1.6.4 The composite luting resin

An important component of the porcelain veneer restoration is the composite luting resin. Composite luting resin can be classified in three ways:

1. The type of filler particles (macrofills, hybrids or microfills).

2. Initiation system (chemical-cure, light-cure or dual-cure).

3. Luting viscosity (heavy, medium or light).

The physical properties to be considered are wear resistance, modulus of elasticity, compressive and tensile strength in relation to enamel and porcelain, shear bond strength at the enamel or porcelain interface, radiopacity in relation to enamel and porcelain, polymerization shrinkage, film thickness, water sorption and hardness. Other properties such as coefficient of thermal expansion, thermal conductivity, thermal diffusivity, and biocompatibility should also be taken into consideration.

1. The types of filler particles

a. Macrofill luting resin

Most macrofill luting cements have an average particle size of less than five micrometres. These smaller particle sizes result in an improvement in surface smoothness, wear resistance, film thickness of the cement and an increase in the surface area per unit volume of filler.

b. Microfill luting resin

The common filler particles used are silica, titanium dioxide and zirconia. They have an average filler particle size of 0.04 micrometres in diameter. The final inorganic loading of the microfill luting cement is usually 35 to 52% by weight. Some silica particles are included in the resin in a homogeneous dispersed way; others are agglomerated with 0.07 to 0.2 micrometre pellets or larger 3 to 5 micrometre complexes. Agglomerated complexes are made by more extensive sintering. They are heavily filled (74% by weight) for a microfill, resistant to wear and are easily finished (Lambrechts et al., 1991).
c. Hybrid luting resin

These materials are a blend of the microfilled and macrofilled resins. The maximum particle size is 2-3 micrometres, with some containing 0.1 micrometre or larger agglomerated microfiller pellets in addition to small amounts of 0.04 micrometre microfiller. Most hybrid luting cements contain ceramic fillers combined with silicon dioxide, which increase the strength and decrease expansion and contraction. The addition of the microfilled particles reinforces the resin matrix by stopping propagation of microcracks. It also improves the resin's wear resistance. However, the wear resistance of the hybrid resin is still inferior to the microfilled resins (Essig et al., 1991).

The microfilled or hybrid resin is recommended for the cementation of porcelain veneers as the microfilled resin offers a smooth finish. The hybrid resin combines the best properties of both the microfilled and macrofilled cements, such as lower polymerization shrinkage, superior physical and mechanical properties. Table 1.6.1 shows some common resin cements suitable for porcelain veneer cementation.

2. Initiation system

The initiation systems available for composite luting resin are chemical-cure, light-cure or dual-cure. The chemical-cure system has a very short working time (Calamia, 1983) and poor colour stability. A longer time for finishing is also required. This system is ideal in deep areas where light penetration may be difficult (Lambrechts et al., 1991), such as cementation of composite or ceramic inlays. The light-cure system is not recommended for porcelain veneer cementation. Studies have shown that porcelain samples of thickness comparable to clinically fabricated porcelain veneers absorbed 40-50 per cent of the light emitted from the polymerizing light source (Strang et al., 1987). This results in a decrease in the resin-porcelain shear bond strength (Nathanson and Hassan, 1987). The use of a dual-cure cement allows a working time of up to seven minutes (Wei and Tang, 1989). There is now a preference to use dual-cure resin as maximum polymerization is ensured. This is especially indicated when the veneers are thicker than one millimetre (Fleiter et al., 1992). However, Rueggeberg and Caughman (1993) found that the chemically induced polymerization of the dual-cure resins was not substantial after light exposure was completed. Research to quantify the degree to which the dual-cure resins would cure under various lighting conditions and times is therefore required. The degree of resin polymerization is also dependent on the type of ceramic veneer. Blackman et al. (1990) found that better curing was obtained with Dicor® glass ceramic compared with feldspathic porcelain of the same thickness.
3. **Luting viscosity**

Viscosity refers to the resistance to flow due to internal frictional forces within the liquid (Phillips, 1982). The medium viscosity resin is more suitable for veneer cementation compared to the heavy or light viscosity. This is because the heavy viscosity resin has little ability to flow spontaneously at room temperature which makes placement very difficult. This type of cement is more suitable for inlay cementation where maximum marginal integrity and compressive support is required. The low viscosity resin has no body at room temperature. It is unsuitable for veneer cementation, as it can weep out before polymerization and the "suck back" of air from under the restoration can cause marginal void formations. The medium viscosity resin flows slowly at room temperature and provides moderate support for the veneer (Lambrechts et al., 1991).

**Properties of composite luting resins**

**Film thickness**

A minimal film thickness is a criteria of luting cement as it may affect occlusal relations, marginal fit and stress distribution in relation to the weakening effects of microvoids in thicker cement film. Most of the resin luting agents have a film thickness of 20-40 micrometres (Levine, 1989).

**Coefficient of thermal expansion**

The coefficient of thermal expansion of a composite luting resin is around 26-70 X 10⁻⁶/°C compared to enamel (11.4 X 10⁻⁶/°C) (Lambrechts et al., 1991). Feldspathic porcelain (Vitadur-N) has a coefficient of thermal expansion of about 7 X 10⁻⁶/°C. This difference, together with polymerization shrinkage of the composite resin may result in the failure of the marginal seal. Microscopic gaps may form, allowing the penetration of fluids, oral debris and bacteria. Marginal cement thickness should therefore be kept to a minimum in order to obtain a good marginal fit and to alleviate these problems.
Thermal conductivity

Composite luting resin has a similar thermal conductivity (0.0023-0.0031 cal/sec/cm²) to enamel (0.0022 cal/sec/cm²) and feldspathic porcelain (0.0030 cal/sec/cm²). This low thermal conductivity may reduce sensitivity from hot or cold foods (Lambrechts et al., 1991).

Thermal diffusivity

The thermal diffusivity of composite luting resin (0.31-0.67 mm²/sec) is similar to enamel (0.469 mm²/sec) and feldspathic porcelain (0.640 mm²/sec). This similarity may decrease any thermal shock between the materials at the interface (Lambrechts et al., 1991).

Water sorption

Water sorption is highest in microfilled resins (1.2-2.6 mg/cm²), followed by hybrid (0.8-1.7 mg/cm²) and the macrofilled resins (0.4-0.7 mg/cm²) (Lambrechts et al., 1991). "Swelling" of the luting resin due to water sorption results in weak shear bond strengths (Ibsen, 1987).

Modulus of elasticity

The modulus of elasticity of the composite luting resin is low (6-16 GPa) compared to enamel (84 GPa) and other restorative materials. It is not very stiff and deforms readily and can, therefore, withstand transmitted stress better than one with a higher modulus of elasticity.

Polymerization shrinkage

Polymerization shrinkage is inherent in all resin systems. Microfilled resins have the highest volumetric polymerization shrinkage (1.7-2.1%), followed by the hybrid, then the macrofilled resins (1.0-1.7%). Polymerization shrinkage causes stress at the tooth-resin and resin-restoration interfaces, when resin cements are used for luting. If the bond strength of
either surface is unable to resist the forces induced by polymerization shrinkage, microscopic
gaps and subsequent microleakage may result (Tjan et al., 1989).

Compressive, tensile and shear strengths

The forces of compression can be resolved into forces of shear and tensile forces. The
compressive strength of composite luting resin is 175-320 MPa, which is lower than enamel
(384 MPa), dentine (297 MPa), feldspathic porcelain (862 MPa), castable (820 MPa) and
machinable glass ceramic (828 MPa) (Lambrechts et al., 1991).

Hardness and wear resistance

The luting cement for veneers may not be as abrasion resistant as the cements for luting
posterior restorations. This is because the cement margins are not (and should not be)
placed under occlusal stress. However, it should still be within a reasonable range to
resistant abrasion caused by toothbrushing. The hardness of composite luting agent is 21-
100 KHN, which is much less than enamel (343 KHN).

Biocompatibility

The composite luting resin should be non-toxic to the pulp and the periodontium. Toxicity
of the resin is more of a problem to the periodontium than to the pulp because the entire
veneer preparation is intraenamel and the resin is never near enough to the pulp to cause any
harm. However, should any dentine be exposed during veneer preparation, the passage of
resin monomer through the dentinal tubules would cause irritation to the pulp (Stanley et al,
1975). It is therefore advisable to apply a layer of dentine bonding agent to the exposed
dentine to prevent any adverse pulpal reactions. The excess composite luting resin should be
removed completely from the cervical margins because of its proximity to the gingival
tissues. Excess resin may cause irritation to the gingival tissues if the patient were allergic to
the resin.
Table 1.6.1

Types of composite resins for luting porcelain veneers (modified from Sheth and Jensen 1988, Lambrechts et al 1991 and CRA newsletter 1993;17:5)

<table>
<thead>
<tr>
<th>Product</th>
<th>Composition</th>
<th>Manufacturer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Porcelite</td>
<td>Light-cure; hybrid</td>
<td>Kerr/Sybron</td>
</tr>
<tr>
<td>Insure</td>
<td>Light-cure;hybrid</td>
<td>Cosmedent</td>
</tr>
<tr>
<td>Mirage FLC</td>
<td>Light-cure;hybrid</td>
<td>Chameleon Inc.</td>
</tr>
<tr>
<td>Chameleon bonding Kit</td>
<td>Light-cure; hybrid</td>
<td>Chameleon Inc.</td>
</tr>
<tr>
<td>Symphony porcelain</td>
<td>Light-cure; hybrid</td>
<td>Dental Arts lab</td>
</tr>
<tr>
<td>Ultrabond</td>
<td>Light/dual-cure; hybrid</td>
<td>Den-Mat Corp.</td>
</tr>
<tr>
<td>Dicor cementation kit</td>
<td>Dual cure,hybrid with try-in paste. For Dicor veneers only</td>
<td>Dentsply/York Division</td>
</tr>
<tr>
<td>Twinlook cement</td>
<td>Dual cure;hybrid</td>
<td>Kulzer</td>
</tr>
<tr>
<td>Indirect Porcelain System</td>
<td>Dual cure, hybrid with try-in paste</td>
<td>3M Dental Products</td>
</tr>
</tbody>
</table>
1.6.5 The Silane Coupling Agent

A coupling agent is defined as "an agent which acts by adsorbing on to and altering the surface of a solid, to facilitate either a chemical or physical process" (Quinn et al., 1986). It also improves the adhesive bond of polymer to mineral across the organic-inorganic interface to help overcome the problems of hydrolysis and stress related to the mismatch of the coefficient of thermal expansion in the composite resin (Plueddemann, 1982). Some examples of silane coupling agents are gamma aminopropyltriethoxysilane, vinyltriethoxysilane and methacryloxypropyltrimethoxysilane.

