HARDNESS AND FRACTURE TOUGHNESS BEHAVIOURS OF CAD-CAM DENTAL CERAMICS

by

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HARDNESS AND FRACTURE TOUGHNESS BEHAVIOURS OF CAD-CAM DENTAL CERAMICS

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ABSTRACT

HARDNESS AND FRACTURE TOUGHNESS BEHAVIORS OF CAD-CAM DENTAL CERAMICS

The purpose of this research is to study the effect of machining on the CAD/CAM dental materials and to evaluate surface roughness, hardness and fracture toughness for a 4different types of dental materials (Vita Enamic, GC Cerasmart, Celtra Duo and IPS e.max ZirCAD). These dental materials also called as CAD/CAM Dental Ceramics. In dental ceramics, actually there are glass-ceramics, composite materials, oxide based ceramics. All these CAD/CAM dental ceramic materials need cutting and polishing steps during the preparation for individual patient.

Cutting and polishing are mechanical processes and usually result with a surface with various surface roughness depends on the equipment and polishing powders used.

Surface roughness is an important material characteristic which influence the optical properties and mechanical behaviors of the materials.

In the present study; surface roughness's of the dental ceramics were evaluated according to the mesh numbers of the polishing papers (600-1200-2500 mesh). The effect of the surface roughness's on the mechanical properties namely hardness (HV) and fracture toughness (K_{IC}) were studied by applying Vicker's Indentation technique in all the samplesafter various polishing steps.

Hardness and fracture toughness values were evaluated and compared for all the dental materials. As expected that, ZrO_2 based ceramic was the hardest and toughest and these values were lover with increasing polymer content in dental materials.

ÖZET

HARDNESS AND FRACTURE TOUGHNESS BEHAVIORS OF CAD-CAM DENTALCERAMICS

Bu araştırmanın amacı, kesme ve parlatma gibi mekanik işlemlerin, 4 farklı tipte dental malzemelerin (Vita Enamic, GC Cerasmart, Celtra Duo ve IPS e. max ZirCAD) CAD/CAM mekanik özellikleri üzerine etkilerini incelemektir. Dental CAD/CAMmalzemeleri, cam-seramikler, kompozit malzemeler ve oksit bazlı seramikler gibi malzemelerdir ve bu malzemelerden, hastalara özel diş yapısı üretilirken kesme ve parlatma işlemleri uygulanmaktadır.

Kesme ve parlatma işlemleri mekanik işlemler olup, kullanılan cihaz ve parlatma tozunun boyutuna bağlı olarak, işlenen malzeme yüzeyinde farklı yüzey pürüzlülüğüne sebep olmaktadırlar.

Yüzey pürüzlülüğü önemli bir malzeme karakteristiği olup, optik özellikleri ve mekanik davranışları etkilemektedir.

Bu çalışmada, dental seramiklerin yüzey pürüzlülükleri, parlatma kağıtlarının Grit (Mesh) numaralarına göre (600-1200-2500 grit) incelenmiş ve değerlendirilmiştir. Yüzey pürüzlülüğünün, sertlik ve tokluk üzerindeki etkilerini incelemek için Vickers İndentasyon yöntemi kullanılarak, sertlik ve tokluk ölçümleri yapılmıştır.

Sertlik (HV) ve tokluk (K_{IC}) sonuçları tüm dental malzemeler için değerlendirilmiş ve kıyaslanmıştır.

Beklendiği gibi; ZrO_2 bazlı seramik malzemesi en sert ve en tok malzeme olarak ortaya çıkmıştır. Dental malzemeler içindeki polimer oranı arttıkça sertlik değerleri düşmektedir.

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LIST OF SYMBOLS/ABBREVIATIONS

CAD/CAM	Computer-Aided Design/Computer-Aided Manufacturing
HV	Vickers hardness
P	Load
c	Inclining of break length
K1C	Fracture toughness
c	Half slanting of the break length
Ra	Arithmetic mean of the surface
µm	Micrometre
MPa	Mega Pascal
N	Newton
GPA	Giga Pascal
ISO	The International Organization for Standardization

1. INTRODUCTION

Hardness, fracture toughness, and frictional resistance are physical material-dependent characteristics that influence wear. These also have anything to do with how abrasive ceramic materials are. Ceramic materials should have sufficient fracture toughness. Otherwise, brittle fracture may occur during the grinding process. Brittle eruptions can lead to increased wear rates and resharpening of broken edges depending on the type of ceramic material [1]. Ceramic materials are widely used in dentures due to their unique properties such as biocompatibility, chemical integrity, mechanical durability and optical properties. In recent years, digital technology in the field of dentistry has developed rapidly, and high-precision computerized manufacturing processes have improved the quality of materials [2,3]. The development of ceramic-based and computer-aided design/computer-aided manufacturing (CAD/CAM) materials has opened up new possibilities [2,3]. Most studies have investigated the damage properties of varied ceramic materials that counter solid body substance. With the growing popularity and clinical application of CAD/CAM ceramic restorations and therefore the increasing prevalence of patients with high masticatory strength, it's important to grasp the wear and tear potential of both the fabric and its enamel antagonists. The aim of this project is to calculate surface roughness , hardness and fracture toughness for different materials (Vita Enamic, GC Cerasmart,Celtra Duo and IPS e.max ZirCAD), which are used in dentistry field and compare these results to the standard values. Finally, conclude the best testing method used in thisdomain.

1.1. DENTAL CERAMICS

To restore the comfort and functionality of genuine human teeth in cases of partial or complete tooth loss, the damaged or missing portion must be repaired [4]. Dental ceramics are materials that were developed with the intention of replacing missing or damaged tooth structures [5]. Ceramics are described as compounds of steel and non-steel factors which include steel oxides, borides, nitrides, carbides, silicates and complicated combos of those materials. Si-tetrahedrons, SiO_4^{4-} are standard shape of silicates (Figure 1.1) [6].

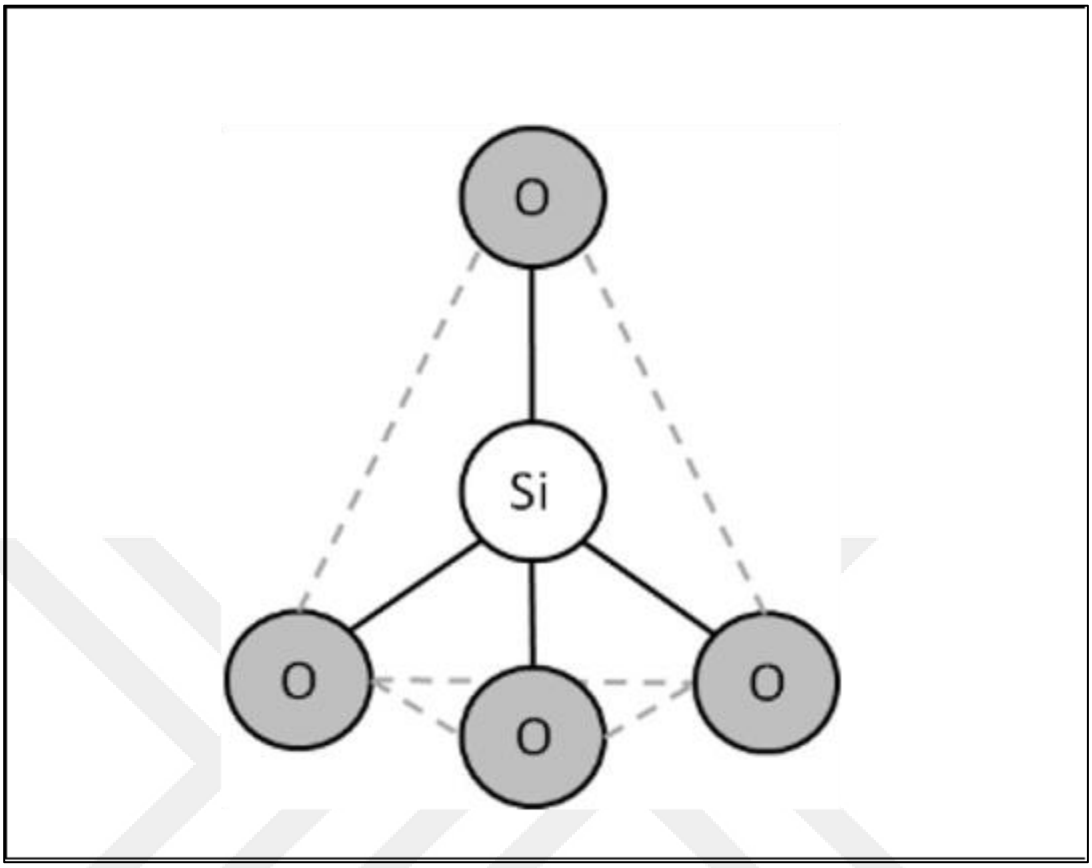

Figure 1.1. Si-tetrahedron (SiO_4^{4-}) setup of ceramic with a solitary silicone molecule (Si^{4+}) at the middle, encompassed by four oxygen iotas (O^-) at the corner.

Si-based inorganic materials, for example, feldspar, quartz and silica are the primary parts of dental ceramics. The expression "porcelain" is frequently utilized for conventional feldspar-based earthenware production on account of the great extent of silica. The proportion of feldspar, quartz and silica content in the ceramic decides the distinction between a typical ceramic and a dental one. A dental ceramic contains a scattered glasslike stage encompassed by a nonstop undefined polished stage, which can be alluded to as a multiphase framework. Ceramics production exist in the underlying type of crystalline solids or glasses [6]. They are generally utilized biomaterials in supportive dentistry because of their natural properties of biocompatibility, synthetic trustworthiness, mechanical opposition, and optical characters [7]. They have appealing clinical properties and stylishly satisfying because of their variety, shade and shine [8].

1.1.1. History of dental ceramics production

In 1774, the French specialist Alexis Duchateau had made the principal effective dental prosthesis made of porcelain. Dental porcelain was first delivered in 1838 with enhancements in clarity and shades to match normal teeth. In the mid-1900s, porcelain coat crowns containing either feldspar or alumina, otherwise called aluminous, were first made. In any case, because of the perception of unfortunate match in thermal expansion coefficients between metal combination structure bases and veneering pottery, leucite- containing feldspar ceramics were created in 1960s [9]. In late many years, scientists have zeroed in on all-ceramic rebuilding efforts to foster reclamation without metal bases.Today, high-strength centre ceramic production, for example, zirconia are all the more regularly utilized and have replaced metal foundations in prosthetic dentistry [10].

1.2. DENTAL MATERIALS

1.2.1. Glass Ceramics

Using a ceramic block made of fine-grained feldspathic porcelain (VitaTM Mark I, Vita Zahnfabrik, Bad Sackingen, Germany), the first inlay fabricated via CAD/CAM was produced in 1985 [11]. The block was fully sintered before vigorous machining. A success rate of 90.4% was reached in a 10-year prospective study examining the therapeuticefficacy of these CAD/CAM inlays and onlays. [12]. But after two years, a substantially greater breaking rate of up to 36% was also found [13]. Vita TM Mark II (Vita Zahnfabrik,Bad Sackingen, Germany), which was first developed in 1991 solely for CEREC (Cerec TM 1 - Siemens GmbH, Bensheim, Germany), displayed exceptional mechanical properties with a reported flexural strength ranging from approximately 100 MPa to 160 MPa when glazed. The ingredients used to make 6 Vita TM Mark II blocks are identical to those used to make traditional feldspathic ceramic, however they are produced using a distinct technique called extrusion moulding. A plasticized ceramic mixture is squeezedand extruded via a nozzle to give it shape. After several days of drying, the blocks are subsequently sintered. Following five years, survival rates for Vita TM Mark II inlays were94.7%, eight years, 90.6%, and ten years, 85.7-89%. According to an in vitro analysis of mandibular crown specimens created from Vita TM Mark II blocks using Cerec TM 3, the marginal gap may be obtained between 53 and 67 mm (Sirona Dental Systems, Bensheim, Germany).

1.2.2. Reinforced Glass Ceramics

By combining the ideal combination of leucite ceramic, this ground-breaking novel feldspar ceramic block offers the greatest aesthetics of conventional feldspathic porcelain with increased flexural strength. Flexural strength and resistance to potential crack forms and chipping at the edges are provided by leucite reinforcement of glass ceramic. Leucite crystals' particle size and particle distribution contribute to their beautiful appeal since they reflect incident light similarly in nature. These ceramic particles are uniformly dispersed and dense, giving your patients restorations that are not only stunning and aesthetically pleasing but also sturdy and long-lasting. ProCAD, which came out in 1998, was the first glass-ceramic CAD/CAM block with leucite reinforcement.

(Ivoclar).

It changed into the current IPS Empress CAD, a glass ceramic similar to IPS Empress I but with particles that are 1 m to 5 m in size and a leucite reinforcing percentage of 35% to 45%. The blocks are available in nine well-liked colors and two translucency levels, high translucency (HT) and low translucency (LT).The LT type has a brighter value than the HT type, which has increased translucency, and is available in four bleach tones. IPS Empress CAD blocks come in a variety of colors. The block, which comes in five colours, mimics the change of colour and translucency in the natural dentition by having a colour gradient from cervical to incisal. With the use of IPS Empress Universal Stains, individual shade modification of either the monochromatic or multicolour blocks can be achieved. Leucite crystals in the IPS Empress CAD (Ivoclar Vivadent) glass-ceramic, which has a SiO_2- Al_2O_3-K_2O materials combination, range in size from 5 to 10 µm [14]. The crystalline phase absorbs fracture energy, whereas the leucite ($KAlSi_2O_6$) crystals boost the material's strength and slow down or deflect crack propagation. Giordano asserts that the strength and surface characteristics of this leucite-reinforced ceramic material are comparable to thoseof Vita blocs Mark II [15].

1.2.3. Hybrid Ceramics

The first dental hybrid ceramic with a dual-network structure is called Vita Enamic. In this dental material, a polymer network that is totally interwoven with the main ceramicnetwork strengthens it. This novel hybrid ceramic ensures a particularly high load capacity following adhesive bonding in addition to a high degree of flexibility.

Features/Benefits of VITA ENAMIC include:

1. a large load capacity due to the absorption of masticatory stresses;
2. the ability to reduce wall thickness to generate restorations that are soft on oral material;
3. exceptionally accurate outcomes;
4. and quick and effective CAM production.
5. material attributes like teeth [16]

It is made of 86 weight percent sintered feldspar ceramic with holes filled with 14 weight percent UDMA/TEGDMA polymer resin. A block with feldspar ceramic-polymer infiltration is called Vita Enamic [17].

