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Direct Posterior Composites: A Practical Guide

Abstract: The restoration of posterior teeth with directly placed resin-bonded composite requires meticulous operative technique in order to ensure success. Case and material selection; cavity preparation; matrix selection; isolation; bonding; management of polymerization shrinkage; placement; finishing and curing of posterior composites – all present a series of challenges that dentists must master in order to ensure high-quality, long-lasting restorations. This paper describes and discusses these aspects of the provision of composites for load-bearing situations in posterior teeth.

Clinical Relevance: Successful restoration of posterior teeth with composite is an essential component of contemporary dental clinical practice.

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Conflicting opinion and a wealth of contradictory data present difficulties for dentists in choosing which materials, instruments and techniques to employ when considering restoration of posterior teeth with direct composite.

In some areas of the world, resin composite is the first (or only) choice for direct restorations in teeth, with the setting up of 'amalgam-free' practices and a dental school which has not taught amalgam placement techniques for over a decade.[1,2] In this respect, although amalgam has served dentistry for over a century and, if well placed, may provide restorations which function beyond 30 years,[3] encouraging clinical outcomes have caused some clinicians to favour composite, even when restoring large cavities.[4] There has been a consequent decline in the worldwide use of amalgam over the last decade[3] and a concomitant increase in the use of composite.[5]

This situation has been brought about by:

- Alleged health concerns and environmental considerations regarding amalgam;
- The dental profession's desire for an adhesive material that demands less invasive cavity preparations;[6,7]
- Patient demand for tooth-coloured restorations in posterior teeth.[1,4,6,8,9]

With good case selection, proper adhesion and placement, posterior composites can provide successful and predictable restorations[1,8] that may match the appearance of natural teeth (Figure 1).[10,11]

As a result, it may be considered that the use of posterior composites is set

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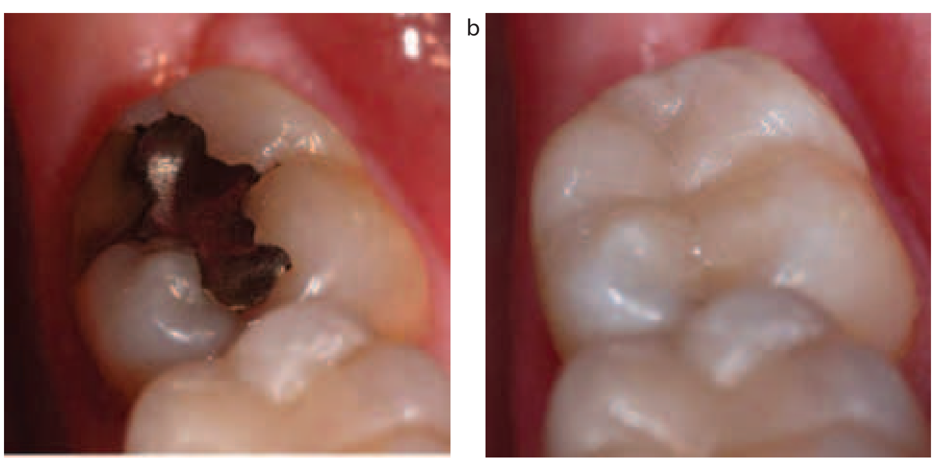


Figure 1. (a, b) Occluso-lingual restoration of a lower second molar in *Clearfil Majesty* (Kuraray, Japan).

a b c

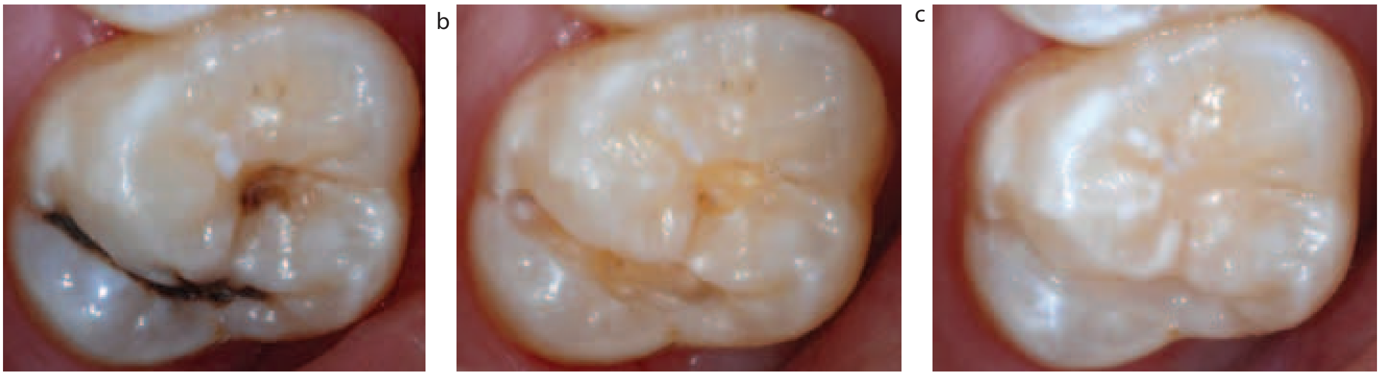


Figure 2. (a–c) Preventive resin restorations in an upper second molar using *X-Flow* (Dentsply International, Inc York, PA, USA).

Figure 3. (a–c) Occlusal restoration of an upper molar in *APX* (Kuraray, Japan). Unsupported enamel can be retained, after preparation, if composite is selected.

to increase, alongside improvements in materials, instruments, dentine adhesion and restorative techniques.[5,10,12] The profession's knowledge and confidence in the use of posterior composite will be further enhanced by better and more comprehensive undergraduate and postgraduate teaching of the subject.[2,5]

However, if composite is to compete truly in terms of prognosis and longevity, material performance, adhesion and restorative techniques must be optimized.[11,13]

Indications for posterior composites

Preventive resin restorations

Resin composites may be considered to be the material of choice for ultra-conservative restoration of discrete carious lesions in the fissures of posterior teeth, where it is impossible to facilitate effective plaque removal and fissure sealing alone is inappropriate. Depending on the size of the lesion (and the possible need to seal adjacent, unaffected, fissures), various protocols have been proposed for preventive resin restorations[14] and have been demonstrated to produce excellent long-term results (Figure 2).[15]

Larger initial lesions

Posterior composites may also be considered to be the logical choice for the treatment of more extensive primary carious lesions, where minimally invasive techniques can still be applied.[1,10] Since composite may be adapted to any shape or size of cavity,[5] the undermined enamel that remains after conservative removal of dentine caries can be retained, where it will be supported by bonded composite.[10] (Figure 3) The resultant, smaller surface area restoration will be easier to shape and will be subject to reduced occlusal loading.[9] When composite is used in the treatment of primary occlusal lesions, such restorations have been shown to occupy 80% less tooth surface area than a traditional amalgam restoration.[5]

Aesthetic restorative dentistry

Although posterior composites may be used cosmetically, they are generally employed in the *necessary* replacement of missing tooth tissue and any failed restoration (Figure 4).

Conservative restorations in the 'aesthetic zone'

Direct composite can be used effectively for the restoration of aesthetically important teeth,[11,13] for example premolars, where it can also prove to conserve tooth tissue,[1,6] avoiding the need for further tooth preparation, which may ultimately involve core build-up and crown preparation (Figure 5).

