The authors’ surface treatment protocols for high-strength ceramics (ie, aluminum and zirconium oxide) include 2 methods. One method requires silica coating of the inner surface of the restoration with CoJet-Sand (Rocatec/CoJet System, 3M ESPE) followed by an application of a silane coupling agent (ESPE Sil). The application of a silica layer to high-strength ceramics such as zirconia creates binding sites for the silane molecules while the silane provides wettability and a chemical coupling with the methacrylate based cements (Figures 5 to 7). Another user-friendly method involves an application of a commercial primer that contains phosphonate or phosphate monomers. Phosphate monomers form covalent bonds with the zirconia surface and have polymerizable resin terminal ends that copolymerize with the resin cements. The recent developments of several special ceramic primers indicate their importance. Even if a resin cement contains the same adhesive monomer as the priming agent, the primer offers a better wetting effect to the intrinsically rough intaglio surface of an all-ceramic restoration. Currently, there are several ceramic primer systems for zirconia surface preparation available such as Monobond Plus (Ivoclar Vivadent); Clearfil Ceramic Primer (Kuraray); AZ-Primer (Shofu Dental); Metal/Zirconia Primer (Ivoclar Vivadent); and Z-Prime Plus (BISCO) (Figures 8 to 12). Air-particle abrasion with small aluminum oxide particles (eg, 30 µm) before application of a ceramic primer is recommended to further increase bond strengths of composite resins to high-strength ceramic materials.
compatible with the bonding agent and resin cement. Therefore, it is imperative to stay within one bonding system and to closely follow the manufacturer’s instructions for application and timing. In addition, silane coupling agents provide excellent long-term durable chemical bonds to silica-based ceramics. Such bonds, however, are not possible to high-strength ceramics that do not contain silica. Also, it is important to remember, that silane coupling agents used for silica-based ceramics can have different chemical compositions. However, they must be compatible with the bonding agent and resin cement.

Clinical considerations for surface treatment of ceramic material

There are several consideration factors for the surface treatment of ceramic material. First, it is important to avoid contamination of pretreated ceramic surfaces, since organic contaminants such as salivary fluids or finger residue can decrease bond strengths. However, if the restoration is contaminated prior to cementation, any contaminated surface should be cleaned with a phosphoric acid solution for 15 seconds. It is important to remember that different silanes or “ceramic primers” are not the same and, for high-strength ceramics, it is imperative that the priming agent contains special monomers that bond to metal oxides.

Conventional silane coupling agents and resin composite luting agents provide excellent long-term durable chemical bonds to silica-based ceramics. Such bonds, however, are not possible to high-strength ceramics that do not contain silica. Also, it is important to remember, that silane coupling agents used for silica-based ceramics can have different chemical compositions. However, they must be compatible with the bonding agent and resin cement. Therefore, it is imperative to stay within one bonding system and to closely follow the manufacturer’s instructions for application and timing. In addition, silane coupling agents provide excellent long-term durable chemical bonds to silica-based ceramics. Such bonds, however, are not possible to high-strength ceramics that do not contain silica. Also, it is important to remember, that silane coupling agents used for silica-based ceramics can have different chemical compositions. However, they must be compatible with the bonding agent and resin cement. Therefore, it is imperative to stay within one bonding system and to closely follow the manufacturer’s instructions for application and timing.

Figure 11: The excess cement was removed using a No. 000 sable brush, leaving a residual amount to compensate for polymerization shrinkage (11a). An oxygen inhibitor layer (Oxyguard II, Kuraray) was placed at the interface to accelerate the set of the resin cement (11b).

Figure 12: The completed all-ceramic restoration with a zirconium substructure and Vita surface ceramics (VITA VM9, Vident). Notice the healthy biological framework and the integration of color with the adjacent dentition.
are dispensed in single or multiple-bottle applications. Single-bottle products typically contain greater amounts of solvents and are, therefore, more susceptible to solvent evaporation, hydrolysis, and polymerization that renders the solution ineffective. Thus, it is essential to periodically review shelf life and remember to seal containers immediately after use. Also, the color of the solution can be a reliable indicator of the efficacy of the solution and if it appears milky, it should be discarded.

