

Recent Advances in Dental Composites: An Overview

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Received Date: September 03, 2024; Published Date: September 25, 2024

Abstract

Until recent decades, apically immature necrotic teeth were indicative of apical growth. With advances in dentistry such as improved irrigation in procedures, better visualization of the surgical field, and advanced skills of endodontists, endodontic surgery has become the focus of attention. This review article addresses the tissue engineering, pulp regenerative strategies used in the past, current guidelines according to the American Endodontic Association, and future dental concepts.

Keywords: Regenerative Endodontic Procedures (REPs); Restoration; Non-Carious Cervical Lesions

Introduction

“Composite” refers to a mixture. In materials science, a composite is a mixture produced from at least two of the different classes of materials, i.e., metals, ceramics, and polymers. Dental composites are complex, tooth colored filling materials composed of synthetic polymers, particulate ceramic reinforcing fillers, molecules which promote or modify the polymerisation reaction that produces the cross-linked polymer matrix from the di-methacrylate resin monomers, and silane coupling agents which bond the reinforcing fillers to the polymer matrix [1]. Each component of the composite is critical to the success of the final dental restoration. However, the most significant developments in the evolution of commercial composites to date have been a direct result of modifications to the filler component [1,2].

Composite resins first started to be used in conservative dentistry in the 1940s to minimise the disadvantages created by acrylic resin which was replacing silicate cements. In 1955, Buonocore used orthophosphoric acid to strengthen the adhesion of acrylic resins to the enamel surface. In 1962, Bowen developed bisphenol A glycidylmethacrylate (BISGMA) to improve the physical characteristics of acrylic

resins. Despite more than 50 years of the Bowen formulation, no significant developments have been recorded in mechanical properties [1-4] (Figure 1).

After the 1970s, composite materials emerged which were polymerised with electromagnetic radiation. An ultraviolet light source at 365 nm wavelength was first used to provide the light energy. However, due to poor polymerisation and iatrogenic side-effects, this was replaced by light seen at 425-491 nm wavelength [2]. From then on, the development of composites has continued [5].

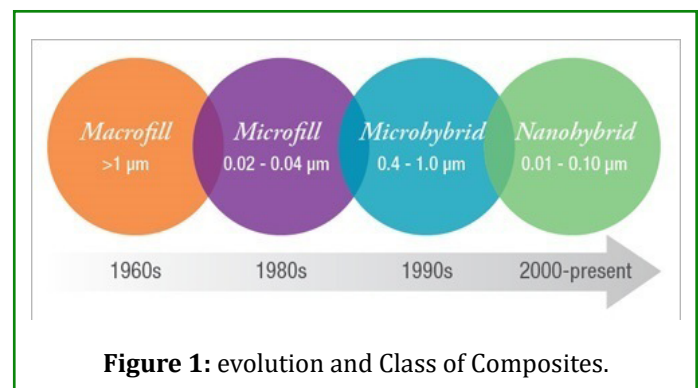


Figure 1: evolution and Class of Composites.

Composite resins have several applications in various fields in dentistry apart from use as a direct restorative material [5,6]. Some of the applications are listed as follows:

1. They are used as a direct and indirect esthetic restorative material.
2. They are a component of the fiber reinforced composites used in FRC posts, fiber splints, etc.
3. They are also used for direct splinting of mobile teeth with or without glass fiber or metal wire.
4. They are also used as luting agents and as root canal

sealers.

5. Chemical cure and dual cure resins are also used as core buildup materials in postendodontic restorations.
6. Filled and unfilled composite resins are used in preventive dentistry as pit and fissure sealants and in preventive resin restorations (PRR).
7. They are used in bonding of orthodontic brackets during orthodontic treatment.

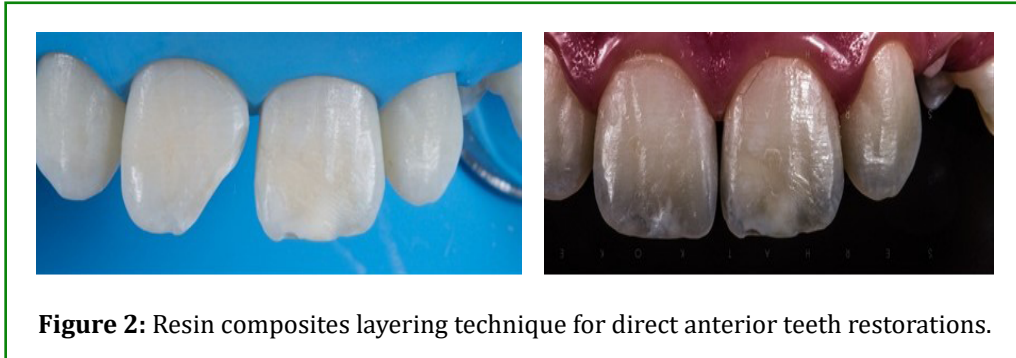


Figure 2: Resin composites layering technique for direct anterior teeth restorations.

The Advantages of Composite Restorations

Esthetics: Tooth-colored restorative material with different shades and translucency makes composite resins an ideal direct restorative material over silver amalgam [6,7].

Conservative cavity preparations: A major advantage of composite resins over amalgam is the ability to prepare very conservative cavity designs, resulting in preservation of tooth structure.

Reparability: Composite resin can be repaired by the addition of another composite layer, even though the oxygen-inhibiting layer has been removed, if the surface is first etched, silanated, and then a compatible bonding agent applied.

4. Low coefficient of thermal conductivity: When compared to silver amalgam (30 times more conductive than dentin) and gold (500 times more conductive) that require an insulating base, composite resins offer greater insulation than enamel and hence do not require insulating bases (Figure 2).

