DENTAL MATERIALS

a problem-oriented approach

Edited by

ROBERT G. CRAIG

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with 262 *illustrations*

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PREFACE

Traditional publications in dental materials have approached the subject as a basic or applied science. The subject matter has been subdivided into discussions reviewing atomic structure, physical and mechanical properties, and metallurgy, as well as descriptions of various types of dental materials such as waxes, gold alloys, plastics, impression materials, and ceramics. Although examples of clinical applications are included in such books, it is not their purpose to systematically relate the clinical use of materials in the various disciplines in dentistry to their particular application or selection. Also, materials used in orthodontics and endodontics are discussed only briefly, if at all, in dental materials publications.

The objective of this book is to develop the subject of materials as they apply to the disciplines in which they are used and to present the information using a case- or problem-oriented approach. Each chapter includes brief reviews of the material and in many instances information not otherwise available in dental materials publications, plus a series of cases or problems and suggested solutions. Since discussion of some materials occurs in several chapters, a limited amount of repetition is intentionally present. This arrangement was developed so that each chapter could be used independently. The cases do not include all possible problems, and no doubt as the reader progresses through the text, additional problems will come to mind. It should be emphasized that this book is written for individuals who have previously taken a basic course in dental materials and have a fundamental knowledge of the subject. It is the main thrust of this book to relate dental materials to clinical cases and problems.

I am indebted to several persons who have contributed substantially to the preparation of this book. A great number of the illustrations and photographs were prepared by Christine Sadler. Much of the manuscript was typed by Cara Hurst and Paula Wagner. I am most grateful to them for their excellent service. Finally, I would like to thank Cara Hurst for her assistance in proofreading the typeset material.

Robert G. Craig

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1 ⪢ Restorative materials for direct application

JOSEPH B. DENNISON

PIT AND FISSURE SEALANTS

Objectives for use

- Physical obturation of the anatomic defects along the pits and fissures of posterior teeth and the lingual surfaces of maxillary anterior teeth.
- Sealing of all coated pits and fissures from the ingress of oral fluids and bacteria, which contribute to the initiation and propagation of caries.
- Achieving micromechanical retention against conditioned enamel sufficient to resist the dislodging forces of the oral environment for a clinically acceptable period of time.
- Providing clinical effectiveness in the reduction of pit and fissure caries.

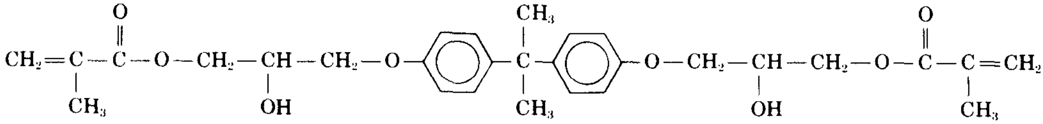
Composition and reaction

Documentation can be found in the dental literature for the use of such materials as silicophosphate cement, germicidal cements, and polymers impregnated with diamond particles for the obturation of occlusal pits and fissures, but with only minimal clinical success. The more recent development of specific materials associated with accepted techniques for the preparation of enamel as a suitable substrate has enhanced clinical success and revitalized interest in the use of sealant coatings. Polyurethanes, cyanoacrylates, glass ionomer cements, and dimethacrylate polymers are all materials that have met with varying degrees of clinical success.

The cyanoacrylate systems have been utilized with moderate effectiveness as both sealants and fluoride holding agents. The cyanoacrylates polymerize readily on exposure to moisture, such as that found in biologic tissue. In the early 1960s Buonocore used methyl-2-cyanoacrylate mixed with an inorganic silica filler and documented both clinical retention of the material and a positive reduction in caries for treated teeth. More recently an α-cyanoacrylate system was used in conjunction with the topical application of fluoride to improve the fluoride uptake in treated enamel. Both systems displayed a measure of clinical success, but neither is currently being marketed commercially.

All the presently used sealant materials are formulated from the aromatic dimethacrylate resin BIS-GMA, which was developed by Bowen. The BIS-GMA resin is the reaction product of bisphenol A and glycidyl methacrylate, as shown at the bottom of the page.

