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Trends in Indirect Dentistry: 5. Impression Materials and Techniques

Abstract: A fundamental pre-requisite for the construction of satisfactory indirect restorations is the ability to record an accurate and detailed impression of the dental structures. Knowledge of the key properties of the available impression materials and their handling behaviour is necessary if they are to be used effectively. A variety of techniques can be employed in different situations, each of which can be highly successful, but only if attention is paid to the detail of their execution and the clinician is aware of their individual limitations and pitfalls. Where imperfections occur, an appreciation of how they have been caused, and the strategies to take to prevent them will lead to greater success in impression taking.

Clinical Relevance: Current materials exceed our needs in terms of accuracy and stability, and yet the impressions produced are frequently flawed. By realizing why faults occur, being aware of the range of techniques available and having an understanding of the behaviour of materials, clinicians can achieve the quality in their impressions that is possible and necessary to provide excellence in indirect restorations.

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Until the advent of intra-oral scanning and computer-aided manufacturing techniques, the construction of indirect restorations required a model or cast to be made, this being an accurate three-dimensional facsimile of the mouth and teeth. To create a cast, a mould or impression of the oral structures is obtained. The quality of the subsequently produced restoration depends first on having an accurately fabricated cast, which in turn depends on the ability of the impression to record the dimensions of the target objects faithfully. Dimensional accuracy is therefore the most fundamental property needed in an impression material. While there are many further steps in the manufacture of an indirect restoration at which errors and inaccuracies can occur, it is the dentist's responsibility to provide the technician with high quality impressions and records with which to work and, should returned restorations be ill-fitting or have defects, the clinician should first examine his or her own technique for flaws before looking elsewhere for possible culprits.

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	Polysulphide	Condensation Silicone	Polyether	Addition Silicone
Polymerization shrinkage (%)	0.4–0.45	0.4-0.6	0.2-0.25	0.14-0.17
Percentage recovery	97-95	98-97	98.5-98	99.9-99.6
Tear strengths (MPa)	0.5	1.6	2.0	2.4

Table 1. Properties of elastic impression materials. Low viscosity formulations quoted first.

Key properties

Which is the best impression material for indirect restorations? The choice is between:

- The inaccurately termed hydrocolloids (reversible – Agar, and irreversible – Alginate) and
- The elastomers: polysulphide, polyether and the silicones (type 1 condensation-cured; type 2 addition-cured).

Dimensional accuracy is dependent on the changes occurring as the material sets. Shrinkage occurs as the molecules move together to form polymer chains, and form cross linkages. There is also some

shrinkage as the material cools on removal from the warm mouth (Table 1). Although the polyethers and addition silicones achieve the highest dimensional accuracy, all of these materials (even alginate with a specific technique) are capable of *sufficient* dimensional accuracy for use in making indirect restorations.

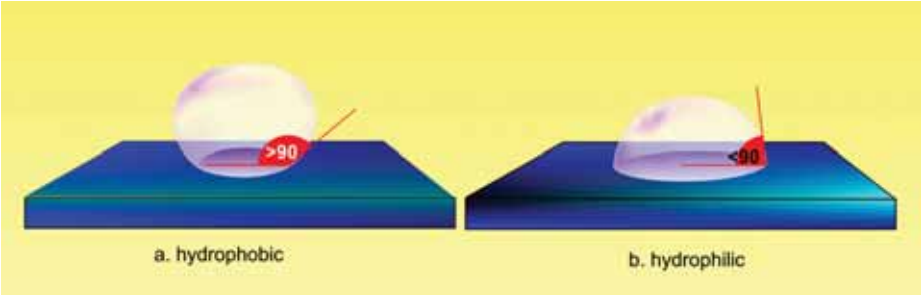


Figure 1. Contact angles of a water droplet on a hydrophobic and a hydrophilic surface.

Dimensional stability

As well as being able to record accurately, it is clearly desirable for the material to maintain that accuracy for a convenient length of time, ie the material should have good dimensional stability, or at least one should know for how long the impression will be sufficiently accurate so that it can be used intelligently, and how storage conditions may affect its stability. Polysulphide and type-1 silicones produce water and ethanol, respectively, during their polymerization. This results in their shrinkage, with over half of the total shrinkage occurring in the first hour after removal. Although the distortion occurring is not as severe as in the hydrocolloids, it is advisable to pour these materials quickly – within 48 hours in the case of polysulphides.[1] For type-1 silicones the recommended times range from 30 minutes[2] to within 6 hours.[1] The polymerization of polyethers and type-2 silicones involves an addition reaction with no volatile by-products being created, and their polymerization shrinkage is very small. The chemistry of the polyethers, however, encourages water absorption and swelling, and so they must be stored dry until casting. They should also be shielded from strong sunlight during storage. Reversible hydrocolloid, when set, is composed mainly of water (85%) and will swell or shrink as it absorbs or releases water, according to its environment. Even when stored in 100% humidity, it must be poured within one hour to prevent clinically unacceptable distortion occurring.[3] Alginate is similarly affected but to a lesser degree; comparable storage for up to two hours is advised before pouring. However, disinfection by immersion will affect dimensional stability.

Hydrophilicity

As the mouth is a wet environment, a moisture-loving material would be expected to work better in the presence of blood and saliva. The hydrocolloids are truly hydrophilic and can produce detailed impressions in a wet field. The polyethers are hydrophilic in that they will absorb moisture, but still require an essentially dry field to capture detail. The other elastomers are hydrophobic and do not readily wet surfaces, ie they have no natural tendency to flow across prepared teeth. This makes it difficult for the casting material to wet and flow into the set impression material, and may give rise to voids or loss of detail in the produced casts. To combat this, manufacturers of the addition silicones have added surfactants to lower surface tension, creating the so-called hydrophilic silicones.[4,5] It is important for clinicians to understand what this means in terms of the use of such materials. The degree of hydrophilicity is often quoted in terms of contact angle measurements. This refers to a test which essentially involves placing a drop of water on to the set surface of the material, and examining the shape formed after a fixed time period. On materials which are difficult to wet, the drop will be well rounded, and a high contact angle is created (Figure 1). Conventionally, angles greater than 90° define a hydrophobic material; less than 90° indicates hydrophilicity. Unfortunately for the clinician, test results from different manufacturers are rarely comparable as there are many test variables which are not standardized between different test laboratories. Also, testing the set material is only an indication as to which impressions are easiest to cast. Testing the unset material, which has been less frequently undertaken (because it is a more difficult test to perform) gives a better assessment of the likely wetting behaviour in the mouth.[6] The only practical benefit of increasing the hydrophilicity, however, is likely to be an improvement in the quality of casts, as studies suggest that the quality of impressions obtained clinically is unrelated to the surface activation of the material; the other material characteristics exert a greater influence on quality.[7,8] Despite their name, hydrophilic impression materials will not compensate for poor moisture control!