The Disadvantages of Composite Restorations

1. Technique sensitive: Posterior composite restorations are more technique sensitive than silver amalgam restorations and require almost twice the time for completion [1,7].
2. Proper contact and contour: Accomplishing proper contacts and contours of the proximal surface with composite resins is quite challenging due to its plastic consistency.
3. Isolation: Isolation is critical in composite restorations, especially in gingival areas of deep class II and class V

lesions, when compared to silver amalgam and glass ionomer cements, since moisture contamination of composite resins results in reduced physical properties.

4. Nonantimicrobial: Unlike glass ionomer cements, composite resins cannot arrest the growth of microorganisms. Hence, the incidence of secondary and recurrent caries is more with composite restorations.
5. Polymerization shrinkage stress: During polymerization shrinkage of the composites, stresses are induced within the material. When this stress is greater than the bond strength of the adhesive used, debonding can occur, leading to marginal gap formation, postoperative sensitivity, and irritation to the pulp due to bacterial ingress [1,8,9].

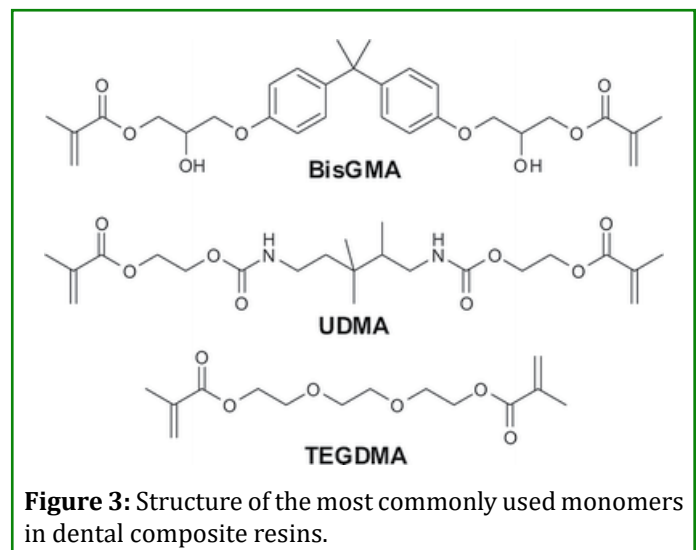


Figure 3: Structure of the most commonly used monomers in dental composite resins.

Therefore, to enhance properties and to overcome drawbacks of previous materials, R Bowen introduced a dental restorative material 2 fortified with silica particles (1962), widely called “composites” [10]. Its decent properties and excellent appearance helped it phase out previous unaesthetic materials. Initially, use of composites was limited to restoration of anterior teeth only. However, today because of their improved mechanical properties, they are used even in posterior areas. Not only this, their versatility has also led to their utilization in other areas of dentistry including splinting and bonding orthodontic brackets. Therefore, this article gives a review of the advancements of composite materials that had taken place over the years [11-13] (Figure 3).

Chemical Compositions of Dental Composites

A composite is defined as a three-dimensional compound

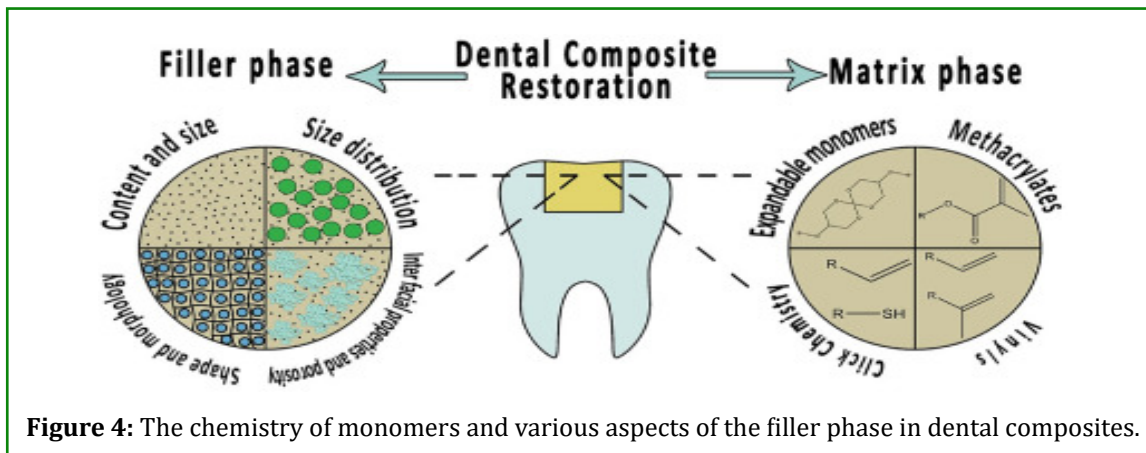


Figure 4: The chemistry of monomers and various aspects of the filler phase in dental composites.

which can enhance the hardness, wear resistance, and translucency of the composite. The coupling agent system usually consists of organic silane such as 3-methacryloxypropyltrimethoxysilane and 10-methacryloyloxydecyl dihydrogen phosphate (10-MDP), whose chemical functional groups can enhance the bonding strength between the reinforcing filler and the resin matrix. The polymerization of composite is initiated by an initiator system, such as camphorquinone (CQ), phenylpropanedione (PPD), when external energy (light or heat) is applied. Different types of composites require different light energy levels for proper curing, which has been reviewed. Catalyst is added to control the polymerization speed. Other constituents such as dimethylglyoxime can also be used to improve certain physical properties such as flow ability [18-20] (Figure 4).

Composite System Classification of Dental Composites

There are many types of composite products available in clinical use by several different classification systems. Dental

which is composed of at least two different chemical components, or can be described as a blend of hard inorganic particles bound together in a resin matrix. A dental composite includes a resin matrix, inorganic fillers after surface treatment, as well as the initiator and catalyst systems [14,15].

The resin-based oligomer matrix is most commonly composed of bis-GMA, a hydroxyethylmethacrylate (HEMA), triethylene glycol dimethacrylate (TEGDMA), and urethane dimethacrylate (UDMA).² Inorganic fillers usually include silicon dioxide (silica), quartz, other glass powders, ceramic fillers, and so forth [16,17], (Figure 2).

composites can be divided into the following categories, according to their different compositions and performance characteristics [20,21].

