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DENTAL CERAMICS: A COMPREHENSIVE REVIEW ARTICLE

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ABSTRACT

High aesthetic standards for prosthodontics restorations have steered the scientific development of materials towards all-ceramic materials that can take the place of porcelain-fused-to-metal systems. The technological development of ceramics for applications in dentistry has advanced significantly over the last four decades, with the steady introduction of novel compounds and processing methods. The expansion of the range of indications to include implants, implant abutments, and long-span fixed partial prostheses has been made possible by improvements in both strength and toughness. The state of ceramics for applications in dentistry is presented in this review.

KEYWORD: all-ceramics, sintering, feldspar, silica, glass, firing, slip casting, zirconia, CAD-CAM.

INTRODUCTION

Partially stabilised zirconia's unparalleled mechanical qualities, coupled with its arrival to the dental the marketplace nearly ten years ago, significantly increased the range of possibilities for ceramics in dentistry. This field traditionally relies on ceramics because of their chemical inactivity and a wide range of optical properties that allow for excellent aesthetics. Metal frameworks for dental restorations are still frequently veneered with ceramics, despite the current trend towards the development of all-ceramic systems.[1]

But it also have limitations as restorative materials, primarily because they cannot withstand the functional forces found in the oral cavity. As a result, they were initially only used in the premolar and molar regions, but advancements in these materials have made it possible for them to be used as posterior long-span fixed partial prosthetic restorations and structures over dental implants comparing to other materials, like metals, reveals that all of them have low fracture toughness.[2]

Overall, dental ceramics continue to evolve with advancements in materials science, offering increasingly stronger and more aesthetically pleasing options for patients seeking restorative dental treatments. This article reviews the composition, structure and properties and developments of dental ceramic systems over the last decade and considers the state of the art in several extended materials and material properties.

CLASSIFICATION OF DENTAL CERAMICS

Dental ceramics can be categorised in a number of ways, such as by their microstructure, translucency, fracture resistance, abrasiveness, fusing temperature, composition, and processing method.

Ceramics can be categorised into three groups based on their composition.[3]

- glass-based ceramics,
- glass-filled ceramics,
- polycrystalline ceramics

Table 1: Fusion temperature ranges of various dental porcelains and their clinical applications.[4]

Porcelain Type	Fusion temperature range	Clinical Applications
High fusing	> 1300°C	Denture Teeth
Medium Fusing	1000°C- 1300°C	Jacket Crowns, Bridges and Inlays
Low Fusing	850°C - 1000°C	Veneers over cast metal crowns
Ultra-low Fusing	< 850°C	Used with Titanium and its alloys

Based on their processing techniques all-ceramic restorations are widely classified into sintered porcelains, castable glass ceramics, machinable ceramics, slip-casted ceramics, heat pressed and injection molded ceramics **(Figure – 1)**[5]

Name of Processing technique	Type of ceramic	Crystalline Phase	Brand & Manufacturer
Sintered porcelains	Leucite- reinforced Feldspathic porcelain	Sanidine	Optec HSP, Jeneric/Penetron Inc.,
	Alumina based porcelain	Alumina	Hiceram, Vident, Baldwin Park, CA.
	Magnesia based core porcelain	Forsterite	Vident, Baldwin Park, CA.
	Zirconia based porcelain	Mirage II	Myron International, Kansas City, KS
Castable glass ceramics	Mica based porcelains	Tetrasilicic fluoromica	DICOR, Dentsply International
	Hydroxyapatite based porcelains	Oxyapatite	Cerapearl, Kyocera, San Diego, CA.
	Lithia based porcelains	Lithium Disilicate	Vident, Baldwin Park, CA
Slip cast ceramics	Slip-Cast + Glass Infiltrated	Alumina	In-Ceram® Alumina, Vident, Baldwin Park, CA
	Slip-Cast + Glass Infiltrated	Spinel	In-Ceram® Spinell, Vident, Baldwin Park, CA
	Slip-Cast + Glass Infiltrated	12 Ce-TZP-alumina	In-Ceram® Zirconia, Vident Baldwin Park, CA
		3Y-TZP	Cercon®, Dentsply
Hot pressed, injection-molded ceramics	Leucite-based	Leucite	IPS Empress®, Ivoclar
	Lithium based	Lithium disilicate	IPS Empress® Eris, Ivoclar
	Cerestore	Spinel	Alceram, Innotek Dental Corp, Lakewood, CA.
Machinable ceramics	Cerec system	Tetrasilicic fluoromica	DICOR MGC, Dentsply International, Inc., York, PA
		Sanidine	Vitablocs®, Mark II Vident, Baldwin Park, CA.
	Celay system	Sanidine	Vita-Celay, Vident, Baldwin Park, CA
		Alumina	In-Ceram® AL, Vident, Vident, Baldwin Park, CA.
	Procera system	Alumina	Procera All Ceram, Nobel Biocare, USA
	CAD Based	Leucite	IPS Empress® CAD, Ivoclar
		Lithium disilicate	IPS e.max CAD, Ivoclar
	Lava CAD/CAM System	Y-TZP	Lava CAD/CAM, 3M ESPE, St. Paul, Minnesouta