Organofunctional silanes are long chain silicone hybrid molecules which have an active organic group at one end and an active inorganic group at the other end. The inorganic group bonds to inorganic substrates such as glass or porcelain, and the organic group bonds to organic substrates such as acrylic or resins (McLaughlin and Morrison, 1988). The bond between the organic resin and the silane coupling agent is mainly covalent, while that with the inorganic porcelain is mainly ionic (Plueddemann, 1982). (Figure 1.6.2).

Organofunctional silanes were first used in the 1940s in an attempt to overcome the problems of bonding organic resins with glass fibers for reinforcement. Silane coupling agents have been applied in dentistry to chemically bond silica to acrylic or BIS-GMA and enhance the bonding between the porcelain teeth and acrylic denture base (Semmelman and Kulp, 1968; Myerson, 1969). Paffenbarger et al. (1967) also found that when porcelain teeth were treated with gamma-methacryloxypropyltrimethoxysilane, the bond between the teeth and the acrylic denture base was so strong that failure took place in the porcelain.

The current silane coupling agents are technique sensitive and require clean, dry areas and strict attention to directions. After using a silane bonding agent, stress should be avoided for 24 hours as the silane bond is weak at first. Waiting 20 minutes will allow the bond to strengthen. Finishing of the restoration should therefore be delayed to avoid disturbing the newly created silanated bond (Horn, 1983). Examples of silane coupling agents currently available are found in Table 1.6.2.
Mode of action of silane coupling agent on etched porcelain and resin cement

*Covalent bonding*

ETCHED ENAMEL → ORGANIC SUBSTRATES (E.g. RESIN MATRIX) → ACTIVE ORGANIC GROUP → SILICON MOLECULE → ACTIVE INORGANIC GROUP → SILICA IN PORCELAIN

*Ionic bonding*

ETCHED ENAMEL → COMPOSITE LUTING CEMENT → SILANE COUPLING AGENT → ETCHED PORCELAIN

92
Table 1.6.2

List of some silane coupling agents (modified from Sheth and Jensen, 1988; Lambrechts et al., 1991)

<table>
<thead>
<tr>
<th>Product</th>
<th>Composition</th>
<th>Manufacturer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scotchprime</td>
<td>Single component</td>
<td>3M Dental Products</td>
</tr>
<tr>
<td>PVS Porcelain Bond</td>
<td>Single component</td>
<td>Cercom Int. Inc.</td>
</tr>
<tr>
<td>Symphony Silane Bond</td>
<td>Single component</td>
<td>Dental Arts Lab</td>
</tr>
<tr>
<td>Cerinate Prime</td>
<td>Two component</td>
<td>Den-Mat Corporation</td>
</tr>
<tr>
<td>Mirage Bond Enhancer</td>
<td>Two component</td>
<td>Chameleon Inc.</td>
</tr>
<tr>
<td>Porcelain Primer</td>
<td>Two component</td>
<td>Kerr/Sybron</td>
</tr>
<tr>
<td>Silanit</td>
<td>Two component</td>
<td>Vivadent</td>
</tr>
<tr>
<td>Silicoup</td>
<td>Two component</td>
<td>Kulzer</td>
</tr>
<tr>
<td>Fusion</td>
<td>Two component</td>
<td>G. Taub</td>
</tr>
<tr>
<td>Dicor Silane Coating</td>
<td>Two component</td>
<td>Dentsply</td>
</tr>
</tbody>
</table>
Bonding between porcelain veneer and tooth structure

The success of porcelain veneers depends very much on the reliable bonding between the tooth structure and the porcelain. When studying the bond strength of porcelain to tooth structure, two interfaces must be considered:

i. Between the porcelain and the composite luting cement.
ii. Between the composite luting cement and the tooth structure (enamel/dentine).

The porcelain veneer is retained on the enamel surface mostly via micro-mechanical retention. This is achieved by acid etching the enamel and fitting surfaces of the porcelain veneer. Another mechanism is the use of a silane coupling agent which forms a chemical bonding between the composite luting agent and the fitting surface of the etched porcelain (Figure 1.6.3). Numerous investigations have been carried out to study the bond strengths of:

a. Etched porcelain with composite resin.
b. Silanized etched porcelain with composite resin.
c. Composite resin with enamel.
d. Composite resin with dentine.
e. Composite resin with glass ionomer cement.

a. Bond strength of etched porcelain with composite resin

In 1982, a study was done to test the bond strength between etched porcelain and composite resin. The porcelain was also etched for different periods of time to create microporosities in the surface similar to those found in etched tooth enamel (Simonsen and Calamia, 1983). The highest tensile bond strength (7.5 MPa) was obtained with a 20 minute etching time using a solution containing 7.5% hydrochloric acid, whereas the bond strength between unetched porcelain and composite resin was 0.6 MPa.

Etching porcelain has also been shown to increase the tooth-restoration bond strength by Calamia et al (1985). They found that different etchant concentrations and etch times must be used for different porcelains in order to improve the bond strengths of etched porcelain to resin cement. Increasing the porcelain thickness has also been found to decrease the bond strength between the light activated composite resin and porcelain (Nathanson and Hassan, 1987). This is because of the inverse relationship between light intensity transmission and

94
the thickness of porcelain (Chan and Boyer, 1989). This problem could be overcome by increasing the exposure time of the composite resin to the light source (Watts et al., 1984).

b. **Bond strength of silanized etched porcelain with composite resin**

The bonding of a ceramic restoration to enamel using a silane coupling agent was first reported by Rochette in 1975. After that, the coupling agent was used to repair fractured porcelain (Eames and Rogers, 1979; Nowlin et al. 1981). In 1984, Calamia and Simonsen showed that the silane coupling agent could enhance the bond strength between the resin and etched porcelain (Calamia and Simonsen, 1984). The highest tensile bond strength, 14.3 MPa, was obtained between the composite resin and silanized, acid etched porcelain. It was concluded that etching the porcelain surface was of greater importance in overall bond strength than was silane coupling agent alone. However, the best results were obtained with etching and application of a silane coupling agent (Calamia and Simonsen, 1984).

Ibsen et al. (1987) and Hsu et al. (1985) also observed a significant increase in the shear bond strength of composite resin cement to etched porcelain of 22.4-24 MPa when the latter was silane treated.

c. **Bond strength of composite resin with enamel**

The tensile bond strength of restorative composite resin to enamel varies between 13.8 MPa and 20 MPa (Bowen, 1983) while that of orthodontic luting resin to enamel was reported to be between 11.1 MPa and 16.9 MPa (Jassem et al., 1981). The tensile bond strength of resin bonded bridge resin cements to etched enamel also ranges from 11.98 MPa to 15.26 MPa (Wiltshire et al., 1987). Thus, it can be concluded that the average tensile bond strength of restorative and luting resin systems to etched enamel varies between 13 MPa and 20 MPa.

d. **Bond strength of composite resin with dentine**

The close adaptation of restorative materials to the smear layer and underlying dentine is currently a topic of active research. Removal of the smear layer increases adaptation and bonding strength, but may increase the incidence of pulpal inflammation. It has been found that when the smear layer is removed by acid etching, dentine permeability increases.
Increased dentine permeability has been shown to decrease the shear bond strength between the dentine and the composite resin and conversely, when dentine permeability is low, the shear bond strength is high (Lambrechts et al., 1991). Composite resins are bonded to dentine via dentine adhesives and these agents are not strong enough to produce gap-free dentine bonding under present composite luting resin shrinkage loading (Lambrechts et al., 1991). Tensile bond strength between dentine and composite varies between 0.1-5.8 MPa for polyurethanes and 10.8-16.7 MPa for hydroxyethyl methacrylates (HEMA) plus glutaraldehyde as bonding agents (Lambrechts et al., 1991).

e. **Bond strength of composite resin with glass ionomer cement**

It is important that any deep area of dentine exposed during tooth preparation be lined with glass ionomer cement to protect the dentine from the etchant. As a result, the composite resin is now bonding with the glass ionomer cement (which can be etched) instead of the enamel. Therefore, a strong bond between the glass ionomer and the composite is crucial to ensure a successful complete bonding system. A study measuring the shear bond strength of resin and etched glass ionomer samples indicated significant bond strength (8-14 MPa) between the two (Calamia et al., 1986).
(a) Longitudinal section of a cemented veneer demonstrating veneer-tooth interface

(b) An enlarged diagram of porcelain veneer-tooth interface
1.6.6 Factors affecting bonding of porcelain to tooth structure (Nathanson, 1988)

a. Complete polymerization of luting resin

Complete polymerization of the composite luting resin is important for a strong bond to form between the porcelain veneer and the tooth, since retention and mechanical support to the brittle porcelain is directly related to the degree of polymerization. Incomplete polymerization may be caused by a gradual reduction and non-uniform light intensity (Young et al., 1975), resulting in a weak bond strength (Nathanson and Hassan, 1987). This may cause early delamination of the restoration. Nathanson (1988) feels that immediate retention of thick or thin veneers will not be affected, even if polymerization is incomplete. This is because thin sections of the resin will be cured, resulting in the restoration appearing to be secured in place. However, it may contain unreacted resin that could wash out, eventually causing marginal caries. Dual-cure cement is therefore recommended. Factors which may hinder complete polymerization of the luting resin have been discussed in section 1.6.4.

b. The use of porcelain which demonstrates good etching qualities

Different porcelains have different etching patterns (Al Edris et al., 1990). Calamia et al. (1985) demonstrated that aluminous porcelain does not etch as well as feldspathic porcelain as measured by their shear bond strength to composite resins. In fact, etching aluminous porcelain has been shown to decrease its strength (Hussain et al., 1979).

c. Good fit of porcelain restoration to dental substructure

A good fit of the restoration to tooth preparation is essential as the resin luting cement exposed around the margins is the weak link in the etched, bonded porcelain mechanism. This is because the luting cement is susceptible to water sorption and polymerization shrinkage (Calamia, 1988).