**Conclusion**

The primary objective of any cementation procedure is to achieve a durable bond and a good adaptation of the luting material to the restoration and the tooth. Conventional cementation techniques for indirect ceramic restorations rely on only one physico-chemical interaction – mechanical interlocking. Adhesive cementation techniques provide a combination of micromechanical interlocking and true chemical bonding. In addition, adhesive bonding of indirect restorations can increase retention, marginal adaptation, and fracture resistance of the restored tooth and the restorative material when compared to conventional luting techniques. This article has provided the clinician and technician with various alternative materials and techniques for achieving an optimal, long-term, durable adhesive bond to different ceramic microstructures.

**References**


Disclosure
Dr. Terry reports no disclosures.

Disclosure
Dr. Blatz receives research grants/support from the following: Nobel Biocare, Straumann, Noritake, Ivoclar Vivadent, Kuraray, Heraeus Kulzer, 3Shape, 3M ESPE, Shofu, Premier, Tokuyama Dental, DMG, and Zirkonzahn. He is not a paid consultant for any company but has received occasional speaking honoraria from Nobel Biocare, Noritake, Ivoclar Vivadent, Kuraray, and CUSP Dental Research.

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New clinical innovations and the benefit of magnification to ensure predictable posterior composite restorations – Part 1

Peet van der Vyver1

Introduction
For many years gold and amalgam have been the materials of choice for restorations in the posterior dentition due to the clinician’s desire for predictable function and a lack of viable aesthetic treatment choices. Today, the benefits of posterior resin restorations extend far beyond appearance alone. Features and benefits include functional stability, conservative cavity preparation, tooth reinforcement, biocompatibility and repairability (Jackson, 1999).

Posterior composite resin restorations are generally performed as fine detail work. The restorative phase requires attention to detail while following a meticulous clinical technique. According to Liebenberg (2002), the direct Class II posterior composite resin restoration is one of the most challenging restorations due to the operative intricacy and proximal precinct. Clinical performance is affected by the degree of fine detail that can be seen by the clinician during any given dental operation. The use of magnification in dentistry is expanding rapidly. It has revolutionized endodontics and will improve many aspects of clinical dentistry. The Dental Operating Microscope (DOM) (Figure 1) improves visual acuity, provides increased precision and is also of important ergonomic benefit to the clinician.

As reported by van As (2008), 10X microscope magnification can provide the clinician with 25 times more visual information compared to that obtained from the use of entry level loupe magnification (2X) and 100 times more information compared to the naked-eye view. In a study by Leknius and Giessberger (1995) they demonstrated that dental students who performed fixed prosthodontics procedures while using magnification were found to make fifty per cent less errors than students who performed the same procedure without the aid of magnification. In 2004, Zaugg, Stassinakis and Hotz illustrated the influence of magnification on the recognition of simulated preparation and filling errors. They mounted 37 mistakes or filling errors onto a phantom head model and asked 39 dentists to examine the jaws under clinical conditions using either no visual aid (n=13), magnifying glasses (n=13) or a microscope (n=13). The group using the microscope for examination spent more time on examination and found significantly more defects than the groups using magnifying glasses or no visual aids.

The accuracy of any given procedure is increased when the stereoscopic view of the microscope is combined with the shadowless coaxial light source. Combining magnification with illumination allows the clinician to

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Figure 1: Global 6-Step Dental Operating Microscope (DOM) fitted with a dual-iris, LED light source, beam splitter and HD video camera.
visualise vital information that can influence the outcome of treatment which is not otherwise perceptible to the naked eye. In general, the benefits of microscope magnification include: magnified images, increased precision (van As, 2008), shadowless illumination, improved ergonomics and posture for the operator, digital documentation of findings by means of integrated photography or video (van As, 2008) that can be used for communication with the patient.

This article will review the benefit of magnification during the placement of direct posterior composite restorations with emphasis on how to achieve adequate interproximal contact, bonding procedures and composite insertion techniques.

Achieving Adequate Interproximal Contact and Integrity

One of the major clinical problems with direct posterior composite resin restorations is the clinician’s inability to achieve an ideal interproximal contact (Burke and Shortall, 2001). The primary challenge with Class II composite restorations is to create functional, predictable proximal contact that emulates the physiological ideal (Morgan, 2004). According to Maitland (1993) some of the failures of composite restorations, which are a result of manipulative deficiencies, are open contacts which leads to continuous food impaction and periodontal disease, as well as inadequate proximal contours, faulty occlusion and excessive wear.