1.2.4. Polymers

Acrylic temporary materials are the newest material to be added for CAD/CAM chairside repairs. Temporary crowns and fixed partial dentures (FPDs) can now be created using CAD/CAM technology in laboratories and with the use of digital impression systems. On traditional self-cure or VLC acrylics, the CAD/CAM method prevents shrinkage from polymerization as well as an air-inhibited top layer [18]. Thin-walled restorations can frequently be inserted with enough room thanks to the reconstruction of the occlusal vertical dimension. High-density polymer materials appear to be suitable for these minimally invasive or non-invasive restorations, such as temporary veneers and onlays, because they may be manufactured in thicknesses as thin as 0.3 mm. The natural enamel coating typically has a thickness of more than 1 mm, although these restorations can be made much thinner. A process called adhesive luting can be used to put them. As a result, these actions significantly preserve tooth structure. In order to support multiple-unit FPDs, Vita CAD-Temp* (Vident) is a highly crosslinked micro-filled polymer that comes in extended block sizes, including lengths of 40 mm and 55 mm. It is available as a four- shade monochromatic block or, for more aesthetically pleasing applications, as a multicolour form with four shade layers. Ivoclar Vivadent's Telio® CAD, a millable cross- linked polymethylmethacrylate block for temporary crowns and FPDs, was just released. The block is a component of the Telio system, which also consists of cement, desensitizers,and a self-curing composite. It comes in five different colours. The manufacturers advise using both temporary products for up to a year of clinical use.

1.2.5. Oxide Ceramics (Infiltrated Ceramics & Sintered Ceramics)

The transition to larger volume percentages of crystalline material with progressively less glass until there is no glass at all can be visualized as the development of better strength ceramics for veneered all-ceramic prostheses. John McLean published a paper in 1965 on the use of aluminium oxide particles to reinforce feldspathic glass [19]. By first mildly burning packed alumina powder and then introducing glass into the remaining porous alumina compact, it was possible to dramatically enhance the aluminium oxideconcentration (from about 55 mass% to 70% vol%) in the late 1980s [19]. Adjacent alumina particles bond where they come into contact during the first light firing, creating a 3D network of connected particles. Low viscosity glass is dragged into the porous alumina network by capillary pressure during infiltration, resulting in the formation of an interpenetrating three-dimensional composite (both the alumina and glass are continuous throughout the ceramic, neither acting as an isolated "filler"). This ceramic (In-Ceram Alumina, Vita), despite containing just 70% aluminium oxide, has the same strength and fracture toughness as several ceramics made entirely of polycrystalline alumina [20].

1.2.6. ZrO_2 based ceramics and their use in dentistry

A ceramic material with suitable mechanical qualities for the production of medical devices is zirconia (ZrO_2). Structural ceramics have been enhanced and have grown in popularity in dentistry with the goal of replacing the framework of metallic dental prosthesis. Due to its biological, mechanical, and optical characteristics, zirconia hasdistinguished itself among dental ceramics as a versatile and promising material. This has undoubtedly expedited its frequent application in CAD/CAM technology for many formsof prosthetic treatment. Zircon is a bright, grey-white metal that, when in powder form, canhave a blue-black appearance.

High tensile strength, high hardness, and corrosion resistance are all characteristics of the oxide zirconia. In nature, it is not found as a pure oxide. Most of the zirconium utilized is chemically derived from the minerals zirconate (ZrO_2-SiO_2, $ZrSiO_4$) and baddeleyite (ZrO_2), which are the main sources of the metal. Although more plentiful, zirconate is less pure and needs extensive processing to become zirconia [21]. Zirconia possesses mechanical qualities that are comparable to those of stainless steel. For dental applications,zirconia has reportedly been shown to have superior mechanical qualities than other ceramics. Its fracture resistance has been estimated to be 6–10 MPa/m1/2, flexural strengthto be 900–1200 MPa, and compression resistance to be 2000 MPa. Zirconia restorations typically have a load capacity of 755 N. There have been instances of fracture loads between 706 and 4100 N [22].

1.2.7. Sintering Metal

Sinter metal blocks can be identified by their fully contoured crowns and bridges, copings and bridge frameworks, telescope crowns, bars, and attachments. Non-precious metal continues to be used in the vast majority of restorations created worldwide. The CoCr alloy-based in Coris CC (block) and in Coris CCB (discs) sintering metals are analogous tothe well-known zirconium oxide method, compressed by dense sintering in a furnace with an argon gas environment (in Fire HTC speed with Superspeed + Metal).

1. Uniform material quality, consistent shrinkage, and absence of deformations, inclusions, or comparable flaws;
2. Simple, clean, and quick

Use of the metals present in one or more of the alloys should be avoided in the event of a confirmed intolerance [23].

1.3. ARRANGEMENT OF DENTAL CERAMICS

Characterization of dental ceramics production as indicated by their clinical applications: There are three main indications for ceramics in dentistry through their clinical use, metal-ceramic crowns and fixed fragmented dentures, all ceramics reclamations like crowns, decorates, onlays, facade, limited capacity to focus spans, and ceramic dental replacement teeth [24]. For the most part, certain ceramic production are utilized to supplant thecomplete loss of hard tissue. However, ceramic overlay veneers are utilized to cover the facial surface of the tooth by holding with glue frameworks [25].

Arrangement of dental ceramics as indicated by their design:

High-melding ceramic temperature (1315-1370°C) Medium-melding ceramic temperature (1090-1260°C)Low-melding ceramic temperature (870-1065°C) Ultra-low-melding ceramic temperature (650-850°C)

High-melding ceramics have higher strength, insolubility, clarity and precision in rehashed firings than medium-and low-combining ceramics [26].

1.4. GROUPING OF DENTAL CERAMIC PRODUCTION AS INDICATED BY THEIR MINIATURE DESIGN

The glass-to-translucent proportion in the synthesis of the ceramic decides its microstructure. Present day dental ceramics containing a higher extent of the crystalline stage are created to improve biomechanical properties [16]. Customary ceramic materials that have variable micro structures can be grouped into four essential compositional classifications with a few subgroups:

Dominatingly glass based materials with high glass content: Glass-based frameworks predominantly comprise of silicon dioxide (SiO_2), otherwise called silica or quartz, and different measures of alumina/aluminium oxide (Al_2O_3). Normally happening aluminosilicates containing differing measures of potassium and sodium are known as feldspars. Feldspars are changed in different ways for the manufacture of dental ceramics.

Glass-based materials were first used to make porcelain dental replacement teeth. These days, the material has signs, for example, veneering materials for metal or ceramic foundations because of its low flexural strength, which is as a rule in the scope of 60-70 MPa [25].

Molecule filled glass based materials (generally leucite or a lithium disilicate): The ceramic materials in this classification are portrayed by a large number of glass-to-gem proportions and gem types. The materials have basically a similar unadulterated glass structure, the distinction being expected to changing measures of various gem types added or filled in the lustrous framework. As of now, the essential precious stone sorts are leucite, lithium disilicate, or fluorapatite.

Glass filled translucent based materials (for the most part alumina): The material in this class is glass-penetrated, somewhat sintered alumina. The framework is an option incontrast to customary metal-ceramics.

Polycrystalline ceramic production without glass content (alumina and zirconia): Materials of this classification are strong sintered, and monophasic ceramic framed by direct sitering of precious stones together with next to no mediating grid. Alumina and zirconia are polycrystalline solids. Strong sintered zirconia or alumina systems can be created bydifferent handling strategies.

1.5. CHARACTERIZATION OF DENTAL CERAMIC PRODUCTION ASINDICATED BY THEIR HANDLING METHODS

Handling procedures address a more noteworthy relationship with the clinical achievement or disappointment of dental ceramic production. The handling approach upgrades or debases the last properties. There are various strategies to handle different ceramic materials. For dentistry, they can be extensively delegated:

- Powder/fluid strategy
- Pressable blocks
- CAD/CAM systems

1.5.1. CAD/CAM systems

Dentistry is a steadily developing field that has been at the cutting edge of clinical disciplines in embracing new advancements like CAD/CAM. The primary use of CAD/CAM innovation in dentistry was by Duret and Preston during the 1970s [26].During the 1980s, Moermann followed them with his work to proceed with the improvement of this framework. Since that time, CAD/CAM has been acknowledged in current dental research centres and by most dental specialists at the dental chairside [27]. There are three components in view of the improvement of CAD/CAM as follows: (1) information securing, (2) information handling, and (3) creation.

Information securing requires intraoral scanners. With intraoral scanners, it is feasible to make a three-layered (3D) model of the oral pit without taking an impression, projecting a model, and afterward digitizing it. The computerized model can be utilized to plan false teeth like crowns, extensions, and systems for incomplete partial teeth. There are numerous product choices accessible today for plan. Previously, the digitization, plan, and manufacture steps were alluded to as a shut framework. At present, utilizing open access systems is conceivable. The framework is opened, and it is feasible to obtain the parts of the CAD/CAM framework. It sets out a freedom for information to be procured from a scope of sources and assembling strategies. The information can be coordinated with fitting plan programming for creation. Crown andbridge systems, incomplete dental replacement structures, even custom embeds and embed projections are the opportunities for creation. The most appropriate creation process and related materials can be chosen [8].

1.6. CHARACTERIZATION OF ALL CERAMIC AND CERAMIC LIKEHELPFUL MATERIALS

There are a few order frameworks for ceramics utilized in dentistry, as referenced above, to choose the right material by zeroing in on clinical applications, synthesis, microstructure, handling strategies, and so on [23-27]. Proceeding with propels in the properties of ceramics like strength, feel, and assembling strategies bring about numerous items for the clinician to choose. Order of dental ceramic production as per their micro structure, which is connected with the glass content, doesn't mirror the central improvement in ceramic innovation. The assembling system of ceramic materials has developed, and new supportive materials have arisen. The current groupings do exclude tar lattice CAD/CAM materials that are exceptionally loaded up with ceramic organizations. These materials are suggested as stylish choices for different clinical signs and have as of late been coded as "ceramic production" by the American Dental Association (ADA) with their ceramic like properties, so they ought not be disregarded in ceramic grouping frameworks [25]. Subsequently, another way to deal with the characterization of dental ceramic has been proposed. In this manner, another way to deal with the characterization of dental ceramics production has been proposed. Ceramic helpful materials were classified by Gracis S, et al.in three gatherings of all-ceramic and ceramic like materials, in light of their syntheses as shown in (Figure 1.2) [28].

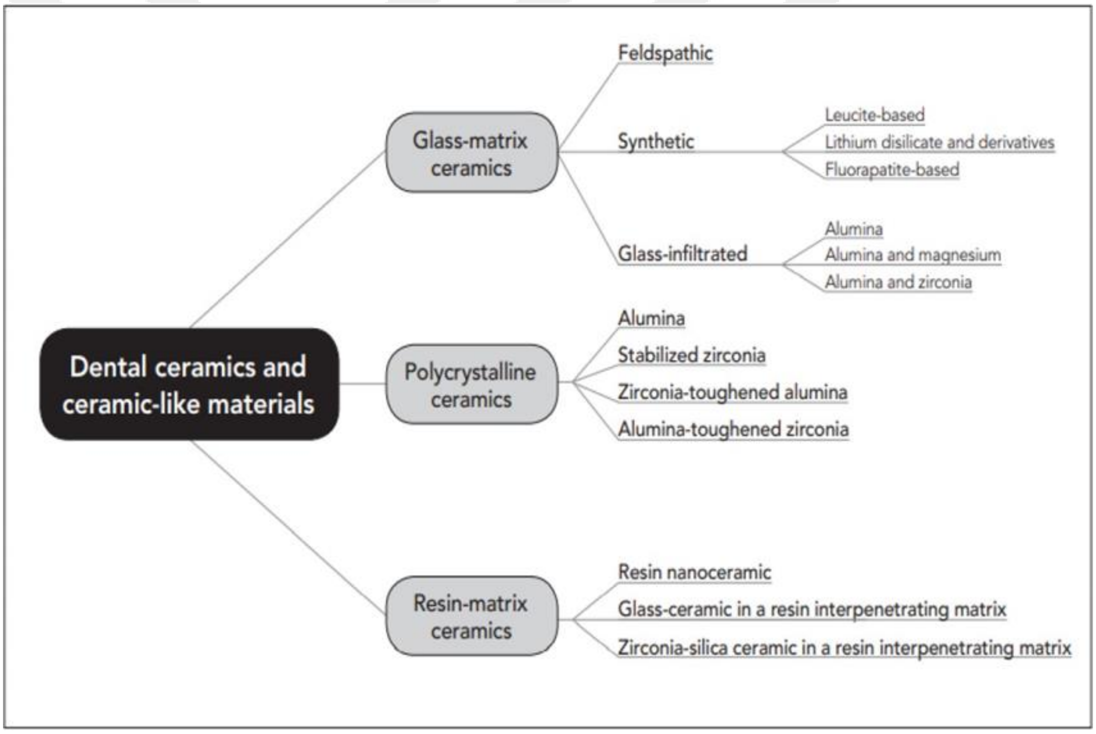

Figure 1.2. Outline of the proposed arrangement of all-ceramic and ceramic like materials byGracis et al [28].

1.6.1. Glass matrix ceramics

Glass-lattice ceramics are alluded as customary ceramics and comprise of feldspar, quartz (silica), and kaolin. The non-metallic inorganic ceramic materials contain a glass stage.

Feldspathic ceramics: Feldspathic ceramic production could be characterized as the conventional kind of dental ceramics and made out of normally happening feldspar (a combination of potassium and sodium aluminosilicates), quartz (silica), and kaolin (hydrated aluminosilicate). Most ceramics have two particular stages, a glassy stage, and a glasslike stage. While the translucent stage is connected with mechanical strength, theshiny stage is in many cases answerable for tasteful way of behaving. Leucite gems in the translucent stage shaped by potassium feldspar ($K_2A1_2Si_6O_{16}$), increment the inborn strength of the material and make the porcelain venerable, contingent upon how much potassium feldspar. The veneering ceramic has a coefficient of thermal extension that is roughly 10% or less lower than that of the system [29,30].

