CHAPTER 3: GENERAL DENTISTRY

Introduction

Materials science changes constantly in the field of dentistry. The information presented here is intended to provide the current state of the art of materials. Also included in this chapter are techniques for restoration of teeth in the public health practice of dentistry.

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Restorative Dentistry

Restorative dentistry plays a vital role in the maintenance of the dentition of individuals. The nature of the public health practice often limits dental care to basic emergency, preventive, and restorative care. Because cost and labor-intensive procedures involving prosthodontics are

limited, the existing dentition must often be restored using amalgam and composite materials as final restoration. These materials can provide durable and acceptable restorations when the essential elements of mechanics and placement techniques are followed.

Retention

Retention is necessary for a restoration to remain in a tooth once it is placed. There are actually three designs of the cavity preparation that are vital in maintaining restorations both initially and for the life of the restoration. Retention form is the form of the cavity preparation that holds the restoration in place. Tensile forces are important with retention form. Resistance form is the form of the cavity preparation that resists displacement of the restoration from the preparation. Shearing forces require adequate resistance form. Rotational form is the form of the cavity preparation that resists rotation of the restoration around the long axis of the tooth.   For the purpose of this discussion, the term retention will be used for techniques utilized to counteract all of these forces.

Tooth Structure

Tooth structure is the ideal material for retaining restorations. It is obviously biocompatible, and has superior strength when supported by adequate dentin. Differences in coefficient of thermal expansion are not an issue, and there is one less interface of dissimilar materials with the amalgam or composite and tooth. Amalgam requires more tooth structure for retention than composite, because of the relatively larger retention features required. Composite restorations are retained on a microscopic level.

When inadequate tooth structure remains, other methods of retention can be utilized.

Pins

Threaded or cemented pins can be utilized to add resistance form to the cavity preparation. Pins are manufactured from stainless steel, titanium and cobalt-chrome-molybdenum. Stainless steel is a satisfactory combination of low cost, corrosion resistance and strength for a pin. Pins are retained by either a self-threading mechanism or by cementation. Most practitioners prefer self-threaded pins for ease of placement. While pins provide adequate retention, there are several disadvantages to their use:

- Potential stress fractures of tooth structure
- Incomplete seating
- Threads may strip
- If the pin must be bent, tooth may crack or pin may loosen
- Difficult to replace pin-retained restoration
- Pin may show under composite restoration or ceramic crown

Other problems with pins include potential placement into the pulp or periodontium of a tooth, failure to bind and shearing of tooth structure next to pin.

Pinholes must be positioned carefully to prevent some of the problems listed above. Anatomy of the tooth dictates placement of the pin, and they are not recommended in anterior teeth. Pins should be placed at the line angles of the tooth, in sound dentin a minimum of 0.5 mm from the dentinoenamal junction and no closer than 1 mm to the pulp.

Pins are not recommended in endodontically-treated teeth due to the brittleness of the tooth structure. There are two theories as why endodontically-treated teeth are more brittle. One theory attributes the brittleness to the significant loss of tooth structure during preparation for the endodontic therapy. The second theory involves brittleness secondary to loss of vitality during removal of the pulp.

Posts (Dowels)

Posts can be placed in the canal space of an endodontically-treated tooth to increase resistance to displacing forces. Design of the final restoration must consider the occlusion to prevent significant shearing forces that may fracture the tooth. Posts can either be prefabricated in several sizes or custom cast for the individual tooth. Posts can be manufactured from the same metals as pins and from ceramic, carbon fiber, composite and noble or non-precious metals.

Prefabricated posts can be cemented or threaded. Cemented posts are either parallel-sided or tapered. Parallel-sided posts have better retention than tapered posts, but have poorer conformation to the tapered root. Threaded posts have the best retention, but apply significant stresses to the tooth that can fracture the root (Fig. 1). Prefabricated posts can be placed at the same appointment as a Cusp-Protected Alloy (CPA) or core build-up, thus saving an additional appointment as compared to a custom cast post. Prefabricated posts can be placed in non-parallel canals and have better retention because of their parallel sides. The custom cast post, however, conforms to the anatomy of the root canal system better and allows the post and core to be the same material.

Careful consideration needs to be given to the root of the tooth being restored before the decision to place a post is made. The post must have the minimum length of the restored crown and at least two-thirds the length of the root. The post must not be wider than one-third the width of the root, and needs minimally 1mm of dentin on all sides of the post. The anatomy of the roots of individual teeth can have variations that could allow perforations or stripping of the root during preparation of the posthole. Maxillary first premolars, for instance, have a mesial concavity on the root. First molars have the potential to perforate into the furcation of the roots. Finally, these criteria must be met while leaving a minimum of 3-5mm of gutta percha at the apex of the root.
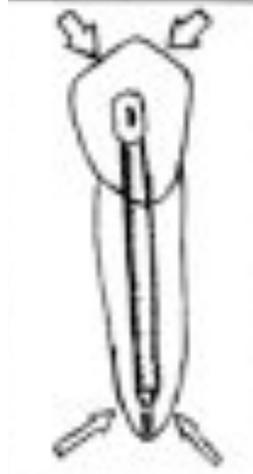
Figure 1, Stress transfer with post

Intracoronal Retention Features

Other techniques are available to provide retention that do not have the disadvantages of pins and posts. The advantages of using tooth structure were elaborated earlier. Microscopic retention is utilized in placing composites with etching of the enamel and dentin. The selective etching of dentin and enamel creates a physical matrix of holes and rods that allows a significant bond to the bonding agents in use today.

Amalgam requires larger retention features because of the nature of the material. Amalgam is stronger in bulk, thus retention features must be designed to maximize this property. Retention form involves parallel or slightly undercut walls of tooth structure. In teeth with minimal to moderate caries the prepared inner cusp walls and proximal boxes provide substantial retention for the restoration. The pulp chamber of endodontically-treated teeth also makes an excellent retention feature.

Teeth that are missing all buccal or lingual cusps lose considerable ability to retain an amalgam restoration. Retention feature such as slots and amalgapins can replace traditional pins as retentive features. Less reduction of tooth structure is required for slots or amalgapins, and the tooth structure is not stressed as it is during traditional pin placement. There is also no dissimilar metal interface.

