The continuum of restorative materials in pediatric dentistry—a review for the clinician

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Abstract

Many choices are available to the practitioner of restorative dentistry for children. With the introduction of several new classes of restorative materials in recent years, some confusion has been created about what these materials are, making it difficult to identify their appropriate clinical use. This paper reviews glass-ionomer materials, resin-modified (reinforced) glass ionomers, compomers, and composite resins for the practitioner. Definitions of these materials, a general description of their contents, and usage-selection criteria are provided. Although more choices for tooth restoration can make the selection of the right material more difficult, a better understanding of the components and the strengths and weaknesses of each category of materials offers the opportunity to select the right material for the right situation. (Pediatr Dent 20:2 93–100, 1998)

Over the past 50 years, many changes have occurred in the development and availability of restorative materials for children. The daily practice of pediatric dentistry at the time of the formation of the American Academy of Pediatric Dentistry didn't enjoy the numerous choices available in today's practice. For posterior teeth, the practitioner was limited to amalgam, stainless-steel crowns, or possibly steel orthodontic bands retained with a luting cement, which were also used as a restoration. The anterior teeth were restored with silicate cement, acrylic, or other esthetically less-than-desirable restorations.

Today, the pediatric dental practitioner is confronted with many materials from which to select for each restorative situation. The number of choices, while allowing more control of the final result, also creates confusion in terms of how to distinguish the uses of these various materials.

This paper will provide a brief review of the intracoronal restorative materials used for the modern pediatric dental practice. It will define the various categories of restorative materials described, and discuss the distinctions in their clinical selection and use. Because of the relatively rapid and sudden appearance of some of the newer materials, misinformation has been promulgated regarding what these materials are, making it difficult at times to appreciate the value of having so many choices. Clarification of these matters will allow the practitioner to perform the right restorative treatment for each situation.

Definitions and descriptions of product categories

Four materials will be discussed in this paper. Glass ionomers are fluoride-releasing materials used in a variety of forms in restorative dentistry and they serve many purposes. Resin-modified glass ionomers, light-polymerizable versions of traditional glass ionomers, offer facilitated use and easier handling. Compomers, the newest member of the restorative family, will be reviewed as modifications of resin composites, the fourth type of material, which are the most esthetically desirable of the groups. These four different materials offer the clinician numerous choices in determining the right material for each individual situation.[1]

Glass ionomers

Glass-ionomer cement (GIC) is a salt, by chemical definition, which is formed by the reaction between a polyalkenoic acid and an aluminum-containing glass.[2] Aluminum, as a constituent element in the glass, is critical for the glass-ionomer reaction to occur. Most commonly, glass-ionomer glass, the "base" part of the reaction, is an aluminum-fluorosilicate glass. Water is a necessary ingredient of GIC, as an acid/base reaction can only occur in an aqueous medium. The fluoride in the glass material is released over time,[3] with a very high fluoride release occurring for a period of several weeks, dissipating to a level of around 10% of the original level in 3–4 weeks, and remains at this level for 1 year or more. Some research has shown that these materials, often called "traditional glass ionomers" as distinguished from modified materials to be discussed later, can be "recharged" in the presence of ambient fluoride (such as that given during a professional fluoride treatment), which can replenish the fluoride in the material.[4]

Glass ionomers can be used as a liner, a luting cement, or a base/core material. As a restorative material, glass ionomer offers the advantage of being the only material with a true chemical bond to tooth structure.[5,6] Even though the measured in vitro bond strength of glass ionomer to tooth structure is significantly lower than the bond strengths for the other materials, clinical experience shows glass ionomers to be well retained. This may be due to the fact that the chemical bond has a different character than the purely mechanical bond of the other materials.

