ACP
AMERICAN COLLEGE OF PROSTHODONTISTS®

Impression Materials in Fixed Prosthodontics: Influence of Choice on Clinical Procedure

Techkouhie A. Hamalian, DChD,[1] Elie Nasr, DChD,[2] & José J. Chidiac, DChD, MSc[3]

[1] Resident, Division of Prosthodontics, Columbia University College of Dental Medicine, New York, NY
[2] Lecturer, Faculty of Dentistry, Saint Joseph University, Beirut, Lebanon
[3] Professor, School of Dentistry, Lebanese University, Beirut, Lebanon

Keywords
Impression; models; fixed prosthodontics; physical properties.

Correspondence
Jose J. Chidiac, School of Dentistry, Lebanese University, PO Box 40105, Baabda, Lebanon. E-mail: RJCHID@cyberia.net.lb

Accepted March 25, 2010

doi: 10.1111/j.1532-849X.2010.00673.x

Abstract

The purpose of this article is to review impression materials used for fabricating fixed restorations in dentistry. Their compositions, properties, advantages, and disadvantages are presented and compared. How these properties influence clinical decisions is also described. This review helps the clinician choose which material is more suitable for a specific case. A broad search of the published literature was performed using Medline to identify pertinent current articles. Textbooks, the Internet, and manufacturers' literature were also used to supplement this information. It is limited to impression materials used in fixed prosthodontics. The review gives basic knowledge of ideal impression material properties and discusses traditional and, primarily, more recently developed products, such as polyethers, poly(vinyl siloxane), polysulfides, and condensation silicone materials. Clear advantages and disadvantages for these impression materials are provided along with the role that compositional variations have on the outcome of the impression. This should enable clinicians and technicians to easily identify the important physical properties of each type of impression material and their primary clinical indications.

The success rate of prosthetic tasks relies on several factors including dimensional accuracy, detail reproduction of impressions, and the corresponding models from which a restoration can be manufactured in the laboratory.[1] This success rate is imperiled when one looks at clinical studies. Impression making is an important step to get a perfect cast, as the aim of an impression is to produce a dimensionally stable "negative" to serve as the cast mold. To attain this goal, many impression materials are suitable for use. The materials should reproduce the static and oral structures accurately for an optimum cast.[2] The exactitude of the final restorations depends greatly on the impression materials and techniques used. In fact, the accurate reproduction of preparation margins in an impression is a necessary requirement for achieving good marginal quality. In vitro, the marginal precision of a dental restoration is 50 μm on average.[3-5] This margin is the sum of all relative and absolute errors accumulated throughout the process, starting from the impression until the restoration is finally produced. It is therefore important to have a minimal error rate in each stage to reduce the cumulative effect of all the steps (e.g., using a CAD/CAM system). Despite rapid technical progress in the CAD/CAM field, conventional impressions are still required for transporting information from the dentist to the dental laboratory. CAD/CAM systems (such as Procera, Everest Kavo, Lava 3M) scan the finish line from the master cast made of gypsum. In the future, intraoral chairside scanners (e.g., the CEREC-Sirona dental systems) might replace the need for making impressions. Digital impressions will be sent to the laboratory where the technician will digitally cut and mark the margins, thus eliminating the impression step.

Until this technical skill becomes a common procedure, the use of conventional impressions is still the gold standard for dentists. To be accurate, these impressions need good impression materials.

The aim of this review is to give a detailed overview of all appropriate dental impression materials for fixed prosthodontics. An emphasis on clinical implications in relation to their properties will also be given.

Brief history of dental impression materials

In the 1950s and 1960s, hydrocolloids were the preferred impression materials. Since the introduction of hydrocolloids in the mid-1930s, the impression of undercuts became possible. In the 1950s, polysulfides and condensation reaction silicones (C-type silicones) were used reliably in fixed prosthodontics.

The great disadvantage of all these dental materials was the shrinkage over a period of several hours, intrinsic to the system. With hydrocolloids, shrinkage was due to the evaporation of water, while in condensation-cured elastomers, it was the evaporation of low-molecular side products.[6,7] In the late 1960s, polyether, a hydrophilic product cured by the cationic ring opening polymerization reaction, was introduced to the market. Its high mechanical properties, good elastic recovery, and small shrinkage made it superior to hydrocolloids and C-type materials. Ten years later, the hydrophobic addition-cured silicones [poly(vinyl siloxane)] (PVS) were introduced. The level of hydrophobicity was reduced by the addition of surfactants. PVS has a very high dimensional stability over time and temperature, even in a moist environment; it is known for its superior elastic recovery. According to Christensen in 1997, "The past 20 years have brought significant improvement in polyether and [PVS] categories, and now they appear to be the most acceptable product categories for most prosthodontic uses. In 1997, three categories of impression materials dominate fixed, removable, and implant prosthodontic use: addition reaction silicone, polyether, and reversible hydrocolloid, listed in order of decreasing use."[8]

Impression material general properties

An ideal impression material should exhibit certain characteristics in the clinical and laboratory environment. Clinically, it should produce a dimensionally stable, accurate impression with optimal mechanical properties (optimal Young's modulus, yield strength, and thermal expansion coefficient) for adequate elastic recovery and to resist tearing. It should also set within a reasonable amount of time and demonstrate biocompatibility: hypoallergenic nature and minimal amount of toxicity. It should be hydrophilic for making a good impression and for accurate pouring of multiple casts. It should not be affected by dimensional accuracy upon disinfection. Finally, reasonable cost is recommended.[9-12]

This ideal type of impression material is difficult to obtain in reality. A detailed description of each property will help in understanding how they interact.

