CERAMIC VENEERS IN GENERAL DENTAL PRACTICE. PART 1: TREATMENT PLANNING

PHILIP NEWSOME AND SIOBHAN OWEN

Introduction

Ceramic veneers were introduced in the late 1930's (Pinkus 1938), but only became widely accepted by the dental profession some 50 years later following the introduction of acid etching and porcelain silanisation. Although the literature contains a variety of recommendations with regard to tooth preparation, luting cement and ceramic material (Sadowsky 2006), the technique almost invariably comprises a thin ceramic laminate veneer bonded, ideally, to a predominantly enamel substrate by means of a composite resin luting cement aided by the application of silane to the etched porcelain fitting surface. the main advantages of veneers are as follows:

1. Minimally invasive
2. Aesthetically pleasing
3. Durable
4. The ability to elicit a good tissue response

The above features mean that, when used appropriately, ceramic veneers can dramatically transform unaesthetic, damaged dentitions in ways once thought impossible. Indeed, their aesthetic and strength characteristics are closer to those of natural tooth structure than almost any other dental restoration. They are not, however, without limitations:

- They are technique-sensitive and time-consuming to place
- Some tooth preparation is usually necessary
- Repair can be difficult
- More than one appointment is required
- Their colour cannot easily be modified once placed
- Satisfactory provisional restorations can be difficult to make and retain
- Prior to cementation they are fragile and difficult to manipulate
- They are more costly than a number of possible alternatives

Given Their advantages and despite their limitations, ceramic veneers have been recommended for use in a wide variety of differing clinical situations:

- For treatment of discoloured teeth that do not respond to tooth-whitening or micro-abrasion procedures
- The closure of interdental spacing and restoration of malformed teeth where crowns are not indicated
- Realignment of in-standing, rotated or protruding teeth
- Discrepancies in the size and shape of teeth that are not correctable by orthodontics alone

The use of veneers to rectify malocclusions (Figure 1) has provoked considerable controversy and a number of authors have expressed grave concerns about what they view as a 'disturbing', even 'objectionable' trend (Friedman 2001, Christensen 2006). There are also concerns about the use of veneers in other clinical situations, for example:

- Heavily restored teeth, worn teeth and any teeth with insufficient enamel available for bonding or teeth too weak to withstand functional forces
- Where the spaces requiring closure are too wide to be closed just by increasing tooth width alone
- Where any tooth discolouration is too severe to be masked by a thin porcelain veneer and where thickening of the veneer would require extensive preparation into dentin.
- non-vital teeth for reasons of tooth weakness and the possibility of subsequent, unfavourable, colour changes.

The treatment planning process

In general terms, an appropriate treatment plan comes about as the natural consequence of following a sequence of carefully considered steps (Newsome 2003). Whenever one is

Figure 1: This patient presented requesting veneers so that she could smile like 'Miss America'. Clearly a case exhibiting this degree of malocclusion is beyond the scope of ceramic veneers and the patient was persuaded to have orthodontic therapy to realign her teeth

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Figure 2a, b and c: Veneers can be useful in treating anterior spacing. In this particular case, it was felt that direct composite restorations were unsuitable and the four incisor teeth were therefore restored using ceramic veneers. However, even with minimal tooth rotation dentine exposure can be quite marked – as in this case on the upper right lateral incisor - and this may adversely affect the retention of the veneer.

considering a cosmetic treatment option such as veneers, it is especially important to follow this logical sequence of events.

Step 1. Collect and collate information by means of history and examination

As well as the obvious clinical history and examination and the collection of physical information such as radiographs, photographs and study casts (a duplicate of which is used to create a diagnostic wax-up), it is vital that some insight is gained into the patient's expectations, in other words, the problem as he or she sees it, together with an idea of what the patient sees as a satisfactory treatment outcome.

It has been said that treatment cannot be considered truly successful unless the patient is satisfied. patients tend to grade the care we provide in terms of pain control (Did the dentist hurt me?), aesthetics (Am I happy with my new appearance?) and function (Can I chew comfortably after treatment? Are the restorations durable?). Problems arise in the small number of

Figure 3a and b: Treatment planning must take into account the need to replace any old restorations prior to tooth preparation. Failure to do so will significantly reduced the strength of the adhesive bond retaining the definitive veneers

patients who hold what most people might consider unrealistic expectations, most commonly with respect to the aesthetic outcome. Although we would dearly wish to fulfill all our patients' expectations, trying to do so in the patient with unrealistic demands usually courts disaster as common sense and fundamental principles end up being ignored. It is better to err on the side of caution, even to the extent of refusing to treat the patient. With this in mind, great care must be exercised in using 'off-the-shelf' examples of treated cases to demonstrate to the patient the results of various clinical procedures as they may engender unrealistic expectations. Far better, if possible, to show patients examples of your own work.