Detail capture

Elastomeric impression materials are required to record detail down to 20µ.[9] Such discriminatory ability is probably more than is required for indirect restorations, especially when it is considered that die-stones are only required to reproduce detail down to 50µ. However, these materials are successfully used to create replicas for microscopic examination of tissues and biological samples where there is a need to see structures considerably smaller than 20µ in size.

Permanent deformation

Impressions of the mouth will need to be withdrawn from tooth and tissue undercuts, and therefore must be sufficiently elastic to deform as they exit undercuts but then return to their original shape. Although international standards define the maximum permissible permanent deformation, manufacturers frequently refer to the converse, ie percentage recovery. Not surprisingly, highly-filled materials have slightly less elastic recovery than lower viscosity formulations. The addition silicones achieve over 99% recovery, and the type 1 silicones and polyethers reach between 98% and 99%. Flexibility is measured by strain in

	Polysulphide	Condensation silicone	Polyether	Addition silicone
Handling	Very sticky	Easy removal Protect hands while mixing	Sticky	Easy removal Reaction affected by some latex gloves. Protect hands while mixing
Taste	None	None	Bitter	None/some flavoured
Smell	Sulphurous odour	None	None	None/some scented
Colour	Usually brown	Wide variety	Limited	Wide variety
Setting time	Long – 10 minutes	4-6 minutes. Variable set times available	Fast	4-6 minutes Variable set times available Sensitive to temperature
Die plating	Silver	Usually not possible	Silver	Silver or Copper
Toxicity	Low	Very low	Some reactions reported in past[10,11]	Very low
Cost	Least expensive	Moderately expensive	Moderately expensive	Most expensive

Table 2. Additional impression material characteristics.

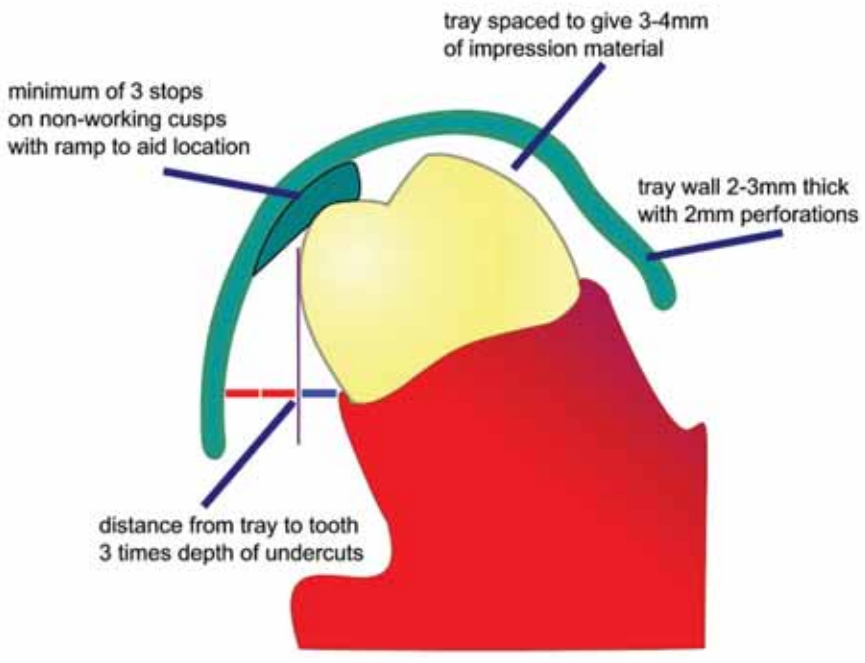


Figure 2. Features of a good individual tray, with particular reference to inclined teeth.

compression, the percentage change in length of a sample under a specific load. The polysulphides are more flexible than the other elastomers, among whom the condensation silicones are slightly more flexible than the type 2 silicones or polyethers of similar consistency. Where significant undercuts exist which need to be recorded, for example on tilted teeth, an addition silicone is less likely to distort on removal than the other materials. However, as it is also a stiff material when set, it could be difficult to disengage physically. To overcome this, a tray should be selected which allows an adequate bulk of material in the area – three times the depth of the undercut (Figure 2). A very rigid material may be indicated when it is crucial to prevent distortion of the relative positions of dies, as is the situation with implant restoration, but it may prove difficult to remove where moderate tissue undercuts are present. It may also be impossible to remove such an impression from a cast

with the same undercuts without dies and/or teeth breaking off in the process. The dentist should be alert to these potential problems and consider blocking out such undercuts clinically with cotton wool or waxes. Retrieved impressions should be cut back to remove material which reproduces these undercuts, prior to sending to the laboratory.

Tear strength

An impression should be able to record detail in narrow spaces such as the gingival crevice and preparation features like slots and grooves. It therefore needs to be strong in thin section if it is to be withdrawn intact from these sites. Polysulphides have recorded the highest tear strengths but, because they also have poor permanent deformation characteristics, they are not very reliable for recording areas of thin section. The type 2 silicones and the polyethers both have high tear strengths but there is little difference between them and the type 1 silicones. The hydrocolloids have much lower tear strengths. There are several other desirable characteristics to be considered when choosing an impression material as listed in Table 2.

Impression technique

As implied above, any of these materials has sufficient inherent accuracy for them to produce high quality restorations. Realizing their potential depends on the clinician understanding the material's properties and behaviour, and handling it so that any deficiencies are minimized. With the high quality of materials available to dentists over the past 40 years, technique is a much bigger factor in determining success or failure in indirect work than are material differences.

Figure 3. A poorly executed two-stage putty wash impression. Only a section of the putty has been covered by the wash, and the tray has not been fully seated, which resulted in a stepped cast.

Irreversible hydrocolloid and polysulphides will not be considered in this section. Most UK dentists are now using silicones or polyether, as they are more user and patient friendly than polysulphide. Those who are using reversible hydrocolloid are most likely to be specialist practitioners well versed in its use.

Putty/wash technique

Two-stage

Since elastomers shrink on polymerization, it follows that using a small volume of material will reduce the net effect of the shrinkage on the accuracy of the impression. Only a closely adapted custom tray would allow a small volume to be used. An alternative approach was proposed for the condensation silicones which allowed cheaper, time-saving stock trays to be used. A heavily filled 'putty' version, which therefore has reduced shrinkage, is effectively used to convert the stock tray into a close-fitting custom tray. As a second step, a lightly filled (higher shrinkage) material (the wash) is placed inside this 'tray' and re-seated. Very little of this low viscosity material is needed, hence little net shrinkage occurs, while good detail is recorded by its ability to flow more readily than the high viscosity putty. However, there are some problems with this technique. With such a close adaptation of the putty to the teeth, there is little space in which the wash material can flow, and the trapped material makes it difficult to reseat the tray (Figure 3). This leads to an uneven thickness in the wash, and uneven shrinkage. More importantly, the build-up of hydrostatic pressure acts to push the set putty and the walls of the tray outwards. When the impression is removed, the putty recoils and the resulting dies, which may appear flawless, will be narrower than the preparations, and the crowns made on these dies are unlikely to seat easily on the teeth.[12]

The use of more rigid (specifically metal) trays reduces the recoil from the tray but, to reduce the recoil which will occur in the set putty, modification of the putty must be made to allow release of the pressure. The putty should be generously cut back in the depths of the sulci (and palate in the upper arch), and several buccal and lingual sluices cut to

Figure 4. A first-stage putty impression. On the right side the impression has been marked to show where trimming has been carried out to remove the sulcus depths, and create several sluices. The interdental collets will also be removed to allow easy, positive re-seating.