Figure 1: All-ceramic restorative materials based on their processing technology.

STRUCTURE OF DENTAL CERAMICS

Ceramics can be either crystalline or amorphous (also known as glasses). Ceramics can be classified into two types: non-crystalline (amorphous solids or glasses) and crystalline. Dental ceramics' mechanical and optical properties are primarily determined by their crystalline phase composition.[6,7]

Non- Crystalline Ceramics

These consist of an amorphous (non-crystalline glass matrix) vitreous phase containing a mixture of crystalline minerals (feldspar, silica, and alumina). The fundamental silicone oxygen (Si-O) network is used in the glass-forming matrix of dental porcelains. Four oxygen atoms combine with silicon to form a tetrahedral configuration, in which the larger oxygen atoms act as a matrix and the smaller metal atoms, like silicone, are inserted into the spaces between the oxygen atoms. A single silicone atom (Si) encircled by four oxygen atoms (O) makes up each silica unit. This glass structure is stable due to the covalent and ionic nature of its atomic bonds, which also enable silica units to link with one another to form a chain configuration. In glass, a continuous SiO4 (tetrahedral network) is made up of several such connected silicate unit chains (Figure – 2). This stable structure, which has no free electrons and strong atomic bonds, gives the glass matrix important properties like inertness and translucency as well as good thermal and optical insulating capabilities. Nevertheless, even in applications with low tensile stress, these robust dual bonds may also give the glass matrix brittleness, which could result in fracture.[4,8,9]

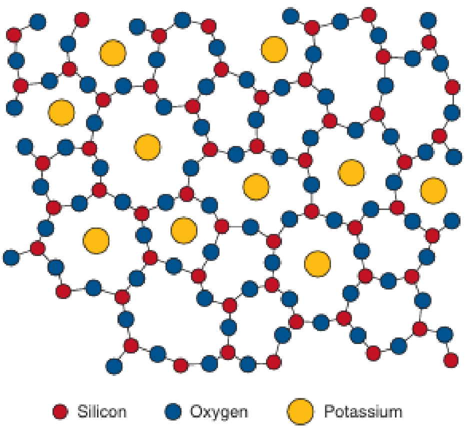

Figure: 2 Two-dimensional amorphous structure of potassium silicate glass.

Crystalline Ceramics

To strengthen the material and increase its resistance to fracture, ceramics are reinforced with crystalline inclusions like leucite and alumina into the glass matrix to create crystal glass composites (dispersion strengthening). The first generation of reinforced porcelains, known as "Aluminous porcelains," were first introduced by McLean and Hughes (1965) for porcelain jacket crowns. Covalent crystals, like silicone carbide, are extremely hard and have a high melting point (Figure – 3).[4]

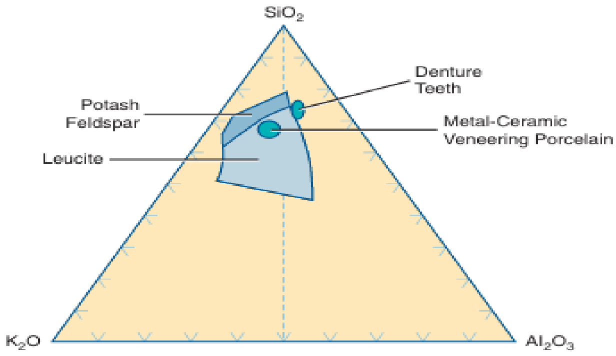

Figure 3: Principal phase fields of feldspathic ceramics in the ternary K2O-Al2O3-.