The resin can be polymerized by free radical formation at the double bond sites, followed by addition polymerization utilizing a peroxide initiator and an amine accelerator. To obtain a thinner viscosity, the more viscous BIS-GMA resin is usually diluted with either methyl methacrylate or a glycol dimethacrylate. Most of the sealant materials are marketed as unfilled resins to maintain



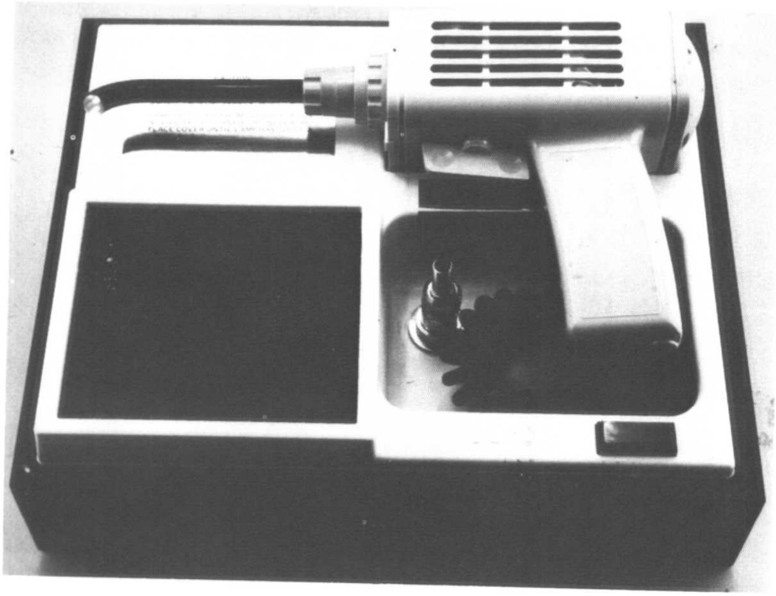


Fig. 1-1. Ultraviolet light for polymerization of sealants and composites.

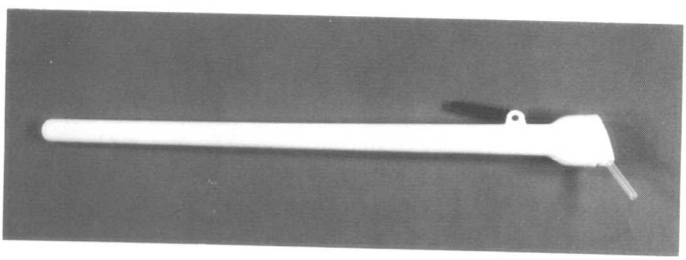


Fig. 1-2. Applicating syringe for self-curing sealant.

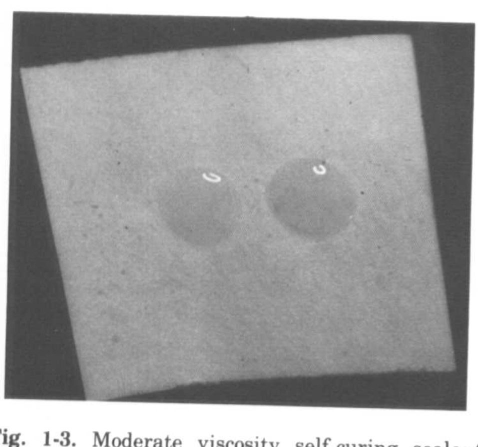


Fig. 1-3. Moderate viscosity self-curing sealant showing one drop each of catalyst and base on a mixing pad.

the lower viscosity that permits better flow against enamel and improves penetration.

One modification of the BIS-GMA system utilizes ultraviolet light as the accelerator and incorporates benzoin methyl ether as an ultraviolet absorber. The reaction then proceeds at an accelerated rate in the presence of benzoyl peroxide as an initiator. The ultraviolet light source (Fig. 1-1) is a mercury vapor lamp filtered to remove short wavelength radiation. The beam of ultraviolet rays is focused on the surface of the resin by transmission along a quartz rod, the end of which is held 2 mm from the surface of the material. Precautions must be exercised to avoid overexposure of adjacent soft tissue when the light is used. Cumulative overdosages could prove harmful to either the patient or operating dental personnel.