Figure 5. Putty with spacer sheet of polythene prior to taking first-stage of two-stage impression.

Figure 6. First-stage putty impression with spacer removed.

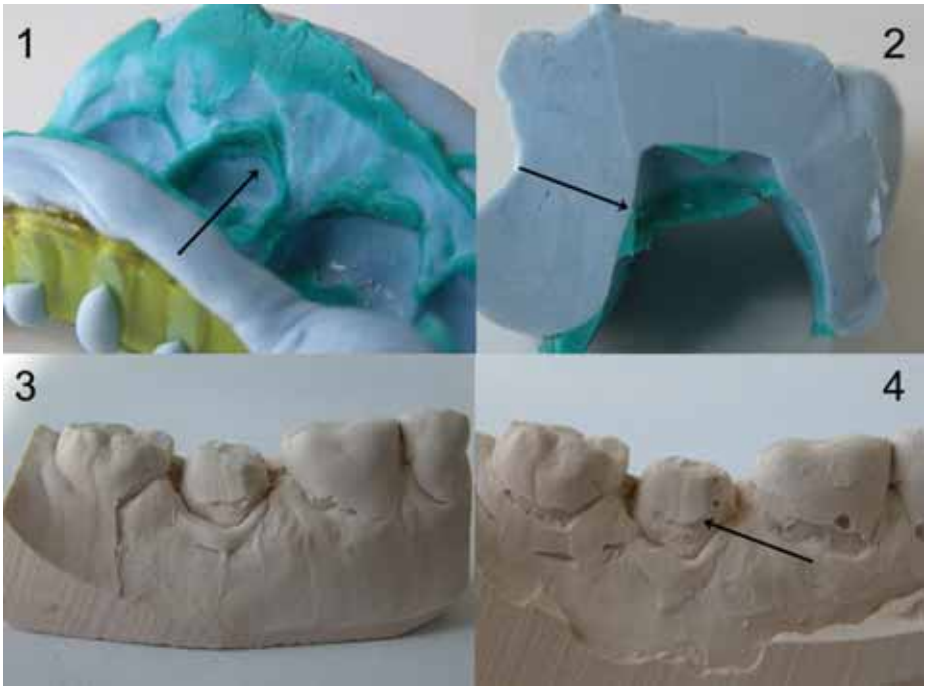


Figure 7. Impression showing failure of blending by putty and wash phases creating horizontal crease; arrowed **(1)** and in cross-section **(2)**. Resulting die shows corresponding ridge on preparation surface **(3, 4)**, with similar drag defects on adjacent teeth.

provide escape channels for the wash. The interdental collets should also be removed, and the modified putty impression replaced to check that it can be easily relocated (Figure 4). It may be thought that, if the first-stage putty impression is taken before any tooth preparation is performed, sufficient space will be created locally around that tooth. However, for this to be an effective method of overcoming recoil, the operator would have to place the exact volume of light body required to fill this space into the putty. Any excess would be unable to escape from the surrounding close-fitting putty, leading again to outward displacement of the putty and tray and/or difficulty seating the impression. Any flow of the light-bodied material which occurred across nearby teeth would create a step in the impression at the limit of its flow. A quicker method of creating room for the wash material to escape is to place a thin sheet of polythene over the putty as the first-stage is put into the mouth (Figure 5). On removal from the mouth, the polythene is discarded. This provides a thin space allowing movement of the wash in the second stage, and prevents the putty material passing interdentally or to the full sulcus depth (Figure 6). Spacer sheets can be purchased which have a raised pattern designed to increase the surface area for adhesion of the putty and wash. Bonding of the two phases does not appear, however, to be a problem as long as the putty surface has been carefully cleaned of saliva etc., and dried.

One-stage

Decreasing the number of steps should increase efficiency, and placing both materials in the tray for a one-stage impression is therefore an attractive option. Although seating difficulties are overcome, recoil of flexible trays still occurs. With such a contrast in the viscosities of the two materials, the wash may be pushed away by the putty, resulting in drags below undercut areas such as the axial surfaces of teeth and inclined preparations; critical areas (slots, grooves, finish margins) may be recorded by the putty alone which is less able to record fine detail. Where margins are extended into the gingival crevice, the unset putty will act to close up the gingival crevice, pushing out the wash and giving poor definition of essential margin detail. In the two-stage technique described previously, while the first putty phase is recorded, the crevice can be held open by retraction cord. At the second wash step, the pressure build-up occurring as the impression is re-seated tends to drive the wash into the opened crevice and clearer recording of the margins occurs.

A defect which, in the author's experience, occurs more with type 2 rather than type 1 putty/wash impressions and is not often recognized by the clinician, is failure of the two viscosities to blend fully. This manifests as a crease in the completed impression on the axial surfaces of teeth, frequently on the prepared teeth (Figure 7). This may be as a result of the relative differences in the surface tensions of the two viscosities, or it may be because the setting reaction of addition silicones starts earlier than for condensation silicones or polyethers, which means it develops elasticity quickly, and this effect is accelerated at increased temperature.[13] On placing the wash around the teeth, the material against the warm tooth will start to polymerize while the bulk of the wash still appears fluid. When the putty is applied, this partially set skin may be displaced or distorted, forming a crease. Since the wash is applied first to the prepared tooth, this effect is more likely to occur there. It is advisable, therefore, always to chill the wash material. Conversely, once apparently set, addition silicones need to be given longer to complete the reaction fully or distortion may occur on removing the impression. Although more steps are involved in a two-stage technique, it can be completed with a minimal increase in time. As the purpose of the first stage is only to create a custom tray, the putty impression can be removed before it has fully set, and this stage can be carried out at the start of the appointment while awaiting anaesthesia. Some practitioners make use of the putty taken before tooth preparation as a matrix with which to make a provisional restoration. This avoids the need for a separate impression with which to create a temporary restoration, and can also save time in temporization compared with the time taken to trim crown forms. However, any methacrylate type compounds, eg bis-acryl or methacrylate temporary crown materials, and also bonding resins which come into contact with addition silicones,

Figure 8. An excellent impression of multiple units achieved by careful preparation, moisture control, and gingival displacement. An individual tray with stops was indicated and a heavy and light combination of silicones used. Produced by a final year dental student (by kind permission of Ms E Hopkins).

will contaminate the platinum-containing catalyst and impede the setting of, and the bonding to, the light body silicone, so the putty must be carefully cleaned with alcohol to remove any temporary crown material residue.