Cosmetic restorations

Resin composite may be used to

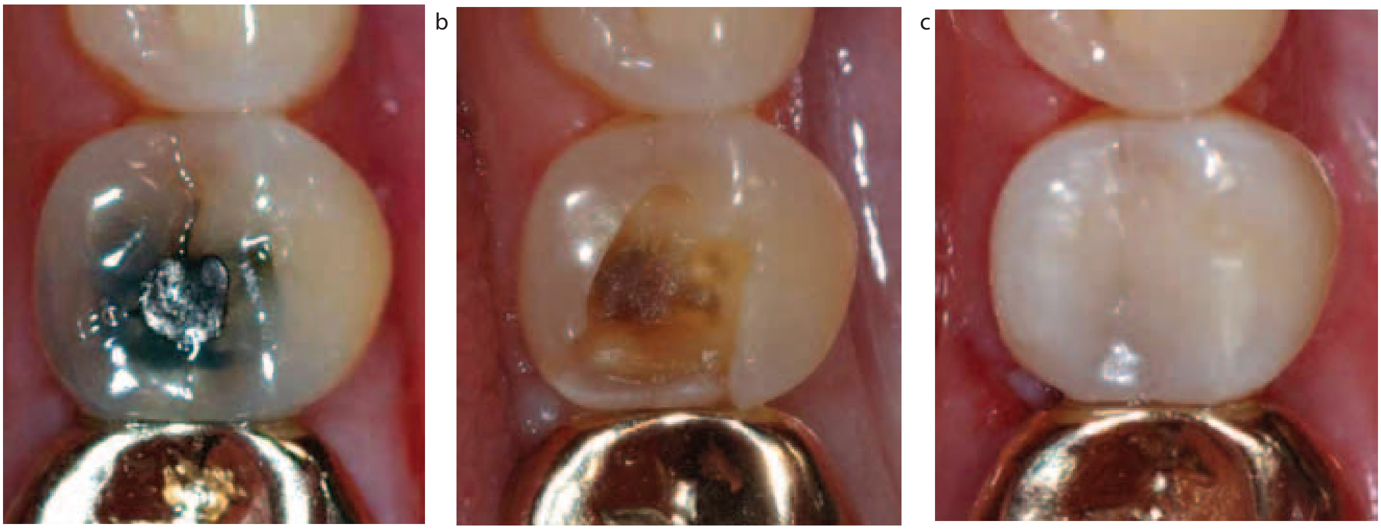


Figure 4. (a–c) Disto-occlusal restoration of a lower premolar in *Clearfil Majesty* (Kuraray, Japan).

Figure 5. (a, b) Conservative restoration of an upper first premolar following a buccal cusp fracture using *Filtek Silorane* (3M ESPE, St Paul, MN, USA).

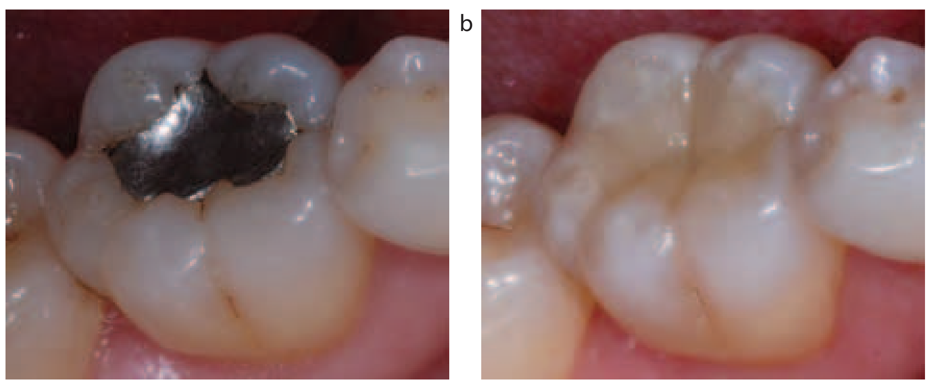


Figure 6. (a, b) Cosmetic replacement of an occlusal amalgam using *Filtek Silorane* (3M ESPE, St Paul, MN, USA).

replace failed or unattractive, moderate to large Class I and II restorations,[1] where the preparation outline form does not place the margins under direct parafunctional loading (Figure 6).

Treatment of cracked teeth

The use of direct composite has been shown to be effective for the immediate treatment of painful, cracked teeth.[5,16] The validity of this form of treatment and the need to provide cuspal coverage is the subject of debate and merits further investigation (Figure 7).

Other uses

Resin composite may be used effectively for the restoration of Class V cavities[17] and for the conservative repair of indirect restorations. It may also be used to replace amalgam restorations implicated in lichenoid reactions and in cases of proven allergy to metal restorations.

Worldwide, the acknowledged range of indications for which directly-placed composites can be used is growing, as clinicians' confidence and skill in placing such restorations increases. Their motivation should also be to perfect the least invasive methods for the preservation and repair of teeth throughout a lifetime.[7]

Case selection

Patients should have an acceptable level of oral hygiene, as restorations formed in resin composite have been considered to attract greater levels of pathogenic bacteria than amalgam restorations.[11] Occlusal contact(s) on enamel may be considered desirable and, ideally, all cavity margins should be in enamel. In this respect, a superior prognosis can be expected from a restoration bonded to an uninterrupted enamel margin.[18]

Contra-indications

Posterior composites should

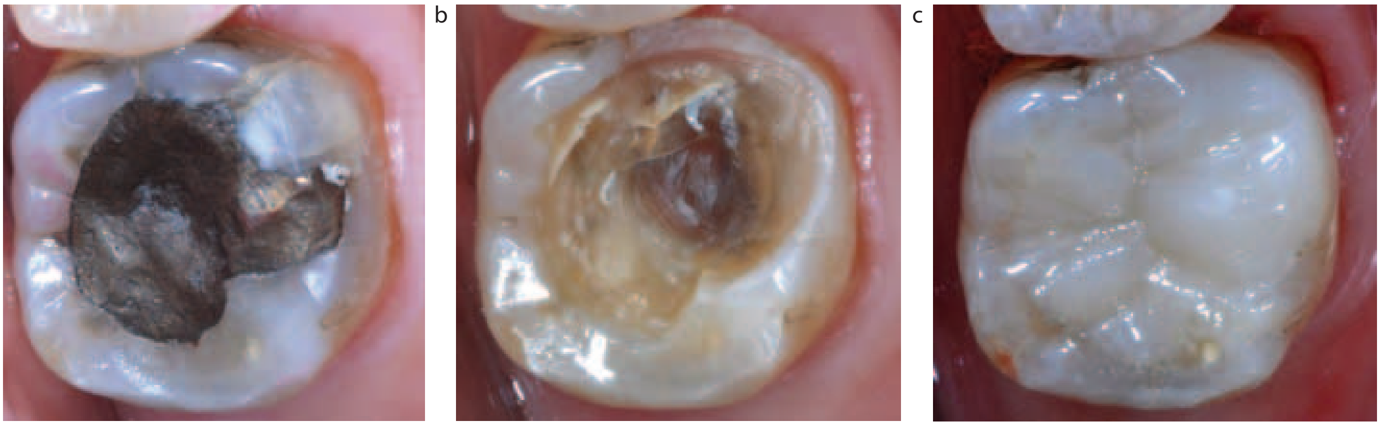


Figure 7. (a–c) Direct composite (*Clearfil Majesty* – Kuraray, Japan) used to relieve symptoms of a cracked lower molar.

be avoided in patients with a high caries rate that cannot be controlled,[13] or where the tooth to be restored is subject to high occlusal loads.[1]

Careful thought should be given before considering using direct composite to restore large cavities,[19] where cuspal contacts require restoration and where cavity margins extend beyond enamel, for example, in deep proximal boxes.

Posterior composites are contra-indicated if meticulous isolation cannot be guaranteed throughout the operative procedure, by the use of rubber dam or other equivalent methods of moisture control.[1]

Posterior composites should not be attempted if there is insufficient surgery time available to complete the procedure, as composite placement techniques cannot be rushed[13] and they should be avoided in proven cases of sensitivity to resin composite materials and/or adhesives.[1]

Informed consent

Although one recent, large, five-year study reported comparable longevity of composite to amalgam in Class I and II restorations,[20] patients should be informed that posterior composites may not last as long as an amalgam restoration in some situations and that, in common with amalgam, the number of restored surfaces may have a significant effect on survival.[1,20]

Patients should also be made aware that:

- In some cases, the procedure may be much longer (2.5 times[13]) than an equivalent amalgam restoration;
- Placement will often require rubber dam isolation;
- The treatment will be more expensive;
- Post-operative complications may be likely if the restoration is not adequately bonded, adapted and polymerized, or there is incomplete control of the problems associated with polymerization shrinkage.

