**Editor**

**Doç. Dr. Şeyhmus BAKIR**

gece kitaplığı

# International Research and Evaluations in the Field of Restorative Dentistry

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# INTERNATIONAL RESEARCH AND EVALUATIONS IN THE FIELD OF RESTORATIVE DENTISTRY

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**CONTENTS**

# Chapter 1

## BULK-FILL COMPOSITE RESINS

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## Introduction

Due to their easy processing, lower cost compared to ceramics, adequate aesthetic and mechanical properties, and ability to bond to tooth structure, composite resins are widely used in daily clinical practice. (Barutcigil, Ç., Barutcigil, K., Özarslan, M. M., Dündar, A., & Yilmaz, B., 2018). Since composite resins were first used in dentistry, they have been getting better and better. This has been because of changes to the chemistry of the materials used, the technology used to make the fillers, and the structure and physical and chemical properties of the resins.(Ilie & Hickel, 2011). Bulk-fill composites have been developed by dentists to overcome the challenges associated with traditional layering techniques in restorative dentistry.Layering, while effective in achieving desired esthetic and mechanical properties, is both time-consuming and technically demanding. Each layer must be carefully applied and cured, which can be labor-intensive and requires significant precision to ensure optimal results. The restorative process is made easier by bulk-fill composites, which allow for the placement of a single, thicker layer of material.This innovation not only reduces chair time for patients but also minimizes the risk of procedural errors such as the risk of contamination, the risk of gaps between layers, difficulties in placing the material due to limited access in some cavities and enhances overall efficiency in clinical practice (Abbas, G., Fleming, G., Harrington, E., Shortall, A., & Burke, F., 2003),(Sarrett, 2005) .

Bulkfill resin composites aimed to facilitate clinical placement of resin composites by allowing polymerization in 4-5 mm increments. These materials have improved light transmission and depth of cure compared to conventional resin composites. Filler modifications are a more translucent material with improved curing ability with high molecular weight monomers and new alternative photoinitiators(Ersen Ka Gurbuz O Ozcan, 2020),(Ilie N Bucuta S Draenert, 2013). Monomers and photoinitiators have been modified to improve optical properties, reduce polymerisation shrinkage and increase polymerisation depth.(Ilie N, 2014).

Bulk-fill materials are available in various formulations such as flowable, full body and fiber-reinforced resin. The bonding procedure can be shortened and postoperative sensitivity reduced by the operator through the use of self-adhesive bonding systems.(G., 2015),(Perdigão J, Frankenberger R, Rosa BT, Breschi L., n.d.). Other clinical advantages include the reduced likelihood of contamination of the primed bonding surfaces with saliva or water droplets, especially when most dentists do not use rubber dam isolation for the placement of restorative materials(Sabbagh J, McConnell RJ, Clancy McConnell M., 2017); and in a period of airborne virus

transmission such as COVID-19, the minimization of aerosol formation by applying a minimally invasive approach and rapid placement of the restorative material is an advantage for the operator and other members of the healthcare team.

**Composition of Bulk-Fill Composites**

Bulk-fill composite resins have a similar chemical composition to conventional resin based composite resins (RBCs), with some variations regarding filler particles and resin matrix. In general, the main monomers that make up the resin matrix of most composites are Bis-GMA, UDMA, TEGDMA and medium molecular weight EBPDMA. However, other monomers with lower viscosity have also been added (Corral-Núnez C, Vildósola-Grez P, Bersezio-Miranda C, Alves-Dos Campos E, Fernández GE., 2015).

A common property of all bulk-fill composites is that they are applied and polymerized in layers of 4 mm and even 5 mm for some products. Various modifications have been made to the bulk-fill formulations, especially regarding translucency, polymerization modulator and the use of a specific photoinitiator. There is no generalized composition for all bulk-fills as each product is manufacturer dependent. For example, Surefil SDR flow (DENTSPLY/Caulk) contains a special monomer called UDMA; (dimethacrylate urethane). The manufacturers claim that it has stress-reducing resin (SDR) technology from which it takes its name. This provides superior molecular flexibility, so it is relieved of polymerization stress during curing. Filtek Bulk-Fill flowable (3M) is based on a combination of four different monomers: Bis-GMA, UDMA, Procrylat and Bis-EMA. The UDMA monomer has been modified to contain a photoactive group that the manufacturer calls a "polymerization modulator". The material's exposure to light causes a decrease in polymerisation shrinkage and a separation of the photoactive groups.(Fugolin APP, 2017).Procrylat monomer is responsible for greater flowability, thus reducing polymerization stress.

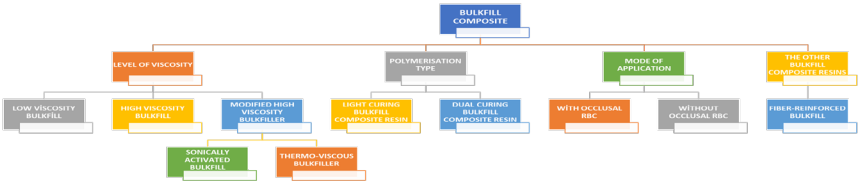
Bulk-fill composites are advanced nanohybrid resins that typically include ytterbium trifluoride, barium glass, mixed oxides, proacrylate, and zirconium/silica particles. These components enhance radiopacity and light penetration, improving both the aesthetic quality and depth of cure. Despite their lower inorganic filler content and larger filler particles compared to traditional composites, bulk-fill resins often achieve deeper polymerization. This is because there is less surface area between fillers and matrix, which helps to reduce light scattering and improve curing efficiency.

In bulk-fill composites, CQ has been utilized as a polymerization ini-

tiator. Tetric has added a new photoinitiator to Evoceram bulk-fill, Ivocerin by Ivoclar Vivadent. This photoinitiator acts as a polymerization promoter. It is also claimed to provide a more favorable clinical study duration by reducing light pollution (Corral-Núnez C, Vildósola-Grez P, Bersezio-Miranda C, Alves-Dos Campos E, Fernández GE., 2015).

## Classification of Bulk-fill Composites

The exact composition of many of the bulk-fill materials currently available is not provided by manufacturers, making it impossible to develop an accurate classification of materials (Van Meerbeek B., n.d.). The classification of bulk-fill composite resins is based on two key factors: their density and polymerisation type.




### According to Viscosity

### Low Viscosity Bulk-fill

Base bulk-fill is a low viscosity flowable material that facilitates insertion through a small nozzle of a syringe. This helps their adaptation to deeper and less accessible cavities. They show lower mechanical properties; the surface shows less wear resistance due to the lower amount of filler present compared to conventional/micro-hybrid or nanohybrid resin composites. Therefore, they need to be coated with a conventional composite representing a two-stage bulk-fill technique. These base bulk-fills are also referred to as fluid bulk-fill composites (Van Meerbeek B,.),(Chesterman J, Jowett A, Gallacher A, Nixon P., 2017).

### High Viscosity Bulk-fill

Full body bulk-fill composites have a higher inorganic filler content compared to low viscosity base bulk-fills, making them more wear resis-

tant and better able to withstand the chewing force. Therefore, they can be used to fill the entire cavity and shape its occlusal surface as a final layer without the need to cover it with a conventional composite (Van Meerbeek B., n.d.),(Chesterman J, Jowett A, Gallacher A, Nixon P., 2017),(Veloso et al., 2019).

**Modified High Viscosity Bulk-filler**

**Sonically Activated Bulk-filler**

Sonic-activated bulk-fill material (SonicFill and SonicFill 2 and more recently SonicFill 3 Kerr; Orange, CA, USA) is a highly viscous bulk-fill that is dispensed through an air-powered handpiece using sonic vibration, resulting in a reduction in the viscosity of the materials by almost 84%. This makes it simple to use as a flowable composite in the cavity, before it changes back into its more viscous state and is shaped into the required anatomy.(Van Meerbeek B., n.d.),(Chesterman J, Jowett A, Gallacher A, Nixon P., 2017),(Reis AF, Vestphal M, Amaral RC, Rodrigues JA, Roulet J-F, Roscoe MG., 2017).Sonic energy contributes to increased flowability through better dispersion of inorganic particles (dos Santos-Almeida Júnior L-J Tavarez R-R-DJ Firoozmand L-M., 2020).

**Thermo-Viscous Bulk-filler**

VisCalor bulk-fill is a material that is applied in a flowable consistency via a composite heater or the new VisCalor distributor, but can be shaped like normal temperature packable composites.

**According to Polymerisation Type**

Bulk-fill composites can be categorized as light-cure or dual-cure bulk-fill composites according to their photopolymerization mode (Aggarwal N, Jain A, Gupta H, Abrol A, Singh C, Rapgay T., 2019),(Lima et al., 2018).

**Light Curing Bulk-fill Composite Resin**

The development of a new type of composite that can be placed in a single layer of up to 4–5 mm was driven by the need for a faster and easier way to repair teeth.(Jackson, 2012). It is advocated by the manufacturers of light-cured bulk-fill resin-based composites (RBCs). They claim that their RBCs can be adequately light-cured in just one increment. This may

be up to 5 mm thick. This would save time. It could also reduce defects and porosity within the bulk of the restoration. Consequently, the popularity of bulk-fill RBCs has grown, with some studies reporting that they have an adequate depth of cure and good mechanical properties.(Fronza et al., 2015; Ilie & Stark, 2014; Van Ende et al., 2017),(Li et al., 2015; Lima et al., 2018)

The depth of cure is usually improved by making the material more translucent, increasing the content of photo-initiators, or using an additional type of photo-initiator.(Ilie, 2017). Despite the improved formula, these light-cure, bulk-fill composites can still undergo unsatisfactory polymerisation in the deeper layers due to restricted access or reduced curing light penetration.(Tarle et al., 2015).

**Dual Curing Bulk-fill Composite Resin**

The slower initial polymerisation reaction of the dual-cure bulk-fill resin composite prior to light activation has further advantages. It enables viscoelastic flow and stress relaxation within the material as the resin composite and adhesive copolymerise at the base of the cavity.

The compatibility of the adhesive with the bulk-fill composite is one aspect that should be considered. Although light-cured adhesive and composite systems are generally considered to be compatible, dual-cure bulk-fill composite may not be compatible with certain adhesives. This is particularly the case with one-bottle self-etch adhesives that use acidic functional monomers.An adverse acid-base reaction with the basic tertiary amine of the dual-cure composite may prevent polymerization of the dual-cure composite. Some adhesive manufacturers therefore recommend the use of an adhesive-incompatible dual-cure activator to reduce these adverse reactions with amine-based dual-cure composites(Meda et al., 2019).

To overcome adhesive incompatibilities, amine-free low-viscosity dual-cure bulk-fill composites have been introduced (e.g. BulkEZ, Danville Materials, Carlsbad, CA, USA). A comparison of cavity formation at the base of cavities between dual-cure and various light-cured bulk-fill composites has demonstrated the superiority of the dual-cure method when bonding to deep preparations.


*Comparison of bulk-fill bulk fill shades and conventional composite*

**The Other Bulk-fill Composite Resins:**

**Fiber-Reinforced Bulk-fillers**

Fiber-reinforced composites offer high stiffness and strength per weight compared to other structural materials along with sufficient stiffness (Scribante A Vallittu Pk Özcan, 2018). Short fibers have increased the material's ability to resist crack progression as well as reduced the stress concentration at the crack tip, where the crack progresses unstably. Several manufacturers have developed short-fibre-reinforced composites (SFRCs) that claim to overcome the weaknesses of the conventional PFC. The properties of SFRCs depend heavily on microstructural parameters such as fibre diameter, length, orientation, loading, and adhesion to the polymer matrix.(Pk., 2014). Recent studies have shown that millimeter- and micrometer-scale SFRCs (everX Posterior and everX Flow; GC Corporation) have significantly superior fracture toughness and reinforcement capacity compared to other commercial SFRCs (Alert, NovaPro-Flow, NovaPro-Fill, EasyCore, Build-It and TI-Core) (Garoushi et al., 2017),(Lassila et al., 2020).

SFRCs have the ability to transmit and distribute curing light better than conventional PFCs and are therefore suitable for use in bulk with a layer thickness of 4-5 mm (Lassila et al., 2019),(Garoushi S, Vallittu P, Shinya A, Lassila L., 2015),(Miletic V, Pongprueksa P, De., Munck, J., Brooks, N.R., Van., Meerbeek, B., 2017). Such an approach has the advantages of not only better wear resistance, but also higher strength and fatigue resistance. SFRCs are suitable as bulk base or core base and should not be used as final restoration.

Clinically, it is now widely recommended to use a composite bulk base (dentin substitute) material layer to improve aesthetics, reduce polymerization stress and develop better mechanical properties(Moorthy A, Hogg CH, Dowling AH, Grufferty BF, Benetti AR, Fleming GJP., 2012). The SFRC base has been used to reinforce large direct composite restorations in vital teeth(Fráter M, Forster A, Keresztúri M, Braunitzer G, Nagy K, 2014),(Garoushi et al., 2013) and endodontically treated teeth(Ozsevik AS, Yildirim C, Aydin U, Culha E, Surmelioglu D., 2015),(Fráter, Sáry, Jókai, et al., 2021), as a prosthetic foundations(Keulemans et al., 2010),(Nagata et al., 2016), onlay restorations(Garoushi et al., 2013),(Bijelic-Donova J, Keulemans F, Vallittu PK, Lassila LVJ., 2020) and endodontic post/core foundations(Fráter, Sáry, Néma, et al., 2021),(Fráter, Sáry, Jókai, et al., 2021).