Some laboratory studies suggest that the dies produced with single stage impressions are more dimensionally accurate than those from two-stage techniques.[14,15] Unfortunately, one can also find evidence that one-stage is superior[16,17] and that there is no significant difference in accuracy between the techniques.[18] Accuracy, however, is only one determinant of quality. Where margins extend into or close to the gingival crevice, the clear recording of the margins is also critical to producing acceptable restorations, and a careful two-stage technique can give superior marginal definition and avoid drag formation.

Heavy/light

The technique most often used with addition silicones is that originally devised for the condensation silicones, namely, one-stage putty and wash. Using any putty will give rise to recoil problems in non-rigid trays, and the potential offered by the superior material properties of the addition silicones will not be realized. Since the setting shrinkage of type 2 silicones is less than half that of the type 1 silicones, a less heavily filled material can be safely used in bulk in a stock tray placed simultaneously with a lighter viscosity material to capture detail. This gives the dentist the convenience of a single-stage method without its disadvantages; distortion of plastic trays is reduced, and the viscosities of the two materials are closer, which reduces drags and improves blending of the two phases. The lower viscosity material is not as readily displaced from the gingival crevice, permitting good margin definition, and the higher viscosity material can record detail better than a putty can (Figure 8). The heavy material is generally sufficiently thixotropic not to run out of the tray, but it requires some effort to express enough material from an automix syringe to fill a tray quickly. Automatic mixing machines introduced in the past few years overcome this problem; their extra cost must be weighed against the risks of repetitive strain injury! The polyether materials are not formulated as putties as they would be too rigid to use, and are used in a heavy/light combination, or in a single medium body viscosity – otherwise known as a monophase technique.

Monophase

The advantages of making impressions with a medium-bodied presentation are that the possible co-ordination problems of using two mixing guns and the need to stock more than one material are avoided, and there is no conflict between different viscosities. However, as this one material is not as heavily filled as the high viscosity described above, polymerization shrinkage will increase slightly, and it will have increased flow compared with the heavy tray material. For these reasons, it is probably safer to use monophase materials in a custom tray, which reduces volume and contains them better than would a stock tray. However, the thicker consistency compared with a light- or very light-bodied material may limit the ability of medium-bodied materials to flow into intra-coronal features or the gingival crevice.

Tray selection

The influence of the tray on the creation of a successful impression has been touched on in the preceding sections. However, the importance of correct tray selection is often overlooked. Clinicians will consider many other possible sources of failure when restorations do not fit, and may change their impression material, but rarely think of their tray. Trays should be as rigid as possible and not all disposable trays will resist deformation while loading heavy-bodied materials.[19,20] Metal trays offer the greatest rigidity but should be used with caution with polyether and type 2 silicones – if there are significant tissue undercuts the tray may need to be cut off, which is a lengthy, laborious and very traumatic procedure for the patient!

Custom trays can improve the chances of producing an accurate impression because they can offer greater rigidity, and allow control of the thickness of impression material. An optimum thickness (approximately 2–4 mm) of material[21] will provide the best compromise between having enough bulk of material to minimize the permanent deformation caused by removing the material from undercuts, and the need to reduce the volume so as to minimize the effect of shrinkage (and reduce cost)(Figure 2). Trays made from self-curing acrylics require a delay of 24 hours to allow complete polymerization before use, while light-curing materials can be safely used almost immediately. Both should have a thickness of 2–3 mm to ensure sufficient rigidity.[22,23] Impression materials adhere better to the light-curing composite tray materials and adhesion is also helped if, during manufacture, the spacer wax is covered with metal foil before the tray material is applied.[24] Requesting a custom tray is not the end of the matter. An even distribution of material can only be obtained if the tray is precisely positioned, and this control of position requires either luck, or the incorporation of stops in the tray which can guide the clinician in seating it. If the rationale for having a custom tray spaced is accepted, it is illogical not to have stops. They should give at least three widely spaced supports to the tray, offer very positive seating, and be on non-critical areas, ie non-functional cusps of unprepared teeth, edentulous areas or the palate. If a ramp is created leading to the stops, it will help direct the tray into position as the impression is seated.[25] When a custom tray is indicated, a putty/wash combination must not be used for several reasons:

Figure 9. Electrosurgical tip for gingival troughing.

■ First, it is illogical since the purpose of the putty is to fill the large space of a stock tray and minimize the volume of the wash material – a custom tray is shaped to minimize impression material volume.
■ Secondly, a close-fitting tray containing putty will be very difficult to seat without setting up enormous stresses in the putty, and
■ Thirdly, most of the previously mentioned problems associated with the putty-wash technique will persist.

A custom tray will not always give a significantly better outcome clinically than a stock tray. A stock tray will suffice when:
■ The stock tray is of a rigid type;
■ The shape of the patient's arch conforms to that of the tray, ie an even thickness of impression material can be accommodated in the completed impression;
■ Only one or two single units are being restored;
■ Stops are placed as described;
■ Overextensions are removed – these may prevent outflow of impression material at the peripheries and contribute to recoil (as can happen when a lower tray is used in the upper arch);
■ The chosen materials (preferably avoiding putties) are used correctly.

On the other hand, where several units or a bridge are being constructed, the impression is required to deliver not only accurate individual dies, but also to reproduce the spatial relationships between the units. An individual tray is more likely to achieve this extra level of accuracy, and the extra cost will be recouped in less adjustment time and less material used.

Retention of the impression in the tray as it is removed is essential. Trays for elastomers should be perforated with holes of at least 2–3 mm diameter, to allow material to escape and lock on to the outer surface of the tray, and have an appropriate adhesive coating extending on to the outer surface. These are contact adhesives and, in the case of the silicones, need to be painted on at least 7–15 minutes before use.[26] If insufficient time is allowed for the solvents to evaporate, the adhesive will act more as a lubricant. Removing any impression made with an elastic material (this includes alginate) should be as rapid as possible. They are all visco-elastic, which means that, if pulled gradually or rocked out of the mouth, they will deform. With quick removal they will behave more elastically and not distort. Where the prepared teeth are tilted relative to the rest of the teeth, the impression should be brought out along the line of the prepared tooth to minimize any excessive strain and distortion of the impression of the preparation. With marked tilting, a correctly shaped custom tray should be used.

Tissue management

The most frequent visible fault identified in impressions received in laboratories is poor margin definition.[27] This may be owing to poor preparation, but is mostly attributable to inadequate displacement of the gingivae when the restoration is extended close to or below the gingival crest. Without an open gingival cuff, the precise extent of the margin will not be recorded, and the technician has to guess where to finish the restoration. Where sufficient depth exists, recording the shape of the tooth surface below the margin will help the technician to create a natural emergence profile, avoiding sudden changes in direction from the root to the restoration, which results in over-contoured margins which will encourage plaque retention.[28,29] For the elastomeric impression materials, the crevice needs to be opened to 0.2–0.3 mm to allow accurate detailed reproduction.[30,31] This can be achieved by surgical widening or mechanical displacement with or without chemical adjuncts.

Surgical widening

This entails removing the lining of the gingival crevice and can be accomplished using an electrosurgery unit, a rotary instrument, or with a laser.