The amalgapin hole is placed in dentin 0.5mm from the dentinoenamel junction, same as the traditional pinhole. The depth is the same as well at 2.0 mm. The orifice of the hole is beveled with a round bur to prevent stresses in the amalgam as it is placed (Figure 2). Amalgam tends to fracture at sharp line angles. Slots are also prepared 0.5 mm into dentin using an inverted cone at a depth of 0.5 to 1.0mm. Care must be taken with both of these features during placement of the amalgam and removal of the matrix band. Improper condensation or rotational movement of the restoration as the matrix band is removed will cause a failure of the amalgam in the retentive feature, thus negating the advantage of the intracoronal retention feature.

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Figure 2, Amalgapin Preparation

Resin Bonding Agents

Dual-cure or self-cure bonding agents have been developed for bonding amalgam to tooth structure. These agents are dentinal bonding agents that have been modified to polymerize in the absence of light. Advantages of this system include conservation of tooth structure, direct bonding to tooth and increased fracture resistance of the tooth. The bond is not very strong, however, and will not save an otherwise hopeless restorative situation. Other disadvantages include high cost, technique sensitivity and unknown long-term success. During placement of the bonding agent the operator must insure the agent does not spread beyond the dentin or excessively puddle in areas of the tooth. All bonding agents eventually experience microleakage, and corrosion of the amalgam will not seal the dentin-bonding agent interface.

Occlusion

The occlusal scheme is often overlooked when placing single-tooth direct restorations. Occlusion is just as important when placing amalgam and composite restorations as when placing fixed or removable prostheses. Failures of large composite build-ups or CPA's can often be traced to unrecognized occlusal patterns.

The most obvious aspect of occlusion is centric relation (CR). Because of the depth of the subject and the focus of this discussion, the relationship of CR and the optimum position of the condyles in the glenoid fossa will not be discussed. Unless the patient is symptomatic and/or is being treated temporomandibular joint dysfunction (TMD), maxillary intercuspation might be the more appropriate position for the single-tooth restoration. Maxillary intercuspation (MI) is the tooth-directed interaction of the maxillary and mandibular teeth, guided by physiology and independent of condylar position. In most individuals MI is slightly forward of CR. MI can be

considered acceptable occlusion if the patient's TMJs are asymptomatic, MI is less than 0.5 mm from CR and there is no evidence of primary occlusal trauma.

Excursive movements of the arch are the next component of occlusion to be discussed. Excursive contacts are particularly important with amalgam restorations, because of the final set time of the material and its propensity to fracture before setting. It is also important to not create an excursive contact that did not exist before the restoration was placed. Appropriate occlusal schemes of CPAs will be discussed later in the CPA section of this chapter.

Excursive contacts define the different occlusal schemes. <u>Balanced occlusion</u> has all teeth contacting in all excursions. It is not a common, naturally-occurring occlusal scheme, but is utilized in fabricating full dentures. <u>Group function occlusion</u> is supported in lateral excursion by the working side canine and posterior teeth. The balancing side is discluded. <u>Mutually protected occlusion</u> means the posterior teeth protect the anterior teeth in CO and anterior teeth protect posterior teeth in all excursions. Canine-protected occlusion is part of this scheme. This is considered the best occlusal scheme for preservation of tooth structure. Many individuals are a combination of the above schemes, often with one side of the arch differing from the other side. Individuals may also have occlusal interferences in which a posterior tooth contact will interfere with anterior guidance. Occlusal interferences differ from working and balancing contacts as it disrupts guidance instead of sharing guidance.

<u>Amalgam</u>

Amalgam is defined as an alloy of one or more other metals. Amalgam has been used as a dental restorative material for hundreds of years. G. V. Black devised "modern" amalgam in 1890, consisting of silver, tin and mercury. The alloy of dental amalgam is still primarily silver and tin, with small amounts of copper, zinc or gold added to emphasize specific properties. Amalgam has several significant advantages over other restorative materials, especially its low cost and relative ease of placement.

High copper amalgam has excellent physical properties and is in wide spread use today. The copper helps to eliminate the weak gamma 2 phase, thus maximizing the stronger gamma phase. This results in an amalgam with higher compressive and tensile strength, more corrosion resistance and less marginal breakdown. Restorations utilizing high copper amalgam exhibit longevity approaching 80% at twelve years.

Amalgam alloys can be classified according to shape of the alloy particles. Particle sizes of all of the types discussed here range between 15 and 35 microns. <u>Spherical</u> particles are spherical in shape, and are created by atomizing liquid amalgam alloy and spraying it through an orifice. The resulting particle requires less mercury for handling than lathe-cut particles because of the smaller surface area per volume. By minimizing the amount of mercury in the amalgam, the properties tend to improve. Spherical alloys tend to flow under condensation pressure. This means that while they tend to fill voids better, they do not hold their position during condensation, thus making it more difficult to establish interproximal contacts.

<u>Lathe-cut</u> particles are produced by milling or grinding an amalgam alloy ingot. The resulting particles are rough and needlelike, and vary in size. The larger surface area increases the amount of mercury in the amalgam, weakening the final restoration somewhat. The shape of the particles offers more resistance to condensation, making it easier to hold proximal contours. <u>Admixed</u> particles are a combination of spherical and lathe-cut particles, thus improving the strength of the restoration over a pure lathe-cut alloy and improving handling of a spherical alloy. All of these modern alloys have adequate strength and longevity.

Microleakage exists with all dental restorative products. A unique characteristic of amalgam is its ability to seal microleakage by corrosion of its outer surface. High copper amalgam does not corrode as easily as low copper amalgam, but it is still able to seal the tooth-amalgam interface against microleakage. High copper amalgam is also resistant to marginal breakdown due to its ability to deform under load, further improving its longevity.

Cusp-Protected Alloy (CPA) (Also called the Amalgam Build-up (ABU))

Posterior teeth with endodontic treatment require cuspal coverage to prevent catastrophic fracture of cusps and/or marginal ridges. CPAs can also be used to replace cusps on vital teeth that have been compromised by fracture, enamel defects or caries. Cusp-protected alloys (CPAs) are a cost-effective, viable alternative to cast crowns. Appointment time is also considerably less than cast crowns. Disadvantages of amalgam include poor esthetics and the need for sufficient tooth structure for retention.