Fiber-reinforced composites have been suggested as a means of reducing polymerization shrinkage and increasing toughness and impact strength, thereby improving the fracture resistance of restored teeth. (Karbhari & Wang, 2007). It has been reported by Nayar and others (Nayar et al., 2015) that strength properties over a wide range of conditions can be maintained by E-glass fibers and that they are relatively insensitive to moisture and are chemically resistant. The 'layered colour matching' technique is not appropriate for the new generation of sculptable 'bulk-fill' dental composites. These materials, which are applied in 4–5 mm thick layers with a fewer number of available shades, are intended for use as single-shaded materials, often for restoring the entire cavity in a single layer. An exception is the EverX Posterior (GC) fiber-reinforced material, which requires a capping layer of universal composite. This ensures optimal aesthetic results and prevents the glass fibers from hindering polishability. (Marjanovic et al., 2018).It is recommended by GC corporation that everX-Posterior requires a layer of a universal composite as a capping layer. The everX-Posterior showed lower surface roughness before polishing; however, its roughness drastically increases after polishing. The higher surface roughness of this resin composite after polishing may result from abrasion of the resin matrix and its glass fibers, which reduces its polishability. The increased surface roughness also compromises the restoration's esthetic, which might be one of the reasons for the capping layer recommended by GC corporation(Marjanovic et al., 2018).

The table shows the recommended using, manufacturers, chemical composition, filler content, and shade availables of bulk-fill composites available today.

| Composite BF | Recommended Using | Manufacturer | Composition | Filler loading | Shades available |
|---|---|---|---|---|---|
| Bulk-fill RBC | | | | | |
| Filtek Bulk-fill | 5 mm | 3M ESPE | Monomers:1,12-dodecane-DMA, UDMA,AUDMA<br>Fillers:20 nm silica filler, 4–11 nm zirconia filler (non-agglomerated, non-aggregated),Aggregated zirconia/silica cluster filler (composed of 20 nm silica and 4–11 nm zirconia particles),Ytterbium trifluoride filler (agglomerated particles, ~100 nm) | 76.5% wt<br>58.4% vol | A1, A2, A3, B1, C2 |
| Filtek One Bulk-fill | 5 mm | 3M ESPE | Monomers: UDMA, DDDMA,AUDMA<br>Fillers:Zirconia/silica cluster filler (4–20 nm), Ytterbium fluoride (100 nm) | 76.5 % wt<br>58.4% vol | A1, A2, A3, B1, C2 |
| Tetric Evo Ceram Bulk-fill | 4 mm | Ivoclar-Vivadent | Monomer: Dimethacrylates (20–21% by weight)<br>Fillers (78–81% by weight): Barium glass, Ytterbium trifluoride, Mixed oxide, Prepolymer<br>Other Components (<1.0% by weight): Additives, Catalysts, Stabilizers, Pigments | 78%–81% wt<br>53–54% vol | IVA (Universal A shade) IVB (Universal B shade) IVW (white) |
| Tetric N-Ceram Bulk-fill | 4 mm | Ivoclar-Vivadent | Monomers: Bis-GMA,UDMA<br>Filler: Ba-Al-silicate glass prepolymer filler (particle size: 0.04–3 µm) | 77%wt<br>55%vol | IVA (Universal A shade) IVB (Universal B shade) IVW (white) |
| X-tra fil | 4 mm | VOCO | Monomers: Bis-GMA, UDMA, TEGDMA Filler: Barium–boron–alumino–silicate glass (2–3 µm) | 86%wt<br>70.1% vol | Universal shade |
| Aura Bulk-fill | 5 mm | SDI Dental | Monomers: UDMA, Bis-EMA, Bis-GMA Fillers: Amorphous $SiO_2$, Barium aluminosilicate glass, Prepolymerized filler | 81%wt | BKF universal shade |
| Beautifil Bulk Restorative GIOMER | 4 mm | SHOFU | Monomers: Bis-GMA, UDMA, Bis-MPEPP, TEGDMA<br>Fillers:S-PRG filler (based on fluoroboroaluminosilicate glass)<br>Other Components:Polymerization initiator, Pigments, Others (unspecified additives, stabilizers, etc.) | 87% wt<br>74.5% vol | Universal, A |
| Palfique Bulk Flow | 4mm-10sec no capping layer required | Tokuyama Dental | Monomers:Bis-GMA, TEGDMA, Bis-MPEPP<br>Additives:Mequinol, Dibutyl hydroxyl toluene (BHT), UV absorber | 70%wt<br>56%vol | A1, A2, A3, B1, U |

| | | | | | |
|---|---|---|---|---|---|
| EverX Posterior | mm | GC | Monomers:Bis-GMA,PMMA,TEGDMA<br>Fillers:Short E-glass fiber, Barium borosilicate glass | 74.2 wt%, 53.6 vol%) | Universal shade (transparent) |
| Ecosite Bulk-fill | 5 mm | DMG | Monomers:Bis-GMA Filler: Barium glass | 82%wt<br>65%vol | Light, universal, contrast for core build ups |
| Opus Bulk-fill APS | 5 mm | FGM | Matrix:Urethane dimethacrylate (UDMA)<br>Filler:Nanofiller, Inorganic load consisting of silanized silicon dioxide (silica) and barium glass aluminosilicate<br>Additional System:Photoinitiating Advanced Polymerization System (APS) | 76.5%wt-58.4%vol | A1, A2, A3 |
| Reveal HD bulk-fill | 5-6 mm | BISCO | Monomer:Urethane dimethacrylate (UDMA),Bisphenol A-glycidyl methacrylate (Bis-GMA)<br>Filler:Ytterbium fluoride | Not obtained from company | A1, A2, A3, B1 |
| Alert Condensable composite | 5 mm | Pentron | Filler: Conventional glass fiber, Micro glass fiber | 84 wt%<br>62 vol% | A2, A3, A3.5, B1, C2 |
| Bulk-fill Base RBC | | | | | |
| Surefil SDR flow Universal | 4 mm | Dentsply Sirona | Monomers / Resins: Modified urethane dimethacrylate resin, Ethoxylated bisphenol A dimethacrylate (EBPADMA) Triethylene glycol dimethacrylate (TEGDMA)<br>Fillers:Barium aluminofluoroborosilicate glass,Strontium aluminofluorosilicate glass<br>Other Components:Camphorquinone (photoinitiator),Butylated hydroxytoluene (BHT – inhibitor),UV stabilizer,Titanium dioxide (pigment),Iron oxide pigments | 68%w<br>44%vol | A1, A2, A3 |
| Filtek Bulk-fill Flowable | 4 mm | 3M ESPE | Monomers:Bis-GMA, UDMA, Bis-EMA,Procrylat resin<br>Fillers:Ytterbium trifluoride ($YbF_3$), Ceramic fillers<br>Additives:Initiators, Stabilizers | 64.5%w<br>42.5%vol | Universal, A1, A2, A3 |
| Venus Bulk-fill | 4 mm | Heraeus Kulzer | Monomers:Multifunctional methacrylate monomers (UDMA, EBADMA)<br>Fillers:Barium aluminum fluorosilicate (Ba-Al-F) glass,Ytterbium fluoride ($YbF_3$),Silicon dioxide ($SiO_2$) | 65%w<br>38%vol | Universal |

| | | | | | |
|---|---|---|---|---|---|
| Tetric EvoFlow Bulk-Fill | 4 mm | Ivoclar-Vivadent | Monomers:Bis-GMA,Urethane dimethacrylates<br>Fillers and Others:Barium glass filler, Ytterbium trifluoride, Highly dispersed silica, Mixed oxide,Prepolymers | 68%wt<br>46%vol | Universal shades IVA, IVB, IVW |
| X-tra base | 4 mm | VOCO | Monomers: Bis-EMA,UDMA<br>Fillers:Inorganic fillers embedded in a methacrylate matrix (aliphatic dimethacrylate) | 75%wt<br>61%vol | Universal, A2 |
| QuiXX Posterior | 4 mm | Dentsply Sirona | Monomers:UDMA-TEGDMA (di- and tri-methacrylate resins), Carboxylic acid modified dimethacrylate<br>Fillers:Strontium-alumino-sodium fluoro-silicate glass | 86%wt<br>66%vol | Universal |
| Beautifil Bulk Flow GIOMER | 4 mm | SHOFU | Monomers:Bis-GMA,UDMA,Bis-MPEPP,TEGDMA<br>Fillers:S-PRG filler (based on fluoroboroaluminosilicate glass)<br>Other Components:Polymerization initiator,Pigments,Others | 72.5 wt%,<br>51.0 vol% | Dentin(D)<br>Universal(U) |
| Capo Bulk-fill plus | 4 mm | Schütz dental | Monomers:Aliphatic urethane dimethacrylate,Tetramethylene dimethacrylate Fillers:Glass powder, Silicon dioxide | 77% wt<br>57%vol | Universal dentin colour natural appearance |
| Estelite Bulk-fill Flow | 4 m | Tokuyama Dental | Monomers:Bis-GMA,Bis-MPEPP,TEGDMA<br>Filler:Supranano spherical filler (spherical $SiO_2$-$ZrO_2$, 200 nm) | 70%w<br>56%vol | U, B1, A1, A2, A3 |
| EverX Flow | Bulk shade-5.5 mm<br>dentin shade-2mm | GC | Monomers:Bis-EMA,TEGDMA,UDMA<br>Fillers:Micrometer scale glass fiber filler, Barium glass | 70%wt<br>46%vol | Bulk shade, dentin shade |
| Geanial Bulk Injectable | 4 mm | GC | Monomers:Bis-EMA,UDMA<br>Fillers:Barium glass,Silica | 69 wt% | A1, A2 |
| LC Base | 4 mm | Parkell | Monomers:Bis-MPEPP,Polyglycol diacrylate,Aromatic urethane diacrylate | 70%wt | Dentin shade |
| Opus Bulk-fill Flow | 4 mm | FGM | Monomers:UDMA,Bis-EMA,Bis-GMA, TEGDMAFillers:Treated silanized ceramics,Ytterbium fluoride<br>Additives:Benzotriazole,Ethyl 4-dimethylaminobenzoate | 50–60%wt | A1, A2, A3 |
| Sonic Activated Bulk-fill | | | | | |

| | | | | | |
|---|---|---|---|---|---|
| SonicFill | 4 mm | Kerr | Monomers:Bis-GMA, TEGDMA, EBPDMA<br>Fillers:Silica, Glass, Oxide | 83.5wt%, 83 vol% | A1, A2, A3, B1 |
| SonicFill 2 | 5 mm | Kerr | Monomers:Bis-GMA,TEGDMA,Bis-EMA,Poly(oxy-1,2-ethanediyl), α,α′-[(1-methylethylidene) di-4,1-phenylene]bis[ω-[(2-methyl-1-oxo-2-propen-1-yl) oxy],2,2′ ethylenedioxydiethyl dimethacrylate<br>Fillers:Silicon dioxide ($SiO_2$), Glass, Oxides | 81.3% wt<br>%vol unreported | A1, A2, A3, B1 |
| SonicFill 3 | 5 mm | Kerr | Monomers:Ethoxylated bisphenol-A-glycidyl methacrylate,Bisphenol-A-glycidyl dimethacrylate,Triethylene glycol dimethacrylate<br>Fillers:Oxides, Aluminum, Barium glass, Silica, Ytterbium fluoride ($YbF_3$) | 81.5 wt%<br>65.9 vol% | A1, A2, A3 |
| Thermo viscous technology | | | | | |
| VisCalor Bulk | 4 mm | VOCO | Monomers:Bis-GMA, Aliphatic dimethacrylate<br>Fillers: Inorganic fillers | 83 % wt | U, A1, A2, A3 |
| Dual cured bulk-fill | | | | | |
| Fill Up | no capping | Coltene-Whaledent | Monomers:TMPTMA,UDMA,Bis-GMA,TEGDMA Fillers:Zinc oxide coated fillers<br>Initiators / Additives:Dibenzoyl peroxide,Benzoyl peroxide | 65 wt%<br>49 vol%. | A2, A3 |
| HyperFil | LIGHT-CURE: 40 seconds with curing light • SELF-CURE: 4 minutes | Parkell | Monomers:Bis-EMA,UDMA,Other dimethacrylate monomers,Mixture of methacrylate resins including Bis-GMA<br>Initiators and Stabilizers:Benzoyl peroxide initiators, Stabilizers<br>Fillers:Silane-treated glass fillers (barium glass/silica) | 70–75 wt% | A1, A2, B1, B2<br>universal shade<br>enamel shade |
| Injectafil DC (Dual-cure composite) | | Apex Dental Materials Inc., Lack Zurich, IL, USA | Monomers: Mixture of methacrylate resins including Bis-GMA, Filler: Silica glass Additives: Catalysts, Stabilizers, Pigments | 75 wt% | A2 |