Synthetic ceramics: The ceramic business has started to utilize manufactured materials to stay away from reliance on regular wellsprings of unrefined components. The structure as a rule incorporates silicon dioxide (SiO_2), potassium oxide (K_2O), sodium oxide (Na_2O), and aluminium oxide (Al_2O_3), albeit the sums change contingent upon the maker. The glass stages can be joined with apatite precious stones, for example, leucite, lithium disilicate, or fluorapatite to further develop strength and accomplish thermal expansion similarity with metal systems. Glasslike stage supported feldspathic porcelains are accessible with upgraded mechanical properties for utilization of trims, onlays, crowns, and three-unitfixed prostheses in the front district and use as a foundation material [31]. Glass ceramics improved with lithium disilicate gems (SiO_2-Li_2O) were created by Ivoclar Vivadent for the lost wax/hot press process (IPS Empress 2 and IPS e.max Press) and later for the CAD/CAM innovation (IPS e.max CAD). The high gem content (70% by volume) is altogether higher than that of leucite materials. The clay structure comprises of emphatically interlocked lithium disilicate precious stones with a length of 5 mm and a width of 0.8 mm [32,33]. Machinable lithium disilicate blocks (IPS e.max CAD) have as oflate been produced for the CAD/CAM machining innovation. These blocks go through a two-stage crystallization process. In the primary stage, 40% by volume lithium metasilicate gems Li_2SiO_3 (with a typical size of 0.2-1.0 μm) are framed, coming about in a flexural strength of 130 MPa to 150 MPa, which permits simpler machining and intraoral occlusal variation. During the last crystallization process, 70% of the precious stone volume (with a typical size of 1.5 μm) is integrated into a glass framework, which expands the last strength(Figure1.3).

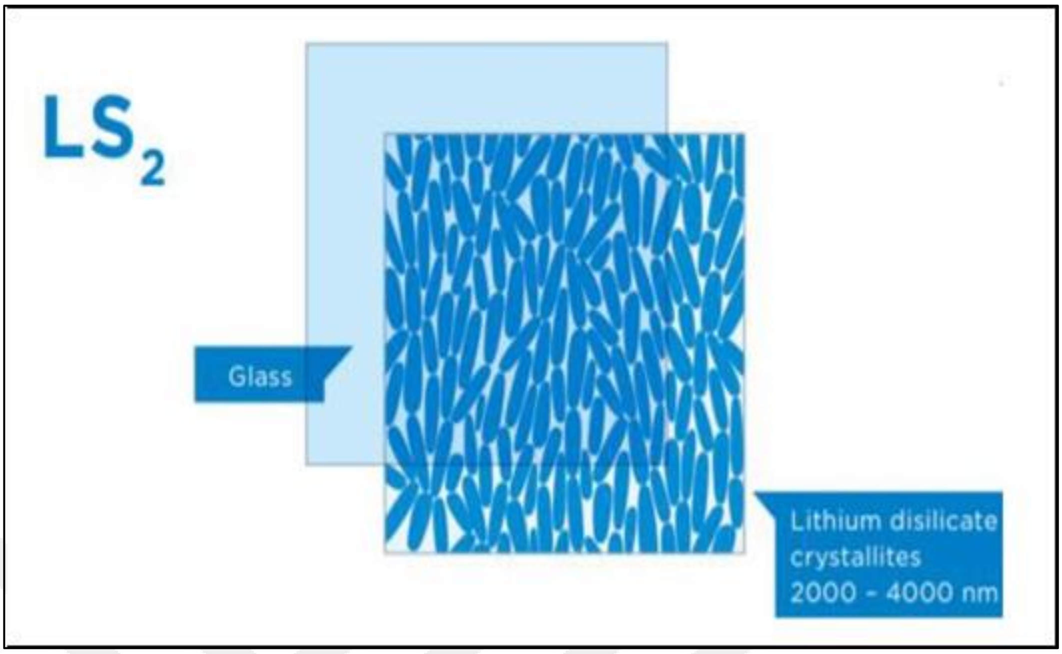

Figure 1.3. Design of lithium disilicate ceramic [34]

Also, at this stage, the blue shade of the pre-solidified block is changed to the chose tooth tone. The last rebuilding has a flexural strength of 360 to 420 MPa; these are demonstrated for front or back crowns, embed crowns, trims, onlays and façade [26,35]. The innovative work of new supportive materials fully intent on accomplishing high mechanical and stylish execution has prompted the presentation of zirconia-reinforced lithium silicate(ZLS) pottery, which can be utilized with CAD/CAM advances. In 2013, ZLS was created by two organizations, Vita Zahnfabrik and **Dentsply Sirona** and advertised independently as various items: Vita Suprinity and **Celtra Duo** [36]. These materials have comparable microstructures with a homogeneous polished network containing a translucent part of round and submicrometric lengthened grains of lithium metasilicates and lithium orthophosphates, tetragonal zirconia fillers to build the strength values up to 360 MPa by and large. This sub-micron measured scattered zirconia particles implanted in a fine-grained glass grid of 500 to 700 nm, and 10% by weight, and improve mechanical properties by expanding the flexural strength and crack durability contrasted and traditional lithium disilicate ceramics (Figure 1.4) [35].

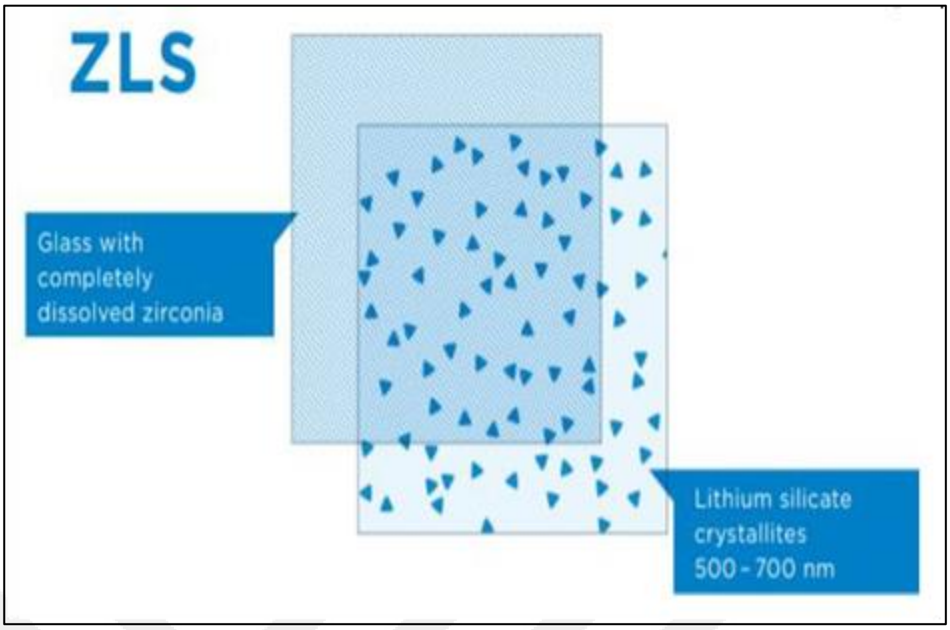

Figure 1.4. Design of zirconia-supported lithium silicate ceramic [34]

After a crystallization cycle, lithium disilicate grains are shaped. Lithium metasilicate is accounted for to have become bigger in Celtra Duo than in Vita Suprinity (up to ~1 or ~0.5 μm long) [36]. This primary typology was created to join ideal optical properties with further developed mechanical properties contrasted with other glass-ceramics, albeit this presumption stays questionable right up 'til now [37-40]. The solid Vita Suprinity blocks are presented in a meta-sintered stage to work with crushing, and the later piece goes through a last crystallization terminating. Celtra blocks are accessible in a pre-solidified (Celtra CAD) or completely sintered (Celtra Duo) stage. Decorates, onlays, facade and crowns are the signs of utilization [36,41].

Glass infiltrated ceramics: In 1989, the primary glass-penetrated material In-Ceram Alumina was presented and created by slip projecting. Because of the mistiness of the material, a porcelain facade was required. The composition is Al_2O_3 (82%), La_2O_3 (12%), SiO_2 (4.5%), CaO (0.8%) and other oxides (0.7%), according to the manufacturer.

In-Ceram Spinel was introduced and produced in a similar way in 1994, with the exception that the glass is penetrated into a synthetically made permeable magnesium aluminate ($MgAl_2O_4$) centre. In-Ceram Zirconia, a replacement for In-Ceram Alumina, is introduced by incorporating slightly balanced out zirconia (PSZ) into the slip synthesis of the Al2O3 to strengthen the ceramic. The prevalence of zirconia and lithium disilicate, particularly for CAD/CAM fabrication, has made this class of materials less important. Vita Zahnfabrik offered In-Ceram Alumina, In-Ceram Spinel, and In-Ceram Zirconia.

1.6.2. Polycrystalline ceramics

The fine-grained translucent design, as the fundamental quality of the ceramic production ordered in this gathering, gives strength and crack sturdiness, however will in general show restricted clarity. Furthermore, there is no glass work in polycrystalline ceramic. This makes it challenging to carve these earthenware production with hydrofluoric corrosive, which requires higher temperatures or long drawing times[42].

Alumina: This material, comprising of high-virtue Al_2O_3 (to 99.5%), was first presented during the 1990s by Nobel BioCare with a brand name of Procera All Ceram as a centre material for manufacture by CAD/CAM. It has very high hardness values from 17 to 20 GPa and somewhat high strength. It has most elevated flexible modulus among all ofdental ceramics as 300 GPa [26]. The propensity toward centre crack and the improvement in mechanical properties of materials, for example, the change sturdiness capacity tracked down in balanced out zirconia, have prompted diminished utilization of alumina [43,44].

There are three allotropic varieties of **stabilized zirconia**: the monoclinic structure, which is stable up to 1170°C, is the first. Then it changes to the second tetragonal structure at that time, and when the temperature exceeds 2370 °C, it changes to the third cubic structure. (Figure1.5)[45,46].

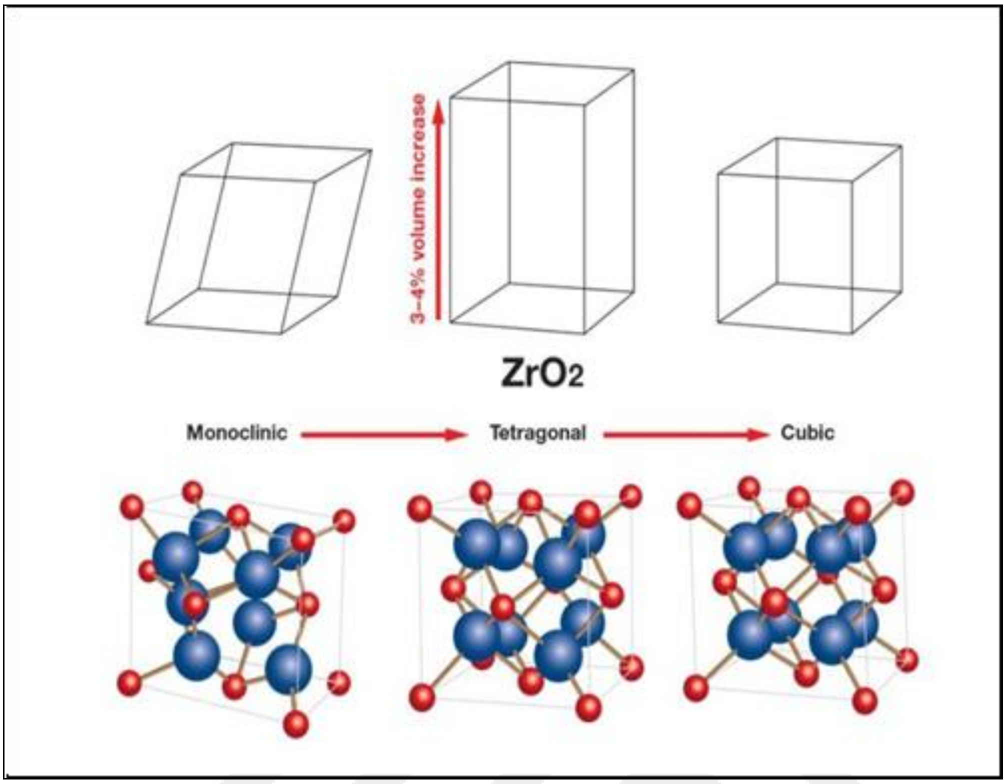

Figure 1.5. Three allotropic types of zirconia with a uniform, polycrystalline design [47]

Shear strain and 4% enormous volume increment go with the transformation of the tetragonal to the monoclinic stages. This increase in volume enables material cracks to be sealed and significant increases in fracture toughness to be observed. By alloying pure zirconia with oxides such as yttrium, magnesium, calcium, and cerium, the tetragonal or cubic phases should be settled at room temperature in order to practically apply this property of changing strength. These elements need to be resolved either fully or partially. [48]. A proposed microstructural order of zirconia ceramics can be as completely settled zirconia (FSZ), somewhat balanced out zirconia (PSZ), and tetragonal zirconia polycrystals (TZP) [49]. Dental zirconia all have a place with the TZP type, which is generally ordinarily balanced out with yttria as Y-TZP. This structure accomplishes the most noteworthy strength and fracture toughness in the wake of machining and sintering techniques.

Zirconia ceramic is a material that has generally been utilized to manufacture structure material for prosthetic veneering. Today, it can likewise be utilized to manufacture solid reclamations. It very well may be utilized as monochromatic uniform material and, if necessary it tends to be stained by penetration. There has been a critical expansion in the utilization of polychromatic (or blended) CAD/CAM manufacture materials as blocks and plates to emulate dentin to finish variety varieties. Also, there are presently material choices that are manufactured with expanding clarity. IPS e.max ZirCAD (Ivoclar Vivadent), Katana Zirconia ML (Kuraray), Lava Plus (3M Espe) are a few instances of balanced out zirconia.

Alumina toughened by zirconia and zirconia toughened by alumina: Alumina-zirconia (zirconia-hardened alumina [ZTA]) and zirconia-alumina (alumina-hardened zirconia [ATZ]) materials have been developed as a result of zirconia's general persistence in the tetragonal stage and alumina's modest durability [50,51]. Claussen was the first scientist to demonstrate in 1976 that adding unstabilized zirconia to alumina increases the strength of the material's break because the transition from tetragonal to monoclinic zirconia causes communication between the break and earlier microcracks. [52,53]. The level of zirconia or alumina in the piece can be controlled in like manner and changed on a case by case basis. There are a few technique es where nanoparticles of zirconia are saved on alumina microparticles before the sintering system [54,55]. Contrasted with Y-TZP, these materials enjoy benefits like lower temperature corruption, higher strength and crack durability [56,57], also, beyond two times cyclic exhaustion strength of Y-TZP [58]. In these variations of polycrystalline materials, the glass is penetrated into the outer layer of alumina or zirconia substrates. This penetration makes an additional harm lenient and tasteful framework for further developed clinical performance. Limiting the break inception incredibly further develops the weariness life of both alumina and zirconia [59,60].