The occlusal scheme for a CPA is important for function and longevity of the restoration. Centric occlusion is the goal when placing a CPA, with elimination of any excursive contacts. This is not always possible due to individual occlusal schemes, but excursive contacts should be minimized if they cannot be eliminated.

The procedure for placing a CPA will be described for an endodontically-treated tooth:

1. Assess tooth position
    a. Alignment in arch
        1) Alignment of cusp height
        2) Buccal-lingual positioning
    b. Occlusion
        1) Mark occlusion before isolation
        2) Check excursive movements
            a) Note flattening of cusps and wear facets
2. Isolation
    a. Place rubber dam
        1) Isolate a minimum of one tooth on either side of the tooth to be restored when feasible. Sextant isolation is ideal.
3. Preparation
    a. Remove temporary restoration
    b. Remove any remaining caries
    c. Remove gutta percha from pulp chamber

          1) Remove 2-3 mm gutta percha from largest canal
              a) Bicuspid – main canal
              b) Maxillary first molar – palatal canal
              c) Mandibular first molar – distal canal

d. Prepare interproximal boxes
    1) Open all contacts
    2) Extend for undermined enamel

e. Reduce cusp height
    1) 2mm minimally, more if occlusion requires

f. Place additional retention features, if needed
    1) Slots, amalgapins, boxes, posts
    2) Consider pins only if tooth is vital

g. Place matrix band
    1) Tofflemier, automatrix.
    2) Wedge tightly
    3) May have to stabilize manually

h. Place amalgam
    1) Incrementally – don't place entire mix
        a) Inadequate condensation produces open margins, voids
        b) Condense thoroughly

i. Carve amalgam
    1) Initial reduction
        a) Remove amalgam-rich layer
        b) Approximate marginal ridge heights to adjacent teeth
        c) Refine occlusal anatomy
    2) Remove matrix band
        a) Burnish margins
        b) Carve buccal and lingual contours
        c) Carve interproximal contours and margins
        d) Carve basic occlusal anatomy
    3) Refine restoration
        a) Confirm marginal ridge height
        b) Reduce cusp height – check with adjacent teeth

j. Remove rubber dam

k. Check occlusion
    1) Centric first, then excursive
    2) Want only centric contact
    3) Ask patient for feedback for final adjustment

Dental Adhesives

Dental adhesives play a vital role in restorative dentistry. The development of dental adhesives has allowed more conservative restorations and repair of formerly non-restorable teeth. It also creates a stronger restoration because of its ability to bond tooth and restorative material together.

Dental adhesives depend on a mechanical bond to the enamel and dentin of the tooth. To achieve this bond the tooth must be prepared with an acid etchant. Phosphoric acid at a strength of 37% is the most common acid etchant utilized for dental adhesives. The etchant selectively dissolves enamel to a depth of 10-20 microns, leaving an enamel matrix the dental adhesive for mechanically bonding. Dentin is also etched to expose dentin-anchored collagen fibers. Post-operative sensitivity was initially thought to result from etching of the dentin, but later studies show no pulpal damage from the acid etchant. There should, however, be a minimum of 0.5mm of dentin over the pulp to protect it from the acid. Acid etchant should remain on the tooth for 15 seconds, then be thoroughly rinsed.

Dentinal bonding requires moisture to assure the collagen fibers remain upright. This can become problematic if a hydrophobic bonding agent is utilized. The advent of hydrophilic bonding agents has significantly increased bond strengths to dentin, and negates the need to thoroughly dry the enamel. The degree of wetness is a source of controversy. The most common recommendation is the dentin should glisten, but not have any puddles of water. A dentinal primer is then utilized to remove the smear layer from the dentin, thus exposing the collagen to the bonding agent.

Current bonding agents bond to both enamel and dentin. There are six generations of bonding systems. It is generally accepted that an ideal bonding agent must have a minimum bond strength of 17 Mpa, tolerates moisture, be easy to handle and have no microleakage. All the criteria except the last are met in the newest generations of bonding agents. All bonding agents still exhibit microleakage at some point after placement. The following table synopses the generations of bonding agents and key properties.

Generation	Bond Strength	Steps	Hydrophilic
First	3 Mpa	2 – etch, bond	No
Second	2-7 Mpa	2 – etch, bond	No
Third	9-18 Mpa	3 – etch, prime, bond	No
Fourth	17-24 Mpa	3 – etch, prime, bond	Yes
Fifth	20 Mpa	2 – etch, combine prime and bond	Yes
Sixth	20 Mpa	1 – combine etch, prime, bond	Yes

The advantages of the fifth and sixth generation bonding agents are reduction of steps during application. There is no improvement of physical properties, and, in fact, maybe a slight degradation of properties. There are no good long-term studies of the sixth generation to determine clinical longevity. Both fourth and fifth generation bonding agents have been around long enough to have excellent long-term properties both in the lab and in the mouth. Long term success is proven and both yield excellent clinical results.

Composite Restorations

The need for more esthetic conservative restorations began the development of tooth-colored restorations. Silicate cements were developed in the 1871 for anterior restorations, but suffered from poor esthetics, significant pulpal trauma and high solubility in the oral environment.

Synthetic resins with no filler were developed in 1945, providing a restoration with significantly reduced solubility and improved esthetics. Unfortunately these resins exhibited a high wear rate, high polymerization shrinkage and large thermal dimensional changes. Composite resins were developed in the 1960's by combining hard filler particles with a dimethacrylate polymer. This composite had much better physical properties, significantly reducing wear and improving strength and esthetics.

Modern Composites

Modern composite restorations provide a highly esthetic, strong and durable alternative to porcelain restorations. Cost and time savings are significant in the public health setting, and the clinical results are quite good. Major components of composites are inorganic filler particles made of a glass and a resin matrix to hold the glass together. The strength of a composite is in the filler particles, with the resin matrix allowing ease of handling and adhesion of the filler particles. In general, the higher the volume of filler particles in the composite, the stronger and more translucent the composite restoration.

