643	645±2.4
Ave±SD	643	648	645	648±6.9

Table 2.10. Initial microhardness values of the Cerasmart group.

Cerasmart Microhardness Initial	1. Measure	2. Measure	3. Measure	Ave±SD
1	112	116	120	116±3.7
2	111	106	112	110±3.1
3	118	118	116	117±1.4
4	107	110	112	110±3.0
5	112	115	115	114±1.8
6	121	117	118	119±2.0
7	130	127	123	127±3.6
8	118	112	115	115±2.8
9	120	123	123	122±1.8
10	116	112	113	114±2.0
11	122	123	124	123±1.4
12	114	113	114	114±0.7
13	113	114	115	114±1.1
14	113	112	116	114±2.2
15	134	136	132	134±2.3
16	121	125	126	124±2.5
17	130	131	131	131±0.5
18	113	114	120	116±4.0
19	126	123	129	126±2.8
20	127	127	123	126±2.4
Ave±SD	119	119	120	126±2.3

Table 2.11. Evaluation of the surface roughness (μm) values when glaze was applied to the surface

	Surface roughness			² p
	Initial	After Glaze	After Thermocycling	
	Mean $\pm$ SD	Mean $\pm$ SD	Mean $\pm$ SD	
CS	1,06 $\pm$ 0,07	0,31 $\pm$ 0,02	0,34 $\pm$ 0,02	0,000*
E.max	1,30 $\pm$ 0,06	0,16 $\pm$ 0,004	0,16 $\pm$ 0,003	0,000*
Empress	1,14 $\pm$ 0,04	0,19 $\pm$ 0,01	0,19 $\pm$ 0,01	0,000*
Cerec	0,98 $\pm$ 0,04	0,39 $\pm$ 0,01	0,39 $\pm$ 0,02	0,000*
1p	0,000*	0,000*	0,000*	
¹ Oneway ANOVA Test		² Repeated measures ANOVA		*p<0.05

Table 2.12. Post hoc evaluation of materials when glaze was applied to the surface

	Surface roughness		
	¹ Initial	² After Glaze	² After Thermocycling
	p	p	p
CS-E.max	0,000*	0,000*	0,000*
CS-Empress	0,011*	0,000*	0,000*
CS-Cerec	0,006*	0,000*	0,000*
E.max-Empress	0,000*	0,000*	0,000*
E.max-Cerec	0,000*	0,000*	0,000*
Empress-Cerec	0,000*	0,000*	0,000*
¹ Tukey HSD Test	² Tamhane's T2 test		*p<0.05

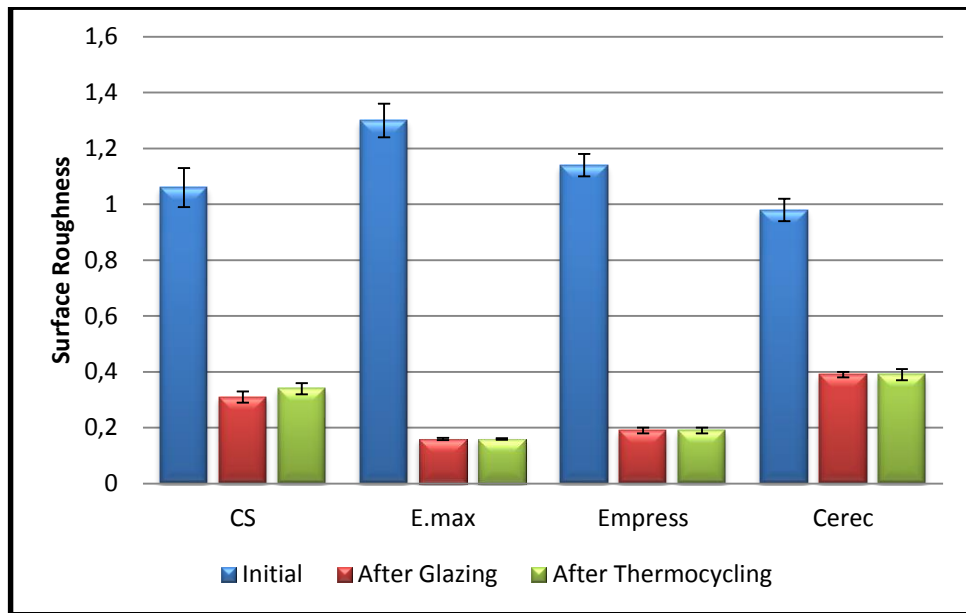


Figure 2.56. Surface roughness values initial, after glazing and after thermocycling

When the surface roughness values of the samples were evaluated, the values decreased significantly after the glaze was applied.

When glaze was applied to the surface, there is a significant difference among the materials in terms of initial surface roughness averages ($p:0.000$; $p<0.05$) (Table 2.11.). the results were listed in descending order as E.max > Empress > CS > Cerec. As a result of the post hoc Tukey HSD test performed to determine which material the significance originates from; The initial surface roughness of the Emax group was significantly higher than that of the CS, Empress and Cerec groups ($p_1:0.000$; $p_2:0.000$; $p_3:0.000$; $p<0.05$). The initial surface roughness of the Empress group was significantly higher than that of the CS and Cerec groups ($p_1:0.011$; $p_2:0.000$; $p<0.05$). The initial surface roughness of the CS group was significantly higher than that of the Cerec group ($p:0.006$; $p<0.05$) (Table 2.12.).

When glaze was applied to the surface, there was a significant difference between the materials in terms of post-glazing surface roughness averages ($p:0.000$; $p<0.05$) (Table 2.11). The results were listed in descending order as follows: Cerec > CS > Empress > E.max. When the initial surface roughness values and the surface roughness values after the glaze were compared, a decrease was observed in all values. As a result of the post hoc Tamhane's T2 test carried out to determine which material the significance originates from; The surface roughness of the Cerec group after glazing was significantly higher than that of the CS, Emax and Empress groups ($p1:0.000$; $p2:0.000$; $p3:0.000$; $p<0.05$). The surface roughness of the CS group after glazing was significantly higher than that of the Emax and Empress groups ($p1:0.000$; $p2:0.000$; $p<0.05$). The surface roughness of the Empress group after glazing was found to be significantly higher than the Emax group ($p:0.000$; $p<0.05$) (Table 2.12.).

When glaze is applied to the surface, there is a statistically significant difference between the materials in terms of surface roughness averages after thermocycling ($p:0.000$; $p<0.05$) (Table 2.11.). As a result of the post hoc Tamhane's T2 test carried out to determine which material the significance originates from; The surface roughness of the Cerec group after the thermocycle was significantly higher than that of the CS, Emax and Empress groups ($p1:0.000$; $p2:0.000$; $p3:0.000$; $p<0.05$). The surface roughness of the CS group after the thermocycling was significantly higher than that of the Emax and Empress groups ($p1:0.000$; $p2:0.000$; $p<0.05$). The surface roughness of the Empress group after the thermocycle was found to be significantly higher than the Emax group ($p:0.000$; $p<0.05$) (Table 2.12.).

Table 2.13. Post hoc evaluation of surface roughness measurements initial, after glazing and after thermocycling when glaze was applied to the surface.

	Surface Roughness		
	Initial / After Glazing	Initial / After Thermocycling	After Glazing / After Thermocycling
	p	P	p
CS	0,000*	0,000*	0,010*
E.max	0,000*	0,000*	0,234
Empress	0,000*	0,000*	0,099
Cerec	0,000*	0,000*	0,068
Bonferroni test	*p<0.05		

When evaluating the surface of CS material; there is a statistically significant difference between the mean surface roughness at baseline, after glazing and after thermocycling ($p:0.000$; $p<0.05$) (Table 2.11.). As a result of the post hoc Bonferroni test performed to determine from which period the significance originated; initial surface roughness values were found to be significantly higher after glaze and after thermocycling ($p_1:0.000$; $p_2:0.000$; $p<0.05$). Surface roughness values after thermocycling was found to be significantly higher than values after glaze ($p:0.010$; $p<0.05$) (Table 2.13.). When evaluating the surface of the Emax material; there is a statistically significant difference between the mean surface roughness at initial, after glazing and after thermocycling ($p:0.000$; $p<0.05$) (Table 2.11.). As a result of the post hoc Bonferroni test performed to determine from which period the significance originated; initial surface roughness was found to be significantly higher after glaze and after thermocycling ($p_1:0.000$; $p_2:0.000$; $p<0.05$). There was no significant difference between the surface roughness averages after glazing and after thermocycling ($p:0.234$; $p>0.05$) (Table 2.13.). When evaluating the surface of Empress material; There is a statistically significant difference between the mean surface roughness at baseline, after glazing and after thermocycling. ($p:0.000$; $p<0.05$) (Table 2.11.). As a result of the post hoc Bonferroni test performed to determine from which period the significance originated; initial surface roughness was found to be significantly higher after glaze and after thermocycling ($p_1:0.000$; $p_2:0.000$; $p<0.05$). There was no significant difference between the surface roughness averages after glazing and after thermocycling ($p:0.099$; $p>0.05$) (Table 2.13.).

When evaluating the Cerec material; there is a significant difference between the mean surface roughness at initial stage, after glazing and after thermocycling ($p:0.000$; $p<0.05$) (Table 2.11.). As a result of the post hoc Bonferroni test performed to determine from which period the significance originated; initial surface roughness was found to be significantly higher after glaze and after thermocycling ($p1:0.000$; $p2:0.000$; $p<0.05$). There was no significant difference between the surface roughness averages after glazing and after thermocycling ($p:0.068$; $p>0.05$) (Table 2.13.).

When the values with glazing were compared with the values after aging in glazed subgroup, insignificant increase was found in the CS group. There was no difference in the values between glaze and thermocycle in E.max, Empress and Cerec groups.

Table 2.14. Evaluation of the surface roughness (μm) values when glaze was not applied to the surface.

Materials	Surface Roughness		² p
	Initial	After thermocycling	
	Mean $\pm$ SD	Mean $\pm$ SD	
CS	1,04 $\pm$ 0,06	1,29 $\pm$ 0,04	0,000*
E.max	1,30 $\pm$ 0,03	1,39 $\pm$ 0,02	0,000*
Empress	1,14 $\pm$ 0,02	1,10 $\pm$ 0,21	0,543
Cerec	0,96 $\pm$ 0,06	1,24 $\pm$ 0,04	0,000*
¹ p	0,000*	0,000*	
¹ Oneway ANOVA Test		² Paired samples t test * $p<0.05$	

Table 2.15. Post hoc evaluation of materials when glaze was not applied to the surface.

	Surface Roughness	
	Initial	After thermocycling
	p	p
CS-E.max	0,000*	0,000*
CS-Empress	0,000*	0,114
CS-Cerec	0,036*	0,074
E.max-Empress	0,000*	0,010*
E.max-Cerec	0,000*	0,000*
Empress-Cerec	0,000*	0,347
Tamhane's T2 test	*p<0.05	

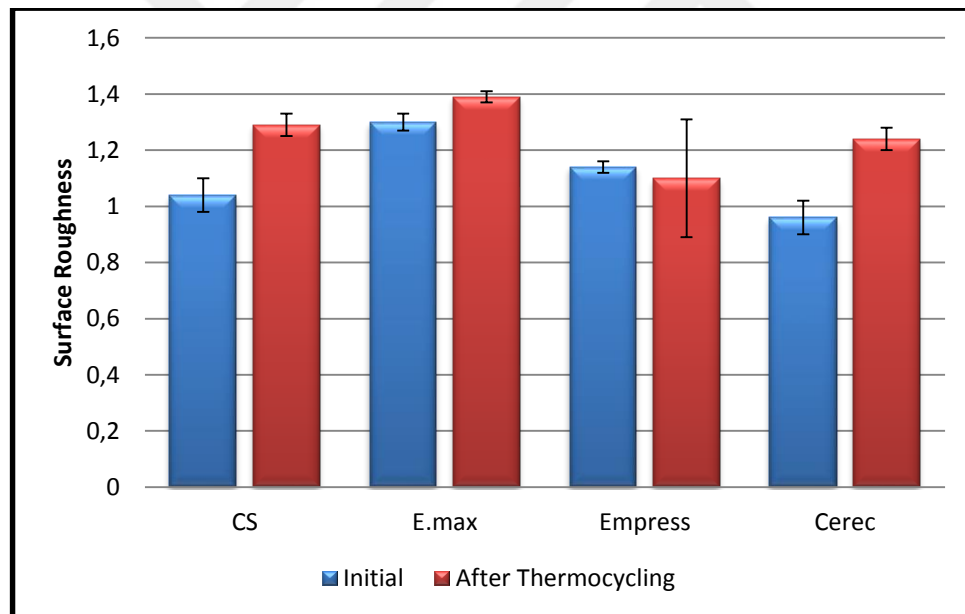


Figure 2.57. Initial surface roughness and after thermocycling

When glaze was not applied to the surface, there was a significant difference between the materials in terms of surface roughness averages after milling process ($p:0.000$; $p<0.05$) (Table 2.14.). As a result of the post hoc Tamhane's T2 test carried out to determine the significance of which material originates from; The surface roughness values after milling process of the Emax group was significantly higher than that of the CS, Empress and Cerec groups ($p1:0.000$; $p2:0.000$; $p3:0.000$; $p<0.05$). The surface roughness values after milling process of the Empress group was significantly higher than that of the CS and Cerec groups ($p1:0.000$; $p2:0.000$; $p<0.05$). The surface roughness values of the CS group after milling process was significantly higher than the Cerec group ($p:0.036$; $p<0.05$) (Table 2.19.).

When the surface roughness values of the samples were evaluated in the non-glazed group, the values were listed as E.max > Empress > CS > Cerec from high to low. These examples are listed as E.max > CS > Cerec > Empress from high to low after thermocycling. When the initial values were compared with the values after aging, the values increased in the CS and E.max groups. Values decreased in Empress and Cerec groups.

When glaze was not applied to the surface, there is a statistically significant difference between the materials in terms of surface roughness averages after the thermocycling ($p:0.000$; $p<0.05$) (Table 4). As a result of the post hoc Tamhane's T2 test carried out to determine which material the significance originates from; The surface roughness of the Emax group after the thermocycling was significantly higher than that of the CS, Empress and Cerec groups ($p1:0.000$; $p2:0.010$; $p3:0.000$; $p<0.05$). There was no significant difference between the other groups in terms of surface roughness after the thermocycle ($p>0.05$) (Table 2.19.).

When evaluating the surface of the CS material, the surface roughness after thermocycling was found to be significantly higher than the initial stage ($p:0.000$; $p<0.05$) (Table 2.18.). When evaluating the surface of the E.max material the surface roughness after the thermocycling was found to be significantly higher than the baseline ($p:0.000$; $p<0.05$) (Table 2.18.). When evaluating the surface of the Empress material there was no significant difference between the initial and post-thermocycling surface roughness values ($p:0.543$; $p>0.05$) (Table 2.18.). When evaluating the surface of the Cerec material the surface roughness after the thermocycling was found to be significantly higher than the initial values ($p:0.000$; $p<0.05$) (Table 2.18.).

After the aging process, there was no significant difference between the values of glazed samples and samples after thermocycling, except Cerasmart group.

Table 2.16. Evaluation of microhardness values when glaze was applied to the surface.

Materials	Microhardness			² p
	Initial	After Glaze	After Thermocycling	
	Mean±SD	Mean±SD	Mean±SD	
CS	116,28±5,39	75,85±1,02	75,64±1	0,000*
E.max	644,13±13,67	600,98±13,36	598,13±13,12	0,000*
Empress	602,97±27,97	574,99±11,91	572,68±10,76	0,009*
Cerec	497,17±10,57	453,21±16,42	452,85±16,01	0,000*
1p	0,000*	0,000*	0,000*	

¹Oneway ANOVA Test

²Repeated measures ANOVA *p<0.05

Table 2.17. Post hoc evaluation of materials when glaze is applied to the surface.

	Microhardness		
	Initial	After Glaze	After Thermocycling
	p	p	p
CS-E.max	0,000*	0,000*	0,000*
CS-Empress	0,000*	0,000*	0,000*
CS-Cerec	0,000*	0,000*	0,000*
E.max-Empress	0,006*	0,000*	0,000*
E.max-Cerec	0,000*	0,000*	0,000*
Empress-Cerec	0,000*	0,000*	0,000*

Tamhane's T2 test

*p<0.05

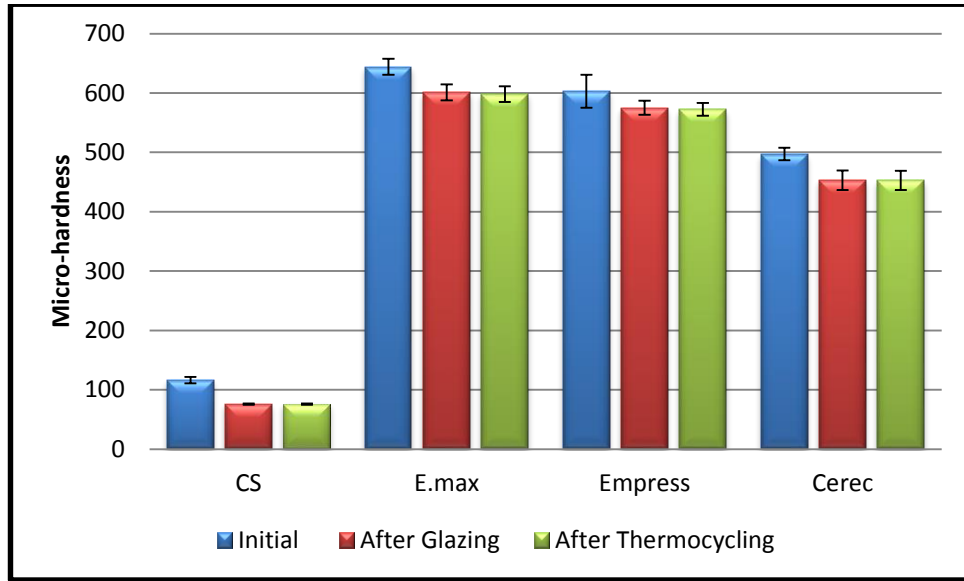


Figure 2.58. The histogram of the microhardness values of every stage.

When glaze was applied to the surface, there is a statistically significant difference between the materials in terms of initial microhardness averages ($p:0.000$; $p<0.05$) (Table 2.16.). As a result of the post hoc Tamhane's T2 test carried out to determine which material the significance originates from; The initial microhardness of the Emax group was significantly higher than that of the CS, Empress and Cerec groups ($p_1:0.000$; $p_2:0.006$; $p_3:0.000$; $p<0.05$). The initial microhardness of the Empress group was significantly higher than that of the CS and Cerec groups ($p_1:0.000$; $p_2:0.000$; $p<0.05$). The initial microhardness of the Cerec group was found to be significantly higher than that of the CS group ($p:0.000$; $p<0.05$) (Table 2.17.).

When glaze was applied to the surface, there was a statistically significant difference between the materials in terms of post-glazing microhardness averages ($p:0.000$; $p<0.05$) (Table 2.16.). As a result of the post hoc Tamhane's T2 test carried out to determine which material the significance originates from; The microhardness of the Emax group after glaze was significantly higher than that of the CS, Empress and Cerec groups ($p_1:0.000$; $p_2:0.000$; $p_3:0.000$; $p<0.05$). The microhardness of the Empress group after glazing was significantly higher than that of the CS and Cerec groups ($p_1:0.000$; $p_2:0.000$; $p<0.05$). The microhardness of the Cerec group after glazing was significantly higher than that of the CS group ($p:0.000$; $p<0.05$) (Table 2.17.).