Choosing a posterior composite

In recent years, successful long-term clinical performance of posterior composites has been attributed to an improvement in the physical properties of composite restoratives and improved effectiveness of dentine-bonding agents.[1,4,9]

In the UK, there are currently over 50 different brands of composite resin on the market and, as a result, it is difficult for practitioners to make an informed choice when selecting a material.[5] Many composites have similar constituents and manufacturers modify their formulation to optimize their properties and clinical performance for anterior, posterior or universal use. Composites which are advocated for posterior use have a matrix of resin monomers containing a high volume (≥60%) of inorganic filler particles. This high filler load conveys the fracture resistance necessary for the loads exerted on restorations in molars and premolars.[5] Posterior composites are usually *hybrid* materials, indicating that the filler particles are a mixture of sizes.[9,10]

As handling characteristics are such a critical determinant of success, this property may be considered to be one of the most important. When choosing a composite, the following should be assessed:

- How easily can the composite be removed from the syringe or applied from the compule?
- How easily can the material be adapted to the floor and walls of the cavity, without sticking to instruments?
- Do individual increments integrate well (without obvious voids)?
- How easily can the material be sculpted to the correct anatomical form?
- How long does it hold its shape before curing, without slumping?
- Does it have a good working time under ambient lighting conditions?

Other considerations that may be important are:

- Cost;
- Whether it is also to be used for anterior teeth (heavily filled *hybrid* composites may compromise aesthetics when used anteriorly);
- Shade range (although some materials have many shades, a very limited shade range for posterior teeth may satisfy most dentists and patients).[5]

Most materials are available in syringes and compules. The use of compules may result in better adaptation,[21] provided that the tip is small enough to be placed close to the bottom of the cavity.[5] Some operators favour a less viscous material and use warmers to achieve the handling characteristics that they prefer. Others transfer material from a syringe to a fine transfer tip (which may be lubricated with a solvent-free resin) to facilitate accurate direct placement.

Figure 8. (a–c) Examples of two surface restorations in *Synergy Duo* (Coltène-Whaledent, Switzerland) 7–9 years post-placement. Despite excellent handling and aesthetic properties, this material has been superseded by a new 'nano-technology' product.

Packable composites

While the current tendency is to market materials with increased viscosity, very stiff materials may deliver inferior results, creating voids along cavity walls and porosities between increments.[5,21] When using a packable composite, it has been suggested that the use of a flowable composite lining may reduce this tendency.[12] Further claims that the consistency of a composite has a significant effect on contact tightness have not been substantiated.[1,5,22]

Clinical trials

Unfortunately, manufacturers may be driven by market forces to launch new composites regularly.[5] Accordingly, by the time independent research has revealed deficiencies, these products may have been withdrawn.[5] Even more annoyingly, composites with proven excellent long-term clinical performance may be discontinued in favour of further innovative materials and concepts[5] (Figure 8).

Even the best laboratory research is only partially capable of predicting clinical performance.[12] Clinical trials are the ultimate tool for evaluation, but poor quality data and lack of standardization can make results difficult to interpret.[12] It has therefore been recommended that efforts should be made to meet published standards for improving the quality of randomized trials,[12] as it is the patient and dentist who will face the consequences of an underperforming material.[5] It has also been recommended that, prior to marketing, it is desirable to evaluate a dental restorative material carefully, *in-vivo*, for at least 2 years (and up to 4 years)[23] to determine its potential clinical success.[12] However, the commercial viability of such a concept must be questionable.

Choosing an adhesive system

With well over 40 different brands of adhesive and alternative permutations of etch, primer and bonding resin being available, choosing an adhesive system is a difficult task. Fortunately, virtually all adhesive systems are compatible with any composite. Irrespective of the number of bottles, an adhesive typically contains resin monomers, curing initiators, inhibitors, stabilizers, solvents and, sometimes, an inorganic filler. Each of these components has a specific function and the chemical formulation determines, to a large extent, the adhesive performance.[24] It has been demonstrated that there is a large range in the ability of general dental practitioners to manipulate adhesive systems correctly.[25] Well-established 3-step etch and rinse adhesive protocols routinely show reliable and predictable clinical performance,[26,27] and remain the 'gold standard' method of bonding to dentine.[27] However, there is now a tendency towards marketing adhesives with simplified 'user-friendly' application procedures. While these two- or one-bottle bonding systems may save a small amount of clinical time and offer promising adhesion in the early life of the restoration, they may prove to be a false economy in the longer term, failing to deliver the sustained adhesion desired by practitioners and patients alike.[26,27]

As with composite materials, adhesive systems are frequently replaced by modified 'next generation' successors, claimed to be better, without clinical validation.[28]

Figure 9. Mesio-occlusal restoration of a lower molar at 3 years (*Synergy Compact*, Coltène-Whaledent, Switzerland). Natural contour renders the restoration undetectable to the casual observer, despite a shade mis-match and some marginal chipping.

Clinical stages for restorations using direct posterior composites

Shade taking

The shade should be taken before isolation, as teeth may dehydrate and lighten in colour.[11] Shade matching is less of a concern for posterior composites than with restorations in anterior teeth and, indeed, some operators favour a slight mis-match to assist finishing (Figure 9).[5,13] The shade may

a

b

c

d


be taken with the proprietary shade guide, but greatest accuracy is attained by applying a test piece of composite to the tooth.[10] This should be cured as there is usually a shade-shift on polymerization.[11]

Occlusal record

Prior to isolation, articulating paper should be used to assess the occlusion in the intercuspal position and in all excursions.[8,13] Careful consideration of occlusion pre-operatively will facilitate planning of margin placement,[13] reduce finishing time and enable accurate reproduction of the occlusal scheme (which cannot be re-assessed until the rubber dam is removed). Opposing and adjacent teeth should be examined. If their position or contour is likely to compromise successful restoration, they should be adjusted appropriately.

Cavity preparation

The main aim of preparation is to *remove diseased tissue only*. Access should be limited to that required to visualize and remove carious tooth tissue and/or any previous restoration[1,8] and to permit access for instruments (Figure 10).[1] In the UK, the majority of restorations involve replacement of old fillings. Here flat floors, definite walls and undercuts may be present and will

e


Figure 10. (a) Upper premolar with a distal carious lesion. **(b)** Initial access. **(c)** Access sufficient to assess carious lesion. **(d)** Cavity preparation complete. **(e)** Isolation, wedging and matrix placement.

provide resistance form, thereby reducing stress on the adhesive bond during occlusal loading. Rounded internal line angles will aid adaptation of the composite and further reduce stress concentration.[10,12] As bond strengths of adhesives to enamel are generally greater than those to dentine and dentine-bonded interfaces have been shown to degrade with time,[11,24,26,28]every effort should be made to preserve enamel at the cavity margins, especially on the cervical floor of boxes.[1]

No extension into sound fissures is indicated and a smooth, flowing outline form, that avoids loading of margins, will make filling and finishing easier.

Interproximal boxes should be extended just past the contact point cervically to allow complete caries removal, aid matrix placement and permit caries diagnosis (Figure 11).[13] Vertical box margins may be left in contact, if this does not compromise matrix placement.

Bevelling is not recommended occlusally, as this may result in a thin margin of composite, which could be prone to fracture under occlusal load. Proximal bevels are advocated by some to optimize the marginal seal.[29] However, proximal bevels may be difficult to achieve accurately without damage to the adjacent tooth.

The use of loupes (+/– light) will facilitate minimal preparation and caries removal.[13] Care must be taken to avoid all contact with adjacent teeth,[10] which should

Figure 11. Proximal box preparation extended just below contact point cervically.