Step 2: Establish diagnosis

The best treatment plan is the one that represents the most appropriate treatment option given a) the diagnosis of the presenting condition and b) the patient's wishes and expectations. It is a basic principle that a definitive diagnosis must be established before the various treatment options can be fully explored.

Step 3. Consider the various treatment options

In order to decide which option is the most appropriate one has to establish what it is we are trying to change and improve and this, of course, is intimately linked to the clinical diagnosis, for example.

Tooth discolouration

Assuming this to be intrinsic then the cause of the discolouration must be established. For example, is it a consequence of ageing, habits, loss of vitality or is it congenital in nature, perhaps the result of systematically-administered drugs during tooth formation, most notably tetracycline. Are one or several teeth affected? In many cases, tooth whitening would be the preferred option, while at the other extreme if the teeth are too heavily discoloured and are resistant to bleaching, then masking by means of a thin layer of ceramic, even when using an opaque luting cement, may not be possible. Masking such dark discolouration often necessitates tooth reduction into dentin and yet the longevity of a bonded veneer is a direct function of the amount of enamel substrate supporting it (Friedman 1998). In such cases, extra-coronal restorations, for example, dentin-bonded all-ceramic crowns, are likely to be more successful. They will allow for greater tooth reduction as they depend less on bonding for retention.

Tooth shape

In situations requiring an alteration of tooth morphology, a diagnostic wax-up is especially useful to confirm if veneers are capable of producing an aesthetically pleasing result with teeth in the correct proportions to one another. In some cases, a more conservative option may be applicable, such as directly bonded composite resin or cosmetic contouring.

Figure 4a and b: This young circus entertainer fractured both central incisors whilst juggling. There is precious little enamel remaining and so dentine-bonded all-ceramic crowns were placed as opposed to veneers, which were to considered to have a less predictable prognosis

Tooth position and/or shaping

Where the teeth ar maligned or there is spacing, the decision must be taken as to whether orthodontic treatment is th more preferred option and if so, is the patient willing to undergo such treatment? it is certainly possible to rectify some small rotations using veneers, but in most cases orthodontic therapy is more appropriate. In the case of tooth spacing, directly-bonded composite can be useful to close small spaces but the greater the spacing, the greater the argument in favour of using indirect veneers (Figure2). Once, however, the spacing becomes too severe, then orthodontic therapy followed by prosthodontic tooth replacement is likely to be more effective.

Old restorations

Ceramic veneers are often placed to improve the aesthetics of previously-filled teeth. the larger the restorations the more likely it is, however, that full coverage restorations will be a better choice. Such teeth are likely to be weaker, perhaps as a result f a loss of vitality, and will certainly have less enamel available for bonding.

When the decision is taken to place veneers then the old restorations must be removed and the ensuing veneers placed within the two week period following composite replacement to ensure adequate bond strength. (Figure 3). Water sorption, exposed un-silanated surfaces of filler particles and limited opportunities for further polymerisation of the resin component of the set material have all been used to explain the reduced bond strength to existing long-standing composite restorations (Walls et al 2002).

Trauma

As in the case of old restorations, ceramic veneers can be an excellent means of restoring teeth damaged by trauma, but once again, consideration must be given to the amount of enamel available for bonding, pulp vitality as well as the presence of crack lines.

Whenever there is any doubt about the degree or quality of remaining enamel, then all-ceramic crowns once again are usually the preferred option (Figure 4).