1.6.3. Resin Matrix Ceramics

Tar framework ceramic production have a natural network content that is exceptionally loaded up with ceramic particles restricting together through coupling specialist (Figure 1.6) [61].

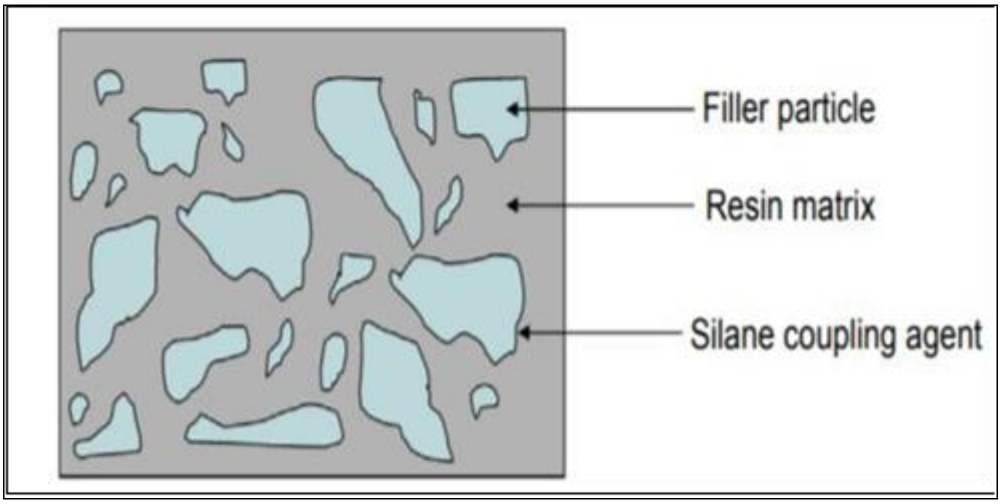

Figure 1.6. Microstructure of resin-matrix ceramics [61]

The presence of a natural grid doesn't meet the customary meaning of ceramics as: non-metallic inorganic materials usually handled by terminating at high temperature to accomplish advantageous properties [62,63]. Be that as it may, as indicated by the 2013 variant of the ADA Code on Dental Procedures and Nomenclature [25] the term porcelain/ceramic is characterized as "squeezed, terminated, cleaned, or processed materials containing prevalently inorganic unmanageable mixtures, including porcelains, glasses, earthenware production, and glass-ceramics. This definition adds the tar network ceramics classification to the ceramic arrangement. Makers created gum lattice ceramic materials to (1) give a material that reproduces a nearer modulus of elasticity to dentin than customary ceramics, (2) give a material that is simpler to process and modify contrasted with glass grid ceramics, for example, lithium disilicate family engineered ceramics or polycrystalline ceramics, and (3) permit fix or change of the material with composite resin. They alluded to this class as "hybrid" ceramic production due to their microstructure. Almost certainly, a few new materials being presented for tasteful dental reclamations will squeeze into the class of pitch-grid ceramics.

As per the producers, the signs for these ceramic like materials in helpful dentistry are exceptionally different. Notwithstanding their creations change significantly, they are uniquely figured out for the CAD/CAM framework. These days, the resin-matric ceramics materials can be isolated into a few subcategories as indicated by their inorganic organization. Nanoceramic resin: It is made of a greatly improved pitch grid that is supported by nanoceramic particles. The flexible nano ceramic material GC Cerasmart (GC

Corporation) refers to is made up of generally tiny and uniformly dispersed alumina barium silicate particles that have been inserted into a polymer lattice. It contains 29% composite resin and 71% by weight silica and barium glass nanoparticles. Magma Ultimate (3M Espe), another product in this category, has 20% composite resin and about 80% nano ceramic particles by weight. This high nanoceramic content is due to the material's composition of discrete silica nanoparticles (20 nm in width), zirconia nanoparticles (4 to 11 nm in distance across), and zirconia silica nanoclusters (bound totals of nanoparticles). Urethane dimethacrylate, triethylene glycol dimethacrylate, bisphenol A glycidyl methacrylate (Bis GMA), and bisphenol A diglycidyl methacrylate ethoxylated are all ingredients in the composite gum (Bis EMA). Flexural strength is significantly higher (about 242 MPa), while flexural modulus is significantly lower (approximately 10.0 GPa), as is Vickers hardness (around 64.1 HV), compared to Lava Ultimate (170.5 MPa/14.5 GPa/97.9 HV) [64]. When compared to other ceramics or half-breed materials, the modulus of elasticity of 3.07 0.45 MPa is the most notable [65]. Half breed ceramics can only be used for single tooth rebuilding projects like facade, decorates and onlays (Lava Ultimate), as well as with respect to front and back crowns and embed upheld crowns (GC Cerasmart) due to the polymer component, poor flexural strength, and high flexibility [41].

Glass ceramic embedded in a matrix of interpenetrating resin: One manufacturer has combed ceramics and resin composites into a single material to enhance the presentation of these supporting materials. This reality appears to be a good choice to combine the ceramic's long-lasting fashionable dependability with the flexible modulus of resin composite that resembles dentin [66]. This substance, known as "polymer-infiltrated ceramic network (PICN)," has recently gained recognition as a hybrid substance. The substance Vita Enamic (Vita Zahnfabrik) serves as an example of this group. A double organization, such as 86% by weight of feldspathic ceramic organization and 14% by weight of polymer organization, is typically used to make it. The synthesis and microstructure of dental materials decide their mechanical and actual properties. Specifically for ceramics, the microstructure is subject to sintering and fundamentally influences the coefficient of thermal expansion, resistivity values, compound dissolvability, clarity, and optical appearance [67]. Compositional examination of PICN uncovers a predominant ceramic network with leucite as the fundamental stage and zirconia as a minor stage related with a polymer-based network. A lot of carbon exists in the polymer stage [66]. The arrangement of the polymer network is

UDMA and TEGDMA. The flexural strength of this cross breed material can arrive at a worth of around 150-160 MPa, a lot higher than that of a permeable ceramic (under 30 MPa) and a polymer (135 MPa) alone. The unrivalled flexural strength of the resin penetrated ceramic material contrasted with the singular parts shows a reinforcing component of the polymer organization to the predominant ceramic organization [68]. The upsides of elastic modulus, hardness and fracture toughness are as per the following: 30.14 GPa, 2.59 GPa, and 1.72 MPa.m1/2, separately,[69] which are all between those for human dentin and veneer. With the most elevated filler content (73.1 mass-%) contrasted with other half and half ceramic production and composites, Vita Enamic has the most noteworthy Vickers hardness of

189.8 [64]. The signs are negligibly intrusive reclamations and back crowns, veneers, decorates and onlays for back teeth and embed upheld crowns [70].

Zirconia silica ceramic in a resin interpenetrating matrix: These materials have an inorganic substance includes over 60% by weight and are ready by different natural grids with the variety of ceramic weight rate, for example, silica powder, zirconium silicate, UDMA, TEGDMA, miniature seethed silica, shades. Shofu Block HC (Shofu) and Paradigm MZ100 (3M ESPE) are the instances of this classification [71]. A composite comprising of 85% ultrafine zirconia ceramic particles (round 0.6 µm) implanted in a polymer network of Bis-GMA, TEGDMA and a licensed ternary initiator framework.

1.7. HARDNESS AND MEASURMENTS

Hardness is the opposition of the material to plastic misshaping. It is estimated utilizing a pointed, pyramid-formed precious stone indenter with a square base of the Vickers hardness analyser with a foreordained power to leave an extremely durable distortion or space on the outer layer of the material (Figure 1.7) [71].

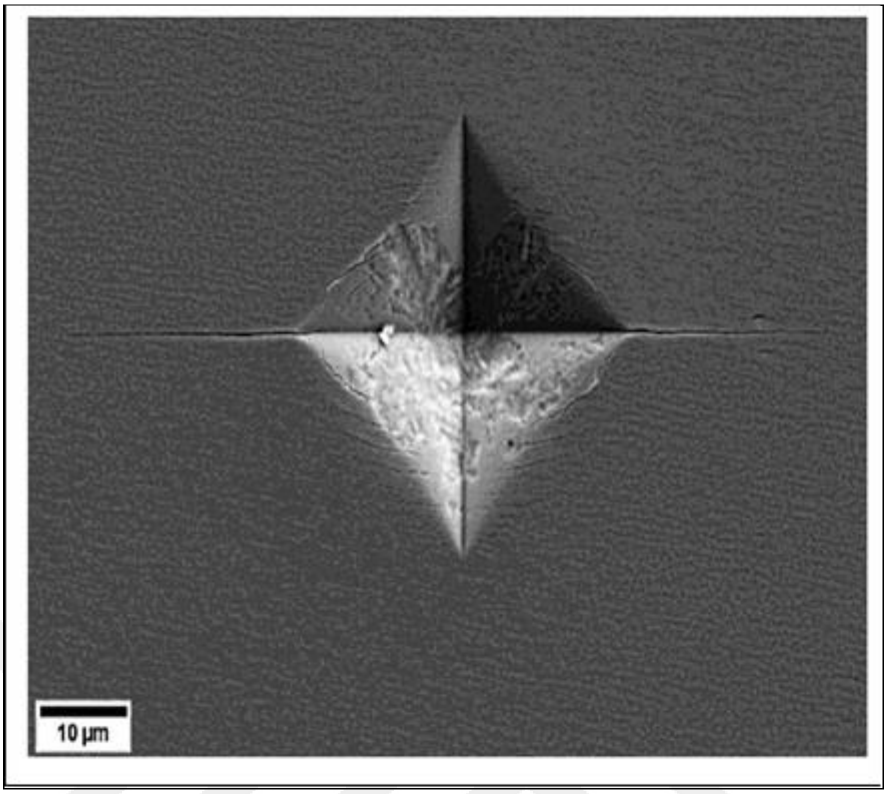

Figure 1.7. Space region staying from Vickers hardness indenter [72]

The power applied by the indenter and the typical corner to corner size are consequently used to compute Vickers hardness (HV).

HV=1.8554 x $P_1/(d)_1^2$

(HV: Vickers hardness, P: load, c: inclining of break length)

Hardness is one of the critical properties used to ceramics production. A few endeavours have been made to relate the hardness of dental materials to their more noteworthy abrasiveness and wear obstruction [73-77]. Notwithstanding, other material-related factors have likewise been displayed to impact the wear properties of a ceramic, for example, microstructure, porosity, precious stone substance, surface unpleasantness, and climate [78]. It isn't helpful to characterize a severe connection amongst hardness and wear of weak materials, as they wear by subsurface cracks and not by plastic distortion, in contrast to metals and veneers. With respect to precious stone substance, glasslike materials can bomb under space loads because of separation components of gems in a shiny lattice. The inhomogeneous circulation of precious stones in a glass grid fired is an essential consider deciding the disappointment method of the material in view of microhardness spaces. In non-translucent materials, space harm happens basically by plastic distortion and resulting break of the more vulnerable polished grid. The direction of the indenter to the precious stones likewise decides the microhardness of glasslike materials. This fluctuation might make sense of the unfortunate connection between material hardness and finish wear [4,79].

1.8. FRACTURE TOUGHNESS AND MEASURMENTS

Fracture toughness (K1C) not entirely set in stone as the general obstruction of the material to fast break proliferation under pliable pressure. This natural material property relies upon the pressure power at a break tip in the material and the size of the break comparative with the microstructural qualities of the material, for example, precious stone size, perspective proportion, and direction/circulation of the glass stage, and porosity.
Fracture toughness can be determined as follows by the recipe as indicated by break lengths [80]:
$K_1C = 0.0824P/C^{\#/2}$
(K1C: fracture toughness, P: load, c: half slanting of the break length)

K1C of a ceramic material might be pertinent to the wear interaction since disappointment of the earthenware happens without perceptible plastic disfigurement. This kind of wear process starts with the development of a break, with resulting development of the break after some time, lastly the disastrous disappointment/crack of the material. Ceramic materials ought to have adequate durability to oppose crack, generally fragile chipping can happen during the scraped area process. Weak chips can cause re-honing of the break edges with an expansion in wear rate. The sharp edges of broken glass don't lose as fast since they have a higher hardness relying upon the kind of ceramic material.

1.9. MICROSTRUCTURAL FACTORS

The microstructural factors are connected with porosity, gem content, ceramic layer and concealing. The gem size is the microstructural factor that might assume a part in this proposal are as per the following:

Crystals: These Precious stones integrated into the polished grid might have likely abrasiveness on restricting teeth relying upon the kind, content, morphology, and dispersion of translucent particles in the material [81]. The lower abrasiveness of a ceramic might be connected with the gem type, precious stone circulation example, and gem sizes. Be that as it may, foreseeing the wear properties of an earthenware material dependent just upon the abrasiveness of the crystals isn't right. There are a few material-related factors that influence the wear conduct of the material, for example, the grain size and shape, the presence of polished as well as translucent stages, the idea of the building up glasslike stage, and the ceramic synthesis, particularly the presence of certain components or oxides [82-84]. To further develop the wear conduct and mechanical properties of ceramic, a few elements, like the extent, type, morphology, and conveyance of translucent particles in a polished grid, should be enhanced. As a rule, with the exception of materials with polycrystalline design, materials contain grains limited by a generally feeble shiny or polymeric network. Deformity of these holding stages is related with interfacial microcracks that work with gem separation and disengagement. In lithium disilicate materials, the engendering of microcracks starts along frail gem glass interfaces, a shortcoming answerable for the machinability of this material and the subsequent spread of shot out garbage because of wear [85]. In any case, it has been accounted for that zirconia- built up lithium silicate (ZLS) glass-earthenware has a somewhat homogeneous fine translucent construction, dissimilar to other lithium disilicate glass-ceramic with the trademark thin moulded and fine-grained gems. The homogeneous fine construction emphatically affects the flexural strength, which decreases the chance of wear [37].

1.10. IMPACT OF SURFACE FINISH

The surface completion of the supportive material decides the wear pace of veneer [86]. Ceramic materials have non-homogeneous circulation of precious stones in a polished grid, which might present characteristic different imperfections. During the handling of ceramics, extra imperfections might foster that diminish the strength of the material[87]. Fixing the deformities with surface treatment can further develop strength and decrease the abrasiveness of the dental ceramic to the contradicting tooth structure. Surface coating of ceramic at a somewhat low temperature creates a smooth, polished, stylish, and clean surface and expands the strength of the ceramic framework [88,89]. Coating is likewise viewed as a stage that diminishes wear of the rebuilding and contradicting teeth. Notwithstanding, the coating layer is something like 30-50 μm thick and can be effectively eliminated following capability or by chairside occlusal change [90]. As indicated by many examinations, ceramic production with cleaned surfaces cause less veneer wear than coated ones [90,91,92-93].