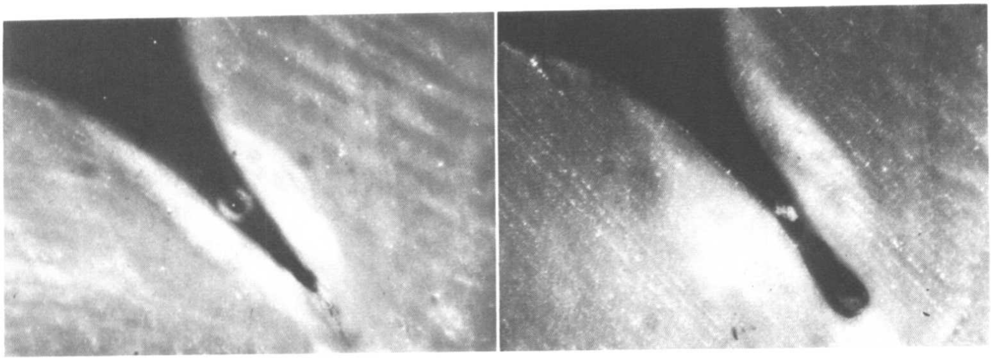


Fig. 1-4. A, Wide V-type fissure. **B,** Narrow bottleneck-type fissure.

The self-curing BIS-GMA system has also been modified to produce a faster setting resin that is very low in viscosity and must be applied with a special syringe (Fig. 1-2). The addition of approximately 40% of treated glass filler particles to improve the wear resistance has resulted in a moderate viscosity two-paste system (Fig. 1-3) that can be applied directly with a brush or metal applicator.

Properties

The setting time of a resin system must be within the limits of patient acceptability. A material that sets too quickly would increase in viscosity too fast to allow adequate penetration and adaptation to take place. Since the material is primarily intended for application as early in the eruption sequence as possible, a long setting time could tax a child's behavior and result in physical disruption or contamination of the material before initial setting is reached. The self-curing resins now being marketed reach initial set between 45 and 90 seconds from the beginning of mixing. The ultraviolet-accelerated materials have the advantages of an unlimited working time to permit maximum penetration and a rapid set on application of the light source.

Viscosity of the sealant material is important as it relates to surface wetting, adaptation, and penetration. Penetration of the sealant into a cleaned pit or fissure resembles penetration of a fluid into a closed capillary tube. This penetration has been related to the configuration of the fissure in cross section, with a wide V-type fissure being penetrated more readily than a narrow bottleneck-type fissure (Fig. 1-4). Penetration has also been linked to viscosity of the sealant, surface tension of the sealant, and the contact angle formed by a drop of the sealant on prepared enamel. Retention of polymer coatings against enamel is related directly to the number and length of the resin tags that form in the surface irregularities created during acid pretreatment. A higher viscosity resin or one that did not wet an etched enamel surface very well would have fewer complete resin tags to retain it and should show the earliest signs of leakage or bond failure.

Bond strength of the resin to enamel is the cumulative effect of the tag formation and the actual shear strength of the resin. The BIS-GMA resin has a higher shear and tensile strength than poly(methyl methacrylate) and therefore should have a higher bond strength as well, tag configurations being similar.

Durability of a sealant coating may well be influenced by its resistance to abrasion. One means for improving abrasion resistance is by the addition of silane-treated filler particles, as will be explained more completely in the later discussion of composite resins. Up to 40% glass filler particles have been added to a resin without interfering with tag formation. Only comparative clinical studies will be able to document the actual value of filler addition.

Enamel pretreatment

The pretreatment of enamel substrate with an acid conditioning agent is necessary to secure resin to enamel. Cleansing of the enamel surface with a non–fluoride-containing prophylaxis paste or a slurry of triple x fine silex will remove the enamel cuticle and attached microscopic debris. Further cleansing

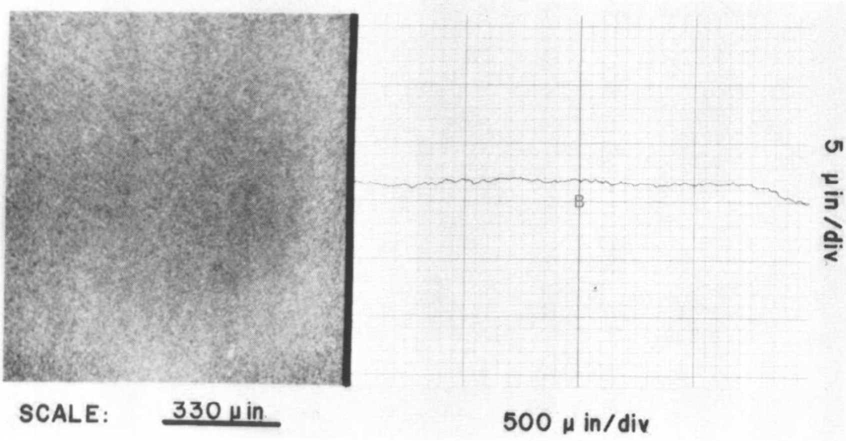


Fig. 1-5. Scanning electron micrograph (left) and surface profile tracing (right) of polished enamel.