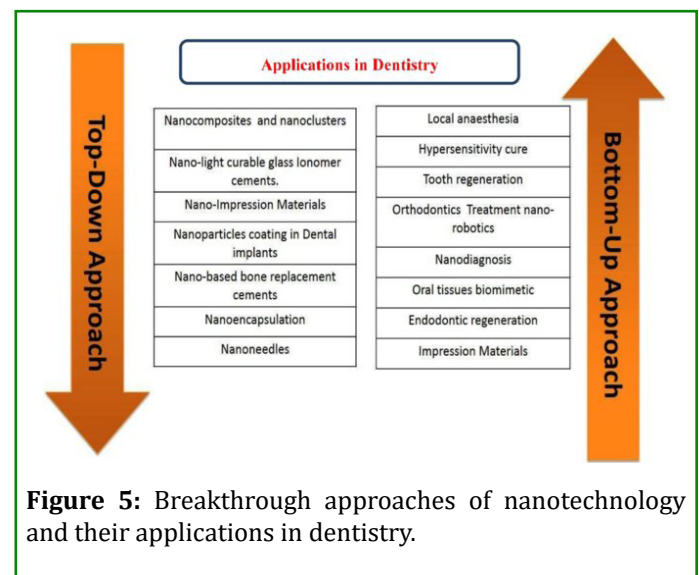


Figure 5: Breakthrough approaches of nanotechnology and their applications in dentistry.

Filler Particle Size

The most common classification system for composites considers the distribution and average filler particle size [14,15]. Based on the classification systems by Lutz and Phillips in 1983, composites can be classified into: macrofilled, microfilled, hybrids, modern hybrids, and nanofilled composites. With filler particle sizes ranging from about 10 to 50 μm , conventional or macrofilled composites were mechanically strong, but difficult to polish and to retain a favorable color match. Later, amorphous spherical silica of approximately 40–50 nm were incorporated to formulate “microfill” composites, which were more esthetic but showed significantly more fractures and a significant loss of anatomical shape due to wear. To address the important issue of long-term esthetics and mechanical properties, the particle size of conventional composites was reduced to produce what was ultimately called the hybrid composites. Hybrid composites can be considered among the best

materials for posterior restorations. The new generation of hybrid composites comprises about a couple of micrometers or less filler particles of glass and small amounts of colloidal silica particles (10–50 μm and 10–50 nm), with lower shrinkage, improved polishing performance, and better esthetics [4]. Compared to the limited range of shades of the early macrofilled and microfilled composites, modern hybrid composites (0.5–1.0 μm and 10–50 nm) are ideal for esthetic restorations of anterior teeth, because of a variety of different shades with tailored opacity and translucency [16]. Furthermore, with the rise of nanotechnology, nanofilled composites came into being with inorganic phases of characteristic dimensions in the range of 10–100 nm. Because of the increased filler loading and reduced amount of resin matrix, nanofilled composites thereby reduced the polymerization shrinkage while providing esthetics and strength [14] (Figure 5).

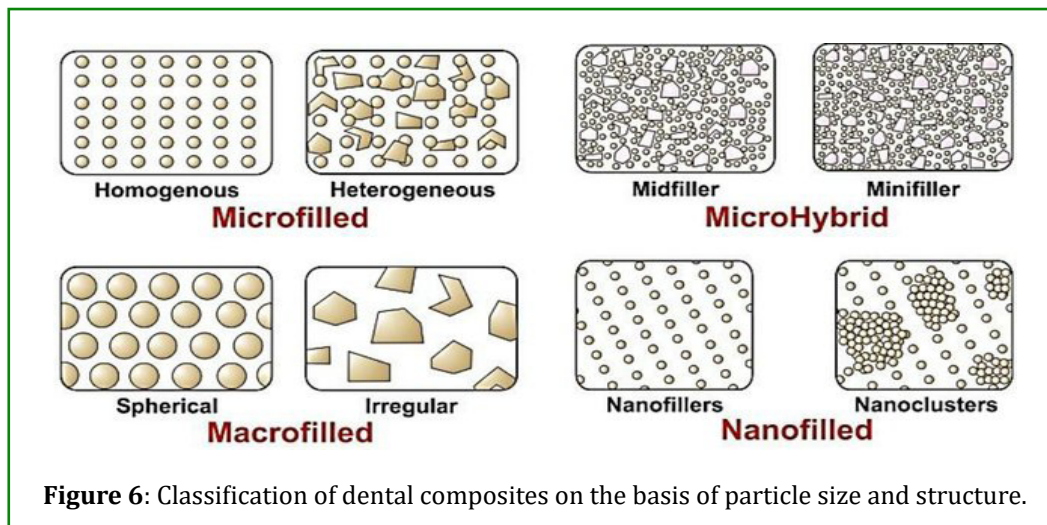


Figure 6: Classification of dental composites on the basis of particle size and structure.

Curing Modes

Most dental composites cure via radical chain polymerization in which monomers are converted to polymers. Various types of initiation systems and activation methods can be used to generate a free radical that initiates the polymerization process. They have significant effects on the kinetics of

polymerization and the polymer structure, thus affecting various properties of the composites [18]. According to the initiation systems or cure mechanisms, composites can be divided into chemically initiated/self-cured, light-activated, heat-cured, or dual-cured composites [19] (Figure 6).



Figure 7: Direct Esthetic Composite Restorations in Anterior Teeth.