COMPOSITION (Table – 2)[4]

Ingredient	functions
Feldspar (naturally occurring minerals composed of potash [K2O], soda [Na2O], alumina and silica)	It is the lowest fusing component, which melts first and flows during firing, initiating these components into a solid mass.
Silica (Quartz)	• Strengthens the fired porcelain restoration. • Remains unchanged at the temperature normally used in firing porcelain and thus contribute stability to the mass during heating by providing framework for the other ingredients.
Kaolin (Al2O3.2 SiO2. 2H2O - Hydrated alumina-silicates)	• Used as a binder. • Increases moldability of the unfired porcelain. • Imparts opacity to the finished porcelain product
Glass modifiers, e.g. K, Na, or Ca oxides or basic oxides	They interrupt the integrity of silica network and acts as flux.
Colour pigments or frits, e.g. Fe/Ni oxide, Cu oxide, MgO, TiO2, and Co oxide	To provide appropriate shade to the restoration.
Zr/Ce/Sn oxides, and Uranium oxide	To develop the appropriate opacity.

PROPERTIES[10]

In addition to being chemically inert in the oral cavity, dental ceramics have outstanding biocompatibility with the soft tissues of the mouth. Their aesthetics are superb. Perhaps the most crucial mechanical feature of porcelain restoration is its structure.

- Compressive strength - 50,000 psi
- Tensile strength - 5000 psi
- Shear strength – 16000psi
- Elastic modulus – 10 x 10^6psi
- Linear coefficient of thermal expansion - 12X10^{-6}/ °C
- Specific gravity - 2.2 to 2.3
- Liner shrinkage - High fusing - 11.5 %

Low fusing – 14.0 %

- Refractive index - 1.52 to 1.54
- When contrasted with tensile or shear strength, porcelain's compressive strength is relatively high.
- Tensile strength is low due to inevitable surface flaws and low shear strength due to the material's lack of ductility. Both overfiring and underfiring are detrimental to its power. While excessive vitrification happens when porcelain is overfired (firing at temperatures higher than normal or for longer periods of time), the required quantity of vitrification does not occur when porcelain is underfired (firing at temperatures below normal or for insufficient periods).
- The specific gravity of porcelain is generally lowered by internal voids, including blebs and voids.
- Because porcelain is a very hard material with a high abrasion resistance, it wears down the restorative material or its neighbouring natural tooth structure excessively.
- The brittleness of porcelain is one of its main disadvantages. (Ceramic teeth are naturally brittle under stress.)
- Porcelain lets light through. (The highest translucency, ranging from 45 to 50%, is found in incisal porcelain, while body porcelain has a translucency of 20 to 35%.)
- Because porcelain is chemically stable, corrosion-resistant, and relatively inert, it is very biocompatible.
- Achieve extremely polished and smooth surfaces; prevent plaque buildup; thus, promote gingival health.

STRENGTHENING OF DENTAL CERAMICS

Fatigue - Fatigue is defined as a progressive loss of strength. In clinical settings, ceramic crowns must function in wet conditions (with cement material inside and saliva outside). Two loading scenarios, namely static and cyclic stresses, lead to fatigue. The oral environment incorporates both cyclic and static stresses. The ceramic fatigue process may be caused by a chemical reaction among water molecules and the glass surface, which is followed by increased crack propagation because of stress concentration as long as the stress is released or removed. The best prosthesis design, the creation of remaining compressive stress, and the prevention of crack propagation are the three main components of strengthening ceramics using more recent techniques (Figure – 4).

Formation of the Material's Residual Compressive Stress

- Thermal compatibility – bonding to metal.
- Chemical tempering.
- Thermal tempering.
- Glazing.

Interrupting the Spread of Cracks

- Dispersion strengthening.
- Transformation toughening.

Making Component Designs

- To minimize tensile stresses.[5,11]