According to Varlan et al., (2008) you need a properly contoured matrix band that is stabilized and adequately adapted gingivally with a wedge to establish the correct interproximal contact and convex contour. If a conventional Tofflemire matrix (uncontoured or contoured) is stabilized gingivally with a wedge it will still often result in open or light contact points if the clinician does not use additional separation (Wirshing et al., 2008). One of the major problems with a circumferential band is that the matrix often flatten out interproximally due to tensioning of the band and when the interproximal box preparation is very wide (bucco-lingual direction) an open contact is the only possible outcome (Boksman, 2010). The inability to properly condense composite resin materials, the fact that they demonstrate unconstrained volumetric shrinkage of 2-5% and that the matrix band itself take up some interproximal space during the placement phase are also reasons that can contribute to open contacts with posterior composite restorations (Boksman, Margeas and Buckner, 2008).

Precontoured sectional matrices in combination with separating rings can provide the clinician routinely with predictable interproximal contacts (Van der Vyver, 2002). The precontoured metal matrices are very malleable, they can usually be sealed more completely at the gingival margin to prevent overhangs and are less likely to lose their contour if aggressively wedged (Reality, 2001). Separating rings has become indispensable when the clinicians want to achieve tight interproximal contact. These rings are placed between the teeth adjacent to the box preparation after placement of the matrix band. The engaged ring then exerts a continuous separating force on the two adjacent teeth, creating a small space that will promote adequate interproximal contact. In addition, the tines of the ring can also ensure good adaptation of the matrix band against the preparation walls of the cavity preparation to minimise or eliminate any excess of composite material at the line angles (Reality, 2001).

It is well documented in the literature that precontoured sectional matrices in combination with separating rings will result in the strongest contacts (Boksman, Margeas and Buckner 2008; Loomans et al., 2006; Saber et al., 2010) and stronger marginal ridges (Loomans et al., 2008).

There are many sectional matrix systems on the market that can help the clinician to achieve good interproximal contact and convex contour (Table 1). The author prefers to use the V3 Matrix System (Triodent) that is also marketed as the Palodent Plus System (Dentsply) in certain regions.

The curved matrix bands (available in sizes from 3.5mm up to 7.5mm) of this system are designed with a rounded gingival contour as well as with an occlusal marginal ridge

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**Table 1: Sectional Matrix Systems for Class II Posterior Composite Restorations**

<table>
<thead>
<tr>
<th>Separating Ring and Contoured Sectional Matrix System</th>
<th>Recommended Wedge</th>
<th>Manufacturer</th>
</tr>
</thead>
<tbody>
<tr>
<td>V3 Matrix System Sectional Matrix System</td>
<td>Wave-Wedge</td>
<td>Triodent</td>
</tr>
<tr>
<td>Palodent Plus Sectional Matrix System</td>
<td>Palodent Plus Wedge</td>
<td>Dentsply</td>
</tr>
<tr>
<td>Composi-Tight Silver Plus Sectional Matrix System</td>
<td>Wedge Wands</td>
<td>Garrison Dental</td>
</tr>
<tr>
<td>Composi-Tight 3D Sectional Matrix System</td>
<td>Wedge Wands</td>
<td>Garrison Dental</td>
</tr>
</tbody>
</table>
The V3 contour that routinely provide the clinician with an anatomically formed contact point, excellent marginal ridge contour and restorations that require minimal finishing (Figure 2).

The V3 separating rings (Figure 3) are available in two different sizes, a universal (green) and a narrow ring (yellow) (for narrow embrasure spaces) fabricated from nickel titanium. The nickel titanium ring is partially covered with glass reinforced plastic tines that are V-shaped. The wide occlusal footprint of the plastic tines ensure excellent adaptation of the matrix band against the cavity margins while the V-shape tips allow for easy placement over the wedge. However, more important is the fact that these V-Shaped tines allow the operator to move, replace or add additional wedges if needed during the procedure to ensure proper adaptation of the matrix band at the gingival margin, without disassembling the matrix setup as it is the case with many other systems.

Another significant cause of failure of posterior composite resin restorations is secondary caries. Gap formation at the cavity margins can also be a result of polymerization shrinkage of the composite resin (Eick & Welch, 1986; Lutz, Krejci & Barbakow, 1991). According to Letzel (1989) marginal gaps can permit the ingress of bacteriogenic bacteria and oral fluids (Mejare, Mejare & Edwardson, 1979; Quist, 1980), resulting in the formation of secondary caries.