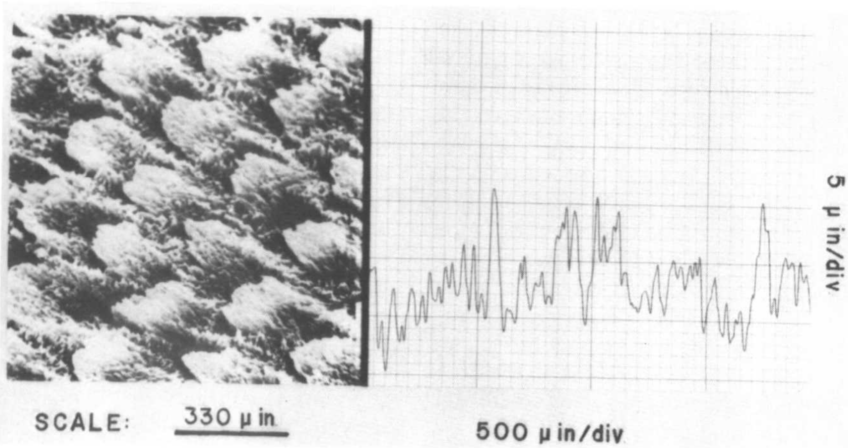


Fig. 1-6. Scanning electron micrograph (left) and surface profile tracing (right) of enamel etched with 50% phosphoric acid.

with an acid solution creates a chemically clean surface with a higher surface energy and one that is more readily wetted by monomer. Acid conditioning also removes several micrometers of the surface and increases the surface area of enamel exposed for bonding. Decalcification of the exposed ends of enamel rods also takes place, creating porous irregularities into which sealant can penetrate and in which retentive polymer tags can form. The increase in surface area and change in surface structure of enamel after treatment with a 50% solution of phosphoric acid can be seen by comparing Figs. 1-5 and 1-6.

Sufficient etching is obtained on most teeth after 60 seconds' exposure to the acid solution. An additional 30 to 60 seconds' exposure to a second application of acid may be required for specific teeth in which the characteristic color and texture of the etched surface does not appear to be uniformly developed. Prolonged exposure of enamel to acid etchant solution appears to result in undue loss of surface enamel and crater formation rather than a regular, even pattern of enamel rod decalcification (Fig. 1-7). Among the many acid solutions tested on enamel in recent years are citric, phosphoric, acetic, lactic, and pyruvic

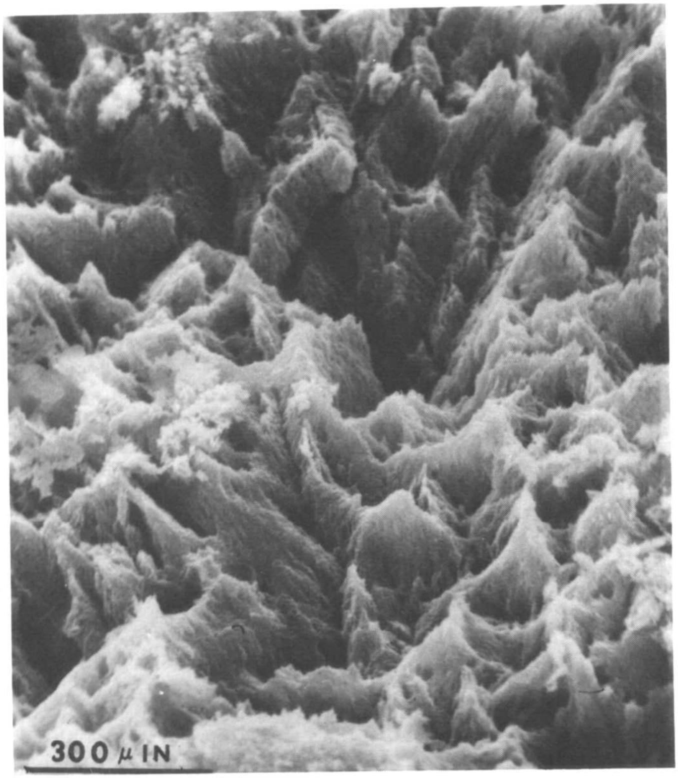


Fig. 1-7. Scanning electron micrograph of enamel subjected to prolonged etching of 2 minutes.