When glaze was applied to the surface, there is a statistically significant difference between the materials in terms of microhardness averages after aging ($p:0.000$; $p<0.05$) (Table 2.16.). As a result of the post hoc Tamhane T2 test, which was carried out to determine which material the significance originates from; post-aging microhardness of the Emax group was significantly higher than that of the CS, Empress and Cerec groups ($p1:0.000$; $p2:0.000$; $p3:0.000$; $p<0.05$). The microhardness of the Empress group after aging was found to be significantly higher than the CS and Cerec groups ($p1:0.000$; $p2:0.000$; $p<0.05$). The microhardness of the Cerec group after aging was found to be significantly higher than the CS group ($p:0.000$; $p<0.05$) (Table 2.17.).

Table 2.18. Microhardness measurements initial, after glazing and after thermocycling when glaze was applied to the surface.

	Microhardness		
	Initial phase and after glaze	Initial phase and after thermocycling	After glaze and after thermocycling
	p	p	p
CS	0,000*	0,000*	0,086
E.max	0,000*	0,000*	0,012*
Empress	0,032*	0,020*	0,074
Cerec	0,000*	0,000*	1,000
Bonferroni test		* $p<0.05$	

When evaluating the surface of CS; there is a significant difference between the mean microhardness at baseline, after glazing and after thermocycling ($p:0.000$; $p<0.05$) (Table 2.23.). As a result of the post hoc Bonferroni test performed to determine from which period the significance originated; initial surface roughness was found to be statistically significantly higher after glaze and after thermocycling ($p1:0.000$; $p2:0.000$; $p<0.05$). There was no statistically significant difference between microhardness levels after glazing and after thermocycling ($p:0.086$; $p>0.05$) (Table 2.18.).

When evaluating the surface of Emax material; there is a statistically significant difference between the mean microhardness at baseline, after glazing and after thermocycling ($p:0.000$; $p<0.05$) (Table 2.16.). As a result of the post hoc Bonferroni test performed to determine from which period the significance originated; initial surface roughness was found to be statistically significantly higher after glaze and after thermocycling ($p1:0.000$; $p2:0.000$; $p<0.05$). Microhardness values after glazing is significantly higher than after thermocycling ($p:0.012$; $p<0.05$) (Table 2.18.).

When evaluating the surface of Empress material; there is a significant difference among the mean microhardness at baseline, after glazing and after thermocycling ($p:0.009$; $p<0.05$) (Table 2.16.). As a result of the post hoc Bonferroni test performed to determine from which period the significance originated; initial surface roughness was found to be statistically significantly higher after glaze and after thermocycling ($p1:0.032$; $p2:0.020$; $p<0.05$). There was no statistically significant difference between microhardness levels after glazing and after thermocycling. ($p:0.074$; $p>0.05$) (Table 2.18.).

When evaluating the surface of Cerec material; there is a statistically significant difference between the mean microhardness at baseline, after glazing and after thermocycling ($p:0.000$; $p<0.05$) (Table 2.16.). As a result of the post hoc Bonferroni test performed to determine from which period the significance originated; initial surface roughness was found to be statistically significantly higher after glaze and after thermocycling ($p1:0.000$; $p2:0.000$; $p<0.05$). There was no statistically significant difference between microhardness levels after glazing and after thermocycling ($p:1.000$; $p>0.05$) (Table 2.18.).

Table 2.19. Evaluation of microhardness values when glaze was not applied to the surface.

Materials	Microhardness		² p
	Initial	After Thermocycling	
	Mean±SD	Mean±SD	
CS	122,17±7,5	113,63±6,78	0,000*
E.max	647,94±6,42	640,77±6,60	0,000*
Empress	617,29±13,01	606,66±15,7	0,008*
Cerec	511,64±25,9	502,71±21,68	0,005*
1p	0,000*	0,000*	
¹ Oneway ANOVA Test		² Paired samples t test *p<0.05	

Table 2.20. Post hoc evaluation of materials when glaze was not applied to the surface.

	Microhardness	
	Initial	After thermocycling
	p	p
CS-E.max	0,000*	0,000*
CS-Empress	0,000*	0,000*
CS-Cerec	0,000*	0,000*
E.max-Empress	0,000*	0,000*
E.max-Cerec	0,000*	0,000*
Empress-Cerec	0,000*	0,000*
Tamhane's T2 test	*p<0.05	

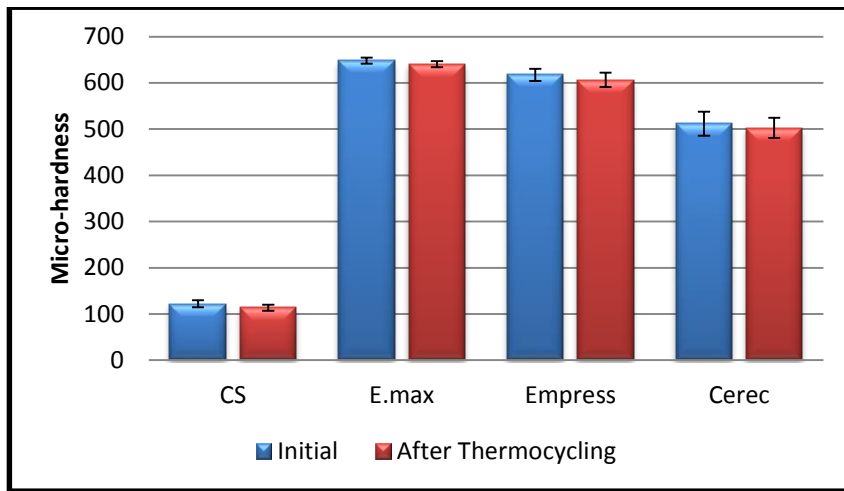


Figure 2.59. The microhardness values after milling process and after thermocycling.

When glaze was not applied to the surface, there is a significant difference between the materials in terms of microhardness averages after milling process ($p:0.000$; $p<0.05$) (Table 2.19.). The values were determined as E.max > Empress > Cerec > CS from high to low immediately after the samples were produced. After the glaze was applied, there was no difference in ordering the values from high to low. However, after the glaze was applied, the microhardness values of all samples were found to be significantly lower than the initial values. The values of these samples were found to be insignificantly lower after thermocycling. As a result of the post hoc Tamhane's T2 test carried out to determine which material the significance originates from; The initial microhardness of the Emax group was significantly higher than that of the CS, Empress and Cerec groups ($p_1:0.000$; $p_2:0.000$; $p_3:0.000$; $p<0.05$). The initial microhardness of the Empress group was significantly higher than that of the CS and Cerec groups ($p_1:0.000$; $p_2:0.000$; $p<0.05$). The initial microhardness of the Cerec group was significantly higher than that of the CS group ($p:0.000$; $p<0.05$) (Table 2.20.). When glaze was not applied to the surface, there is a significant difference among the materials in terms of microhardness averages after thermocycling ($p:0.000$; $p<0.05$) (Table 2.19.). As a result of the post hoc Tamhane's T2 test carried out to determine which material the significance originates from; The post-thermo-cycle microhardness of the Emax group was significantly higher than that of the CS, Empress and Cerec groups ($p_1:0.000$; $p_2:0.000$; $p_3:0.000$; $p<0.05$). The microhardness of the Empress group after thermocycle was found to be significantly higher than that of the CS and Cerec groups ($p_1:0.000$; $p_2:0.000$; $p<0.05$). The microhardness of the Cerec group after thermocycling, was found to be significantly higher than that of the CS group ($p:0.000$; $p<0.05$) (Table 2.20.).

When the initial microhardness values of the samples in the non-glazed groups were evaluated, the listing shows E.max > Empress > Cerec > CS from high to low. When the values between the groups were compared after thermocycling, no difference was found in the ranking. However the values after thermocycling were found to be lower, when the values at the initial stage were compared with the values after thermocycling.

Table 2.21. Microhardness values of the glazed IPS E.max CAD group.

Glazed E.max Microhardness	1. Measure	2. Measure	3. Measure	Ave±SD
1	601	611	610	607±5.8
2	580	593	599	591±9.4
3	575	580	591	582±8.2
4	590	585	592	589±3.6
5	603	603	611	606±4.7
6	611	612	613	612±1.1
7	608	620	621	617±7.2
8	621	623	619	621±2.2
9	589	592	598	593±4.8
10	592	593	587	591±3.1
Ave±SD	597	601	604	601±5.0

Table 2.22. Microhardness values of IPS Empress CAD group after glazing.

Glazed Empress Microhardness	1. Measure	2. Measure	3. Measure	Average
1	580	575	570	575±4,8
2	550	554	543	549±5.5
3	585	608	575	590±17
4	600	575	581	586±13
5	575	565	562	568±6,7
6	566	579	573	573±6,8
7	585	574	573	577±6,8
8	572	570	569	570±1.5
9	600	583	583	588±9.9
10	575	573	570	573±2.8
Ave±SD	579	576	570	575±3.9

Table 2.23. Microhardness values of the glazed Cerasmart group.

Glazed Cerasmart Microhardness	1. Measure	2. Measure	3. Measure	Average
1	77	75	76	76±1.3
2	75	76	78	76±1.4
3	74	77	78	76±2.0
4	78	76	77	77±1.2
5	73	74	73	73±0.5
6	74	75	76	75±1.0
7	78	76	77	77±0.7
8	75	76	76	76±0.5
9	76	75	75	76±0.5
10	76	74	77	76±1.4
Ave±SD	76	75	76	76±1.0

Table 2.24. Microhardness values of the glazed Cerec group.

Cerec Microhardness Glazed	1. Measure	2. Measure	3. Measure	Ave±SD
1	453	421	423	432±18
2	443	442	448	444±3.1
3	421	439	433	431±9.0
4	441	443	444	443±1.5
5	461	464	469	464±4.3
6	463	471	472	469±5.2
7	442	442	443	442±0.8
8	460	461	464	462±1.9
9	471	464	469	468±4.0
10	471	469	488	476±11
Ave±SD	453	452	455	453±5.8

Table 2.25. Surface roughness (μm) values of the glazed Empress group.

Empress Surface roughness Glazed	1. Measure	2.Measure	3. Measure	Ave $\pm$ SD
1	0.19	0.19	0.20	0.19 $\pm$ 0.01
2	0.21	0.19	0.20	0.20 $\pm$ 0.01
3	0.17	0.18	0.19	0.18 $\pm$ 0.01
4	0.18	0.18	0.19	0.18 $\pm$ 0.00
5	0.19	0.19	0.20	0.19 $\pm$ 0.00
6	0.19	0.19	0.18	0.19 $\pm$ 0.00
7	0.20	0.19	0.19	0.19 $\pm$ 0.01
8	0.19	0.19	0.19	0.19 $\pm$ 0.01
9	0.18	0.18	0.19	0.18 $\pm$ 0.00
10	0.18	0.19	0.18	0.18 $\pm$ 0.00
Ave $\pm$ SD	0.19	0.19	0.20	0.19 $\pm$ 0.00

Table 2.26. Surface roughness (μm) values of the glazed Cerasmart group.

Cerasmart Surface roughness Glazed	1. Measure	2.Measure	3. Measure	Ave $\pm$ SD
1	0.22	0.32	0.31	0.28 $\pm$ 0.05
2	0.30	0.33	0.33	0.32 $\pm$ 0.02
3	0.33	0.32	0.31	0.32 $\pm$ 0.01
4	0.30	0.36	0.35	0.34 $\pm$ 0.03
5	0.34	0.30	0.34	0.32 $\pm$ 0.03
6	0.30	0.27	0.28	0.29 $\pm$ 0.01
7	0.30	0.31	0.33	0.31 $\pm$ 0.01
8	0.27	0.29	0.33	0.29 $\pm$ 0.01
9	0.34	0.32	0.34	0.33 $\pm$ 0.01
10	0.30	0.31	0.32	0.31 $\pm$ 0.01
Ave $\pm$ SD	0.30	0.32	0.31	0.31 $\pm$ 0.02

Table 2.27. Surface roughness (μm) values of the glazed E.max group.

E.max Surface roughness Glazed	1. Measure	2.Measure	3. Measure	Average $\pm$ SD
1	0.16	0.16	0.15	0.16 $\pm$ 0.01
2	0.14	0.16	0.15	0.15 $\pm$ 0.01
3	0.15	0.15	0.16	0.15 $\pm$ 0.01
4	0.16	0.15	0.16	0.16 $\pm$ 0.01
5	0.16	0.16	0.16	0.16 $\pm$ 0.00
6	0.15	0.17	0.16	0.16 $\pm$ 0.01
7	0.15	0.15	0.15	0.15 $\pm$ 0.00
8	0.15	0.16	0.15	0.15 $\pm$ 0.00
9	0.16	0.16	0.16	0.16 $\pm$ 0.00
10	0.14	0.15	0.15	0.15 $\pm$ 0.01
Average $\pm$ SD	0.15	0.16	0.15	0.15 $\pm$ 0.01

Table 2.28. Surface roughness (μm) values of the glazed Cerec group.

Cerec Surface roughness Glazed	1. Measure	2.Measure	3. Measure	Average $\pm$ SD
1	0.36	0.37	0.35	0.36 $\pm$ 0.01
2	0.41	0.41	0.39	0.40 $\pm$ 0.01
3	0.36	0.37	0.40	0.38 $\pm$ 0.02
4.	0.37	0.38	0.39	0.38 $\pm$ 0.01
5	0.36	0.36	0.41	0.38 $\pm$ 0.03
6	0.40	0.39	0.39	0.39 $\pm$ 0.01
7	0.37	0.37	0.37	0.37 $\pm$ 0.00
8	0.40	0.40	0.38	0.39 $\pm$ 0.01
9	0.39	0.37	0.37	0.38 $\pm$ 0.01
10	0.41	0.41	0.40	0.40 $\pm$ 0.01
Ave $\pm$ SD	0.38	0.38	0.38	0.38 $\pm$ 0.01

When evaluating the non-glazed Cerec group; microhardness values after thermocycling was found to be significantly lower than initial values. (p:0.000; $p<0.05$) (Table 2.19.).

When evaluating the non-glazed E.max group; microhardness values after thermocycling was found to be significantly lower than initial values. (p:0.000; $p<0.05$) (Table 2.19).

When evaluating the non-glazed Empress group; microhardness values after thermocycling was found to be significantly lower than initial values. (p:0.008; $p<0.05$) (Table 2.19).

When evaluating the non-glazed Cerasmart group; microhardness values after thermocycling was found to be significantly lower than initial values. (p:0.005; $p<0.05$) (Table 2.19).

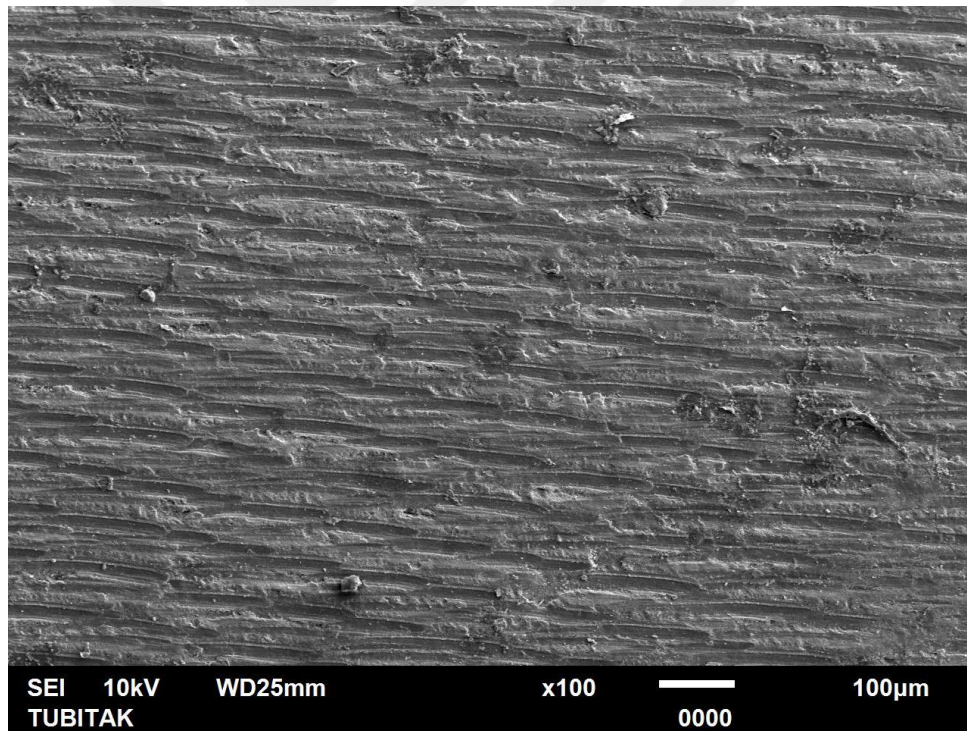


Figure 2.60. The 100x SEM image of the Cerasmart sample after thermocycling.

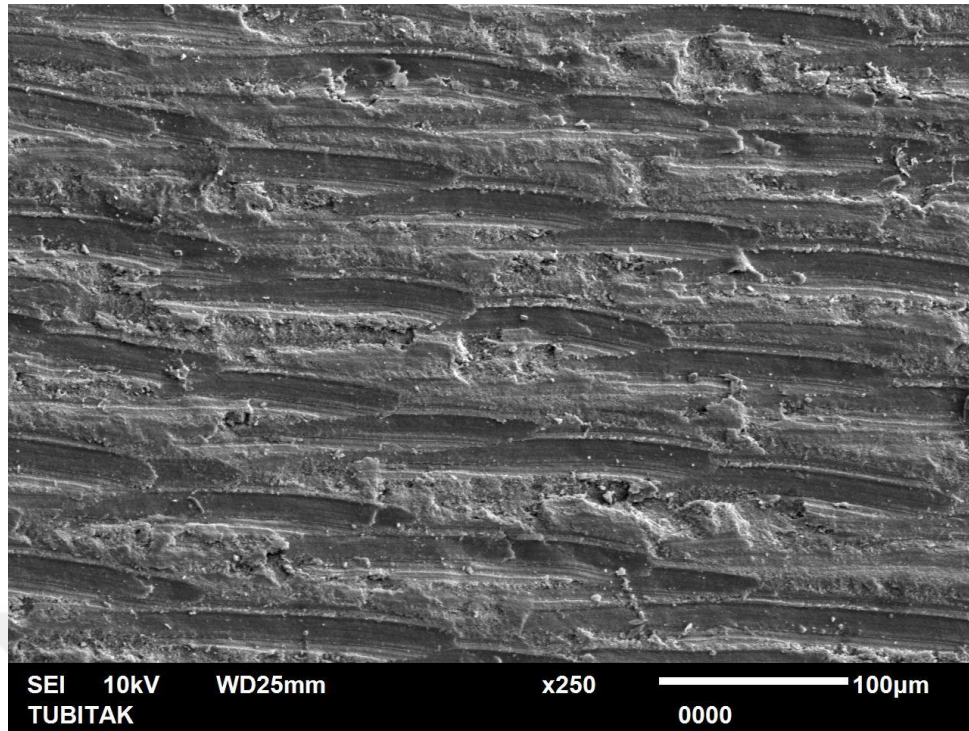


Figure 2.61. The 250x SEM image of the Cerasmart sample after thermocycling.