Particles are made of inorganic glass particles. Early particles were made of quartz, which was very strong but was radiolucent and was difficult to polish. Most composites now contain barium glass, which has good color, is radio-opaque and polishes better than quartz. Particle size is also important for the properties of the composite. The particle filler for various composite types range from 0.1 to 100 microns. The filler particle size should be less than 1 micron for adequate anterior esthetics. Larger particles do not polish well. They also do not "fill" well, having a lower volume of filler and a higher volume of resin matrix. Particles with a diameter of less that 0.1 microns have excellent esthetics but loose strength and wear resistance. A combination of larger and smaller particles allows higher filling volume, optimizing the physical properties of the composite.

The resin matrix is comprised of diacrylate monomers that have been modified with TEGDMA or VEDMA to reduce the viscosity of the material, thus improving handling. The mixture of the monomer and these modifiers also yield a refractive index similar to the glass filler, providing sufficient translucency to the composite. Polymerization shrinkage is one significant disadvantage of the resin matrix. Polymerization shrinkage is 2-3%, and can create stress in the tooth structure if the composite is not incrementally placed. The composite can also pull away from the composite-bonding agent interface, creating voids. Classifications and characteristics of composites are listed in the table below.

Classification	Particle size	Fill by volume	Advantages	Disadvantages
Macrofilled	8-12 microns	60-65%	Hardness	Difficult to polish
Microfilled	.04-.4 microns	50-55%	Esthetics	Decreased strength
Small-particle	1-5 microns	65-77%	Strength	Fair esthetics
Hybrid	.6-1 microns	60-65%	Strength, esthetics	
Flowable	3-10 microns	<60%	Handling(?)	Poor wear, esthetics
Condensable	15-80 microns	65-70%	Strength	Handling, esthetics

Macrofilled composites are the traditional composite restoration, first developed in the 1970s. Particles as large as 50 microns are present, creating a hard restoration with poor esthetics. Microfilled composites are highly polishable and very esthetic, but have inferior strength characteristics. Small particle composites are stronger than microfilled, but the esthetics are only fair. Hybrid composites are an excellent restorative material, with combining excellent strength and esthetics. Hybrids are recommended for both anterior and posterior composites. Flowable composites are not very esthetic and exhibit high wear rates, but may have some use in non-load bearing restorations. They are chosen for their ease of handling, but even this point is debatable among practitioners. A hybrid can be used in any situation a flowable might be used. Condensable (or packable) composites are designed to handle like amalgam. Because of the nature of the material, a composite can never truly be condensed, but merely give the sensation of condensation because of its consistency. These composites have excellent strength and wear characteristics, but are difficult to handle because of their lack of flowability. Voids, open margins and poor contacts often result during placement. Also, because of filler particle size, esthetics are inadequate for anterior restorations.

Posterior Composites

There has always been debate on the use of posterior composites in the public health setting. The caries rates of the populations served by the Public Health Service are considerably higher than the caries rate of the general population; thus requiring a change of treatment philosophy. Posterior composites are in widespread use in private practice, but are not indicated for use in patients with high caries rates. Advantages include esthetics and the non-mercury formulation. They are, however, still quite technique-sensitive. Proper isolation of the tooth is required. Though the new materials are hydrophilic, that does not mean they should be placed in the presence of saliva contamination. The proteins found in saliva will interfere with the adhesion of the materials to the tooth. It is also still vital to place the composite incrementally, due to the stress that can occur from polymerization shrinkage and the limited depth of cure from the curing light. The curing light cannot penetrate any deeper than 1.5 mm. Research has not proven the krypton curing lights can cure any deeper than the halogen lights. Posterior composites also exhibit more interproximal wear than amalgams. The decision to place a posterior composite

must be based on individual treatment needs. They should not be placed strictly to avoid placing amalgam due to alleged mercury toxicity.   An otherwise serviceable amalgam should never be replaced with composite because of concern of mercury toxicity.

Core Build-up Composites

Composites can be used as core as a build-up for fixed prostheses. They are not as strong as amalgam in compression, but are adequate under a well-designed fixed prostheses. Caution needs to be exercised that the core material is compatible with the bonding agent, as some will use core-specific composite material with the bonding agent from another source. A significant advantage is the time savings of placing the core material and preparing it for the crown at the same appointment.

Repairing Old Composites

There is also debate on whether old composite restorations can be repaired. A serviceable amalgam can be repaired as long as mechanical retention can be achieved, since there is no chemical interaction involved. The composite restoration needs chemical bonding to be successful. A composite restoration can be built up in increments because 50% of the methacrylate groups are still unreacted even after light curing, due in part to the oxygen-inhibited layer of resin on the surface. This layer is removed during finishing and polishing, reducing the ability of additional composite to bond to the surface. Also, the methacrylate groups continue to polymerize for several weeks after placement of the restoration, further reducing methacrylate groups available for bonding. Contamination by plaque interferes with bonding as well. Studies show the strength of repair of composite is, at best, only half the strength of the original restoration.

Procedure for Placing Composites

The clinical technique for placing composite restorations is described below. The restorability of the tooth should obviously be determined before beginning the procedure. Check the depth of subgingival margins and for any root fractures. Tooth extrusion and/or crown lengthening may be options to improve the restorability of a tooth.

1. Assess tooth position in arch
    a. Adequate freeway space
2. Isolation
    a. Minimum one tooth on either side of prepared tooth
    b. Preferable canine to canine
3. Prepare for caries removal
    a. Mechanical retention not necessary, but may be helpful if minimal tooth structure present.
    b. Bevel enamel
4. Etch enamel and dentin
    a. 37% phosphoric acid
    b. Rinse 15 seconds

    c. Remove excess water
       1) Don't desiccate – water allows collagen matrix in dentin to stand up
       2) How wet should it be
          a) Overdry – collagen lies down, poor bonding
          b) Overwet – void spaces created by phase separation of primer components
          c) Recommend blot drying – glistens, but no pooling

5. Primer
    a. Instructions vary per manufacturer
    b. General
       1) Apply several layers, dry with air between layers