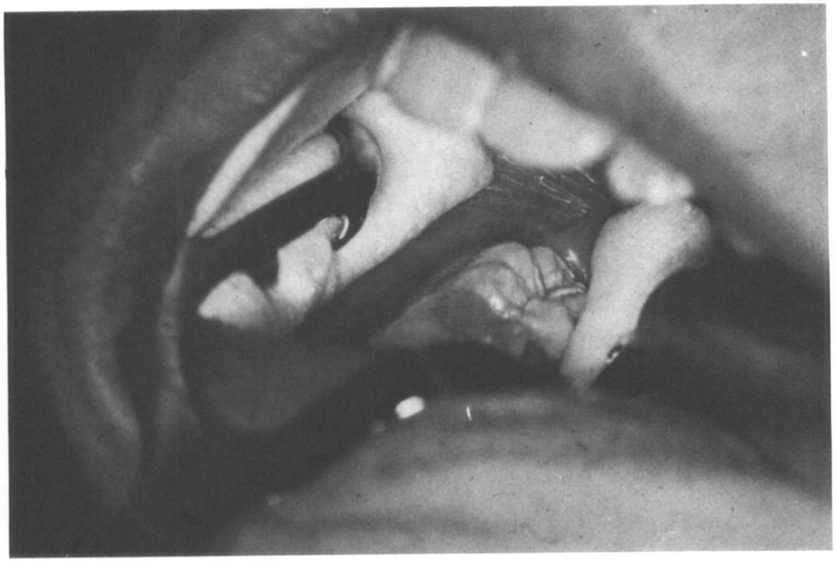


Fig. 1-8. Isolation of lower molar for application of sealant.

acids. Most commercial products suggest the use of phosphoric acid in a concentration between 35% and 50%.

The enamel should be kept moist with acid during the etching period or it may form phosphate crystals that can act as a contaminant during bonding. At the end of the selected exposure time, usually 60 seconds, the enamel should be rinsed thoroughly with a continuous stream of water for 15 to 20 seconds. Immediately after rinsing, the enamel should be dried thoroughly with warm air and the surface inspected carefully. It is extremely important that the sealant be applied quickly to this dry surface before saliva or any other contaminant can touch the freshly etched enamel. Even the dried proteins from saliva are capable of contaminating the surface and interfering with the polymer bond when sealant is applied. Thus isolation becomes probably the most important aspect of the application procedure as far as sealant durability is concerned. Adequate isolation of a posterior tooth during the early stages of eruption should involve the use of cotton rolls, Theta Driangles, high-volume evacuation (Fig. 1-8), and even rubber dam isolation on occasion.

Sealant manipulation

Mixing of the sealant should be done carefully on either a flat surface or a shallow dappen dish, with every effort made to avoid air incorporation. The material should be applied uniformly across the occlusal surface of the tooth, again with an attempt to avoid air entrapment at the base of fissures. Self-curing sealants should be kept free of occlusal contacts or other physical disruptions for a period of 3 minutes from the beginning of mixing; sealant accelerated by ultraviolet light can be exposed to the oral environment immediately after the 30-second exposure period. Occlusal prematurities should be relieved with a rotating abrasive wheel or stone prior to dismissing the patient.

Clinical evaluation of effectiveness

The true test of success for any material is an evaluation of its clinical performance under controlled conditions. Many such clinical studies have been undertaken in recent years to evaluate pit and fissure sealants. In a 4-year study at Kalispell, Montana, utilizing an ultraviolet-accelerated sealant, the U.S. Public Health Service found a retention rate of 50% and a clinical effectiveness of 41% in the reduction of occlusal caries. There is a range of results associated with the various self-curing sealant systems. An early unfilled, self-curing system tested in England showed a retention rate of 51% and a caries reduction rate of 30% after 2 years. A newer modified formulation of an unfilled self-curing sealant material was tested in Colombia, South America, and elicited a retention rate of 92% and a clinical effectiveness of 90% after 1 year. Another self-curing resin system with the incorporation of about 40% glass filler was evaluated in Chelsea, Michigan, and also proved successful over a 2-year period, with a retention rate of 71% and a clinical effectiveness of 75% in the reduction of occlusal caries. It should be evident that there is sufficient data to justify the use of pit and fissure sealants on a selected basis and as an integral part of a total preventive program.