| | | | | | |
|---|---|---|---|---|---|
| Bulk EZ | | Danville | Monomers: Bis-EMA, TEGDMA, Bis-GMA, UDMA,EBPDMA<br>Technologies:Patent-pending self-cure IntelliTek Technology<br>Fillers:Fluoride compound (Proprietary)<br>Glass compound (Proprietary) | Barium glass 50–70 wt%<br>YbF3 1–20 wt% | A1, A2, A3 |
| Bulk EZ Plus | Unlimited depth of cure | Zest dental solutions | NA | 60-70%vol | A1/B1, A2/ B2, A3/A3.5/ B3, C2/ C3, Bleach Opaque, and Core White shades |
| Profil Bulk-fill | Unlimited depth of cure | Silmet | Fillers: Glass filler, Amorphous silica<br>Monomers:Methacrylate resin monomers | 60 wt% | U, enamel |
| Light-core (fiber reinforced) | 5 mm | BISCO | Monomers:Bis-GMA,Ethoxylated bisphenol A dimethacrylate<br>Filler:Glass fiber | (>60wt%) | Translucent and blue shades |
| N'Durance Dimer Core | 3,6 mm | Septodont | Monomers: Bis-GMA, UDMA, Dicarbamate dimethacrylate dimer acid<br>Fillers:Ytterbium fluoride (silanated), Barium glass (silanated),Silica (particle size range: 0.01–0.5 µm) | 80wt%<br>65 vol% | Bleach white shade<br>natural shade |
| ParaCore | Core build-ups | Coltene/ Whaledent | Monomers:Methacrylates<br>Fillers:Fluoride, Barium glass, Amorphous silica | 68%wt<br>50%vol | Dentin, white, translucent |
| Activa bioactive | | Pulpdent | Monomers / Polymers: Diurethane modified with hydrogenated polybutadiene, Methacrylate monomers, Modified polyacrylic acid<br>Initiators: Camphorquinone, Self-cure initiator<br>Fillers:Bioactive glass, Silica,Sodium fluoride | 56 wt% | A1, A2, A3, A3.5 |
| Admira fusion x-tra | 4 mm-ormocer<br>no capping | VOCO | Monomer:ORMOCER® resin<br>Fillers:Barium aluminium borosilicate glass,Silicon dioxide<br>Additives:Initiators, Stabilizers, Pigments | %84 w/w | universal shade |
| Bis-core (DC) | core material-dual curing | BISCO | Base: Bisphenol-A-glycidyl methacrylate (Bis-GMA), Glass filler, Urethane dimethacrylate (10 µm),Fused silica<br>Catalyst: Bis-GMA, Triethyleneglycol dimethacrylate, Glass filler,Fused silica | 78 wt-%, 60 vol.-% | Natural and opaque |

| | | | | | |
|---|---|---|---|---|---|
| Bisfil 2B (CC) Self-cure | chemicaly curing | BISCO | Monomers: Bis-GMA, Bis-EMA, TEGDMA Fillers: Glass filler, Fused silica, Amorphous silica | 65%vol | Universal, A3 and A3.5 shade |
| Bisfil II Self-cured | chemicaly curing | BISCO | NA | NA | Universal |
| Clearfil Core (CC) | core material-chemicaly curing | Kuraray Noritake | NA | NA | Neutral colour shade |
| Clearfil DC Core Plus (DC) | core material-dual curing | Kuraray Noritake | Monomers:Bis-GMA (<5%), Hydrophobic aliphatic dimethacrylate (<5%),Hydrophilic aliphatic dimethacrylate,Hydrophobic aromatic dimethacrylate<br>Fillers: Silanated barium glass filler Silanated colloidal silica Colloidal silica<br>Additives:dl-Camphorquinone, Initiators,Pigments | NA | White |
| Clearfil PhotoCore | 7 mm-core material | Kuraray Noritake | Monomers:Bis-GMA (<13%),Triethylene glycol dimethacrylate (<6%)<br>Fillers: Silanated silica filler,Silanated barium glass filler<br>Additives:dl-Camphorquinone,Catalysts & Accelerators | NA | Translucent |
| Core-Flo DC | core material-chemically curing | BISCO | Monomers:Bis-GMA,Ethoxylated Bis-GMA,TEGDMA<br>Fillers:Glass filler,Fused silica,Amorphous silica | NA | Natural/A1 and opaque white |
| Core-Flo DC Lite | core material-chemically curing | BISCO | NA | NA | Natural/A1 and opaque white shades |
| Core Restore 2 (DC) | core material-chemically curing | Kerr | NA | NA | Universal, white, blue, untinted |

Bis-GMA: bisphenol A diglycidyl methacrylate, TEGDMA: triethyleneglycol dimethacrylate, UDMA: urethane dimethacrylate, Bis-MPEPP: bisphenol A polyethoxy methacrylate, Bis-EMA: ethoxylated bisphenol A glycol dimethacrylate, Procrylat: 2,2-bis[4-(3-methacryloxy-propoxy)phenyl]propane, Bis-MEPP: bisphenol A ethoxylate dimethacrylate, S-PRG: surface modified prereacted glass, DDDMA:1,12-Dodecanediol dimethacrylate, AUDMA: aromatic urethane dimethacrylate, NA: not available

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99

# Chapter 2

## BULK-FILL COMPOSITE RESINS

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**The Physical and Mechanical Properties of Bulk-Fill Composite Resins**

Differences in mechanical properties and depth of cure can be attributed to differences in resin compositions, material translucency, viscosity, filler type and content (I-N., 2015). The mechanical properties of bulk-fill RBCs have actually been the subject of some controversy. Some authors have reported mechanical properties lower than conventional high-fill RBCs, while others have reported values close to conventional materials (Leprince et al., 2014). The type of organic matrix, filler size and morphology, monomer type and ratio, and photoinitiation chemistries vary greatly between products. This makes comparison of mechanical properties very difficult (Leprince J, Palin WM, Mullier T, Devaux J, Vreven J, Leloup G., 2010).

Differences in mechanical properties have been reported between flowable, full body and fiber-reinforced bulk-fill materials. Due to their poor mechanical properties, the use of low viscosity bulk-fill composites is not recommended in situations of high mechanical stress, such as direct contact with occlusal loads(El-Safty S, Akhtar R, Silikas N, Watts DC., 2012),(Ilie & Hickel, 2011).The previous results have shown that Young's modulus, Vickers hardness and Modulus of Indentation classify some bulk-fill materials (SureFil SDR, Venus bulk-fill and Filtek bulk-fill) between hybrid and flowable composites (Ilie N Keßler A Durner, 2013a). Attik et al. reported that fiber reinforced bulk-fillings showed lower flexural modulus and stiffness than full body bulk-fillings(Attik N, Colon P, Gauthier R, Chevalier C, Grosgogeat B, Abouelleil H., 2022). The authors reported similar flexural strength between these two types of bulk-fill materials. This leads to the conclusion that fiber reinforced bulk-fill materials can withstand higher stresses before failure.Fiber-reinforced materials have significantly higher fracture toughness results, demonstrating the higher toughness generated by the fiber reinforcement. These materials can prevent fractures from spreading within the material and are indicated for the restoration of endodontically treated teeth(Eapen AM, Amirtharaj LV, Sanjeev K, Mahalaxmi S., 2017) . Fiber-reinforced materials are exposed to higher stress during polymerization(Shouha & Ellakwa, 2017).

The mechanical properties of flowable bulk-fill composites are generally lower than those of full body high viscosity materials and are at best comparable to those of conventional flowable composites as given in Table(Leprince et al., 2014),(Osiewicz et al., 2022). The poor mechanical properties of flowable bulk-fill and fiber reinforced composites emphasize the necessity of coating with a conventional RBC. This coating procedure

should be established to overcome poor surface properties, low aesthetics and material degradation(Leprince et al., 2014).

**Comparison of mechanical properties of different restorative material types**

| | CONVENTIONAL FLOWABLE RBC | LOW VISCOSITY BF | FİBER-REINFORCED BF | HIGH VISCOSİTY BF | CONVENTIONAL RBC |
|---|---|---|---|---|---|
| YOUNG MODULUS | * | * | ** | *** | **** |
| VİCKER HARDNESS | **** | ** | *** | **** | ***** |
| İNDENTATİON MODULUS | * | ** | **** | *** | **** |
| FRACTURE TOUGNESS | ** | ** | **** | *** | * |
| FLEXURAL STRENGTH | * | * | *** | ** | ** |

**Degree of Conversion and Shrinkage Phenomena**

Polymerization shrinkage is a reduction in volume that occurs as the methacrylate composite monomer is converted into polymer. The shrinkage stress can pull the adhesive layer away from the margin to disrupt micromechanical retention. The shrinkage force causes fractures within the remaining intact tooth structure, known as composite, adhesive or even cohesive failure.

Cavity formation and loss of marginal seal are not only linked to the size of the restoration, but also to the direction of polymerization shrinkage. Versluis found that the direction of shrinkage is mostly determined by the quality of bonding to the tooth and the presence of unbonded surfaces(Versluis et al., 1998). It is important to establish adequate and timely copolymerization between the adhesive layer and the bulk-fill composite in order to resist competition between the development of shrinkage stress and the maturing dentin bond.

To ensure a well-adapted restoration margin with adhesive resin, the

composite must copolymerize well with the bond in the extensions of the preparation. In the conventional incremental approach, this has been successfully achieved with shallow composite layers that allow repeated and excessive light exposure for polymerization reactions. However, the bulk-fill technique prevents light from reaching the deepest extensions of the preparation. In other words, in conventional incremental placement of the composite, there are several separate light-curing steps each time a small layer of composite is placed. This allows for a gradual maturation of the bond to dentin and an increase in the polymerization performance of the adhesive layer due to increased irradiation. Therefore, an important difference between conventional incremental placement of the composite and bulk-fill is several separate light cures with each layer of composite versus one large layer. Lack of sufficient light irradiation can prevent complete curing of the composite and copolymerization of the composite with the bond. In measuring the difference in the completion of polymerization at various depths, it was found that in various types and shades of conventional composites, incomplete polymerisation occurred at greater depths using the bulk-fill technique, while no significant difference in hardness was observed at various depths using the incremental method(Lazarchik DA, Hammond BD, Sikes CL, Looney SW, Rueggeberg FA., 2007). Some researchers have therefore advocated the application of a composite coating or intermediate layer in these areas prior to the bulk placement of the subsequent layer to allow better polymerization of the adhesive-composite complex (Han et al., 2019),(Yahagi et al., 2012).

The shrinkage stress pattern for light-curing materials has been shown to be bottom-up from the bottom of the cavity to the top surface, generating a stress on the adhesive layer with the largest polymerization stress vectors in the deepest area of the preparation(Cho et al., 2011) . This is a critical issue for light-cured bulk-fill resin composites, especially given the possibility of insufficient irradiation of the adhesive before and after placement of the composite. One strategy in the development of the bulk-fill composite was to increase the overall translucency of the material to provide better light penetration, distribution and internal reflections(Ferracane, 2008).

Recently developed bulk-fill composites exhibit reduced volumetric shrinkage and lower polymerization shrinkage stress(Ilie & Hickel, 2011),(Al Sunbul et al., 2016),(Fronza et al., 2015),(He et al., 2019).Furthermore, BFs beyond the increased depth of cure, also seem to exhibit lower stress during polymerization shrinkage.(Ilie, N., S. Bucuta, and M. Draenert., 2013) These characteristics were obtained by the incorporation of modulators,(Ilie & Hickel, 2011) fillers(Roberts, Thomas Arwel, Kozo Miyai, Kunio Ikemura, Kiyomi Fuchigami, and Toshio Kitamura., 1999)

of different nature, a more powerful photoinitiator system,(Özyurt E Kurt A Yildirim, 2019) and by a higher translucency(Bucuta S, 2014a),(Benetti AR, Havndrup-Pedersen C, Honoré D, Pedersen MK, Pallesen U., 2015),(Ilie, N., S. Bucuta, and M. Draenert., 2013),(Ilie N Keßler A Durner, 2013b),(Flury S, Hayoz S, Peutzfeldt A, Hüsler J, Lussi A., 2012) compared with conventional RBCs.(Son SA, Park JK, Seo DG, Ko CC, Kwon YH., 2017) The latter is a key factor since it allows light to reach deeper layers of the restoration and therefore to be able to activate the polymerization chain reaction(Bucuta S, 2014a).

A newly developed bulk-fill system incorporates a high irradiance LED light curing unit (3s PowerCure, Ivocalt-Vivadent AG, Schaan, Liechtenstein). The light curing process in this system takes only 3 seconds using a high output (3000 mW/cm2) light curing unit. Comparing the high intensity light distribution with normal LED curing (1200 mW/cm2), it was observed that in the initial stage of composite polymerisation, the high intensity system caused copolymer isolation between the bulk-fill composite and the adhesive at the cavity bottom interface, which resists separation during polymerisation. Overall, this light-curing strategy, together with the increased translucency of the composite and improved photoinitiator chemistry, contributed to the preservation of composite bonding to the deepest areas in the preparation(Hayashi et al., 2020).

When the bond to the tooth structure is strong enough to resist an uncontrolled polymerization shrinkage stress and there is no debonding or stress relaxation (via viscoelastic flow of the composite), the shrinkage stress can lead to cuspal deflection, reduced bond strength or worse, crack formation and propagation (Wh., 2004). Therefore, it is clear that for the bulk-fill strategy to work, besides a good bonding ability, the polymerisation shrinkage management of the composite must also be considered for the success of the restoration.