The physical properties of traditional glass ionomers have improved dramatically quite recently with the introduction of high powder-to-liquid ratio glass ionomer materials. These denser materials provide a "condensable" feel, facilitating its use in posterior teeth. These stronger materials have improved compressive and flexural strengths, from 190 to 250 MPa and 30 to 45 MPa, respectively, allowing their use in larger occlusal restorations than previously possible. These stronger GICs were originally developed to be used in areas of the world where atraumatic restorative treatment (ART) was used. This technique employs the use of hand instruments for caries excavation, without the use of rotary instruments, with subsequent restoration using traditional glass-ionomer material. It is important to use only traditional glass-ionomer materials with ART, as light-cured materials are not feasible in parts of the world where electricity, and thus light curing, is unavailable. The technique is quite useful for high-caries populations of children;[7] it could therefore be similarly useful in developed countries where caries control for a transitional period is desired.

The coefficient of thermal expansion (COTE) of glass-ionomer materials is the most similar to tooth structure, particularly to dentin, among all dental materials. The COTE is a measure of the amount of expansion or contraction a material will undergo in the presence of temperature changes. If there is a large disparity in the COTE of the material and the tooth structure, then temperature-related expansion/contraction could eventually lead to fracture or other failure of the restoration.[8]

The strength of traditional glass ionomers resides in the fact that they are cured without light, although this could be seen as a weakness for some clinical indications. Glass ionomers also chemically bond to tooth structure, are brittle, and will crack or break if subjected to strong opposing forces such as dysfunctional occlusion during excursive movements with a hard food substance. Glass-ionomer restorative materials have been combined with silver to provide reinforcement.[9] Success of at least one of these combinations is well documented over many years of clinical use.[10,11] The currently described, high powder-to-liquid ratio materials offer superior physical properties to the silver-reinforced variety without reinforcement, and should prove at least as successful as the silver-reinforced materials. They offer the distinct advantages of the original glass ionomers—high fluoride release,[12] compatible COTE, virtually no shrinkage (polymerization) upon curing, and a chemical bond to tooth structure. As will be subsequently discussed, glass ionomers continue to provide distinct usage indications, and particularly benefit the practitioner of pediatric dentistry.[13]

Resin-modified glass ionomers

Resin-modified glass ionomers (RMGI), sometimes called resin-reinforced glass ionomers (RRGI), were developed to overcome some of the perceived inadequacies of traditional GICs. They contain the same components as traditional GICs, but have resin materials added to provide strengthening, as well as the capability of "command-cure" with a light-initiated curing of the resin composite component.

In addition to the acid (polyalkenoic acids) and base (aluminum-fluorosilicate glass) constituents contained for the GIC reaction, RMGI contains a hydrophilic resin and a light-initiating compound (photoinitiator). The glass can be silanized to allow an adherence of the glass within the resin matrix. There are also the necessary initiators for the self-cured resin reaction, so that even in the dark most varieties of RMGI can obtain a cure of the resin.

Given the additional constituent ingredients, RMGIs offer several advantages over traditional GIC. First, they are stronger in their physical and mechanical properties by virtue of containing resin—a stronger material. The relative amount of resin to glass ionomer in the mixture of RMGI will therefore determine, to some extent, the physical and clinical behavior of the material, i.e., being more glass ionomer-like or more resin-like.

As with traditional GICs, RMGIs must be mixed from a two-component system. The GIC and self-cured resin elements must be separated to prohibit reaction until it is needed in the chair. RMGI is therefore offered in both a hand-mixed as well as a capsulated version to provide facilitated and more precisely measured mixing of the components. The hydrophilic resin contained within RMGI is necessary for miscibility in the water-based GIC material.

RMGIs allow the practitioner to place a GIC-containing material into cavity preparations where an immediate cure is desired in the interest of time. The GIC component offers fluoride release while the resin component offers strength and better esthetics than with traditional GICs. The physical and mechanical properties of RMGI are better than those of GIC alone, providing more resistance to fracture and potential failure when large occlusal forces are present. The disadvantage of these materials remains in their handling properties, although improved compared with traditional GIC. The material must still be mixed, and begins to set thereafter. Because resin exists in the mix, the potential of polymerization shrinkage begins with this material. Although RMGIs have a higher measured bond strength in vitro than traditional GICs, the existence of polymerization shrinkage warrants a higher bond strength to prevent the material from pulling away from the margins and walls of the cavity during polymerization.