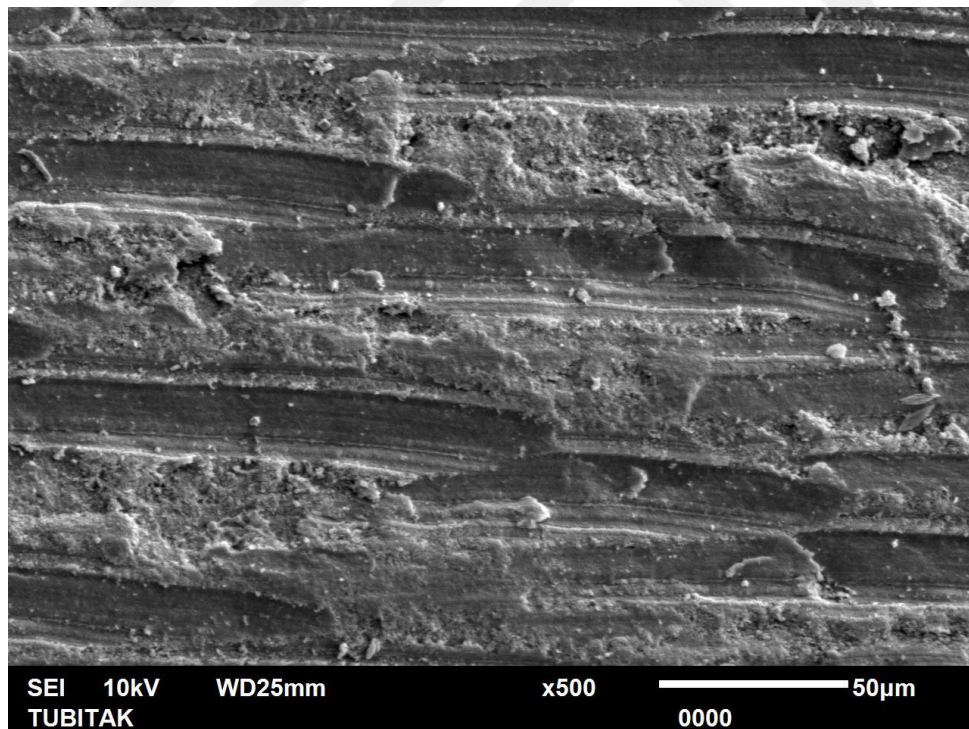


Figure 2.62. The 500x SEM image of the Cerasmart sample after thermocycling.

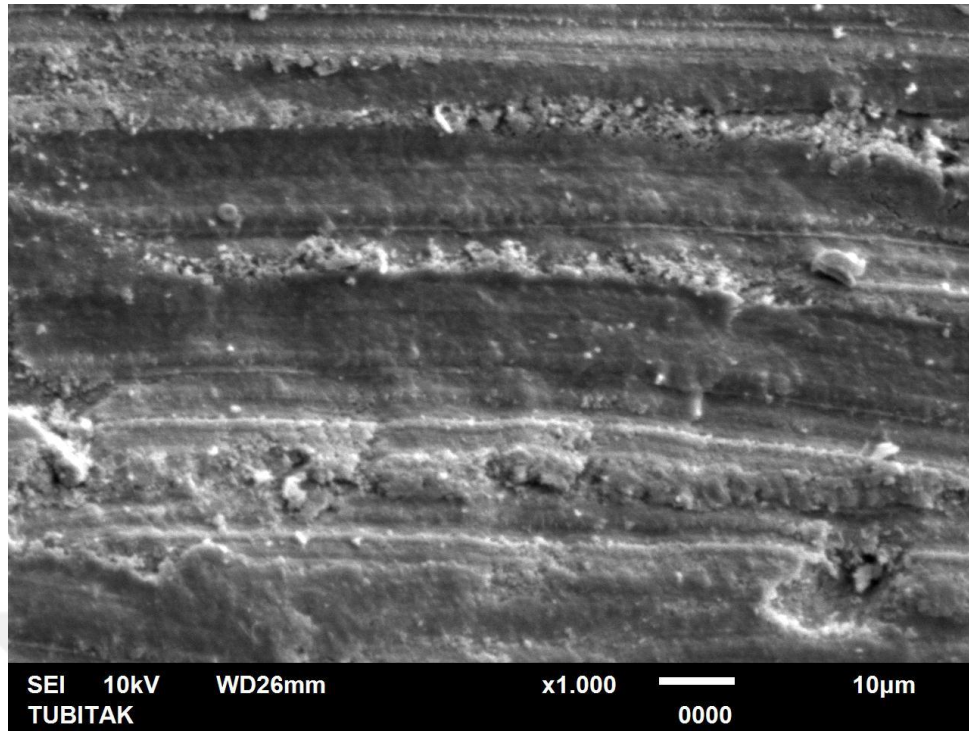


Figure 2.63. The 1000x SEM image of the Cerasmart sample after thermocycling.

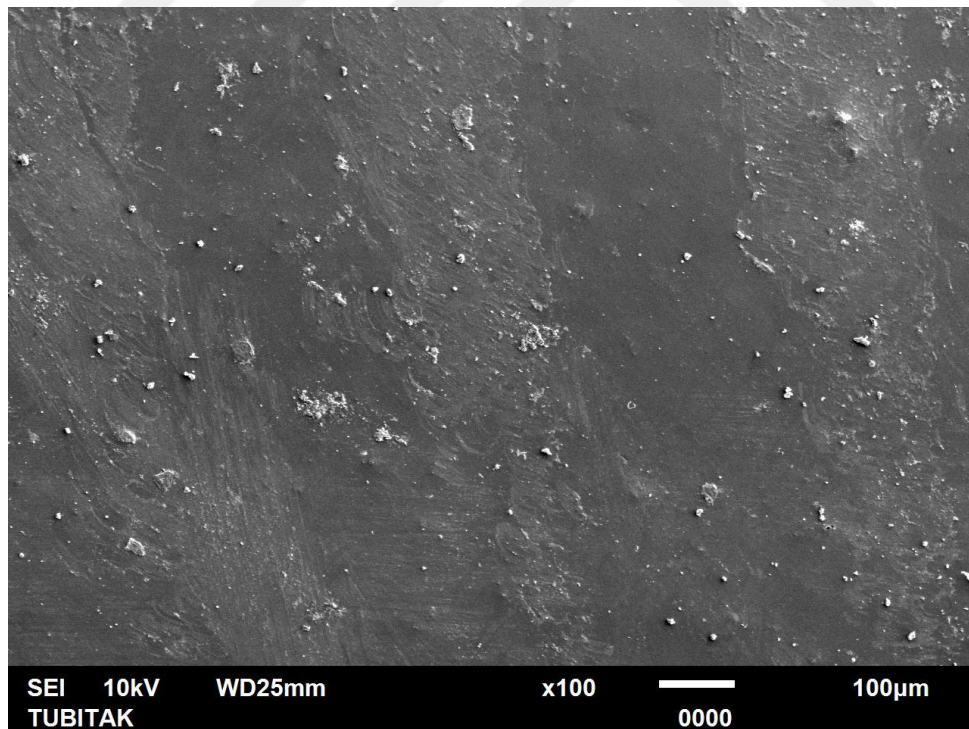


Figure 2.64. The 100x SEM image of the glazed Cerasmart sample after thermocycling.

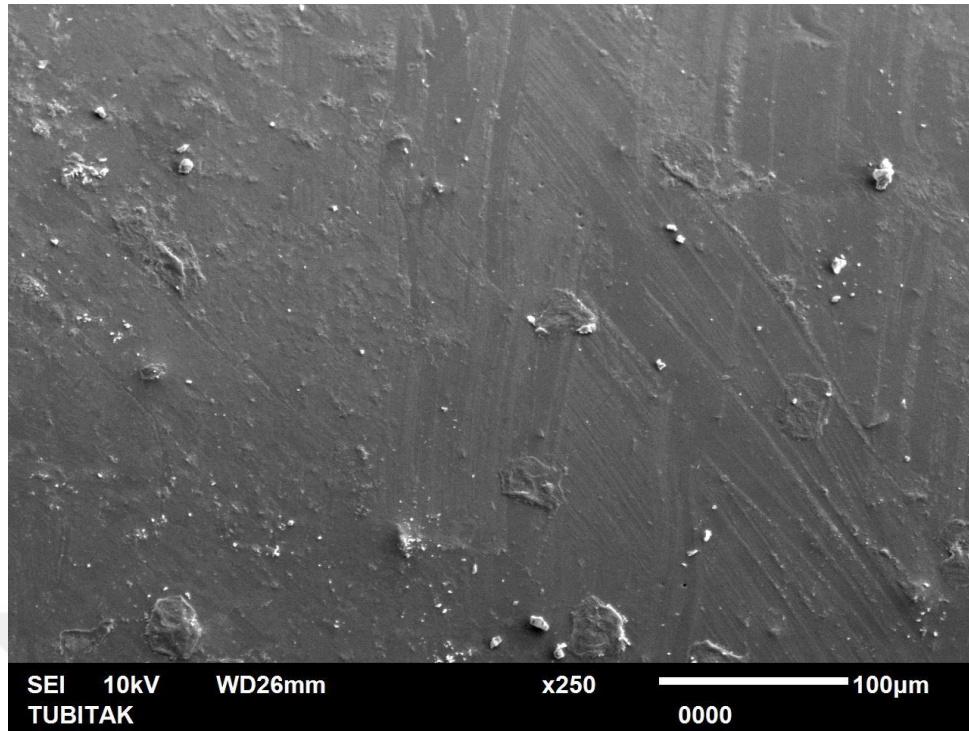


Figure 2.65. The 250x SEM image of the glazed Cerasmart sample after thermocycling.

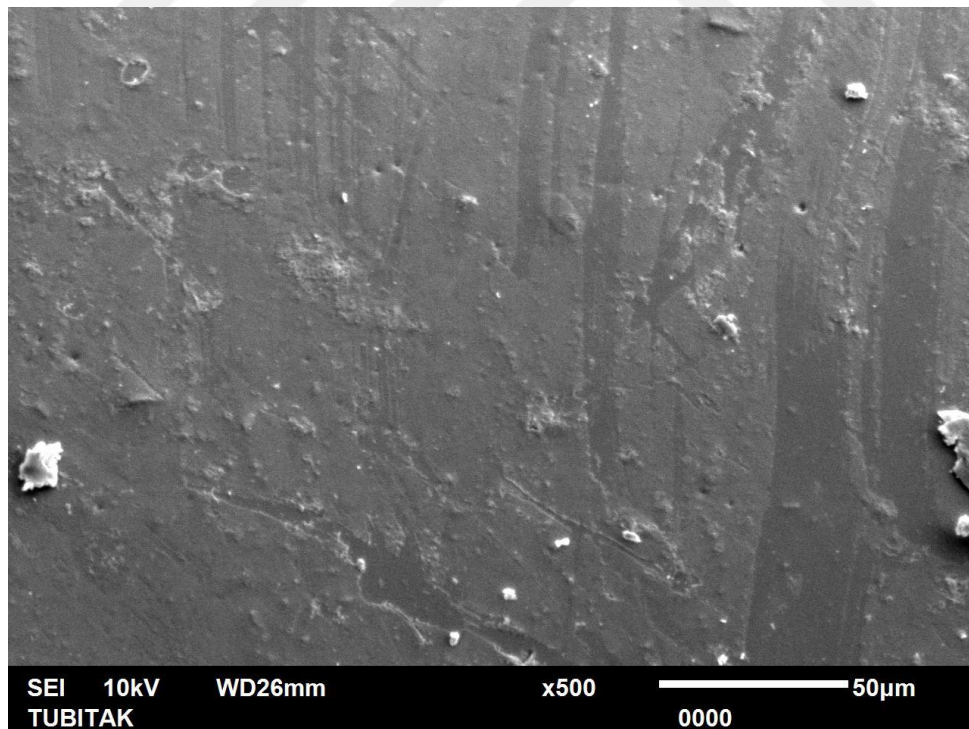


Figure 2.66. The 500x SEM image of the glazed Cerasmart sample after thermocycling.

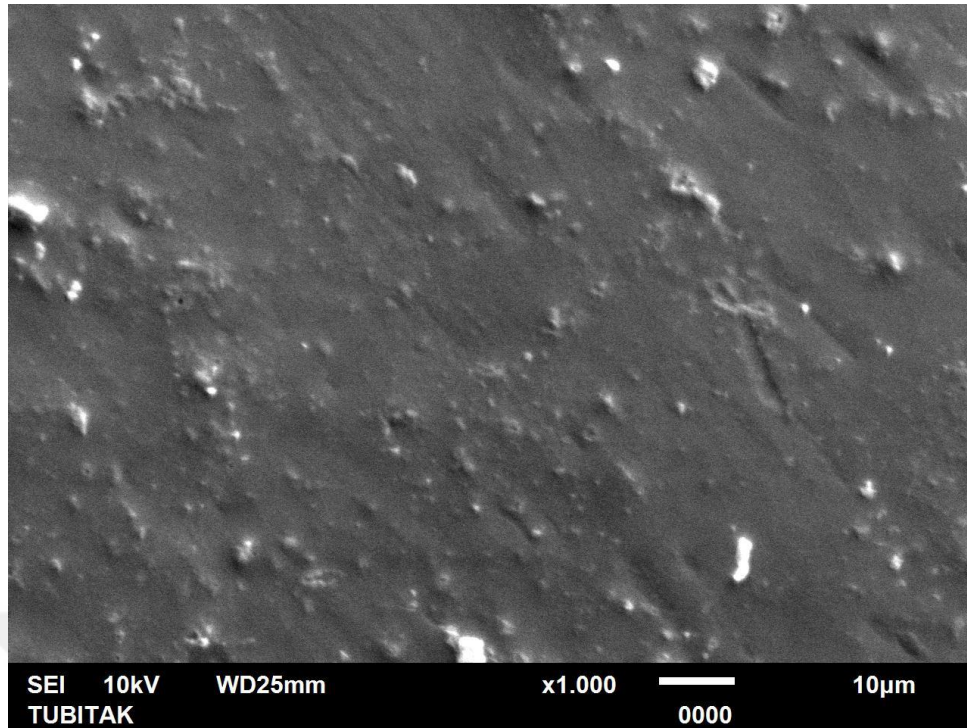


Figure 2.67. The 1000x SEM image of the glazed Cerasmart sample after thermocycling.

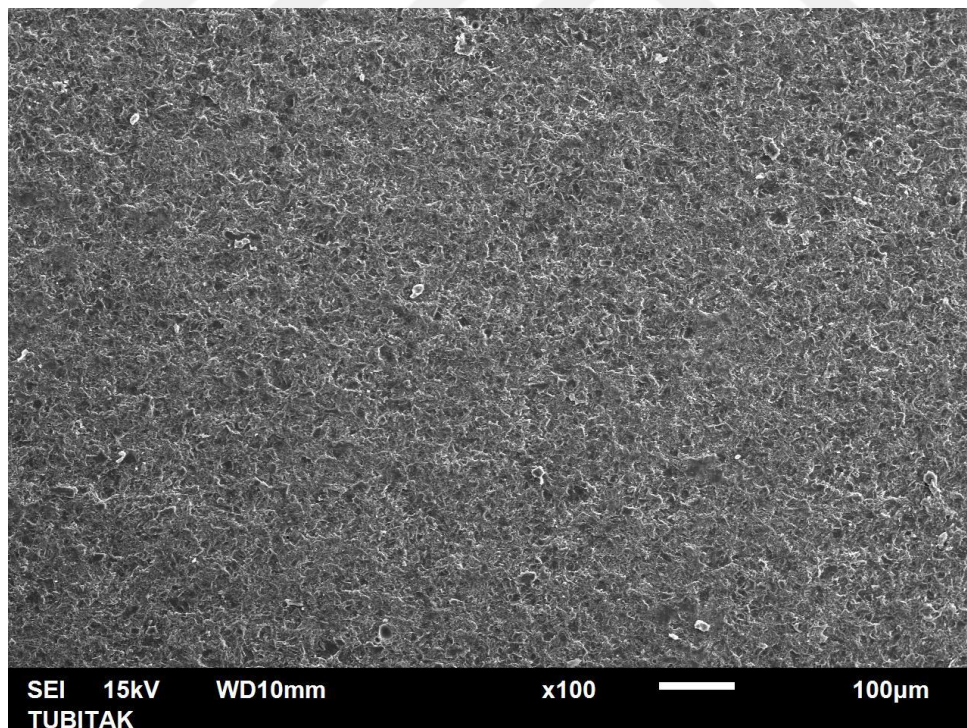


Figure 2.68. The 100x SEM image of the Cerec sample after thermocycling.

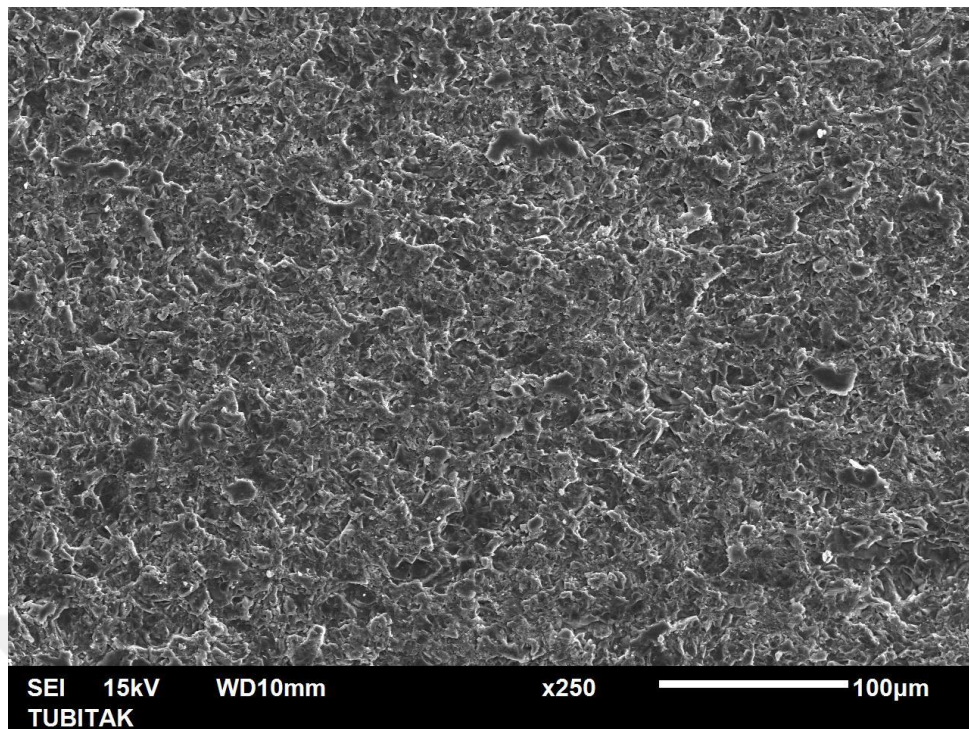


Figure 2.69. The 250x SEM image of the Cerec sample after thermocycling.