Accuracy

According to American Dental Association specification #19, elastomeric impression materials used to fabricate precision castings must be able to reproduce fine detail of 25 μm or less.[3] PVS impression materials can reproduce details of 1 to 2 μm.[14] The various viscosities also play a role in the accuracy of detail reproduction. In fact, the lower the viscosity, the better it records fine detail. Putty materials cannot reproduce fine detail at the 25 μm level and are required only to record details of 75 μm.[15]

Elastic recovery

Elastic recovery of an impression is defined as the ability of a material to return to its original dimensions without significant distortion upon removal from the mouth.[10] No impression material has 100% elastic recovery, and for all impression materials the greater the depth of undercut, the greater its permanent distortion.[13] Thus, the minimum thickness of the material in the tray should be three to four times more than the largest undercut. An excellent procedure to maximize the elastic recovery of the impression material is to eliminate or block out any undercuts in the tooth preparation. PVS showed the best elastic behavior, with over 99% elastic recovery, followed by polyethers and polysulfides.[10,16] Once mixed, PVS develops elasticity rapidly and should be used as soon as possible, especially in high temperatures. On the contrary, polyethers remain plastic for a longer period after being mixed,[17] but their final stiffness is still more than that of PVS, which may affect the ease of removal from the mouth.

Dimensional stability

Ideally, the dimensional stability of an impression material reflects its ability to maintain the accuracy of the impression over time,[10] thus giving the opportunity to pour it at the convenience of the operator. In reality, it is usually a time-dependent procedure, with greater dimensional accuracy occurring immediately upon polymerization completion, declining as the impression is stored for extended periods of time.[13,18-20] This is why these materials should have a low shrinkage upon polymerizing and remain stable. PVS materials possess almost ideal dimensional stability and can be poured within 1 to 2 weeks after making the impression.[10,11,13,18,21] They are followed by polyethers, but these can absorb water from the atmosphere and swell.[22,23] For maximum accuracy, it is recommended to pour them within 1 hour of removal from the mouth. Other impression materials, such as condensation silicone and polysulfides, should be poured no more than 30 minutes after removal from the mouth. The volatile ethyl alcohol and water produced as byproducts of the setting reaction with condensation silicone and polysulfide rubber, respectively, tend to evaporate from the surface of the set impression, resulting in distortion.[24] All types of elastomeric impression materials undergo shrinkage caused by polymerization, and materials with reaction byproducts undergo additional contraction. In numbers, the polysulfides and condensation silicones have the largest dimensional change during setting, in the range of −0.4% to −0.6%. PVS has the smallest change (−0.15%), followed by polyether (−0.2%).

Hydrophilic properties

Since the impression material is in close contact with wet soft and hard tissue, hydrophilicity is one major feature of a modern precision impression material. The hydrophilic nature of an impression material relates to its ability to work, flow in a wet environment, and still provide accuracy in an impression.[2] Hydrophobic materials exhibit a contact angle of 90° or greater with water, while hydrophilic materials have a lower contact angle. Hydrophilic materials contain the functional groups [carbonyl (C=O) and ether (C–O–C)] that attract and interact with water molecules,[25,26] whereas PVS contains hydrophobic aliphatic hydrocarbon groups.[1,10] Hydrophilic materials flow better in humid areas, such as subgingival areas, on mucosa, and moist teeth. They present a higher precision and show a lower risk of air bubbles trapping on the stone model. Despite the hydrophility of polyethers and polysulfides, they require a dry field for making impressions.

Limitations of PVS involve its hydrophobic nature[19,20,27-34] because of its chemical structure and high contact angles. Newer PVS formulas include nonionic surfactants, which improve wettability and reduce contact angles.[35-38] These improvements enhance surface detail reproduction by facilitating the wetting of unset material on moist oral tissues and tooth surfaces.[39] It also becomes significantly easier to pour PVS materials without incorporating voids; however, this improvement has little clinical value, as it is still impossible to make an acceptable impression in a wet environment.[13] Newer formulas seem to release the surfactant from the material surface. It is then diffused in the liquid; in fact, the material remains hydrophobic despite all claims to the contrary.[9,12,21,40,41] Because of their hydrophilic nature, using polyether and polysulfide impression materials is more compatible with the inherent moisture present in mucosal tissues.[2,10,11,21] Moreover, the evidence suggests that polyether material is more likely to produce impressions with superior detail reproduction in the presence of moisture;[47] however, impression materials with hydrophilic structures may also be prone to moisture absorption, resulting in modification of the dimensional accuracy.[42]

Flow characteristics, or rheological properties

Wettability or flowability of an impression material relates to the ability of the material to flow into small areas[10] and reproduce minute details.[13] Impression materials with a low wetting angle flow extensively and are good candidates to be used in prosthodontics. These types of material produce impressions with fewer voids and less entrapment of oral fluids, providing more accurate impressions.[10,12] Most PVSs have a moderately high wetting angle and new PVSs have improved. Finally, impression materials need to readily flow into minute details in the range of 20 to 70 μm, which is necessary for perfectly adapted crowns and bridges.[43-46] A light-body material possesses excellent flow characteristics, but tends to flow off the preparation. The newer PVS and polyether materials have been modified to become thixotropic: they remain in place where syringed, but flow when the heavier body tray materials are placed on top.[13] The intrinsic benefits of these thixotropic materials are controlled flow out of the syringe, and the ability to remain stable while in the tray with no uncontrolled intraoral flow.