Compomers

Compomers are the newest member of the family of restorative materials available for pediatric restorative dentistry. Compomers are defined as polyacid-modified resins. Compomers are essentially resin composites, with the difference that the component resin monomers are modified to contain acidic functional groups capable of participating in an acid/base glass-ionomer reaction after the polymerization of the resin molecule has taken place.

Significant confusion has been created concerning what compomers actually are. Compomers (the name is a hybridization of COMPosite and Glass IonOMER) are not glass-ionomer materials. As mentioned previously, a true glass-ionomer material must be a two-component system, otherwise the acid/base reaction would take place immediately. The only way to use a real GIC is to mix its components prior to use. In the single-component compomer system, there must be no water or moisture to prevent a premature GIC reaction.

With compomers, a resin polymerization takes place, after which the material is completely set. A glass-ionomer reaction then occurs in the presence of water (the necessary medium for an acid/base reaction) only after the restoration is placed and water is absorbed from saliva into the surface. In the presence of water from the ambient environment, the acid functional groups which are attached to the monomer units and are now part of the polymerized material, can react with the glass (base) to initiate a glass-ionomer reaction. As a result of this reaction, fluoride can be released. Although some compomers may have fluoride salts in addition to the fluoride released from the latter GIC reaction, the amount of total fluoride released is significantly lower than that of traditional GIC or RMGI materials.

Because compomers are essentially resin composites, they generally require the use of primers (and possibly adhesives) prior to their placement.[14] These intermediary fluids allow the compomer resin to adhere to the tooth structure in the preparation.

Acid etching has been described as an optional step with some compomers. The primers and/or adhesives used prior to placement of the compomer can contain acidic constituents which could provide etching of the dentin and possibly the enamel. Within the primary dentition, it is possible that the use of compomers in their currently available form without etching may be acceptable. This could be a result of the slightly lower mineralization level of primary compared with permanent tooth enamel. This difference might allow an effective etch from some compomer primers. Experiments are currently being carried out to scientifically evaluate this issue. For the permanent dentition, one must evaluate each case and determine the quality level of enamel bond needed for the situation and the clinical scenario. If the patient is cooperative and the opportunity exists to take the time to etch, rinse, and dry, then the option to etch must be considered.

Compomers have been received with great popularity, and particularly in dentistry for children.[15] Their composite-like esthetics, minimal steps in placement, no mixing, light polymerization (command-cure), and other features combine for highly rated ease-of-use. In addition, the actual handling characteristics of compomers are reported to be among the best of any available materials. Their physical properties approach those of resin composites, the strongest material described heretofore.

As a single-component material, compomers are available in a variety of delivery forms including syringe (screw) tubes, Compules,® and most recently in Aplitips.® It is likely that the success of compomers will continue for the foreseeable future, mainly because of their ease-of-use. Further development of these materials will result in an even easier-to-handle product and will likely offer other enhanced features.

A common question that arises concerning compomers is how they can effect the marginal interface with their fluoride release if the GIC reaction doesn't occur until after the material is set. The answer is that these materials release fluoride from their surface and can impart a fluoride effect to the surrounding environment as the fluoride is incorporated into surrounding tooth structure.

Compomers are thus much more like resins than glass ionomers. Their great acceptance is due primarily to the easy handling of these materials. When placed into a cavity preparation, compomer materials handle exceptionally well, and are described as "staying in place" better than any other unset material. With amalgam as the standard for clinical ease-of-handling, compomers are accepted as having the greatest level of user-friendliness among the nonamalgam materials.