If a strong bond to dentin has been successfully achieved, protecting the tooth and bonded restoration from damaging stresses is the next challenge to overcome. Bulk-fill composites are not zero-shrinkage composites; therefore, it is recommended to apply a stress-absorbing layer such as a resin coating with a flowable composite (Yahagi et al., 2012) or a continuous fiber-reinforced composite layer (Sadr A, Bakhtiari B, Hayashi J, Luong MN, Chen Y-W, Chyz G, et al., 2020) before bulk-filling . Since shrinkage is an intrinsic resin property, reducing resin volume by adding non-monomer components such as organic or non-organic fillers has been recognised as an effective way to reduce the magnitude of shrinkage. The incorporation of plasma-treated leno-weaved ultra-high molecular weight polyethylene fiber (Ribbond, Seattle, WA) at the base of a deep

cavity has had such an effect on polymerisation shrinkage while improving the physical properties of the composite and potentially acting as a crack arrest mechanism. Continuous fiber incorporation would add value to stress distribution and preservation of bond to dentin.

**Aesthetic Properties and Curing Depth of Bulk-fill Composites**

Each manufacturer provides its own color shade for bulk-fill composites. However, these shades tend to be more translucent than similar shades of conventional universal composites. When the refractive index of the resin and organic fillers is almost the same, the material is more translucent. One method of increasing the degree of polymerisation of bulk-fill materials is to increase their translucency (Leprince et al., 2014). This will allow better diffusion of light with increased polymerisation depth and coverage (Van Meerbeek),(Bucuta S, 2014b),(Chesterman J, Jowett A, Gallacher A, Nixon P., 2017). It is a well-known effect that when translucency increases, composite materials tend to have a lower value (clarity or gloss). In other words, the restoration becomes grayish. This is a commonly observed effect in bulk restorative materials, especially in low viscosity bulk-filling materials.

High translucency facilitates the penetration of light into the resin during polymerisation, increasing the degree of conversion and depth of cure. Low viscosity bulk-fill composites have a low filler loading which makes the composite more translucent, hence providing a greater depth of cure. Despite their better DOC, other properties such as aesthetics are compromised to achieve this translucency. If aesthetics are a priority for the patient in the posterior region, a capping layer of conventional composite can be placed as it is compatible with most bulk-fill materials. Some manufacturers, such as Ivoclar, have tried to overcome this limitation by introducing the chameleon-effect bulk-filler "asencio", which has increased opacity after polymerisation. SonicFill (Kerr) can also be used, which can be applied with a single layer technique(Chesterman J, Jowett A, Gallacher A, Nixon P., 2017; Fugolin APP, 2017; Sabbagh J, Hajj M, Feghali M, Mansour H., 2016).

Current bulk-fill restoratives cover basic monochromatic shades and enamel, dentin, body, translucent and opaque shades are not yet available. Instead of using pigments to achieve different shades, structurally coloured resin composites use filler systems with a refractive index similar to that of the hardened resin matrix (Ota M, 2012),(Oivanen et al., 2021). This results in sufficient light diffusivity to create the so-called chameleon effect(Oivanen et al., 2021).In a commercially available conventional res-

in composite (OmniChroma, Tokuyama Dental Corp., Japan), uniformly sized supra-nano spherical zirconia and silica fillers (260 nm) reflect light in the red to yellow spectrum (Tokuyama. Omnichroma: Technical Report; 2021. P. 4–9, n.d.). Similarly, light reflected from the neighbouring tooth structure is in the same spectrum. Combined light reflection from the tooth structure and restoration, as well as diffusion of light from the restoration to the nearby tooth structure, can lead to enhanced colour matching(Tsubone et al., 2012). This has led to the development of universal colour restoratives that can cover a wide range of classic shades. Bulk-fill restoratives can take advantage of these advances in colour chemistry and anterior teeth can be restored in bulk while producing an aesthetically appealing result.

Despite the less pronounced change in chemical composition in high-viscosity BF-RBCs compared to traditional RBCs, the enhanced cure depth (DOC) in certain BF-RBCs does not seem to be attributable to an improved refractive index mismatch between the resin and filler (Shortall et al., 2008). Rather, it appears to be achieved by decreasing the pigment content and increasing the filler particle size (Bucuta S, 2014a). The resulting increased transparency generally compromises aesthetics but allows light to penetrate deeper layers, thereby enabling improved DOC. The introduction of high-viscosity BF-RBCs to the market has been accompanied by claims that these cells are capable of achieving two conflicting objectives: namely, enhancing material opacity and increasing DOC (5 mm). However, a significant limitation of the majority of BF-RBCs available on the market is their capacity to increase by no more than 4 mm, a finding that has been confirmed by in vitro studies (Ilie & Stark, 2015) (Ilie & Stark, 2014).

Despite the rapid restoration process offered by BF-RBC materials, their aesthetic properties are often considered to be inadequate. Despite exhibiting superior transparency in comparison to conventional, layered RBCs (Bucuta S, 2014a), BF-RBCs may not adequately mask the dark visual effect of colour changes in the oral cavity or tooth structure, resulting in a restoration that appears "grayish". In view of the fact that recently marketed high-viscosity BF-RBCs have been promoted as having enhanced opacity and aesthetic properties, this issue is of particular interest in current research. High opacity is generally associated with reduced light transmittance and, consequently, diminished DOC. Research has demonstrated that light loss through various BF-RBCs available on the market is significant, with 9 to 14% of incoming blue light (896 ± 21 mW/cm$^2$) and 9 to 14% of incoming violet light (232 ± 10 mW/cm$^2$) reaching a depth of 2 mm. At a depth of 4 mm, the loss is 9 to 24% and 3 to 9%, respectively (Ilie, 2017). Consequently, enhanced opacity and elevated DOC

levels appear to be discrete objectives.

The dissimilarity between the refractive indices of the monomers and the fillers are mainly responsible for the transparency of the resin composites. The lesser the mismatch, the higher the translucency of the cured material will be. This property is essential for materials beyond the usual 2-mm increments suggested for restorative composite procedures.(Shortall et al., 2008)

Nevertheless BFs, due to their increased translucency, are not suggested for anterior restorations nor for cavities with pigmented substrates where the underlying background could influence the final esthetic result(Kim et al., 2009),(Ikeda et al., 2005)Regardless of the material, the optical appearance of the underlying substrate is in fact pivotal for the esthetic result of an esthetic adhesive restoration(Manauta J, Salat A, Putignano A, Devoto W, Paolone G, Hardan LS., 2014); therefore when the substrate is missing (class IV) or pigmented, an underlying "blocker" is indicated.(Atasayar & Ulusoy, 2023)

**Marginal Adaptation**

Marginal adaptation can be improved with flowable materials(Scholtanus JD, 2007),(Balkaya & Arslan, 2020).Cavity formation at the gingival margin in bulk-fill composites appears to be comparable with conventional composites(El Naga et al., 2020).It seems prudent to use flowable composites for better gingival adaptation, but to limit it to the area below the proximal contacts and to cover it with formable universal or bulk-fill composites because of their generally better mechanical properties. The marginal adaptability of formable composites can be improved by preheating the material(Lucey et al., 2010). A problem with preheated composites is that they cool rapidly(Rueggeberg et al., 2010), so placement should be done as soon as the material is removed from the heater. Gingival gap formation with bulk-fill composites appears to be comparable to conventional composites(El Naga et al., 2020). Flowable bulk-fill composite SDR was found to induce less gap formation in dentin compared to sculptable materials(Peutzfeldt et al., 2018).

**Flexural Strength**

The difference between the flexural properties of various RBCs is useful for different clinical situations(Yap et al., 2002),(de Carvalho RV Demarco FF., 2007). For instance, in Class I, II, III, and IV cavities, the

selection of RBCs with high flexural properties is typically undertaken to minimise fracture or deformation under high occlusal forces. Conversely, in Class V cavities, RBCs with low flexural modulus are favoured as they are able to flex with the teeth during function and parafunction, thereby reducing stresses at the adhesive interface and decreasing the likelihood of adhesive failure (Pontes et al., 2013). In fact, with their higher flexibility, bulk-fill flowable RBCs are preferred over full-bodied bulk-fill restorative or conventional materials in deep class V cavities because they provide better marginal adaptation(Szesz et al., 2017).

Recent studies have demonstrated that high viscosity (full body) bulk-fill resin bonded composites (RBCs) exhibit flexural strength values that are analogous to those of conventional resin composites (Tsujimoto et al. 2018; Jung&Park, 2017; Shibasaki et al., 2017). Bulk-fill flowable RBCs have a lower flexural modulus than full body bulk-fill restorative or conventional resin composites(Jung JH, 2017),(Na., 2020). A material with a low modulus of elasticity will result in higher deformation under masticatory stresses and reduced wear resistance, especially when placed in load-bearing areas. It has been established that high viscosity ("full body") bulk-fill restorative composites (RBCs) generally contain a higher filler content (Goracci et al., 2014; Van Meerbeek B., n.d.). This higher filler content enables them to be utilised in two distinct ways: firstly, to cover softer flowable RBCs, and secondly, to fill entire restorations. The superior wear resistance and improved mechanical properties of these RBCs (Goracci et al., 2014; Van Meerbeek B., n.d.) make them a valuable asset in dental restoration. In addition to the parameters of filler size and shape, the hardness of the fillers, the strength of the bond between the inorganic content and the polymer matrix, and the light curing of the RBC, have also been demonstrated to influence the wear resistance (Ilie et al., 2017).

Melo et al. compared conventional resin composites using incremental filling technique and bulk-fill RBCs. Conventional composites offered good physical properties, but bulk-fill composites showed better results for surface hardness and sub-surface solubility(Melo et al., 2019). Camassari et al. evaluated the physical-mechanical properties of various bulk-fill materials subjected to biodegradation by oral biofilm (S. mutans). It was reported that the roughness of all evaluated composites increased and hardness and gloss decreased. Biodegradation induced by S. mutans negatively affected the mechanical and surface properties. Therefore, to maintain the aesthetics and longevity of RBC restorations, it is imperative to select the appropriate restorative material and advise the patient on the importance of good oral hygiene techniques(Melo et al., 2019).

**Water sorption**

Water absorption alone can reduce the plasticity of an RBC resin by expanding and plasticising its components and causing hydrolysis of the silane binding agents. Expansion is undesirable due to the potential stress causing microcracks and even macrocracks in restored teeth(Sideridou et al., 2015).

Alshali et al. reported higher absorption values for a conventional flow (X-Flow, Dentsply Sirona, Kostanz, Germany) compared to a flowable bulk-fill (X-tra base, Voco GmbH, Cuxhaven, Germany)(Alshali RZ, Salim NA, Sung R, Satterthwaite JD, Silikas N., 2015) .

Glass fillers do not contribute to the water absorption process, but water can be adsorbed on their surfaces. Hydrolytic degradation of resin-filler interfacial bonds can actually cause the release of unreacted monomers, compromising the biocompatibility of the material(Yiu CKY, King NM, Pashley DH, Suh BI, Carvalho RM, Carrilho MRO, et al., 2004). Water absorption is therefore dependent on the filler loading of the material, which shows a higher degree with fluid and low viscosity bulk-fill, rather than the degree of polymerisation characteristic of bulk-fill materials. In other words, it is the fact of being a bulk-fill, not the viscosity, that determines the level of water absorption(Wei et al., 2011)

**Cytotoxicity**

It is imperative to ensure that RBCs are adequately cured to guarantee optimal mechanical properties and biocompatibility (Baharav et al., 1997; Caughman et al., 1991). The cytotoxic potential of these materials has been linked to the quantity and type of residual monomer released. Some studies have reported a correlation between this property and mass loss and/or low conversion rate (Salehi et al., 2015). However, a common concern with bulk-fill materials is whether the conversion rate at a depth of 4 mm is sufficient, which may increase the cytotoxic potential, especially in bulk-fill flowable resins with higher organic matter content (Furness A, Tadros MY, Looney SW, Rueggeberg FA., 2014), (Jan et al., 2014).

Alshali et al (Alshali RZ, Salim NA, Sung R, Satterthwaite JD, Silikas N., 2015) reported that despite the increased thickness of bulk-fill composites, monomer elution from these materials can be comparable to conventional composites and that the elution rate depends on the monomer molecular weight and crosslink density of the polymer (Ferracane, 1994),(Benetti et al., 2009). Highly cross-linked polymers exhibit enhanced resistance to

solvent absorption and swelling, while linear polymers provide greater spatial dimensions and pathways for solvent molecules to diffuse within the structure (Ferracane, 2006) (Cavalcante et al., 2011).

Gonçalves et al. reported no toxic response in gingival fibroblasts for bulk-fill RBCs placed at 4 mm thickness(Gonçalves et al., 2018). In another study, the finding that eluates obtained from both the upper and lower composite surface of the bulk-fill materials tested did not cause genotoxic effects may be explained by the sufficient polymerisation of bulk-fill resin composites even when applied at 4 mm thickness (Tauböck et al., 2017).

**Clinical Use of Bulk Composites**

Bulk-fill composites have shown similar clinical performance to conventional incremental composites in clinical studies. Restoration survival and annual failure rates are similar to traditional incremental composites(Sengupta et al., 2023).The main cause of restoration failure is secondary caries.