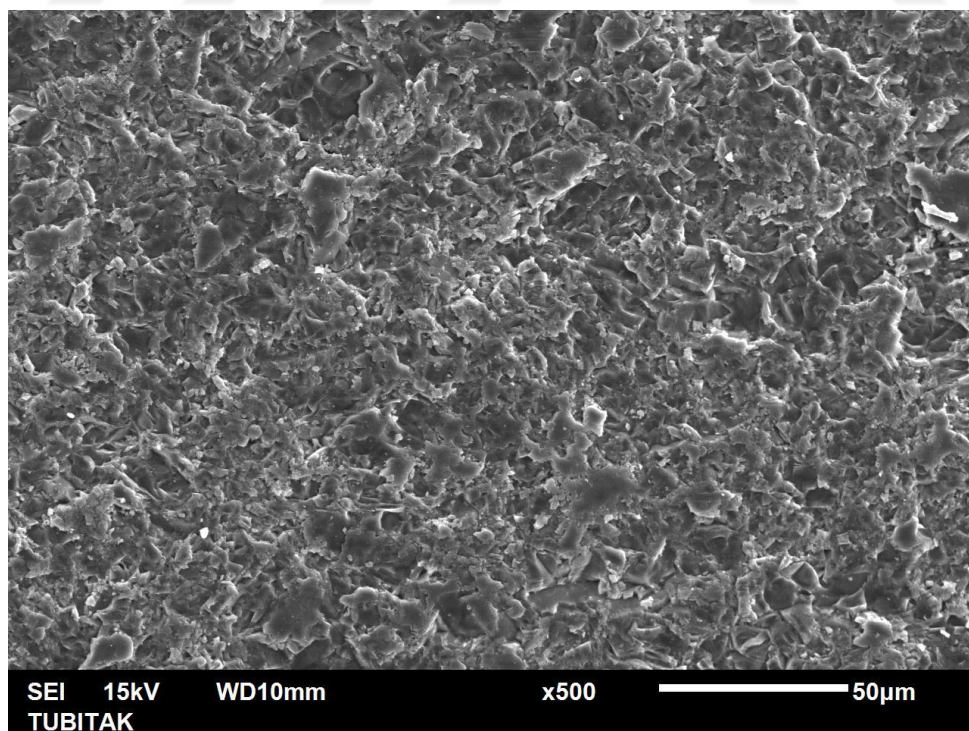


Figure 2.70. The 500x SEM image of the Cerec sample after thermocycling.

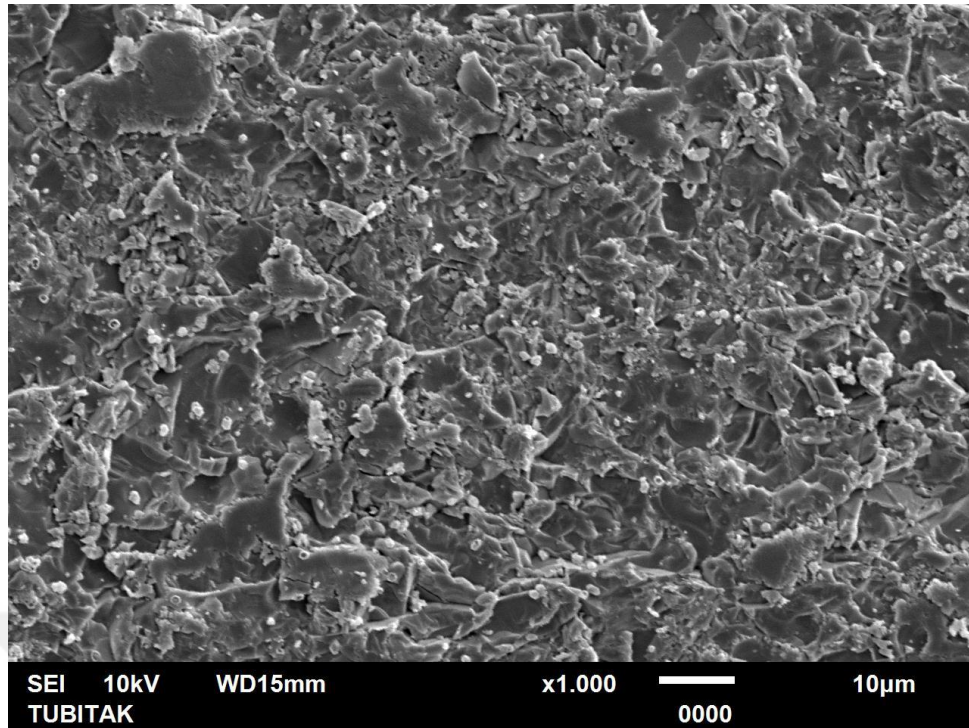


Figure 2.71. The 1000x SEM image of the Cerec sample after thermocycling.

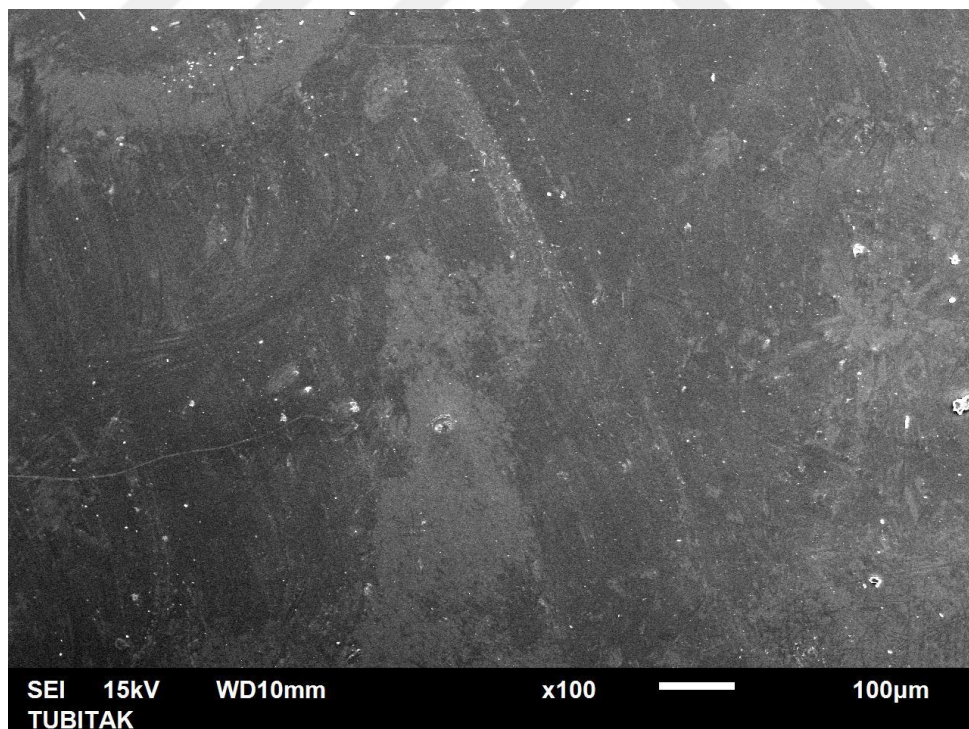


Figure 2.72. The 100x SEM image of the glazed Cerec sample after thermocycling.

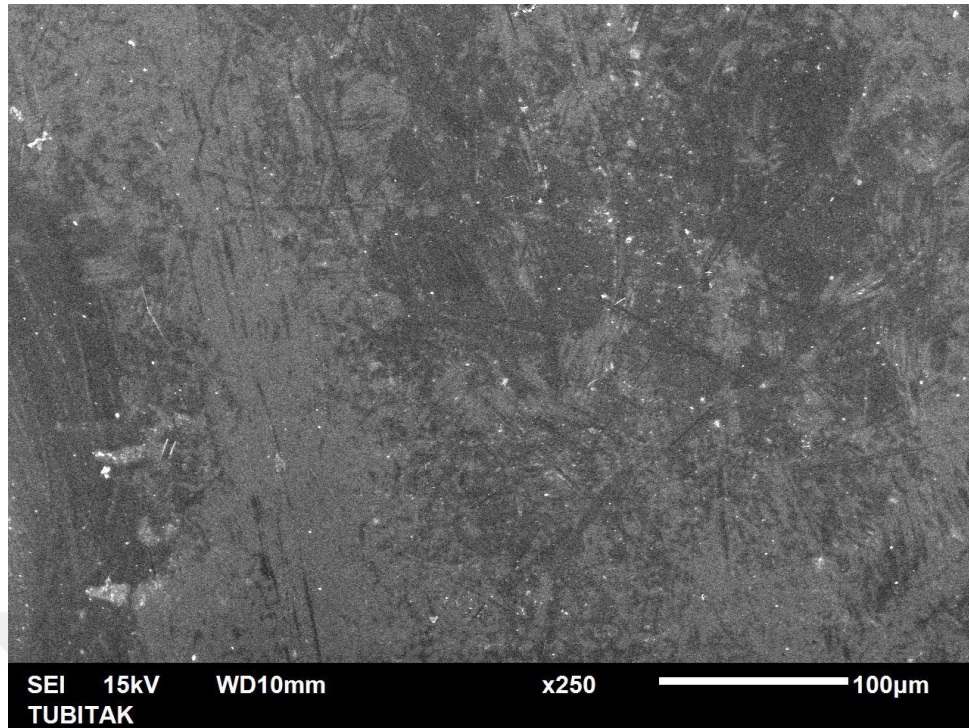


Figure 2.73. The 250x SEM image of the glazed Cerec sample after thermocycling.

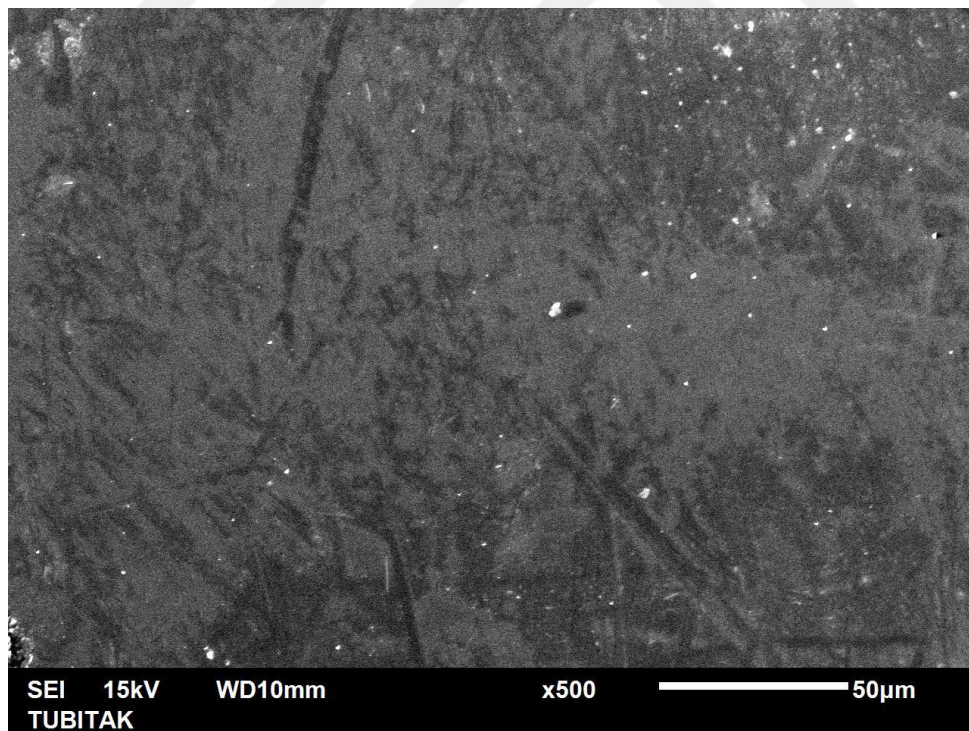


Figure 2.74. The 500x SEM image of the glazed Cerec sample after thermocycling.

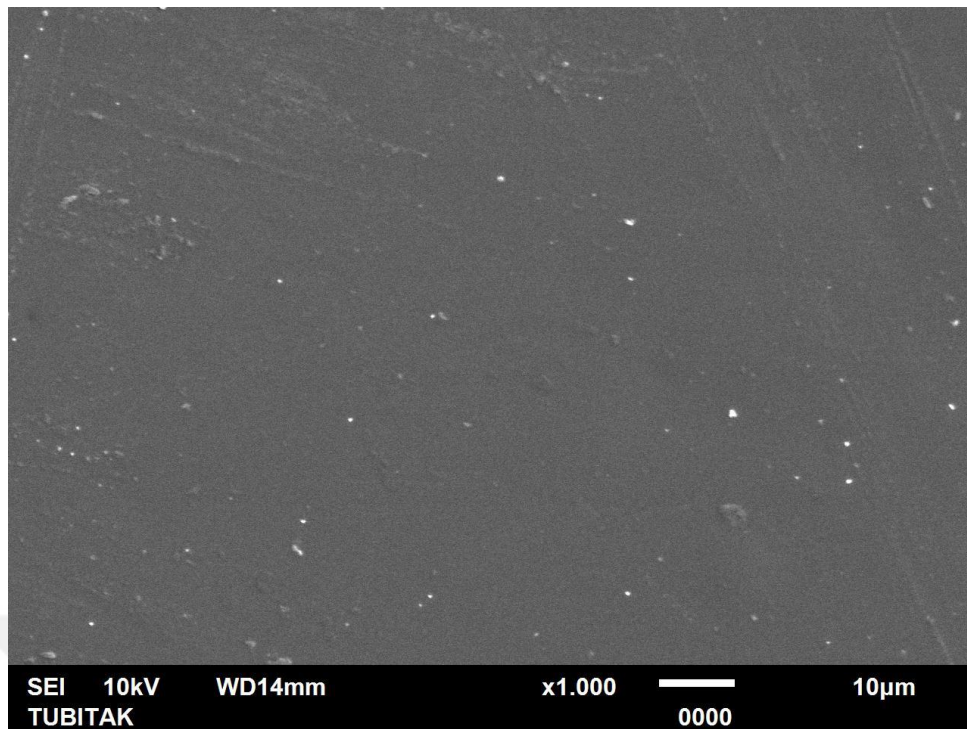


Figure 2.75. The 1000x SEM image of the glazed Cerec sample after thermocycling.

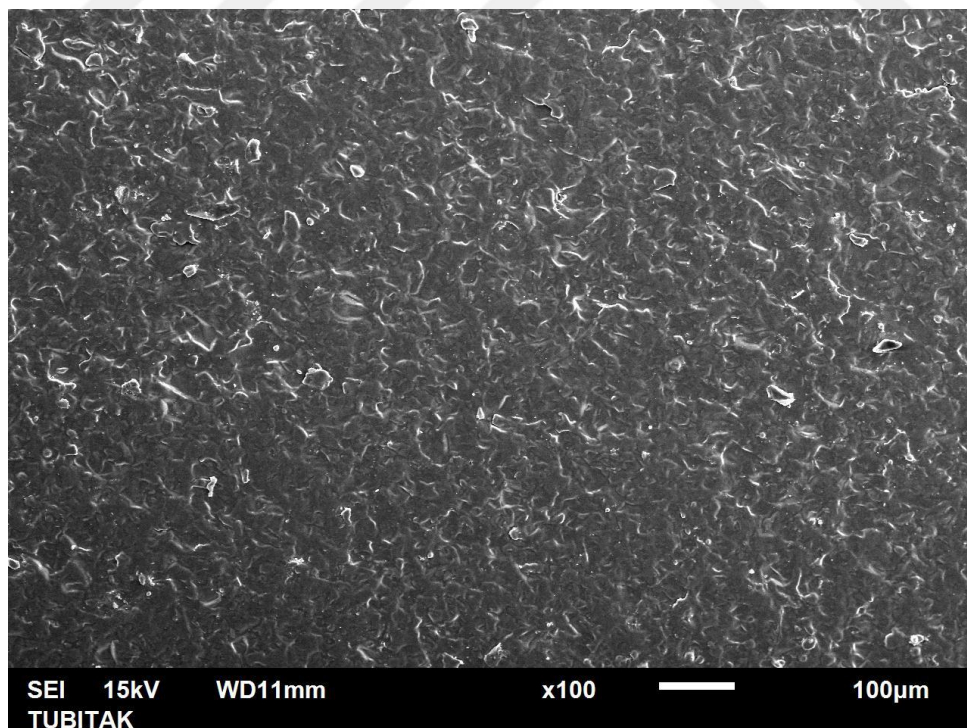


Figure 2.76. The 100x SEM image of the E.max sample after thermocycling.

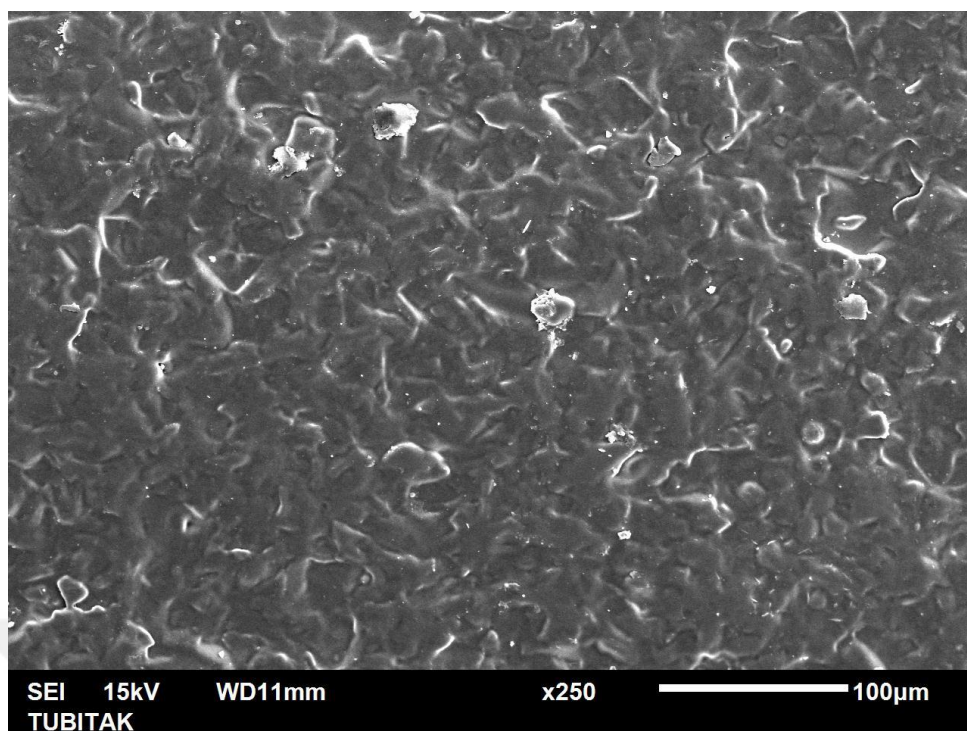


Figure 2.77. The 250x SEM image of the E.max sample after thermocycling.

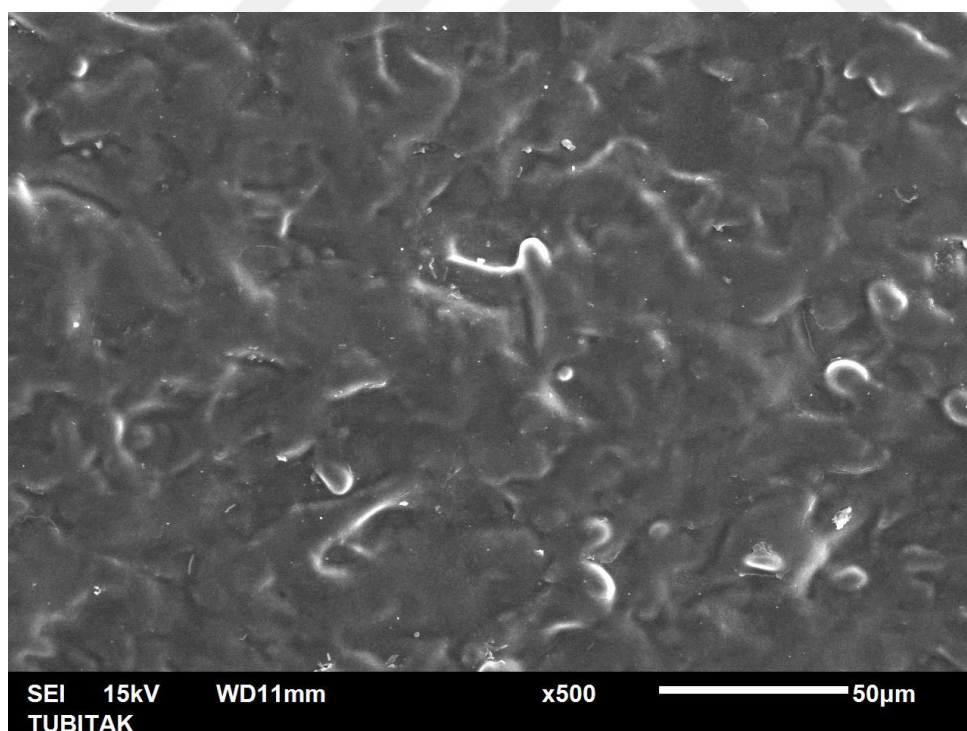


Figure 2.78. The 500x SEM image of the E.max sample after thermocycling.