d. The use of correct porcelain etching procedures

Calamia et al. (1985) showed that different etchant concentrations and etching times should be used for different porcelains in order to maximize the bond strength of etched porcelain to composite resins. The porcelain etchant should also cover the entire fitting surface of the veneer to ensure adequate etching (Jones et al., 1986). Etching porcelain increased the bond
strength of resin to porcelain tremendously. However, maximum bond strength was obtained when the etched porcelain was silane treated (Hsu et al., 1985; Ibsen et al., 1987; Nicholls, 1988).

e. The use of a good silane coupling agent prior to bonding

Certain silane coupling agents require a fresh mix at each application (Dicor® coupling agent43), while others have a shelf life of up to two weeks (Silicoup44). The manufacturer’s instructions should be closely adhered to so as to ensure a successful chemical union between the porcelain and the composite luting resin.

f. The use of appropriate resin with optimal flow and strength

While Wei and Tang (1989) feel that resin of low viscosity is preferable for luting to achieve good adaptation, Tay et al. (1987) feel that the low viscosity composite resin can weep out from beneath the margin of the etched porcelain veneer (before polymerization), resulting in an incomplete seal and eventual failure. The claims that the use of extremely low viscosity resin eliminates the potential for breakage is a misconception. It is now thought that the thixotropic nature of the highly filled composite resins permits more accurately controlled seating, and thus reduces the risk of breakage to the delicate veneers (Friedman, 1987).

g. Attention to detail in carrying out clinical procedure

In addition to the factors mentioned above, contamination from moisture, oil, saliva or blood should be avoided especially in adhesive restorations as moisture contamination has been shown to decrease bond strength by 70% (Young et al., 1975). There are many factors which can affect adhesion. They are the degree of tooth dehydration, the surface roughness caused by diamond burs creating micromechanical retentions, the mechanical undercuts in tooth preparations, the concentration of the etchant, the etching time and washing time on enamel, the fluoride content of teeth, the constituents of temporary cements, the characteristics of dentine canals and the presence of plaque, calculus, extrinsic stains, bases or liners on prepared teeth (Christensen, 1992).

43 Dentsply, York, PA, USA.
44 Heraeus Kulzer, Wehrheim/Ts.
1.7 Clinical Variation and Evaluation of Porcelain Veneers

1.7.1 Clinical variation of porcelain veneers

1. **Buccal etched-retained porcelain laminate bridges**

Successes with porcelain veneers through etching and bonding to enamel have encouraged researchers to develop systems where a porcelain pontic is retained by porcelain veneers on abutment teeth (Ibsen and Strassler, 1986). The indications for these prostheses are very limited and are still very young in their development. Careful selection and judicious judgement must therefore be made before embarking on such a procedure. These bridges should be used for single tooth replacement in areas of low or no stress. They can be indicated in areas whereby a lingual path of insertion is not possible due to occlusal interferences. The buccal etched-retained porcelain laminate bridges allow a labial path of insertion, improving aesthetics (Reid, 1990). However, these bridges require both the bond and the ceramic to function in tension, a feature which is not desirable (Ironside, 1993).

2. **Lingual etched-retained porcelain laminate bridges**

Ibsen and Strassler (1986) advocated the use of lingual veneers carrying a pontic, following the concept of Rochette bridges. It is in the author's opinion that if such a bridge design were to be attempted, a better result would be obtained with the conventional Maryland or Rochette bridges due to the poor fracture toughness of porcelain veneers as retainers in thin sections.

3. **Combined buccal and lingual etched-retained porcelain laminate bridges**

As the name suggests, this prosthesis uses both etched buccal and lingual porcelain veneers as retainers for the pontic. It is felt that the indication for such a prosthesis is rare and should not be treated as a viable option for the replacement of teeth. This is because the forces will be acting differently on the veneers placed in opposite directions, thus stressing the connector and this could result in the fracture of the restorations.
4. **Interproximal retainers**

This refers to the retention of a porcelain pontic via a class III type of preparation on the proximal surfaces of abutment teeth. This is another variation of the etched porcelain laminate bridge, but should not be attempted due to the unsound basis of the concept. This type of design does not take into account the inherent high modulus of elasticity and the requirement of bulk for the higher fracture resistance of the porcelain. The design does not provide a large surface area for bonding nor a retention form for success.

5. **Etched porcelain "pieces"**

These are small pieces of porcelain bonded to teeth to close small spaces and diastemas (Garber et al., 1988; Reid and McCrosson, 1987). As the preparation of the tooth only involves roughening of enamel, there is no definitive seating. This makes accurate location during placement difficult. However, this design could be feasible if appropriate tooth preparation providing retention and resistance form could be established (Ironside, 1993).

1.7.2 **Criteria for clinical evaluation of porcelain veneers**

a. Aesthetics.

b. Marginal leakage or discolouration.

c. Marginal integrity.

d. Retention or delamination rate.

e. Gingival health.

f. Secondary caries.

g. Resistance to abrasive wear.

h. Post operative sensitivity.

i. Patients' acceptance.

1.7.3 **Clinical evaluation of porcelain veneers**

The clinical observation of resin bonded porcelain veneers has only been possible for ten years since Horn revived the technique in 1983 (Horn, 1983) although the first porcelain veneer was placed as long as sixty years ago by Pincus (Pincus, 1938).
The criteria set out in section 1.7.2 can be used to evaluate the clinical performance of porcelain veneers.

a. **Aesthetics**

The colour stability of the porcelain is good, but there were some perceivable changes in the anatomical form (Calamia, 1989). Christensen and Christensen (1991) found that the aesthetic of 93%-96% of porcelain veneers were excellent over a three year period. Rucker et al. (1990) also found the aesthetics of the veneers were acceptable in a two year clinical evaluation of porcelain and resin veneers.

b. **Marginal leakage or discolouration**

Christensen and Christensen (1991) observed that the marginal discolouration was very low over a three year clinical observation. However, the marginal discolouration increased significantly by the third year. Most of the marginal discolouration occurred at the proximal cavosurface and can be attributed to the inability to finish the margin compared to accessible margins (Calamia, 1989).

c. **Marginal integrity**

Christensen and Christensen (1991) evaluated the marginal fit of porcelain veneers over a three year period by clinical observation and not by measurement. Almost all the margins received excellent scores. There was a perceived improvement of marginal fit as the study progressed. They explained that this could be caused by the wear or degeneration of cement, creating the visual illusion of a better marginal fit. On the other hand, Jordan et al. (1989) found that 83% of the margins were excellent. Most marginal changes occur in areas of maximum shear force on the incisal edges. This would be an indication to end the incisal margins palatally so that the restoration is placed under compressive forces rather than shear forces (Ironsides, 1993).

d. **Retention or delamination rate**

In a four year follow up of porcelain veneers by Reid (1988), where veneers were placed
without tooth preparation, out of 217 that were examined, 172 were retained while 45 were delaminated or partially fractured. Reid used two types of cementing medium for luting the veneers to teeth; composite resin and bonding agent. Out of the 45 veneers that delaminated, 36 belonged to the group cemented with bonding agent only. The losses were therefore directly related to the cementing medium used. No veneers that were cemented using a filled resin were completely lost. In another study, a 97% retention rate and generally excellent results were obtained in a four year recall evaluation of labial porcelain veneer (Jordan et al., 1989). Calamia (1989) in his two year clinical studies of about 200 porcelain veneers placed found only 4.1% failure due to dislodgement or fracture. The failure rate of porcelain veneers was found to be less than composite resin or acrylic resin veneers. Similar observations were also made by Rucker et al.(1990) where he found that the incidence of fracture was higher in indirect composite veneers compared with the porcelain veneers. Christensen and Christensen (1991) observed 13% of the cases had some breakage or delamination over three years, some due to trauma or apparent clinician error while others could not be determined. Most breakages were found to occur at the incisal edges.

e. **Gingival health**

Gingival health is not significantly altered in areas around veneers, when compared to gingival tissue in other parts of the patient's mouth (Reid, 1988) or from the baseline probing depth scores taken pre-operatively (Calamia, 1989). However, Christensen and Christensen (1991) observed a slight gingival irritation around the veneers, despite excellent marginal adaptation and acceptable veneer contour over three years of clinical observation.

f. **Secondary caries**

The incidence of secondary caries in porcelain veneers is very low. Calamia (1989) found only one case of incipient caries from the 115 veneers reviewed over a three year clinical observation. Christensen and Christensen (1991) also found that only one out of the 165 veneers reviewed over a three year clinical observation had incipient caries.

g. **Resistance to abrasive wear**

The wear resistance of porcelain veneers was found to be more superior than composite or acrylic resins (Calamia, 1989). Rucker et al. (1990) compares the clinical performance of
porcelain and indirect heat and pressure processed urethane resin veneers after two years and found that the resin veneers chipped more readily. The failed resin veneers were at first thought to be caused by high occlusion. However, subsequent replacement with porcelain veneers was successful. Since identical and compatible bonding materials were used for both types of veneers, it seems unlikely that the failures were related to failure within the bonding resin or at the resin-tooth interface. It was therefore concluded that the resin veneers were less efficient than the porcelain veneer in resisting chipping and fracturing.

h. **Postoperative sensitivity**

Jordan et al. (1989) reported that postoperative sensitivity was absent in his four year recall evaluation of porcelain veneers.

i. **Patients' acceptance**

Christensen and Christensen (1991) found that patients' acceptance of the porcelain veneers was excellent over a three year clinical observation. However, using patients' acceptance as one of the criteria for clinical evaluation of restorations is very subjective and not scientifically based. Interpretations of such observations should therefore be treated with caution.

1.7.4 **Factors determining the longevity of porcelain veneers**

1. **The bond strength between porcelain and composite resin**

The success of porcelain veneers has been attributed to the strong bond which exists between the porcelain and composite resin. This has been obtained mainly via the acid etching of the porcelain and enhanced by the application of a silane coupling agent (Calamia and Simonsen, 1984). This has resulted in bond strengths ranging from 14.4-27.6 MPa (Calamia and Simonsen, 1984; Hsu et al., 1985; Ibsen et al., 1987; Nicholls, 1988). The stability of the coupling agent has also been shown to influence the success of bonding between the porcelain and the enamel with the early stage of shelf life giving a more reliable bonding (Horn, 1983).
2. The extent of porcelain coverage

A greater surface area of coverage provides more surface area for bonding which allows the development of a better load bearing bond between the composite, the enamel and the porcelain (Horn, 1983). This is because a bond has an inherent strength and the area available for bonding will then give an indication of overall load it might support (Ironsode, 1993).