It can also lead to post-operative sensitivity, staining at the margins (Ericksen & Pears, 1978).

The author is of the opinion that gap formation and subsequent secondary caries formation can also be a result of poor matrix management at the gingival margins of the cavity preparations. With poor matrix adaptation to the gingival margins of the preparation, crevicular fluid, blood, saliva or a combination of these fluids will contaminate the adjacent enamel, dentine or cementum. This can compromise the bonds strength of the bonding system to the remaining tooth structure in this critical area of the preparation. Figures 4a (magnification 5X) and 4b (magnification 15X) illustrate a clinical case after cavity preparation and matrix assemblage on an upper right second premolar. Note the poor matrix adaptation at the gingival cavity margin allowing crevicular fluid (arrow) to contaminate the cavity margin.

Figures 5a (magnification 5X) and 5b (magnification 15X) depict another clinical case after cavity preparation and matrix assemblage on an upper right first molar. Poor matrix adaptation at the gingival cavity margin allowed crevicular fluid and blood (arrow) from the sulcus area to contaminate the cavity margin.

It is important to note that with Class II posterior composite resin restorations the function of the wedge is not to provide tooth separation but to seal the matrix at the
gingival margin. The author prefers to use plastic wedges eg. Wedge Wands (Garrison Dental) or Wave-Wedges (Triodent).

The Wave-Wedges (Triodent) (Figure 6a) provide unsurpassed sealing capability at the gingival margin. The wedges have an inverted V-shape (Figure 6b) at the bottom to accommodate the gingival tissue and also allow the wedges to be stacked on top of each other (Figures 7a and b). It is also possible to place one from buccal and one from palatal/lingual aspect to increase the gingival seal. The wave shape of the wedge also allow for optimal approximation of the wedge when placed interproximally between two teeth ensuring a broad gingival seal by optimal adaptation of the interproximal space.

The interface between the gingival margin and the matrix band should be inspected under magnification (at least 10X) to ensure:

- Excellent adaptation between the gingival margin and the matrix band, ensuring the absence of any fluids penetrating between the matrix band and gingival margins. Figure 8a illustrates case where a Class II cavity preparation was done on an upper left second premolar. After matrix assemblage, and examination at 3X and 5X (Figure 8b) magnification the matrix adaptation at the gingival margin appeared to be satisfactory. However, under 15X magnification (Figure 8c), it was evident that the matrix adaptation was not as good as observed at lower magnification. Note the crevicular fluid (arrow) moving up in between the matrix band and gingival cavity margin, that could compromise the bond strength of bonding systems to this gingival margin. After the matrix assemblage was changed Figure 8d demonstrates excellent adaptation between the gingival margin and matrix band (arrow), eliminating the presence of fluid contamination of the restorative margin and hopefully will ensure a more predictable long-term result.

- Adequate adaptation between the matrix band and the facial and lingual proximal margins. Figure 9 (magnification 8x) shows cavity preparation and matrix band assemblage on an upper first molar. Note the good matrix adaptation on the buccal proximal margin (asterisk), and very poor matrix adaptation on the palatal proximal margin (arrow). This poor matrix adaptation on the palatal proximal margin will lead to excess composite material in this area that will prolong finishing and polishing of the final restoration.

- Integrity of the gingival and proximal enamel margins.

Figure 6a: Wave-Wedges (small, medium and large). Figure 6b: Inverted V-shape at the bottom to accommodate the gingival tissue and also allow the wedges to be stacked on top of each other.

Figure 7a and b: Frontal and buccal view of Wave-Wedges stacked on top of each other.

Figure 8a (magnification 5X) and 8b (magnification 5X): Class II cavity preparation on an upper left second premolar. After matrix assemblage, and examination the matrix adaptation at the gingival margin appeared to be satisfactory. Figure 8c (magnification 15X): Under high magnification it was evident that the matrix adaptation was not as good as observed at lower magnification. Note the crevicular fluid seeping in between the matrix band and gingival cavity margin (arrow). Fig 8d (magnification 15X): After the matrix assemblage was changed, excellent adaptation (arrow) between the gingival margin and matrix band was achieved.
Unsupported enamel often chips off when the clinician exerts force on the margins during placement of the wedge (gingival margin) or the separating rings (proximal margins).