For self-cured/chemical-cured composites, when the powder liquid or paste-paste materials are mixed together, polymerization is initiated by an oxidation–reduction initiator system at room temperature. Self-cure composites are composed of a catalyst part containing benzoyl peroxide (BPO) and a base part containing tertiary amine. The tertiary amines, N,N-dimethyl-p-toluidine (DMPT) and N,N-dihydroxyethyl-p-toluidine, are also usually used in self-cure composites. When the two parts are mixed, the radicals formed by the reaction of the BPO and amine are able to react with the monomers that would become polymerization later. However, most self-cure composites are now used as resin-based luting cements or core materials, rather than direct restorations [19]. In contrast, the light-cured method uses ultraviolet (UV) or visible light to promote initiation reaction of resin polymerization. Light activated composites undergo polymerization by irradiation via a blue-light-curing unit in the wavelength range of 410–500 nm [12]. These days, almost all dental restorative composites contain CQ/amine complex initiation, visible light-cured, which is safer compared with UV-curing systems, and one-component systems. The mechanism of the CQ/amine system is different from that of the BPO/amine chemical initiation system. When exposed to visible light, the CQ undergoes excitation first by energy absorption. The CQ molecule in the excited triplet state rapidly interacts via electron transfer with an amine to constitute an excited complex, and then extracts hydrogen from the amine to make up a new compound. The excitation energy is transferred to the amine molecule during

the process, the α -amino-alkyl radical is more efficient at initiating polymerization than the relatively inactive CQ-ketyl radical [20]. Heat-cured composites are polymerized by extra-oral cure involving heat that might help reduce the quantity of remaining double bonds resulting in improvements in mechanical properties. In addition, there still exists another kind of dual-cured composites with combination of various curing systems to form polymers [19,20]. They are widely used for cementing endodontic posts and fabricating core buildups (Figure 6).

Self-Healing Composite

Materials usually have a limited lifetime and degrade due to different physical, chemical, and biological stimuli. These may include external static (creep) or dynamic (fatigue) forces, internal stress states, corrosion, dissolution, erosion, or biodegradation. This gradually leads to a deterioration of the material structure and finally failure of the material. One of the first self-repairing or self-healing synthetic materials reported interestingly shows some similarities to resin-based dental material; it was the epoxy resin composite [16]. If a crack occurs in the epoxy composite material, some of the microcapsules are destroyed near the crack and release the resin. The resin subsequently fills the crack and reacts with a Grubbs catalyst dispersed in the epoxy composite, resulting in a polymerization of the resin and repair of the crack [21,22] (Figure 7).

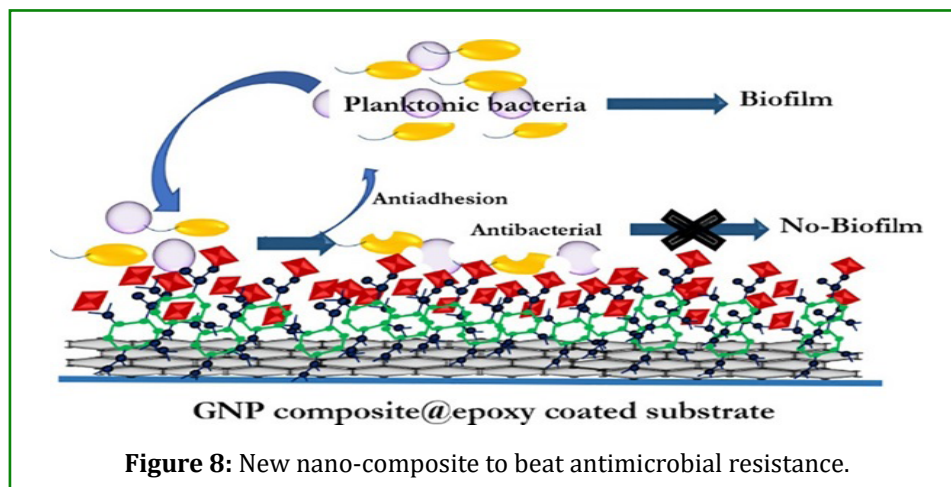


Figure 8: New nano-composite to beat antimicrobial resistance.

Antimicrobial Composite

Antimicrobial properties of composites may be accomplished by introducing agents such as silver or one or more antibiotics into the material. Silver and titanium particles were introduced into dental composites, respectively, to introduce antimicrobial properties and enhance the biocompatibility of the composites [12]. The antibacterial properties of these composites were based on contact mechanism rather than

on leaching. The antimicrobial effect lasted for at least 1 month [13] (Figure 8).

Direct Composite Resin

This concept was developed by Dr. Lars Ehrnford of Sweden. This mainly consists of aluminum oxide and silicon dioxide glass particles or barium aluminum silicate or strontium glasses. The glass particles are liquefied to form a molten

glass which is forced through a die to form thin strands of glass fibers [4]. Traditional light-cured hybrid resin composites cannot be bulk placed because of excessive polymerization shrinkage and the inability to adequately light-polymerize the resin beyond a 2 mm depth [5]. Bulk placement of packable composites was claiming decreased polymerization shrinkage due to increased filler loading and a reported depth of cure reaching 5 mm [4]. Packable resin composites were developed to restore surfaces that previous

resin composites could not. Avoiding saliva and blood contamination of the prepared enamel and dentin surfaces is vital to achieve a proper bond. Packable resin composite should not be viewed as a time saver as bulk placement of packable resin composite is not recommended and may compromise the long-term success of the restoration [5] (Figure 9).



Figure 9: Dental esthetics, rehabilitation.

Flowable Composite

It is termed as “flowable composite” because of its low viscosity and ability to be syringed into a cavity preparation with a needle tip. Most of the flowable composites presently available are not filled, generally containing from 56% to 70% filler by weight. Accordingly, they have reduced mechanical properties such as a higher susceptibility to wear, a higher polymerization shrinkage, and lower flexural strength [6]. Flowable composite resin materials can be useful not only as a liner but to build up cavity preps, to block out small undercuts and to use as an indirect or direct pulp cap. Low modulus flowable resin composites have been described as

potentially radiopaque “filled adhesives” with implications for improved clinical dentin bonding [7]. Flowable composites are used under composites restorations as stress breaker so as to compensate for polymerization shrinkage stress of overlying composite resin, repair of composite resin restorations (Figure 9).