Flexibility

Flexible impressions are easier to remove from the mouth when set. It is therefore important to have an impression material flexible enough to overcome the undercuts in the adjacent teeth and other intraoral structures (mandibular tori, pontics, embasures, etc). Once polyether material has set, it tends to be the most rigid impression material, the opposite of alginates, which are considered the most flexible of all. Polyethers are not recommended in cases presenting long, thin preparations of periodontally involved teeth. PVS is fairly stiff, and depending on the viscosity of the material, flows readily to capture areas of detail. Clinical studies have shown that viscosity is the important factor in producing impressions and dies with minimal bubbles and maximum detail.[10] In fact, fracture of delicate gypsum dies is a common occurrence due to the rigidity of polyether materials, especially if multiple casts are poured from the same impression.[11]

Viscosity

The ability to cease flowing once the impression is fully seated in the mouth is an important characteristic of impression materials. This is often described as thixotropic behavior. Manufacturers claim that when an impression material has high flow under pressure, but low flow under gravity, such material shows thixotropy. Drip or run-off tests have been used to demonstrate this effect.[48] The viscosity of a fluid is its resistance to flow. This parameter is the ratio of the shear stress to the shear rate. Shear stress (T) is the force per unit area acting on a fluid. Shear rate (γ) is the slope of the velocity-distance curve, or velocity gradient of the material. Thus, flow properties can be dependent on shear rate, but they may also depend on the shear history of the material. Thixotropy occurs when shearing a fluid causes reversible structural breakdown.

A number of investigations into the rheological behavior of elastomeric impression materials have been conducted, including the time-dependent viscoelastic behavior of the mixed material,[49,50] after which it undergoes crosslinking reactions,[51] which ultimately produce the final product. Initially, the mixed materials are expected to behave as viscous liquids able to flow easily over prepared teeth, soft tissues, or restorations, to produce an accurate and detailed replica, but over clinically reasonable time periods develop elastic properties to retain the shape and strength of the negative replica.[51,52] The final impression must have an appropriate elastic modulus to permit its removal from the dental surfaces, including undercuts, without damage.[53] Studies have shown mass loss over long periods for polyether impressions compared to PVS.[54,55] Viscoelastic materials are neither ideal solids nor ideal fluids, but show characteristics of both, so the shear stress depends on both strain and strain rate.[56] The nature of such behavior often depends on the strain rate, with more fluid-like characteristics exhibited at low strain rates and more solid-like (elastic) characteristics at high strain rates. For the polymerizing, freshly mixed dental impression materials, one would expect more fluid-like behavior initially, followed by more elastic behavior as crosslinking ensues at a given constant strain rate.

Elastomeric impression materials are found in different viscosities: from very low to very high viscosity putty materials. The main difference between the different viscosities is the amount of inert filler in the material. In fact, the low viscosity material gives better fine detail reproduction but has greater polymerization shrinkage during setting reaction. Thus, the optimum mixture for accurate impression making is to use as little low-viscosity material as possible to capture the fine detail of the prepared margin, while the mass of the impression material should be made with high viscosity.[13]

Deformation and tear energy

According to Chai et al, three mechanical properties of elastomeric impression materials are clinically relevant: the yield strength, the strain at yield point, and the tear energy.[57] The yield strength determines the ability of the impression to withstand stress without permanent deformation. The strain at yield point indicates the amount of undercut an impression material can overcome without permanent elastic deformation, and the tear energy indicates the resistance to tear of the material after setting.[10,11,58] Where subgingival margins are concerned, this can be an important criterion. A performing material should display high tear energy and adequate elastic recovery and should require the expenditure of large amounts of energy to initiate and propagate tearing.

Polysulfides display higher tear energy, but permanently deform after being stretched to 0.4%, which is the critical point of permanent deformation, and do not recover completely elastically.[10,23] PVS and polyethers tear before the limit of permanent deformation and are considered to have the highest tear strengths.[10] Therefore, their clinical use is more suitable, as they will deform in the range of their yield strength.[59]

Material incompatibilities

PVS and polyether materials may react with remnants of hydrogen peroxide. PVS may generate foam, thus preventing an accurate reproduction of the preparation margin.

Metal salts, which are contained in many astringents or retraction solutions with adrenalin and ferric sulphate used for haemostasis, may inhibit the setting process of PVS and polyethers. The result is an insufficient setting of the material, especially in the critical sulcus region. Epinephrines and aluminum sulfate have no inhibitory effect on impression material polymerization.[60] Also, unset residues of methacrylate composites used for abutment completion or core build-up, or a temporary restoration of methacrylate, can interrupt the setting process and, thus, have to be removed carefully with alcohol, followed by water, then thoroughly dried. If large surfaces of dentin have been exposed during the preparation, an immediate bonding of the surface is recommended.[61,62] The smear layer should be removed with alcohol. A better way to avoid interaction with impression materials, the inhibition layer of bonding must be eliminated by curing the adhesive with glycerin gel or DeOx (UltraDent, South Jordan, UT). Plus, individual trays made from polymethylmethacrylate (auto-cured) must rest at least 12 hours to guarantee the end of the shrinking process. Latex gloves used when working with hand-mixed PVS putty materials can negatively influence the setting behavior of the impression materials.[63] The polymerization of PVS can be inhibited by direct contact with 96% of latex products (gloves and rubber dams)[64,65] or indirectly by hands that had previously been wearing gloves.[66] Even intraoral contact of teeth and surrounding soft tissues with latex gloves has been implicated with inhibition of PVS polymerization.[67-69] Vinyl gloves can be worn safely and have no adverse effect on polymerization.[64] No other impression materials are affected by latex gloves.[70] Cleaning agent remnants, such as orange oil, ethanol, and chloroform, may also impair the setting process. Therefore, to avoid negative interactions, the abutments should be carefully cleaned and rinsed with water.