**Etching of Enamel and Dentine**

Enamel bonding plays an important adjunctive role in the long-term retention of adhesive restorations, and recent work confirms the strength and stability of the etched enamel bond (Van Meerbeek et al., 1994). Traditionally, etching enamel with approximately 30 - 60% phosphoric acid solution for 30 - 60 seconds and appropriate washing and drying give reasonable good enamel bond strength.

Dentine bonding systems can consist of a conditioner/etchant, primer and adhesive. Acids or conditioners are applied to the dentine surface in order to remove the smear layer (amorphous layer of cutting debris and bacteria that is left on the dentine after cavity preparation according to Eick et al., 1970) and concurrently decalcify the underlying intertubular dentine.

The extent of the dissolution depends on the type and concentration of the acid, as well as the viscosity and the exposure time of the etchant (Van Meerbeek et al., 1992).

Unsupported enamel often chips off when the clinician exerts force on the margins during placement of the wedge (gingival margin) or the separating rings (proximal margins).

The dentine may be extensively demineralised and weakened if the concentration of the acid is too high or if the exposure time is too long (Wang and Nakabayashi, 1991). The depth of dentine demineralisation has become an important issue in dentine bonding (Perdigão and Lopes, 2001). The incomplete penetration of bonding resin into the demineralised microporous collagen network could result in a delicate zone inside the hybrid layer and the unaltered dentine that could be susceptible to continuous degradation (Sano et al., 1994) and microleakage (Walshaw and McComb, 1998). Therefore, it is recommended that dentine should not be conditioned/etched for longer than 15 seconds (Walshaw and McComb, 1998).

When a dentinal surface is etched with an acid and copiously washed with water, the surface is demineralised for about 3-5 microns (Perdigão, 1995), leaving a collagen network behind. To allow effective penetration of the primer and adhesive into this collagen network the dentinal surface must not be overly dried - if this happens the collagen network will collapse, resulting in low bond strengths (Gwinnett, 1992).

Magnification during the etching of enamel and dentine can benefit the clinician in following ways:

- **It was observed under magnification that there is often incomplete removal of acid etchants at this margin. It is very common in mesial interproximal box preparations of premolar and molar teeth due to the limited perpendicular access of the three-one syringe to this part of the preparation. Leaving phosphoric acid and its by-products on the gingival margin prior to the application of the bonding resin system might influence the bond strength. It can lead to over-etching of the dentine in this area or to dilution and contamination of the bonding system components.**

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*Figure 9 (magnification 8X): Matrix band assemblage on an upper first molar. Note the good matrix adaptation on the buccal proximal margin (asterisk), and very poor matrix adaptation on the palatal proximal margin (arrow).*

*Figure 10a (magnification 3X): Clinical view after matrix assemblage and etching with 35% phosphoric acid on a lower right first molar. Figure 10b (magnification 10X): Higher magnification showed that not all the phosphoric acid (arrow) was rinsed away with water. Figure 10c (magnification 10X): Visible moisture (arrow) at the gingival margin due to poor matrix band adaptation at the gingival margin after removal of the phosphoric acid.*
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magnification (10x) (Figure 10b) it was evident that not all the phosphoric acid was rinsed away with water. Failure to remove this acid properly before application of a dentine bonding system can severely compromise the bond strength in the proximal box preparation. In the author’s experience it is more prevalent in cases where there is poor matrix adaptation between the matrix band and the gingival margin. Figure 10c (magnification 10x) also illustrates visible moisture at the gingival margin due to poor matrix band adaptation at the gingival margin after removal of the phosphoric acid.

- Regulating the amount of water evaporation after etching to create a dry, moist or wet dentine surface (according to the bonding system used) and a dry, frosty white etched enamel surface.

Application of the Primer or Primer/Resin Combinations

The modern trend is to saturate the exposed dentine and enamel with primer (multi-component systems) or primer/resin (single component systems) for approximately 15-20 seconds. After the recommended waiting time, the surface is lightly air-dried to volatilise the solvent of the primer/resin. According to Walshaw and McComb (1998), any solvent remaining on a primed dentine surface will prevent complete adaptation of bonding resin.

The primed surface should appear shiny. If it has a matt finish it probably indicates that the dentinal tubules are not properly sealed and the application of a second coat is advisable. Figure 11 (magnification 10x) shows a magnified view of a cavity preparation and matrix assemblage on an upper right first molar. Note the shiny appearance of the dentine after several applications of primer and evaporation of the solvent, prior to light-curing.