Indirect Composite Resin

The indirect composite resin is based on first and second generations. A number of highly improved indirect resin restorative systems have been introduced with unusually good properties like wear



Figure 10: Indirect Resin Restorative Material.

Resistance, aesthetics, marginal adaptation, and control over polymerization shrinkage [8]. Touati and Mörmann introduced the first generation of indirect resin composites (IRCs). The first generation IRCs had a composition

identical to that of the direct resin composite. The clinical failures endured with the first generation composites and the limitations faced with ceramic restorations led to the development of improved second generation composites

[9]. The second generation composites have “microhybrid” filler with a diameter of 0.04-1 μ , which is in contrast to that of the first generation composites that were micro filled. By increasing the filler load, the mechanical properties and wear resistance is improved, and by reducing the organic resin matrix, the polymerization shrinkage is reduced [9] (Figure 10).

Nanocomposites



Figure 11: Dental Nanocomposites.

Nanotechnology may provide composite resins with a dramatically smaller filler particle size that can be dissolved in higher concentrations and polymerized into the resin system [10]. Nanoparticle filled composites exhibit outstanding aesthetics, are easy to polish and possess an enhanced wear resistance. Nanotechnology can, however, improve this continuity between the tooth structure and the nanosized filler particle and provide a more stable and natural interface between the mineralized hard tissues of the tooth and these advanced restorative biomaterials. Nanocomposites show greater fracture toughness and adhesion to tooth structure [11] (Figure 11).

Fibre Reinforced Composite

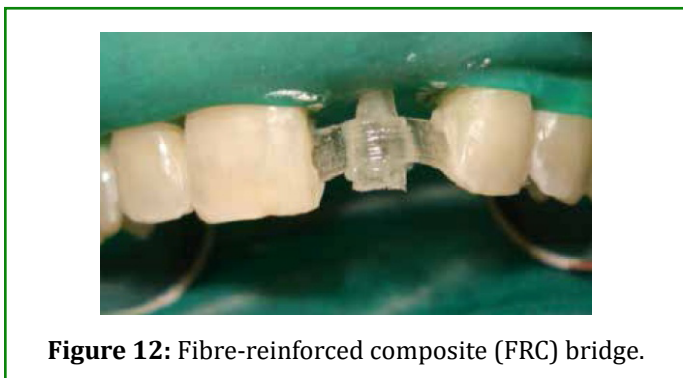


Figure 12: Fibre-reinforced composite (FRC) bridge.

Fiber-reinforced composites have numerous industrial and aerospace applications because they are light, strong and non-flammable. However, with respect to clinical dentistry, they are relative newcomers into the spectrum of

prosthodontic treatment options (Figure 12) [15]. The main advantage of these fibre reinforced composite was they can be used in both direct and indirect restorations [15].

Stimuli Responsive Composite

Stimuli-responsive materials possess properties that may be considerably changed in a controlled fashion by external stimuli. Such stimuli may be for example changes of temperature, mechanical stress, pH, moisture, or electric or magnetic fields [14]. These composites may be very effective against secondary caries. They are used for treating the secondary caries in the posterior teeth region.

Compomers

Compomers were introduced to the market in 1990 as polyacid-modified composite resins, and were derived from a combination of composites and glass ionomer cements as a material which can be attached to dental hard tissues, provides fluoride expression and is biocompatible. The aim of this new material was to attempt to maintain the benefits by minimising the disadvantages of composites and glass ionomers. Due to the superior properties, primarily hardening with light, the use is simple and they have gained popularity in a short time. In respect of physical properties, compomers are worse than composite resins but have superior properties compared to glass ionomers and RMGIs [18,19] (Figure 13).

Compomers have limited indications for clinical use and in accordance with the manufacturer’s recommendations are used in all milk tooth cavity types, and in adults, in cervical erosion and abrasion lesions with or without decay, in anterior proximal restorations, in the second class laminate and sandwich technique, in restorations with small weight-bearing, in the temporary repair of broken teeth and as core material if there is <50% crown dentin present. They should not be used when there are contraindications of direct or indirect capping of the pulp required, when isolation cannot be provided, in the core structure of all ceramic crowns or when the patient has an allergy to dimethacrylate resins [19].



Figure 13: A compomer restorative material, showing the compule and applicator gun.

The content of compomers is formed of methacrylate and polycarboxylate groups with resins which can be polymerised, glass filling particles such as fluoroaluminosilicate, strontium fluorosilicate or barium fluorosilicate glass, photo-triggers (camphoroquinone/amine system) and balancers [19].

Dyract (Dentsply), Compoglass (Vivadent), F 2000 (3M) and Hytac Aplitip (Espe) are examples of compomers.

Ormocers

Ormocers, which were developed by the Fraunhofer Silicate Research Institute and produced from organic modified ceramic, started to be used in dentistry in 1998. This composite group is produced with a change to the resin matrix [20]. Different to conventional composites, they are formed from inorganic-organic copolymers with silanized filling particles. In ormocers, which are formed of three basic components, while the organic polymer structure is responsible for resistance, the optical behaviours and the cross-link capability, the inorganic structure is responsible for thermal expansion and chemical stability and polysilicones do not affect the elasticity and interface properties [21].

The solution and gelation process in ormocers is followed by water and alcohol polycondensation, and the polymerisation of titer oligo methacrylate alcoxysilane induced with multi-functional urethane. As a result of hydrolysis and polycondensation reactions, the alcoxysil groups of silane form an inorganic Si-O-Si network and the methacrylate groups undergo organic polymerisation using traditional phototriggers [22,23]. In ormocers with filling particle size varying from $1\mu\text{m}$ – $1.5\mu\text{m}$, the large size of monomer molecules can increase resistance to wear by reducing polymerisation shrinkage and leakage [6]. In addition to these properties, the resistance to wear of ormocers, which have biocompatibility and highly effective prevention of decay, is higher than that of traditional composites and in respect of shear bond force they are equal to traditional composites which include Bis-GMA matrix. The values of impermeability and polymerisation shrinkage (1.97%) are similar to those of packable composites. Due to the nanoparticle content which increases the polishability of the restoration and microsurface hardness, the roughness values following polishing are similar to those of nanofill composites. Another advantage of these composites is that properties such as the heat expansion coefficient are similar to those of the natural tooth [24].