Composite resin

Composite resin, also known as resin composite, is the most esthetically desirable material described in this paper. Composite resin contains a monomeric or prepolymeric resin that is filled to various levels with glass or quartz. The filler particles are silanized (also referred to as silanated) to allow the hydrophilic filler to bond to the hydrophobic resin matrix. Good silanization is essential for obtaining a stable material which is resistant to wear and homogenous in its composition. Also contained in resin composites are pigments, stabilizers, and a photoinitiator. Radiopaquing agents such as yttrium trifluoride may also be added if the filler itself is not radiopaque, as is the case with quartz and some glass compositions.

The physical and mechanical properties of composite resin are excellent. These properties, such as compressive, flexural, and tensile strengths, meet or exceed the respective strengths of amalgam. Composite resin, however, has not completely replaced amalgam as a restorative material only because of its relative handling difficulty. Several clinical steps must be taken to allow composite resin to adhere to the tooth structure. One must obtain an excellent interfacial bonding of the composite to the tooth, which is generally accomplished through the use of an intermediary bonding agent. Most modern bonding systems (not specifically discussed in this paper)[16] use an intermediary priming agent which allows a hydrophobic bonding agent to bond to the wet surface of the dentin below. This is necessary to create a superficial bond to the hydrophobic composite resin. A mechanical interlocking is achieved by flowing the water-tolerant primer into the surface of the dentin where it permeates the spaces in the networked structure of the collagen that was created by the acid etch. The bonding agent bonds to the primer and the composite resin. In so-called fifth-generation systems (see Swift in this issue), the chemically active agents making up the primer and bonding agents are delivered from the same bottle. Even in these cases, a priming procedure followed by a bonding procedure must be accomplished prior to placement of composite resin.

One must be aware that polymerization shrinkage does occur with currently available composites, and careful bonding and placement are therefore essential. As it is polymerized, composite resin undergoes polymerization shrinkage. This shrinkage, ranging from 2 to 3.5% (volumetrically), causes the composite, which has bonded circumferentially to the cavity walls, to pull towards the center of its mass. This force can create tension that can be relieved by placement technique. Incremental placement has been proposed as a method to minimize polymerization shrinkage. The number of steps and the care required to effectively place a composite-resin restoration is the greatest in this category of materials. In spite of this, their excellent esthetics, clinical durability, and other continuously improving characteristics are winning the support of more practitioners, and their use in both anterior and posterior pediatric restorative dentistry is growing.

Composite resins are available in a variety of shades and opacities. The clinician can easily duplicate the appropriate tooth shades by using a shade guide before cavity preparation. The color stability of composites has also improved considerably in recent years.

It is important to be able to distinguish filler content (quantity) from filler size (particle size) within composite resins.[17] With many recently introduced products described as "flowable" composites or "hybrids" or other designations, it is critical to distinguish between these different composite resins and to understand the clinical use implications.

Filler content is merely a description of the quantity of filler in a composite. It is generally measured as the weight:weight quantity of filler placed into the resin matrix, and is expressed as a percent (Table 1). If there is no filler in the resin matrix, the material may be called an "unfilled" resin. These materials are used as unfilled sealants, and sometimes as components of bonding agents. If the resin matrix is filled approximately 30% by weight, the material may be designated as a "filled" sealant. Many sealants are filled to this extent today. Some bonding agents are also filled as much or even slightly more, and are therefore called filled bonding agents. The introduction of "flowable" composites has created the need to define filler content. Flowable composites are composite-resin materials that are 50- to 70%-filled by weight. What one calls flowable is the definition of the user.

Highly filled, modern, composite-resin materials are 75- to 85%-filled by weight. At this level of filler content, a stiff, easily packable material is achieved, which can be used for both anterior and posterior placements.