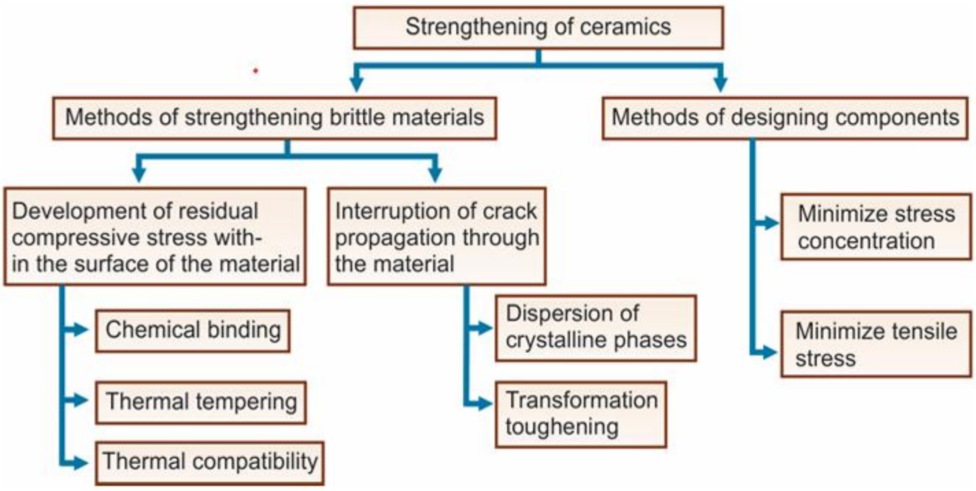

Figure 4: Methods of strengthening dental ceramics.

FIRING PROCEDURE/ SINTERING PROCEDURE[10]

The procedure of firing the consolidated ceramic powder at a high temperature to achieve the best densification is called sintering. Once the firing temperature is attained, this happens through viscous flow and pore elimination. Sintering is among the most widely used fabrication method for ceramic veneer used in metal-ceramic restorations. The technical steps involved in creating a porcelain restoration are as follows: Compaction, firing technique, and glazing.[12]

- Most of the thermo chemical reactions in porcelain are completed during the manufacturing process.
- The role of firing is simply to sinter the particles of porcelain powder together to form a dense restoration.[10]

Firing

Can be fired by following methods.

✔ **Temperature controlled method**: furnance temperature is raised at a constant rate until a specified temperature is raised

✔ **Temperature –time control method** : furnace temperature is raised at a given rate until a preset temperature is reached, after which temperature is maintained for specific time till the reaction is completed .preferred method as produces uniform restoration.

✔ At the initial firing temperature the voids are occupied by the atmosphere of the furnace.

As the sintering of the particles begins, the porcelain particles bond at their points of contact .as temperature is raised; the sintered glass gradually flows to fill up the air spaces. Second change occurs with a further rise in temperature when the particles fuse together by sintering.

Different media can be employed for firing like

A) Air
B) Vacuum
C) Diffusible gas

CONDENSATION OF DENTAL CERAMICS[7]

The process of bringing the particles closer and of removing the liquid binder is known as condensation. Distilled water is the liquid binder used most commonly. However, glycerin, propylene glycol or alcohol has also been tried.

- Several methods of condensation are employed.

1. **Vibration method**- After applying the paste to the platinum matrix, it is gradually vibrated. This causes

the extra water to float to the surface, where it is removed using a clean tissue or a fine brush. Condensation happens in the direction of the brushed or blotted area. Avoid excessive vibration as it may result in the mass slumping.

2. **Spatulation method-** The wet porcelain is applied and smoothed using a tiny spatula. The smoothing action pushes the particles closer together and causes the water to rise to the top, where it is eliminated as previously mentioned.
3. **Dry brush technique -** It entails applying dry powder to a moist surface. A brush is used to apply the powder to the side opposite a wet porcelain increment. The wet particles are drawn together as the water is drawn towards the dry powder.
4. **Whipping method-**, The damp porcelain is lightly dusted with a big, gentle brush. By doing this, extra water is brought to the surface, and any coarse surface particles can be removed with the same brush.
5. It is also possible to combine the vibration and whipping techniques. After vibrating the mixture, a brush is used to whip it.

RECENT ADVANCEMENT OF DENTAL CERAMICS

Kelly states that the ceramic can be characterised as a "composite," which is a combination of two or more separate substances.[12]

The mechanical and optical characteristics of the materials are influenced by the type, quantity, size, and coefficient of thermal expansion of crystalline phases.[13,14]

Sintered Porcelains

Porcelain sintering encourages physical-chemical reactions that give ceramic products their final characteristics. In the final sintering stage, the porosity level decreases. The primary factors that affect the amount of porosity are the sintering temperature, time, and melt viscosity.[5,15]

Leucite-reinforced Feldspathic Porcelain

Optec HSP is a leucite-reinforced feldspathic porcelain that is sold commercially. For metal-ceramics, In comparison to traditional feldspathic porcelain, Vaidyanathan et al. discovered that porcelain with a higher leucite content has a higher modulus of rupture and compressive strength.[16]

Alumina-based Porcelain: The strongest and hardest oxide known is alumina (Al2O3), which can be strengthened into ceramics using a process known as "dispersion strengthening."[17]