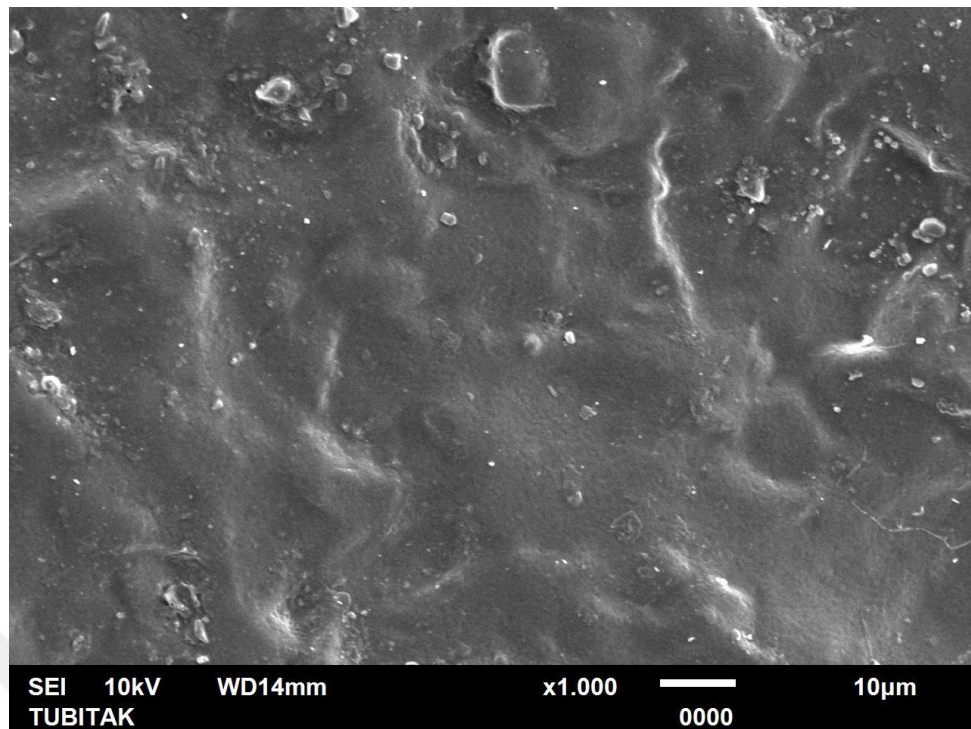


Figure 2.79. The 1000x SEM image of the E.max sample after thermocycling.

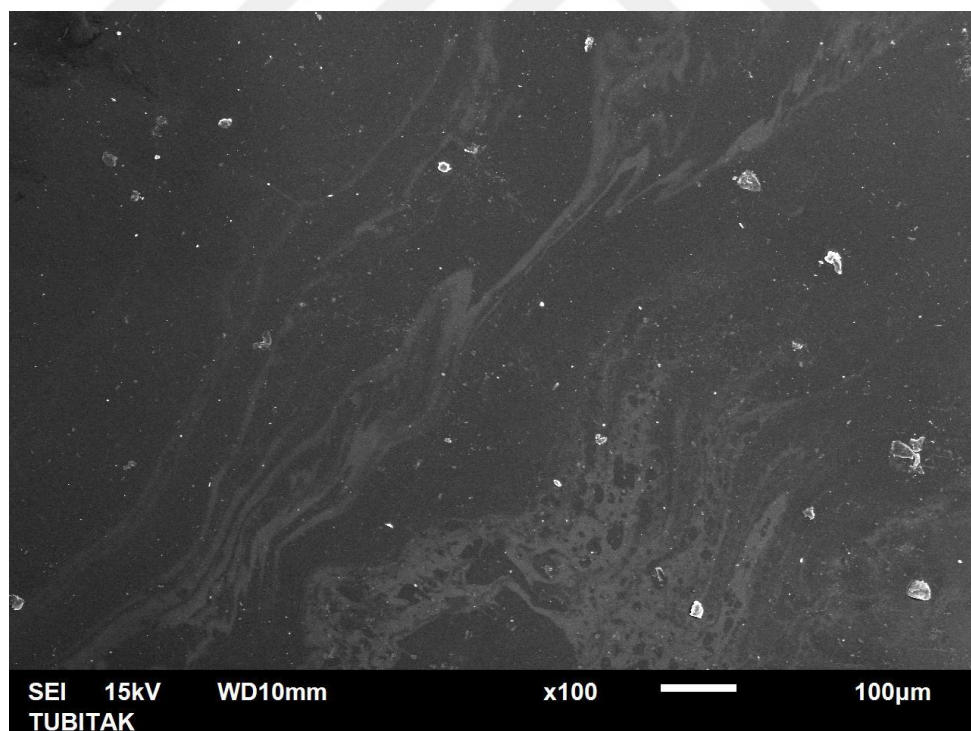


Figure 2.80. The 100x SEM image of the glazed E.max sample after thermocycling.

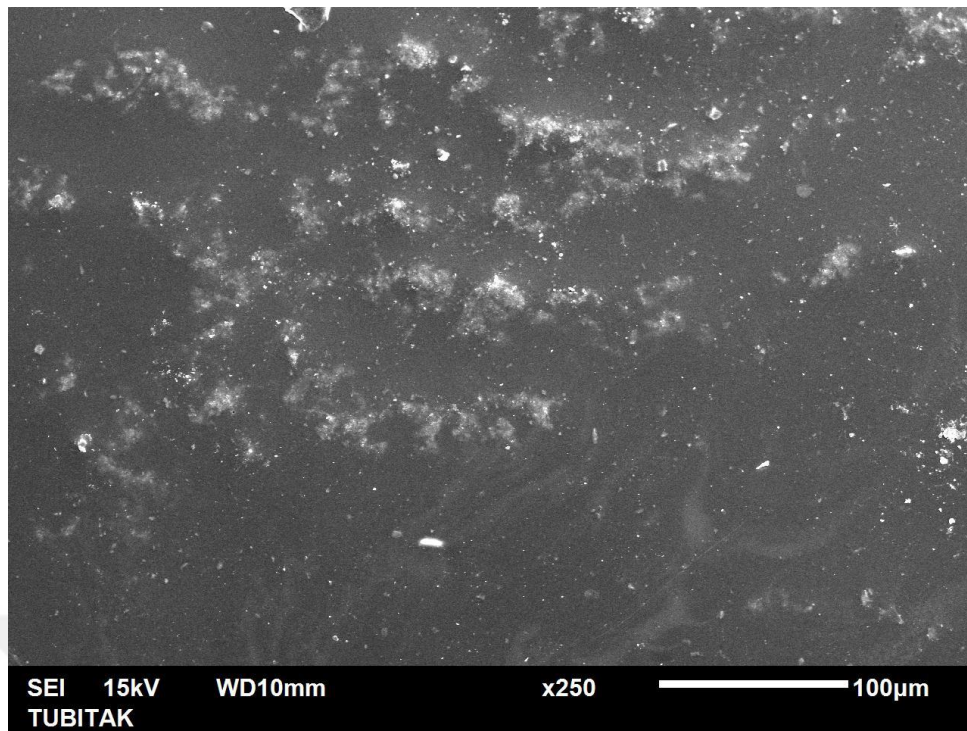


Figure 2.81. The 250x SEM image of the glazed E.max sample after thermocycling.

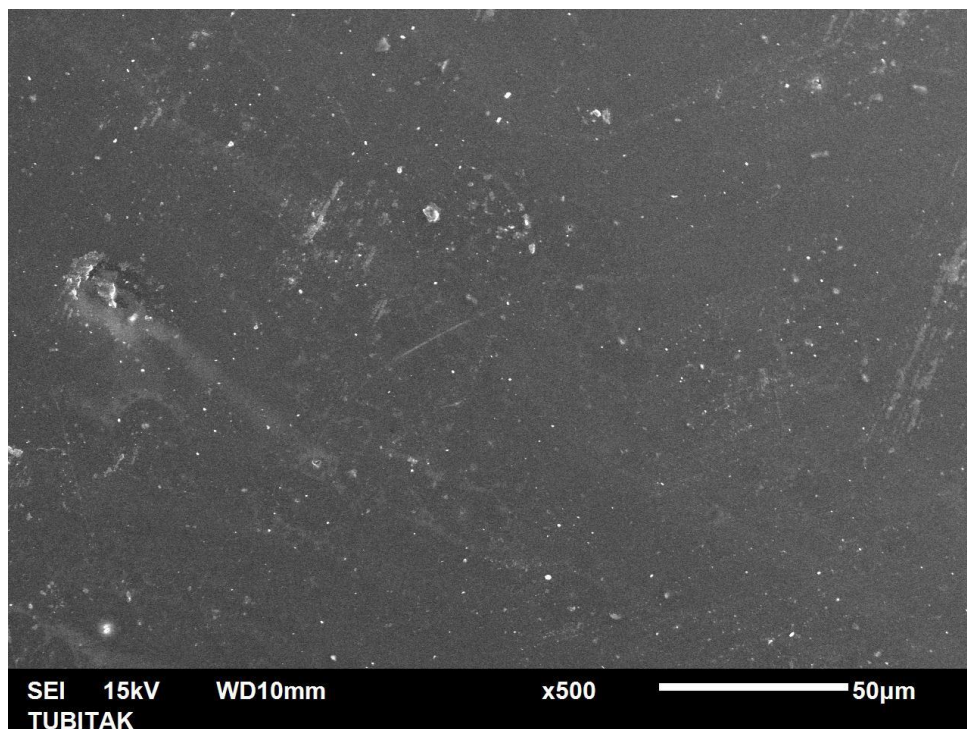


Figure 2.82. The 500x SEM image of the glazed E.max sample after thermocycling.

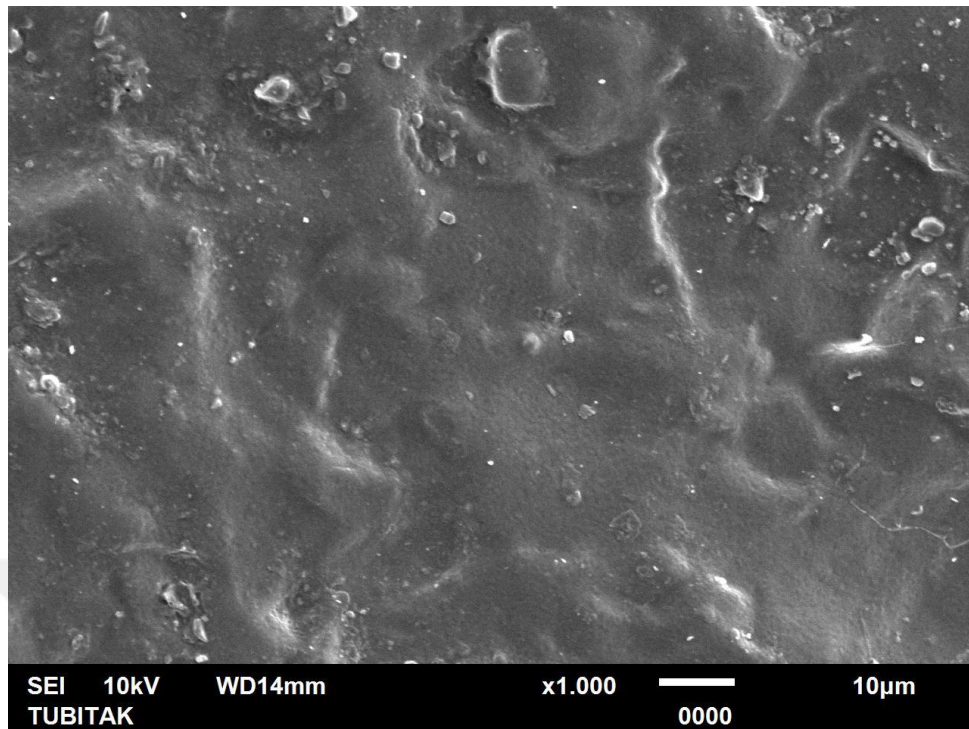


Figure 2.83. The 1000x SEM image of the glazed E.max sample after thermocycling.

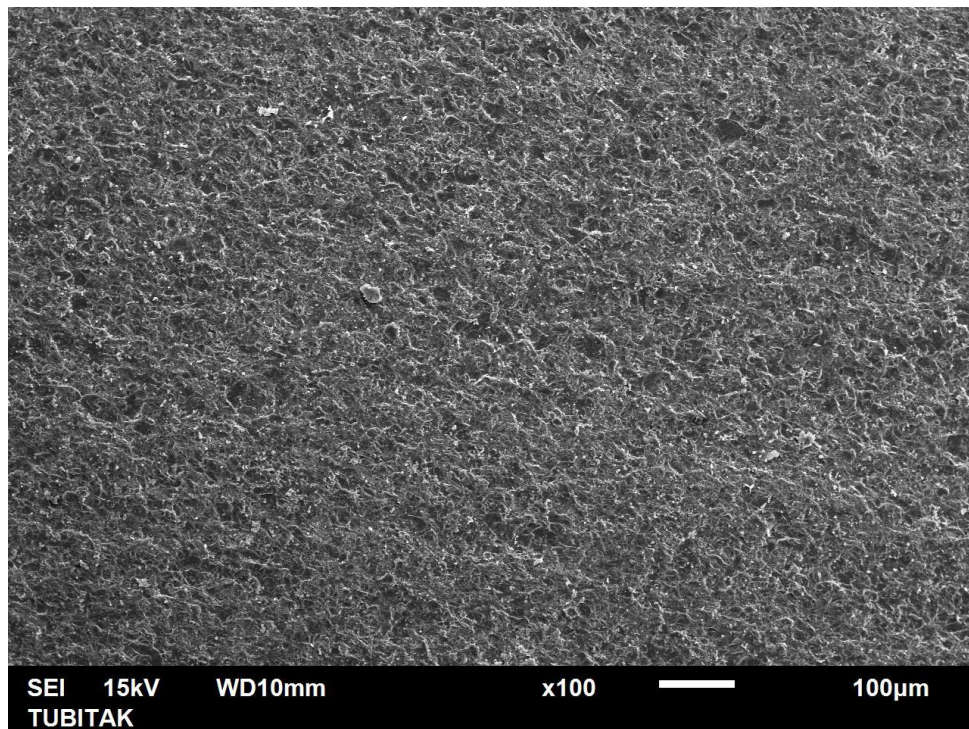


Figure 2.84. The 100x SEM image of the Empress sample after thermocycling.

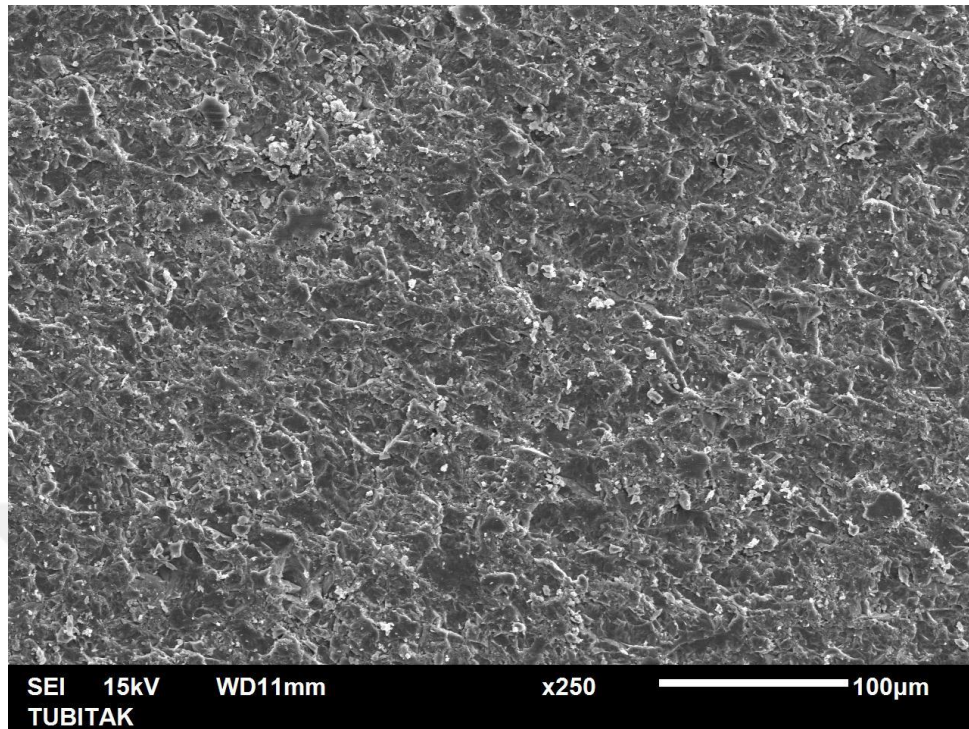


Figure 2.85. The 250x SEM image of the Empress sample after thermocycling.

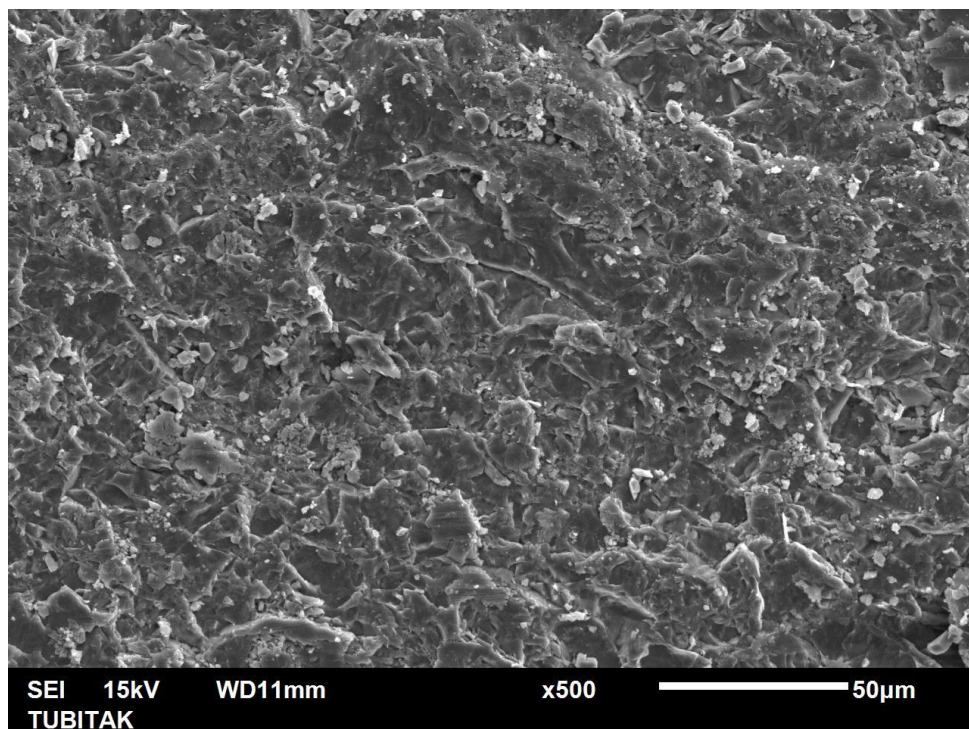


Figure 2.86. The 500x SEM image of the Empress sample after thermocycling.