6. Bonding Agent
    a. Apply to enamel and dentin and light cure
    b. Avoid pooling at margins
    c. Light cure

7. Composite placement
    a. Place and light cure incrementally – 40 seconds each increment
    b. Interproximal wedging
       1) Helps control hemorrhage
       2) Improves contact contour
       3) Minimizes interproximal flash
       4) Controls matrix
    c. Facial and lingual contours
    d. Overbuild incisal edge, then reduce

8. Finish and polish
    a. Incremental Brasseler finishing burs
       1) Carbide or diamond
    b. Soflex discs
    c. Adjust contour with coarser burs
    d. margin
       1) Scalpel – 12 blade
       2) Tapered finishing bur
          a) Easy to gouge
    e. Interproximal contour
       1) Interproximal finishing strips
          a) Steel strip with diamonds
             1) Effective for gross shaping
             2) Abrasive remains on metal backing
             3) Differing abrasives
          b) Mylar with abrasives
             1) Effective for smoothing, final shaping
             2) Abrasive tends to rub off strips
    f. Blend esthetics with adjacent teeth
    g. Can do some "orthodontics" by careful shaping
    h. Polishing
       1) Abrasive-impregnated rubber cups
       2) Tin oxide

9. Check occlusion
    a. Remove isolation
    b. Check occlusion in centric, balancing and protrusive movements
        1) Maintain centric
        2) Minimize or eliminate protrusive and balancing contacts
    c. Have patient check occlusion and esthetics

Cements, Bases and Liners

Cements, bases, and liners have been around as long as dentistry has been practiced. They have been used in an effort to protect the pulp from bacteria, cavity preparation, restorative materials, and thermal irritation. The mechanical goals of their use have been to prevent microleakage, insulate from temperature variations, seal dentin tubules, seal cavity margins, and affix restorations to tooth structure.

Definitions

- **Bases -** Bases were once described as thermal insulators when greater than 0.5 mm in thickness. They were also placed to achieve ideal cavity form.

- **Liners -** Liners were less than 0.5 mm thick and were placed for specific purposes (e.g., to be therapeutic, bactericidal, release fluoride, seal dentin tubules, or bond the restoration to tooth).

    > Note: The distinction between bases and liners is no longer clear. With better understanding of pulp physiology and arrival of new materials (notably glass ionomers and dentin bonding agents), the use of bases and liners is changing and the difference is becoming blurred.

- **Cements -** Cements are used to seal the space between prosthetic castings and tooth structure. They may also be used as bases.

Traditional Cements, Liners, And Bases

Uses of more traditional cements, liners, and bases are becoming increasingly controversial. Some of the more common ones include the following:

- cavity varnishes

- calcium hydroxide

- zinc oxide and eugenol

- zinc phosphate

- polycarboxylate cements

A review of how their use is changing is described in the following sections.

Cavity Varnishes

Cavity varnishes include natural gum (copal or rosin) or synthetic resin dissolved in an organic solvent such as acetone or ether.

- Suggested uses include to--

  - temporarily seal margins (preventing microleakage)

  - temporarily seal dentinal tubules

  - temporarily seal out acids (from various restorative materials) and bacteria

  - help prevent discoloration of tooth (invasion of corrosion products down tubules)

- Disadvantages include--

  - too thin to provide thermal protection

  - varnish washes out from under the restoration in a relatively short time

- Clinical considerations include--

  - Apply at least two layers and allow each to fully dry.

  - Never use under a bonded restoration. This includes composite restorations, glass ionomer or resin based materials (cements, bases, liners, or restoratives), as well as, dentin bonding agents.

  - Keep bottle tightly capped and add thinner if too much of the solvent has evaporated.

  - Try to confine application to dentinal surfaces.

It has always been understood that varnish washes out. The benefit of varnishes was thought to be temporary protection until silver amalgam corroded enough to seal the tubules and margins or to protect under acidic cements until the acid was fully reacted. The need for varnish is questionable because of high copper alloys (with reduced corrosion) and the reduced concern for acid impact on healthy pulpal tissue. Varnishes are increasingly being replaced by dentin bonding agents or in conservative restorations by nothing at all.

Calcium Hydroxide

When used as a liner, calcium hydroxide generally comes in a two-paste system that, when mixed, sets into a firm layer. Light-cured brands are also available.

- Suggested uses include--

    - to seal dentinal tubules

    - neutralizes (degree unknown) phosphoric acid containing cements

    - usage as an antimicrobial agent because of its high pH

    - to stimulate reparative dentin formation

        Note: This is controversial. Currently, it is thought that an insult to the pulp (e.g., caries, preparation of the tooth, and any restorative material) stimulates reparative dentin.

- Disadvantages include--

    - low compressive strength (This means that if it is spread too widely across the preparation, it will undermine the final restoration.)

        Note: Light-cured formulas are stronger, but they do not have the antimicrobial benefit of high pH.

    - soluble in water and will wash out from under an unsealed restoration over time.

        Note: Light-cured formulas are less soluble.

    - a glass ionomer or dentin bonding agent should be placed over it for protection

        Note: If either glass ionomers or dentin bonding agents also seal the dentin and stimulate reparative dentin, the need for calcium hydroxide is questionable. Some manufacturers still recommend calcium hydroxide under their products while others do not. Calcium hydroxide is still recommended by many academics while being put aside by others. If used, it should be used in thin layers over very small portions of the preparation floor. Calcium hydroxide can also can be used as a temporary cement.

Zinc Oxide and Eugenol

A zinc oxide and Eugenol (ZOE) mixture consists of a powder and liquid portion. The powder portion generally consists of zinc oxide, rosin, zinc stearate, and zinc acetate. The liquid portion consists of Eugenol and olive oil (plasticizer). This may be reinforced with various fillers for greater wear resistance.

- Suggested uses include--

  - as a cement (generally temporary)

  - as a temporary or sedative restoration (ph=7 upon insertion)

  - as a pulp chamber/canal obturation in primary teeth

  - as a base (generally not recommended due to poor compressive strength)

- Disadvantages include--

  - when reinforced it is not resorbable (as needed in primary pulp treatments)

  - the eugenol interferes with polymerization of composite restorations

  - poor resistance to wear when exposed to occlusal forces

- Clinical considerations include--

  - Mix to a very firm consistency when using as a temporary restorative material.