PROBLEMS WITH SEALANTS AND SUGGESTED SOLUTIONS

PROBLEM 1. After completing the application of a self-curing resin sealant, a careful inspection of the occlusal surface reveals multiple areas along the central fissure where small air bubbles have been incorporated, some communicating with the surface and others covered by a thin layer of material. What manipulation variables can be used to control this potential problem?

a. In mixing the material prior to application, every effort must be made to avoid the incorporation of air bubbles. In a heavier viscosity material, it is often very difficult to remove air bubbles incorporated during mixing, and sometimes they are not even evident until after polymerization is completed. In a two-paste system, the material should be mixed on a flat surface with the flat end of a mixing stick or spatula held close to the mixing surface. Stirring or folding actions should be avoided. In a two-liquid system, the components can be mixed in a shallow dappen dish or plastic mixing bowl. The tip of the mixing stick should be kept in contact with the base of the container and a steady nonvigorous stirring action used. Vigorous stirring or whipping actions should be avoided.

b. Careful selection of an instrument for application is important. That supplied by the

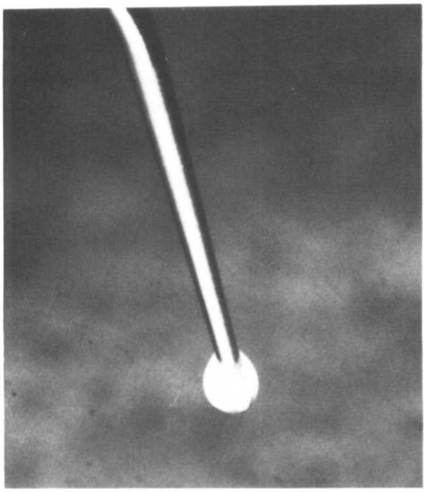


Fig. 1-9. Ball-tipped applicator with a small increment of sealant.

manufacturer or described in an advertising brochure may not be the most ideal for all cases. In general, a brush, particularly a long-bristled or heavily tufted one, will tend to incorporate air during the brushing action of application. In many cases a ball-tipped metal applicator or small ball burnisher is more suitable than a brush. Smaller increments can be picked up (Fig. 1-9) and applied in specific locations along the occlusal fissures. A thinner coating, more confined to the fissures and grooves, can be applied and can be incrementally pushed along the fissures to minimize air entrapment.

c. Moisture contamination can occur during the final stage of application of the sealant after the initial increment has been placed on the tooth. Moisture bubbles are the same as air bubbles after the resin sets and equilibrium is reached through water absorption. These voids may be open to the external surface or may be subsurface until they are exposed by abrasion. Surface voids increase roughness and create foci for the accumulation of plaque and debris. If such voids are along a margin or communicate with underlying enamel, there is a strong possibility that secondary caries could result.

d. Application of the sealant should be completed well before the initial set of the resin is reached. Polymerization begins as soon as the pastes or liquids are mixed together. During the later stages of polymerization, the viscosity of the material increases until a gel-like consistency is obtained at the point of initial set. Manipulation of the material during the later stages of this working time period when the viscosity is approaching its maximum is more likely to incorporate air bubbles. There are a variety of clinical situations under which this could occur.

- The material could have a shortened setting time as a result of unusual chemical instability, storage in a warm environment, or even prolonged storage at room temperature. The shelf life of all polymeric restorative materials can be prolonged by storing them under refrigeration. Any unsuspected change in the setting time of resin materials indicates a problem in the setting reaction and casts suspicion on the physical properties of the set material.
- The oral environment is excessively warm and humid, causing the polymerization to take place at an accelerated rate. Small increments added to the occlusal surface intermittently during the application process will tend to maintain a thin viscosity better than a large initial increment manipulated on the tooth for the same period of time.
- Operator-controlled variables relating to general organization, the use of auxiliary assistance, and the specific operative technique utilized can all have either a positive or a negative effect on the speed of application for a particular material. The proper application of sealant requires an exacting technique with optimum operating efficiency during the application period.
- Patient behavior can also be a modifying factor. An uncooperative child can complicate the procedure and necessitate working with the material later than desirable during the setting reaction.

e. The wetting properties of a material are important in the selection of a sealant. A material that wets the surface well will spread out readily, and any incorporated air voids will tend to rise to the surface (Fig. 1-10). On the other hand, a material that does not wet the surface well will resist spreading and facilitate air incorporation during instrumentation. There is a greater possibility that a more