Electrosurgery, or more accurately radiosurgery since the instrument emits high frequency radiowaves (3–4 MHz), produces rapid heating and cell destruction in the immediate vicinity of the electrosurgery probe as the radio waves pass through the tissue owing to the high resistance of the gingival tissue. A specific probe, which has an insulated tip from which extends a short metal projection, is available for some machines (Figure 9). This design helps to prevent contact with the adjacent teeth as a result of the insulation, and the short tip limits the depth of its use in the crevice. The heat generation helps to cauterize the cut tissue and reduces bleeding, but care must be taken to keep the tip moving whilst activated (0.7 m/sec is suggested) in order to prevent an excessive temperature rise; at least 5 seconds should be allowed before working in the same area again.[32] Touching the teeth, or metal restorations, with the electrosurgical probe can cause rapid heating and damage to the pulp. Rotary gingival curettage, also known as gingitage or gengitage, achieves removal of the crevicular lining with a high-speed diamond or ceramic bur directed around the tooth within the gingival crevice, usually at the same time as the preparation margin is prepared.[33] So-called soft lasers can vaporize superficial tissues and have also been used to widen the gingival crevice surgically for impression taking.[34]

Common concerns with all of these destructive techniques are whether recession of the gingivae will occur, and what potential there is for permanent damage to the tissues. A number of studies have compared these modalities, and each one has been shown to be at least equal, if not superior, to the others.[33-39] This conflicting evidence suggests that any differences between these techniques are likely to be clinically insignificant, *when they are used correctly*. There is, however, great potential for significant damage with all three. Overheating of the tissues with electrosurgery or laser can cause pulp death and alveolar bone necrosis. Rotary gingival curettage involves the least cost in new

equipment and allows the dentist to use an instrument with which he/she is very familiar. Nevertheless, in the interproximal areas, there is a high probability of contacting the adjacent tooth surfaces and permanently marking them. This is likely to encourage caries, and cause sensitivity. All of these methods should be avoided where the gingivae are thin and friable, as significant recession may then be likely.

Figure 10. Dislodging of placed cord by simple vertical packing technique.

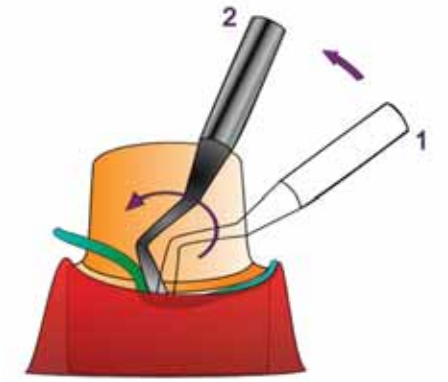


Figure 11. Rotating the packing instrument as the cord is seated helps to keep the earlier packed cord in place.

Mechanical displacement

Rather than destroy tissue to create space in the crevice, the natural elasticity of the gingivae can be exploited and the crevice temporarily widened by inserting a material into it. Cords are convenient for this purpose as they can be produced in varying diameters and are readily cut to length. Made from absorbent cotton strands, they can soak up crevicular fluids or can hold haemostatic agents in order to provide a dry field. Twisted cords have a tendency to unravel during placement, so knitted or braided cords are preferable. Either a single- or a double-cord technique can be used. If a marginal gap of 0.2–0.3 mm is required then, realistically, the clinician should aim to open the crevice by at least 0.3–0.4 mm to allow for some closure to occur while the impression is being placed. Therefore, with one cord, the largest diameter should be chosen which can be inserted *with gentle pressure* into the crevice. This provides displacement of the gingival cuff. The pressure of the cord, possibly supplemented by haemostatic solutions, creates a dry field locally. Additional lengths can be placed if there is a large bulk of gingivae to be pushed back. Before mixing the impression material, the teeth are washed and dried and the cord, which should be moistened to prevent tearing of the crevice lining, gently removed. It is essential to wait for 10–15 seconds to see if any bleeding now occurs. Placing the impression material immediately after removing the cord will not prevent such bleeding, so it makes sense to see if further applications of haemostatic agents are required before wasting time and money on an impression which will be flawed. In the two-cord technique, the functions of haemostasis/drying and displacement are divided between the two cords. A narrow cord is placed first to ensure a dry field but, as it is to stay in place during the impression taking, needs to be cut fairly precisely to the size of the periphery of the tooth. A second, thicker cord is placed on top to open up the crevice, and only this is removed before the impression material is placed. To use two cords requires more depth in the crevice, and so some operators use suture material as their first cord. It also takes more time, but gives greater control of the critical marginal area, and so is particularly useful where an impression of multiple units is being obtained or where persistent gingival bleeding occurs. Retraction cords should not be reserved solely for the impression stage. With the gingivae deflected, the margins can be seen and prepared more accurately, and the tissues are protected from bur damage which can add to the problems of achieving haemostasis. It may also be easier to place cord prior to margin cutting. Cords can themselves be harmful. A recent study suggests a direct effect on fibroblasts;[40] of more importance is direct trauma resulting from excessive force leading to recession. Common sense should guide the practitioner – thin, tight gingivae indicate narrower cords and lighter inserting force; wider diameters and greater pressure where the tissue is tougher. Baharav *et al*.[41] suggest that 4 minutes is needed to achieve an adequate displacement width, while longer times give no further benefit. It would seem sensible not to leave cord in longer than 10 minutes if working on multiple teeth, as this may lead to recession. Once cord is removed, the gingivae can rapidly close up, possibly within 30 seconds[42] therefore, if control of bleeding delays the taking of the impression, replacing the cord may be necessary.

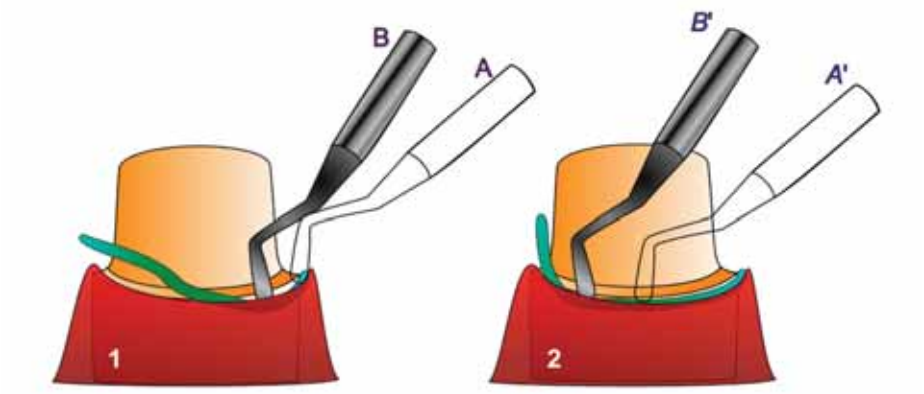


Figure 12. Using two instruments, walk around the tooth, to hold seated cord in place.

Cord placement method

- Explore the gingival crevice around the anaesthetized tooth with a narrow flat plastic instrument – this will help indicate the appropriate diameter of cord to be used. It will also identify where the cord can be easily and securely anchored and so act as

Figure 13. *Expasyl* gingival displacement equipment.

a reliable starting point from which to start cord packing.