  - Mix thin when used as a cement or primary tooth canal filler.

  - Avoid **reinforced** ZOE in pulp canals since it is not resorbable.

  - Do **not** use when final restoration will be a resin since eugenol interferes with polymerization.

  - Water is essential for the setting reaction. Increasing the water content of the mix decreases setting time.

  - Marginal seal is very good.

Zinc oxide and eugenol mixture remains a commonly used material in dentistry for it's sedative value (ph=7), ease of use, and good marginal seal as a temporary. However, as a permanent cement it has many inferior qualities compared to the other permanent cements.

Zinc Phosphate

The zinc phosphate mixture also consists of a powder and liquid portion. The liquid portion consists of orthophosphoric acid (45 to 65 percent) with water (30 to 55 percent), aluminum (2 to 3 percent), and zinc (0 to 9 percent) added. The powder is made up of zinc oxide (90.2 percent) with magnesium oxide (8.2 percent), silicon dioxide (1.4 percent), and bismuth trioxide (0.1 percent).

- Suggested uses include--

  - Most frequently as a cement for crown and bridge including stainless steel crowns. It has--

    o very good strength

    o thin film thickness (when correctly mixed)

  - as a base in deep preparations. It--

    o has excellent compressive strength

    o will support an overlying restoration where lack of adequate dentin floor is available.

- Clinical considerations include--

  - Use 1 to 1.5 minutes mixing time. The longer and more even the mix, the greater the working time.

  - Mix on a cool glass slab, incorporating small increments of powder at approximately 15 second intervals to ensure a very smooth, even mix. As a cement the mix should string out 1 to 1.5 inches. When used as a base the mix should be very firm and not tacky.

  - The amount of water in the liquid affects the setting time. Adding water while mixing will greatly increase the setting time, but it also increases the solubility and decreases the strength. For this reason, it is important to avoid condensation on the mixing slab. It is also important to dispense the liquid portion of the mixture shortly before mixing in order to prevent water loss of the liquid, which can also result in an inconsistent and/or substandard mix. Furthermore, interchanging brands of the powder and liquid may result in an improper powder/liquid ratio due to variable compositions per manufacturer.

  - A cooled mixing slab increases the working time but may result in excess water (condensation) being incorporated into the mix.

- A grainy mix (powder not fully incorporated into the liquid) will result in greater film thickness reducing the strength as a cement and increasing the solubility and risk of washing out.

- When mixed as a base, the zinc phosphate should be very firm and placed with a condenser. Material should feel set before the final restoration is placed over it.

- Deep preparations may require a liner (perhaps CaOH) due to the immediate acid insult to the dentin.

Zinc phosphate remains the standard by which other cements are compared. It is easy to use, has very thin film thickness, good strength, longevity, and a very low cost. Because, it is soluble in water, has no bond to teeth, and is an acid, it has often been replaced by newer and/or more expensive materials.

Polycarboxylate Cement

Polycarboxylate cements consist of a powder and liquid portion. The liquid is a polyacrylic acid (32 to 42 percent) with water and itaconic acid. The powder portion consists of zinc oxide with magnesium oxide (1 to 5 percent) and aluminum oxide (10 to 40 percent). Stannous fluoride may also be added to enhance manipulative properties, strength, and modify setting time. It should be noted that the fluoride release is only 15%-20% of that of the glass ionomer cements.

- Suggested uses include--

    - It is used primarily as a cement; although, the liquid can be used as a dentin primer (removes smear layer) prior to placement of a glass ionomer restoration.

- Clinical considerations include--

    - Mixing should **not** be done the same as with zinc phosphate. The mixing of this cement should incorporate the powder into the liquid at a much faster rate than with zinc phosphate. The total mixing time is approximately thirty seconds (1/3 of zinc phosphate). Setting times range from six to nine minutes if the proper mixing technique is employed (refrigerated powder and slab).

    - It has comparable film thickness and lower solubility, lower compressive strength, and a lower modulus of elasticity than zinc phosphate.

    - It bonds to tooth structure (carboxyl groups with the calcium).

    - It has far less postoperative sensitivity than zinc phosphate.

    - The removal of the smear layer with 10% polyacrylic acid enhances the bonding to tooth structure.

- Cement removal should be completed either before or after the rubbery stage" to avoid pulling the cement from beneath the restoration.

- The most common failure occurs at the cement-metal interface, therefore the restoration surface should be decontaminated via sandblasting or abraded with a small stone.

- It is significantly more expensive than zinc phosphate.

Polycarboxylate cements have largely been replaced by most users with glass ionomer and resin cements (see next section).

Resin-Based Cement

A variety of resin-based cements are available on the market today. Some of these are designed for general use, while others are designed for specific uses such as orthodontic brackets, resin-bonded bridges etc. The chemical composition of the resin-bonded cements consist of a resin matrix with silane treated inorganic fillers. They also have the benefit of dentinal bonding via the addition of active functional groups (4-META, HEMA, Organophosphonates) to the monomer portion of the system. Enamel bonding is accomplished via traditional acid etch techniques. These resin-based cements are available in self- cure, light-cure, and dual-cure systems.

- Suggested uses include--

    - cement for orthodontic brackets. This is an especially valuable cement when using ceramic brackets for increased esthetics.

    - cement for resin-bonded bridges.

    - cement for glass ceramic restorations. This is not only due to increased esthetics, but also fracture reduction of these restorations.

- Disadvantages include--

    - irritating to pulpal tissues

    - material must be removed before the rubbery stage. If not, like the polycarboxylate cement material, it will be pulled from beneath the restoration interrupting the marginal integrity.

- Clinical considerations include--

    - The handling characteristics of the resin-based cements vary tremendously in relation to the curing method(s).

- Cement removal is detrimental during the rubbery stage, and very difficult after complete setting has occurred. The most favorable time is immediately after the restoration is seated.

- Light cure should never be less than forty seconds.

Introduction to Glass Ionomers

Glass ionomer (GI) cements were developed in an attempt to combine the fluoride release and translucency of silicate cements and the bond-to-tooth capability of polycarboxylate cements. True glass ionomers are hydrides of these two classes of cements. They have been in use since the latter 1970s. Since they were first developed, the variety of uses has mushroomed until now there are glass ionomer products designed as bases, liners, cements, and restoratives. Many new glass ionomers have been further hybridized with resins to create the ability to light cure, improve finishing and polishing, shorten setting time, and improve aesthetics. This class of materials are known as hybrid ionomers.