Magnesia-based Porcelain

The flexural strength and COTE of magnesium (MgO) are very high (14.5 x 10'6/°C), which is similar to that of the body and incisal porcelains that are designed to bond to metal (13.5 x 10-6/°C). The strength of these porcelains is further increased by glazing.[18]

Zirconia-based Porcelain

Zirconia is a polycrystalline substance that is incorporated into traditional feldspathic porcelain through a process known as "transformation toughening" to strengthen it.[4,7,13,19]

Yittria stabilised zirconia (YSZ) decreases fusion temperature and transparency while increasing strength, fracture toughness, and resistance to thermal shock.[7,13,20,21]

The majority of dental zirconia ceramics are opaque, so veneering is required for high aesthetics on the copings.[7,22]

Glass Ceramics

A glass ceramic that is made using the lost-wax pattern casting process is also known as a castable glass ceramic. Dentsply International developed "Dicor," the first commercially available castable ceramic material for dental use, which is provided as silicon glass plate ingots containing MgF2.[7,13,23]

The Chameleon effect, in which a portion of the colour is taken from a neighbouring tooth, is the important feature of this ceramics.[5]

Slip-Cast Ceramics

Compared to traditional feldspathic porcelains, ceramics made using the slip-casting technique have higher toughness and less porosity. But in the dental field, this approach might be technique-sensitive, and it's also challenging to achieve an exact fit.[24,25,26]

Table- 3: Composition and Properties of glass infiltrated slip-cast ceramics.

Property	Inceram-Alumina	Inceram-Spinell	Inceram-Zirconia
Composition	Alumina and Lanthanam Glass	MgO and Alumina	Alumina and Zirconia
Flexural Strength (MPa)	500	350	700
Translucency	Translucent	Highly Translucent	Opaque
Indications	Anterior and posterior crowns, Anterior 3-unit bridges.	Anterior crowns, inlays and onlays	Posterior Crown and Bridgeds.

Pressable Ceramics

The pressable ceramics are made by applying external pressure at high temperatures, which causes the ceramic body to sinter. They are also known as "hot-pressed" or "heat-pressed" ceramics, depending on the technology used for processing. With this manufacturing process, ceramics with increased density and better mechanical qualities are produced without porosity, extensive grain growth, or secondary crystallisation.[1,13]

Table-4: Properties of pressable ceramics.[5]

Property	IPS Empress 1	IPS Empress2
Flexural Strength (MPa)	112 ± 10	400 ± 40
COTE (ppm /^{0}C)	15 ± 0.25	10.6 ± 0.25
Pressing Temperature (^{0}C)	**1150** – 1180	890 – 920
Veneering Temperature (^{0}C)	**910**	800

Machinable Ceramics

A new generation of machinable ceramics was created as a result of the advancement of CAD-CAM (Computer Aided Design and Computer Aided Machining) technology for the creation of machined inlays, onlays, and crowns. This system's benefits include avoiding cross-contamination between the dental technician and the patient-dentist operational field and saving the dentist chair time by eliminating the need for impressions.[27,28,29,30]

The patient may receive the machinable ceramic prostheses in a single visit. Nevertheless, this system has certain disadvantages, such as the need for costly equipment and the requirement that the dentist or technician possess sufficient knowledge to operate the system.[30]

CONCLUSION

When it comes to dentistry, ceramics is an incredibly versatile material with many uses. As a result, scientists have been inspired to develop and improve the substance, creating increasingly complex forms. The development of technology has created new opportunities, such as the use of 3D printing for ceramics, in addition to enabling improvements at the microstructural level. These developments have made a substantial contribution to dentistry's advancement and opened the door to a bright future.[31]