Step 4. Formulate final treatment plan

From the discussion so far, it is clear that veneers are not a 'one fit all' solution and there are a number of alternatives which ought to be considered and the most conservative option preferred before progressing to more invasive procedures (Dietschi 2005). Such conservative options include orthodontic treatment, tooth whitening, micro-abrasion, tooth re-contouring and conservative composite restorations. As has already been alluded to, it may even be that veneers are a less favourable option when compared with full-coverage all-ceramic crowns for reasons such as available enamel and degree of tooth wear. It may be that a combination of techniques and therapies may best serve the patient's interests (Figure 5). Other factors must also be considered: the

Figure 5a and b: A combination of non-vital bleaching and direct composite to restore the appearance of the upper right central incisor combined with home whitening of the remaining teeth has produced an acceptable aesthetic outcome without the need to sacrifice healthy tooth tissue.

experience and skills of the dentist, the degree of ancillary support and the quality of laboratory support all must be taken into account before embarking on complex treatment. Finally, there is the question of informed consent. Veneers are often proposed as a more conservative alternative to crowns. While this is undoubtedly true that the patient must be informed of the fact that veneers do require some tooth reduction and ar therefore usually considered to be irreversible in nature.

Summary

Ceramic veneers are an extremely useful form of cosmetic dental treatment, but case selection and careful treatment planning is essential. When such preliminary care and attention is taken and allied with correct tooth preparation and bonding practices, then the technique is extremely predictable, yielding beautiful, aesthetic and functionally exceptional restorations that can be life-changing.

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Ceramic veneers in general dental practice. Part 2: choice of materials

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Introduction

Compared to the time when veneers were introduced as a credible treatment option in the early 1980's, there exists today a far wider choice of different ceramic systems. An understanding of the basic structure of the various dental ceramics is important because their physical properties are a result of their underlying composition and this, accordingly, dictates the most appropriate choice for any given clinical situation. There is considerable confusion amongst many dentists about ceramic choice and it often helps to think about any particular dental ceramic as a composite material sitting at some point on a spectrum comprising at one end an unfilled glassy matrix and, at the other, a virtually wholly crystalline structure with little or no matrix at all. Conceptually, this is very similar to the more familiar resin-based composite restorative materials, but with a glass matrix as opposed to one composed of resin.

Predominantly glassy materials ← Particle-filled glasses and glass ceramics → Polycrystalline ceramics

Predominantly glassy materials

At one end of this spectrum are purely vitreous, or glass, ceramics, three-dimensional networks of atoms having no regular pattern to the spacing and characterised by an amorphous structure. Dental ceramics in this category come from a group of mined materials called feldspar and are based on silica (silicon oxide) and alumina (aluminium oxide) and hence belong to a family called aluminosilicate glasses. In appropriate situations, such feldspathic ceramics can create extremely aesthetic restorations with low opacity/high translucency. Conversely, they are unsuitable for masking dark teeth. Their main drawback though is their poor mechanical properties (flexural strength of 56 MPa) with the result that they are nowadays rarely used as the sole porcelain component of the restoration, but as a veneer over a stronger underlying ceramic core.

Particle-filled glasses and glass-ceramics

1. Particle-filled glasses

As one moves along the continuum, filler particles are added in increasing amounts to the base glass matrix to improve mechanical properties and to control optical effects such as opalescence, colour and opacity. The first fillers to be used in dental ceramics contained particles of a crystalline material called leucite.. This was added (between 17-25% mass) to create porcelains that are thermally compatible during firing with dental alloys and therefore can be fired successfully onto metal substructures. These systems, first developed in 1962, have been so successful that they still comprise over three-quarters of all indirect restorations.

Shortly after the development of leucite-filled porcelain, the search was on for a ceramic core that could act as a more aesthetic alternative to metal, primarily as all ceramic substructures transmit some light, whereas metals do not. The first successful strengthened substructure was made of feldspathic glass filled with particles of aluminium oxide (McLean 1965).

Later on, leucite was used at much higher concentrations (40-55% mass) than those needed for metal-ceramics and in a system in which the ceramic is pressed into a mould at high temperatures resulting in reduced porosity and excellent fit, eg Empress I and, more recently, Empress Esthetic (Ivoclar Vivadent) (Figure 1) and Finesse All-Ceramic (Dentsply). There are two major benefits to using leucite as a filler in dental ceramics (Kelly 2004). Firstly, leucite's index of refraction is close to that of feldspathic porcelain, thus maintaining some translucency and secondly, leucite etches at a much faster rate than the base glass, and it is this 'selective etching' that creates a multitude of tiny features for resin cements to enter and create a strong micro-mechanical bond. Restorations of this type exhibit much improved flexural strength as compared to basic feldspathic porcelain (160-300MPa) as a result of the almost perfect distribution of the leucite crystals within the glass matrix. This is achieved without any significant reduction in translucency.