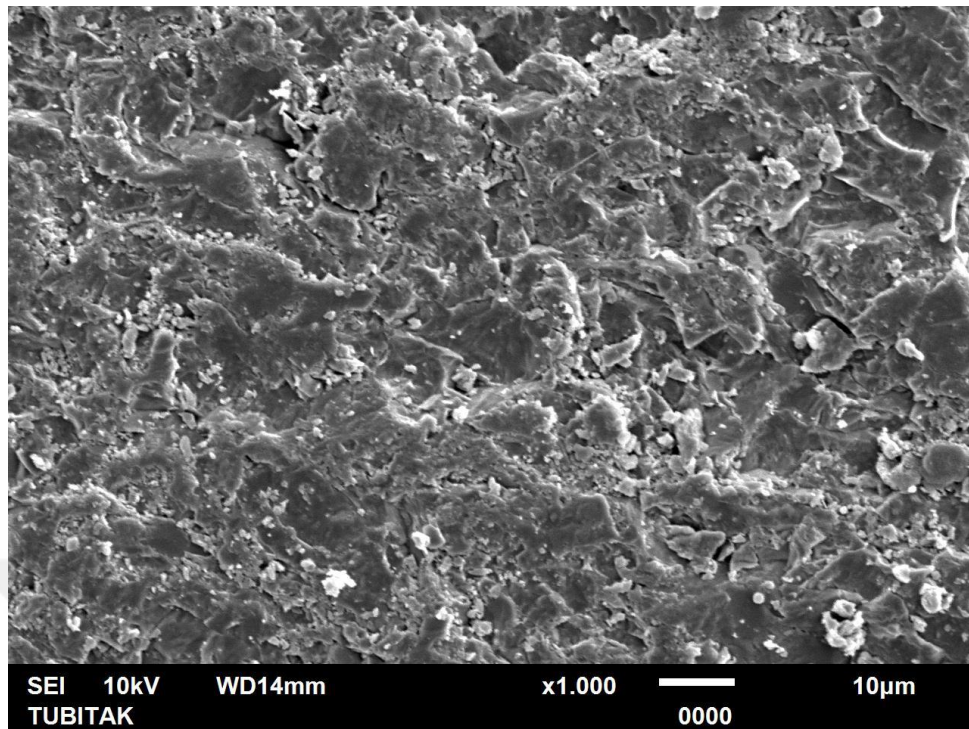


Figure 2.87. The 1000x SEM image of the Empress sample after thermocycling.

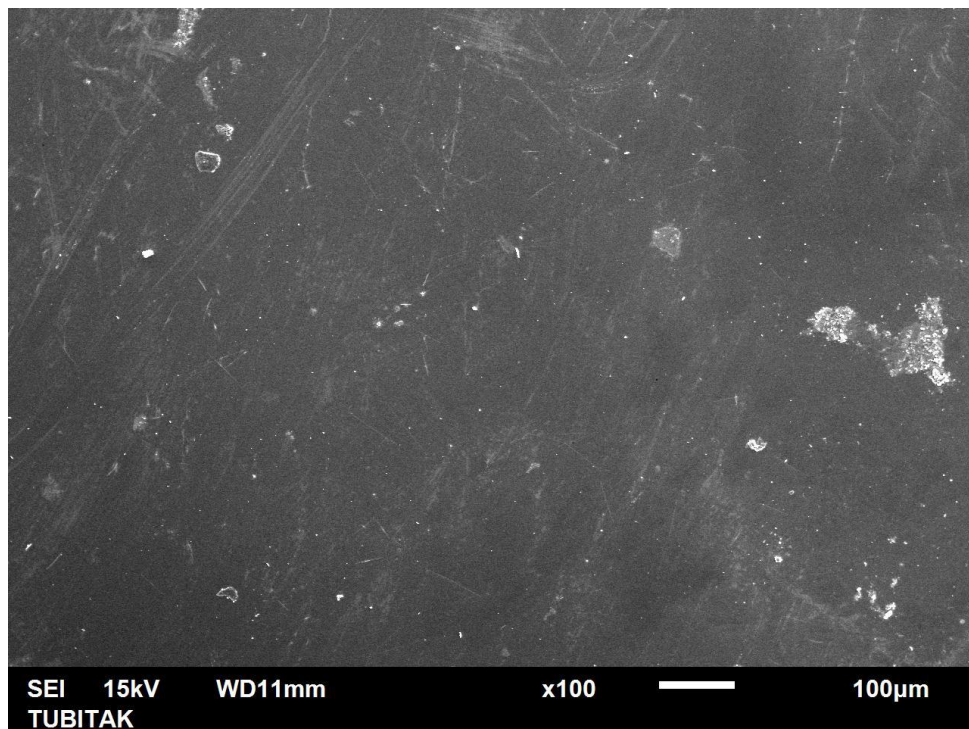


Figure 2.88. The 100x SEM image of the glazed Empress sample after thermocycling.

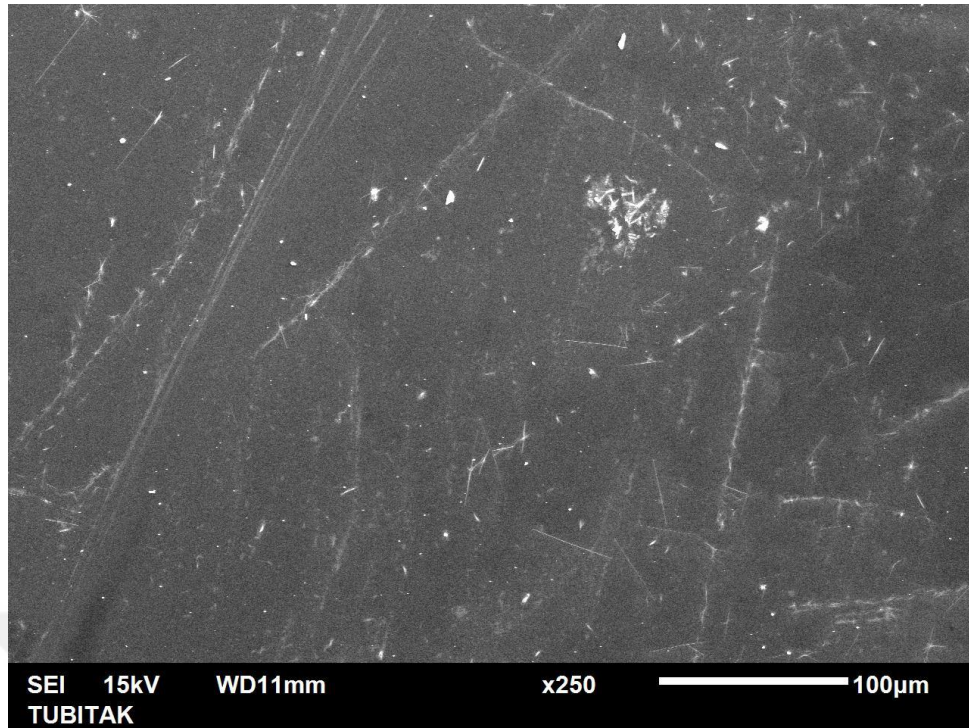


Figure 2.89. The 250x SEM image of the glazed Empress sample after thermocycling.

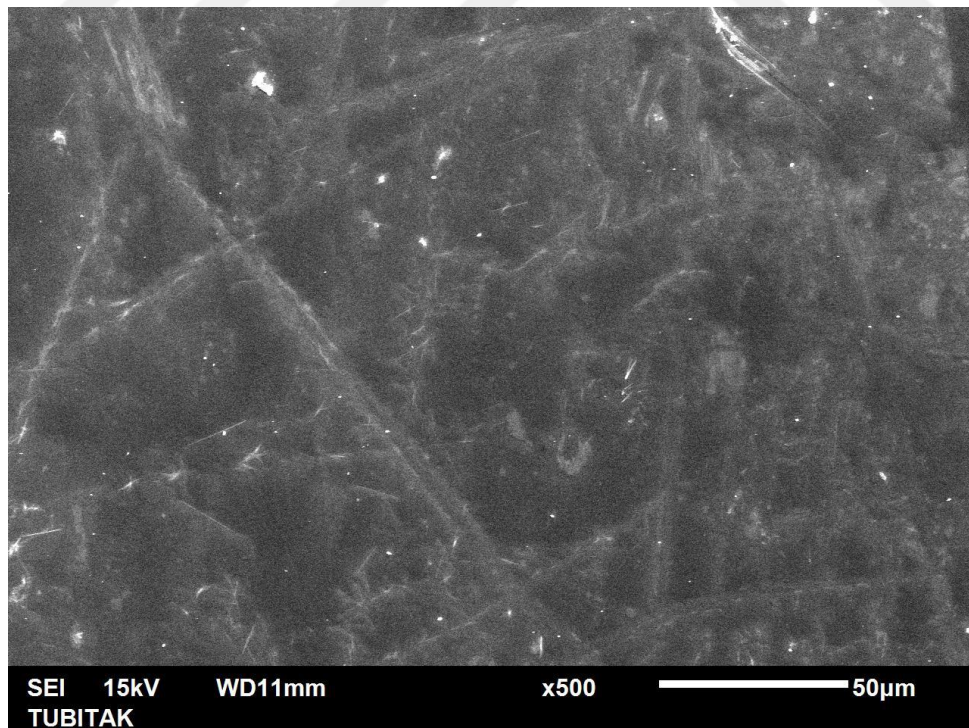


Figure 2.90. The 500x SEM image of the glazed Empress sample after thermocycling.

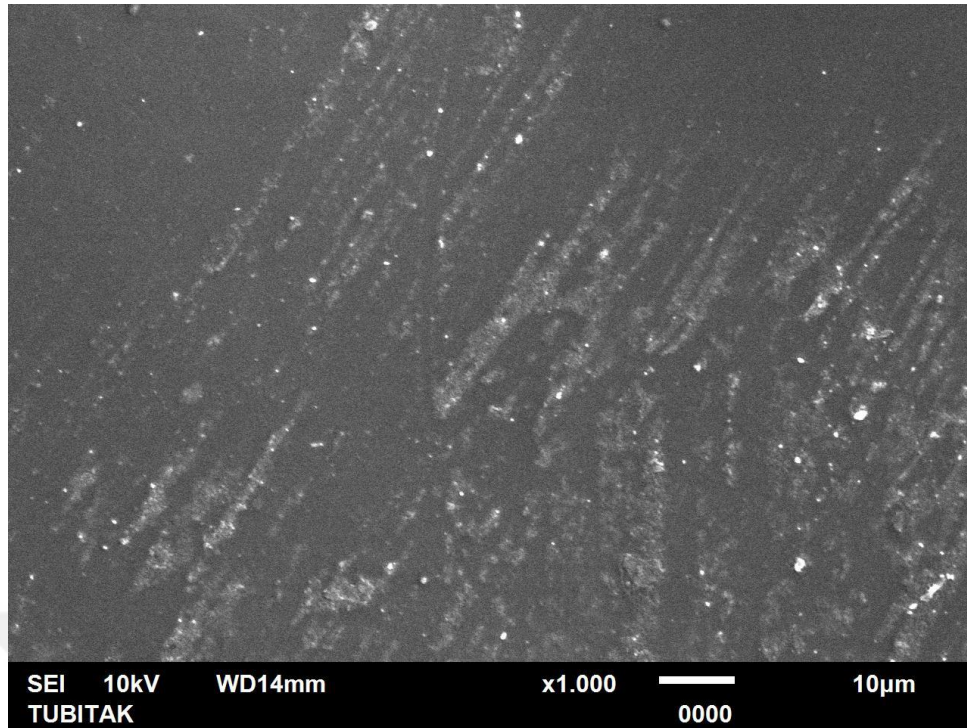


Figure 2.91. The 1000x SEM image of the glazed Empress sample after thermocycling.

The SEM observations revealed that the glazed groups had smoother surfaces compared to the non-glazed groups. In the Cerasmart group, glazed surfaces displayed narrow irregularities. The Empress group showed occasional irregularities and tiny cracks on the glazed layer (the reason for this is thought to occur during microhardness measurements). Glazed E.max surfaces appeared more homogeneous, while the Cerec group exhibited indistinct scratches and a few deep and wide surface irregularities on the glazed layer.

Table 2.29. Surface roughness (μm) values of the surface of non-glazed IPS E.max CAD group after thermocycling.

E.max Surface roughness Non-glazed After thermocycling	1. Measure	2. Measure	3. Measure	Ave $\pm$ SD
1	1.46	1.37	1.41	1.42 $\pm$ 0.00
2	1.35	1.41	1.42	1.39 $\pm$ 0.01
3	1.41	1.43	1.38	1.41 $\pm$ 0.00
4	1.39	1.42	1.37	1.39 $\pm$ 0.00
5	1.38	1.40	1.43	1.40 $\pm$ 0.00
6	1.37	1.41	1.42	1.40 $\pm$ 0.00
7	1.38	1.38	1.37	1.37 $\pm$ 0.00
8	1.31	1.36	1.40	1.36 $\pm$ 0.00
9	1.35	1.39	1.41	1.38 $\pm$ 0.00
10	1.37	1.37	1.39	1.38 $\pm$ 0.00
Ave $\pm$ SD	1.38	1.39	1.40	1.39 $\pm$ 0.00

Table 2.30. Surface roughness (μm) values of the non-glazed surface of IPS Empress CAD group after thermocycling.

Empress Surface roughness Non-glazed After thermocycling	1. Measure	2. Measure	3. Measure	Ave $\pm$ SD
1	1.20	1.20	1.21	1.20 $\pm$ 0.0
2	1.17	0.18	0.17	0.50 $\pm$ 0.6
3	1.21	1.12	1.15	1.16 $\pm$ 0.0
4	1.19	1.20	1.16	1.18 $\pm$ 0.0
5	1.20	1.16	1.16	1.17 $\pm$ 0.0
6	1.12	1.14	1.11	1.12 $\pm$ 0.0
7	1.14	1.15	1.11	1.13 $\pm$ 0.0
8	1.14	1.15	1.15	1.15 $\pm$ 0.0
9	1.20	1.21	1.19	2.00 $\pm$ 0.0
10	1.15	1.16	1.14	1.15 $\pm$ 0.0
Ave $\pm$ SD	1.17	1.06	1.05	1.10 $\pm$ 0.1

Table 2.31. Surface roughness (μm) values of the Cerec group after thermocycling (Non-glazed group)

Cerec Surface roughness Non-glazed After thermocycling	1. Measure	2. Measure	3. Measure	Ave $\pm$ SD
1	1.22	1.22	1.29	1.24 $\pm$ 0.0
2	1.22	1.27	1.27	1.26 $\pm$ 0.0
3	1.27	1.27	1.27	1.27 $\pm$ 0.0
4	1.24	1.24	1.17	1.22 $\pm$ 0.0
5	1.24	1.27	1.25	1.26 $\pm$ 0.0
6	1.21	1.14	1.14	1.16 $\pm$ 0.0
7	1.17	1.21	1.17	1.18 $\pm$ 0.0
8	1.29	1.29	1.27	1.28 $\pm$ 0.0
9	1.24	1.27	1.24	1.25 $\pm$ 0.0
10	1.24	1.23	1.23	1.23 $\pm$ 0.0
Ave $\pm$ SD	1.23	1.24	1.23	1.24 $\pm$ 0.0

Table 2.32. Surface roughness (μm) values of the Cerasmart group after thermocycling (Non-glazed group).

Cerasmart Surface roughness After aging Non-glazed	1. Measure	2. Measure	3. Measure	Ave $\pm$ SD
1	1.26	1.22	1.24	1.24 $\pm$ 0.02
2	1.32	1.30	1.17	1.26 $\pm$ 0.08
3	1.27	1.24	1.19	1.23 $\pm$ 0.03
4	1.31	1.30	1.39	1.33 $\pm$ 0.05
5	1.36	1.27	1.29	1.31 $\pm$ 0.05
6	1.31	1.37	1.29	1.32 $\pm$ 0.04
7	1.27	1.28	1.30	1.28 $\pm$ 0.02
8	1.34	1.37	1.36	1.36 $\pm$ 0.01
9	1.30	1.25	1.22	1.26 $\pm$ 0.04
10	1.27	1.27	1.27	1.27 $\pm$ 0.00
Ave $\pm$ SD	1.30	1.29	1.27	1.29 $\pm$ 0.03

Table 2.33. Surface roughness (μm) values of the glazed Empress group after thermocycling.

Empress Surface roughness Glazed After thermocycling	1. Measure	2. Measure	3. Measure	Ave $\pm$ SD
1	0.20	0.20	0.20	0.20 $\pm$ 0.00
2	0.20	0.21	0.20	0.20 $\pm$ 0.00
3	0.20	0.18	0.19	0.20 $\pm$ 0.00
4	0.19	0.19	0.19	0.19 $\pm$ 0.00
5	0.20	0.19	0.19	0.19 $\pm$ 0.00
6	0.19	0.19	0.20	0.19 $\pm$ 0.00
7	0.21	0.19	0.20	0.19 $\pm$ 0.00
8	0.18	0.19	0.19	0.19 $\pm$ 0.00
9	0.19	0.19	0.18	0.19 $\pm$ 0.00
10	0.19	0.18	0.19	0.19 $\pm$ 0.00
Ave $\pm$ SD	0.1947	0.19	0.19	0.19 $\pm$ 0.00

Table 2.34. Surface roughness (μm) values of the glazed E.max group after thermocycling.

E.max Surface roughness Glazed After thermocycling	1. Measure	2. Measure	3. Measure	Ave $\pm$ SD
1	0.16	0.15	0.15	0.16 $\pm$ 0.01
2	0.15	0.15	0.17	0.16 $\pm$ 0.01
3	0.15	0.15	0.15	0.15 $\pm$ 0.00
4	0.15	0.16	0.16	0.16 $\pm$ 0.00
5	0.17	0.16	0.16	0.16 $\pm$ 0.00
6	0.15	0.16	0.17	0.16 $\pm$ 0.01
7	0.15	0.16	0.15	0.16 $\pm$ 0.00
8	0.16	0.16	0.16	0.16 $\pm$ 0.00
9	0.16	0.16	0.16	0.16 $\pm$ 0.00
10	0.15	0.16	0.16	0.16 $\pm$ 0.00
Ave $\pm$ SD	0.16	0.16	0.16	0.16 $\pm$ 0.00

Table 2.35. Surface roughness values of the glazed Cerec group after thermocycling.

Cerec Surface roughness Glazed After thermocycling	1. Measure	2. Measure	3. Measure	Ave±SD
1	0.37	0.36	0.35	0.36±0.01
2	0.41	0.41	0.42	0.41±0.03
3	0.36	0.41	0.41	0.39±0.02
4	0.37	0.38	0.40	0.38±0.00
5	0.41	0.40	0.40	0.40±0.01
6	0.41	0.39	0.40	0.40±0.00
7	0.38	0.38	0.38	0.38±0.01
8	0.40	0.40	0.40	0.40±0.00
9	0.39	0.38	0.37	0.38±0.01
10	0.41	0.40	0.40	0.40±0.01
Ave±SD	0.39	0.39	0.39	0.39±0.01

Table 2.36. Surface roughness (µm) values of the glazed Cerasmart group after thermocycling.