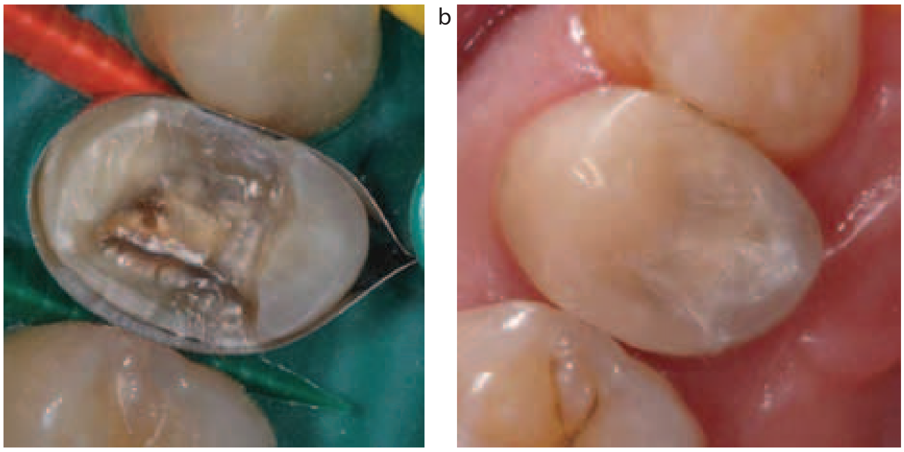


Figure 12. MODB restoration of an upper premolar (*Filtek Silorane*, 3M ESPE, St Paul, MI, USA) displaying anatomically correct proximal contour.

Figure 13. *Flexi-wedges* (Common Sense Dental Products Inc, Springlake, MI, USA)

be inspected for early cavitated lesions that may be restored conservatively while there is direct access. All peripheral stain/amalgam should be removed as this may show through the composite. It is advisable to delay the final decision on choice of restorative material until cavity preparation is complete.

Tunnel restorations

Outcomes for restorations using occlusal tunnel preparations to access proximal caries for restoration with glass ionomer have not proved favourable.[30] While composite may prove more successful, as it offers more support to the overlying marginal ridge, tunnel restorations remain technically demanding and may have a limited life span when compared to conventional Class II composites or amalgams.

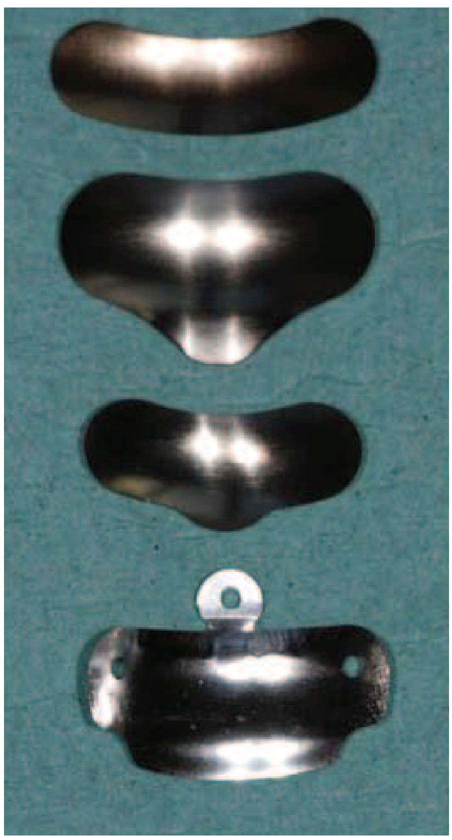


Figure 14. Sectional matrices (top 3: Garrison Dental Solutions, Springlake, MI, USA; bottom: TrioDent, New Zealand).

Moisture control

Blood, saliva and crevicular fluid will all adversely affect adhesion. Careful use of rubber dam will guarantee isolation and improve visibility, making the procedure easier and more predictable.[8] In this respect, recently introduced lip/cheek retractors, such as *Optragate* (Ivoclar Vivadent, Leichtenstein) and *Optiview* (Kerr Mfg Co, Orange, CA, USA) may be of value in cavities towards the front of the mouth.

Tight contacts and natural proximal contour

In the past, composite placement resulted in at least double the number of open contacts compared with amalgam,[31] and this often constituted an 'instant failure' of the restoration. Good matrix technique has been shown to be the most important determinant of contact tightness,[1,5,10,12,22] with recently introduced devices helping to overcome these difficulties.

Matrices must be burnished or held against the adjacent tooth because, unlike amalgam, composite will not so readily push the band out.[8] The aim is not just to get a tight contact, but to recreate embrasure anatomy and facilitate plaque removal from interproximal margins (Figure 12).

Wedging

Wedges reduce the risk of cervical extrusion of composite which, once cured, is virtually impossible to remove accurately without damage to adjacent tissues. The wedge also separates the teeth slightly to compensate for the thickness of the matrix.

New and improved wedges, such as *Flexi-wedges* (Common Sense Dental Products Inc, Springlake, MI, USA) (Figure 13) help to ensure that the wedge does not deform the matrix or encroach upon the contact area.[10]

Matrices

Two general types of contemporary matrix are now available for use with proximal posterior composites:

Sectional matrices and separation rings

Sectional matrices and separation rings have been shown to give the best proximal contact areas[1,10,11,22] and are useful for proximal boxes that are not too wide. These matrices are available in a number of different sizes (Figure 14). Their rounded shape enables the creation of tight,

Figure 15. Forceps to flex open and apply a separation ring (G-ring, Garrison Dental Solutions).

Figure 16. Composi-tight Gold Matrix System in place (Garrison Dental Solutions).

Figure 17. Pin Tweezers and Tab Matrix (TrioDent, New Zealand) – facilitate matrix removal (and placement).

anatomically accurate, contact points that reduce the need for proximal finishing. They are placed, using tweezers, with the concave edge orientated towards the occlusal surface and the convex side towards the adjacent tooth. After wedging, a separation ring is applied to the matrix using designated forceps (Figure 15). The ring tines can be placed on top of the wedge (Figure 16) or between the wedge and the adjacent tooth for wider boxes. Two rings are needed for MOD cavities. They can be orientated so that they face in opposing directions, or in the same direction if different tine lengths are selected.

The ring secures the matrix and further separates the teeth in order to improve contact tightness, but care must be taken to check that the cervical seal has not been lost after ring placement.[8] After filling, sectional matrices can be peeled back to reveal interproximal surfaces. This permits further lateral light curing, which is repeated after complete removal of the matrix.[6] During this curing, the wedge is left in place to prevent haemorrhage.

Removal of sectional matrices can be difficult, as this technique generates very tight contact points. Wrapping the end of the matrix around tweezers or using a bespoke instrument (+/- specialized matrix) expedites removal (Figure 17).

Circumferential matrix systems

In larger cavities and those with wider boxes, circumferential systems may be used in preference to sectional matrices. Traditional 'matrix and holder' circumferential systems often result in anatomically incorrect restorations, with a flat proximal contour and contact points too near the marginal ridge.[8]

New, single use, systems, eg *SuperMat* (KerrHawe, Bioggio, Switzerland) (Figures 18, 19) may be chosen in preference, as they confer a number of advantages:

- Single-use eliminates cross-infection risk inherent in 'multi-use' matrix systems. In this respect, the use of matrices, after cleaning and autoclaving, for more than one patient must be considered inappropriate practice;[32]
- They are simple to use and make tight contacts easier to obtain;
- On tightening, they impart a more rounded proximal contour and are less likely to flex weak cusps;
- The matrix tightener can be easily orientated buccally or palatally/lingually and will permit wedge placement from any angle;
- These systems, rather than interfering with the rubber dam, help to hold the dam in place and improve access;
- They are cost-effective and can also be used for amalgam fillings.

Matrices are applied to the tooth and tightened with a matched instrument.

Metal matrices are favoured over clear ones, which are difficult to use as they are relatively thick, are difficult to insert through tight contact points and cannot be burnished.[6,10] Despite facilitating proximal light-curing, clear matrices have not been shown to enhance margin quality and seal.[33]

Aids to contact formation

Suitably shaped or specially designed hand instruments (eg Trimax-AdDent Inc Danbury, Connecticut, USA) (Figure 20) may be useful in helping to create tight contacts. They are applied to the first increment of box composite and push the matrix against the adjacent tooth (Figure 21). When the composite is cured in this position (through the light-guide when using Trimax), it will help to hold the matrix out while further increments are placed. Such a technique also divides the first increment into two halves, reducing the tendency for the forces of polymerization contraction to pull on both box walls simultaneously.