Application of the Bonding Resin (Multi-component systems only)

The adhesive resin must be placed in an even, thin layer without the need to air-thin. Air thinning of the bonding resin can lower the bond strength and cause surface defects (Hilton and Schwartz, 1995). The optimal thickness for adhesive resin layers is about 100µm (Moon and Chang, 1992) and when placed in such thick layer, the resin may act as a stress-relaxation buffer due to its high elasticity (Van Meerbeek et al., 2001). After application the adhesive must be light-cured for 10 - 15 seconds for direct restorative techniques.

The benefits of magnification during primer/resin application include:
- Ensuring that all the etched dentine surfaces are adequately covered with the primer or primer/resin solutions.
- Assessing the quality of the primed or primer/resin surface - magnification allows the clinician to identify areas that does not appear shiny. Primer or primer/resin solutions can then be reapplied to these areas before application of the bonding resin or composite resin material. Figure 12 illustrates a clinical case of a MOD preparation on an upper left second premolar. Examination under magnification (10X) revealed failure to coat the dentine in the mesial proximal box (arrow) adequately with primer/resin.

![Figure 11 (magnification 10X): Magnified view of a cavity preparation and matrix assemblage on an upper right first molar. Note the shiny appearance of the dentine after several applications of primer and evaporation of the solvent.]

![Figure 12 (magnification 10X): MOD cavity preparation with matrix band assemblage on an upper left second premolar. This magnified view revealed failure to coat the dentine in the mesial proximal box (arrow) adequately with primer/resin.]

van der Vyver
• Ensuring that most of the solvent in the bonding system is evaporated and eliminating excessive amounts of primer solution pooling up in areas that were not reached during the evaporation phase. Leaving excessive amounts of solvent in the mixture can also lead to incomplete polymerization of the bonding resin. Figure 13a (magnification 3x) demonstrates a clinical case where bonding agent was applied and air-thinned to a Class II cavity preparation on an upper right second premolar. Figure 13b (magnification 10X): Evidence of pooling of an excessive amount of bonding resin (arrow) at the junction between the gingival margin and matrix band. Figure 13c (magnification 10X): Final result after careful removal of the excessive amount of resin.

Composite Insertion Techniques

The author prefers to use a modified centripetal build-up technique for Class II restorations as proposed by Bichacho (1994). With this technique the lost tooth structure is replaced from the periphery towards the center of the cavity, ensuring excellent marginal adaptation at the gingival margin. Effectively, a Class II preparation is transformed into a Class I preparation.

The first step is to re-establish the proximal wall. A small drop of flowable composite is dispensed under magnification on the interface between the matrix band and gingival margin (Figure 14a). A regular viscosity composite resin (Enamel shade) is then dispensed onto the uncured flowable material (Figure 14b). The material is condensed towards the gingival margin and towards the matrix band with a composite instrument (Sculp Condensor, Coltène Whaledent). This layer of composite material is manipulated until it forms a thin rim of material (1-1.5mm) extending from the buccal to the lingual proximal margin (Figure 14c).

Excess composite material at the occlusal surface is removed with a sharp probe or composite instrument (Sculp Carver, Coltène Whaledent) (Figure 14d) - ensuring the formation of an anatomically contoured marginal ridge. The height of the marginal ridge should correspond with the marginal ridge height of the adjacent tooth, unless otherwise observed during the initial inspection of the tooth prior to the restorative phase. Overcontouring is one of the most common placement errors with direct posterior composite restorations (Morgan, 2004). Overcontouring of the marginal ridge often leads to subsequent overcontouring of the entire restoration, resulting in excessive finishing and polishing procedures. This envelope of composite material is light-cured for 40 seconds.

At this stage, it is advisable to remove the separating ring and check if a tight contact was established (Figure 15a) (magnification 5x). This is done with an attempt to pull on the sectional matrix band. If the band is firmly wedged between the composite resin and the adjacent tooth, it generally confirms the establishment of an adequate contact. However, if the band can be removed with light force, the contact is inadequate, and the proximal wall should be removed and replaced before proceeding to the next step. The ends of the sectional matrix band are reflected back towards the adjacent tooth (Figure 15a) (magnification 5x) to protect the adjacent tooth and the newly established proximal contact against possible iatrogenic damage that might occur during finishing procedures at a later stage. In addition, it also allows the clinician full view and access to the occlusal surface during placement of composite resin.
After successful creation of the translucent envelope, a horizontal layer of dentine shade composite material (1.5-2mm) is placed into the remaining Class I cavity outline (magnification 5x), to within 1-1.5mm of the cavosurface margin. This layer is light-cured for 20 seconds.