1.11. SURFACE ROUGHNESS AND MEASURMENTS

At the point when two materials contact and slide against one another, the protection from horizontal sliding (frictional opposition) shifts relying upon the relative movement, the properties and construction of the reaching materials, and the climate. The coefficient of friction is impacted by the heap and mathematical boundaries, for example, the surface of the crushing surface, the state of the reaching structure, and the region of the reaching surfaces. Harsh surfaces, high loads and high sliding paces have been displayed to build the coefficient of friction, bringing about expanded wear [4]. It is likewise detailed in a review that albeit the unpleasantness of the ceramic is significant in the underlying phases of wear, when the impact of harshness vanishes as wear advances, the interior properties of the ceramic start to influence the pace of wear [94]. Roughness is in many cases measured by the deviations of the surface from its optimal shape. Assuming the deviations are little, the surface is viewed as smooth, yet on the off chance that they are huge, the surface is viewed as unpleasant. North of 100 variations of boundaries for estimating surface harshness have developed since the first global principles were distributed in 1984. While the surface roughness boundaries named with the letter "R" allude to two-layered (2D) assessments, the 3D surface boundaries all beginning with the letter "S". For instance, as an augmentation of the 3D articulation of the math mean of the surface, Sa; Ra is the 2D articulation for this boundary. The choice of 3D surface portrayal strategies is more sensible. This is on the grounds that they could give more unambiguous and strong portrayals about the assessment of microgeometry and capability related properties for the material surfaces that have similar qualities in their primary files like Sa or Ra [95]. Nonetheless, the most generally utilized revealing boundary of roughness is as yet the surface roughness mean Ra, arithmetic mean (Figure 1.8) or the root mean Rq, mathematical mean in dentistry [96].

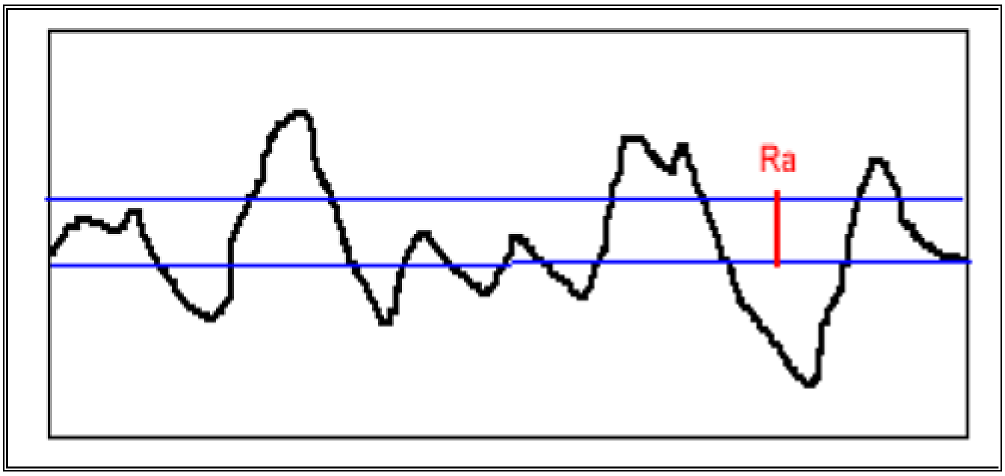

Figure 1.8. 2D surface roughness parameter, Ra (arithmetic mean of the surface) [97]

This makes an overall limit in the subjective assessment of the surface by giving just data about fixed levels at ordinary 2D stretches. Surface profilometry, is a strategy for estimating surface roughness utilizing a reaching pointer straightforwardly or a laser profilometer by implication. Contact pointer profilometry is a more established and more settled method. Truth be told, the ongoing public principles for estimating surface completion are characterized by stylus profilometry. In stylus profilometry, a precious stone tipped pointer gets across the surface. The upward development is switched over completely to a simple/advanced signal as the pointer is hauled across the surface. Because of the idea of the innovation, the stylus is in practically steady contact with the estimation surface. In any case, there is a gamble of the precious stone tip harming the example. The standard profilometry strategy, which alludes to estimating the profile of a surface, is still most usually used to survey surface changes in tooth structure studies [98-101]. The boundaries detailed in these examinations are in many cases restricted and permit little capability of the tooth surface. Laser profilometers can beat large numbers of the detriments of contact profilometry by giving circuitous admittance to the surface. A light spot, normally under 100 mm in measurement, is coordinated onto the surface. In laser profilometers, the surface geography can be profiled either by estimating the diversion of the laser shaft or by utilizing the confocal standard with white light. By organizing the guide of the surface profile, unpleasantness boundaries are much of the time used to report the outcomes. These boundaries have no limits.

1.12. STANDARD MEASURMENTS IN DENTAL CERAMICS

The oldest systems in the world for dental material standardization, testing, and certification are those in the United States, which date back to 1919 [102]. Initially, certification focused mostly on the materials' physical and chemical qualities and gave little consideration to their biological properties. For many years, traditional dental procedures using amalgam, gold alloys, and silicate cements were carried out, typically without any complaints of deleterious biological effects. During the 1950s to the 1960s, numerous new dental materials showed up, and a portion of the developments brought on some issues. For instance, sap based filling materials became related with mash putrefaction in a genuinely high percen-tage of treated teeth. This was unacceptable, therefore researchers started looking for ways to anticipate difficulties like these, notably in the fields of endodontics and operational dentistry. You could think of this as the precursor to standardized biological testing.

Under the moniker ISO (the International Organization for Standardization), a global federation of national standards bodies operates (ISO member bodies). International Standards are often created by technical bodies within ISO. Any member body interested in a subject for which a technical committee has been established has the right to be represented on it. International governmental and non-governmental organizations work with ISO to fulfil the assignment. ISO collaborates closely with the International Electro technical Commission on all matters pertaining to electro technical standards (IEC) [103].

1.12.1. BSI Standard Publication (Dentistry Ceramic Materials)

The specifications and accompanying test procedures for dental ceramic materials for fixed all-ceramic and metal-ceramic restorations and prostheses are laid out in this International Standard. The following steps are typically included in computer-aided design/computer-aided manufacture (CAD/CAM) processes to create a dental restoration or prosthesis: the model, wax-up, or intra-oral being digitally scanned to create a 3D data set; the 3D data set being software-manipulated to create the prosthesis; and the manufacturing process being carried out by a machine tool under computer control [103].

Due to the fact that it is frequently "inherent" in the material and can be used to forecast other properties like strength, fracture toughness is a crucial characteristic of dental ceramics (which is sensitive to flaw size and flaw population). As a result, data for fracture toughness enable accurate comparisons of ceramics employed in structural applications. There are many techniques in use that offer accurate assessments of fracture toughness and range in difficulty to utilize. According to ISO TC 206, the following techniques can be used to assess fracture toughness: single-edge pre-cracked beam (ISO 15732), surface crack in flexure (ISO 18756), or chevron-notched beam (ISO 24370). The yttria-tetragonal polycrystal zirconia can be studied using the SEPB, CNB, and SCF techniques. Each of these approaches has advantages and disadvantages, and some experience might be required to quickly and easily produce exact and accurate findings. It is not recommended to assess fracture toughness using techniques based on indentation crack lengths (e.g. where toughness is estimated based on the surface crack lengths associated with the corners of Vickers indentations) [103].

1.12.2. International Standards

The Worldwide Dental Federation (FDI) started the process of creating international dental standards in 1953, and the International Organization for Standardization (ISO) joined in 1963. It was decided that FDI would handle clinical and biological test criteria, while ISO (]SO/Technical Committee 106-Dentistry) would focus primarily on chemical and physical characteristics [104].

1.12.3. European Standards

There is currently no ISO TR 7405 equivalent in Europe. Although the arrival of the Single Market in Europe has accelerated the standardization effort, the European standardization on dental materials had been dormant for a while. The "New Concept," which acknowledges two different sorts or sets of norms, is crucial. For a certain class of products, such as medical equipment, a single set of standards will apply ("horizontal standards"). Each type of product will have its own set of standards ("vertical standards"). Good manufacturing procedures (GMP), prerequisites for biological testing, clinical research, and sterilization are a few examples of horizontal standards. The specifications for each category of goods are laid out in the "verti-cal standards." The ISO standards have been adopted as European standards for the majority of vertical requirements for dental items. A group of "semi-horizontal" standards have recently been created by CENITC 55- Dental products. Within the framework of this area's European legislation, they are meant to connect the horizontal and vertical standards [105].

1.12.4. Fracture Mechanics And Crack Propagation

Dental ceramics' greater clinical application in multi-unit fixed partial dentures has increased due to their improved hardness and strength [106]. Dental ceramics' durability and initial strength are important, but they are not the only factors that affect long-term survival. Dental ceramics' life time is considerably reduced by subcritical crack growth (SCG) [107]. Crack propagation at stress intensity factor (KI) levels below the critical stress intensity factor, also known as fracture toughness, is referred to as SCG (KC) [108]. Pre-existing subcritical faults may slowly worsen under prolonged or repetitive low-level loading, eventually leading to failure at a level of loading inadequate to destroy the original prosthesis. Stressing rate dependency of strength is a tell-tale indicator of SCG for in vitro testing [109]. When the critical stress intensity factor is reached, every specimen will shatter, although quickly stressed specimens will get there earlier. As a result, stress corrosion has less time to enlarge the crack [110]. A smaller critical fault leads into a higher failure stress if fracture toughness is constant. In addition to the stressing rate, a number of other elements can influence the amount of SCG. A power law function of the stress intensity component governs the rate of SCG [111]. Sharp faults and flaws with large depth-to-width ratios have an impact on the stress intensity factor due to the forms of the imperfections within the material. Compared to blunt defects and flaws with low depth- to-width ratios, correspond to increased stress intensity factor at the same stress level and accelerate SCG [112].The environment can have a significant impact on the development of cracks, with watery situations resulting in higher SCG and, hence, lower strength than inert settings. The strength of some ceramic compositions in watery environments is boosted, nevertheless, as a result of the water's reaction to blunt sharp defects on the ceramic surface [113]. Thus, loading duration, initial fault size distribution, and flaw geometry all affect how long dental ceramics will last. Since dental ceramics function well for extended periods of time when exposed to moisture, it appears likely that the degree of SCG susceptibility will have a significant role in deciding how long they will last. Through the use of cyclic, static, and dynamic loading techniques, the SCG of several dental ceramics has been studied [114].

2. EXPERIMENTAL PROCEDURE

2.1. CAD/CAM CERAMICS

All the CAD/CAM dental materials used in this study were taken from a previous PHD study performed at Yeditepe University. The characteristics of these materials are shown on the table below (Table 2.1) :

Table 2.1. CAD/CAM Dental Materials [140]

Material	Classification	Composition	Lot and Shade /Size	Manufacturer
Vita Enamic	Polymer infiltrated ceramic network (PICN)	86% feldspathic ceramic 14% polymer	73330 2M2 T/ EM 14	Vita Zahnfabrik, Bad Säckingen, Germany
GS Cerasmart	Resin nanoceramic	71% silica and barium nanoparticles 29% composite resin	1907241 A2 LT/14	GC Corporation, Bunkyo ku, Tokyo
Celtra Duo	ceramic made of lithium silicate and zirconia	Along with other minor components, it contains 58% silica, lithium metasilicate, lithium disilicate, phosphate crystals, and 10 zirconia crystals.	16004062 A2 LT/C14	Dentsply Sirona, Pennsylvania, USA
IPS e.max ZirCad	Yttria (3 mol)-stabilized tetragonal polycrystalline zirconia (3Y TZP)	88-95.5 %ZrO2	A2 LT/ Z000W8 98.5 18 mm	Liechtenstein's Ivoclar Vivadent AG Schaan

2.2. SAMPLE PREPARATIONS

2.2.1. Cutting

CAD/CAM restorative materials samples were taken from the previous PHD study as shown in the figure below (Figure 2.1):

Figure 2.1. CAD/CAM materials sample received

The pink part was removed using sand papers and electronic cutter as shown in the figures below (Figure 2.2 and 2.3).