Description of impression material families

The choice of impression materials depends mainly on the subjective choice of the operator. It is based on personal preferences, handling, and the impression techniques used. In recent years, dentists have tended to use PVS and polyethers because of their improved physical and mechanical properties.[9,18-20] A detailed description of the different families of impression materials will be given. It is important to note that if it is theoretically possible to mix different materials from different family categories, doing so is not advised.

Polyethers

Polyethers have been on the market since the late 1960s. Examples are Impregum®, Permadyne® (3M ESPE®, Minneapolis, MN), and Polygel® (L.D. Caulk, Milford, DE). Polyethers contained in the base paste are composed of a long-chain of polyether copolymer with alternating oxygen atoms, methylene groups, and reactive terminal groups. The ends of these macromolecular chains are converted into reactive rings, which transform into crosslinked final products. This is done under the influence of the cationic initiator of the catalyst paste. The reactive ring of the polyether is opened by a cationic catalyst then, as a cation itself, attacks and opens other rings, creating a chain reaction. Whenever a ring is opened, the opening cationic starter remains attached to the former ring, thus lengthening the chain. This unique setting mechanism causes a "snap-set" behavior, which refers to the rapid transition from the working stage to the completed setting.[71] This behavior is an advantage preventing the material from setting before the working time is due and when it sets, it is immediate.[72,73]

Polyethers are moderately hydrophilic and can capture accurate impressions in the presence of some saliva or blood; however, they require a dry preparation to make an acceptable impression. Because their wetting angle is low, they capture a full arch impression easier than with PVS.[10] Their ability to reproduce details is excellent, they are dimensionally stable, and they allow multiple pours of accurate casts for 1 to 2 weeks, provided there is no tearing of the impression. They are rigid materials and are more difficult to remove than PVS.[10,24] In fact, significant force must be used to remove the impression, sometimes exceeding the tear strength of the material. Recent generations have improved formulas such as the "soft" polyethers (Impregum Soft and Impregum Penta Duo Soft, 3M/ESPE) that are easier to remove but still more rigid than PVS. Having high tear strength, they do not tear easily, which allows the clinician to get good subgingival detail on removal. However, the rigidity of polyether materials can be a disadvantage, particularly when the patient has existing fixed prostheses or multiple open gingival embrasures due to loss of periodontal support. In these cases, it is advisable to use a more flexible material and to block the undercuts with utility wax before impression making.[13] Fracture of delicate gypsum dies is a common occurrence due to this rigidity.[13] Strict disinfection guidelines should be respected with polyethers to prevent expansion of the material. Spraying the impression with a disinfectant such as sodium hypochlorite for 10 minutes is recommended,[74] as is rinsing and drying immediately before pouring casts.[75] Dimensional expansion of a polyether impression can only be seen if it has absorbed moisture.[76] The material's taste is bitter. The setting time is short (from 4 to 5 minutes), and the set is not altered or contaminated by latex gloves.

Poly(vinyl siloxane)

PVS impression materials or addition-cured silicones (type A) have been on the market since the mid-1970s. Popular examples are Express (3M Dental Products), Extrude (Kerr Corporation, Orange, CA), and Aquasil (Caulk/Denstply, Milford, DE). PVS has become the most widely used impression material in restorative dentistry.[40] Also called addition silicone and vinylpolysiloxane, PVS exploits the principle of "addition reaction curing." As opposed to condensation curing materials that experience shrinkage as a result of byproduct evaporation, PVS remains dimensionally stable. The reaction involves the linking of a vinylsiloxane in the base material with a hydrogen siloxane via a platinum catalyst.[10,21] The reaction produces hydrogen, which is scavenged by platinum or palladium. PVS has the best fine detail reproduction and elastic recovery of all available materials, and thus is the impression material of choice for fixed prosthodontics.[13,47] It is provided with a wide variety of viscosities: from very low viscosity for use with a syringe or wash material to medium, high, and very high viscosity. The viscosity depends on the amount of silica filler, which results either as a putty or as a less viscous wash material. PVS has one disadvantage: it is susceptible to contamination. PVS contamination is usually a result of sulfur or sulfur compounds[10,13] such as with latex gloves or rubber dams.[77] Small amounts of sulfur interfere with the setting of the critical surface by contaminating the chloroplantinic acid catalyst. A contaminated impression is more likely to produce inaccuracies, therefore leading to distortion.[11] In fact, any contact of unpolymerized PVS with latex will result in direct inhibition of the polymerization of the material. This can also occur if the putty material is mixed while wearing gloves or if latex gloves are worn before mixing.[13,77-79] Indirect inhibition of polymerization can occur intraorally when latex gloves contact tooth preparations or the surrounding periodontium, or during gingival retraction procedures.[66,68,80] Sulfur-containing gingival retraction chemicals may contribute to the inhibition.[81,82] Another source of contamination is the oxygen-inhibited layer on the surface of composites that appears immediately after curing. This thin layer causes impressions to remain tacky around new composite restorations.[13] A film of unset material in isolated areas or the presence of a sticky substance on the surface of the impression is a sign of inhibited polymerization. Polyether and polysulfide materials also coat the preparations with a chemical film that inhibits PVS's set.[9,13] The preparation and adjacent soft tissues can be cleaned with 2% chlorhexidine to remove contaminants.[10] PVS is also thermally sensitive; its setting time is proportional to temperature rise.[13]