An oblique layer of enamel shade material is packed from the surface of the horizontal layer of dentine material up to the external buccal cavity margin. A composite instrument (Sculp Condenser, Coltène Whaledent) is used to shape the resin and to define anatomy using the remaining cuspal inclines as an indicator. After light-curing this layer for 10 seconds, a second oblique layer, extending from the margin formed between the horizontal dentine and oblique enamel material is packed towards the external lingual cavity margin, using the same method. Before this layer is light-cured for 20 seconds, occlusal characterization is done with a sharp composite instrument (Figure 15c) (magnification 5x). The tooth is covered with a thin layer of glycerine gel and light-cured for 20 seconds. This step ensures the transformation of the oxygen inhibit layer to a smooth, completely cured surface that will eliminate clogging of uncured resin into the finishing instruments. The restoration is then fully cured from different angles (buccal, lingual and occlusal) for a total of 60 seconds.

If any excess composite material is visible at the margins of the buccal and lingual proximal margins, it can be removed under magnification with a thin carbide bur. A series of finishing disks (OptiDisc, Kerr) (Figure 15d) (magnification 5x) can be used to contour the marginal ridge and polish the proximal areas. The sectional matrix band is still protecting the interproximal contact against iatrogenic damage during this finishing step and should only be removed once the operator is satisfied with the final contour of the proximal wall.

Rubber dam is removed and occlusal adjustments are made where necessary. It is recommended that accessible margins must be sealed with a surface sealant to reseal any
microcracks that might have been caused by trauma of finishing procedures. Application of a surface sealant can reduce the wear rate of posterior composite restorations (Dickenson & Leinfelder, 1993). Clinically, the restoration margins are etched with phosphoric acid, rinsed and dried before a surface sealant (Fortify, Bisco Dental Products or Permaseal, Ultradent) is applied and adequately light-cured. These products also produce an oxygen inhibited layer and should be cured through a glycerine gel. Alternatively, BisCover (Bisco Dental Products), an acrylate based light-cured surface resin that does not produce an oxygen-inhibited layer, can be used. According to Morgan (2004) it can either be placed as a surface sealant after acid etching to fill any micro-cracks or it can even be placed on the enamel layer of partially cured composite resin (instead of glycerine gel) to interact with the oxygen-inhibited layer and prevent its formation.

The advantages of packing the composite material into the cavity preparation under magnification include:

- It is easier to pack a thin even layer of material against the matrix band and to ensure good adaptation of the composite material to the cavity walls
- Packing of the oblique layers of composite right up to the cavity margins without any excess material. This will minimize the finishing procedure and provide the patient with a restoration with improved physical and mechanical characteristics (Terry, 2005). Duke (1993) demonstrated that a reduction in finishing results in less damage to the composite material. In addition, the restoration will demonstrate less micro-fracture, improved wear and clinical performance.
- Improved precision when any excess of material is removed with rotary instruments.
- Identification of any cracks or microscopic porosities that might have formed during the polymerization or finishing procedures. It is recommended that accessible margins be etched with phosphoric acid, rinsed and dried, before a surface sealant (Fortify, Bisco Dental Products or Permaseal,
Ultradent) is applied into the defective areas and adequately light-cured. These products also produce an oxygen inhibited layer and should be cured through a glycerine gel. Application of a surface sealant can reduce the wear rate of posterior composite restorations (Dickenson & Leinfelder, 1993). Figure 16 (magnification 10x) illustrates the final result after placement of a Class I composite restoration on an upper right first molar. Note the porosity (arrow) in the composite that was evident after finishing of the restoration with a carbide bur.

Conclusion
This paper has described innovative materials and techniques that can be used clinically to improve the long-term success of direct posterior composite restorations. The use of magnification is highly beneficial in eliminating many of the procedural errors that can occur during the restorative phase, thereby improving the overall quality of the bonded restoration. Part 2 of this paper will discuss the pre-operative examination, isolation of the working field, protection of the adjacent tooth as well as the benefit of magnification during cavity preparation.

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