3. The strength of resin cement is considered to be the most important determinant of success (Horn, 1983).

4. The surface area of enamel available for bonding.

5. Dental health education of patients about maintenance of the restoration.

6. Regular recalls to assess restoration and evaluate oral hygiene status.

7. Patient's initiative to maintain high standard of oral health.

8. All the steps leading to the final cementation and polishing of the veneers, that is: correct diagnosis and assessment of occlusion and function, preparation design, impression technique, laboratory fabrication stages, fit, adequate moisture isolation and curing of the resin cement and elimination of overhangs etc.
CHAPTER 2  PURPOSE OF THE INVESTIGATION

Introduction

Ceramic veneers have become popular in the dental profession over the past ten years. They possess life-like qualities and have excellent biocompatibility. The availability of different types of ceramic systems and the improvement in the physical qualities of the bonding resins have also encouraged the popularity of ceramic veneers in the profession. Dentists are now able to offer their patients a longer lasting restoration which is superior in strength and relatively conservative in the preservation of tooth structure (Horn, 1983).

The criteria for any successful restoration should include function, good aesthetics and marginal adaptation, strength and biocompatibility. It is particularly important to obtain a good marginal adaptation in porcelain veneers because composite resins, which have inherent problems, are used to cement the veneer onto the tooth. Problems, such as water sorption, polymerization shrinkage and microleakage, have made composite luting resin the weak link in the porcelain veneer-composite resin-tooth complex. It is therefore important to minimize the amount of the composite luting cement exposed to the oral environment by ensuring a better marginal adaptation between the veneer and the tooth. A superior marginal integrity has also been implicated in the longevity of porcelain veneers (Jordan, 1989).

An increased thickness of composite resin has been associated with an increase in the polymerization shrinkage of the resin (Lutz et al., 1986). The difference in the coefficient of thermal expansion of the tooth and composite resin cement, together with polymerization shrinkage, may result in breaking the seal between the resin and the tooth. This can lead to microscopic gap formation, which allows fluids, oral debris, and bacteria to penetrate beneath the margins. Caries, staining and marginal discolouration are likely to follow (Lambrechts et al., 1991; Asmussen, 1985).

The platinum foil technique (Horn, 1983; Plant and Thomas, 1987; Tay et al., 1987; Greggs, 1988) and the refractory die technique (Calamia, 1985; Kelley and Tombasco, 1985; Harbert and Dudek, 1988; Greggs, 1988; Terry, 1990) have been used for veneer fabrication. Recent advances in ceramic technology have also allowed veneers to be fabricated by the castable glass technique (Hobo and Iwata, 1985b; Garber et al., 1988; Barnes et al., 1992; Lang and Starr, 1992) and the CAD/CAM technique (Siervo et al., 1991; Siervo et al., 1992; Liu et al., 1993; Essig et al., 1991; Gougoulakis et al., 1991; Cerutti, 1991).
The purpose of this study was to investigate the marginal adaptation of veneers fabricated by the refractory die technique (Vitadur®-N\textsuperscript{45}), the castable glass technique (Dicor\textsuperscript{46}) and the CAD/CAM technique (Cerec\textsuperscript{47}) before and after cementation, and to correlate microleakage with the marginal discrepancies observed.

**Aims**

To compare:

1. The pre-cementation marginal adaptation between refractory (R), castable glass (D) and CAD/CAM (C) veneers.

2. The post-cementation marginal adaptation between group R, D and C veneers.

3. The pre and post-cementation marginal adaptation of veneers in each group.

4. The post-cementation marginal adaptation and microleakage between group R, D and C veneers.

An additional study to investigate the marginal adaptation of the refractory and castable glass veneers without sandblasting was undertaken after marginal fractures were observed in the veneers fabricated by these two techniques.

The aims of the additional study were to compare:

1. The marginal adaptation of group R and D veneers without sandblasting.

2. The marginal adaptation of group D veneers with and without sandblasting.

3. The marginal adaptation of group R veneers with and without sandblasting.

\textsuperscript{45} Vita Zahnfabrik, Bad Säckingen, Germany.
\textsuperscript{46} Dentsply, York, PA, USA.
\textsuperscript{47} Siemens Dental Corp., Bensheim, Germany.
CHAPTER 3 MATERIALS AND METHODS

3.1 Sample

48 extracted non-curious human upper anterior teeth were ultrasonically scaled to remove any calculus or periodontal attachments. They were then stored in distilled water at 5°C for an average of three to four weeks post extraction, before tooth preparation. The teeth were all individually mounted in stone and randomly divided into three equal groups of 16 teeth. The division into groups was based on the method of veneer construction; that is, group R (refractory die), group D (castable glass), group C (CAD/CAM).

3.2 Tooth Preparation

Uniform 0.5 millimetre intra-enamel veneer preparations with no undercuts and chamfered margins with labial incisal step (Figure 3.1), to aid seating during cementation, were made with 0.5 millimetre depth cutters and 2-grit chamfered diamond burs. Constant water coolant was used for all preparations. Two standardized templates for Cerec® tooth preparation similar to that designed by B.P. Isenberg, M.E. Essig and P.R. Liu of the University of Alabama were fabricated to ensure the gingivo-incisal and mesio-distal curvature of tooth preparation in group C was within the diameter of the milling disc (Figure 3.2). The tooth preparation for group C was similar to groups R and D except the labial incisal step was omitted (Figure 3.3) due to limitations of the system at the the optical impression stage. A new set of burs was used for each group. The gingival margin ended 0.5 millimetre above the cemento-enamel junction and the incisal height was not reduced.
<table>
<thead>
<tr>
<th>Material</th>
<th>Name of product</th>
<th>Manufacturer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Refractory die material</td>
<td>Vita Hi-Ceram</td>
<td>Vita Zahnfabrik, Bad Säckingen, Germany.</td>
</tr>
<tr>
<td>Die sealant</td>
<td>Vitachrome 725 &quot;L&quot; glaze 30M Vita modelling liquid</td>
<td>Vita Zahnfabrik, Bad Säckingen, Germany.</td>
</tr>
<tr>
<td>Porcelain for refractory die</td>
<td>Vitadur®-N Dentine (354) Opacous Dentine (392 N) powder</td>
<td>Vita Zahnfabrik, Bad Säckingen, Germany.</td>
</tr>
<tr>
<td>Modelling liquid</td>
<td>30M Vita</td>
<td>Vita Zahnfabrik, Bad Säckingen, Germany.</td>
</tr>
<tr>
<td>Glaze</td>
<td>Vitachrome 725 &quot;L&quot; powder Vitachrome L fluid</td>
<td>Vita Zahnfabrik, Bad Säckingen, Germany.</td>
</tr>
<tr>
<td>Investment material</td>
<td>Dicor® castable ceramic investment</td>
<td>Dentsply/ York, PA, USA.</td>
</tr>
<tr>
<td>Ceramming investment</td>
<td>Dicor® castable ceramic embedment</td>
<td>Dentsply/ York, PA, USA.</td>
</tr>
<tr>
<td>Ceramming cones</td>
<td>Dicor®</td>
<td>Dentsply/ York, PA, USA.</td>
</tr>
<tr>
<td>Castable glass ingots</td>
<td>Dicor®</td>
<td>Dentsply/ York, PA, USA.</td>
</tr>
<tr>
<td>Impression material</td>
<td>Extrude™ Extra™ vinylpolysiloxane</td>
<td>Kerr, Michigan, USA.</td>
</tr>
<tr>
<td>Custom made trays</td>
<td>Trayresin</td>
<td>Kerr, Michigan, USA.</td>
</tr>
<tr>
<td>Tray adhesive</td>
<td>VSP Tray adhesive</td>
<td>Kerr, Michigan, USA.</td>
</tr>
<tr>
<td>Dental stone</td>
<td>New Fuji Rock</td>
<td>GC Corporation, Japan.</td>
</tr>
<tr>
<td>Soft lead marker</td>
<td>Vita</td>
<td>Vita Zahnfabrik, Bad Säckingen, Germany.</td>
</tr>
<tr>
<td>Die hardener</td>
<td>Härtgebärd</td>
<td>Renfert, Germany.</td>
</tr>
<tr>
<td>Die lubricant</td>
<td>Lubritex No. 12</td>
<td>Whip Mix® Corp., Kentucky, USA.</td>
</tr>
<tr>
<td>Green milling wax</td>
<td>Fräswachs grün</td>
<td>Bego, Germany.</td>
</tr>
<tr>
<td>Glass beads for sandblasting</td>
<td>Perlablast Micro 50 μm</td>
<td>Bego, Germany.</td>
</tr>
<tr>
<td>Polysorbitol adhesive</td>
<td>Cerec® liquid</td>
<td>Vita Zahnfabrik, Bad Säckingen, Germany.</td>
</tr>
<tr>
<td>Titanium dioxide contrast powder</td>
<td>Cerec® powder mounted on Cerec® propellant</td>
<td>Vita Zahnfabrik, Bad Säckingen, Germany.</td>
</tr>
<tr>
<td>Feldspatic porcelain block</td>
<td>Cerec® Vita Blocs® Mark II</td>
<td>Vita Zahnfabrik, Bad Säckingen, Germany.</td>
</tr>
<tr>
<td>Epoxy die material</td>
<td>Epoxy System No. 736-157</td>
<td>3M Dental Products, USA.</td>
</tr>
</tbody>
</table>
Table 3.2    Materials used in the cementation of the veneers