Figure 18. *SuperMat* matrix and tightener (KerrHawe, Bioggio, Switzerland).

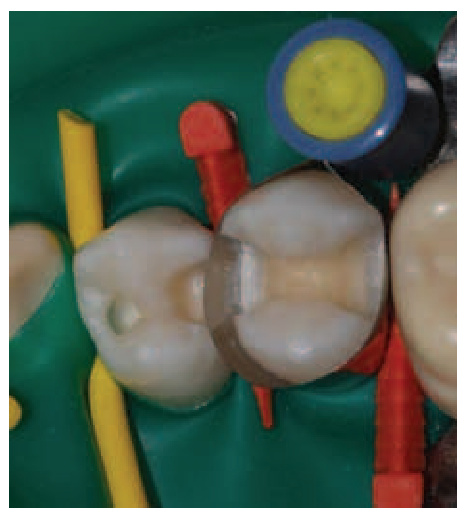


Figure 19. SuperMat Matrix System in place.

Figure 20. Trimax composite instrument (AdDent Inc. Danbury, Connecticut. USA).

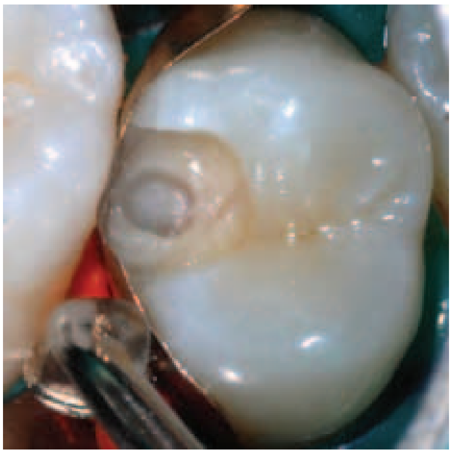
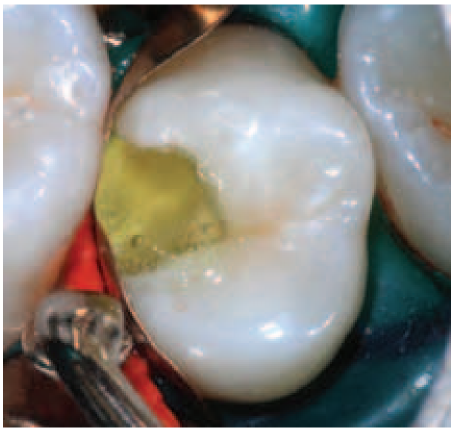


Figure 21. Initial increment of *Ceram X-duo* composite (Dentsply International Inc, York, PA, USA) has been cured with the Trimax (contact forming) tip in place.

a



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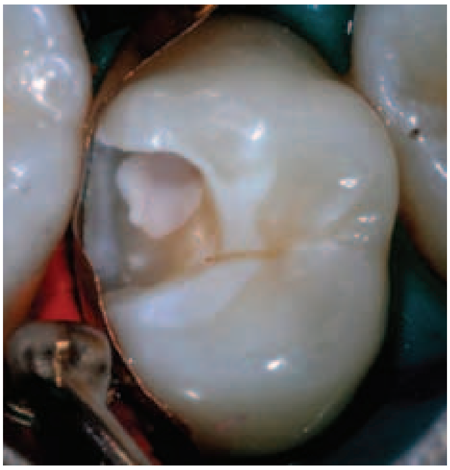

Figure 22. (a, b) Total etch of disto-occlusal premolar cavity (and resin-modified glass ionomer lining).

Figure 23. Moist dentine floor ready for application of adhesive.

Etching

Before etching, the cavity must be thoroughly washed, dried and inspected for any debris. Starting with the enamel, etchant is applied to the whole cavity, and just beyond the margins[10] (Figure 22).

Excessive application of etchant beyond cavity margins will result in excess composite adhering to the etched enamel; this will have to be removed and, when doing so, the underlying enamel may be damaged, notwithstanding the time spent removing the excess composite. When application to the dentine is complete, it is left for 15 seconds and then rinsed off thoroughly.

With total etch systems, enamel can be dried to confirm proper etching (it will appear 'frosty'), but the dentine must be re-wetted to promote dentine bonding.[11] The aim of 'wet bonding' is to leave the cavity slightly but visibly moist, with no obvious pooling (Figure 23).

Self-etching adhesives are applied and then dried to evaporate the solvent.

Bonding

Since successful bonding is a fundamental requirement for long-lasting composites, fastidious attention to the manufacturer's protocols is essential for each adhesive system.[11,13] Mistakes in application will have serious consequences. Gentle air drying and/or aspiration are used to evaporate the solvent[6] and leave a thin uniform layer, coating the entire cavity. If the adhesive continues to ripple under gentle airflow, this implies that solvent evaporation is incomplete, or that excess resin is present. Pooling can be removed by blotting with a micro brush.[6] Conversely, any dry areas should receive further adhesive and be air dried again. All cavity surfaces should now appear glossy/shiny (Figure 24). The adhesive is then light-cured as per manufacturer's instructions.

Polymerization shrinkage

Improvements in modern materials and adhesive technology have overcome many of the historical problems associated with posterior composites,[4,6,8] such as poor wear resistance, as well as practical, technical difficulties, such as contact formation. Many of the remaining problems associated with posterior composites are a direct or indirect result of polymerization shrinkage.[34] On setting, all composites shrink (on average 2-3% by volume)[13] as the matrix monomer converts to polymer. On shrinking, stresses are invariably generated within the material and at the margins; the magnitude of this stress depends on the composition of the composite and its ability to flow before solidification, which in turn is related to the cavity configuration.[35] The *Configuration Factor* (C-factor) is the ratio of bonded to free cavity surfaces. Narrow/deep occlusal cavities, with only one unbonded surface, have the greatest '*C-factor*' and are therefore subject to an increased potential for stress development.[24] The larger the increment of composite, the greater the total shrinkage will be; this will again increase the potential for stress formation.

Other factors influencing the amount of polymerization contraction stress include: cavity volume;[36] the amount and quality of residual mineralized tooth tissue (tooth compliance); location of

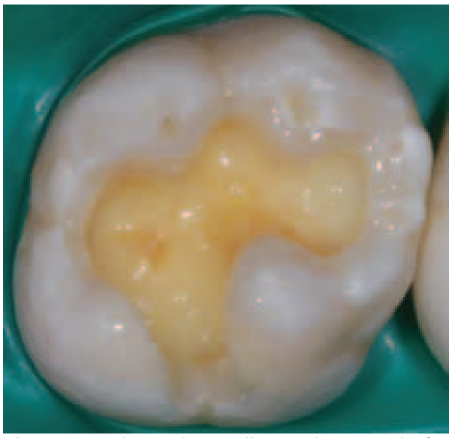

Figure 24. Glossy/shiny adhesive layer ready for light curing.

Figure 25. Stained marginal and surface defects are evident in this restoration at 5 years post placement. Incomplete control of the forces of polymerization contraction may have contributed to loss of marginal integrity.

cavity margins; bond strength of the adhesive; material composition; and curing characteristics.

Consequences of polymerization shrinkage

Polymerization shrinkage occurs towards the walls of the preparation to which the composite is most strongly bonded. If contraction forces at the least retentive cavity margins (those with dentine bond or fragile enamel) exceed those of the bond strength, separation may occur at the interface.[11,34]

Partial or total bond failure may result in loss of the restoration, post-operative sensitivity or marginal gap formation, which in turn may allow ingress of cariogenic bacteria and stain.[11] Even if marginal gaps are not an immediate clinical problem, the stain that ensues may lead to premature removal of the restoration due to subsequent misdiagnosis of secondary caries[37] (Figure 25).

If the bonding interface is preserved, the contraction forces can be transmitted to the adjacent enamel and dentine, causing cusp flexure or fracture (especially if thin) and/or crazing of the enamel or fractures in the composite material.[11,13,34]

Post-operative pain

Despite improvements in materials and techniques, post-operative sensitivity following placement of posterior composites may arise[4,11] if care is not taken to avoid the problems caused by polymerization contraction shrinkage or there are deficiencies in the bonding and/or placement technique.