REFERENCES

1. Denry I, Holloway JA. Ceramics for dental applications: a review. Materials, 2010 Jan; 3(1): 351-68.
2. Arango Santander S, Pelaez Vargas A, Saldarriaga Escobar J, Monteiro FJ, Restrepo Tamayo LF. Ceramics for dental restorations-An Introduction. Dyna, 2010 Sep; 77(163): 26-36.
3. Kelly Jr. dental ceramics: what is this stuff any way? J Am Dent Assoc, 2008; 139(suppl): s4-s7.
4. Babu PJ, Alla RK, Alluri VR, Datla SR, Konakanchi A. Dental ceramics: Part I–An overview of composition, structure and properties. Am J Mater Eng Technol, 2015 Mar; 3(1): 13-8.
5. Datla SR, Alla RK, Alluri VR, Babu JP, Konakanchi A. Dental ceramics: Part II–Recent advances in dental ceramics. Am J Mater Eng Technol, 2015; 3(2): 19-26.
6. Rama Krishna Alla, Dental Materials Science, Jaypee Brothers Medical Publishers Pvt Limited, New Delhi, India, 2013; 1st Edition, 333-354.
7. Anusavice KJ, Phillip's Science of Dental Materials, Elsevier, A division of Reed Elsevier India Pvt Ltd, New Delhi, India, 2010; 11th Edition, 655-720.
8. McLean JW, The science and art of dental ceramics, Volume I: The nature of Dental Ceramics and their clinical use. Quintessence Pub Co., Chicago, 1979.
9. van Noort R, Introduction to Dental Materials, Mosby, Spain, 1994; 201-214.
10. Sikri A, Sikri J. Textbook of conservative and restorative dentistry.
11. Purushothaman S, Jayakumar S, Sridhar D, John BM, Chandran K, Pulidindi H. Strengthening of ceramics: a review. J Sci Dent, 2023 Jul 14; 13(1): 28-30.
12. Kelly JR. Dental ceramics: current thinking and trends. Dental Clinics, 2004 Apr 1; 48(2): 513-30.
13. Denry IL, Recent advances in ceramics for dentistry, Crit Rev Oral Biol Med, 1996; 7(2): 134-143.
14. Raigrodski AJ Contemporary all-ceramic fixed partial dentures: a review Dent Clin N Am, Apr 2004; 48(2): 531-44.
15. Cheung KC, Darvell BW. Sintering of dental porcelain: effect of time and temperature on appearance and porosity. Dental Materials, 2002 Mar 1; 18(2): 163-73.
16. Vaidyanathan TK, Vaidyanathan J, Prasad A. Properties of a new dental porcelain. Scanning microscopy, 1989; 3(4): 5.
17. Kelly JR, Benett P, Ceramic Materials in Dentistry: Historical Evolution and Current Practice. Aust Dent, J., Jun 2011; 56: 84-96.
18. O'Brien WJ, Groh CL, Boenke KM, Mora GP, Tien TY, The strengthening mechanism of a magnesia core ceramic. Dent Mater, Jul 1993; 9(4): 242-245.
19. Sadaqah NR. Ceramic laminate veneers: materials advances and selection. Open Journal of Stomatology. 2014 May 5; 2014.
20. Raut A, Rao PL, Ravindranath T. Zirconium for esthetic rehabilitation: An overview. Indian J Dent Res, Jan Feb 2011; 22(1): 140-3.
21. Aboushelib MN, Kleverlaan CJ, Feilzer AJ, Microtensile Bond Strength of Different

Components of Core Veneered All-Ceramic Restorations. Part 3: Double Veneer Technique. J Prosthodont, Jan 2008; 17(1): 9-13.
22. Badami V, Ahuja B, Biosmart materials: Breaking new ground in dentistry, The Scientific World J, Article ID 986912, 7 pages, Volume Feb 2014.
23. Shenoy A, Shenoy N, Dental Ceramics: An Update, J Cons Dent, Oct 2010; 13(4): 195-203.
24. Griggs JA, Recent advances in materials for all-ceramic restorations, Den Clin North Am, July 2007; 51(3): 713.
25. Pallis K, Griggs JA, Woody RD, Guillen GE, Miller AW. Fracture resistance of three all-ceramic restorative systems for posterior applications. J Prosthet Dent, Jun 2004; 91(6): 561-569.
26. Yeo IS, Yang JH, Lee JB. In vitro marginal fit of three all-ceramic crown systems. J Prosthet Dent, Nov 2003; 90(5): 459-464.
27. Fairhurst CW, Dental Ceramics: The state of the science, Adv Dent Res, Sep 1992; 6: 78-81.
28. Taskonak B, Anusavice K, Mecholsky J, Role of Investment Interaction Layer on Strength and Toughness of Ceramic Laminates. Dent Mater, Oct 2004; 20(8): 701-708.
29. Mormann WH, The Evolution of the CEREC System. J Am Dent Assoc, Sep 2006; 137: 7S-13S.
30. Miyazaki T, Hotta Y, Kunii J, Kuriyama S, Tamaki Y, A review of dental CAD/CAM: Current status and future perspectives from 20 years of experience, Dent Mater J, Jan 2009; 28(1): 44-56.
31. Sharma R, Sharma AR, Madathil E, Tayal R. Recent trends in dental ceramics: A comprehensive. Journal of Academy of Dental Education•, 2025 Jan; 11(1): 61.