True glass ionomers are very technique sensitive and the results in a class of material that varies greatly between products. Mishandling glass ionomer products can result in very negative outcomes. Even variations in use (adhesive vs. a restorative material, for example) change how glass ionomers are handled. Differences in manufacturer also create variations in handling properties and considerations. It is absolutely critical that the user of these products clearly understand the specifications and instructions of the product being utilized.

Composition

Generally, glass ionomer powders consist of ground aluminoflurosilicate glass. The glass is composed of silicon dioxide, aluminum oxide, and calcium fluoride. Aluminum phosphate, aluminum fluoride, and sodium fluoride also may be included. Tartaric acid may also be included to improve handling and increase working time. Particle size varies from about 20 microns for luting products to 50 microns for restorative materials. The component ingredients are melted together to form the glass. The glass is then ground and filtered for particle size.

Initially, in basic glass ionomers, the liquid was an aqueous polyacrylic acid. However, current glass ionomer cements contain a copolymer of itaconic, maleic, and tricarboxylic acid. This copolymer tends to increase the reactivity of the liquid, while decreasing the viscosity and gelation.

- Hydrous Glass Ionomers - Other acids may be added to affect handling and physical properties. These may be called hydrous glass ionomers. The liquid is fairly viscous making mixing and handling more difficult than other cements.

- Anhydrous Glass Ionomers - To compensate for this, some manufacturers may vacuum or freeze dry the liquid and add the remains to the powder. The liquid portion of these products is then primarily water and those acids added to affect the setting properties.

Such "dried" glass ionomer cements are often referred to as anhydrous glass ionomers or water-settable glass ionomers. They have lower viscosity and longer shelf life.

• Semihydrous Glass Ionomers - A third type, known as semihydrous glass ionomers, has denatured acids added to the powder. The liquid also includes the polyacrylic acids. Viscosity and shelf life falls between hydrous and anhydrous products.

Classification

Glass ionomer cements are generally classified by type.

• Type I: Contain small particles (15 to 20 microns) and are used as luting cements. Because of the small particle size, they require more liquid to powder than restorative glass ionomer cements. This ratio change weakens the glass ionomers, and reduces the effectiveness of this type.

• Type II: Contain large particles (50 microns) and require less liquid to powder. They also may have metal (e.g., silver amalgam) added. These are the restorative and buildup glass ionomers.

• Type III: These are chemically set products used as liners, bases, and sealants.

• Type IV: This type is used for light-cured liners and bases. These products are really hybrid forms with resins added to impart additional desirable qualities. Compared to Type III, Type IV glass ionomers bond to dentin better.

Clinical Considerations

The following points should be considered when selecting/using glass ionomers.

• Glass ionomers have good compressive strength and bond to dentin.

• Their coefficient of thermal expansion is closer to dentin than other materials. When properly placed, they have little dimensional change when setting (although they expand under moist conditions and contract under dry conditions).

• Glass ionomers have low fracture resistance (toughness) and low wear resistance, so they should not be used in high stress bearing areas as a final restorative material.

• Glass ionomers are sensitive to air and water during the setting phase; therefore, they must be protected as they initially set.

• Glass ionomers develop their final physical properties very slowly (24 to 48 hours). This is their most inferior quality.

- Glass ionomers require special care during the initial setting period.

  > **Note**: Instructions for the first glass ionomers used as restorative materials recommend the patient be brought back 24 hours after placement for finishing and polishing. The attempt to improve on glass ionomer's disadvantages has lead to the manufacture of increasing numbers of hybrid glass ionomers (resins added).

Glass ionomers release fluoride by leaching of the Fl$^-$ ion primarily from the glass particles. The initial release is high but drops over time until it reaches a steady state with the oral environment. This steady state effect theoretically allows "banking" of fluoride. When in a high fluoride environment, Fl$^-$ is taken up into the ionomer from oral fluids. If the patient then goes to a lower fluoride environment, fluoride is released from the glass ionomer until a steady state is again achieved. The true impact, if any, of this fluoride release has not been clinically demonstrated (inconclusive).

Preparation of the cut dentin surfaces varies depending on the use of the glass ionomer. Original glass ionomer luting agents had problems with slowly developing postoperative pain that ultimately would require the removal of the casting. This is thought to be due to the hydraulic pressure generated when the casting was seated forcing the cement down the tubules. The high viscosity does not allow the cement to flow as easily out from under the casting. This postoperative sensitivity may also be attributed to the lower powder/liquid ratio and slower setting reaction found in the luting agents. It does appear that these three factors play a major role, which would explain why the Type II glass ionomers (less hydraulic pressure, increased powder/liquid ratio, and a faster setting reaction) have a lesser pulp reaction.

- Luting agent - Therefore, when glass ionomers are used as luting agents, the smear layer should be left to plug the orifices of the tubules.

- Restorative material - Maximum bond surface to dentin is needed when used as a restorative material. This can be achieved by removal of the smear layer. Primers are provided with restorative products to accomplish this preparation. The post-operative sensitivity is not a problem since severe hydraulic force is not generated during the placement of restorative ionomers.

- Bases and liners - Products used as bases and liners do not require the higher bond strength required by restorative glass ionomers, so removal of the smear layer is optional.

The dentin surface should not be desiccated prior to placement of a glass ionomer. The dry surface inhibits bond strength by increasing setting contraction at the bond surface. The surface should not be visibly wet either, as increased setting expansion (too much moisture) inhibits final bond strength. The dentin should be kept wet while the glass ionomer is being mixed, then dried with cotton pellets just prior to placement of the glass ionomer. The dentin should not be heavily air dried.

Once the glass ionomer is placed, moisture contamination or desiccation of the setting glass ionomer remains a major concern.

- When used as a luting agent, base, or liner, this is not a problem because the ionomer is covered by the casting or restoration. Although, they should not be rinsed or dried in the interim).