Nevertheless, as with any restoration, a short period of transient post-operative sensitivity may occur and patients should be warned of this. A common mechanism for persistent post-operative pain results when a debond gap forms under a restoration and fills with dentinal fluid (over 24-36 hours). When cold or hot stimuli cause contraction or expansion of the fluid in this gap, the consequent, sudden movement of fluid in the dentinal tubules causes pain.[11,38] Pain in a composite-restored tooth may also relate to the fact that even the stiffest *hybrid* composites are relatively flexible in comparison to the stiffness of tooth enamel. Flexure of the material and/or the tooth that it is bonded to may result in pressure changes in dentinal tubular fluid being transmitted to the pulp, giving pain on chewing (often on release).[11,38]

Treatment of persistent post-operative sensitivity usually involves removal of the restoration so, if at all possible, is to be avoided.[11] It has also been demonstrated that a restoration displaying post-operative sensitivity within one month of placement is more likely to have failed at five years, especially in larger cavities.[4]

Managing polymerization shrinkage

Development of low shrinkage composites is an area of vigorous research[11] and is the subject of a subsequent paper.

Incremental placement technique is a well recognized method of reducing the effects of polymerization shrinkage. Other suggested methods include:

- Use of flowable composite resin as a liner;
- Use of other linings/base layers;
- Incorporation of macro-fillers (eg ready made inserts) to reduce the overall volume of composite;
- Alternative light curing regimes.

Flowable composites

Use of flowable composites as a lining is the subject of divided opinion.[2,5,11,13] It is suggested that a flowable resin with a lower modulus of elasticity may act as a stress relaxation buffer,[13] deforming to absorb the tension stress of the overlying composite,[38] during polymerization and post-cure.

Use of flowables has also been advocated to improve composite adaptation to the cavity.

If a decision is made to use it, then a thin, uniform layer of maximum 0.5mm thickness is applied to the dentine. Lighter shades may be employed as these will cure more easily.[10,11] It is applied to boxes first and any air bubbles are popped with a probe, before curing (Figure 26).

In this respect, flowable composites may be best suited for restoring small cavities in preventive resin restorations[39] (see Figure 2) and for sealing narrow marginal defects when repairing existing restorations.

Flowable composites from different manufacturers show a wide variation in formulation and offer different

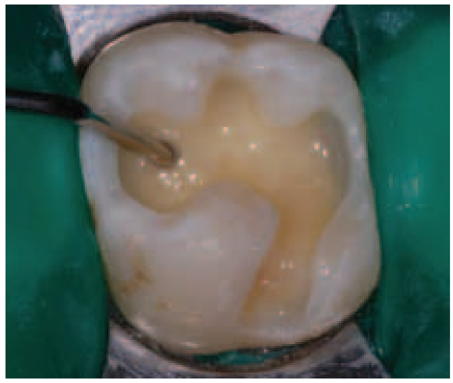

Figure 26. Placement of flowable composite lining.

viscosities, mechanical properties and radio-opacities.

Bases and linings

Glass ionomer, resin modified glass ionomer and chemically cured composite may also be used as part of an open or closed 'sandwich' restorative protocol.

Closed sandwich

Here a resin-modified glass ionomer (RMGI) lining, eg *Vitrebond* (3M St Paul, MN, USA), is placed over pulpal dentine prior to etching. This will adhere to the prepared cavity floor and may help to protect the pulp by sealing deep dentine in an area where bond strengths may be diminished.[4] This, in turn, may lead to a reduction in post-operative sensitivity.[1,4,6,11] *Vitrebond* may also be used to protect calcium hydroxide pulp caps from etchant, but should be confined to as small an area of dentine as is practical and must be kept well clear of cavity margins, where it will dissolve over time.

Open sandwich

Here a glass ionomer, RMGI or chemically cured composite is placed over the dentine and into the cervical part of a box. In this respect, the longevity of restorations has been reported to be reduced by the use of 'elastic' linings and base layers.[21] Potential benefits must be weighed against reported increased fracture rates of restorations overlying such 'shock absorbing' layers.

Composite placement

When placing posterior composites, the use of small increments is recommended by many authors for insertion and polymerization, for a number of reasons:

- Incremental technique gives a more effective and uniform polymerization and reduces total polymerization shrinkage;[1,8,11,38,40]
- Increments decrease the stress generated on cavity walls,[1,10,38] reducing the potential for debond gaps and cuspal deflection;[40]
- Increments lower the *C-factor* ratio. The wide free surface compared to bonded surface in any single increment permits resin flow on polymerization;[38]
- Incremental technique is a more practical method. It allows development of proper anatomy[1] and aesthetics, enhances control of marginal overhangs and reduces the need for finishing;[38]
- Despite promising findings from isolated clinical trials,[41] newer 'bulk-fill' techniques are generally not recommended [12,38,40] as they may promote formation of marginal gaps, increase post-operative sensitivity and encourage incomplete polymerization in deep boxes.[42,43]

Posterior composites may be applied directly from a compule (if the viscosity permits) using the tip in a 'wiping motion' to adapt the material into the cavity corners, undercuts and against cavity walls. Composite may also be applied using hand instruments.

Precise adaptation of the first increment to the cavity is a very important step. This layer is furthest from the light and should therefore be limited to a maximum 1mm thickness[6,11] and be cured for a greater length of time than recommended by the