PVS is generally hydrophobic. The new hydrophilic PVSs, like Aquasil,[12,22] have improved wettability,[9,12,33,40] but they are only clinically acceptable under dry conditions.[43] The hydrophilization of PVS is enhanced with the incorporation of certain nonionic surfactants. The clinical advantage of these less-hydrophobic PVSs is the facility to pour the impression.[40] Moisture from saliva or blood can interfere with accurate impressions. Loss of detail at impression margins is caused by many factors, and moisture presence must be considered.[11,41] PVS has the best elastic recovery (over 99%) of all available impression materials,[13,81] an excellent ability to reproduce detail, and is dimensionally stable, which allows multiple pours of accurate casts for several weeks.[2,83] The material is moderately rigid (less than polyethers), has good tear strength, and can be more easily removed than polyether materials.[83,84] PVS are best used in conjunction with an acrylic resin custom tray.[40] Their setting time is relatively short (4 to 5 minutes). They are clean, odorless, and tasteless. Refrigeration of the syringe material will extend the working time approximately 1.5 minutes without affecting the accuracy.[85] This augmentation of working time is useful in full-arch impression making. PVS can be used with most disinfection protocols and may be cold sterilized without danger of distortion.[75]

Polysulfides

Polysulfides are also called thiocols or "rubber base" (e.g., Permlastic, SDS/Kerr). The crosslinking of polysulfides is brought about by the polycondensation in which water is the reaction product. Some polysulfides may be categorized as a toxic substance, primarily due to the heavy metal (lead) oxides contained in the reactor paste.[86] The base consists of a polysulfide polymer (terminal chain/side chain-SH groups), titanium dioxide, or silica. The accelerator (catalyst) is primarily lead dioxide. The viscosity is altered by adding different amounts of titanium dioxide powder to the base. It sets by oxidation of the –SH groups, which results in chain lengthening and crosslinking, giving it its elastomeric properties.[10,24] Polysulfide impression materials are generally low to moderately hydrophilic and make an accurate impression in the presence of some saliva or even blood. They reproduce details with excellent results, but their dimensional stability is only fair.[18,20,21,24,87] They are not a rigid material, and impressions are easier to remove than with polyethers or PVS. Plus, they generally capture a subgingival margin upon impression without tearing on removal, which is better than PVS. Compared to polyethers and silicones, they do not have a good elastic recovery. After the clinically recognizable hardening, the crosslinking continues. During this ongoing reaction, the elasticity and elastic recovery increase considerably. Polysulfide impressions should therefore be left in the mouth another 5 minutes beyond the clinical set.[88] The setting time is thus relatively long (12 minutes). Immediate pouring is recommended. It may allow for more than one pour if it is not thin in areas. Finally, care should be taken during disinfection procedures to avoid swelling of the impression if it is kept more than 10 minutes in disinfectant or water. The strong bitter taste is also a disadvantage.

Condensation silicones

The base of the condensation silicone category consists of polydimethyl siloxane with hydroxyl-terminated groups and fillers. The base may contain the reactor tetrafunctional alkoxysilanes, which in the presence of a catalyst such as dibutyl or stanneous octoate, will react with the hydroxyl groups, splitting off alcohol, and causing crosslinking. After curing, subsequent and inevitable evaporation of the alcohol results in shrinkage of the material. A further problem encountered is the difficulty of obtaining the correct proportions when hand-mixing. This may cause the working and setting time of the material to vary, thus indirectly affecting the quality of the impression.[81,89] Popular brands are Optosil/Xantopren (Heraeus Kulzer, South Bend, IN), and Speedex (Coltene Whaledent, New York, NY).

Material types and consistencies according to ISO 4823:2000

The accuracy of any impression is closely related to the viscosity of the setting material. In fact, the ISO standard for elastomeric impression materials characterizes materials according to their consistency: Type 0 (putty) and type 1 (heavy-bodied) have consistencies $\leq$ 35 mm, and impressions with these materials should be made in one or two steps. Type 2 (medium-bodied) has a consistency between 31 to 41 mm, and impressions are made in one step. Finally, type 3 (light-bodied) has a consistency $\geq$ 36 mm, and a syringe is used for making the impression.[90]

Presentation

Most materials are provided as base/catalyst systems. They are provided in cartridges (Pentamix, 3M ESPE) or impression guns (Denstply/Caulk or 3M ESPE) for auto-mixing and tubes or containers for hand spatulation. Hand mixing of putty depends on the initial temperature of the pastes. The initial high temperature reduces the working time. Auto-mixing products require no mixing pads or spatulation, and they are less time consuming. There may be less waste of materials associated with mechanically mixing systems[91] because they are loaded from the dispenser directly into the syringe or tray.[91,92] This technique is more homogeneous and bubble-free, with fewer inherent voids, resulting in more accurate casts. There is no risk of negative interaction with gloves.[93,94]

Conclusion

An ideal impression material is still difficult to find. For every physical property there is another affecting it or an environmental factor modifying it. CAD/CAM systems are progressing rapidly; in the near future, they might become accessible to everyone, and impressions will be easier and more precise. The practitioner should be aware of all impression material properties and their interactions to know the limitations of each product when using it, even under the best conditions available. Making an acceptable impression depends on intrinsic factors in relation to the material properties and extrinsic factors like the oral environment (blood, saliva, dry conditions), the skills of the operators (dentist, dental assistant), and the ability to pour the impressions within minutes. All these factors give an accurate and reliable impression as the final result.