- When glass ionomer is used as a restorative material, it is at risk during the initial setting phase. If contaminated by moisture, the surface becomes rough and chalky. If during the initial setting the restoration is overly desiccated, water needed in the setting reaction is lost, resulting in a weaker restoration. Drying will also cause crazing of the surface.

Glass ionomer restorative material should be placed immediately after mixing when it still has a glossy appearance. If the glossy surface fades, the mix should be discarded and another mix started. The glass ionomer should be placed and sculpted with instruments to as close to possible final contour. When using a matrix, the matrix fit should be as close to final contour as possible. Once the ionomer is placed, it should be covered with a protective barrier until adequate setting time has elapsed before finishing is started. Initial trimming can be done using a #12 scalpel. Final contouring and finishing should be done with a #30 fluted-carbide finishing burr. Hybrid glass ionomer/resin products may be treated and finished more like composite products. Again, the restoration should be covered with the barrier agent before dismissing the patient.

Finishing and polishing procedures generally involve heavy water spray on the restoration. Consequently, finishing should not be started too early. Older product lines called for 24 hours of setting time before finishing, and the surface of the glass ionomer had to be protected from the oral moisture throughout that time. Current products call for 10 to 30 minutes of protected setting time before finishing. Failure to follow these time guidelines will lead to poor surface properties and aesthetics. Most restorative ionomer kits will come with a protective barrier component. Unfilled resin (the bond material in resin bonding kits) works well as a protective barrier.

After placement, initial set, and finishing the restoration should not be desiccated for up to 2 weeks. This can be a problem if the patient has a subsequent appointment for dental work in the same area. If the patient is being seen for restorations in the same area and the existing restoration is not covered under the rubber dam, the surface of the existing restoration should be protected with a barrier or bonding agent during the new procedure.

Resin-Modified Glass Ionomers (a.k.a. tri-cure glass ionomers)

Glass ionomer cements are hybrids by initial design, created to incorporate the translucency and fluoride release of silicate cements with the bonding to tooth of polycarboxylate cements. The term resin-modified glass ionomer, as now used, refers to the further hybridization of ionomers with resins. These products are increasingly being used in a variety of settings (e.g., bases, liners, adhesives, luting agents, restorative materials). The resin-modified glass ionomers handle much like visible light-cured composites, yet they also remain much like true glass ionomers. The placement steps have elements of both glass ionomer and resin techniques may vary per manufacturer. Some prime the dentin with polyacrylic acid followed by placement of the restorative material (like a resin). As with light-cured resins, resin-modified glass ionomers

should be placed incrementally in thickness no greater than 2 mm to ensure adequate light penetration. Finishing can begin soon after placement (like a composite), but the restoration should be covered by a barrier agent when the patient is dismissed (like a glass ionomer). Resin-modified glass ionomers can be finished and polished like composites.

Resin-modified glass ionomers have surface roughness greater than resins and mechanical properties (including strength) less than resins. They have greater mechanical properties and have less complicated placement and finishing requirements than ionomers. When used as a buildup material and immediately prepared for a crown, the air-inhibited resin layer may interfere with the addition of the silicone impression materials.

Suggested uses include-

- Bases
- Liners
- Adhesives
- Luting agents
- Restoratives
  - class III,
  - class V,
  - cervical erosion,
  - root caries, and
  - temporary repairs of fractured teeth

Advantages include-

- bonds to both dentin and composite restorations when used as a base or liner (if properly prepared)

- resin-modified glass ionomer restorative compressive strengths are comparable to that of the traditional glass ionomer restoratives

- resin-modified glass ionomer restorative diametral tensile and transverse strengths are approximately twice that of the traditional glass ionomer restoratives

- resin-modified glass ionomer cement compressive and tensile strengths are comparable to the traditional glass ionomers

- bonding to enamel and dentin is approximately twice that of traditional glass ionomers when used as a restorative

- possesses comparable fluoride release as seen with the traditional glass ionomers

- the newer light cure resin-modified glass ionomer hybrids facilitates immediate placement of restorations when used as a base or liner

- minimal post-op sensitivity

- considered to have low solubility

- good polishability (inferior to composites)

Disadvantages include-

- shades of certain products may prohibit their usage as luting agents with all-porcelain restorations

- fracture toughness is less than traditional composites

- inferior compressive strength (cement) as compared to zinc phosphate

Clinical Considerations include-

- These materials should be reserved for conservative class III and V restorations when used as a restorative.

- These materials may not be suitable as a <u>large</u> base prior to alloy condensation due to the need for high compressive strength.

- The bond strengths of a resin-modified glass ionomer to dentin are increased tremendously when a bonding agent is utilized.

Compomers

Compomers are defined as a polyacid-modified resins. They are composite resins with resin monomers that contain acidic functional groups which are capable of participating in an acid/base (glass ionomer) reaction <u>after</u> polymerization of the resin molecule. Since the compomers have only one component they must rely on water (supplied by the saliva surrounding the restoration after placement) to facilitate this type of acid/base reaction.

The compomers, having only this one component, <u>are not considered true glass ionomers</u>. The true glass ionomers must have a two part system that facilitates an acid/base reaction upon mixing. Again, these materials are not considered true glass ionomers by definition, and have the basic composition of composites; therefore they are considered to be more closely related to the traditional resins.

Advantages--

- composite-like esthetics and qualities (light cure)

- minimal steps for proper placement (no mixing)

Disadvantages--

- fluoride release is significantly lower than the traditional glass ionomers

- many require primers and/or adhesives for maximum bond

- less strength, esthetics, and wear resistance than traditional composites

Clinical usage--

- These materials have composite resin qualities with increased ease of usage (light cure and no mixing).

- However, the lack of significant fluoride release, decreased wearability, decreased strength, and esthetics should be considered prior to placement.

- In general their placement should more than likely be reserved for conservative preparations (III and V).

Conclusion of Glass Ionomers and Hybrid Variants

Glass ionomer and their variants show a wide range of manufacturers, uses, placement techniques, and hybridization. The provider must be fully knowledgeable on the nature of the ionomer being used and the recommended technique in the manufacturer's instructions. Do not assume that all of these materials handle the same. Incorrect technique can greatly undermine the desired and expected outcome.