2. Glass ceramics

The filler particles just described tend to be added mechanically to the glass, for example, by mixing together with the glass powder before firing. More recently, an approach has been developed in which the filler particles are grown inside the basic glass restoration after it has been formed. In this approach the glass is given a special heat treatment (ceraming) causing the precipitation and growth of the crystals within the glass. The fillers are derived chemically from atoms of the glass itself. The first such glass-ceramics, as they are referred to, was

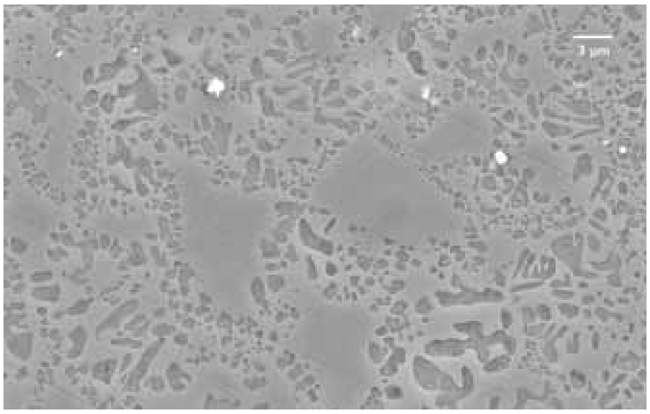

Figure 1: SEM view of Empress Esthetic ceramic

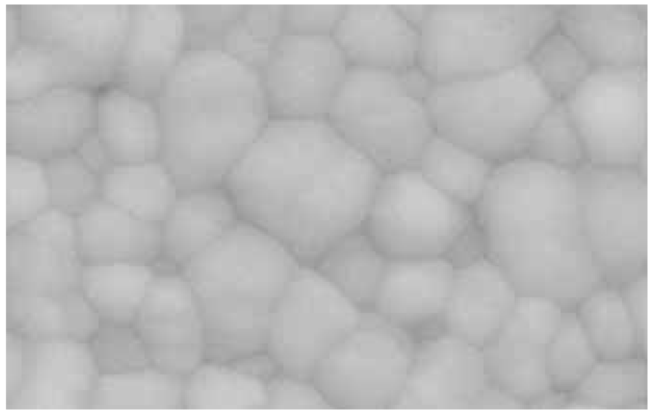

Figure 2: SEM view of Zirconium polycrystalline dental ceramic

Dicor (Dentsply) and this was followed by a glass-ceramic containing 70% crystalline lithium disilicate Empress 2 and more recently Empress Emax (Ivoclar Vivadent). The structure of these porcelains increases flexure resistance to 320-450 MPa as a result of the densely distributed elongated crystals which increase in size after pressing. Such porcelains are used to make the restoration's inner coping which is then covered with a more aesthetic porcelain.

Polycrystalline ceramics

At the other end of the spectrum to the predominantly glassy ceramics are the polycrystalline ceramics that contain densely packed atoms with little o no vitreous 'glass' matrix phase. This arrangement results in restorations which are more difficult to drive a crack through in comparison to the less dense and irregular linkages found in glass structures. As a consequence, polycrystalline ceramics are generally much tougher and stronger than glassy ceramics. They are, however, much more opaque and more difficult to process into complex shapes than are glass ceramics. It was only with the introduction of computer-aided manufacturing that well-fitting prostheses made from polycrystalline ceramics became possible. In general these systems use a 3D data set representing the prepared tooth or a wax model of the desired substructure. There are two basic types of polycrystalline dental ceramics currently available based upon their component crystals.

1. Aluminium oxide

With aluminium oxide content as high as 99%, these materials offer extremely high flexural strength - 689MPa in the case of Procera Alumina (Nobel Biocare). The Procera system was developed by Andersson and Oden (1993) and provides a solution when restorations need to exhibit high strength and aesthetic concerns are not paramount. The manufacturer of these restorations uses a scanning process to machine the densely-sintered ceramics and demands very careful tooth preparation if errors in scanning are to be avoided.

2. Zirconium oxide

Zirconium oxide is a polycrystalline material with a tetragonal structure partially stabilised with yttrium oxide yielding an almost total absence of structural porosities (Figure 2). The result is great strength and fracture resistance (900MPa) and once again, as a consequence of its high opacity, this material is used primarily as an internal coping for crowns and bridge-work. (Figure 3) . Examples include Cercon (Dentsply), Lava (3M ESPE) and Procera (Nobel Biocare).