The disadvantages of ormocer-based composites include the high toxicity shown which can be related to the high amount of Bis-GMA expressed. In a previous in vitro study, Admira, Tetric Ceram and Z250 were compared and it was seen that there was higher exposure to 3T3 fibroblast toxicity with the polymerising discs of Admira. When the use was examined in

clinical applications, it included the same construction stages as direct composite resin. The low number of previous studies in general is not sufficient to evaluate clinical performance [25-27].

Art glass

Belleglass HP was introduced by Belle de St. Claire in 1996 as an indirect restorative material. Resin matrix contains BISGMA and fillers. The Belleglass is polymerized under pressure of 29 psi at elevated temperature of 138°C and in the presence of nitrogen, an inert gas. The elevated temperature increases the polymerization rate. The increased atmospheric pressure reduces the vaporization potential of the monomers at elevated temperatures. Use of nitrogen gas during polymerization process relates to an increase in the wear resistance i.e. nitrogen provides an oxygen free environment, which in turn results in higher levels of polymerization; more translucency of cured mass. Oxygen if gets entrapped in the composite, it interferes with polymerization and reduces translucency. It is esthetically appealing and highly wear resistant [28-30].

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GIOMERS

Giomers are hybrid restorative materials formed from the combination of glass ionomers containing active filling particles and composite resins. In the structure of giomer restorative materials are glass ionomer particles which have formed from a previous reaction to provide production of glass ionomer. By fluoride aluminium previously entering into a reaction with silicate glass polyacid, giomers which form the glass ionomer matrix are then included in the resin producing silica filler [28,33,34].

Giomers have advantages such as good aesthetic properties, being resistant, ease of polishing and being able to express

and store fluoride [29,35]. Gionomers are bonded to the tooth surface through a bonding system like the composite resins. As gionomers do not require acid and washing stages, they save time and application is simple so they can therefore be used safely on paediatric patients. When evaluated in respect of resistance and bonding strength, they are better than glass ionomers. However, previous studies have reported that bonding resistance values are negatively affected in the presence of moisture [30,31,36,37].

Areas of use of gionomers in dentistry are Class II, III, IV and V cavities, milk and permanent tooth restorations, root surface decay and restorations of cervical lesions [38].

The majority of gionomers are used as restorative material in areas where the dentin bonding agent does not have great fissure coverage and strength with conditions of composite indications. When examined generally, gionomers, the glass ionomers of which have gone through a previous reaction, are used more often together with an adhesive system because of the greater water absorbancy following gionomer polymerisation (F-PRG) (12). When previous studies are examined, Mungara et al evaluated the fluoride expression of gionomers and nano-ionomers and it was reported that gionomers did not express as much fluoride as nano-ionomers (32).

In a study by Jyothi, et al. of a 1-year clinical follow-up of cervical lesions without decay, Beautiful II gionomer restorative material was seen to have superior surface finishing compared to RMGIC (Fuji II LC) material [33,39].

In a study by Jingaward, et al. that examined the fluoride expression of Fuji II, Ketac N100 and Beautiful II materials on days 1, 7 and 15 the material with the lowest fluoride expression was determined to be Beautiful II. The material with the highest expression on days 1 and 7 was Fuji II and on day 15, Ketac N100 [34,40,41].

In another clinical study, which compared Beautiful II gionomer restorative material with traditional resin-based material, no statistically significant difference was recorded. In a different study by Itota et al, it was reported that Reactmer expressed more fluoride than a compomer and composite. In contrast to that study, Yap et al reported that there was no initial fluoride expression from the material, but it occurred later and at the end of 28 days, expression from a compomer was lower [35,41,42].

SILORANES

Silorane-based composite resins were developed to increase the clinical performance of composites and have been produced showing cationic ring opening formed as a result

of the sioxane and oxyrane chemical structures reaction. The function of the oxyrane structure in this reaction is to reduce polymerisation shrinkage and the siloxane function is the formation of a hydrophobic structure. According to the manufacturers, the combination of these two chemical structures creates a biocompatible, hydrophobic system with less shrinkage [36,37,43,44].

In addition to reducing polymerisation shrinkage, these resins have several advantages such as reducing marginal discolouration to a minimum, not being mutagenic, increasing resistance to weakening and providing resistance to liquids. Previous studies have found the shrinkage rate of silorane-based composites to be <1% [38,39,45].

BULK FILL COMPOSITES

The area of use in dentistry for resin-based composites is a broad spectrum, from small areas of decay to direct restorations of heavily damaged teeth [40,46]. The reasons for selecting these composites is that the majority have the potential to mimic the aesthetic nuances of dental tissues (Figure 14) [41,47]. There are advantages such as ease of use, good aesthetics and they can be repaired. However, there

i) The low viscosity flowable bulk fill composites such as (SDR (Dentsply), Venus BulkFill (Hereaus Kulzer), Filtek BulkFill (3M/ESPE), X-tra Base (Voco) are placed as a preparation of the lower part dentin layer and then after the placement of a second layer as an enamel layer, polymerisation is applied.



Figure 14: Renamel_BULKfill-Box-with-Compules_1800px_1800px.

ii) As the high viscosity restorative materials, SonicFill (Kerr), X-tra Fill (Voco), Filtek BulkFill (3M ESPE), Tetric Evo Ceram BulkFill (Ivoclar Vivadent) and QuiXfil (Dentsply) do not have good adaptation to cavity walls, a low-viscosity resin is placed as a first layer and polymerisation is then applied with light (Figure 15).

They are also disadvantages such as the high rate of wear, polymerisation shrinkage and postoperative sensitivity, and over time they can cause secondary decay and marginal discolouration [42,43,49].