Acknowledgments

The authors would like to thank Dr. H. Abi Aad for his help in reviewing the manuscript.

References

1. German MJ, Carrick TE, McCabe JF: Surface detail reproduction of elastomeric impression materials related to rheological properties. Dent Mater 2008;24:951-956
2. Rubel BS: Impression materials: a comparative review of impression materials most commonly used in restorative dentistry. Dent Clin North Am 2007;51:629-646
3. Tjan AH, Li T, Logan GI, et al: Marginal accuracy of complete crowns made from alternative casting alloys. J Prosthet Dent 1991;66:157-164
4. Tinschert J, Natt G, Mautsch W, et al: Marginal fit of alumina- and zirconia-based fixed partial dentures produced by a CAD/CAM system. Oper Dent 2001;26:367-374
5. Gelbard S, Aoskar Y, Zalkind M, et al: Effect of impression materials and techniques on the marginal fit of metal castings. J Prosthet Dent 1994;71:1-6
6. Clancy JM, Scandrett FR, Ettinger RL: Long-term dimensional stability of three current elastomers. J Oral Rehabil 1983;10:325-333
7. Lin CC, Donegan SJ, Dhuru VB: Accuracy of impression materials for complete-arch fixed partial dentures. J Prosthet Dent 1988;59:288-291
8. Christensen GJ: What category of impression material is best for your practice? J Am Dent Assoc 1997;128:1026-1028
9. Mandikos MN: Polyvinylsiloxane impression materials: an update on clinical use. Aust Dent J 1998;43:428-434
10. Craig RG: Restorative Dental Materials (ed 11). St Louis, Elsevier, 2001, p. 12
11. Anusavice KJ: Philips' Science of Dental Materials (ed 11). Philadelphia, Saunders, 2003, p. 12
12. Panichuttra R, Jones RM, Goodacre C, et al: Hydrophobic polyvinyl siloxane impression materials: dimensional accuracy, wettability, and effect on gypsum hardness. Int J Prosthodont 1991;4:240-248
13. Donovan TE, Chee WWL: A review of contemporary impression materials and techniques. Dent Clin N Am 2004;48:445-470
14. Pant R, Juszczyk AS, Clark RFK, et al: Long–term dimensional stability and reproduction of surface detail of four polyvinyl siloxane duplicating materials. J Dent 2008;36:456-461
15. Chee WWL, Donovan TE: Fine detail reproduction of very high viscosity polyvinylsiloxane impression materials. Int J Prosthodont 1989;2:368-370
16. Klooster J, Logan GI, Tjan AH: Effects of strain rate on the behavior of elastomeric impressions. J Prosthet Dent 1991;66:292-298
17. McCabe JF, Ariwaka H: Rheological properties of elastomeric impression materials before and during setting. J Dent Res 1998;77:1874-1880
18. Shen C: Impression materials. In: Anusavice KJ (ed): Philips' Science of Dental Materials (ed 11). Philadelphia, Saunders, 2003, pp. 210-230
19. Craig RG, Urquiola NJ, Liu CC: Comparison of commercial elastomeric impression materials. Oper Dent 1990;15:94-104
20. Williams PT. Jackson DG, Bergman W: An evaluation of the time-dependant dimensional stability of eleven elastomeric impression materials. J Prosthet Dent 1984;52:120-125