The mathematics of adding more filler to resin and measuring the weight:weight filler content percentage shows that the more

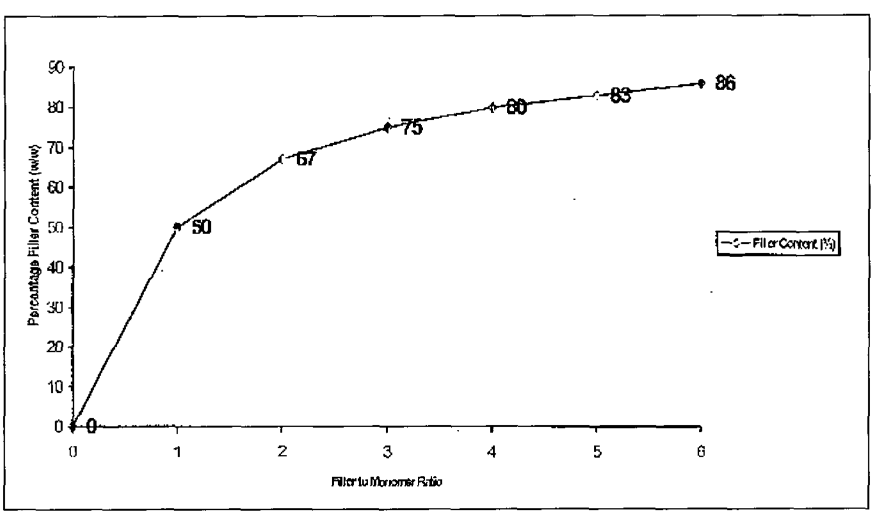

Fig. Relationship of filler:monomer ratio to percentage filler content of composits.

TABLE 1. FILLER CONTENT DESCRIPTORS

Category	*Filler Content (w/w), Approximate Ranges*
Unfilled resin	0 %
Unfilled bonding agent	0 %
Unfilled sealant	0 %
Filled sealant	15–50%
Filled bonding agent	15–50 %
Flowable composite	50–70 %
Composite resin	70–85 %

TABLE 2. FILLER SIZE DESCRIPTORS

Category	*Typical Particle Size Range (μm)*
Microfilled	.01 – .1
Hybrid (contains various mixtures of microfillers and macrofillers)	0.5 – 5.0
Macrofilled	>5.0 – 50

filler added, the less the filler content percentage number will rise (Figure). What this means is that, for example, if a composite is 50% filled (i.e., a low-filled, flowable composite) then the filler-to-resin weight ratio is 1:1. If twice the amount of filler exists in a different composite resin, then the filler-to-resin weight ratio is 2:1. However, the filler content rises only 17 percentage points to 67%. If three times the amount of filler is added in a third example of composite resin, the resulting weight percent is 75%. Thus, one can see that a low-filled flowable composite has only one-third the amount of filler of a minimally filled hybrid composite. Some are filled to as much as 85%.

A separate issue to be considered is the filler size of the particles in the material. The filler size is generally expressed as the median size (usually the mode as well) of the filler particles within the resin matrix (Table 2). Fillers ground to 5–50 μm are referred to as "macrofillers". Fillers that aren't ground but produced by other procedures and range from 0.01 to 0.1 μm are called "microfillers". When various mixes of macro- and microfillers are created, with a resultant typical particle size ranging from 0.5 to 5.0 μm, the material is referred to as a hybrid. These hybrid materials offer the advantage of being suitable for anterior (polishablity due to microfill) and posterior indications (durability as a result of larger particle size).

Therefore, a composite-resin material can be both flowable and a hybrid. It could also be a flowable, microfilled material. It is important to be aware of both the filler content and size to appreciate the appropriate clinical indications for the material. Many clinicians choose to purchase only one material, commonly a hybrid that can be universally used. However, to achieve the best esthetic results for anterior restorations, microfilled materials are sometimes preferred.