- Cut a suitable length of cord and moisten with water or an astringent solution.
- Secure one end in the chosen anchor site using a narrow flat plastic instrument or preferably with a specifically designed cord packing instrument. Magnification will help to ensure that the cord is being pushed into the crevice and not against the gingivae or preparation margin.
- Simply packing vertically will tend to pull in the cord on either side, causing it to rise out of the crevice behind the packer (Figure 10). Rolling the instrument in the direction one is packing helps to avoid this (Figure 11); as does the use of two packers, where one instrument holds down the cord while the other packs the next section, stepping around the tooth (Figure 12). However, this is a more difficult technique to master.
- Inspect the preparation to ensure the margins can all be seen – place additional cord if required.
- Leave the cord for at least 4 minutes, but do not allow the tooth to dehydrate.
- After sufficient time, wash and dry the tooth before gently removing the cord (top cord in the two-cord technique). Washing, and especially forceful air-drying after cord removal, can encourage bleeding.
- Check the crevice for adequate displacement and watch for bleeding which can occur after a few seconds. Clear any coagulum and debris carefully with a CPITN probe. If necessary, dry the crevice with a gentle stream of air.
- If the conditions are right, proceed to the impression – if not, correct the situation; don't waste your expensive impression material.

Haemostatic agents

Pressure alone may not stem gingival bleeding, and it is not uncommon to apply an astringent liquid into the crevice and on to the cord before it is placed. These compounds are usually solutions of metal salts – chlorides and sulphates of aluminium and iron. The most effective astringent, ferric sulphate, is also the most aggressive in its effect on the tissues and can temporarily stain the gingivae black for 24–48 hours. They are all quite acidic,[43] and have the potential to etch dentine, opening its tubules, which may lead to sensitivity and allow bacteria to enter.[44] They also have a terrible taste, and must be placed with care. Some are presented as gels which can give greater control. Concerns over possible inhibition of the setting reaction of addition-cured silicones by the sulphate-containing astringents appear unfounded. Where this inhibition has occurred, it is thought that sulphur-containing additives from latex gloves rubbed on to the teeth have been responsible.[45]

Adrenaline solutions and impregnated cords are not recommended as they have the potential to cause serious systemic effects.[46] Using local anaesthesia has been shown to improve the quality of subsequent impressions.[47] This may be due to the haemostatic effect of the adrenaline contained in the solution when injected locally, but may also be because, once the gingivae are anaesthetized, retraction cords can be more effectively placed and vital teeth adequately dried without causing discomfort.

Expasyl (Kerr UK Ltd, Peterborough, UK) is an alternative mechanical displacement method. Consisting of a blend of kaolin(china clay) with the astringent aluminium chloride, it is presented in cartridges with a dedicated syringe and disposable wide bore delivery tubes (Figure 13). After tooth preparation, the thick, putty-like material is injected into the gingival crevice, which is thereby dilated. After 5 minutes it is removed by water spray, the preparation is dried and impression material can then flow into the opened and dried crevice. This has the distinct advantage of being probably the

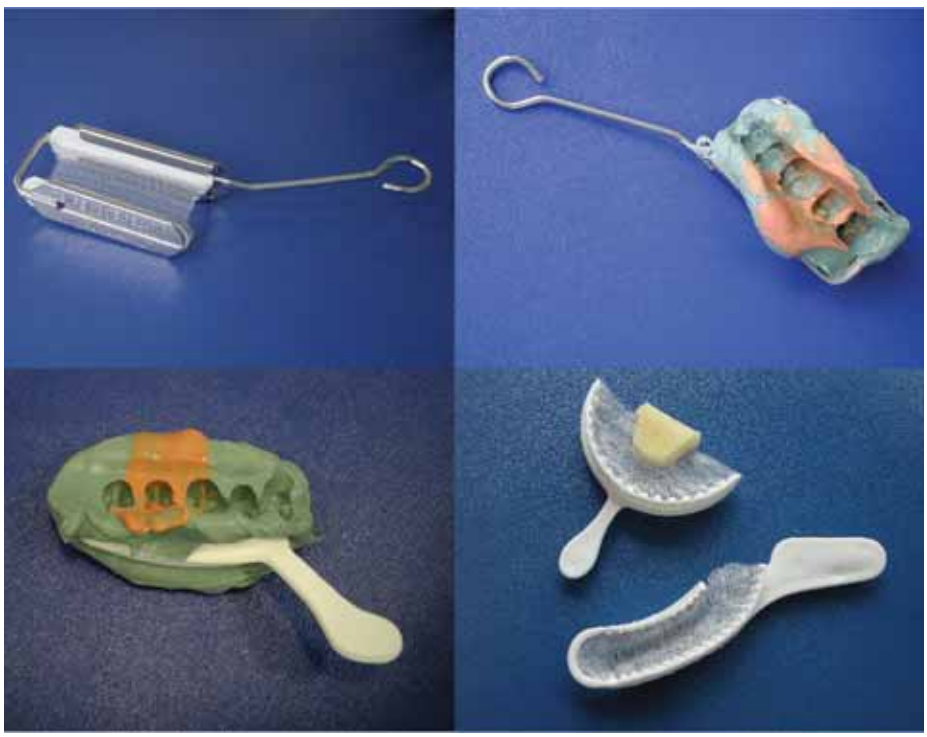


Figure 14. Metal (top) and plastic dual arch trays.

least traumatic, and therefore painless, displacement technique, and does not require additional anaesthesia for its use. However, it may not be sturdy enough to cope with thick gingivae, and cannot easily be used to protect the tissues while margins are being prepared.[48]

Gingival health

Problems of gingival bleeding and concerns about recession will be minimized if the gingivae are free from inflammation. This will be the case when the patient has good oral hygiene and any existing restorations have well-fitting and contoured margins. Dentists should not have to battle against bleeding gums to try and achieve decent impressions. Patients have increasing expectations regarding their dental care but, in turn, must be made aware of the impact poor gingival health will have on the quality of restorations and their responsibility to maintain that health. They also need to appreciate that provisional restorations may be required to allow effective cleaning and a return to stable tissue conditions before they can be provided with first class dentistry.[49]

Dual-arch impression

Also known as closed bite, triple tray or double arch impression, this method has been in use in the US for about five decades, but is still not widely used elsewhere. Various designs of trays are available which aim to achieve the simultaneous recording of the prepared tooth/teeth, the opposing teeth, and their intercuspal relationship (Figure 14). It offers several practical advantages over the traditional method. Less material is needed, it is quicker because both arches are recorded at the same time, and patients have been shown to prefer this technique over traditional full-arch impressions.[50] Laboratory investigations show that dies have comparable accuracy compared to those obtained from full-arch impressions,[51-52] and that the quality of restorations produced is at least equal to that which can be obtained with conventional full-arch impressions.[50,53] Both plastic and more rigid metal trays are available for posterior quadrants and the anterior sextant. No clear superiority has been demonstrated between either, nor between different viscosities of silicone.[52,54] However, if the patient's alveolae or palate contacts the tray on closing it will be distorted, giving an inaccurate result. As the plastic trays are more flexible, the patient may not notice the distortion and not alert the dentist. With any new technique there is a learning curve; this applies to the dentist and possibly even more so to the technician, so initial results may be inferior.[55] The impressions are shallow, and this makes them difficult to pour, and mounting can be problematic without specific cast relators. This method is not recommended for all situations, but where appropriate yields very good results, and has some real advantages.