Figure 2.2. Pink part removal using sand paper machine

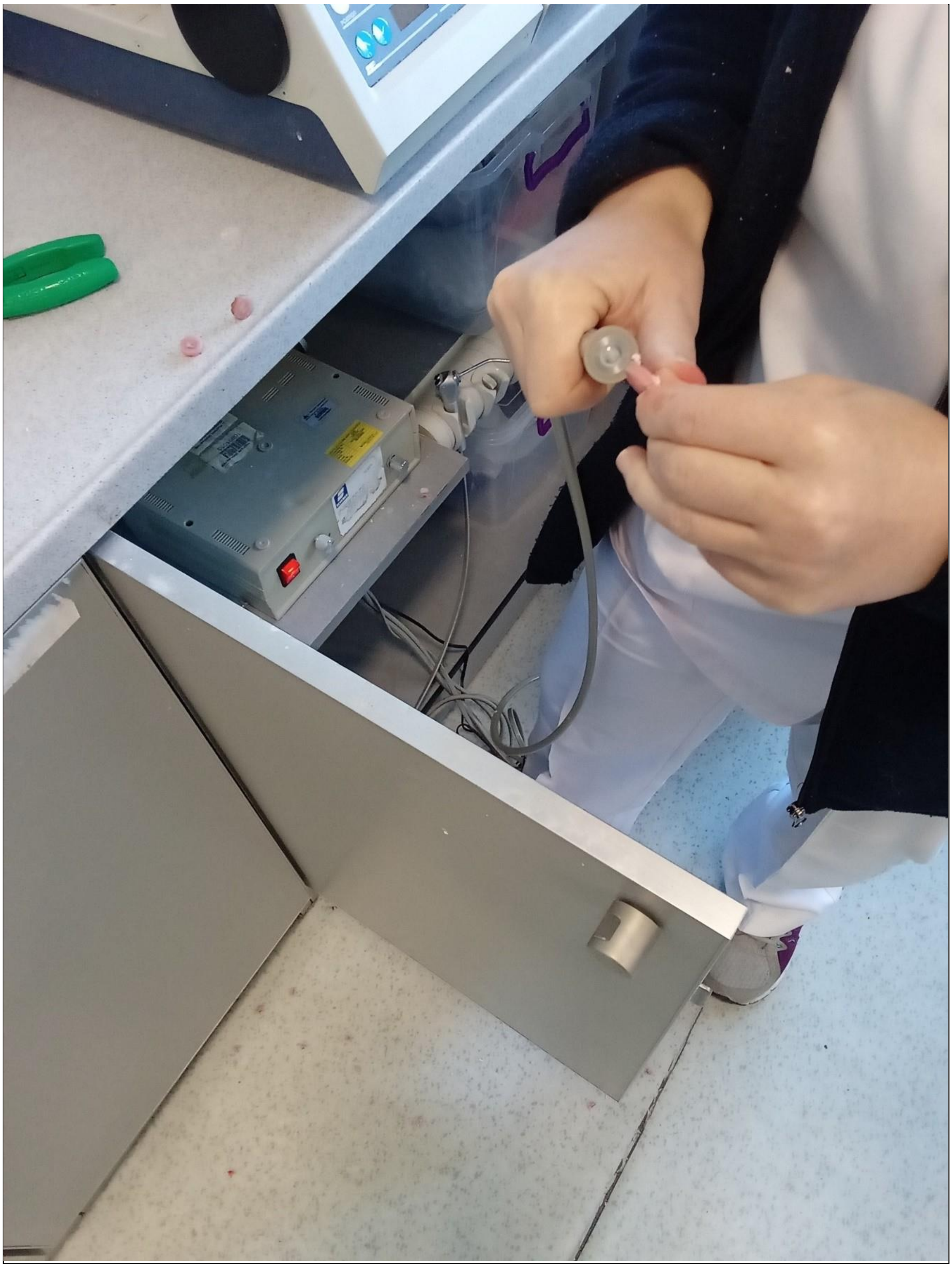

Figure 2.3. Pink part residuals removal using electronic cutter

After removing the pink part, the obtained samples were as followed (Figure 2.4):

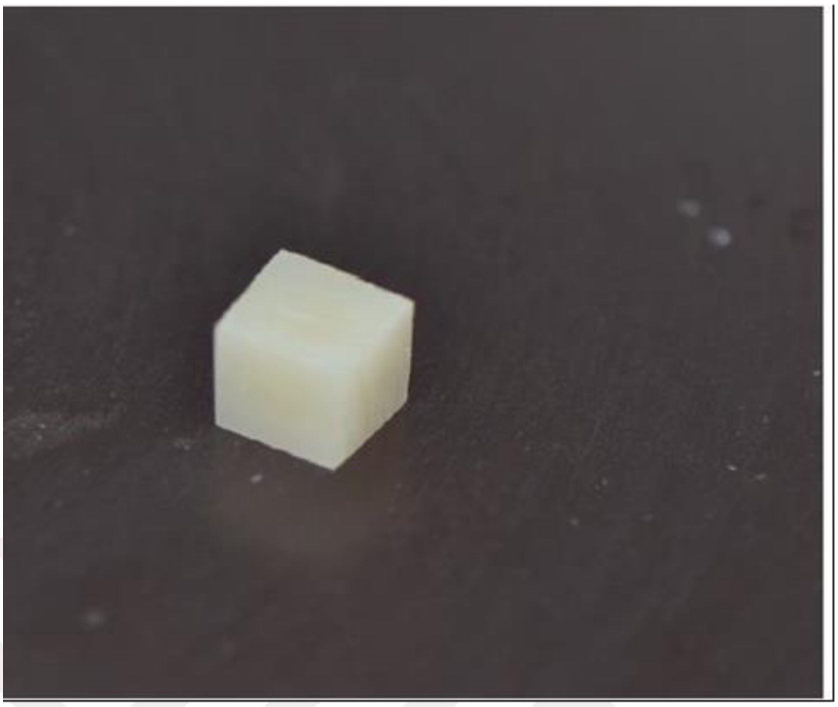

Figure 2.4. Four different types of dental materials and 6 samples were taken from each material.

2.2.2. Molding

Following to this we prepared a mould in which the sample can fit in for an easy handling of the samples. The mould is shown below:

Figure 2.5. Sample mould which was mad from a combination of Epocold –R (Epoxycold mounting resin) and Epocold – H (Epoxy cold mounting resin).

2.2.3. Polishing

Figure 2.6. Silicone carbide sandpapers and polishing machines with granulometry of up to 2500, 1200, and 600 meshes, respectively

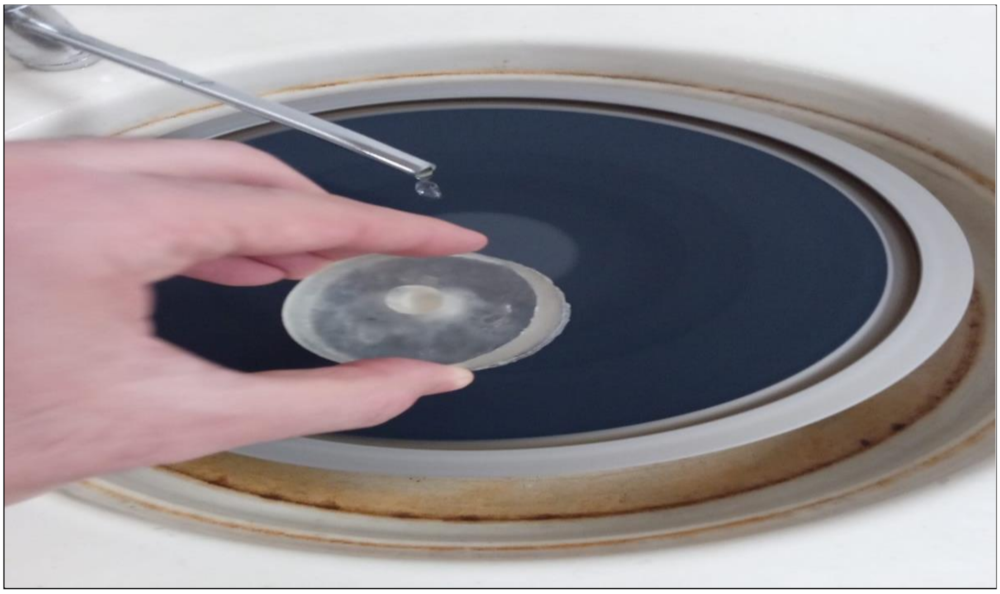

Figure 2.7. Preparing the specimen for the other mechanical tests by polishing it to create a smooth surface

2.3. SURFACE ROUGHNESS MEASURMENT

The design of the study has as its goal evaluating the surface characteristics of CAD/CAM restorative materials (Figure 2.8):

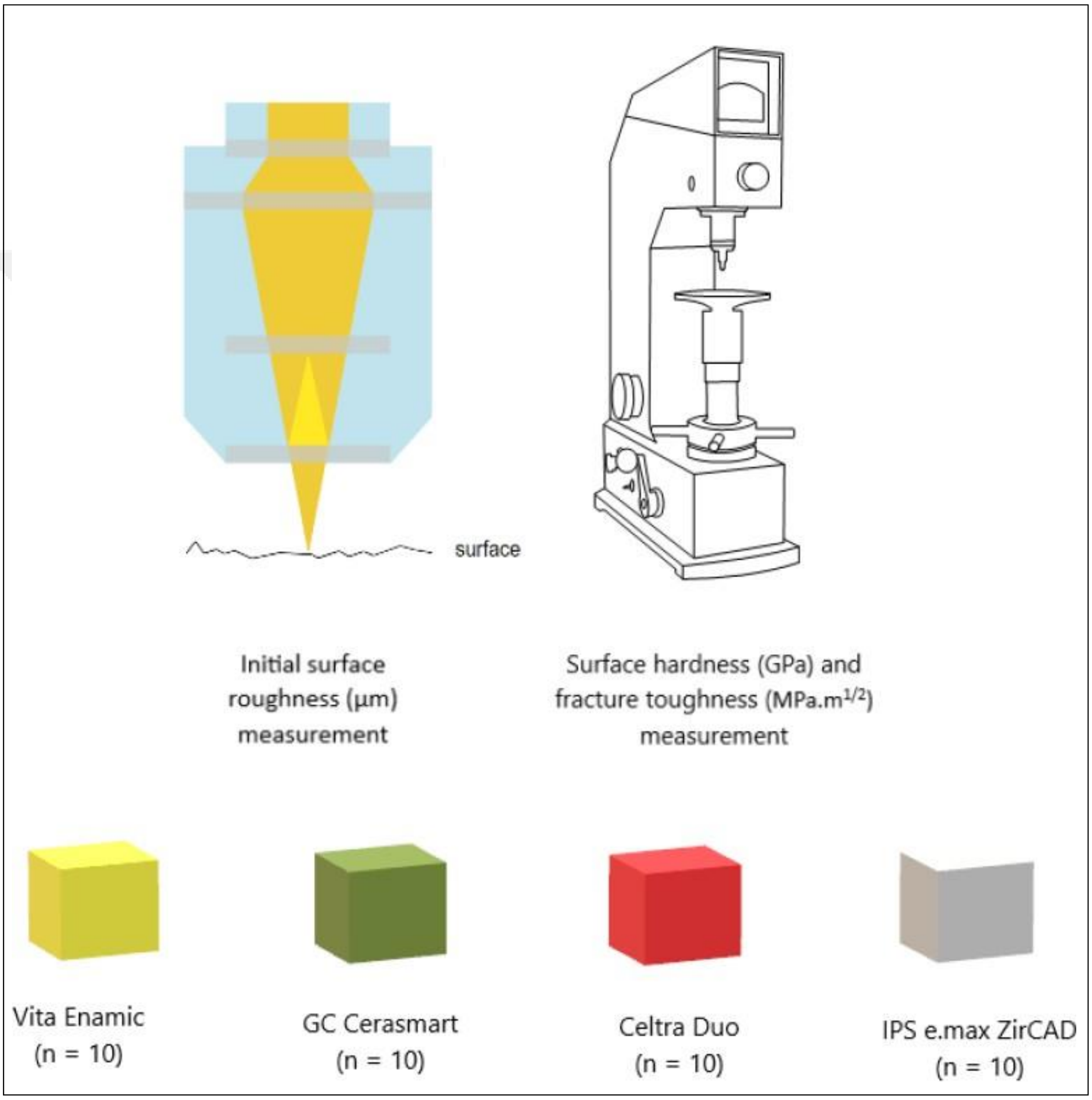

Figure 2.8. Study Design

Evaluation of surface roughness of the CAD/CAM dental materials; To assess the roughness of the material samples, each sample was examined using a surface roughness tester (Perthometer M1, Mahr, Czech Republic).

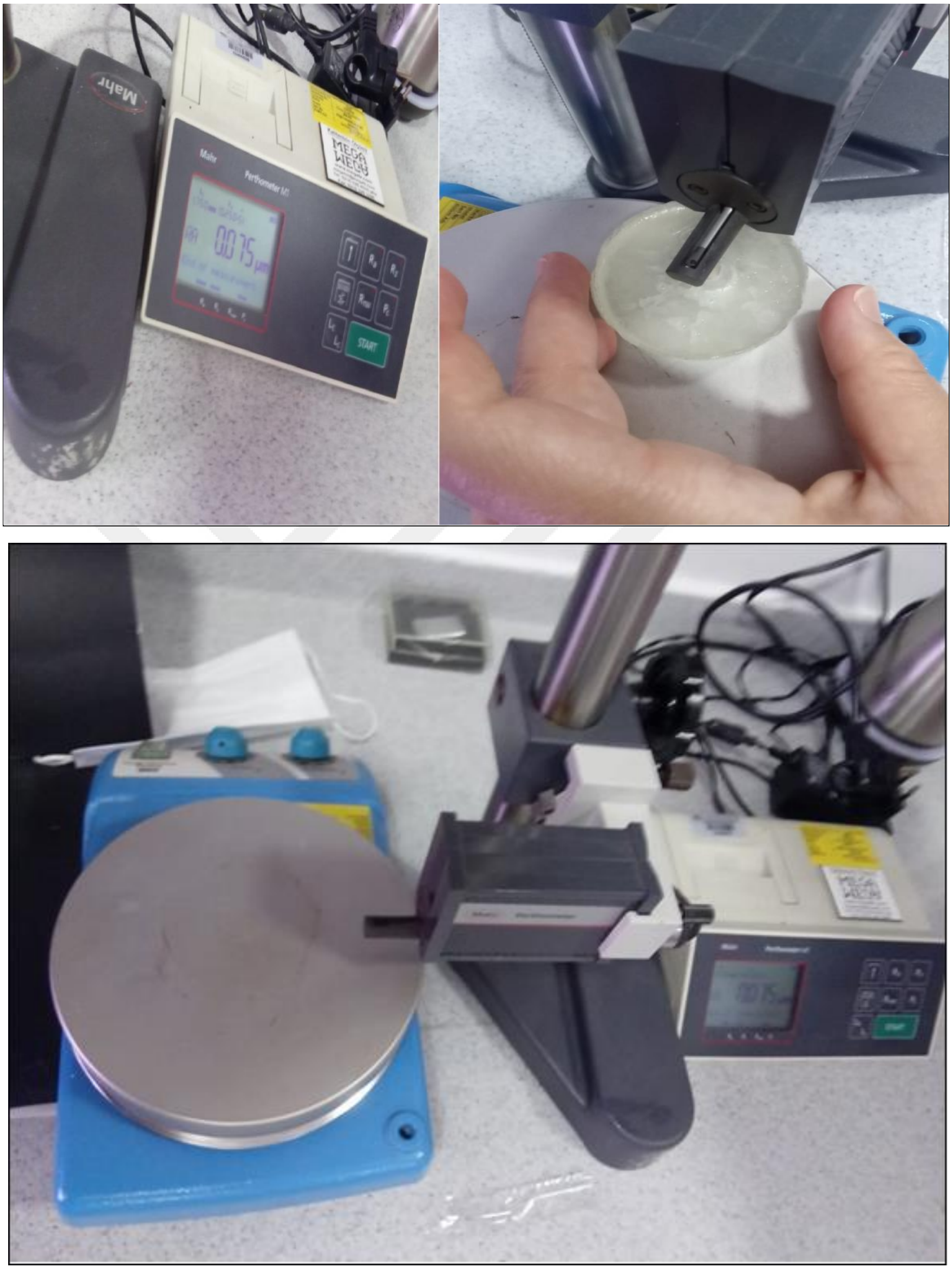

Figure 2.9. A measurement screen and a Perthometer M1 surface roughness tester from Mahr in the Czech Republic

Three trials of each measurement were made. On parallel surfaces, the Perthometer M1 contact profilometer could measure in two dimensions.