<table>
<thead>
<tr>
<th>Material</th>
<th>Name of product</th>
<th>Manufacturer</th>
</tr>
</thead>
<tbody>
<tr>
<td>37% orthophosphoric acid</td>
<td>Vita Cerec® Etchant Gel</td>
<td>Coltène AG, Switzerland.</td>
</tr>
<tr>
<td>4.9% hydrofluoric acid gel</td>
<td>Vita Ceramics Etch</td>
<td>Vita Zahnfabrik, Bad Säckingen, Germany.</td>
</tr>
<tr>
<td>Silane coupling agent for feldspatic porcelain</td>
<td>Silicoup</td>
<td>Heraeus Kulzer, Germany.</td>
</tr>
<tr>
<td>Silane coupling agent for castable glass</td>
<td>Dicor coupling agent</td>
<td>Dentsply/York, PA, USA.</td>
</tr>
<tr>
<td>10% ammonium bifluoride gel</td>
<td>Dicor Etching Gel</td>
<td>Dentsply/York, PA, USA.</td>
</tr>
<tr>
<td>Dual-cure composite</td>
<td>Vita Cerec® Duo cement</td>
<td>Coltène AG, Switzerland.</td>
</tr>
<tr>
<td>Unfilled bonding resin</td>
<td>Vita Cerec® Duo Bond</td>
<td>Coltène AG, Switzerland.</td>
</tr>
<tr>
<td>Diamond polishing paste</td>
<td>Vita Karat diamond polishing paste</td>
<td>Vita Zahnfabrik, Bad Säckingen, Germany.</td>
</tr>
<tr>
<td>Description</td>
<td>Name</td>
<td>Manufacturer</td>
</tr>
<tr>
<td>-----------------------------------</td>
<td>----------------------------------------------------------------------</td>
<td>---------------------------------------------------</td>
</tr>
<tr>
<td>Ultrasonic scaler</td>
<td>Dentsply® Cavitron 2001</td>
<td>Dentsply/York, PA, USA.</td>
</tr>
<tr>
<td>Veneer preparation burs</td>
<td>Komet® Laminate Veneer System Set 4151.(LVS 1 and 3)</td>
<td>Brasseler Gmbh and Co., Germany.</td>
</tr>
<tr>
<td>Porcelain furnace</td>
<td>Vita Vacumat 100</td>
<td>Vita Zahnfabrik, Bad Säckingen, Germany.</td>
</tr>
<tr>
<td>Burn-out furnace</td>
<td>KaVo EWL Type 5627</td>
<td>KaVo, Germany.</td>
</tr>
<tr>
<td>Casting machine</td>
<td>Dicor®</td>
<td>Dentsply/York, PA, USA.</td>
</tr>
<tr>
<td>Ceramming furnace</td>
<td>Dicor®</td>
<td>Dentsply/York, PA, USA.</td>
</tr>
<tr>
<td>CAD/CAM machine</td>
<td>Cerec® unit</td>
<td>Siemens, Bensheim, Germany.</td>
</tr>
<tr>
<td>Sandblasting machine</td>
<td>Renfert &quot;Basic Duo&quot;</td>
<td>Renfert, Germany.</td>
</tr>
<tr>
<td>Fine diamond burs</td>
<td>Komet 7862 M</td>
<td>Brasseler Gmbh and Co., Germany.</td>
</tr>
<tr>
<td>Laboratory ceramic polisher</td>
<td>Komet® white ceramic wheel pre-polisher (9597.900)</td>
<td>Brasseler Gmbh and Co., Germany.</td>
</tr>
<tr>
<td>Light cure unit</td>
<td>Luxor model 4000</td>
<td>ICI, Cheshire, England.</td>
</tr>
<tr>
<td>Tungsten carbide finishing burs</td>
<td>Komet® Laminate Veneer System Set 4151.(LVS 6 and 7)</td>
<td>Brasseler Gmbh and Co., Germany.</td>
</tr>
<tr>
<td>Porcelain polishing wheels and</td>
<td>Identoflex polishing wheels and points</td>
<td>Heraeus Kulzer, Germany.</td>
</tr>
<tr>
<td>points</td>
<td>Epirez</td>
<td>Epirez Pty Ltd, NSW, Australia.</td>
</tr>
<tr>
<td>Epoxy resin embedment</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sectioning machine</td>
<td>Buehler® Isomet™ Low Speed Saw (model 11-1180)</td>
<td>Buehler, Illinois, USA.</td>
</tr>
<tr>
<td>Basic fuchsin dye</td>
<td>C.I. &quot;Certistain&quot;</td>
<td>FSE Scientific.</td>
</tr>
</tbody>
</table>
Table 3.4  Equipment used in the evaluation of specimens

<table>
<thead>
<tr>
<th>Description</th>
<th>Name</th>
<th>Manufacturer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stereomicroscope</td>
<td>Olympus® zoom (SZ 4045 TR)</td>
<td>Olympus Optical Co., Japan.</td>
</tr>
<tr>
<td>Micrometer eyepiece</td>
<td>240 cm 10-100 XY</td>
<td>Olympus Optical Co., Japan.</td>
</tr>
<tr>
<td>Camera</td>
<td>Olympus® SC 35</td>
<td>Olympus Optical Co., Japan.</td>
</tr>
<tr>
<td>Tungsten film</td>
<td>Ektachrome 160T</td>
<td>Eastman Kodak Co., USA.</td>
</tr>
</tbody>
</table>
Figure 3.1  Veneer preparation design for groups R and D

(a)  Proximal view

(b)  Incisal view

113
Figure 3.2  Standardized templates used for group C veneer preparation

a  Gingivo-incisal and mesio-distal templates with milling disc

b  Gingivo-incisal curvature of preparation checked with template
Figure 3.3  Veneer preparation design for group C

(a) Proximal view

(b) Incisal view
3.3 Veneer Fabrication

3.3.1 Impression

Impressions of the veneer preparations in groups R and D were taken at 23°C in vinylpolysiloxane heavy and light body impression material, using autocure custom made trays, sprayed with adhesive. The impressions were removed after eight minutes.

3.3.2 Master and working models

16 master dies were each poured for groups R and D one hour later in dental stone. The dies were removed after 30 minutes. Working dies for group D were poured in the same stone one hour later to allow elastomeric recovery of the impression material. Working dies were poured using refractory material, according to the manufacturer's instructions for group R.

3.3.3 The Refractory Die Technique (Group R)

The refractory dies were removed after three hours. The dies were degassed and the margins subsequently marked with a soft lead marker and fixed. The dies were then sealed with two coats of glaze two millimetres beyond the margins.

Equal amounts of dentine and opaquer dentine powder were mixed with modelling liquid. The dies were moisten with the liquid and over-contoured to compensate for firing shrinkage of the porcelain. A second application of porcelain in deficient areas was performed. Each specimen was limited to a maximum of three firings, followed by glazing after contouring. Flashes of porcelain were carefully trimmed with a fine diamond bur under 2X magnification up to the marked margins. The refractory materials were removed by sandblasting with 50 micrometre glass beads in a sandblasting machine at 1.5 bar, paying attention not to damage the margins. Any thin flashes of porcelain were removed with a ceramic polishing wheel under 2X magnification. The average thickness of the finished veneers was 0.5 millimetres and the fit of each veneer was then checked on their respective master dies (Figure 3.4).
Figure 3.4    Fabrication of refractory die veneer (group R)

(a) Veneer tooth preparation
(b) Refractory die, before degassification

(c) Refractory die, degassed and sealed
(d) Porcelain build up

(e) Completed and glazed veneer
(f) Fit of veneer on master die
3.3.4 Castable Dicor® glass technique (Group D)

The margins of the working dies were marked and two coats of die hardener were applied. Die lubricant was applied onto the die before waxing up. The wax was then carved to the proper contour with the margins thickened to one millimetre under 2X magnification. A pattern of the crucifix was placed across the wax pattern as required by the technique to enable successful casting. The pattern was sprued at the incisal edge of the wax and venting provided at the gingival margin. The pattern was invested as soon as possible in a phosphate bonded investment material according to the manufacturer's instructions. Burn-out of the wax was then carried out over two and a half hours in a burn out furnace at 920°C (Figure 3.5). Casting was performed, according to the manufacturer's instructions, in the Dicor® casting machine with a melt temperature for the four gram glass ingots set at 1355°C (Figure 3.6). After the investment had bench cooled, the bulk of material was carefully removed using finger pressure. The rest of the investment material was sandblasted with 50 micrometre glass beads at 1.5 bar. The divested veneers were then separated from the button and embedded in Dicor® ceramming investment. The embedded veneers were then cerammed at 1075°C in the Dicor® ceramming furnace, according to the manufacturer's instructions (Figure 3.7). Ceramming was verified using the designated ceramming cones (Figures 3.7a and b). The cerammed veneers were subsequently removed by sandblasting the investment and then ultrasonically cleaned in water. The sprue was removed, the labial surface contoured to an average thickness of 0.7 millimetres, and any glass spicules on the fitting surfaces and overhanging margins were trimmed with a fine diamond bur and finished with a ceramic polishing wheel. No further procedures were carried out and the 16 Dicor® veneers fabricated were checked for fit on their master die (Figure 3.8).
Figure 3.5  
Precision controlled burn out furnace

Figure 3.6  
Dicor® casting machine
Figure 3.7  Dicor® ceramming furnace

(a) Before ceramming  
(b) After ceramming
Figure 3.8 Fabrication of Dicor® veneer (group D)

(a) Veneer tooth preparation

(b) Working die

(c) Wax pattern on die

(d) Investment

(e) Cast glass ceramic

(f) Cerammed glass ceramic
3.3.5 The CAD/CAM Cerec® technique (Group C)

An optical impression of each preparation was captured as described in section 1.4.3. Subsequent depth adjustment and mapping of the preparation outline provided information input for the computer which then milled the veneer out of feldspathic porcelain blocks (Figure 3.9). The labial surfaces of the veneers were contoured to a thickness of 0.5 millimetres and the fitting surfaces adjusted accordingly to obtain maximal adaptation.
Figure 3.9  Fabrication of Cerec® veneer (group C)

(a) Cerec® Unit

(b) Tooth preparation with contrast powder

(c) Optical image captured

(d) Optical image mapped

(e) Milling completed

(f) Fit of veneer on tooth
3.4 Study of Pre-cementation Marginal Adaptation of Veneers in groups R, D and C

3.4.1 Method

A consistent location and plane of sectioning must be established in order to make any comparisons between the marginal adaptation of the pre-cementation and post-cementation specimens. A half round high speed bur was therefore used to create "dimples" about one millimetre from the margins of the preparation on the mid-lingual, incisal, mesial and distal surfaces of tooth as points of reference for sectioning (Figure 3.10). The veneers in each group were then secured on their respective teeth with a minimal amount of composite luting resin. Acid etching was omitted at this stage to allow removal of the veneer. A light body vinylpolysiloxane impression material was syringed around the margins and the reference points, followed by the heavy body (Figure 3.11a). The specimens were removed after eight minutes and the impressions were poured in dental stone and based (Figure 3.11b) to fit the chuck of the low speed sectioning machine. Lines of sectioning, joining the reference points gingivo-incisally and mesio-distally, were drawn on the surface of the stone models. The margins were subsequently reinforced with epoxy die material before sectioning (Figure 3.11b). This was because earlier pilot studies showed that the fracture toughness of the stone die was not sufficient to withstand the effects of the sectioning blade, as the margins demonstrated areas of chipping (Figure 3.12a).