Cerasmart Surface roughness Glazed After thermocycling	1. Measure	2. Measure	3. Measure	Ave±SD
1	0.37	0.37	0.37	0.37±0.00
2	0.34	0.34	0.29	0.32±0.03
3	0.34	0.35	0.37	0.35±0.02
4	0.37	0.37	0.38	0.37±0.00
5	0.30	0.33	0.37	0.33±0.04
6	0.30	0.30	0.32	0.31±0.01
7	0.33	0.36	0.35	0.35±0.01
8	0.31	0.32	0.33	0.32±0.01
9	0.34	0.35	0.35	0.34±0.00
10	0.32	0.34	0.35	0.34±0.02
Ave±SD	0.33	0.34	0.35	0.34±0.01

Table 2.37. Microhardness values of the glazed E.max group after thermocycling.

E.max Microhardness Glazed After thermocycling	1. Measure	2. Measure	3.Measure	Ave±SD
1	610	609	600	606±5.3
2	593	585	580	586±6.5
3	581	585	576	581±4.9
4	583	592	586	587±4.3
5	600	601	601	601±0.2
6	609	609	611	609±1.0
7	617	619	616	618±1.4
8	611	613	618	614±3.4
9	591	597	586	591±5.7
10	590	592	584	589±4.1
Ave±SD	598	600	596	598±3.7

Table 2.38. Microhardness values of the glazed Cerec group after thermocycling.

Cerec Microhardness Glazed After thermocycling	1. Measure	2. Measure	3.Measure	Ave±SD
1	423	427	423	424±2.5
2	443	442	448	444±3.5
3	441	444	442	442±1.9
4	443	442	444	443±1.0
5	461	462	468	463±3.7
6	472	471	470	471±1.1
7	444	441	440	442±2.4
8	460	461	461	460±0.8
9	470	464	468	467±3.2
10	468	468	479	471±6.6
Ave	452	452	454	453±2.7

Table 2.39. Microhardness values of the glazed Cerasmart group after thermocycling.

Cerasmart Microhardness Glazed After thermocycling	1. Measure	2. Measure	3.Measure	Ave±SD
1	78	75	76	76±1.4
2	78	76	74	76±1.6
3	73	78	78	76±2.5
4	78	75	77	77±1.3
5	74	72	74	73±1.2
6	74	75	76	75±1.3
7	77	76	78	77±1.0
8	76	76	76	76±0.4
9	77	74	74	75±1.6
10	74	77	74	75±1.7
Ave±SD	76	75	76	76±1.4

Table 2.40. Microhardness values of the glazed Empress group after thermocycling.

Empress Microhardness Glazed After thermocycling	1. Measure	2. Measure	3.Measure	Ave±SD
1	578	576	569	574±4.5
2	542	555	551	549±6.8
3	584	598	577	586±10
4	575	581	600	585±13
5	561	563	571	565±5.2
6	572	573	569	571±2.0
7	572	573	582	575±5.3
8	571	562	569	567±4.6
9	570	579	590	579±10
10	575	568	576	573±4.2
Ave±SD	570	573	575	573±6.6

Table 2.41. Microhardness values of the non-glazed E.max group after thermocycling.

E.max Hardness Non-glazed After thermocycling	1. Measure	2. Measure	3.Measure	Ave±SD
1	645	641	639	642±3.1
2	642	649	642	644±4.2
3	639	641	633	638±4.2
4	629	627	624	627±2.8
5	641	637	630	636±5.3
6	655	647	649	650±4.2
7	638	646	643	642±4.3
8	633	649	650	644±9.6
9	647	650	642	646±3.9
10	640	633	640	638±3.8
Ave±SD	641	642	639	641±4.5

Table 2.42. Microhardness values of the non-glazed Empress group after thermocycling.

Empress Hardness Non-glazed After thermocycling	1. Measure	2. Measure	3.Measure	Ave±SD
1	596	593	612	601±10
2	627	629	611	622±9.9
3	591	592	583	588±5.0
4	610	628	622	620±9.1
5	613	588	583	595±16
6	600	603	609	604±4.7
7	609	613	611	611±1.8
8	625	629	628	627±2.0
9	597	576	582	585±11
10	625	622	585	611±22
Ave±SD	609	607	603	606±9.2

Table 2.43. Microhardness values of the non-glazed Cerasmart group after thermocycling.

Cerasmart Hardness Non-glazed After thermocycling	1. Measure	2. Measure	3.Measure	Ave±SD
1	120	120	121	120±0.5
2	111	109	105	108±2.6
3	107	101	108	105±3.4
4	107	104	105	105±1.2
5	120	126	125	124±3.3
6	115	118	117	117±1.4
7	119	122	124	122±2.6
8	102	117	109	109±7.3
9	115	114	113	114±1.2
10	110	111	113	111±1.7
Ave±SD	113	114	114	114±2.5

Table 2.44. Microhardness values of the non-glazed Cerec group after thermocycling.

Cerec Hardness Non-glazed After thermocycling	1. Measure	2. Measure	3.Measure	Ave±SD
1	500	498	500	500±1.3
2	468	476	508	484±21
3	500	569	606	558±54
4	502	505	511	506±4.5
5	500	576	488	521±48
6	475	488	484	482±6.4
7	491	502	503	499±6.6
8	503	500	502	502±1.8
9	512	503	518	511±7.5
10	485	490	504	493±9.5
Ave±SD	464	511	512	506±16

5. DISCUSSION

All-ceramic restorations are frequently chosen in dental procedures when it is crucial to achieve a natural-looking tooth appearance because of their high esthetics, biocompatibility, and wear resistance. These restorations are often utilized in dentistry because they might offer characteristics that are comparable to those of natural teeth. It is crucial that ceramic materials used in inlays, onlays, single-tooth restorations, and three-unit bridges have long-lasting aesthetic qualities (240).

Using various finishing and polishing techniques, a smooth and shiny surface resembling natural teeth can be achieved in CAD-CAM aesthetic restorations. Resin-ceramic CAD-CAM materials can be smoothened in a single visit, without firing, utilizing manual polishing procedures, even though ceramic restorations are typically smoothened by firing (241,52).

A key element in achieving desired aesthetic results is the natural translucency of dentin and enamel. Restorations should strive to mimic nearby teeth in terms of their form, surface properties, and visual characteristics, which are displayed by natural teeth (242,243). A range of aesthetic CAD/CAM materials have been created as a substitute to conventional metal-supported restorations as a result of the advancement of CAD-CAM technology and the rising need for cosmetic restorations (244,245).

Metal-supported ceramic restorations have used a lengthy history in the field of dentistry. However, the growing emphasis on achieving aesthetic outcomes has driven a transition towards the utilization of all-ceramic restorations (244,264). The preference for all-ceramic restorations over traditional metal-supported ones stems from their superior cosmetic, biocompatible, and mechanical properties (242,246,266).

The development of all-ceramic restorations and other metal-free dental materials with various mechanical and optical qualities utilized with CAD/CAM technology is a result of the patients' high aesthetic expectations (247). Complete ceramics' exceptional aesthetic attributes include high biocompatibility, plaque prevention, light transmittance, a thermal expansion coefficient that is close to that of actual tooth tissues, thermal conductivity, and color depth (248).

Aesthetic materials used in prosthetic treatment applications are developing at the same time as dental aesthetic requirements are rising. Crowns made entirely of ceramic are frequently used, particularly in locations with high aesthetic standards. The surface characteristics of feldspathic ceramics, in particular, are comparable to those of natural teeth. They also have good abrasion resistance and color stability in the oral environment, as well as the ability to transmit color and light (translucency) (249). These factors led to the feldspathic ceramic being selected as the test substance.

To ensure long-term success in clinical trials, it is imperative to adequately refine all milled materials for optimal smoothness (250,251). To establish a surface that discourages plaque buildup, it is advisable to employ glazing and polishing techniques during repairs. Rough surfaces tend to attract plaque accumulation, which, over time, can lead to a range of problems such as gingivitis, surface stains, cavities, secondary caries, and discoloration (252).

Within the dental literature, material surface smoothness has been quantified using various characteristics, with a common tool being the surface profilometer. Among these measurements, Ra, which represents the arithmetical average of all absolute distances within the linear roughness profile, stands out as the most frequently utilized parameter (253). Surface roughness can be assessed using a surface profilometer. Typically, measurements are taken at select locations on the samples. However, it's important to note that there are instances where these measurements may not precisely depict the topographical characteristics of the ceramic samples (254,255).

After going through thermocycling, the glass-ceramics under research showed noticeable changes in their microstructure, microhardness, and surface roughness. These differences in surface micro- and nano-roughness were noticed and connected to elements including the manufacturing procedure, the surface treatments used, and the particular measuring techniques used for evaluation (256). Our study's conclusions showed that the materials' surface roughness and microhardness values were significantly impacted by thermocycling. Over the course of the inquiry, there were significant changes in the ratings of the tested materials' microhardness and surface roughness.

In 2020, Vasiliu et al. (257) investigated the impact of thermocycling on the surface roughness of various milled CAD/CAM glass ceramics, including feldspathic (Vita Mark II, Germany) and lithium disilicate (E.max CAD, Vita Zahnfabrik, Germany), among other materials. Surface roughness values were measured both before and after subjecting the samples to thermocycling. To standardize the thickness of the samples, a grinding machine (Mecatech 264, France) in combination with 600-2000 grit silicon carbide abrasive papers, while continuously applying water, was used. The final thickness of each specimen was verified with a caliper, ensuring it adhered to the specified thickness of 1.5 ± 0.03 mm. All specimens underwent a specific treatment process: one side was glazed (G), and the other side was polished (P), resulting in a total of 96 surfaces for analysis. For the glazed specimens, two thin layers of a glaze were applied following the recommendations of manufacturer. The study's findings indicated that, in terms of Ra values after thermocycling, the feldspathic ceramic group had an mean Ra value of 0.09 ± 0.06 μm , while the lithium disilicate group had an mean Ra value of 0.03 ± 0.07 μm . Additionally, the study revealed that glazed feldspathic ceramic exhibited higher Ra values, with a Ra value of 0.39 ± 0.01 after thermocycling, compared to the glazed lithium disilicate with a Ra value of 0.16 ± 0.004 . These differences in values may be attributed to variations in the glaze materials used.

Al-Harbi et al. in 2015 (258) investigated how thermocycling affected the surface roughness and microhardness parameters of CAD/CAM milled feldspathic ceramics (Vitablock Mark II: VM) and resin composite ceramics (Lava Ultimate: LU) following the operation. Blocks (Isomet 5000, Buehler) were cut. Using silicon carbide paper with a 1200-grit size, the specimens were wet polished. Thermocycling was conducted: 12.000 cycles, 5 and 55°C, 30 sec dwell time, 2 sec transfer time. After any aging situation, VM's hardness did not significantly alter. After thermocycling the mean surface roughness value of resin composite ceramic and feldspathic ceramic were $0.07 \pm 0.01 \mu\text{m}$ and 0.05 ± 0.00 , respectively. The mean microhardness value of composite based ceramic after thermocycling was $171.8 \pm 4.9 \text{ MPa}$, the mean microhardness value of feldspathic ceramic was $890.1 \pm 15.9 \text{ MPa}$. In our study, the mean surface roughness values of resin composite ceramic and feldspathic ceramic after thermocycling were $1.3 \pm 0.03 \mu\text{m}$ and $1.24 \pm 0.02 \mu\text{m}$, respectively. The mean microhardness value of composite based ceramic in non-glazed group after thermocycling was $114 \pm 2.5 \text{ MPa}$. The mean microhardness value of feldspathic ceramic was $506 \pm 16 \text{ MPa}$. In our study, composite based and feldspathic ceramic materials also did not show significant changes after thermocycling. When the composite containing ceramic and feldspathic ceramic are compared, insignificant decrease after thermocycling were evaluated in our study. The surface area roughness of composite ceramic (GC, Cerasmart) was higher than feldspathic ceramic (Sirona, Cerec) in our study. The difference in value with the above study may be related to the brand and composition differences with materials in our study.

It is stated that tests like atomic force microscopy and scanning electron microscopy can assist in obtaining precise imaging of the surface roughness. (259). Additionally, it is stated that scanning electron microscopy (SEM) can be used to examine samples that don't have a metal coating (260).

SEM micrographs of ceramic materials can show information on their exterior shape, crystalline structure, and chemical composition (261). In our study SEM was used for observation the morphology of the samples. Glazed surfaces were also observed to visually evaluate the difference between the glazed and non-glazed materials. In our study the smoothness of glazed surfaces was observed in SEM images.

Even though all of the materials were polished with the same paste and method, it was discovered that varied roughness levels were measured for the examined materials. It appears that the polishing technique was not as efficient for all ceramic materials. Press pieces presenting the same results (262,263). Another study by Sarac et al. also stated that that a material's structure affects how well it can be polished (264).

According to Bollen et al., the maximum surface roughness for the glazed samples was 0.41 ± 0.03 m, and after thermocycling, it was 0.84 ± 0.18 m and 0.58 ± 0.14 m, respectively. After thermal aging, the mean surface roughness value for the glazed samples doubled.

After milling and postmilling processes, Mota et al. (265) analyzed the surface roughness and examined the surface topography of five distinct CAD/CAM ceramics and one composite-based CAD/CAM for CEREC. Before and after milling, crystallization, polishing, and glazing, as well as blocks made of the composite-based Lava Ultimate, feldspathic ceramic Mark II, leucite enhanced Empress CAD, lithium disilicate E.max CAD, Suprinity and Enamic, were all done at CEREC MCXL. When necessary, the surface roughness (Ra) test was also done. Surface roughness was dramatically raised as a result of the CAM milling process. Surface roughness (Ra) measurements ranged from baseline values of $0.23 \mu\text{m}$ for IPS e.max CAD up to milled values of $2.71 \mu\text{m}$. Glaze greatly lessened the IPS e.max CAD surface roughness. The results were $0.810.11 \mu\text{m}$ after the surfaces were polished. The average value was reduced to $0.32 \pm 0.10 \mu\text{m}$ when the glazing procedure was used. Except for ceramics made of lithium, roughness might be brought down to baseline levels using polishing techniques. Lithium-based ceramics' roughness was greatly decreased by glaze without affecting the baseline. Glazed surfaces are smoother than surfaces that were polished, according to SEM and AFM pictures. In our study the average surface roughness values of IPS e.max CAD after milling was $1.30 \pm 0.06 \mu\text{m}$ and after glaze process the value decrease to $0.16 \pm 0.004 \mu\text{m}$ respectively. It is revealed that glazing significantly decreased the surface roughness values of lithium disilicate ceramic. Because of the absence of polishing procedure, the values may be different with the above study.

In particular for the Vita PM9 ceramic, glazing generated the smoothest surface, suggesting glazing due to its high leucite content among the investigated materials (266). This characteristic was identified both before and after thermocycling. Surface hardness is a quantitative indicator of resistance to repeated indentation.

The ability of the material to be polished and its resistance to occlusal wear are both directly impacted by indentation (267). Ceramics' mechanical characteristics and surface roughness are determined by their microstructure, particularly their crystalline phase (268). Emax samples' maximum microhardness can be attributed to their crystal formations. Lithium disilicate crystals were consistently dispersed throughout the structure, as seen by SEM photos of Emax specimens (269). Recent investigations revealed that feldspathic ceramic was outperformed in terms of hardness by disilicate lithium ceramic (270,271). This finding was also seen in our study. Lithium disilicate ceramic showed the highest microhardness values compared to other tested materials.

Aldosari et al. in 2021 (272) and compared the impact of surface roughness (Ra) on tested feldspathic (Vita Mark II, Germany), lithium disilicate Zirconia (Vita Suprinity, Vita, Germany), and hybrid resin (Vita Enamic, Vita, Germany) glazed and polished ceramics that were submerged in hot, cold, and thermocycling coffee. demonstrated that after immersion and thermocycling, an increase in Ra was seen for all of the glazed and polished samples. The samples' surface roughness before and after thermocycling varied, and the findings showed that Ra was strongly impacted by thermocycling, especially on polished surfaces. After thermocycling, the mean Ra values for the polished, glazed, and VE samples were 0.51, 0.35, 0.48, and 0.68, 0.76, 0.67 μm , respectively. Alhabdan et al. (295) measured 0.56 μm for glazed surfaces of feldspathic ceramic and found similar results. It was determined that all the glazed with polished subgroups showed increased surface roughness during immersion and thermocycling. The value was highest in the polished feldspathic ceramic (VM II) group. It was also discovered that the polished samples had higher roughness than the glazed samples did in the SEM pictures. In our study, mean Ra value of feldspathic ceramic was found 0.38 μm , similar to the Ra value of the feldspathic ceramic (0.35 μm) mentioned in the study above. However decreased Ra values were observed after glazing and thermocycling. A few differences were observed in distinct results with the study above. It may be due to the difference in the method of the study.

According to Ludivichetti et al.'s study (273) SEM provided an evaluation of the glazed surfaces' quality and showed the structural differences between the surfaces before and after thermocycling. Crystals of particular sizes may be seen in the structure of the evaluated ceramics prior to thermocycling when viewed in SEM micrographs. After thermocycling, these crystals in the feldspathic glass-ceramic are more challenging to identify. Lithium disilicate glass-ceramics were the least affected by thermocycling. The mean Ra (m) values for the glazed groups were 0.061 0.05 m in profilometry and 0.11 0.001 m in thermocycling for the glazed samples.

In 2022, Limpuangthip N. et al. (274) assessed the microhardness and surface roughness of CAD/CAM materials such clear zirconia, lithium disilicate glass ceramic, and zirconia lithium silicate ceramic (IPS E.max CAD). The study's objective was to compare the effects of grinding and polishing on the surface roughness of various materials. A digital vernier caliper, an ultrasonic cleaner, and a specialist pressure control polishing unit were among the instruments the authors employed to obtain accurate measurements. Surface roughness was the major outcome of interest and was measured with a noncontact optical profilometer. The authors outline the measurement process as well as their choice to focus primarily on a few areas of the specimens for evaluation. In order to give a suitable point of comparison for the inquiry, the complete polishing roughness of the specimens is compared to laboratory specimens and human enamel as-received. After 60 seconds of fine polishing, IPS. Emax CAD's surface roughness was determined to be 0.936 0.110. After polishing, the mean microhardness of the IPS e.max CAD was found to be 557.930.7 MPa and 554.74.2. In our study Ra of IPS E.max CAD material after glazing was found (0,16±0,004). The mean microhardness values in our study were found 643±9.2 MPa and 601±5.0 MPa after glazing. We think that this difference may be due to the difference of the method of the study.

In 2015, Fasbinder et al. (48) carried out a study to assess the surface roughness of CAD/CAM (computer-aided design/computer-assisted machining) chairside restorations milled from various CAD/CAM materials. The purpose of the study was to evaluate the ability of various contouring and polishing technologies to produce surfaces that were clinically acceptable. One hundred onlays were created utilizing an MCXL milling chamber (Sirona Dental) using monolithic CAD/CAM blocks. These onlays were made of 40 leucite-reinforced ceramic (Empress CAD, Ivoclar, Germany), 30 hybrid ceramic (Enamic, Vita, Germany), and 30 resin nano-ceramic (Lava Ultimate, 3M ESPE). Empress CAD onlays from one batch were fired with glaze in a porcelain oven (Programat CS2, Ivoclar, Germany). An abrasive-polish technique and a brush-polish technique were used as finishing and polishing processes, respectively. Using an Olympus OLS4000 LEXT three-dimensional measuring laser microscope, surface roughness was determined. Leucite-reinforced ceramic (Empress CAD) had the roughest surface, whereas resin nano-ceramic (Lava Ultimate) had the smoothest surface. The initial surface roughness of the various CAD/CAM materials greatly differed. Surfaces produced by all polishing techniques were smoother than the leucite-reinforced ceramic's standard level of roughness. Additionally, compared to surfaces created by glazing in a porcelain kiln, all polishing techniques produced surfaces that were substantially smoother. Both the hybrid ceramic and nano-ceramic materials had smoother surfaces compared to their initial degree of roughness after completing both polishing techniques. Ceramic surfaces that had been polished in general were smoother than those that had been glazed. In conclusion, the study showed that different finishing and polishing processes can be used to achieve comparable smooth surfaces for chairside CAD/CAM restorative materials compared to milled ceramics. Furthermore, compared to glazed ceramic surfaces, polished ceramic surfaces exhibited smoother features. In our study, it was revealed that after glazing, the surface of all materials become smoother comparing with the baseline surface. When comparing the smoothness of tested materials, Empress (leucite reinforced ceramic) showed higher surface roughness value (1.14 ± 0.04) than Cerasmart (1.06 ± 0.07). However, after glazing Cerasmart (Composite based Hybrid Ceramics) showed higher surface roughness value (0.31 ± 0.02) than Empress (0.19 ± 0.01) material. Values may be different with the study above because of the difference in measurement methods and the methods that was used in the study.