Formable bulk-fill composites shorten restoration time, but the same has not been confirmed for flowable bulk-fill materials, probably due to the required capping layer of a formable composite(Ilie, 2022). When deciding to restore a posterior cavity with a resin composite, various characteristics of the cavity, including the depth of the cavity, remaining tooth structure and position, will guide the dentist in the selection of the most appropriate material. Bulk-fill resin composites are indicated for medium to deep posterior cavities in permanent teeth (Class I and II). They can also be used to create and fill access cavities in root-treated teeth with or without fiber posts prior to crown placement. For cavities less than 4 mm deep, one layer of composite material is sufficient to restore the cavity, while deeper cavities may require two to three layers(Sabbagh & McConnell, 2023).

The scientific evidence has shown comparable polymerisation shrinkage and stress(Cidreira Boaro et al., 2019), depth of cure (M. V. P. P. D. M. J. B. N. Van Meerbeek B., 2017),(Ilie N Kessler A Durner, 2013), physico-mechanical properties (Ilie N Bucuta S Draenert, 2013),(El Naga et al., 2020) and marginal adaptation (El Naga et al., 2020),(Baltacioğlu et al., 2024)of bulk-fill and universal composites. In vitro data indicate that these materials can be used as recommended for dentin replacement in posterior teeth in increments of up to 4-5 mm (flowable bulk-fill) or as complete restorations in posterior cavities without cusp replacement (formable bulk-fill) (Leprince et al., 2014).

Over the last decade, all major manufacturers have at least one bulk-fill composite in their portfolio, and many have a second "generation" of the original material as well as various bulk-fill types (flowable and formable. Bulk-fill composites are expected to reduce clinical study time as fewer increments are required to restore posterior cavities compared to universal composites, which are recommended for 2 mm increments. Indeed, a recent meta-analysis by Bellinaso et al. confirmed that malleable ("full-body") bulk-fill composites shorten restorative time in posterior teeth compared to conventional composites. However, the same was not found for flowable bulk-fill composites. The true value of these findings should be confirmed by further research, as only three studies with moderate to significant heterogeneity were included in the above meta-analysis(Ro., 2019). However, scientific and clinical interest in these materials and continued developments reflect the potential for bulk-fill composites to change clinical practice regarding posterior restorations. A summary of variations in score definitions in clinical studies of bulk-fill composites using modified USPHS criteria is presented in a recent meta-analysis by Veloso et al.(Veloso et al., 2019)

The remaining cavity wall thickness, even in the range of 1-1.5 mm, does not appear to significantly reduce the fracture resistance of the teeth when appropriate cuspal protection is provided (ElAyouti et al., 2011). Composite materials with filler content above 74% volume (compact composites (Randolph LD, Palin WM, Leloup G, Leprince JG., 2016)) may be suitable for complex composite restorations with cusp replacement, as their flexural modulus approaches the 20 GPa expected for load-bearing restorations (Gw., 2003).

Formable bulk-fill composites do not show the mechanical conformability of compact composites(Leprince et al., 2014),(Shibasaki et al., 2017) and therefore should not be used for complex composite restorations. In the available RCTs, the annual failure rates of Class I and II bulk-fill restorations generally did not exceed the annual failure rate of composites (Laske M, Opdam NJ, Bronkhorst EM, Braspenning JC, Huysmans MC., 2016), indicating that bulk-fill composites can be used for posterior restorations without pulp involvement.

Fiber-reinforced bulk-fill composite (introduced as Xenius, later everX posterior, GC) is proposed to replace dentin as the base material in large cavity defects, especially in high-stress restorations(Garoushi et al., 2013). In addition to conventional filler particles in the BisGMA/TEGDMA-based resin matrix, this composite contains 1-2 mm glass fibers to improve fracture toughness and mechanical properties in general(Garoushi S. In: Miletic M, 2018). At 3 years, a slightly lower clinical success

rate was found in the fiber-reinforced bulk-fill composite group (78.3%) compared to the incremental microhybrid composite restoration (91.3%) in endodontically treated molars of 24 patients, with fracture being the main cause of failure(Tekçe et al., 2020). In another prospective clinical study using only fiber-reinforced composite in posterior restorations of vital and non-vital molars and premolars, an overall success rate of 88.9% was reported over a period ranging from 1.3 to 4.3 years(Tanner J, Tolvanen M, Garoushi S, Sailynoja E., 2018). This is generally in agreement with the findings obtained for other composite materials and suggests that fiber-reinforced bulk-fill may be a suitable base material for large cavities in posterior teeth. As previously mentioned, similar clinical performance has been reported for bulk-fill composites to conventional microhybrid composites in terms of aesthetic, functional and biological FDI criteria. Failures occur at different time intervals, including short-term (1-3 years), mid-term (3-6 years) and long-term (6 years or more). The management of these failures depends on the type of defect or problem and may include monitoring, repair or complete replacement of the restoration(Hickel et al., 2013).

**Clinical Trials of Bulk-Fill Composites**

One of the first randomised controlled trials (RCT) compared the performance of an early malleable bulk-fill material (QuiXfil, Dentsply) with a hybrid composite (Tetric Ceram, Ivoclar) with their respective adhesive systems. Comparable results were reported between the two composites at 3 years, with significantly worse results for marginal discolouration and integrity of QuiXfil and marginal discolouration of Tetric Ceram(Manhart J Chen Hy Hickel, 2009). The main causes of failure were secondary caries and marginal discolouration, followed by tooth fracture, restoration fracture, post-operative sensitivity and marginal disruption of integrity(Heck K, Manhart J, Hickel R, Diegritz C., 2018). Statistical significance was related to cavity/restoration size, i.e. large restorations failed significantly more often than small restorations (Heck K, Manhart J, Hickel R, Diegritz C., 2018). To date, this study is the only RCT comparing bulk-fill and conventional composites with a 10-year follow-up period.

**Systematic Reviews and Meta-Analyses**

Clinical trials on bulk-fill composites have increased since 2014 and the annual number of published clinical trials has risen steadily over the last few years. Besides regular clinical trials (RCTs), several systematic

reviews and meta-analyses comparing the clinical efficacy of bulk-fill with conventional methacrylate-based composites have been published in the last 3 years(Cidreira Boaro et al., 2019),(Ro., 2019),(Veloso et al., 2019),(Arbildo-Vega et al., 2020),(Kruly et al., 2018). Arbildo-Vega et al.(Arbildo-Vega et al., 2020), included 16 unique RCTs with follow-up periods ranging from 6 months to 10 years in which malleable bulk-fill, flowable and malleable two-stage restorations were compared with conventional incremental composites. The clinical efficacy of bulk-fills is comparable to that of conventional composites, irrespective of the type of restoration (class I, II or caries-free cervical lesions), the type of tooth restored (primary or permanent teeth) or the restoration technique used (incremental, bulk or two-stage bulk). This finding has been corroborated by numerous studies (Arbildo-Vega et al., 2020). No significant differences were found between conventional and bulk-fill composites in terms of fractures, marginal staining and adaptation, secondary caries, colour stability and translucency, surface texture and anatomical form. In terms of postoperative sensitivity, the meta-analysis found no difference between conventional and two-stage bulk restorations. However, reduced or no post-operative sensitivity was seen with conventional materials in non-carious cervical lesions and with the incremental technique in permanent teeth.

Cidreira Boaro et al. (Cidreira Boaro et al., 2019) included 11 RCTs ranging from 12 months to 10 years. No significant difference in the clinical performance of bulk-fill and conventional composites was reported. In addition to RCTs, this meta-analysis included 137 other in vitro studies comparing a range of material properties. Polymerisation stress and cusp deflection were found to be significantly lower in bulk-fill composites. No difference was found between bulk-fill and conventional composites in flexural and fracture strength. As for volumetric shrinkage, microhardness and degree of transformation, the results varied depending on material viscosity and specimen thickness. The differences detected in vitro in the above-mentioned properties did not lead to differences in the clinical performance of bulk-fill and conventional composites. It should be emphasised that only 1 RCT was evaluated for each of the 5, 6 and 10-year follow-up periods and most of the RCTs reported a 1-year follow-up period (Cidreira Boaro et al., 2019).

Veloso et al.(Veloso et al., 2019) included 10 RCTs with follow-up periods between 1 and 6 years. No significant difference in clinical performance was found between bulk-fill and conventional composites, regardless of the bulk-fill material (formable or flowable, requiring a sealer layer). Reasons for restoration failure were reported as secondary caries (23%), tooth and resin fractures (19% each), post-operative sensitivity

(9%), anatomical shape and marginal adaptation (7%), marginal discoloration (9%), caries associated with tooth fracture (5%) and retention (2%).

Kruly et al (Kruly et al., 2018) performed a meta-analysis on various types of composites, combining conventional methacrylate-based composites with non-traditional composites (ormocer, silorane and bulk-fill). Three of the 21 studies included in the review investigated bulk-fills with follow-up periods of 1-3 years. All non-conventional composites were grouped when assessing post-operative sensitivity, secondary caries, retention, marginal adaptation and discoloration, so no conclusions were drawn specifically for bulk-fill materials as a separate group. Restorations made with low polymerization shrinkage composites such as siloran, ormocer and bulk-fill type showed similar clinical performance to restorations made with conventional methacrylate-based composites(Kruly et al., 2018). According to Hickel et al(Hickel R, Roulet JF, Bayne S, et al., 2007) restoration failures are categorized as early (0-6 months), mid-term (6-24 months) and long-term (after 18 or 24 months). The majority of RCTs evaluated in the meta-analyses reported findings at 12 months follow-up, with fewer and fewer studies reporting after longer follow-up periods (Cidreira Boaro et al., 2019),(Veloso et al., 2019),(Arbildo-Vega et al., 2020) and thus largely only short- and medium-term failures were identified.

Eight studies were RCTs comparing bulk-fill and conventional incremental composites in a split-mouth design (do Prado AM et al., 2021),(ElAziz et al., 2020),(Afifi et al., 2019),(Cieplik F, Scholz KJ, Anthony JC, et al., 2022),(Hardan L, Sidawi L, Akhundov M, et al., 2021),(Tardem et al., 2019),(Torres et al., 2021), five RCTs evaluating only bulk-fill composites with a different test group (Castro et al., 2022),(Fahim SE, Mostafa MA, Abi-Elhassan MH, Taher HM., 2019),(Loguercio et al., 2019),(Suneelkumar C. et.al. 2021),(Torres CRG, Mailart MC, Rocha RS, et al., 2020a), one RCT comparing bulk-fill and incremental composites but in a parallel group design and evaluating only post-operative tenderness (Hickel R, Peschke A, Tyas M, et al., 2010) and two studies were prospective clinical trials with only a bulk-fill test group without a control group(Akalın et al., 2018),(Sarrett et al., 2006).

The overall success or survival rate of bulk-fill composites ranged from 100%(Balkaya H Arslan S Pala, 2019; Sarrett et al., 2006),(Cieplik F, Scholz KJ, Anthony JC, et al., 2022),(Hardan L, Sidawi L, Akhundov M, et al., 2021),(Castro et al., 2022),(Suneelkumar C, Harshala P, Madhusudhana K, Lavanya A, Subha A, Swapna S., 2021)and 97.1%(ElAziz et al., 2020) to 88.1%(Fahim SE, Mostafa MA, Abi-Elhassan MH, Taher HM., 2019) at 12 months , 100%(Torres CRG, Mailart MC, Rocha RS, et al., 2020b)

to 99.1%(Akalın et al., 2018) at 2 years, 100%(Loguercio et al., 2019) to 94.44%(do Prado AM et al., 2021) with an annual failure rate of 1.26% at 3 years , 94,28 (Yazici AR, Kutuk ZB, Ergin E, Karahan S, Antonson SA., 2021) to 93.9% at 6 years with an annual failure rate of 0.95% (Yazici AR, Kutuk ZB, Ergin E, Karahan S, Antonson SA., 2021) to 1%(van Dijken & Pallesen, 2017). At 10 years, the overall success rates for bulk-fill and conventional composite were 76.9% and 86.7%, respectively, while the annual overall failure rate was 2.5% for bulk-fill and 1.6% for conventional composites(Heck K, Manhart J, Hickel R, Diegritz C., 2018). Reasons for failure included recurrent caries, unacceptable marginal adaptation(do Prado AM et al., 2021), pulpal or peri-apical inflammation(do Prado AM et al., 2021; ElAziz et al., 2020), crown replacement (cause not specified) (Yazici AR, Kutuk ZB, Ergin E, Karahan S, Antonson SA., 2021) and "lost restoration" (cause not specified)(Fahim SE, Mostafa MA, Abi-Elhassan MH, Taher HM., 2019).

Similar clinical performance was reported for ormocer bulk-fill composite (Admira Fusion x-tra, Voco) compared with conventional, incremental ormocer (Admira Fusion, Voco) at 2 years in terms of aesthetic, functional and biological FDI criteria(Torres et al., 2021). Placement of mouldable bulk-fill composites required less seat time than incremental placement(Tardem et al., 2019),(Torres et al., 2021).