Sectioning

The specimens from groups R, D and C were mounted on a low speed sectioning machine fitted with a high diamond concentration wafering blade. The sectionings were performed along the lines drawn and perpendicular to the margins (Figure 3.10). A total of four sections were obtained from each specimen, providing eight points for observation per specimen at G1, G2, M1, M2, D1, D2, I1 and I2 (Figure 3.13). The sectioned surfaces were subsequently finished with 600 grit silicone carbide abrasive paper under running water, prior to examination under a stereomicroscope.
Figure 3.10  Reference points and planes of sectioning

(a) Gingival reference point  (b) Incisal reference point

(c) Mesial reference point  (d) Distal reference point
Figure 3.11  Study of pre-cementation marginal adaptation of veneer

(a) Impression of margin

(b) Reinforcement of stone margin with epoxy die material
Unreinforced and fractured stone margin

Figure 3.12a

Reinforced stone margin with epoxy die material

Figure 3.12b
Figure 3.13  Sectioning of the specimen
3.5 Additional study: The Marginal Adaptation of Refractory Die Veneers and Castable Glass Dicor® Veneers Without Sandblasting

3.5.1 Purpose of the investigation

Some margins from group R and D specimens appeared rounded or fractured (Figure 3.14). It was suspected that the process of sandblasting might have caused this problem. A small additional study was therefore undertaken to investigate if the marginal accuracy could be improved by not sandblasting near the margins during the manufacturing process of veneers in these groups.

3.5.2 Method

Five teeth were selected randomly from the pool of sixteen in groups R and D. Five veneers were subsequently fabricated from each group using the method previously mentioned. The main bulk of refractory and investment material was removed using a tungsten carbide bur, leaving the remaining investment surrounding the veneer margins intact. The final traces of investment material were then removed by immersion in 10% sodium citrate solution in an ultrasonic bath for ten minutes. This method aimed to protect the margins from fracture possibly caused by sandblasting.

3.5.3 Study of marginal adaptation of veneers in groups R and D without sandblasting

The same method described in section 3.4.1 was attempted for the study of marginal adaptation of group R and D veneers without sandblasting. However, as the margins were not finished, the impression material could not flow into the marginal gaps. Where the impression material did flow into the gaps, it was in very thin sections, which collapsed when the stone dies were being poured. Trials to cement the veneers with the vinylpolysiloxane impression material were also unsuccessful as the impression material separated from the veneer and the stone die during sectioning. Another method of studying the margins was devised. The veneers were cemented onto their respective dies with epoxy resin die material with the excess overflowing to cover the margins (Ironside, 1993). The specimens were then based and sectioned accordingly as above (Figure 3.15).
Figure 3.14  Representative margin profile of group R and D veneers with sandblasting

Figure 3.15  Study of margins in group R and D without sandblasting
3.6 Study of Post-cementation Marginal Adaptation of Veneers in groups R, D and C

3.6.1 Method

Cementation

The 16 teeth in each group were cleaned with pumice powder and water, then etched with 37% orthophosphoric acid for 30 seconds. The teeth were washed and dried for 15 seconds each. The fitting surfaces of the refractory and Cerec® veneers were etched with 4.9% hydrofluoric acid gel for 60 seconds, washed for 30 seconds and dried. They were then treated with silane coupling agent and left to dry according to manufacturer's instructions.

The fitting surfaces of Dicor® veneers were etched with 10% ammonium bifluoride gel for 60 seconds, washed and dried for 15 seconds each. They were then treated with Dicor® coupling agent. Unfilled bonding resin was then applied to the fitting surface of the veneers and tooth preparations and thinned out. A dual-cure hybrid composite luting resin was applied to the fitting surfaces of the veneers. Excess composite resin was removed by dipping a brush in the bonding agent and then lightly going over the excess composite resin at the margin (Tay et al., 1987). The specimens were first cured palatally at the gingival half for 30 seconds, followed by the incisal half for 30 seconds. This was to direct polymerization shrinkage towards the tooth. The specimens were subsequently cured buccally on the incisal half for 30 seconds, gingival half for 30 seconds, mesial and distally for 20 seconds each, the gingival margin 10 seconds and incisal for an additional 10 seconds. The total curing time for each specimen was 3 minutes (Figure 3.16). The cemented veneers were stored in distilled water at 37°C after cementation.

Polishing

The specimens were polished the day after cementation. Tungsten carbide burs at high speed were used to remove any excess cement, followed by porcelain polishing wheels and points with diamond polishing paste. The polished veneers were then stored in distilled water at 37°C for 24 hours.
Figure 3.16  Direction of cure for cementation of veneers

10 seconds

30 seconds

30 seconds

30 seconds

30 seconds

10 seconds

10 seconds

10 seconds
3.7 Study of Microleakage of Veneers in groups R, D and C

3.7.1 Method

Thermocycling

Thermocycling consisted of 550 cycles. Each cycle consisted of 25 seconds dwell time at 7°C ± 2°C, a 5 seconds transfer between baths, 25 seconds at 54°C ± 2°C and 5 seconds transfer back to the cold bath. Both baths contained water only.

Dye penetration

After thermocycling, all the specimens, including the roots and their apices, were sealed one millimetre beyond the margins, with two coats of nail varnish. They were then immersed in 0.5% basic fuchsin dye for 24 hours at 37°C. The superficial dye was removed under running water the next day. The reference "dimples" created earlier on the tooth surfaces were marked with permanent ink and lines of sectioning were drawn on the surfaces of the specimens. To fit the specimens into the mould, six to seven millimetres of the root of each specimen had to be amputated. The specimens were then embedded in epoxy resin. Each specimen was attached to the base of the mould with wax and positioned such that the sectioning blade would cut through points G and I along the longitudinal axis of the tooth. The epoxy resin was left to cure for 24 hours at 37°C. The specimens were then sectioned with a low speed sectioning machine fitted with a high diamond concentration wafering blade under continuous water coolant. The sections were cut at the same reference points along the same plane as in section 3.4.1.
3.8 Determination of Marginal Adaptation

The measurement of marginal discrepancies should be consistent, reproducible and standardized for impartial comparisons (Sorensen, 1990). A number of methods and definitions have arisen in relation to the study of marginal adaptation for veneers. Some researchers have measured the absolute marginal discrepancy (Harasani et al., 1991; Sim and Ibbetson, 1993) or vertical marginal discrepancy (Sorensen et al., 1992) by sectioning the embedded specimens. Others have observed the veneer-tooth complex directly and perpendicularly from above (Liu et al., 1993; Essig et al., 1991). Tay et al. (1987) made impressions of the margins and observed them under a scanning electron microscope without sectioning. When a rounded margin is viewed in this manner, the tendency is to measure from a point at the edge of the cement (Figure 3.17, point a to b) rather than a point where the gap is created from marginal rounding (Figure 3.17, point c to d). The restoration-tooth or restoration-die complex should be sectioned and viewed in cross-section to ensure the consistency of measurement and a realistic evaluation of marginal gap. This view produces a more reliable assessment of the actual surface of the marginal opening for plaque habitation (Figure 3.17, point c to d). Measurement at point e is not an accurate reflection of the dimension of the niche created for micro-organisms and debris. This is because to get to point e clinically, the cement would have to be chipped away or dissolved in oral fluids from b to e. Three main points can be chosen for the measurement of marginal discrepancies with rounded margins at f, g or h (Figure 3.18).

Consistency in the point of measurement is more important than the actual point of measurement on the tooth-die or tooth-restoration complex (Sorensen, 1990). Marginal adaptation of veneers has also been described in terms of the presence or absence of deficiencies, excess luting cement, and marginal fracture (Coyne and Wilson, 1987).
Figure 3.17  Determination of marginal adaptation with rounded margins

Figure 3.18  Possible points of reference for rounded margins
Study of the vertical marginal discrepancy

In this experiment, marginal adaptation of the veneer to the tooth was determined by measuring the vertical marginal discrepancy between the two (Sorensen et al., 1992).

This was achieved with a stereomicroscope mounted with a cross haired X-Y axes micrometer eyepiece at 40 times magnification. The Y axis was first aligned against the emergence profile of the tooth preparation. The distance in micrometres between the intersection of the cavosurface margin of the preparation and the Y axis and that of the veneer was measured and taken to be the vertical marginal discrepancy (Sorensen, 1992) (Figure 3.19). When the margins of the veneer or tooth preparation were rounded, the midpoint of the margin was chosen (Figure 3.18, point f).

A total of eight measurements were taken for each specimen at G1, G2, M1, M2, D1, D2, I1 and I2 after sectioning (Figure 3.13). Photograph of each specimen was taken with a camera attached on the stereomicroscope.

The same method of observation was used in the marginal adaptation study of specimens in sections 3.4, 3.5 and 3.6.

3.9 Determination of Microleakage

Microleakage was determined by measuring the distance, in micrometres of dye penetration from the cavosurface margin along the veneer-cement (v-c) margins and cement-tooth (c-t) margins at G1, G2, M1, M2, D1, D2, I1 and I2 (Figure 3.20). These measurements were made using a stereomicroscope mounted with a cross haired X-Y axes micrometer eyepiece at 40 times magnification. A camera was also affixed to the stereomicroscope to take photographs. The range of dye penetration along both interfaces was observed in micrometres. The extent of microleakage along the cement-veneer (c-v) margins and cement-tooth (c-t) was also expressed as a percentage of the total number of observations (Table 4.9).
Measurement of vertical marginal discrepancy

(a) No over or under-extension of veneer margin

(b) Over-extension of veneer margin

(c) Under-extension of veneer margin
Figure 3.20 Determination of microleakage

veneer

veneer-cement interface

cement

cement-tooth interface

tooth preparation
CHAPTER 4  RESULTS

Introduction

Eight readings of the vertical marginal discrepancy and the extent of microleakage were measured for each specimen in each group at G1, G2, M1, M2, D1, D2, I1 and I2 (Figure 3.13) using the method described in sections 3.8 and 3.9. The mean vertical marginal discrepancy and standard deviation for each group were calculated. The average of two readings at each location for each specimen at location G, M, D and I were also calculated. The extent of microleakage along the cement-veneer (c-v) interface and cement-tooth (c-t) interface was compared in each group and correlated with the mean vertical marginal discrepancy.