Choosing the right porcelain

It should be clear by now that there is no single ceramic that is suitable for every clinical situation requiring ceramic veneer(s). In order to make a rational decision one needs to ask the following types of question:

• Does the veneer need to mask tooth discolouration? If so, how severe is this discolouration?

• What is the functional loading on the new restoration?

• Does the patient exhibit signs of tooth wear or parafunctional habits?

By balancing the requirements for aesthetics, strength and avoidance of further tooth wear, one can start to choose a porcelain that is most suitable for any given clinical scenario. Fundamentally, the rationale driving this choice is based on an assessment of the need for translucency versus opacity and on the demands on the strength of the restoration/tooth unit. A further consideration is the abrasiveness of the particular ceramic against natural tooth structure. Ideally, this should match that of natural tooth enamel. It is this interplay between light transmission, strength and clinical requirements which must be considered when choosing the type of porcelain to be used (Fons-Font et al 2006). For example, in many clinical situations, there is a need to mask deep discolourations and therefore a highly opaque porcelain is desirable as is the ability to deliver this level of opacity while still maintaining a thin cross-section and hence the porcelain should also be very

Figure 3: The opacity and great strength of zirconium based ceramics makes them ideal for use as internal copings in posterior crowns and bridges

strong. In this case an aluminium oxide ceramic such as Procera would be appropriate. In other clinical situations there is less need for such a high degree of opacity and, in fact, this can be highly undesirable when no change of tooth colour is required and a reinforced high-resistance feldspathic porcelain such as Empress Esthetic would be suitable. Where strength is the prime concern, as in cases where occlusal loading is high, then clearly a high-strength porcelain is required and the accompanying higher opacity means that aesthetics may have to compromised. Again an aluminium oxide ceramic would be appropriate although, as was discussed in Part One, the decision to use veneers in such cases in the first place should be thought through very carefully.

As far as abrasiveness is concerned, low-fusing ceramic (Empress 2, Finesse, Procera) has been shown to cause less wear of opposing teeth than conventional porcelain (Christenson 2000). It is also well documented that rough, abraded porcelain is extremely damaging to opposing unrestored teeth. One recent study compared various ceramic materials with gold (Elmaria 2006). While gold, unsurprisingly, proved to be a least abrasive, polished low-fusing porcelains also resulted in minimal tooth wear. This suggests that should intra-oral adjustment be required thorough polishing will lead to an acceptably smooth surface.

What about the idea of using zirconium to make veneers? As was discussed earlier, they are very strong compared to more traditional ceramics and in theory at least, its opacity might be useful when trying to mask heavy discolouration. Unfortunately, as a material for laminate veneers, it has two major drawbacks. The first problem is that, while being very strong, it is also extremely opaque and is therefore only suitable for use in copings and substructures. The second problem is that the fitting surface of a zirconium restoration cannot be etched in the way that materials like Empress or Procera can be and so cannot rely on micro-mechanical retention. With these two factors in mind it become clear why Zirconia veneers simply won't work. The restoration is far too thin to allow a core of Zirconia plus a veneering, more aesthetic, translucent porcelain, and secondly there would be inadequate retention as a result of the inability to etch the fitting surface. In short they would look terrible and would probably fall off quite quickly!

Bonding materials

Although porcelain laminate veneers are fragile and require great care while being handled, once cemented the combined porcelain/luting composite/tooth unit is very strong (Stacey 1993). Stacey showed that the strength of this combined bond (63MPa) was significantly higher than the separate composite/etched enamel (31MPa) and luting composite/etched and silanised porcelain (33MPa) bond strengths. Other studies have confirmed this finding that adhesive cementation increases the strength and resistance of ceramics to fracture (Nathanson 1991 and Chen 1998).

Surface treatment of the ceramic

One of the main factors behind the successful bonding of porcelain veneers has been recognition that the way that the ceramic surface is treated is vital. Various techniques have been suggested including micro-etching with aluminium oxide particles and chemical preparation of the porcelain surface by etching with orthophosphoric or hydrofluoric acid (Oh 2003, Ozcan M 2003). Treatment with hydrofluoric acid has been shown to produce the best bond strengths, particularly when combined with the use of 3-methacryloyl oxypropyl trimethoxy

Figure 4: This patient had lost much enamel through over-exposure to soft drinks. Ceramic veneers were deemed inappropriate given the lack of sufficient enamel substrate for bonding, coupled with the need to increase vertical dimension. Empress dentine-bonded crowns were placed instead

silane coupling agent (Filho 2004). The etching process is carried out in the laboratory but silanisation is better postponed until just before bonding to the tooth. Single component systems (silane in alcohol or acetone) are the simplest to silanate. With the two-component systems the silane is mixed with an aqueous acid solution to hydrolyse the silane so that it can react directly with the porcelain surface. It it is not used within several hours the silane will polymerise to an unreactive polysiloxane thus reducing the bond strength (Suh 1991). With such two-component systems the coupling agent should therefore be applied immediately before cementing the veneer.