In most randomised clinical trials (RCTs), there was little difference between bulk-fill and conventional control composites, with slightly lower incidence, intensity and duration of post-operative tenderness (Afifi et al., 2019), lower pain and marginal discolouration in the bulk-fill group at 12 months(Hardan L, Sidawi L, Akhundov M, et al., 2021), both bulk-fill and conventional composite, lower marginal discolouration(Yazici AR, Kutuk ZB, Ergin E, Karahan S, Antonson SA., 2021), in the bulk-fill at 6 years , surface gloss(Durao MA, Andrade AKM, Santos M, Montes M, Monteiro GQM., 2021), in one of the two bulk-fills tested compared to the conventional control at 3 years , marginal integrity but worse than conventional composite onlays in terms of colour matching (ElAziz et al., 2020). The overall risk for post-operative tenderness was found to be 4% and was significantly higher in the first 48 hours after restoration (Tardem et al., 2019). This overall risk of post-operative tenderness was found to be independent of material (bulk vs. conventional), adhesive strategy (total-etch vs. self-etch) or method of application (capsule vs. syringe), but was significantly higher in cavities deeper than 4 mm(Tardem et al., 2019).

Similarly, in another study comparing different placement and bonding techniques and using only a bulk-fill composite, post-operative pain

was mostly recorded within the first 48 hours after restoration(Costa et al., 2017). This study is similar to(Loguercio et al., 2019) but reported only post-operative tenderness. However , unlike(Tardem et al., 2019), Costa et al(Costa et al., 2017) reported an overall post-operative tenderness risk of 20.3%. Cavities with 3-4 surfaces had a significantly higher risk of post-operative pain than cavities with 1-2 surfaces. The adhesive strategy or composite placement technique had no effect on the incidence or intensity of post-operative pain. The differences in the risk of post-operative tenderness between these studies warrant further investigation, especially considering the operator factor. Several RCTs have compared the clinical performance of bulk-fill composites in both test and control groups, but with different placement techniques (bulk vs. incremental)(Loguercio et al., 2019),(Suneelkumar C, Harshala P, Madhusudhana K, Lavanya A, Subha A, Swapna S., 2021;46:e24.), bonding techniques (wet vs. dry bonding of 2-stage total-etch(Castro AS, Maran BM, Gutierrez MF, et al., 2020) or total-etch vs. self-etch adhesive(Loguercio et al., 2019)), with or without liner material(Torres CRG, Mailart MC, Rocha RS, et al., 2020b) or with high-density vs. low-density light-cured units(Fahim SE, Mostafa MA, Abi-Elhassan MH, Taher HM., 2019).

In general, comparative performance in the short and medium time frame of 12-36 months has been reported. The percentage of marginal continuity including occlusal margins was reported to be significantly greater in the "high intensity" group than in the "low intensity" light-cured group at 12 months(Fahim SE, Mostafa MA, Abi-Elhassan MH, Taher HM., 2019). In another study, marginal staining and adaptation at 36 months was found to be significantly worse when bulk-fill composite was used with self-etch than with total-etch adhesive(Loguercio et al., 2019).

In an RCT comparing a formable bulk-fill composite (Filtek One Bulk-fill, 3M) with a self-adhesive bulk-fill composite (SABF, 3M), statistically significant differences were found with more unfavourable scores for the latter in terms of surface gloss, marginal staining and colour matching at 12 months(Cieplik F, Scholz KJ, Anthony JC, et al., 2022) . The self-adhesive bulk-fill composite is designed to be used without an adhesive system due to the presence of a phosphoric acid-functionalised methacrylate. The manufacturer's instructions recommend mixing for 15 seconds, placing in non-ionised cavities in a bulk increment and light curing, although the material is dual-cure and therefore allows only limited forming time during auto-polymerisation. These preliminary results show that the aesthetic performance of self-adhesive bulk-fill is inferior compared to other bulk-fill and conventional composites. Negative marginal staining as early as 12 months after restoration demonstrates the inability of the phosphoric acid-functionalised methacryl in this self-adhesive composite to substitute an adhesive system.

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99

# Chapter 3

## ENDOCROWNS: BIOLOGICAL FOUNDATIONS AND RESTORATIVE PROTOCOLS

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## Introduction

The restoration of endodontically treated teeth with significant coronal destruction remains a major challenge in restorative dentistry (Ferrari et al., 2022). Traditionally, these teeth have been restored using post-core systems followed by full-coverage crowns. While widely used, this approach can require the removal of healthy tooth structure and further shaping of the root canal space to accommodate the post. These procedures may compromise the tooth's biomechanical integrity and increase the risk of complications such as root fractures or perforations. Consequently, the long-term prognosis of such restorations can be affected, particularly in cases where conservative approaches are not prioritized (Mously et al., 2025).

Advancements in adhesive dentistry have introduced more conservative treatment modalities that preserve tooth structure and reduce procedural risks. Among these, endocrown restorations have emerged as a promising alternative to traditional post-retained systems (Lenz et al., 2024). Endocrowns are monolithic indirect restorations that rely on retention achieved through the pulp chamber and cavity walls. Unlike conventional methods, they do not require the insertion of a post within the root canal. This method offers a more conservative and biologically compatible solution for the restoration of severely compromised teeth (Govare & Contrepois, 2020).

The term "endocrown" was first introduced by Pissis in 1995, who described these restorations as monoblock porcelain constructions. A more comprehensive and widely accepted definition was later provided by Bindl and Mörmann in 1999. (Bindl & Mormann, 1999; Pissis, 1995) Their work emphasized that endocrowns achieve retention through a combination of macromechanical engagement with the internal cavity and micromechanical bonding via adhesive luting agents.

Although endocrowns can theoretically be applied to all tooth types, clinical usage has shown that molar teeth are the most suitable candidates. Molar teeth possess a larger occlusal surface area and provide greater internal volume for retention. Additionally, they are subjected to less lateral stress when compared to premolars. These anatomical and functional characteristics contribute to the superior biomechanical performance of endocrowns when used in posterior regions (Lenz et al., 2024). However, due to the high occlusal loads in molar teeth, the selection of restorative material should be made carefully.

Studies have shown that endocrown restorations produce lower internal stress concentrations and offer a more favorable distribution of func-

tional loads compared to post-core restorations (Lenz et al., 2024; Lin et al., 2020; Mously et al., 2025). Moreover, the monolithic structure of endocrowns ensures a direct adhesive interface between the restoration and the tooth, reducing the number of bonding interfaces. This characteristic helps to minimize the risk of adhesive failure and improves the overall longevity of the restoration (Ahmed et al., 2022; Qamar et al., 2023).

In vitro studies have consistently demonstrated that endocrowns exhibit higher fracture resistance than traditional post-retained restorations (Kassis et al., 2021; Mously et al., 2025; Sahebi et al., 2022). These findings suggest that endocrowns provide a reliable and durable restorative option, especially for endodontically treated teeth with severely compromised coronal structure. Their minimally invasive nature, combined with favorable mechanical performance and aesthetic properties, makes them a valuable tool in modern restorative dental practice.

**Advantages of Endocrown Restorations**

Endocrowns offer numerous clinical advantages over conventional post-core restorations, particularly in endodontically treated teeth with extensive coronal tissue loss. A primary benefit is the preservation of healthy tooth structure during preparation. Unlike traditional methods that often require removal of radicular dentin for post placement, endocrowns utilize the pulp chamber for macromechanical retention, significantly minimizing the risk of root perforation or fracture (Hiraba et al., 2024).

They are more economical and require fewer clinical appointments, enhancing patient compliance (Naved et al., 2024). Their simplified technique allows for restoration in teeth with short or curved roots, calcified canals, or reduced interocclusal space where conventional crown preparation is challenging. Since the margins are designed to remain supragingival, endocrowns promote improved periodontal health by reducing plaque accumulation and facilitating better oral hygiene (Ali et al., 2024; Lin et al., 2020).

The monolithic structure of endocrowns also reduces the number of adhesive interfaces, minimizing the risk of debonding and increasing longevity (Zou et al., 2022). Furthermore, their compatibility with Computer-Aided Design and Manufacturing (CAD/CAM) technology allows for the fabrication of precise restorations in a single visit, provided that appropriate equipment is available (Keskin et al., 2024).

**Clinical Indications of Endocrown Restorations**

Endocrowns are indicated in a range of clinical scenarios (Lenz et al., 2024; Mously et al., 2025; Soliman et al., 2021):

- Teeth with severe coronal destruction where direct composite restorations are not viable
- Cases where full crown retention is compromised due to insufficient axial wall height or ferrule effect
- Molars and premolars with wide pulp chambers, providing substantial surface area for adhesive retention (Nevertheless, careful case selection is required for premolar teeth, as the higher magnitude of lateral forces in this region increases the risk of failure compared to molars)
- Short, curved, calcified, or fragile roots where post placement poses significant risk
- Teeth with reduced interocclusal space that does not allow conventional crown thickness
- Patients with financial or time constraints, requiring efficient yet effective restorative solutions

**Contraindications of Endocrown Restorations**

Despite their versatility, endocrowns are not suitable in all clinical contexts. Contraindications include (Ahmed et al., 2022; Mously et al., 2025; Tiew et al., 2024):

- Pulp chambers with a depth less than 3 mm, limiting retentive surface area
- Cervical margin widths narrower than 2 mm, reducing bonding area
- Severely compromised enamel or dentin quality, impairing adhesion
- Subgingival carious lesions extending below the cementoenamel junction, obstructing isolation and bonding
- Patients with extreme parafunctional habits (e.g., bruxism), which may challenge the structural integrity of ceramic materials

**Complications of Endocrown Restorations**

Although endocrowns have shown high success rates, certain complications are observed (Ali et al., 2024; Jalali et al., 2024; Mously et al., 2025; Qamar et al., 2023; Tiew et al., 2024):

- Debonding remains the most frequent cause of failure, often due to inadequate adhesion protocols or moisture contamination
- Vertical root fractures, although rare, have been reported in restorations with excessive occlusal forces or poor stress distribution
- Marginal discoloration and microleakage can result from inadequate marginal sealing or adaptation
- Catastrophic failure such as severe fractures below the cementoenamel junction typically leads to tooth extraction

To mitigate such risks, the use of high-strength ceramics like lithium disilicate or leucite-reinforced glass ceramics is recommended (Vervack et al., 2024). Fiber-reinforced composite variants have also been explored for their superior stress distribution properties (Hafez et al., 2025). However, further studies are required to validate the long-term clinical performance of these materials.

**Classification of Endocrown Restorations**

Endocrowns can be classified based on the quantity and height of remaining axial tooth structure following cavity preparation (Belleflamme et al., 2017; Demachkia et al., 2023) (Figure 1):

**Class 1**: At least two intact axial walls remain. These offer the best prognosis due to enhanced retention and resistance form.

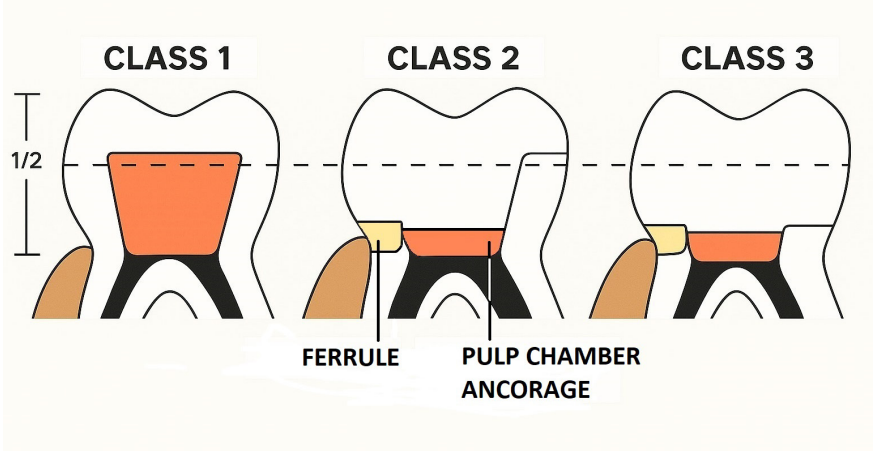
**Class 2**: One axial wall retains more than half of its original height. These cases may still be suitable for endocrown retention if adhesive protocols are optimized.

**Class 3**: All axial walls are reduced to less than half of their original height. These require careful assessment, as the risk of debonding and biomechanical failure increases significantly.

This classification provides a practical guide for selecting appropriate candidates for endocrown therapy and tailoring the preparation design accordingly.

Recent studies emphasize that attention should be given not only to wall height but also to wall thickness, pulp chamber depth, and the adhesive surface area (Demachkia et al., 2023; Zheng et al., 2025).

**Figure 1.** *Classification of Endocrowns according to the amount of tooth tissue remaining after preparation (Belleflamme et al., 2017)*




**Preparation Principles in Endocrown Restorations**

The long-term success of endocrown restorations is intrinsically linked to the design of the preparation. An effective endocrown preparation must ensure sufficient biomechanical stability and optimal adhesive bonding, while preserving as much sound tooth structure as possible. In accordance with the principle of minimal invasiveness, the preparation should be conservative yet capable of providing adequate retention and resistance for the restoration (Soliman et al., 2022; Turker Kader et al., 2025).