The null hypotheses for this experiment are:

a. there is no difference in the marginal adaptation of veneers fabricated by the refractory die technique (group R), the castable glass Dicor® technique (Group D) or the CAD/CAM Cerec® technique (Group C) pre and post-cementation,

b. there is no difference in the marginal adaptation of groups R and D veneers fabricated with or without sandblasting,

c. there is no difference in the extent of microleakage in groups R, D or C

at a confidence level of 95% (P<0.05).

The results are presented in the following order:

4.1 Marginal adaptation of pre-cemented veneers.

4.2 Marginal adaptation of post-cemented veneers.

4.3 Comparison of pre and post-cementation marginal adaptation.

4.4 Marginal adaptation of refractory and Dicor® veneers without sandblasting (an additional study).
4.5 Comparison of refractory and Dicor® veneer marginal adaptation with and without sandblasting.

4.6 Microleakage along cement-tooth and veneer-cement interface in each group.

4.7 Correlation between marginal adaptation and microleakage.

4.8 Summary of experimental results.

4.1 **Marginal Adaptation of Pre-cemented Veneers**

Some veneer margins in groups R and D were observed to be rounded and fractured (Figure 4.1).

The mean vertical marginal discrepancy was the greatest in group C, followed by group D and group R (Table 4.1 and Figure 4.2).

A Kruskal Wallis test to compare the mean marginal vertical discrepancy between the groups gave a calculated overall average p-value of 0.000008. This indicates that there is a significant difference in the pre-cementation mean vertical marginal discrepancy amongst the groups at p<0.05. Although the standard deviation in each group is relatively large, the mean value in each group also differs considerably from one another (Table 4.1).

**Pre-cementation mean vertical marginal discrepancy at mid-gingival (G), mid-mesial (M), mid-distal (D) and mid-incisal (I) points.**

From Table 4.2, it can be summarized that the mean vertical marginal discrepancy of each group at G, M, D and I is in the decreasing order of:

a. Group R: I>G>M>D
b. Group D: M>I>G>D
c. Group C: G>I>D>M

Figure 4.3 illustrates the mean vertical marginal discrepancy of pre-cemented veneers at points G, M, D and I in each group. The greatest variation at each point within a group occurred in group C, followed by group D and group R.
Figure 4.1  Representative margin profile of pre-cemented veneer with sandblasting
Table 4.1  Pre-cementation mean vertical marginal discrepancy in groups R, D and C

<table>
<thead>
<tr>
<th>Group</th>
<th>mean±S.D.(µm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>R</td>
<td>114.4±43.2</td>
</tr>
<tr>
<td>D</td>
<td>143.1±68.7</td>
</tr>
<tr>
<td>C</td>
<td>165.9±57.5</td>
</tr>
</tbody>
</table>

mean±standard deviation (S.D) in micrometres (µm)

n=16

Table 4.2  Pre-cementation mean vertical marginal discrepancy at G, M, D, I in groups R, D and C

<table>
<thead>
<tr>
<th>Group</th>
<th>G</th>
<th>M</th>
<th>D</th>
<th>I</th>
</tr>
</thead>
<tbody>
<tr>
<td>R</td>
<td>113.3±33.0</td>
<td>101±27.3</td>
<td>100.8±42.9</td>
<td>118.8±46.5</td>
</tr>
<tr>
<td>D</td>
<td>145.6±62.8</td>
<td>160.7±69.1</td>
<td>121.9±51.1</td>
<td>149.2±78.2</td>
</tr>
<tr>
<td>C</td>
<td>207.3±45.1</td>
<td>139.1±51.0</td>
<td>148.2±45.2</td>
<td>189.6±48.5</td>
</tr>
</tbody>
</table>

mean±standard deviation (S.D) in micrometres (µm)

n=16
Figure 4.2  Histogram of pre-cementation mean vertical marginal discrepancy in groups R, D and C.
Figure 4.3 Histogram of pre-cementation mean vertical marginal discrepancy at G, M, D, I in groups R, D and C
4.2 Marginal Adaptation of Post-cemented Veneers

An ideal veneer-cement-tooth margin, where there is a smooth transition from the veneer towards the tooth, is desirable (Figure 4.4a). However, excess luting cement on the tooth was observed on 77 specimens out of a total of 384 specimens (Figure 4.4b).

Results show that the mean vertical marginal discrepancy of group C to be the greatest, followed by group D and group R (Table 4.3 and Figure 4.5).

A Kruskal Wallis test to compare the mean vertical marginal discrepancy between the groups gave a calculated overall average p-value of 0.000015. This indicates that there is a significant difference in the post-cementation mean vertical marginal discrepancy amongst the groups at p<0.05. Although the standard deviation in each group is relatively large, the mean value in each group also differs considerably from one another (Table 4.3).

Post-cementation mean discrepancy at mid-gingival (G), mid-mesial (M), mid-distal (D) and mid-incisal (I) points.

From Table 4.4, it can be summarized that the mean vertical marginal discrepancy of each group at G, M, D and I is in the decreasing order of:

a. Group R: G>I>M>D
b. Group D: M>I>G>D
c. Group C: G>D>D>M

Figure 4.6 illustrates the mean vertical marginal discrepancy of post-cemented veneers at points G, M, D and I in each group. The greatest variation at each point within a group occurred in group C, followed by group D and group R.
Figure 4.4  Representative margin profile of cemented veneer

(a)  Ideal cemented veneer-tooth margin

(b)  Cemented veneer with excess resin on tooth
Table 4.3  Post-cementation mean vertical marginal discrepancy in groups R, D and C

<table>
<thead>
<tr>
<th>Group</th>
<th>mean±S.D. (µm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>R</td>
<td>89.6±55.2</td>
</tr>
<tr>
<td>D</td>
<td>125.5±61.3</td>
</tr>
<tr>
<td>C</td>
<td>154.5±59.3</td>
</tr>
</tbody>
</table>

mean±standard deviation (S.D) in micrometres (µm)
n=16

Table 4.4  Post-cementation mean vertical marginal discrepancy at G, M, D, I in groups R, D and C

<table>
<thead>
<tr>
<th>Group</th>
<th>G</th>
<th>M</th>
<th>D</th>
<th>I</th>
</tr>
</thead>
<tbody>
<tr>
<td>R</td>
<td>103.1±78.5</td>
<td>87.9±45.0</td>
<td>75.8±47.3</td>
<td>93.0±39.8</td>
</tr>
<tr>
<td>D</td>
<td>113.4±56.0</td>
<td>157.5±53.2</td>
<td>109.2±60.4</td>
<td>126.7±63.4</td>
</tr>
<tr>
<td>C</td>
<td>178.9±68.9</td>
<td>130.0±53.4</td>
<td>145.8±43.7</td>
<td>159.8±52.6</td>
</tr>
</tbody>
</table>

mean±standard deviation (S.D) in micrometres (µm)
n=16
Figure 4.5  Histogram of post-cementation mean vertical marginal discrepancy in groups R, D and C
Figure 4.6  Histogram of post-cementation mean vertical marginal discrepancy at G, M, D, I in groups R, D and C
4.3 Comparison of Pre and Post-cementation Marginal Adaptation

The difference between the post-cementation and pre-cementation mean vertical marginal discrepancy in each group was generally smaller than anticipated. The greatest difference was in group R, followed by group D, and the least difference was in group C (Table 4.5).

Group R

A signed rank test was carried out to determine if a significant difference in the mean vertical marginal discrepancy existed between the pre and post-cemented veneers. An overall average p-value of 0.006 was obtained. This indicated that there was a significant difference in the mean vertical marginal discrepancy of pre-cemented and post-cemented veneers in group R. The null hypothesis was therefore rejected.

Groups D and C

Similar signed rank tests were performed on group D and C veneers for comparison of pre and post-cementation mean vertical marginal discrepancies. An average p-value of 0.073 was obtained for group D and 0.171 for group C. This indicated that there was no significant difference between the mean vertical marginal discrepancies of pre and post-cemented veneers in groups D and C. The null hypothesis was therefore accepted.

Comparison of pre and post-cementation mean vertical marginal discrepancies at G, M, D, I in groups R, D and C

There was a general decrease in the post-cementation mean vertical marginal discrepancy for each group at points G, M, D and I when compared to the pre-cementation mean vertical marginal discrepancy (Tables 4.2 and 4.4).
Table 4.5  Mean vertical marginal discrepancy of pre and post-cementation in groups R, D and C.

<table>
<thead>
<tr>
<th>Group</th>
<th>Pre-cementation</th>
<th>Post-cementation</th>
</tr>
</thead>
<tbody>
<tr>
<td>R</td>
<td>114.4±43.2</td>
<td>89.6±55.2</td>
</tr>
<tr>
<td>D</td>
<td>143.1±68.7</td>
<td>125.5±61.3</td>
</tr>
<tr>
<td>C</td>
<td>165.9±57.5</td>
<td>154.5±59.3</td>
</tr>
</tbody>
</table>

mean±standard deviation (S.D) in micrometres (µm)

n=16
4.4 Marginal Adaptation of Refractory and Dicor® Veneers Without Sandblasting (An additional study)

Sandblasting is the recommended method for removing the investment material following fabrication of the refractory and Dicor® veneers. The groups of veneers constructed by this method will be designated "with sandblasting" (+s) to differentiate them from the additional study of refractory and Dicor® veneers fabricated "without sandblasting" (-s).

General observation of the small sample size of specimens finished without sandblasting showed the margins to be sharp and well defined, with occasional overhangs (Figure 4.7).

The mean vertical marginal discrepancy for the refractory and Dicor® veneers (groups R-s and D-s) was similar (Table 4.6). This finding was confirmed by a Wilcoxon two sample rank test which showed that there was no significant difference between the two groups without sandblasting (p-value=0.816).

For group R-s, the mean vertical marginal discrepancy at points G, M, D and I was in the decreasing order of G>I>D>M, while the mean vertical marginal discrepancy at points G, M, D and I for group D-s was I>D>M>G (Table 4.7).