21. Derrien G, Le Menn G: Evaluation of detail reproduction for three die materials by using scanning electron microscopy and two-dimensional profilometry. J Prosthet Dent 1995;74:1-7
22. Lacy AM, Bellman T, Fukui H, et al: Time-dependent accuracy of elastomeric impression materials. Part II. Polyether, polysulfides, and polyvinyl siloxane. J Prosthet Dent 1981;45:329-333
23. Williams PT, Jackson DG, Bergman W: An evaluation of the time-dependent dimensional stability of eleven elastomeric materials. J Prosthet Dent 1984;52:120-125
24. Giordano R 2nd: Impression materials: basic properties. Gen Dent 2000;48:510-516
25. McMurry J: Fundamentals of Organic Chemistry (ed 4). Pacific Grove, CA, Brooks/Cole Publishing Co., 1998, pp. 36-45
26. Anusavice KJ: Phillips' Science of Dental Materials (ed 11). Philadelphia, Saunders, 2003, pp. 205-231
27. McCabe JF, Carrick TE: Recording surface detail on moist surfaces with elastomeric impression materials. Eur J Prosthodont Restor Dent 2006;14:42-46
28. Walker MP, Petrie CS, Haj-Ali R, et al: Moisture effect on polyether and polyvinylsiloxane dimensional accuracy and detail reproduction. J Prosthodont 2005;14:158-163
29. Pratten DH, Craig RG: Wettability of a hydrophilic addition silicone impression material. J Prosthet Dent 1989;61:197-202
30. Mc Murry J: Fundamentals of Organic Chemistry: Their Correlation with Chemical Structure (ed 4). Pacific Grove, CA, Brooks/Cole Publishing, 1998, pp. 36-45
31. Johnson GH, Lepe X, Aw TC: The effect of surface moisture on detail reproduction of elastomeric impressions. J Prosthet Dent 2003;90:354-364
32. Peutzfeldt A, Asmussen E: Impression materials: effect of hydrophilicity and viscosity on ability to displace water from dentin surfaces. Scand J Dent Res 1988;96:253-259.
33. Boening KW, Walter MH, Schuette U: Clinical significance of surface activation of silicone impression materials. J Dent 1998;26:447-452
34. Mandikos MN: Polyvinyl siloxane impression materials:an update on clinical use. Aust Dent J 1998;43:428-434
35. Craig RG, O'Brien WJ, Powers JM: Dental Materials. Properties and Manipulation (ed 6). St. Louis, Mosby, 1996, pp. 136-177
36. Craig RG, Powers JM: Restorative Dental Materials (ed 11). St Louis, Mosby, 2001, pp. 348-367
37. Pratten DH, Craig RG: Wettability of a hydrophilic addition silicone impression material. J Prosthet Dent 1989;61:197-202
38. Panichuttra R, Jones RM, Goodacre C, et al: Hydrophilic poly(vinyl siloxane) impression materials:dimensional accuracy, wettability, and effect on gypsum hardness. Int J Prosthodont 1991;4:240-248
39. Ritter AV, Swift EJ Jr: Medium-viscosity polyether impression material: a case report. Compend Contin Educ Dent 2000;21:993-996, 998, 1000
40. Chee WWL, Donavan TE: Polyvinylsiloxane impression materials: a review of properties and techniques. J Prosthet Dent 1992;68:728-732
41. Balkenhol M, Haunschild S, Lochnit G, et al: Surfactant release from hydrophilized vinylpolysiloxanes. J Dent Res 2009; 88:668-672
42. Walker MP, Petrie CS, Haj-Ali R, et al: Moisture effect on plyether and polyvinylsiloxane dimensional accuracy and detail reproduction. J Prosthodont 2005;14:158-163
43. Shillingburg HT, Hobo S, Whitsett, LD, et al: Fundamentals of Fixed Prosthodontics (ed 3). Chicago, Quintessence, 1997, pp. 299-300
44. Petrie CS, Walker MP, O'Mahony AM, et al: Dimensional accuracy and surface detail reproduction of two hydrophilic vinyl siloxane impression materials tested under dry, moist and wet conditions. J Prosthet Dent 2003;90:365-372
45. Bindl A, Mormann WH: Marginal and internal fit of all-cermaic CAD/Cam crown copings on chmafer preparations. J Oral Rehabil 2005;32:441-447
46. Boeckler AF, Stadler A, Jurgen M: The significance of marginal gap and overextension measurement in the evaluation of the fit of complete crowns. J Contemp Dent Pract 2005;6:1-12
47. Michalakis KX, Bakopoulou A, Hirayama H, et al: Pre and post set hydrophilicity of elastomeric impression materials. J Prosthodont 2007;16:238-248
48. Zech J, Reusch B: Rheological properties of different type 3 PVS [sic] impression materials. J Dent Res 1999;78:317(Abstract no 1692). Cited in: Martinez JE, Combe EC, Pesun IJ: Rheological properties of vinyl polysiloxane impression pastes. Dent Mater 2001;17:471-476
49. Braden M: Characterization of the setting process in dental polysulfide rubbers. J Dent Res 1966;45:1065-1071
50. Omori K, Arikawa H: Rheological properties of elastomeric impression materials based on surface compressive strength. J Oral Rehabil 2001;28:320-327
51. Herfort TW, Gerberich WW, Macosko CW, et al: Viscosity of elastomeric impression materials. J Prosthet Dent 1977;38:396-404
52. Craig RG: Restorative Dental Materials (ed 11). St. Louis, Mosby, 2001, pp. 330-369
53. Powers JM, Wataha JC: Dental Materials. Properties and Manipulation (ed 7). St. Louis, Mosby, 2000, pp. 139-140, 162-177
54. Lepe X, Johnson GH, Berg JC: Surface characteristics of polyether and addition silicone impression materials after long term disinfection. J Prothet Dent 1995;74:181-186
55. Lepe X, Johnson GH, Berg JC, et al: Wettability, imbibitions and mass change of disinfected low viscosity impression materials. J Prosthet Dent 2002;88:268-276
56. Darby R: Viscoelastic Fluids: An Introduction to Their Properties and Behavior. New York, Dekker, 1976, pp. 76-77
57. Chai J, Takahashi Y, Lautemschlager EP: Clinically relevant mechanical properties of elastomeric impression material. Int J Prosthodont 1998;11:219-223
58. Little J: Dental Management of the Medically Compromised Patient (ed 6). St. Louis, Elsevier, 2002, pp. 545-547
59. Hondrum SO: Tear and energy properties of three impression materials. Int J Prosthodont 1994;7:517-552
60. de Carnago LM, Chee WWL, Donovan TE: Inhibition of polymerisation of polyvinylsiloxane by medicaments used on gingival retraction cords. J Prosthet Dent 1993;70:114-117
61. Bertschinger C, Paul SJ, Luthy H, et al: Dual application of dentin bonding agents. Effect on bond strength. Am J Dent 1996;9:115-119
62. Paul SJ, Schärer P: The dual bonding technique. A modified method to improve adhesive luting procedures. Int J Periodontics Restorative Dent 1997;17:536-545
63. Kahn RL, Donovan TE: A pilot study of polymerization inhibition of poly (vinyl siloxane) materials by latex gloves. Int J Prosthodont 1989;2:128-130
64. Kahn RL, Donovan TE, Chee WWL: Interaction of gloves and rubber dam with poly (vinyl siloxane) impression material: a screening test. Int J Prosthodont 1989;2:342-346
65. Noonan JE, Goldfogel MH, Lambert RL: Inhibited set of the surface of addition silicones in contact with rubber dam. Oper Dent 1986;2:46-48