Continuum

Based on the definitions and descriptions of the various categories of restorative materials, one could imagine a continuum over which these four materials could be viewed with respect to their characteristics, with glass ionomers on the left through composite resins on the right (Table 3). Construction of such a continuum is logical when one considers the overlap in clinical-use indications.[18] The behaviors and physical properties of these materials warrant an understanding of their relationship to each other.[19]

Traditional GICs release high levels of fluoride, bond to tooth structure,[20] and don't shrink.[21] However, GICs are somewhat opaque in color, must be mixed, and lack strength for some posterior indications. The RMGIs were developed to overcome some of the inadequacies perceived with the GICs. They are light polymerizable because of their resin component and have better esthetic properties than GICs. It is interesting to note, however, that in order to improve upon GICs, technology was borrowed from the right side of continuum, the composite resins.

Similarly, because of perceived inadequacies in the ease-of-use of composite-resin materials despite their excellent physical properties, compomers were developed. Compomers are essentially composite resins, as mentioned, which borrowed the glass-ionomer reaction from the left side of the continuum, the GICs. This GIC reaction takes places only after the material is polymerized via a typical resin-polymerization process.

One can visualize the interrelationships of the four materials of this continuum. Cognizance of the specific strengths, weakness, and features of each material will enhance the clinician's ability to make the best choices for each individual situation.[22]

Clinical distinctions and situations

When evaluating materials for a given clinical situation, one must first accept the fact that such evaluation is needed. In other words, if it is predetermined in the practice that a certain material is always used for certain clinical situations, then it is pointless to offer several options. However, if one is open to selecting a material based on its appropriateness for the given clinical scenario, then all available options should be included in the selection procedure.

TABLE 3. THE CONTINUUM OF RESTORATIVE MATERIALS

	Glass Ionomers	*Resin-mwodified Glass Ionomers*	*Compomers*	*Composite Resins*
Setting	• Self-cure (acid/base reaction)	• Self-cure (acid/base reaction) • Resin cure • Light-cure	• Light-cure	• Light-cure
Mixing	Two-component system Mixing required	Two-component system Mixing required	One-component system No mixing required	One-component No mixing required (dual- or self-cured composites, require mixing)
Delivery System	Capsule or hand mix	Capsule or hand mix	Compules,® screw tubes, or Aplitips®	Compules,® screw tubes, or Aplitips®
Fluoride-release	High	Moderate – High	Moderate	Minimal – None
Adhesion	Chemically bonds to tooth (self-adhesive)	Chemically bonds to tooth (self-adhesive, some require primer)	Mechanically bonds to tooth, bonding agents required (not self-adhesive)	Mechanically bonds to tooth, bonding agents required (not self-adhesive)
Esthetics	Opaque	Good	Very Good	Excellent
Physical Properties	Good	Good – Very Good	Very Good	Excellent
Handling Properties	Fair	Good	Excellent	Very Good
Ease-of-use	Initially moisture-sensitive, relatively few steps, slower curing	Less moisture sensitive, relatively few steps	Tolerates more moisture, requires bonding agent	Technique sensitive-rubber dam and acid-etching/priming/bonding required
Solubility	Low	Moderate – Low	Moderate	Low
Dimensional Changes	Thermal expansion/contraction similiar to tooth structure	Higher thermal expansion/contraction and polymerization shrinkage	Higher thermal expansion/contraction and polymerization shrinkage	Highest thermal expansion/contraction and polymerization shrinkage
Examples	Fuji IX™ Ketac®-Molar Fuji II™	Fuji II™LC Vitremer™ Photac-Fil® Quick	Dyract™ Compoglass F™ Hytac®Aplitip® F2000™	TPH Spectrum™ Prodigy® Z100 Charisma® Renamel™ Tetric Ceram® Pertac®II

Selection of the appropriate material should be made prior to beginning treatment, where possible, and preferably at the time of diagnosis and treatment planning. In some cases, however, selection of the material cannot be accurately performed until the cavity preparation is completed and a clearer assesessment of the remaining tooth structure, etc., can be made (Table 4).