Traditional resin-based composites are hardened with light in the form of 2 mm layers. To shorten the application time

and provide ease of use of resin-based composites, bulk-fill composites have been produced which can be placed at a thickness of 4 mm and in the form of a single block [44,50]. There are several properties required of these composites; these can be said to be ease of application, little polymerisation shrinkage, a fluid texture for good adaptation and for polymerisation to be effective up to 4 mm [45,51,52].

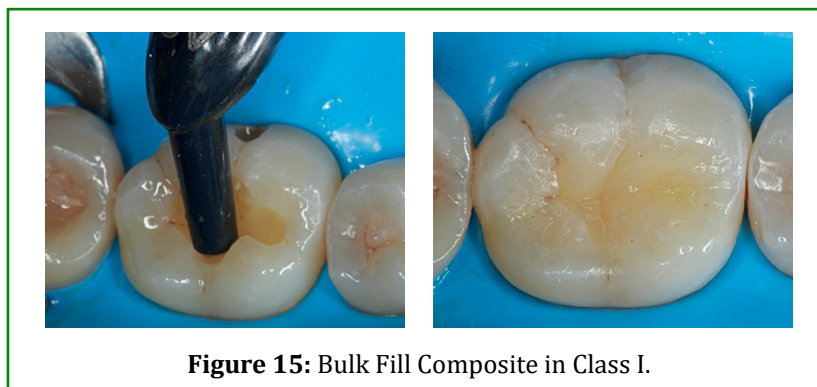


Figure 15: Bulk Fill Composite in Class I.

Bulk fill composites are examined in 2 categories, as low viscosity flowable composites and high viscosity restorative materials:

i) The low viscosity flowable bulk fill composites such as (SDR (Dentsply), Venus BulkFill (Heraeus Kulzer), Filtek BulkFill (3M/ESPE), X-tra Base (Voco) are placed as a preparation of the lower part dentin layer and then after the placement of a second layer as an enamel layer, polymerisation is applied [45,52,53].

ii) As the high viscosity restorative materials, SonicFill (Kerr), X-tra Fill (Voco), Filtek BulkFill (3M ESPE), Tetric Evo Ceram BulkFill (Ivoclar Vivadent) and QuiXfil (Dentsply) do not have good adaptation to cavity walls, a low-viscosity resin is placed as a first layer and polymerisation is then applied with light [45,53,54].

Bioactive glass nanoparticles

These have excellent regenerative properties in mineralised tissues. The high surface area of nanoparticles may facilitate the dissolution of ions from the glass and thus accelerate dentin mineralization. These nanoparticles induce the formation of apatite in dentin [46,55-57].

Calcium phosphate nanoparticles

Calcium phosphate such as Hydroxyapatite phosphate, anhydrous calcium phosphate, tetra calcium phosphate and dicalcium phosphate anhydrous have been used as fillers. To make mineral releasing dental composites. The incorporation of these particles improves stress-bearing capacity and ion release that inhibit dental caries [47,48].

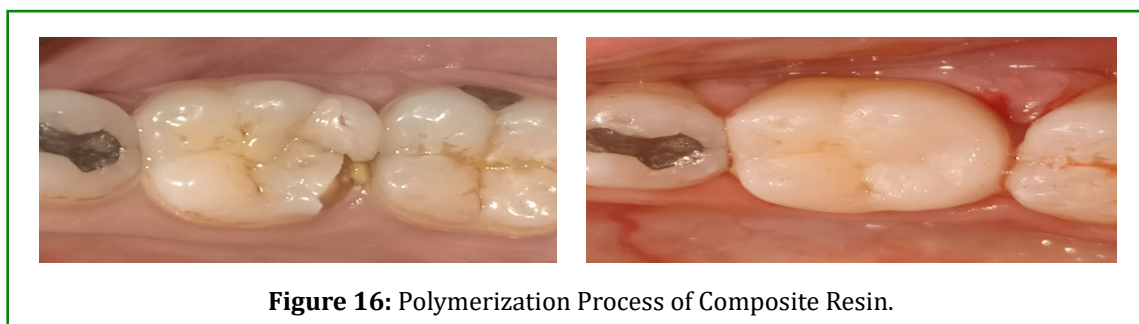


Figure 16: Polymerization Process of Composite Resin.

In dentistry, nearly all types of composite resin use monomer types in the same group and the same polymerization process. The polymerization process is vinyl-free-radical polymerization [49,50]. The polymerization process of composite resin starts with releasing free radical from

methacrylate monomer structure an external energy in the form of heat, chemical, or radiant energy. When free radical is formed, the monomer looks for the electron-rich monomer to form covalent bond [52,53]. The combination of those monomers forms a new polymer [52,53]. Based on the

activation energy, composite resin is classified into two type, i.e. chemically activated and light activated composite resins [49,53-55].

Chemically activated composite resin consists of two tubes contain different paste each. Polymerization occurs when both pastes are mixed. The chemically activated composite

resin reaction was shown in Figure 16. The tubes contain benzoyl peroxide initiator and aromatic tertiary amine activator (N, N-dimethyl-p-toluidine). When both pastes are mixed, benzoyl peroxide initiator and aromatic tertiary amine activator will produce a free radical and the polymerization starts [54,55].



Figure 17: Post Ortho Bonding and Replacing Missing Tooth with Composite Bridge.

Light activated composite resin consists of one type of paste in a syringe. The composition and the reaction of the light activated composite resin was shown in (figure 2). The paste consists of photosensitizer and amine initiator. When the composite resin paste is illuminated with the wavelength 468 – 470 nm, the resin will formed free radical. The photosensitizer commonly used is camphoroquinone which can absorb light with the wavelength of 400 – 500 nm and composition in the resin is ≤ 0.2 % of the weight of

composite resin paste (figure 17). The amine initiator type used together with camphoroquinone is dimethylaminoethyl methacrylate (DMAEMA). The composition in the resin is ≤ 0.15 % of the weight of composite resin paste. When the composite resin is illuminated with camphoroquinone, it will excite and interact with DMAEMA to produce free radical [49,50,56-59].