2.4. HARDNESS AND FRACTURE TOUGHNESS MEASURMENT BYINDENTATION

Each material sample's Vickers hardness and fracture toughness values were calculated using the Vickers hardness tester (Buehler UK Ltd., England) (Figure 2.10):

Figure 2.10. Vickers hardness device (Buehler Britain Ltd., England), and a screenshot of theresult interface

As per suggestions of ASTM/C1327-15139, a controlled heap of 1 kgf (≈ 9.807 N) with a stay season of 15 sec. was applied to the outer layer of the sample. For each material, three measurements were taken. The Vickers hardness values that were acquired were converted into GPa units. Additionally, the materials' fracture toughness values (K_{1C}) were measured using the following equation in MPa.m $^{1/2}$ units:

K_{1C}= 0,0824. P/c $^{3/2}$ (K_{1C}: toughness for fractures, P: load, c: half of the crack's diagonal)

2.5. OPTICAL MICROSCOPE STUDIES

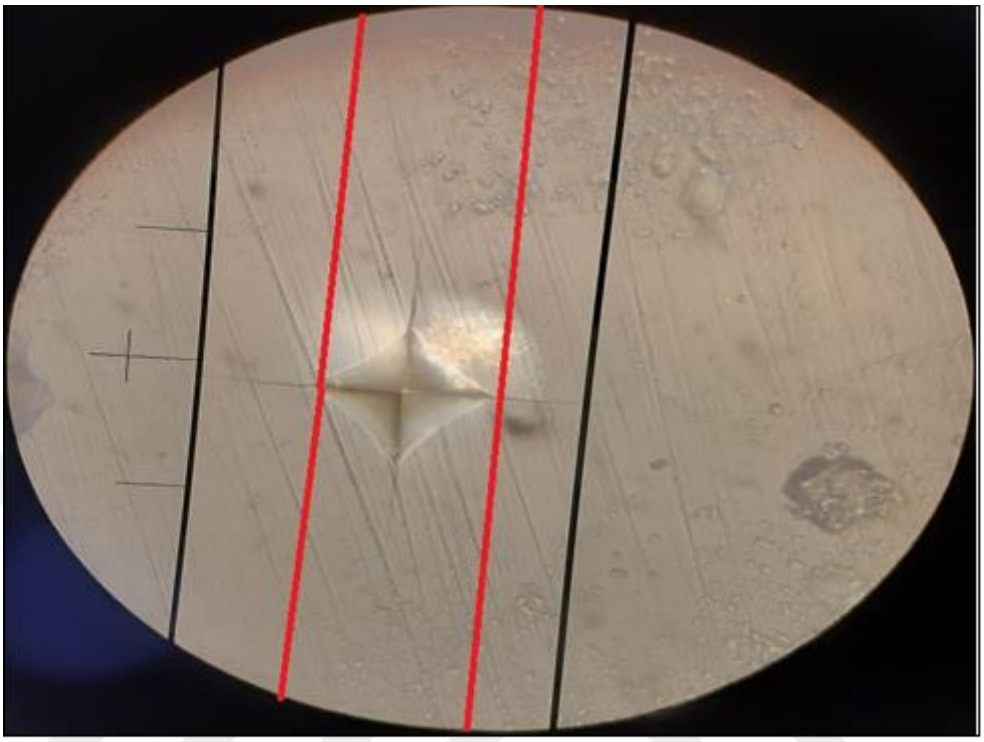

Figure 2.11. An indentation (two straight lines) was observed: Black Lines: reference for measuring fracture toughness, Red lines: reference for the measurement of Vickers hardness).

3. RESULTS AND DISCUSSIONS

3.1. SURFACE ROUGHNESS RESULTS

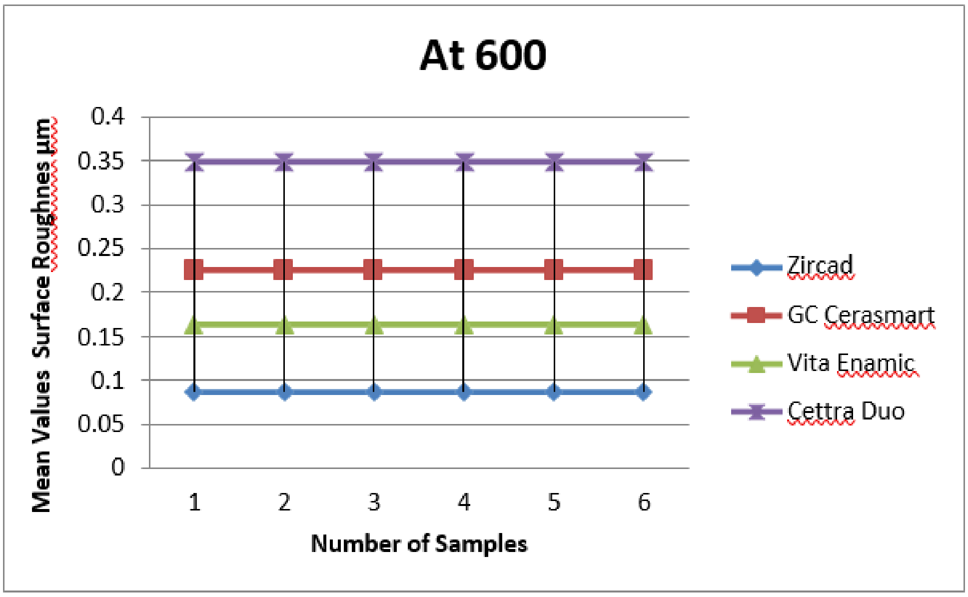

Figure 3.1. Changes in the mean values using sandpaper with a mesh size of 600, measurethe surface roughness relative to each substance.

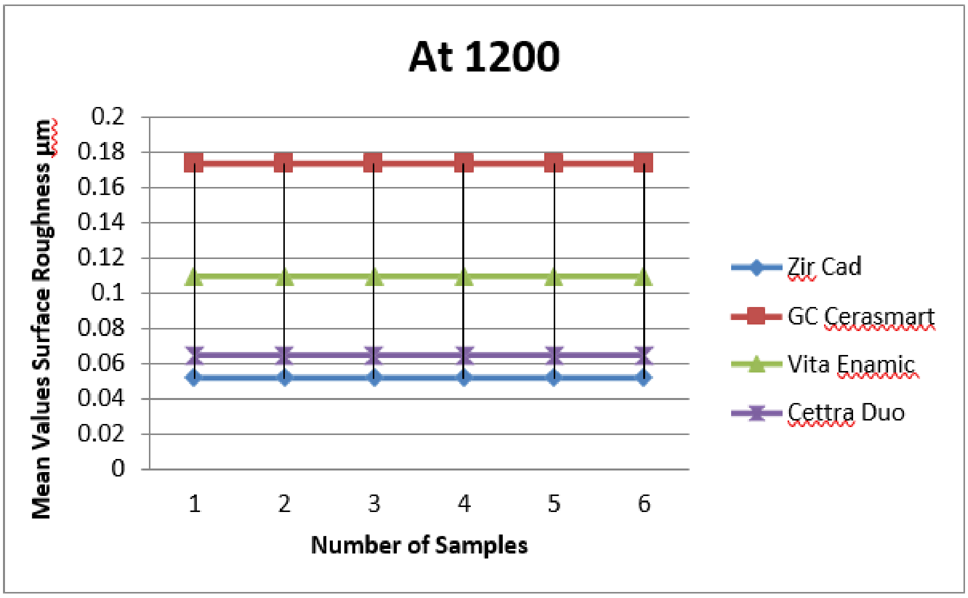

Figure 3.2. Changes in the mean values utilizing 1200 mesh sand paper, the surface roughness of each material

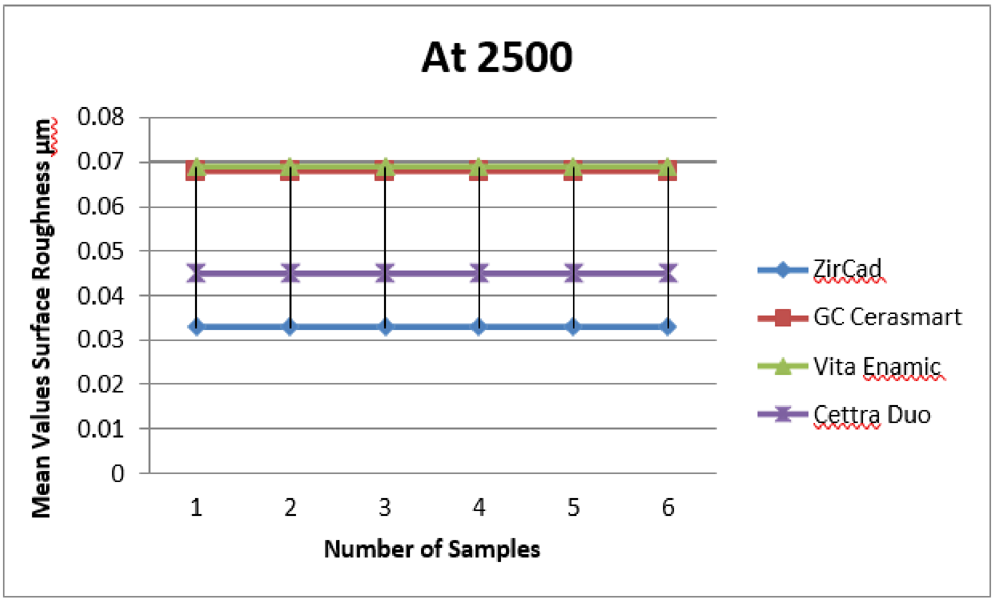

Figure 3.3. Changes in the mean values using sandpaper with a mesh size of 2500, measure the surface roughness relative to each substance.

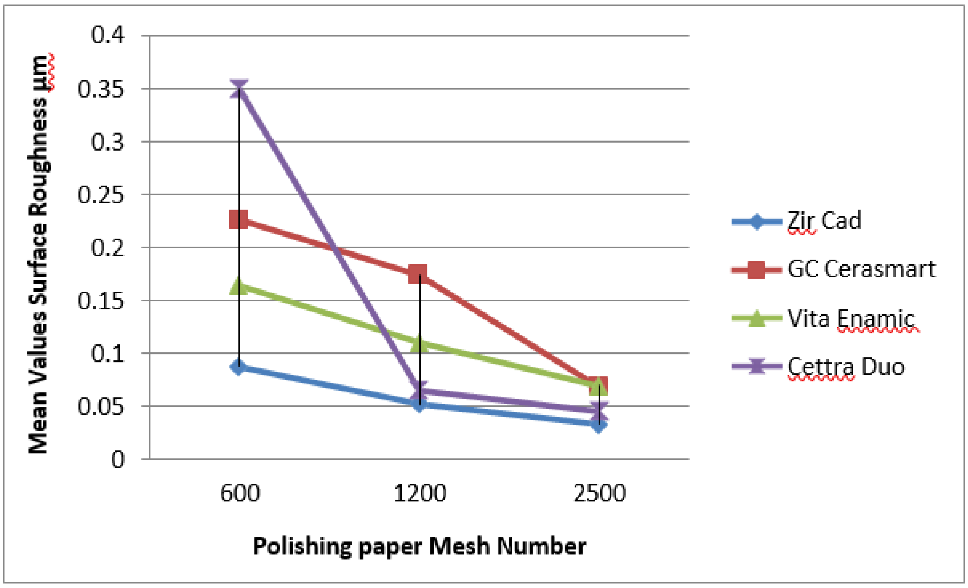

Figure 3.4. Changes in the mean values surface roughness in relation to each material's polishing paper mesh number

While using 600 mesh polishing paper: The surface roughness was arranged as ZirCad (0.087 µm) < Vita Enamic (0.164 µm) < GC Cerasmart (0.226 µm) < Celtra Duo (0.349 µm).

While using 1200 mesh polishing paper: The surface roughness was arranged as ZirCad (0.052 µm) < Celtra Duo (0.065 µm) < Vita Enamic (0.11 µm) < GC Cerasmart (0.174 µm).

While using 2500 mesh polishing paper: The surface roughness was arranged as Zir Cad (0.033 µm) < Celtra Duo (0.045 µm) < GC Cerasmart (0.068 µm) < Vita Enamic (0.069 µm).

Therefore, ZirCad was the smoothest.