Occlusal reduction is one of the key steps and should range between 2 and 3 mm. This allows for sufficient restorative material thickness, thereby enhancing resistance to occlusal loading and minimizing the risk of material fracture (Abbas et al., 2024). Within the pulp chamber, any undercuts must be eliminated to ensure the proper seating of the restoration. If complete removal is not feasible, these areas may be blocked using flowable composite resin (Turker Kader et al., 2025).

The margin design should be finished perpendicular to the occlusal plane in a butt-joint configuration, typically at 90 degrees (Sun et al., 2019). This provides a stable marginal architecture capable of resisting

compressive forces and ensures a clean interface for adhesive luting. The axial walls should be prepared with a slight taper, converging occlusally at approximately 8 to 10 degrees (Biacchi et al., 2013). This conicity facilitates passive insertion of the restoration and improves resistance to dislodging forces.

A flat pulpal floor is essential for both mechanical stability and even load distribution across the restoration. This configuration also aids in achieving intimate adaptation between the restoration and the tooth structure (Brătoiu et al., 2025).

While these fundamental principles are widely accepted, certain aspects of endocrown preparation remain subject to academic debate. One such area is the design of the finishing margin. Although the butt-joint is the most commonly recommended configuration, alternative designs, such as shoulder margins, have been associated with increased fracture resistance. These designs may help redistribute functional stresses by creating short axial walls that resist shear forces and minimize stress concentration on the pulpal floor (Gupta et al., 2025; Zheng et al., 2022).

The dimensions of the pulp chamber and the central retention cavity play a critical role in the biomechanical performance of endocrown restorations. For premolars, a cavity approximately 3 mm in diameter and 3 mm in depth is generally considered optimal, while molars perform best with a cavity of about 5 mm in diameter and 3-4 mm in depth. Excessive depth beyond 5 mm may increase root stress and compromise marginal integrity (Binaljadm, 2025; Shams et al., 2022; Zhang et al., 2022). Some studies suggest that even a central cavity as shallow as 2 mm may be sufficient, provided that the adhesive surface area is optimized (Babaei et al., 2022; Elagwany et al., 2025). More than depth, the shape of the cavity appears to have a significant influence on stress distribution. Anatomical, rounded cavity forms tend to better dissipate occlusal forces compared to geometrically sharp designs (Al-naqshabandi et al., 2023; Zheng et al., 2022).

Anatomical, rounded cavity designs provide more uniform stress distribution and reduce peak stresses in both the tooth and cement layer, especially under oblique loading. This can lower the risk of catastrophic fractures and improve restoration longevity. Sharp or irregular angles in cavity preparation, even in anatomically based designs, can create localized stress concentrations, increasing the risk of fracture. The benefit is maximized when anatomical shapes are smooth and rounded, not angular. Butt-joint designs are easier to prepare but tend to concentrate stress at the cervical margin and pulp chamber floor, potentially leading

to more frequent failures in these regions (Al-naqshabandi et al., 2023).

In cases where the depth of the pulp chamber is insufficient, the incorporation of intraradicular extensions has been proposed to enhance retention. However, such extensions have been shown to compromise marginal and internal fit, while also increasing stress concentrations within the root. Therefore, their clinical use is not routinely recommended (Al-tamimi et al., 2025).

The concept of the ferrule effect, traditionally considered essential for the success of full crown restorations, has also been evaluated in the context of endocrowns. While some evidence supports a potential reinforcing effect, other studies question its relevance or even suggest that unnecessary removal of sound tissue to create a ferrule may increase the risk of failure. As such, this remains an area requiring further investigation and clinical validation (Mously et al., 2025; Stoilov et al., 2024; Tribst et al., 2021).

In conclusion, endocrown preparations should adhere to evidence-based biomechanical principles, while allowing for case-specific modifications based on the patient's clinical presentation. Factors such as residual tooth structure, pulp chamber morphology, occlusal load, and esthetic requirements must be considered during treatment planning. By balancing structural preservation with functional stability, the longevity and clinical success of the endocrown restoration can be maximized.

**Clinical Impact of Digital and Conventional Impressions on Endocrown Restorations**

The impression stage is one of the most important steps for the success of endocrown restorations. Conventional impression techniques have been used as the standard method for many years in fixed prosthodontics. Materials such as polyether and vinyl polysiloxane provide good detail reproduction and dimensional stability. However, these materials can deform, and the expansion of stone models or laboratory handling errors may cause marginal gaps or thicker cement layers. Because endocrowns depend on accurate adaptation to the pulp chamber, even small dimensional changes can reduce bond strength and clinical durability. The manual workflow also requires more time and involves several steps that can introduce small inaccuracies, which limits reproducibility and precision when compared with digital systems (Ardekani et al., 2024; Keskin et al., 2025).

In recent years, digital impression systems have become more popular for endocrown fabrication. Digital scanning provides high accuracy and reduces clinical chair time. It allows a detailed record of the cavity and pulp chamber without the distortion risks seen in conventional impressions. This results in better marginal fit and internal adaptation of the restoration. In some clinical situations, such as limited mouth opening, deep margins, or poor moisture control, optical scanners may still face difficulties. For this reason, hybrid approaches, which combine digital and conventional steps, can still be useful in selected cases. Overall, both methods can produce acceptable outcomes, but digital impressions offer advantages in speed, accuracy, and reproducibility, making them particularly suitable for CAD/CAM endocrown restorations (Ardekani et al., 2024; Keskin et al., 2025).

**CAD/CAM Workflow and Digital Precision**

The integration of CAD/CAM systems into endodontic restorative procedures has led to a paradigm shift in precision, efficiency, and reproducibility. CAD/CAM technology enables the reconstruction of dental morphology with high fidelity. As a result, post-core and endocrown restorations fabricated through this workflow demonstrate significantly greater fit accuracy and marginal adaptation compared to conventional methods (Vogler, Billen, Walther, & Woestmann, 2023).

The combination of CAD/CAM systems with digital imaging tools such as digital radiography and cone-beam computed tomography (CBCT) provides a three-dimensional analytical framework for endodontic diagnosis and treatment planning. This integration is particularly valuable in guided endodontics, where digital planning ensures micron-level accuracy during access cavity preparation (Krug et al., 2020).

In fully digital workflows, digital impression acquisition plays a crucial role in determining restoration success. Chairside CAD/CAM systems enable same-day fabrication of post-core restorations, enhancing both patient comfort and clinical productivity (Ijaz, 2024). Moreover, the digital manufacturing chain minimizes operator-dependent errors and improves overall treatment predictability while reducing material waste (Shah & Lundholmb).

Studies have shown that even semi-digital workflows can improve restorative adaptation; however, fully digital workflows yield superior outcomes in marginal accuracy and morphological precision (Çin et al., 2023; Perucelli et al., 2021). This precision is clinically relevant for pre-

serving the integrity of weakened dentin structures in endodontically treated teeth. Furthermore, CAD/CAM-based digital workflows have been reported as effective and time-efficient even in pediatric endodontic applications, demonstrating the versatility and adaptability of this technology across age groups (Davidovich et al., 2020).

CAD/CAM-assisted digital workflows have become a cornerstone of restorative success in modern endodontics. These systems enable the fabrication of restorations that are biomechanically durable, aesthetically precise, and clinically efficient, while significantly reducing treatment time and variability. Looking ahead, the integration of artificial intelligence-assisted design, automated milling strategies, and augmented reality-guided endodontic procedures is expected to elevate digital precision to unprecedented levels (Keir et al., 2022).

**Materials Used in Endocrown Restorations**

Endocrown restorations represent a minimally invasive alternative to post-core systems, utilizing the pulp chamber for retention. The success of such restorations is critically dependent on the type of ceramic material used. Contemporary literature categorizes ceramics for endocrowns into feldspathic porcelain, glass ceramics (including lithium disilicate and zirconia-reinforced systems), and hybrid ceramics (Che et al., 2024; Govare & Contrepois, 2020).

The evolution of CAD/CAM technology has greatly enhanced the precision and reproducibility of ceramic restorations. This progress allows for optimized microstructures, improved marginal adaptation, and stronger adhesive interfaces. Among available options, lithium disilicate ($Li_2Si_2O_5$) glass ceramics are considered the gold standard due to their excellent balance of strength, translucency, and bonding potential. Their flexural strength (350-450 MPa) and elastic modulus closely approximate those of natural dentin, providing predictable long-term clinical outcomes (Alwadai et al., 2023).

Additionally, the development of zirconia-silicate nanocrystalline glass ceramics has yielded materials with superior mechanical resilience and thermal expansion compatibility compared to traditional feldspathic porcelains, enhancing both marginal integrity and wear resistance during CAD/CAM milling (Fu et al., 2020).

**Feldspathic Porcelain and Glass Ceramics**

Feldspathic porcelain is one of the earliest ceramic systems used in restorative dentistry and remains valued for its exceptional esthetics. Composed of approximately 86% glassy matrix, it exhibits high translucency and enamel-like optical properties, making it ideal for anterior restorations where esthetics are paramount (Uzun et al., 2024). However, its relatively low fracture toughness limits its use in high-load posterior endocrowns.

A randomized clinical trial compared feldspathic, lithium disilicate, and zirconia-based endocrowns, reporting high patient satisfaction and survival across all materials but recommending feldspathic porcelain only for low-stress regions due to its brittle nature (El-Ma'aita et al., 2022). Similarly, it has been emphasized that the clinical success of feldspathic ceramics relies heavily on adhesive bonding protocols rather than intrinsic material strength (Warreth & Elkareimi, 2020).

For maximum bond strength, etching with 9-10% hydrofluoric acid for 60 seconds, followed by silane coupling agent application, can be employed. This procedure enhances siloxane network activation, promoting a strong chemical bond with resin cement (Morimoto et al., 2016). However, this aggressive etching protocol may compromise the ceramic surface, as it increases the risk of microcrack formation and potential weakening of the restoration. Therefore, shorter etching times with lower HF concentrations are generally preferred for maintaining both bond durability and structural integrity.

Glass ceramics, particularly lithium disilicate and zirconia-reinforced lithium silicate, have become the most widely utilized materials for endocrown restorations. Lithium disilicate ceramics (e.g., IPS e.max CAD) exhibit flexural strengths of 350-450 MPa, nearly three times that of feldspathic porcelain, while maintaining enamel-like translucency and bonding behavior. Recent scoping reviews reported clinical survival rates of 94-97% for endocrowns fabricated from lithium disilicate and zirconia-reinforced lithium silicate systems (Kontakou Zoniou et al., 2025). These materials allow for 20-second etching with 5% hydrofluoric acid followed by silane treatment, achieving excellent micromechanical and chemical adhesion to resin cements (Alwadai et al., 2023).

Zirconia-reinforced glass ceramics such as VITA SUPRINITY® incorporate nanocrystalline $ZrO_2$-$SiO_2$ matrices, enhancing both flexural strength and marginal adaptation (Al Ahmari et al., 2023). These ceramics also exhibit low wear rates during milling and superior thermal stability, facilitating efficient chairside fabrication workflows (Fu et al., 2020).

**Emerging Hybrid and Polymer-Based Material**

Advances in material engineering have introduced hybrid ceramics, resin-matrix composites, and high-performance polymers that combine ceramic esthetics with polymer toughness. These materials are designed to reduce brittleness, improve machinability, and provide stress-absorbing behavior similar to natural dentin.

Resin-matrix ceramics (RMCs), such as Cerasmart® and Grandio blocs®, are resin-based composites highly filled with ceramic nanoparticles, whereas polymer-infiltrated ceramic networks (PICNs), such as Vita Enamic®, consist of a porous ceramic network infiltrated with a polymer phase. This dual-structure configuration yields enhanced fracture resistance, marginal accuracy, and ease of milling compared to traditional ceramics (Suksuphan et al., 2023). Endocrowns fabricated from RMCs exhibit comparable fatigue resistance but generally lower flexural strength than lithium disilicate restorations (Moukarab et al., 2025).

Polymer-infiltrated ceramic networks (PICNs), such as Vita Enamic®, exhibit a modulus gradient that replicates the biomechanical behavior of the dentin-enamel junction, thereby reducing interfacial stress between the restoration and tooth structure. Surface conditioning typically involves hydrofluoric acid etching followed by silane application to achieve stable and durable adhesion with resin cements. Due to the hybrid polymer-ceramic composition of Vita Enamic, an etching duration of 60-second with 5% hydrofluoric acid provides sufficient surface roughness for effective bonding, while excessive etching may compromise the material's structural integrity. The partial polymer content of PICNs enhances their repairability and fatigue resistance under cyclic loading, offering an optimal balance between strength and flexibility for endocrown restorations (Jovanović et al., 2021).

Hybrid nano-ceramic composites, including Lava Ultimate® and Grandio blocs®, show high fatigue resistance and minimal tool wear, enabling efficient chairside CAD/CAM workflows with reliable marginal adaptation (Skorulska et al., 2021). Among high-performance polymers, Polyetheretherketone (PEEK) has emerged as a promising alternative for endocrown restorations. PEEK exhibits a flexural modulus of approximately 3-4 GPa, which is lower than that of dentin but provides a biomechanical behavior more compatible with natural tooth structure, allowing better stress distribution and reducing the risk of root fracture in endodontically treated teeth. (Ge et al., 2025). CAD/CAM-milled PEEK restorations show excellent marginal adaptation, low antagonist wear, and outstanding fatigue resistance (Karimi et al., 2025).