Since resilient CAD/CAM restorative materials are still relatively new on the market, there haven't been many research that focus exclusively on them. The surface roughness of the more recent CAD/CAM materials was assessed in an in vitro investigation (275). Following the glazing technique, surface roughness and microhardness were assessed right away, and again after six months of storage using artificial toothbrushing. According to their findings, storage and artificial toothbrushing tend to have less of an impact on Enamic's surface. Even though there was no statistically significant difference between the materials, it is interesting that the average Ra values recorded for Lava Ultimate were lower than the values reported for Enamic. This was consistent with the results of the current investigation. Although the abrasive rubber polisher systems appear to have a clear clinical advantage, the brush/paste polishing strategy (VH Technology) was able to achieve equally smooth surfaces for all three of the investigated CAD/CAM materials. The use of abrasive rubber points or wheels tends to flatten and erase surface anatomy when compared to the brush/paste method while providing a smooth surface by adapting to the existing surface anatomy. This in vitro experiment should be followed by clinical research to determine the extent to which the smooth surfaces on flat specimens may be reached on clinical anatomical surfaces. In our study surfaces of the samples were not polished. Surface structure of the samples were evaluated after application of glaze layer (48).

Ceramic glaze is made from a colorless glass powder. It is applied to the restoration's surface and burned to give it a shiny sheen. The molten glass fills and seals the pores on the surface. (276). The idea was supported by the study's findings, which revealed that monolithic ceramic restorations that had undergone glazing and thermocycling processes displayed variations in their surface roughness (Ra) and microhardness (VH) values. In order to reduce the amount of bacterial retention, dental materials' surface roughness values should be less than 0.2 μm , according to Bollen et al. (277). However, when the findings of some studies in the literature were examined, it was found that this value could not be attained (278,255,279). The average surface roughness in all of the glazed groups in our investigation was greater than. Surface roughness values of E.max and Empress group were found less than 0.2 μm after glazing. However, Cerec and Cerasmart group exhibited values higher than 0.2 μm .

When placing a ceramic restoration, the occlusion and contacts must be adjusted since a rough surface is more prone to staining and plaque buildup, which increases the risk of gingivitis and tooth decay (280). Additionally, rough ceramic restorations are abrasive and may cause opposing teeth or restorations to wear more quickly (281). Ceramics' strength can be negatively impacted by roughness, leading to cracking, chipping, and fracture. Studies have shown a strong relationship between surface roughness and biaxial flexural strength (61). The ceramic repair is stronger when the surface is smoother. For a multitude of reasons, including esthetic appeal, patient comfort, and biological considerations, achieving a smooth ceramic surface is crucial. (280).

Numerous researches have shown that reglazing firing techniques result in a smooth surface, but other studies have found that mechanical polishing may produce a surface that resembles the real tooth more. Due to their greater level of control throughout the final surface's polishing, these latter persons like the polishing methods (302,94). The research is divided on the optimal method for performing surface treatments, and there isn't a publication that compares all surface treatments. (263,302,282).

Most often, authors utilize a profilometer in conjunction with mean roughness value (Ra) measurements to assess the surface roughness values in dentistry (283,259,284,284)

The mean arithmetic value of all the absolute distances along the measured length from the roughness profile to the intermediate height is known as the Ra, which describes the texture of a surface (253).

Carrabba et al. (285) in 2016 For chairside CAD/CAM systems, the surface gloss and roughness of feldspathic ceramic blocks were compared before and after finishing and polishing. To create 70 specimens (14x18x3 mm), perpendicular cuts were made in Vita Mark II ceramic blocks. The area was flattened using silicon carbide paper with a 120-grit rating. A profilometer (Mitutoyo, Japan) was used to measure the surface roughness (Ra) of 10 crowns that were milled using the MC-XL InLab milling unit (Sirona, Germany). In the investigation, various polishing techniques and glazes were applied. It was claimed that there were no appreciable differences between the polishing groups and the Akcent Glaze Spray group.

The surface roughness values of glaze group were as follows: $0.99 \pm 0.19 \mu\text{m}$ at baseline and $0.79 \pm 0.25 \mu\text{m}$ after glazing. In our study the mean surface roughness (Ra) values of feldspathic ceramic (Cerec) were $0.98 \pm 0.02 \mu\text{m}$ and $0.38 \pm 0.01 \mu\text{m}$ after glazing, respectively (285). In our study, the mean Ra value after glazing was lower ($0.38 \pm 0.01 \mu\text{m}$) compared to the study above. We think that this might be caused by variations in glaze composition and ceramic brand. Due to these variations, the current study's comparison of values may not be accurate.

In 2019, Amin et al. (286) conducted a study that examined how four CAD/CAM materials' surface roughness and hardness changed as a result of thermo-mechanical aging. The study looked at four commercially available CAD/CAM materials, including Cerec Blocs and Celtra Duo, two ceramic materials, and Cerasmart and Vita Enamic, two hybrid ceramics. Five disks of each material were made for the investigation, and utilizing a mechanical chewing simulator, these disks underwent 250,000 thermocycles of thermo-mechanical aging. Each material's surface roughness and micro-hardness were measured both before and after the thermo-mechanical aging procedure. Vickers hardness testing equipment was used to assess micro-hardness, and digital image processing was employed to assess surface roughness. Surface roughness among the investigated materials did not significantly differ prior to thermo-mechanical aging. Except for Cerasmart, which showed a notable rise, other materials after aging showed minor variances among them and negligible increases in surface roughness. Prior to aging, the evaluated materials showed a noticeable variation in terms of surface micro-hardness. They were Cerasmart, Enamic, Cerec Blocks, and Celtra Duo, in that order. However, after aging, there were no discernible variations in the surface micro-hardness of the materials, and there was barely any change in micro-hardness between the two times. In our study regarding the surface micro-hardness values, the tested materials showed significant difference pre aging in the ascending order of Cerasmart < Cerec < Empress < E.max. Regarding the surface roughness values, the tested materials showed significant difference pre aging in the ascending order of Cerec < Cerasmart < Empress < E.max. After thermocycling, the ascending order of materials was Empress < Cerec < Cerasmart < E.max. After aging, similarly to the study mentioned above, all materials showed insignificant difference in surface micro-hardness between each other and insignificant change between before and after the test. However, all values decreased after the test.

In 2021, Çakmak et al. (287) carried out a study to look into how polishing and glazing affected surface roughness and microhardness. Polymer-impregnated ceramic networks, lithium disilicate, monolithic zirconia, ceramic specimens reinforced with leucite, ceramic specimens reinforced with zirconia, and ceramic specimens made of feldspathic material were some of the materials covered by the study. The findings demonstrated that interactions between material types and surface finishing procedures had a substantial impact on changes in surface roughness, hardness, volumetric material loss, and enamel height loss. In our study the results obtained in the pre and post glaze roughness measurements were similar to this study. In our study it was reported that glazing affected the microhardness and surface roughness values of all tested materials. However, polish, wear test and zirconia were not tested in our study. Indeed, comparing the results of current studies may be challenging due to these inherent differences among the materials and testing methods employed.

Tekçe et al in 2018 (288) investigated how accelerated aging affected the surface characteristics of glazed CAD/CAM composite blocks. They employed three distinct materials: Cerasmart (GC, Japan), VITA Enamic (Vita, Germany), and LAVA Ultimate (3M ESPE, USA). According to the study, CAD/CAM resin materials' surfaces were smoothed by the glaze material Optiglaze Color, and these glazed surfaces appeared to be resistant to wear even after 5000 heat cycles.

Kim et al in 2022 (289) evaluated modifications in the mechanical and surface characteristics of various CAD-CAM materials after exposure to mechanical loads and thermocycling. In addition to feldspathic ceramic (Vita Mark II, Vita, Germany), lithium disilicate ceramic (E.max, Vita, Germany), zirconia-reinforced lithium silicate glass-ceramic (Celtra Duo, Sirona, Germany), polymer-infiltrated ceramic network (Vita Enamic, Vita, Germany), and resin-nanoceramic (CS; Cerasmart), several other types of ceramic materials were also looked at. Each type was split into two groups of fifteen (n=15). One group underwent 50 N mechanical loading for 1.2106 cycles and 6000 cycles of thermocycling in distilled water at 5 C to 55 C. The alternate group was kept in water at 37 C for 24 hours. In order to analyze the mechanical properties, three parameters were measured: nanoindentation hardness, young modulus, and 3-point flexural strength. To examine the surface properties, measurements of surface roughness, surface microstructure, and elemental composition were made. The lowest hardness values were found in CS both before and after the aging procedure, while the highest surface roughness values were found in Cerasmart. After thermocycling, Vita Mark II, E.max, and Vita Enamic materials' hardness significantly decreased and all the materials' surface roughness significantly increased, along with changes to their microstructures. The mechanical parameters and surface characteristics of the CAD-CAM materials were significantly affected by age, with resin-nanoceramic exhibiting the lowest hardness and maximum surface roughness. With the exception of Empress material, which did not show any significant increases in surface roughness after age in the unglazed group, these data underscore the significance of material type and aging in determining these attributes. In our study it was revealed that, after thermocycling significant increases were observed in the surface roughness of all materials in non-glazed groups except Empress material. Because of the difference of the measurement techniques and material methods values in comparison with the above studies were different.

Zanoboni et al. in 2022 (290) conducted studies to evaluate the effects of various glaze firing techniques and microhardness values on the properties of CAD/CAM ceramics. This in vitro investigation's main goal was to determine how different glaze firing techniques impact CAD-CAM ceramics' resistance to abrasion, surface roughness, microhardness, and brittleness index. The materials from CEREC, E.max CAD and Empress CAD were tested as part of the study. Based on the glaze firing technique each group experienced, the materials were classified into five groups, each with eight examples. The following groups made up these: Only optical polishing was given to the Control group (CO). The conventional glaze firing group's (GF) samples were glazed according to the supplier's instructions. Following the procedure outlined by Aurélio et al. (291), the Extended Glaze Firing group (EG) had an extended glaze firing in which specimens were kept at glaze temperature for 15 minutes. Conventional Glaze Firings (GF2) group specimens underwent two conventional glaze firings, much like the GF group. Extended Glaze Firings (EG2) group specimens were subjected to two extended glaze firings utilizing the identical techniques as the EG group's single firing.

All glaze firing procedures and the crystallization of EMAX samples were completed in a particular oven (Programat P310, Ivoclar, Germany). The mean microhardness values of tested CAD/CAM materials after optical polishing (CO group) were found as follows: IPS E.max CAD: 615.7 ± 27.9 MPa, IPS Empress CAD: 655.0 ± 59.7 MPa, Cerec: 729.9 MPa. The mean microhardness values after glazing in GF (Glaze Firing) were found as follows: IPS E.max CAD: 579.7 ± 52.2 , IPS Empress CAD: 629.2 ± 26.2 MPa, Cerec: 555.0 ± 42.5 MPa. The mean microhardness values after glazing in GF2 (Glaze Firing 2) were found as follows: IPS E.max CAD: 531.6 ± 60.6 MPa, IPS Empress CAD: 608.4 ± 30.2 MPa, 586.1 ± 36.1 MPa. In our study the mean microhardness values of tested CAD/CAM materials after glazing procedure were found as follows: IPS E.max CAD: 598 ± 3.7 MPa ± 5 , IPS Empress CAD: 573 ± 6.6 MPa, Cerec: 453 ± 2.7 MPa, respectively. These findings in our study suggest that the microhardness values of the Cerec and Empress groups were lower compared to the study mentioned above, while the E.max group exhibited similar microhardness values (290).

In 2020, Kara et al. (292) conducted a study to assess the surface area roughness of three distinctive CAD/CAM restorative materials after the glazing and polishing processes. The aim of this research was to investigate how various polishing techniques affect the surface properties of CAD/CAM composite-based blocks. The materials used in this study included Shofu Block, Cerasmart and Lava Ultimate. CAD/CAM specimens with a thickness of 3 mm were obtained by cutting with a low-speed diamond saw (Isomet 1000, Buehler, USA) to create a total of 150 specimens (50 for each material). Subsequently, a polisher and grinder device equipped with 600 Silicon Carbide grit (MetaServ, Lake Bluff, Buehler, IL, USA) was used for surface treatment. Air blasting with Al₂O₃ particles of 50 µm size (Basic Eco, Renfert, Germany) was applied to the specimens using 2.5 bars of pressure at a 10 mm distance. G-Multi Primer silane from GC Corp. was then applied to the specimens for 30 seconds and air-dried. The glazing process followed the manufacturer's recommendations, using Optiglaze Color (GC Corp.), and the polymerization was carried out for 5 minutes using Labolight Duo (GC Corp.). The study included four additional groups where specimens were polished using various polishing systems and techniques. Surface area roughness values, denoted as Ra, were measured and compared. After the application of Optiglaze Color, the mean surface roughness (Ra) values were determined as follows: Cerasmart: 0.170 ± 0.06 µm, Lava Ultimate: 0.164 ± 0.03 µm, Shofu Block HC: 0.226 ± 0.08 . The study concluded that Optiglaze Color creates smooth resin CAD/CAM surfaces. The similar statement was found in our study. However, in our study the mean surface roughness (Ra) value after the application of Optiglaze Color glaze layer was found 0.31 ± 0.02 µm, that was higher than the study above. The value difference may be related to the different methods of the study above. In our study, the specimens were milled by CAD/CAM Cylinder Pointed bur 12S and Step Bur 12S bur Therefore, the glaze that was applied on the rougher surfaces may cause the higher values in comparison with the study above (292).

In a study by Flury et al. in 2010 (293) examined the surface roughness values of two types of dental porcelain materials, namely, feldspathic porcelain (Vita Mark II, Vita) and leucite-enhanced porcelain (IPS Empress CAD, Vita), after applying glaze and various polishing systems. They utilized Vita Akzent Glaze and Universal Empress Glaze materials, along with EVE Diacera, OptraFine-System, Sof-Lex, and Brownie/Greenie/Occlubrush polishing systems. For the study, sixty blocks of each material were cut in two half using an Isomet (Low-Speed Saw, USA). They further prepared 120 specimens from two groups by roughening them with a grinding machine (Struers Tegra Pol 15, Denmark) and wet sandpaper under water cooling (Struers, Silicon Carbide grit 120m, diameter 200mm) for 20 seconds at a speed of 200 rpm with a pressure of 10 N. Surface roughness measurements, denoted as Ra, were conducted using a surface roughness tester machine (Perthometer S2, Mahr, Germany), with three measurements taken for each specimen. VITA Akzent Glaze (Vita, Zahnfabrik) glaze layers were applied to the Vita Mark II specimens, while Empress Universal Glazing Paste (Ivoclar Vivadent AG) glaze layers were applied to the IPS Empress CAD specimens. The specimens were then fired using a Programat P500 furnace (Ivoclar Vivadent AG). Additionally, twenty roughened ceramic specimens of Vita Mark II and twenty roughened porcelain samples of Empress CAD were glazed to evaluate as reference samples, which were subsequently sonicated for 3 min in ethanol (Telsonic TPC-25) and dried with air. The mean surface roughness value (Ra) of Vita Mark II after using Sof-Lex polishing system was found 0.198 μm , which was lower compared to the glazed group (mean Ra=0.306 μm). The mean surface roughness (Ra) value IPS Empress CAD after using JOTA polishing system was found 0.342 μm , that was lower than the glazed group (0.433 μm). In our study, the mean surface roughness (Ra) value of IPS Empress CAD after glazing was found 0.189 μm , which is lower than the study above. It was also found in our study that the mean surface roughness (Ra) value of Cerec (Feldspathic Ceramic, Sirona, Germany) was found 0.385 ± 0.01 μm , which is higher than the study above. The difference in values with the study above may be related to the difference in glaze materials. In our study IPS Ivocolor (Ivoclar, Germany) was used as a glaze material.

Comparing the findings of the study to those of previous research can be complex due to various factors, such as the specific ceramic types used, the presence of any voids or surface irregularities, and differences in surface roughness. It is worth noting that the Ra value obtained through Profilometer measurements can be influenced by several variables, including the diameter of the stylus used, scanning speed and length, applied force, and frequency response. These factors may contribute to variations in the reported results and should be considered when interpreting and comparing data from different studies (263).

The findings we obtained from our in vitro thesis study, mechanical characteristics of, E.max CAD, Empress CAD, Cerasmart and Cerec monolithic ceramic materials were found to be sufficient for clinical use. However, further clinical trials are needed to support the results of our study.

Based on the results of our study, the lower surface roughness values that were found after glazing process contributes to increased longevity of the materials in clinical use, enhancing their overall performance and durability in clinical settings.

The in vitro nature of this study, which does not reproduce oral cavity conditions including wear, occlusal forces, and salivary presence, is one of its limitations.

Other research is required to assess the surface properties of other CAD/CAM monolithic ceramic restorations subjected to various surface treatment regimens and to simulate other oral environment parameters.

6. CONCLUSION

Within the limitations of this in-vitro study, the following conclusions may be drawn

1. The hypothesis of the study was approved. There is a difference between glazed and non-glazed samples in terms of surface roughness and microhardness values.
2. There is a difference between tested materials in terms of surface roughness and microhardness values.
3. Thermocycling influences surface roughness and microhardness of the samples.

It was concluded that there is a statistically significant difference between glazed and non-glazed CAD/CAM materials in terms of surface roughness and microhardness values.

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9. CIRRICULUM VITAE

Kişisel Bilgiler

Adı	Farid	Soyadı	Ahmedbeyli
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Öğrenim Durumu

Derece	Alan	Mezun Olduğu Kurumun Adı	Mezuniyet Yılı
Doktora	Restoratif Diş Hekimliği	Yeditepe Üniversitesi	2023
Yüksek Lisans			
Lisans	Diş Hekimliği	Yeditepe Üniversitesi	2013
Lise	-		

* Başarılmış birden fazla sınav varsa (KPDS, ÜDS, TOEFL; EELTS vs), tüm sonuçlar yazılmalıdır

Bildiği Yabancı Dilleri	Yabancı Dil Sınav Notu (#)

İş Deneyimi (Sondan geçmişe doğru sıralayın)

Görevi	Kurum	Süre (Yıl - Yıl)
		-
		-

Bilgisayar Bilgisi

Program	Kullanma becerisi

* Çok iyi, iyi, orta, zayıf olarak değerlendirin

Bilimsel Çalışmaları

SCI, SSCI, AHCI indekslerine giren dergilerde yayınlanan makaleler

Diğer dergilerde yayınlanan makaleler

Uluslararası bilimsel toplantılarda sunulan ve bildiri kitabında (*Proceedings*) basılan bildiriler

Hakemli konferans/sempozyumların bildiri kitaplarında yer alan yayınlar