3.2. HARDNESS RESULTS

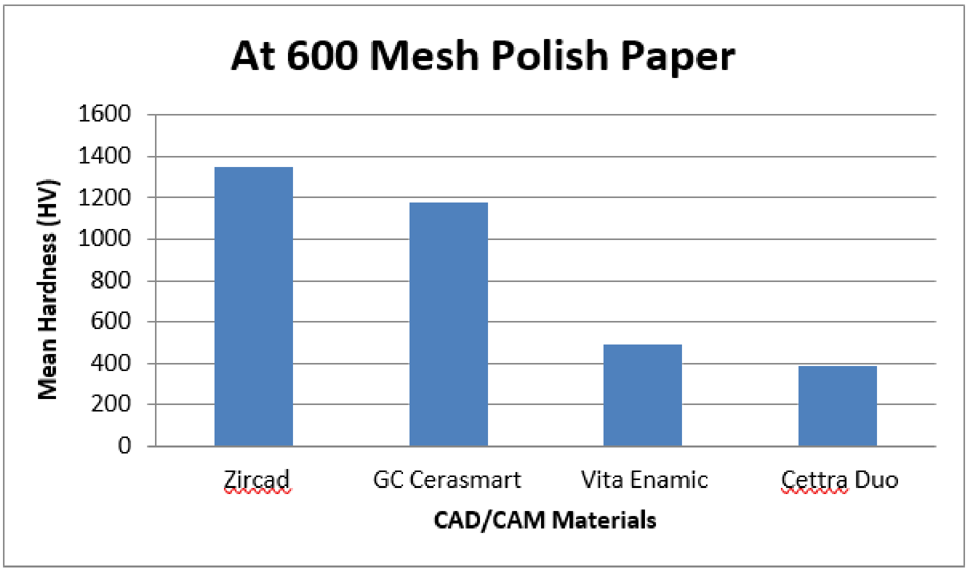

Figure 3.5. Mean Hardness (HV) values for each CAM/CAD material once using 600 meshpolish paper

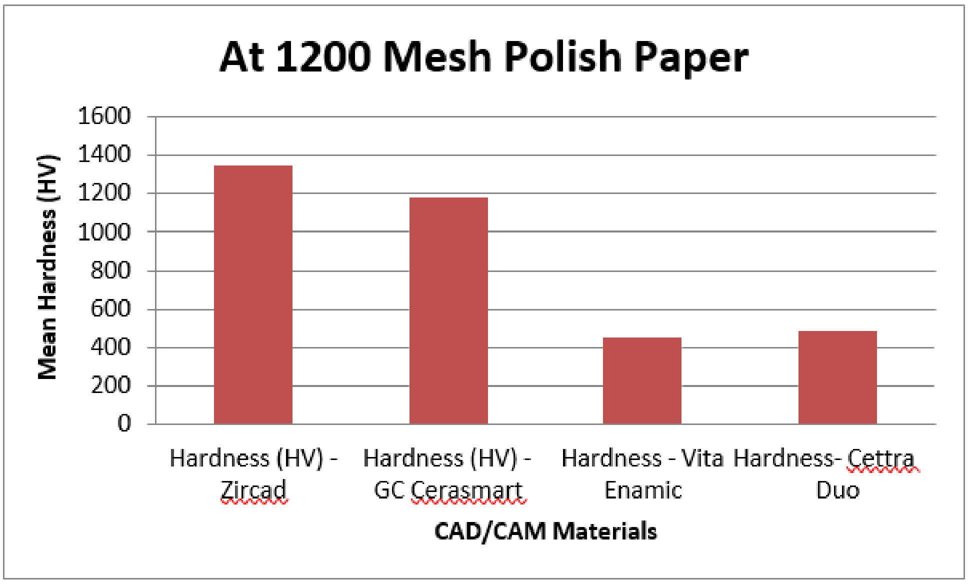

Figure 3.6. Mean Hardness (HV) values for each CAM/CAD material once using 1200 mesh polish paper

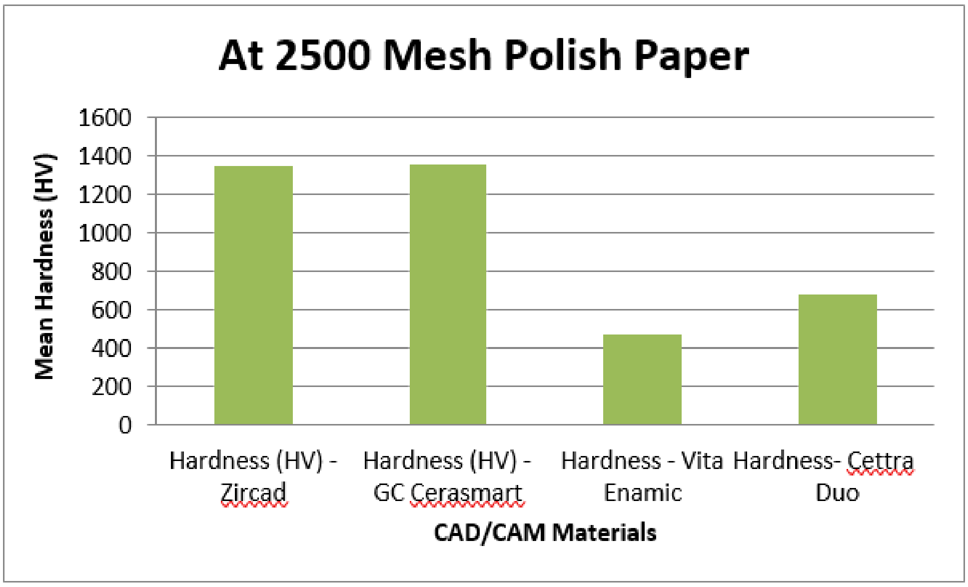

Figure 3.7. Mean Hardness (HV) values for each CAM/CAD material once using 2500 mesh polish paper

While using 600 mesh polishing paper: The Hardness (HV) was arranged as Zir Cad (1346 HV) < GC Cerasmart (1175 HV) < Vita Enamic (494 HV) < Celtra Duo (388 HV).Thus, Zir Cad has the highest hardness and Celtra Duo the lowest one.

While using 1200 mesh polishing paper: The Hardness (HV) was arranged as Zir Cad (1348 HV) < GC Cerasmart (1188 HV) < Celtra Duo (483 HV)< Vita Enamic (448 HV). Thus, Zir Cad has the highest Hardness and Vita Enamic the lowest one.

While using 2500 mesh polishing paper: The Hardness (HV) was arranged as GC Cerasmart (1355 HV) < Zir Cad (1344 HV) < Cetlra Duo (681 HV)< Vita Enamic (472 HV). Thus, GC Cerasmart has the highest Hardness and Vita Enamic the lowest one.

Therefore, ZirCad and GC Cerasmart has the highest hardness in the 3 cases.

3.3. FRACTURE TOUGHNESS RESULTS

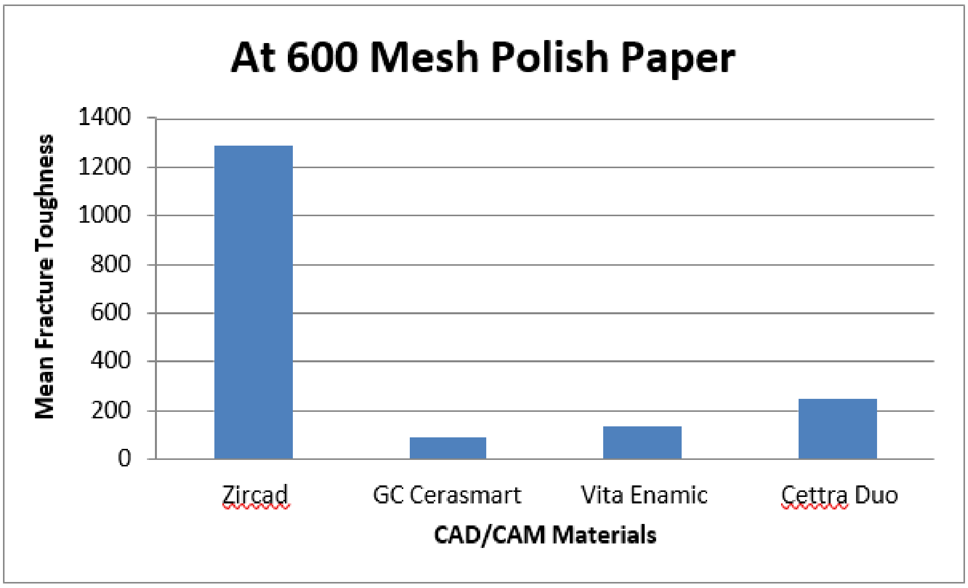

Figure 3.8. Mean Fracture Toughness (MPa.m$^{1/2}$) values for each CAM/CAD material onceusing 600 mesh polish paper

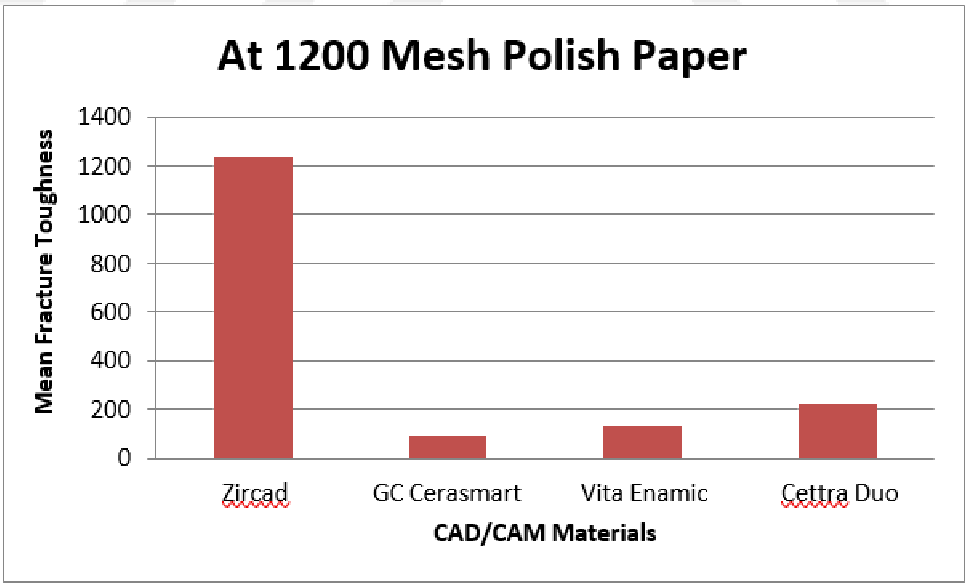

Figure 3.9. Mean Fracture Toughness (MPa.m$^{1/2}$) values for each CAM/CAD material onceusing 1200 mesh polish paper

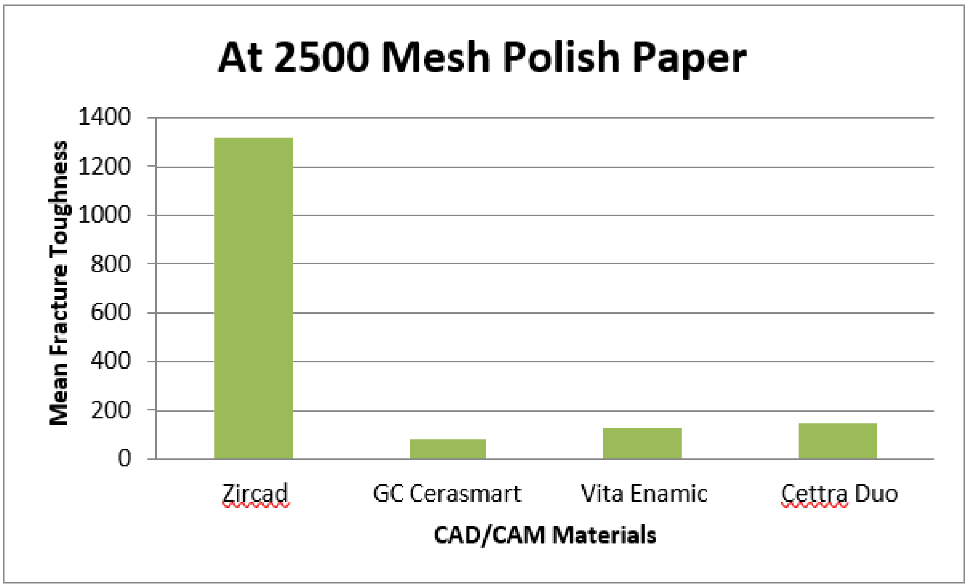

Figure 3.10. Mean Fracture Toughness (MPa.m$^{1/2}$) values for each CAM/CAD material onceusing 2500 mesh polish paper

While using 600 mesh polishing paper: The Fracture Toughness (MPa.m$^{1/2}$) was arranged as ZirCad (1287 MPa.m$^{1/2}$) < Celtra Duo (248 MPa.m$^{1/2}$)< Vita Enamic (136 MPa.m$^{1/2}$) < GC Cerasmart (90 MPa.m$^{1/2}$).

While using 1200 mesh polishing paper: The Fracture Toughness (MPa.m$^{1/2}$) was arranged as ZirCad (1236 MPa.m$^{1/2}$) < Celtra Duo (228 MPa.m$^{1/2}$)< Vita Enamic (135 MPa.m$^{1/2}$) < GC Cerasmart (93 MPa.m$^{1/2}$).

While using 2500 mesh polishing paper: The Fracture Toughness (MPa.m$^{1/2}$) was arranged as ZirCad (1318 MPa. $^{1/2}$) < Celtra Duo (146 MPa.m$^{1/2}$)< Vita Enamic (126 MPa.m$^{1/2}$) < GC Cerasmart (85 MPa.m$^{1/2}$).

Therefore, ZirCad has the highest fracture toughness and GC Cerasmart the lowest one in the 3 cases.

4. CONCLUSIONS

In this study it was aimed to investigate the effects of the surface roughness of the four commercial CAD/CAM dental materials, on the mechanical behaviours namely hardness and fracture toughness.

CAD/CAM dental materials used in the present study are;

1- Polymer Infiltrated Ceramic Network (PICN), a composite materials which contains86wt% Feldispathic ceramic and 14wt% polymer (Vita Enamic)

2- Resin nanoceramic is a composite materials contains 71wt% silica and barium nanoparticles, 29wt%composite resin (polymer) (GS Cerasmart)

3- Zirconia reinforced Lithium Silicate glass-ceramic with 58wt%glass-ceramic,10wt%zirconia and some other additives (Celtra Duo)

4- TZP partially stabilized with 3mol%Y2O3 (3Y-TZP) ceramic material (IPS-e.max ZirCad).

5- 3 different polishing papers (600-1200-2500 mesh number) were used in the polishing of the CAD/CAM dental materials to produce surfaces with various roughnesses.

Vicker's Indentation technique is the common method in the measurements of the hardness values in ceramics or composites. On the other end, fracture toughness measurements especially in brittle materials like ceramics and glass-ceramics, are quite difficult because when notched beams are used because of the large size requirements and to produce sensitive notches on the ceramic samples. As shown by Gunay and Hampshire (80) that, Vickers indentation technique can be used in the Kıc measurements in ceramics and composites. Due to the sizes available in the commercial CAD/CAM materials, Vicker's Indentation technique was used in the present study.

The results were found at the end of this dissertation study are listed below;

1- In the surface roughness results, ZrO2 based CAD/CAM dental ceramic has the lowest roughness values and as a result smoothest surface.

2- In the hardness (HV) results, as expected ZrO2 based ceramic material was the hardest in all and hardness values were lower with increasing polymer content in the CAD/CAM dental materials.

3- In the fracture toughness results, ZrO2 based dental ceramics has the highest Kıc values with a far superior values from others.

4- It was observed that, surface roughness values were not an effective parameters on the mechanical behaviours in the CAD/CAM materials in the studied range. This is important for dentist because, during the shaping (machining) of the tooth shape from the CAD/CAM pre-ceramics, they have to use cutting and polishing steps.

5- Cutting and polishing of these CAD/CAM dental materials can easily be carried out with simple laboratory equipments.

6- Results indicated that the polishing of these CAD/CAM materials especiall with 2500 mesh polishing paper did not create surface flows on the materials.

CAD/CAM dental materials are getting more popular every day and mechanical processes such as cutting and polishing are needed to shape the materials for individual patient. There are some studies on machining of the CAD/CAM dental materials but some more studies needed especially by using the chair-side machining equipments which used by the dentists.

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