Figure 18: Fixed Ribbon Orthodontic retainer.

Clinical Performance

Factors of importance which may affect the longevity of composites include ability to resist high stress without fracture, ability to resist smaller cyclic stresses without

degradation, ability to resist abrasive forces without undergoing wear and ability to resist chemical degradation [56,59,60] (Figure 18).



Figure 19: Composite restoration steps with Pizza technique.

Factors of importance which may affect the longevity of composites include ability to resist high stress without fracture, ability to resist smaller cyclic stresses without

degradation, ability to resist abrasive forces without undergoing wear and ability to resist chemical degradation [61,62].



Figure 20: premolar restoration.

Conventional composites: The presence of macrofillers in conventional composites makes it difficult to give the resin a smooth surface, and trimmed restorations soon become rough, leading to plaque accumulation and staining. Hydrolysis of the interfacial bond and rapid wear of the organic matrix cause protrusion and dislodgment of the macrofillers. For this reason, rather poor wear properties

result in both stress-bearing and contact-free situations¹⁴²¹. When macrofilled composites are abraded by food, only the polymer matrix between the filler particles is worn down; the filler particles themselves are not abraded, but fall out with time as they lose their grip in the surrounding polymer [57-59,63,64]



Figure 21: Lateral Diastema Closure.

The use of conventional composites in posterior teeth may lead not only to overeruption of the tooth or teeth in the opposing arch but also the mesial migration of teeth distal to those undergoing loss of interproximal contact [45,46,65,66].

In general, conventional composites are unsuitable for areas of heavy masticatory force, but their marginal adaptation seems to be superior to that of amalgam [47-51,67,68] (Figure 19).

Microfilled composites: The introduction of a microfine filler into a composite resin system has overcome the finishing problems associated with conventional composites. The smooth surface produced by abrasion of microfine filled composites reduces friction and therefore eliminates the type of abrasion seen in conventional composites, which exhibit selective wear of the soft matrix and not the inorganic filler, this producing a rough surface [52,69]. The ability to produce and maintain a smooth surface texture is a major advantage, and it is possible that the extremely small filler particles impart some degree of matrix protection [53,70].

Some investigators, based on the results of short-term clinical trials, have indicated that in terms of abrasion resistance, microfilled materials are better than conventional composites [53,54,71]. When compared to amalgam, it was concluded that microfilled composites showed quantitatively similar wear resistance to that of amalgam [55,56,72]. Although considerable clinical success has been achieved, the results obtained have been mainly from short-term investigations, and thus the use of microfilled composites in posterior teeth is not yet justified [57,73] (Figure 20).



Figure 22: Lower diastema closure with Bioclear matrices.

Hybrid composites: These materials are increasingly advertised and promoted as an alternative to amalgam. It has been reported that compared to microfills, hybrid composites exhibit superior abrasion resistance, a lower coefficient of thermal expansion, reduced polymerization shrinkage, improved tensile strength and reduced water absorption [3,73,74]. Since they are heavily loaded inorganically, they have a high degree of fracture resistance [20,75] (Figure 21). It has been reported that hybrid composites show better wear resistance than conventional and microfilled

composites, but lower resistance than Dispersalloy amalgam [58,74,75]. However, a contradictory findings were reported by MCCOMB AND BROWN [59,76]. Using silver amalgam as a control they found that the wear resistance of hybrid composites after two years of clinical observations was lower than that of microfilled composites and amalgam; amalgam showed the highest wear resistance. SETCOS, et al. [60,76] evaluated about 400 posterior restorations using Occlusin (light-activated, urethane-based radiopaque hybrid composite), with 100 amalgam restorations (Figure 22).

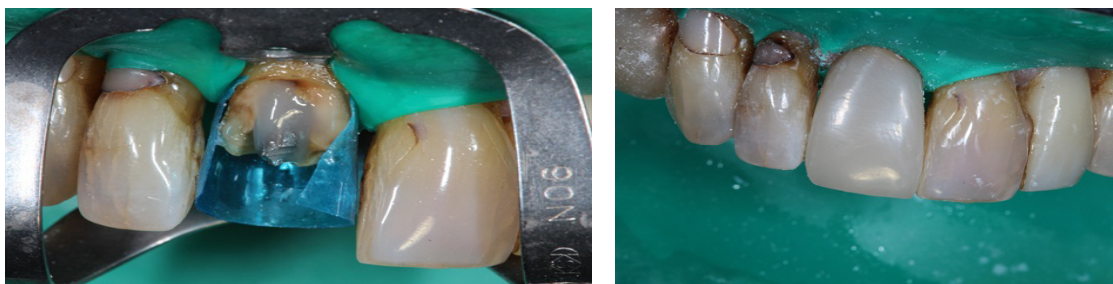


Figure 23: Composite Crown Step by Step.

Hybrid composites offer a structural compromise between wear-resistant conventional composites and fatigue-resistant microfilled materials. This compromise results from an improvement in the character, form, size and

distribution of the filler phase. Generally, these materials are as highly filled as possible, with a wide range of filler particle size. The upgraded properties of the hybrids resemble those of dentine and lathe-cut amalgams. These changes favor the

use of these materials in the premolar-molar region, and they are now commonly indicated as the posterior composites of choice [68-77] (Figure 23).

Conclusion

The science and technology of composites have significantly improved compared with their predecessors. Although composites have not evolved to the point of totally replacing amalgam, they have become a viable substitute for amalgam in many clinical situations. As we know the development of high-performance restorative materials is essential to the success of dental treatment but with composite resin materials, problems still exist. Together with the use of nanotechnology, knowledge of materials and developments in biomaterials, it is thought that high quality dental composites will be produced in the future. Accordingly, there is a need for further clinical research to achieve these goals.

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