Composite luting cement

The composite luting cement is the weakest link in the tooth/cement/veneer chain for a number of reasons:

• Polymerisation shrinkage which may create a marginal gap with loss of marginal seal.

• Wear of the composite luting cement because the wear resistance is low and this is more pronounced when gaps are increased.

• Dissolution of the resin matrix in oral fluids.

Light-cured and dual-cured resin luting cements are available for use with veneers. Wholly light-cured materials are to be preferred because of greater control of the setting process and because dual-cure cements are susceptible to colour change over time. The aromatic tertiary amines used in dual cure resins are thought to readily oxidize to form colored oxidised products whereas the amines used in light-cured materials are more resistant to such oxidation (Lu and Powers 2004).

Bonding to enamel and dentine

The notion of etching enamel to accept resin luting cement is very well accepted and this will be familiar to all dentists. It has taken more time for the idea of dentine bonding to be accepted (Perdigao et al 1999). In principle, for dentine bonding to be effective the dentine surface must be conditioned and then primed to form a hybrid layer onto which an adhesive is placed and which copolymerises with the composite luting agent. The first bonding agents used a four-step process to etch enamel, etch dentine, prime the dentine followed by application of the adhesive. This evolved into the so-called ‘total-etch’ system in which the dentine and enamel are etched simultaneously while the prime and bond remain separate components. More recently ‘self-etch bonding’ systems have been introduced which combine all the steps. These have had a mixed reception (Tay 2005) despite the obvious convenience they represent, claims that they reduce post-operative sensitivity and despite manufacturers’ claims of bond strengths equivalent to those with enamel.

As far as ceramic veneers are concerned, the advent of dentinal adhesives has created the illusion that veneers bonded to dentine will be as successful as those bonded to enamel, thus encouraging dentists to use the technique in a wider range of clinical situations. Why is it that practitioners increasingly feel the need to extend veneer preparations into dentine and interproximally to the extent of breaking contacts with adjacent teeth? The main reasons would seem to be the ability of a thicker layer of porcelain to hide dark discolorations and mildly crowded teeth as well as greater ease of handling. Technicians also tend to find making thick ceramic veneers less challenging than very this ones. As a result, tooth reduction into enamel alone can lead to bulky veneers and so in many cases the dentist will cut further into the tooth to prevent overbuiding of the final restoration. Unfortunately, in spite of the considerable advances made in the field of dentine bonding, the longevity of a veneer continues to be a direct function of the amount of enamel substrate supporting it (Friedman 2001). There is an almost complete lack of clinical evidence to support the technique of bonding veneers to dentine as opposed to enamel. As Swift (2006) has observed, recent reports of 50% failure at six years and 34% fracture is disturbing when compared with 93% to 100% success rates of 15 years observation in the 1980s i.e. at a time when veneers were universally bonded almost entirely to enamel.

Why is this the case when reported dentine bond strengths appear to match those achieved when bonding to enamel? Most longitudinal studies of dentine adhesives are performed using composite restorations directly-bonded onto non-carious Class V lesions where the strength and elastic modulus of the teeth are hardly affected (Peumans 2005). The difficulty of dentine bonding in the context of ceramic veneers is the disparity in flexibility between a rigid veneer and less rigid dentine. As Barghi and Overton (2007) have observed, removal of facial enamel or selection of teeth without facial enamel for veneer restorations is an attempt to match up high elastic modulus porcelain with lower elastic modulus dentine. It is predictable that functional loading of the veneered tooth will transfer this energy to the interface resulting in debonding or cracking in the porcelain. For this reason, the smaller the amount of enamel available for bonding and the greater the amount of dentine that is exposed during laminate veneer preparation the greater the likelihood that a full coverage restoration should be chosen. Such restorations rely far more on conventional retention form in addition to any retention gained thru dentine bonding (Figure 4). The subject of the difficulties of bonding ceramic veneers to dentine will be explored further in a future paper.

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