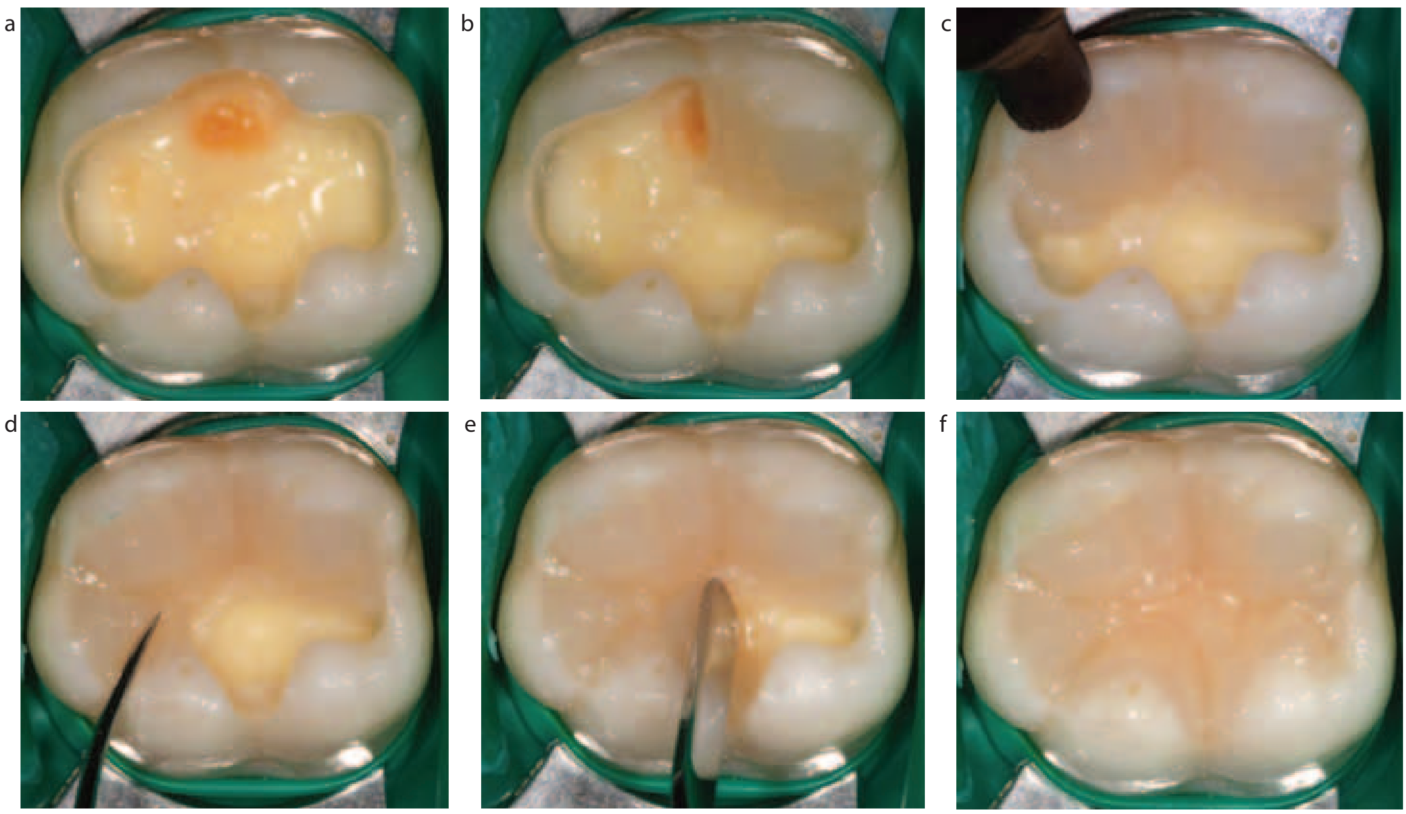

Figure 27. (a) Adhesive applied to an occlusal cavity in a lower first molar: **(b)** mesio-lingual increment; **(c)** disto-lingual increment; **(d)** disto-buccal increment; **(e)** centro-buccal increment; **(f)** mesio-buccal increment.

manufacturers (x2). Subsequent increments should be 2 mm or less, and touch only one wall, to create a more favourable *C-factor*.[11,13] The use of the correct amount of composite will minimize finishing.[11,13] Each increment is cured for a time, at least, in accordance with the manufacturer's instructions.

While various protocols have been proposed for layered placement of composite in posterior cavities,[40] no individual incremental technique has been demonstrated as consistently superior in terms of minimizing the adverse effects of polymerization and post-cure stress[44,45] and optimizing marginal seal.[46] Three variations of the basic oblique-layering technique are described:

- Successive cusp build-up;
- Separate dentine and enamel build-up;
- Separate dentine and enamel build-up – using an index.

Successive cusp build-up

Here individual cusps are restored one at a time (Figure 27), up to the level of the occlusal enamel. Small sloping increments are applied to each corner of the cavity in turn and manipulation is kept to a minimum, to avoid folding voids into the material. This method, while initially time consuming, can greatly reduce finishing time by careful attention to progressive reconstruction of natural morphology.[11]

Separate dentine and enamel build-up

Here sloping increments are again applied to cavity walls (and cured in turn) but only to the level of the amelo-dentinal junction (ADJ) occlusally (Figure 28). Final 'enamel' increments are then applied. Careful control of the final layer will again reduce the finishing stage.[8,11] Some operators (if agreeable to the patient) place composite pit and fissure stain before placement of the final layer.[8] An alternative method of achieving a more natural appearance is to use a dark (eg A4) shade of composite for the bulk of the restoration and a translucent or light shade for the 'enamel' increment(s).

Separate dentine and enamel build-up – using an index

This variation can be used when restoring a carious tooth with an intact occlusal surface. After dam placement, a pre-operative impression is taken of the occlusal surface (a number of materials, including translucent ones, may be used for this purpose). Once layered 'dentine' restoration

a b c d e f g h

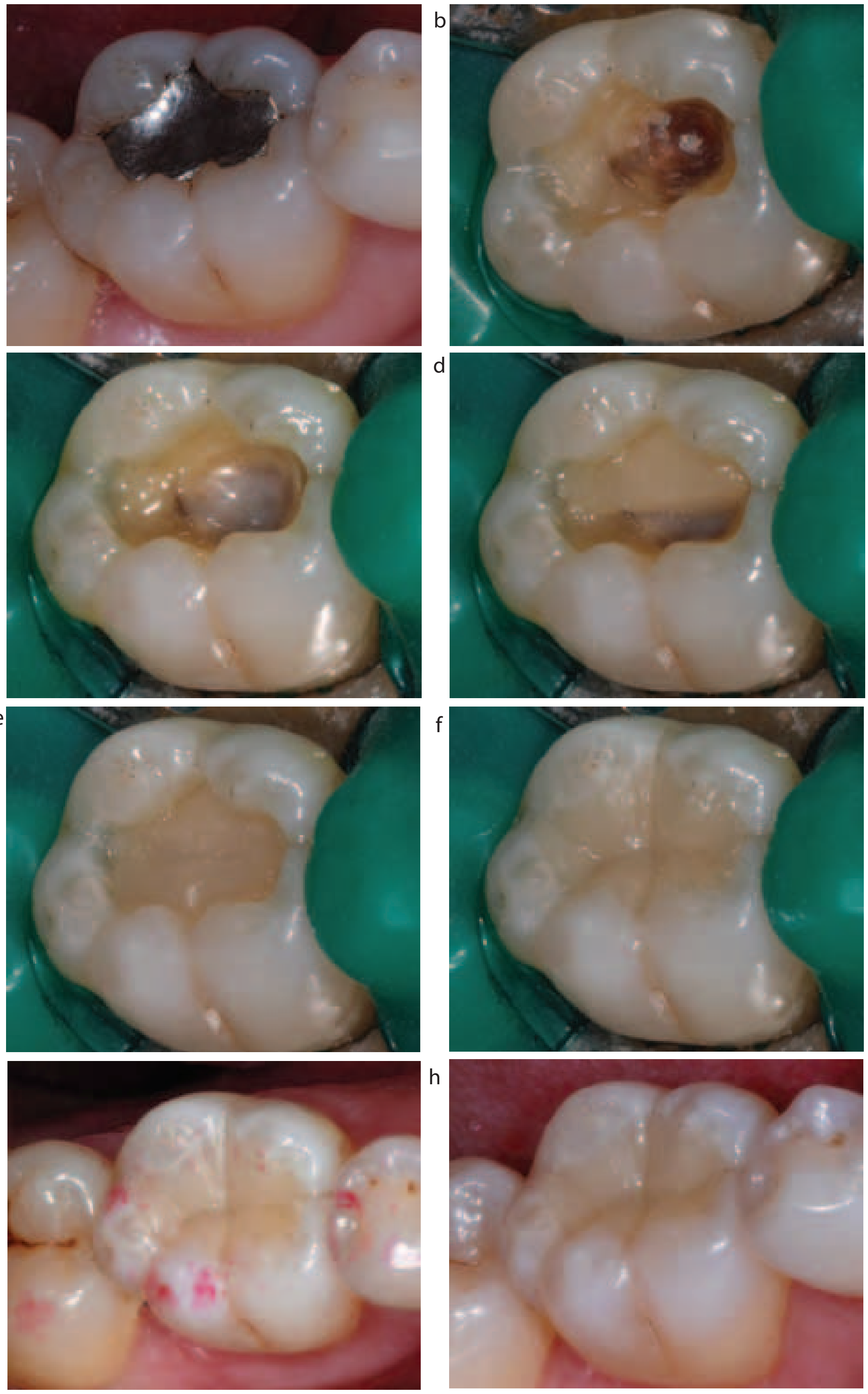

Figure 28. (a) Occlusal amalgam LR6. **(b)** Prepared cavity. **(c)** Adhesive layer (over localized, very thin, *Vitrebond* lining). **(d)** Lingual 'dentine' restored. **(e)** Buccal 'dentine' restored. **(f)** 'Enamel' restored. (g) Occlusal contacts recorded. **(h)** Finished restoration.

Figure 29. (a) Isolation. **(b)** Pre-operative impression of the occlusal surface (silicone putty is used here). **(c)** Impression must record morphology accurately. **(d)** Access to lesion. **(e)** Cavity preparation complete. **(f)** Incremental restoration up to ADJ. **(g)** Final increments of composite applied and silicone index seated over the unset material. **(h)** Minimal excess to be removed before curing. **(i)** Finished restoration requires no occlusal adjustment.

is complete, the impression material is used to aid precise adaptation of the final 'enamel' increment(s) (Figure 29). With careful control of the amount of composite used, this technique may completely eliminate the finishing stage.[11]

Instruments for composite placement

A multitude of specialized instruments are now available for use with posterior composites, designed to simplify placement and shaping.[13]

It is vital that they are kept spotless and unscratched, in order to prevent composite sticking to them. The use of a small selection of favoured instruments will improve efficiency and it may be advisable to keep a special set of instruments for 'composite only' (Figure 30).