Although PEEK is opaque, its esthetics can be enhanced by adding a composite veneer or applying a thin ceramic coating. Surface treatments such as sulfuric acid etching, plasma activation, or silica coating improve bonding with resin cements. These modifications help overcome the low surface energy of unmodified PEEK and create a stronger adhesive interface (Çin et al., 2023). New generations of PEEK reinforced with fibers or nano-hydroxyapatite show higher stiffness and better translucency. These materials are also more biocompatible and suitable for posterior endocrowns exposed to high chewing forces (Wang et al., 2022).

Modern endocrown materials have evolved from purely brittle ceramics to resilient hybrid and polymer-based systems that better replicate natural tooth biomechanics. Feldspathic porcelain remains the most esthetic but weakest option. Lithium disilicate and zirconia-reinforced glass ceramics provide a proven combination of strength and beauty, while hybrid ceramics and PEEK-based polymers introduce flexibility, repairability, and enhanced fatigue resistance. Together, these materials form the foundation of biomimetic, digitally fabricated endocrowns designed for long-term durability and esthetic excellence.

**Posterior and Anterior Endocrowns**

Posterior and anterior endocrowns share the same minimally invasive restorative principle but differ in anatomy, loading conditions, and clinical outcomes. Posterior endocrowns are primarily indicated for molars and premolars because these teeth have a wide pulp chamber and thick dentin walls, which provide a larger bonding surface and allow better stress distribution during mastication. This anatomical advantage contributes to their predictable adhesion, structural stability, and long-term clinical success (Thomas et al., 2020). In contrast, anterior endocrowns face greater biomechanical challenges. Anterior teeth possess smaller pulp chambers and thinner enamel walls and are exposed mainly to lateral and shear forces rather than vertical compressive loads. These factors limit the bonding surface area and increase the risk of debonding, marginal gaps, and incisal fractures, especially if preparation design or adhesive procedures are inadequate (Mously et al., 2025).

Material selection plays a critical role in the performance of both posterior and anterior endocrowns. High-strength ceramics such as lithium disilicate and zirconia-reinforced lithium silicate are widely used for posterior restorations because of their favorable mechanical properties and compatibility with adhesive bonding. Their fracture resistance and fatigue performance have been shown to meet the functional demands of poste-

rior teeth under occlusal stress. In anterior regions, esthetic integration is a priority; therefore, feldspathic porcelain and hybrid ceramics are often preferred for their translucency and enamel-like optical qualities, even though they offer lower mechanical resistance. Hybrid and polymer-infiltrated ceramics have also been proposed for anterior cases because their dentin-like elasticity allows better absorption of lateral forces (Samra et al., 2024).

Preparation design varies depending on tooth location. Posterior endocrowns typically feature a flat occlusal surface with an internal extension into the pulp chamber, ensuring mechanical stability and resistance to vertical loading. Anterior endocrowns, on the other hand, often incorporate incisal or palatal coverage to increase bonding surface and counteract tensile stresses during function (Machry et al., 2023).

Clinically, posterior endocrowns demonstrate higher predictability and fewer catastrophic failures. When failure occurs, it usually involves adhesive loss or superficial ceramic chipping rather than structural fracture. Anterior endocrowns, though less documented in long-term studies, have shown encouraging performance when fabricated from high-strength ceramics and bonded using advanced adhesive protocols. Finite element analyses confirm that posterior endocrowns distribute stresses more evenly at the adhesive interface, while anterior endocrowns require optimized designs and materials to prevent marginal stress concentration (Cruzado-Oliva et al., 2023; Zheng et al., 2022).

Overall, posterior endocrowns remain the most reliable and clinically validated indication due to their favorable anatomy and loading conditions. Anterior endocrowns, supported by digital workflows, modern adhesive systems, and esthetic high-strength ceramics, represent a promising conservative option that continues to evolve toward predictable long-term success (Mously et al., 2025).

**Cementation Protocols and Marginal/Internal Adaptation in Endocrown Restorations**

The long-term success of endocrown restorations is closely linked to the quality of their cementation and the precision of their marginal and internal fit. The cementation process for endocrowns involves a multiphase adhesive protocol. It begins with enamel etching using 35% orthophosphoric acid, which conditions the tooth surface and enhances micromechanical retention (Kassis et al., 2021; Shams et al., 2022). For dentin, either a selective-etch or self-etch approach using a universal adhesive is generally preferred to reduce technique sensitivity.

Following this, for etchable glass ceramics such as feldspathic, lithium disilicate, or zirconia-reinforced lithium silicate, the internal surface of the restoration is conditioned using hydrofluoric acid to create micro-retentive irregularities, followed by the application of a silane coupling agent to promote durable chemical bonding with the resin cement. In contrast, for monolithic zirconia restorations, hydrofluoric acid etching is ineffective; therefore, airborne-particle abrasion with 50 μm alumina particles is recommended, followed by the application of a phosphate monomer-based primer containing 10-meth acryloyloxydecyl dihydrogen phosphate (MDP) to achieve reliable chemical adhesion. The luting phase is then completed with the application of resin cement, commonly based on bisphenol A-glycidyl methacrylate (Bis-GMA) or urethane dimethacrylate (UDMA), materials widely recognized for their superior mechanical strength and aesthetic translucency compared to conventional glass ionomer or zinc phosphate cements (Yoshinaga et al., 2021).

Adhesive failure between the endocrown and tooth structure is a leading cause of clinical failure, with debonding frequently reported as the most common complication. The polymerization method of the resin cement plays a critical role in bond strength and clinical longevity. Depending on the translucency, thickness, and optical density of the restorative material, resin cements are chosen in three main categories: light-cured, chemically-cured, or dual-cure. Light-cured cements are suitable for restorations up to approximately 2 mm in thickness in highly translucent ceramics, where light transmission is adequate. In cases with increased thickness, reduced translucency, or deeper cavities, dual-cure resin cements are preferred to ensure complete polymerization. Chemically-cured cements are reserved for highly opaque or thick prostheses where light cannot penetrate effectively (Ikemoto et al., 2024).

Each curing mechanism exhibits distinct performance characteristics influenced by material composition and restoration thickness. Light-cured systems rely on direct energy transmission through the restorative material, making them suitable for translucent ceramics and shallow preparations. Dual-cure cements combine photo-initiated and chemical polymerization, ensuring adequate polymerization even in deeper or less translucent areas. This mechanism supports stable marginal adaptation and minimizes microleakage, maintaining long-term bond integrity. The polymerization efficiency of both light-cure and dual-cure resin cements decreases with increasing restoration thickness, a condition commonly observed in endocrowns. Therefore, resin cement selection should always consider the optical properties of the restorative material, restoration thickness, cavity depth, and internal geometry to ensure optimal polymerization and mechanical stability (Ikemoto et al., 2024; Wicaksono et al.,

2023).

The marginal and internal fit of endocrowns significantly influence their biomechanical performance and long-term success. Marginal adaptation refers to the morphological alignment between the finish line of the preparation and the margin of the restoration. Poor marginal integrity can lead to increased microleakage, cement dissolution, bacterial ingress, and ultimately pulpal inflammation or secondary caries. Internal adaptation describes the consistency of the luting space between the inner surface of the restoration and the axial or pulpal walls of the tooth. Non-uniform internal gaps can lead to stress concentration and compromise fracture resistance (El-Farag et al., 2023).

In clinical practice, acceptable marginal discrepancies are typically ≤120 μm, while internal gaps should preferably range between 100-150 μm, with an upper clinical limit of 200 μm. To assess these values, multiple techniques are employed. Direct measurement under optical or scanning electron microscopy is common in laboratory studies. Alternative non-destructive methods include the use of resin or silicone replica techniques, which allow visualization and measurement of internal space without sectioning the specimen. Advanced modalities such as micro-computed tomography (micro-CT) provide three-dimensional high-resolution imaging and enable precise digital evaluation of adaptation. Other techniques include profilometry, virtual measurement microscopy, and digital micrometry (Saad et al., 2025).

CAD/CAM fabrication techniques generally improve the accuracy and reproducibility of marginal and internal fit. Comparative evaluations of pressed and milled lithium disilicate endocrowns have demonstrated superior adaptation with milled restorations, attributed to enhanced accuracy and fewer processing variables inherent in digital workflows. Furthermore, intraoral and extraoral digital scanning workflows yield more consistent fits than conventional impression methods (Keskin et al., 2025).

Restorative material type also influences adaptation and performance. Lithium disilicate remains the most studied and widely used ceramic due to its optimal balance of esthetics, mechanical strength, and etchability. PEEK, a newer thermoplastic polymer, has been introduced due to its low modulus of elasticity, which mimics dentin and may reduce crack propagation. However, despite its favorable stress distribution, lithium disilicate generally provides superior marginal and internal adaptation compared to PEEK (Godil et al., 2021).

Additional factors impacting adaptation include preparation design and cement space. An axial taper of around 10 degrees has been associat-

ed with improved seating and internal adaptation (Hajimahmoodi et al., 2023). Cement space values between 80-120 μm are generally considered optimal; excessively narrow spaces may hinder seating, while excessively wide gaps can compromise retention. Restoration thickness, cavity depth, and intracoronal extension all interact to influence marginal sealing and fracture resistance (Zheng et al., 2022).

As new materials and fabrication methods evolve, continuous assessment of their influence on adaptation remains essential. The cumulative evidence indicates that dual-cure resin cements combined with lithium disilicate ceramics and CAD/CAM workflows collectively enhance the performance and longevity of endocrown restorations. While the current body of literature supports these approaches, individual clinical decisions should still be guided by case-specific anatomical, functional, and esthetic factors (Ikemoto et al., 2024; Wicaksono et al., 2023; El-Farag et al., 2023; Saad et al., 2025).

**The Therapeutic Journey and Outcomes of Endodontically Treated Teeth**

In the restoration of endodontically treated teeth, traditional approaches often involve the use of cast or prefabricated post systems. However, advancements in material science and increasing aesthetic demands have led to the growing preference for fiber-reinforced posts with light-transmitting properties. The selection of an appropriate post system depends on several clinical factors, including the tooth's position in the arch, the amount of remaining tooth structure, and the type of restorative material to be used (Hafez et al., 2025; Saad et al., 2023).

While cast post-core systems have demonstrated long-term clinical success, the extensive dentin removal required during their placement remains a major drawback (Vogler, Billen, Walther, & Wöstmann, 2023). Additionally, prefabricated posts made of metal or zirconia possess greater hardness and higher elastic modulus compared to dentin, which can result in unfavorable stress distribution within the root and, consequently, unexpected fractures. In contrast, fiber posts exhibit mechanical properties more closely aligned with natural dental tissues, providing more homogeneous stress distribution and reducing the risk of root fractures (de Morais et al., 2023).

Zirconia posts, characterized by excellent chemical stability and mechanical strength, also exhibit an elastic modulus similar to that of stainless steel alloys. Nevertheless, their rigidity may contribute to the

occurrence of non-restorable vertical or deep root fractures under excessive occlusal loads. Furthermore, even when minor fractures are deemed restorable, the removal of zirconia posts from the root canal can be highly challenging (Lawson et al., 2021; Ying et al., 2022). Although fiber posts are easier to retrieve in failure cases, they are not without complications. Mechanical inadequacies or bonding failures at the post/cement or post/core interfaces may lead to microleakage, secondary caries, or root canal reinfection. Loss of retention is one of the most common failures of fiber posts, particularly in the anterior region (de Morais et al., 2023; Tsolomitis et al., 2024).

Recent developments in adhesive dentistry have minimized the reliance on traditional post-core systems and enabled the adoption of more conservative techniques. These approaches aim to preserve remaining tooth structure and utilize the pulp chamber for retention without engaging the root canal system (Marques et al., 2025). The clinical applicability of high-strength, acid-etchable ceramics and durable resin-based materials in posterior teeth has further expanded the possibilities for alternative restorations in endodontically treated teeth (Caussin et al., 2024).

Laboratory-based studies suggest that endocrowns, which integrate the pulp chamber into a monolithic restoration, may lead to more favorable, restorable failure patterns compared to conventional fiber post-supported crowns. Short posts combined with endocrown restorations have been associated with a reduced risk of catastrophic root fractures under functional loading (Lin et al., 2020). Furthermore, finite element analysis-based simulations indicate that ceramic endocrowns, when properly cemented, maintain structural stability under masticatory forces, without evidence of debonding or cracking (He et al., 2021; Lin et al., 2020).

## Conclusion

In light of these findings, endocrown restorations made from advanced ceramics and polymer-based materials can be considered a minimally invasive, aesthetic, and durable option for restoring endodontically treated teeth. Their use is not limited to posterior molars but can also be effective in premolars and other teeth with sufficient coronal structure. The combination of modern CAD/CAM fabrication, adhesive resin cements, and innovative materials such as lithium disilicate, zirconia-reinforced ceramics, and PEEK provides excellent marginal adaptation, retention, and biomechanical performance. Overall, endocrowns represent an innovative and biomimetic restorative concept that integrates tissue preservation, functional reliability, and digital precision, making them a

promising solution in contemporary restorative dentistry. Nevertheless, further well-designed in vitro and in vivo studies are warranted to support the routine incorporation of endocrowns into clinical practice.

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