66. Reitz CD, Clark NP: The setting of vinyl polysiloxane and condensation silicone putties when mixed with gloved hands. J Am Dent Assoc 1988;116:371-375
67. Chee WWL, Donovan TE, Kahn RL: Indirect inhibition of polymerization of a polyvinyl impression material : a case report. Quintessence Int 1991;22:133-135
68. Kahn RL, Donovan TE: A Pilot study of polymerization inhibition of poly (vinyl siloxane) materials by latex gloves. Int J Prosthodont 1989;2:128-130
69. Kahn RL, Donovan TE, Chee WWL: Interaction of latex gloves and poly (vinyl siloxane) impression materials: a screening survey. Int J Prosthodont 1989;2:342-346
70. Baumann MA: The influence of dental gloves on the setting of impression materials. Br Dent J 1995;179:130-135
71. Powers JM, Sakaguchi RL: Impression materials. In Powers JM, Sakaguchi RL (eds): Craig's Restorative Dental Materials (ed 12). St. Louis, Mosby, 2006, pp. 294-295
72. Phoenix RD: Stewart's Clinical Removable Partial Prosthodontics (ed 3). Chicago, Quintessence, 2002, pp. 162-167
73. Adabo GL, Zanarotti E, Fonseca RG, et al: Effect of disinfectant agents on dimensional stability of elastomeric impression materials. J Prosthet Dent 1999;81:621-624
74. Johnson GH, Drennon DG, Powell GL: Accuracy of elastomeric impression materials disinfected by immersion. J Am Dent Assoc 1988;116:525-530
75. Cottone JA, Molinari JA: State-of-the-art infection control in dentistry. J Am Dent Assoc 1991;122:33-41
76. Hembree JH, Jr., Nunez LJ: Effect of moisture on polyether impression materials. J Am Dent Assoc 1974;89:1134-1136
77. Noonan JE, Goldfogel MH, Lambert RL: Inhibited set of the surface of addition silicones in contact with rubber dam. Oper Dent 1986;2:46-48
78. Neissen LC, Strassler H, Levinson PD, et al: Effect of latex gloves on setting time of polyvinylsiloxane putty impression material. J Prosthet Dent 1986;55:128-129
79. Reitz CD, Clark NP: The setting of vinyl-polysiloxane and condensation silicone putties when mixed with gloved hands. J Am Dent Assoc 1988;116:371-375
80. Kahn RL, Donovan TE: A pilot study of polymerization inhibition of poly (vinyl siloxane) materials by latex gloves. Int J Prosthodont 1989;2:128-130
81. Anusavice KJ: Phillips' Science of Dental Materials (ed 11). Philadelphia, Saunders, 2003, p. 216
82. Boening KW, Walter MH, Schuette U: Clinical significance of surface activation of silicone impression materials. J Dent 1998;26:447-452
83. Lacy AM, Fukui H, Bellman T, et al: Time-dependant accuracy of elastomeric impression materials. Part II: polyether, polysulfides, and polyvinylsiloxane. J Prosthet Dent 1981;45:329-333
84. Donovan TE: A review of contemporary impression materials. Calif Inst Cont Educ 1988;27:9-19
85. Chew CL, Chee WWL, Donovan TE: The influence of temperature on the dimensional stability of poly (vinyl-siloxane) impression materials. Int J Prosthodont 1993;6:528-532
86. Spranley TJ, Gettleman L, Zimmerman KL: Acute tissue irritation of polysulfide rubber impression materials. J Dent Res 1983;62:548-551
87. Ciesco JN, Mlaone WF, Sandrik JL, et al: Comparison of elasotmeric materials used in fixed prosthodontics. J Prosthet Dent 1981;45:89-94
88. Nayyar A, Tomlins CD, Fairhurst CW, et al: Comparison of some properties of polyether and polysulfide materials. J Prosthet Dent 1979;42:163-167
89. Wöstmann B: Zum gegenwärtigen stand der abformung in der zahnheilkunde. Berlin, Quintessenz, 1998. In: A Guideline for Excellent Impressions in Theory and Practice. Espertise Magazine. Minneapolis, 3M ESPE 2008:1-60
90. ISO 4823 for Elastomeric Impression Materials. International Organization for Standardization (ISO) Technical Committee: Tc 106/Sc 2; 2000
91. Craig RG: Evaluation of an automatic mixing system for an addition silicone impression material. J Am Dent Assoc 1985;110:213-215
92. Soh G, Chong YH: Defects in automixed addition silicone elastomers prepared by puttywash impression technique. J Oral Rehabil 1991;18:547-553
93. Keck SC: Automixing: A new concept in elastomeric impression material delivery system. J Prosthet Dent 1985;54: 479-483
94. Di Felice R, Scotti R, Belser UC: The influence of the mixing technique on the content of voids in two polyether. Schweiz Monatsschr Zahnmed 2002;112:12-16