The use of adhesives to lubricate instruments is not recommended, as they contain solvents that will degrade the properties of the restorative material.

Light curing

Various alternative regimes have been proposed for light curing, including soft-start, ramp, step, pulse and pulse delay. The clinical significance of these protocols is the subject of debate[6] and may have a limited effect on polymerization shrinkage and therefore stress formation.[31] It is generally accepted that:

- The light tip should be placed as close to the cavity as possible;[11]
- While composite cannot realistically be over-cured (25–40% remains un-reacted), care must be taken not to overheat the pulp, or to waste time;
- Lighter shades will cure more readily than dark shades, which absorb more light;[10,11]
- Light units should be metered regularly[6,11,13,47] as low intensity light still looks bright. Separate radiometers may be expected to offer greater accuracy than those built-in to curing lights;
- Care must be taken to prevent premature polymerization by the overhead chair light.[6]

Shaping/finishing/polishing

The best mechanical properties of set composite are to be found *just* below the surface, close to the light source, but where polymerization has not been inhibited by oxygen. Gross adjustments are therefore contra-indicated unless the clinician plans to re-light-cure on completion of finishing. A 'dark-curing' phase follows application of the light and early finishing (<3minutes) has been shown to affect microleakage significantly.[11] Therefore, a delay in finishing, for as long as is practical, will be beneficial. Heavy, immediate finishing will also increase the potential for formation of 'white-line' fractures around the restoration. It is believed that these are related to enamel fractures occurring 10–50 µm from the margin of the restoration. To help reduce their prevalence, an even longer delay in final finishing (>24 hours) will give the composite time to absorb water (and undergo hygroscopic expansion), relieving stresses at the bonded interface.

Despite best efforts, slight adjustments are usually necessary and an array of specialized diamond and tungsten

a b c d

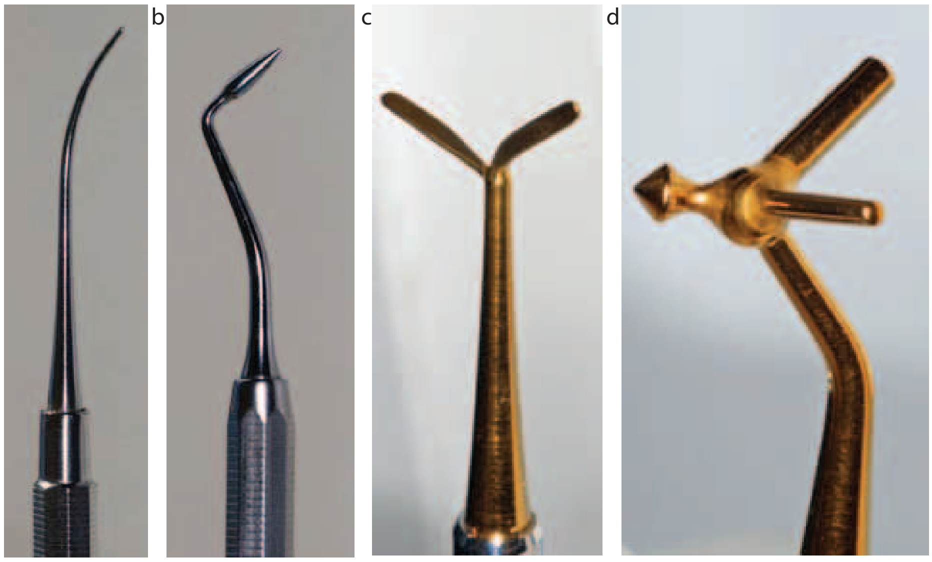

Figure 30. (a) P.K.T 2 **(b)** P.K.T 3 (both instruments are available from many dental and technical suppliers). **(c, d)** Multi-function composite instrument (Garrison Dental Solutions, Springlake, MI USA).

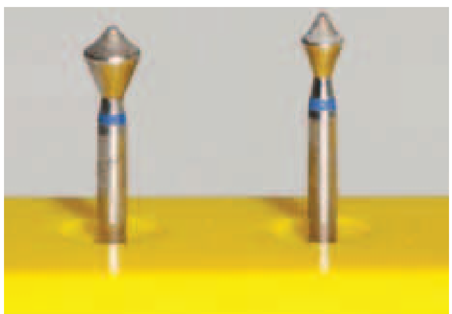

Figure 31. *Bertolotti 'Top-Spin'* diamonds (Pollard-dental, CA, USA). Specialized composite finishing burs for accurate shaping of fissures and fossae.

Figure 32. Occlusal restoration in an upper first molar at 2 years (*Synergy Duo*, Coltène-Whaledent, Switzerland). Finishing bur marks are evident on the palatal cusps, adjacent to the restoration margin.

carbide burs are available to facilitate this[8,11,13] (Figure 31). They should be applied intermittently with light pressure and water spray to prevent overheating.[6] The use of loupes will facilitate removal of excess[6] and reduce the risk of damage to marginal enamel (Figure 32).

A variety of polishing discs are available (Figure 33). These may be used to impart a smooth surface and are especially useful for marginal ridges, where they are less likely to damage adjacent teeth. Discs may be followed by rubber or silicone discs/cups/points or brushes, which may be impregnated with particles that impart a high shine. Again, discs and polishers should be used intermittently and with water cooling, if necessary, to combat excessive temperature rise.

Surface sealers, eg *Biscover* (Bisco Inc, Schaumburg, Illinois, USA), may be applied to seal surface defects and further improve texture and aesthetics.[8] (Their application will also permit an additional curing cycle.)

Practising posterior composites

Carefully recording which materials and techniques have been employed will enable a long-term clinical audit of restorations. *In-vitro* practice on extracted teeth is a useful method of testing new materials and perfecting techniques[13] (Figure 34).

Figure 33. Super-snap finishing and polishing discs (Shofu Dental Corporation, San Marcos, CA, USA).

a
b
c

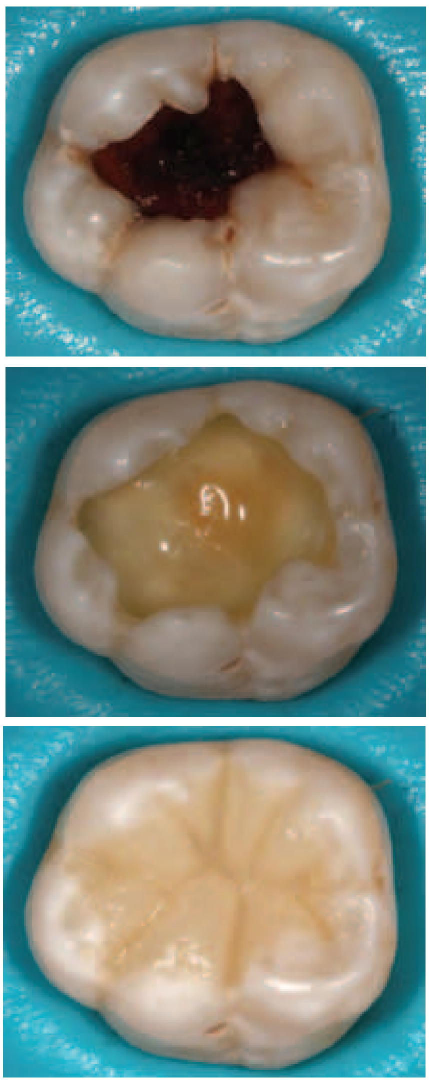

Figure 34. (a–c) Extracted teeth (here set in silicone putty) can be used to test adhesive systems and composites and to practise techniques.

Conclusion

Posterior composites, while time consuming and demanding, can yield great patient and dentist satisfaction. Learning and mastering techniques is well worth the effort.

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