Indications and requirements for dual-arch impressions are as follows:

- One or two units bounded by intact and opposed teeth;
- Stable, reproducible and obvious intercuspal position;
- Co-operative patient able to close directly into intercuspal position on request;
- Tray does not contact axial tooth surfaces, or the adjacent tissues on closure;
- In quadrant trays, there is space for the connector bar behind the last molars;
- Technician familiar with the specific pouring and mounting procedures.

A checklist for the dual-arch technique includes the following:

- Check that the tray can be placed into the appropriate position with the tray sidewalls out of contact with the tissues, ie is the tray wide enough?;
- Check that the patient can close with the tray in place, ie no contact. (This is best done before anaesthesia so the patient can identify any obstruction);
- Check that the patient can close repeatedly into intercuspal with tray in place, ie not contacting teeth on opposite side;
- Complete tooth preparation and cord placement if required;
- Apply adhesive to tray but not the gauze;
- Dry prepared tooth and remove cord – check haemostasis;
- Assistant fills top and bottom of tray (heavy or monophase) while the dentist syringes impression material around prepared tooth (light or monophase);
- Orient and seat tray over arch with prepared tooth;
- Ask patient to close (into intercuspal position) and maintain closure until instructed to open. Check correct closure using reference teeth noted previously;
- Once completely set, ask patient to open quickly and forcefully. Dentist completes removal from other arch.

Alternative techniques

Reversible/irreversible technique

While the dual-arch method is popular in the US, the use of irreversible with reversible hydrocolloid has been used in Sweden to fabricate indirect restorations with similar survival rates as those made with other impression materials.[56] Suggested in 1951 by Schwartz,[57] the combined use of reversible and irreversible hydrocolloid can produce casts of sufficient accuracy and detail on which to make indirect restorations.[58] A low viscosity reversible hydrocolloid is syringed over all the teeth to record fine detail, and an alginate in a stock tray is placed over it to contain the wash and fill the tray. The wash material is simple to keep fluid in a small heated water bath, ready for use. This method allows the operator to use inexpensive materials and gain the benefits of reversible hydrocolloids' hydrophilic properties and accuracy; using alginate as the tray material avoids the need for expensive bulky water-cooled trays. Poor dimensional stability and low tear strength are still a concern, and specific alginates formulated for this technique should be used to avoid the two materials separating on removal as can happen if a conventional alginate is used.

Injection techniques

The principal claimed advantage of the two-stage putty/wash method is that the low viscosity material can be driven in to the gingival crevice by the set putty, enhancing the definition of the margins. There is still the risk that the build–up of pressure which causes this may give rise to the problems of recoil. To avoid this, Lococo[59] described his hydrodynamic impression technique whereby a high viscosity silicone material is first used to obtain an impression of the teeth. Channels are cut into this, leading to the teeth to be prepared. After preparation and gingival displacement, the tray is reseated and a light-bodied material is

Figure 15. Extreme example of dies produced from impression with vertical drags as a result of poor flow of putty phase.

then injected through one hole until the excess is seen escaping from the other. The force of injection acts to push the wash material into the crevice, opening it further. Similar approaches have been described by Schoenrock[60] in his laminar impression technique using a dual-arch tray, and by Millar[61] with a full arch tray where the injection hole is sited over the occlusal surface of the prepared tooth with a buccal relief hole.

Matrix impressions

Despite improvements in material properties, capturing marginal detail can still be a problem which has inspired some alternative solutions. We need a material which has sufficient viscosity to be directed into the crevice and displace it (while being able to record detail), but then we need to prevent it from being displaced and the crevice collapsing, as more impression material is placed to record the rest of the arch. The now largely abandoned copper ring technique achieved some of these goals – the gingivae were displaced by a trimmed metal tube and the viscous thermoplastic compound, which was the impression material. An overall impression of the arch was made over the copper ring, usually in alginate, to relate the prepared tooth to the rest of the teeth. Improvements on this technique included substituting elastomers for the inflexible compound and alginate, and using plastic crown forms which are easier to adjust as the matrix.[62,63] Livaditis[64] has further extended this concept by using an initial impression of the prepared teeth taken in rigid occlusal registration type polyether. This is trimmed to the gingival margins and is then used as a matrix to carry a higher viscosity material which, as it is seated, drives the unset material into the gingival crevice. Once set, a third impression is taken in a conventional tray with a lower viscosity material over the matrix, which joins all three elements together. Martignoni,[65] in his 1990 text, describes using a putty silicone matrix and provisional restorations trimmed as before to carry a silicone foam which again is driven into the crevice, and held under pressure. In this case, however, the purpose is to achieve gingival displacement only; a conventional impression technique is then followed to produce the working cast. Recently, Coltene (Coltene/Whaledent Ltd, Burgess Hill, West Sussex, UK) have produced *Magic FoamCord*, which uses the same principle of a silicone which expands on setting to open the crevicular space prior to the working impression. It is syringed around the gingival margins, and then an appropriately sized cotton wool 'thimble' is positioned over the tooth and pressed down by the operator, and then by the patient's opposing teeth for five minutes. For multiple preparations, it is suggested that a putty in a sectional tray be used to provide the additional force. The action of the expanding foam and the pressure applied to the carrier opens the crevice atraumatically.

Troubleshooting

Impression pulling out of the tray

Increase the retention with more perforations of appropriate size and paint on the adhesive at least 5 minutes ahead. If there are deep tooth or tissue undercuts gripping the impression, block them out with soft wax or cotton wool.

Persistent bleeding

If persistent bleeding is the result of general inflammation of the tooth's gingivae:

- Provide a provisional restoration with good margins;
- Ensure that the patient can and will keep the area plaque free; and
- Delay impression taking for at least 10 days.

If, on the other hand, it is the result of bur damage, insert cord before preparing subgingival margins to deflect the gingivae. Local measures will usually cope with isolated bleeding points. Try burnishing a very small cotton wool pledget or microbrush soaked in ferric or aluminium sulphate directly against the site. Papillary injections of local anaesthesia can temporarily halt bleeding and are particularly useful if some oozing starts at the moment of placing the impression. The two cord technique gives better moisture control than a single cord.

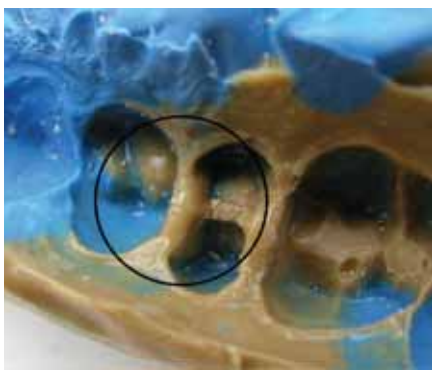
Margin defects

These are more commonly seen with the one-stage putty wash method.