For the primary dentition, in Class I, II, III, or V situations, all four materials can be used.[23–25] In such cases, you only need to determine the relative impor-

TABLE 4. CLINICAL USE SELECTION — BLACK CAVITY CLASS USAGE

	Glass Ionomer	*Resin-modified Glass Ionomer*	*Compomer*	*Composite*
Class I or Preventive Restoration	Primary teeth Permanent teeth (small)	Primary teeth Permanent teeth (small)	Primary teeth Permanent teeth (small)	All situations where excellent esthetics are needed
Class II	Primary teeth (small) Good for high fluoride-release scenarios	Primary teeth Good for high fluoride-release scenarios	Primary teeth Permanent teeth (small or transitional)	All situations where excellent isolation is possible
Class III	Primary teeth (transitional) where high fluoride release is needed	Primary teeth (small) Permanent teeth (transitional)	Primary teeth Permanent teeth (select situations)	All situations where excellent isolation is possible and ultimate esthetics are needed
Class IV	Primary teeth (temporary)	Primary teeth (transitional)	Primary teeth (small) Permanent teeth (transitional)	Required for best esthetics—good for incisal stress areas
Class V	Primary and permanent teeth where fluoride release is more important than esthetics	Primary and permanent teeth	All situations where good isolation is possible and good esthetics are needed	All situations where excellent isolation is possible and ultimate esthetics are needed

tance of the inherent strengths and weaknesses of the different material options. For example, if the patient has a high caries risk, a high fluoride-releasing material may be the best choice. If esthetics is the main concern, a composite resin or a compomer should be used. If there is concern about occlusal stress, the materials with better resistance to wear should be chosen. Similarly, if ease of placement is the important consideration, a RMGI or a compomer should be considered. For Class IV restorations of the permanent dentition, only composite resin can provide the appropriate strength, wear resistance, and translucency/ esthetics needed for this situation. However, even in Class IV preparations, compomers or even RMGIs can be used as long-term transitional restorations.

In the permanent dentition, where tooth and restoration wear, esthetics, and longevity have different importance, care should be given to the longer term aspects of the restoration, with particular attention to wear resistance. Therefore, for Class II restorations in permanent teeth, only composite resin should be used for long-term durability. Other materials can be used as transitional restorative materials. Modern hybrid composites, when placed according to the manufacturer's directions, can provide excellent esthetic results with long-term success.

For Class I restorations, including preventive resin restorations (PRRs),[26–28] one can choose any of the described materials depending on needs and the size of the preparation. Glass ionomers can be used as the filling material beneath the surface sealant of a PRR,[29, 30] as can RMGIs, compomers, or composite resins. For Class III restorations in permanent teeth, only composite resin can provide the ideal esthetics of the natural dentition. Compomers might also be used for Class III restorations in permanent teeth, but they will not have the same esthetic quality as composite resins, although their handling is simpler. For Class V restorations in the primary or permanent dentition, any of the listed materials could be used, the selection being made based on the priority of needs for the individual situation.

It is difficult to say that one should use a certain material in every case of a certain situation. Given an understanding of the properties of each of the materials available, the clinician must choose the correct material based on the needs of the individual.

Future developments

It is clear that even with today's many choices, new ones will emerge. It is likely that changes in composite resins will make them easier to handle, with attendant improvements to other problems, including polymerization shrinkage and strict isolation requirements. Compomers, on the other hand, will become more composite-like, while retaining the handling features and fluoride release they currently possess. It will therefore be likely that compomers and composites will become difficult to distinguish, as future iterations of these materials bring them closer together, allowing a superimposition of their combined favorable qualities.

Glass ionomers and RMGIs will also undergo further development, moving toward a stronger, condensable material that offer more universal application—and the likely emergence of more esthetically desirable materials. In addition, GICs will retain the feature as the material of choice when high fluoride release is desired through a transitional period.

Conclusions

Many new developments have occurred in restorative dentistry for children in recent years. One must develop a clear understanding of the unique features, strengths, weaknesses, and requirements of each material available to be able to apply the right material to the right situation.

Continued development of the existing materials will make them more user-friendly with improved properties. Development in new directions will likely add materials to the selection portfolio in the years ahead.

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