Horizontal ridges

These are not obvious unless deliberately looked for, and are often seen on the buccal/lingual side of prepared teeth when a one-stage putty wash technique has

a



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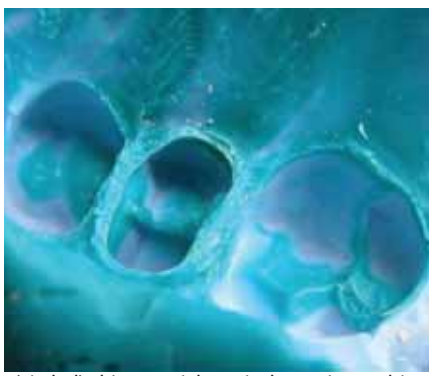

Figure 16. **(a)** Impression of onlay preparation showing (circled) shiny mesial cervical margin resulting from poor moisture control, and no clear edge to the margin. **(b)** A further attempt made using a two-cord technique has achieved a dry field, and the margins are easily identified.

been used. They represent poor blending of the two viscosities and do not occur on the interproximal areas as the materials are enclosed and there is a greater build-up of pressure here. Heat from the prepared tooth causes the wash in this area to start to react first and become more elastic, reducing its ability to homogenize with the putty. All addition-cured silicones should be placed as quickly as possible before the polymerization starts; chilling them, especially the wash material, gives the operator some extra time. Teardrop defects may be seen at the back of the last tooth, particularly on tall teeth and at edentulous areas as the putty escapes posteriorly. The tray needs to be closed off with self-cure acrylic or greenstick additions. In a two-stage technique, the wash material will fill up any such putty defects.

Vertical drags

Commonly seen extending from below undercuts when one-stage putty impressions are taken (Figure 15). This is again owing to the poor flow characteristic of putties preventing them adapting well to irregular contours. Where marked undercuts present on prepared teeth, use a two-stage, or a heavy-light combination. The sensitivity of the polymerization reaction to temperature of the vinyl polysiloxanes can also contribute to drags. If partial setting occurs, the material's ability to flow will be reduced. Refrigerating these materials and ensuring their rapid placement once mixed should prevent this problem. Allowing additional time before removing the impression, beyond the manufacturer's recommendations, will ensure that complete cure has occurred.

Margin defects

Voids are the result of air or moisture inclusions. Hand-mixing is more likely to trap air within the mix than using the more current auto-mix guns. When injecting wash materials, ensure that the tip remains within the expressed material and pushes it ahead while moving around the preparation margin. If grooves or boxes have been included in the resistance form, fill the base of these first and move the syringe tip up to the occlusal surface. The appearance of rounded polished margins in the impression indicates a wet surface (Figure 16). Small teardrop defects can occur as small amounts of fluid within the gingival crevice are driven around the crevice by impression material, and then across the margin as the tooth is completely encircled. Thorough but gentle use of the air syringe should avoid this, but also consider using a two cord technique. Unclear margins may be due to poor preparation, or inadequate gingival displacement. Where margins are at or below the gingival crest, some form of gingival displacement is essential and needs to provide sufficient separation of the gingivae from the tooth for the technician to identify the preparation's limits.

Conclusions

Obtaining impressions of sufficient detail and accuracy for the construction of indirect restorations is dependent on the interplay of several factors. Modern materials are more user-friendly than their predecessors but can still produce poor results if not manipulated correctly. The increased choice of viscosities now available brings with it the need to understand how best to use them. Inappropriate use of trays, poor moisture control, and inadequate retraction methods will negate the potential of the best impression material. Dentists should have an appreciation of all these factors, and understand how each influences their results. More critical examination (with magnification) of impressions, and especially the resulting casts before they are trimmed, may reveal defects which can be corrected in the future, if the clinician can recognize how each has been caused. The apparently small details of technique are important and can mean the difference between impressions which visually appear adequate and ones which are truly accurate. Going to these lengths will result in restorations which fit more accurately and require less adjustment. Not only will chairside time be saved, but patients will feel more confident, your technician will be happier to make your restorations and, most importantly, your job satisfaction will increase.

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Cochrane Synopses

M Esposito, P Coulthard, P Thomsen, HV Worthington. Interventions for replacing missing teeth: different types of dental implants. *The Cochrane Database of Systematic Reviews* 2005, Issue 1. Art. No.: CD003815. DOI: 10.1002/14651858. CD003815.pub2.

'There is limited evidence showing that implants with relatively smooth surfaces are less prone to loose bone due to chronic infection (perimplantitis) than implants with rougher surfaces. However, there is no evidence showing that any particular type of dental implant has superior long-term success.

Missing teeth can sometimes be replaced with dental implants into the jaw, as bone can grow around the implant. A crown, bridge or denture can then be attached to the implant. Many modifications have been developed to try to improve the long-term success rates of implants, and different types have been heavily marketed. More than 1300 types of dental implants are now available, in different materials, shapes, sizes, lengths and with different surface characteristics or coatings. However, the review found there is not enough evidence from trials to demonstrate superiority of any particular type of implant or implant system.'

JM Zakrzewska, H Forssell, AM Glenny. Interventions for the treatment of burning mouth syndrome. *The Cochrane Database of Systematic Reviews* 2005, Issue 1. Art. No.: CD002779. DOI: 10.1002/14651858. CD002779.pub2.

'There is insufficient evidence to show the effect of painkillers, hormones or antidepressants for 'burning mouth syndrome' but there is some evidence that learning to cope with the disorder, anticonvulsants and alpha-lipoic acid may help.

A burning sensation on the lips, tongue or within the mouth is called 'burning mouth syndrome' when the cause is unknown and it is not a symptom of another disease. Other symptoms include dryness and altered taste and it is common in people with anxiety, depression and personality disorders. Women after menopause are at highest risk of this syndrome. Painkillers, hormone therapies, antidepressants have all been tried as possible cures. This review did not find enough evidence to show their effects. Treatments designed to help people cope with the discomfort and the use of alpha-lipoic acid may be beneficial. More research is needed.'

JV Keenan, AG Farman, Z Fedorowicz, JT Newton. Antibiotic use for irreversible pulpitis. *The Cochrane Database of Systematic Reviews* 2005, Issue 2. Art. No.: CD004969. DOI: 10.1002/14651858. CD004969.pub2.

'Antibiotics do not appear to significantly reduce toothache caused by irreversible pulpitis.

Irreversible pulpitis, where the dental pulp (nerve) has been damaged beyond repair is characterised by intense pain and considered to be one of the most frequent reasons that patients attend for emergency dental care. This review, which included 1 trial (40 participants), found that there is a small amount of evidence to suggest that the administration of penicillin does not significantly reduce the pain perception, the percussion perception or the quantity of pain medication required by patients with irreversible pulpitis.'