4.5 Comparison of Refractory and Dicor® Veneer Marginal Adaptation With and Without Sandblasting

The mean vertical marginal discrepancy of refractory and Dicor® veneers without sandblasting (groups R-s and D-s) appeared to be smaller than those which were fabricated by the conventional method, that is with sandblasting (groups R+ and D+; Table 4.8 and Figure 4.8). However, the difference in the mean vertical marginal discrepancy with and without sandblasting was greater for group D than group R (Table 4.8). It can, therefore, be deduced that sandblasting seemed to have a greater effect in reducing the marginal accuracy of group D veneers compared to group R. Paired t-tests to compare groups R+ and R-s and D+ and D-s confirmed the above findings. There was a significant difference in mean vertical marginal discrepancy with and without sandblasting in group D at p=0.038, while no significant difference was observed in group R.

A general decrease in the mean vertical marginal discrepancy at G, M, D, I in groups R-s and D-s was also observed when compared to groups R+ and D+, except at point G where the mean vertical marginal discrepancy of group R-s was greater than group R+ (Figure 4.9).
Figure 4.7 Representative margin profile of veneer without sandblasting
Table 4.6  Mean vertical marginal discrepancy without sandblasting in groups R and D

<table>
<thead>
<tr>
<th>Group</th>
<th>mean±S.D.(μm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>R₆</td>
<td>96.1±42.3</td>
</tr>
<tr>
<td>D₆</td>
<td>95.6±45.6</td>
</tr>
</tbody>
</table>

mean±standard deviation (S.D) in micrometres (μm)
n=5

Table 4.7  Mean vertical marginal discrepancy without sandblasting at G, M, D, I in groups R and D

<table>
<thead>
<tr>
<th>Group</th>
<th>G</th>
<th>M</th>
<th>D</th>
<th>I</th>
</tr>
</thead>
<tbody>
<tr>
<td>R₆</td>
<td>131.3±26.0</td>
<td>52.5±436.9</td>
<td>100.0±25.0</td>
<td>118.8±7.2</td>
</tr>
<tr>
<td>D₆</td>
<td>77.5±37.9</td>
<td>95.0±52.7</td>
<td>97.5±37.9</td>
<td>121.9±43.8</td>
</tr>
</tbody>
</table>

mean±standard deviation (S.D) in micrometres (μm)
n=5

Table 4.8  Comparison of mean vertical marginal discrepancy in groups R and D with and without sandblasting

<table>
<thead>
<tr>
<th>Group</th>
<th>With sandblasting</th>
<th>Without sandblasting</th>
</tr>
</thead>
<tbody>
<tr>
<td>R</td>
<td>114.4±43.2</td>
<td>96.1±42.3</td>
</tr>
<tr>
<td>D</td>
<td>143.1±68.7</td>
<td>95.6±45.6</td>
</tr>
</tbody>
</table>

mean±standard deviation (S.D) in micrometres (μm)
Figure 4.8  Histogram of mean vertical marginal discrepancy in groups R and D with and without sandblasting
Figure 4.9  Histogram of mean vertical marginal discrepancy at G, M, D, I in groups $R_{-s}$, $D_{-s}$, $R_{+s}$ and $D_{+s}$. 
4.6 Microleakage Results in Groups R, D and C

There was a minimal amount of microleakage observed at the margins. Where microleakage was present, it occurred more frequently along the cement-tooth interface than the cement-veneer interface (Figure 4.10). Microleakage at the cement-tooth interface was generally greater at the mid-gingival point compared to the mid-incisal or mid-proximal points.

To compare the amount of microleakage amongst groups R, D and C, the number of specimens which showed microleakage were observed. The results are presented in table 4.9. The amount of microleakage in each group was then expressed as a percentage of the total number of interface observed. The total percentage of microleakage in each group was then subdivided into the percentage of leakage along the cement-tooth (c-t) and cement-veneer (c-v) interfaces (Table 4.10).

The range of microleakage at each interface in each group was as follows:


b. Group D: 25 μm-550 μm for the cement-tooth interface, 50 μm-525 μm for the cement-veneer interface.

c. Group C: 25 μm-350 μm for the cement-tooth interface, 50 μm-125 μm for the cement-veneer interface.

A Kruskal Wallis test to compare the average microleakage amongst groups R, D and C at c-t interface gave a p-value of 0.078 and 0.220 for c-v interface. There was, therefore, no significant difference in the extent of microleakage amongst the groups at p<0.05.

Comparison of microleakage along veneer-cement and cement-tooth interfaces.

Although the microleakage along the cement-tooth interface was generally greater than along the cement-veneer interface across the groups, only group R showed a significant difference with the Wilcoxon signed rank test at p=0.004. P-values of 0.163 and 0.206 were obtained for groups D and C on application of the same statistical tests. Since the p-values obtained were larger than the p-value set for this experiment (p<0.05), there was no significant difference between the microleakage along the cement-tooth and cement-veneer interfaces in group D and C veneers.
Figure 4.10  Microleakage along cement-tooth interface
4.7 Correlation between Marginal Adaptation and Microleakage

Pearson's correlation between c-t and c-v microleakage with the mean vertical marginal discrepancy in group R:

<table>
<thead>
<tr>
<th></th>
<th>G</th>
<th>M</th>
<th>D</th>
<th>I</th>
</tr>
</thead>
<tbody>
<tr>
<td>c-t</td>
<td>-0.145</td>
<td>-0.076</td>
<td>0.057</td>
<td>0</td>
</tr>
<tr>
<td>c-v</td>
<td>-0.155</td>
<td>-0.365</td>
<td>0.671</td>
<td>0</td>
</tr>
</tbody>
</table>

Pearson's correlation between c-t and c-v microleakage with the mean vertical marginal discrepancy in group D:

<table>
<thead>
<tr>
<th></th>
<th>G</th>
<th>M</th>
<th>D</th>
<th>I</th>
</tr>
</thead>
<tbody>
<tr>
<td>c-t</td>
<td>0.520</td>
<td>-0.244</td>
<td>0.368</td>
<td>-0.039</td>
</tr>
<tr>
<td>c-v</td>
<td>0</td>
<td>-0.370</td>
<td>0.115</td>
<td>0</td>
</tr>
</tbody>
</table>

Pearson's correlation between c-t and c-v microleakage with the mean vertical marginal discrepancy in Group C:

<table>
<thead>
<tr>
<th></th>
<th>G</th>
<th>M</th>
<th>D</th>
<th>I</th>
</tr>
</thead>
<tbody>
<tr>
<td>c-t</td>
<td>0.101</td>
<td>-0.118</td>
<td>-0.148</td>
<td>-0.256</td>
</tr>
<tr>
<td>c-v</td>
<td>0.275</td>
<td>0.313</td>
<td>0.072</td>
<td>0</td>
</tr>
</tbody>
</table>

A Pearson's correlation coefficient of 0 indicated an absence of microleakage. A negative value indicated that there was an inverse relationship between the mean vertical marginal discrepancy and the extent of microleakage. Overall, there was no indication that microleakage increased with an increase in marginal discrepancy. There was, therefore, no correlation between the amount of mean vertical marginal discrepancy and the extent of microleakage.

4.8 Summary of the Experimental Results

Table 4.11 summarizes the results of the mean vertical marginal discrepancy and microleakage in groups R, D and C. Generally, the marginal adaptation of veneers fabricated by the refractory die technique was superior to the cast glass Dicor® technique and the CAD/CAM Cerec® technique. The extent of microleakage observed was greater in group R, followed by groups D and C. This indicated that there was no correlation between marginal discrepancy and microleakage.
Table 4.9  Microleakage in groups R, D and C

<table>
<thead>
<tr>
<th>Group</th>
<th>Total no. of interface observed (a)</th>
<th>No. of interface which showed leakage (b)</th>
<th>No. of c-t interface which showed leakage (c)</th>
<th>No. of c-v interface which showed leakage (d)</th>
</tr>
</thead>
<tbody>
<tr>
<td>R</td>
<td>256</td>
<td>41</td>
<td>26</td>
<td>15</td>
</tr>
<tr>
<td>D</td>
<td>236</td>
<td>37</td>
<td>20</td>
<td>17</td>
</tr>
<tr>
<td>C</td>
<td>256</td>
<td>26</td>
<td>16</td>
<td>10</td>
</tr>
</tbody>
</table>

Table 4.10  Percentage of microleakage in groups R, D and C

<table>
<thead>
<tr>
<th>Group</th>
<th>% Total microleakage (b/a x 100%)</th>
<th>% c-t microleakage (c/a x 100%)</th>
<th>% c-v microleakage (d/a x 100%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>R</td>
<td>16.0</td>
<td>10.1</td>
<td>5.9</td>
</tr>
<tr>
<td>D</td>
<td>15.7</td>
<td>8.5</td>
<td>7.2</td>
</tr>
<tr>
<td>C</td>
<td>10.2</td>
<td>6.3</td>
<td>3.9</td>
</tr>
</tbody>
</table>

Table 4.11  Summary of the experimental results

<table>
<thead>
<tr>
<th>Group</th>
<th>Without sandblasting*</th>
<th>With sandblasting* (pre-cementation)</th>
<th>Post-cementation*</th>
<th>% Microleakage</th>
</tr>
</thead>
<tbody>
<tr>
<td>R</td>
<td>96.1±42.3</td>
<td>114.4±43.2</td>
<td>89.6±55.2</td>
<td>16.0</td>
</tr>
<tr>
<td>D</td>
<td>95.6±45.6</td>
<td>143.1±68.7</td>
<td>125.5±61.3</td>
<td>15.7</td>
</tr>
<tr>
<td>C</td>
<td>Not applicable</td>
<td>165.9±57.5</td>
<td>154.5±59.3</td>
<td>10.2</td>
</tr>
</tbody>
</table>

* Mean vertical marginal discrepancy ± standard deviation in micrometres (µm)
CHAPTER 5        DISCUSSION

Introduction

Casting glass and CAD/CAM technology have recently been adapted for the fabrication of
dental veneers. Veneers constructed with casting glass are believed to be superior in
marginal accuracy, strength and aesthetics (Lang and Starr, 1992). The advantage of
CAD/CAM technology is the ability to complete ceramic restorations in a single visit
(Leinfelder et al., 1989). The aim of this investigation was to compare the fitting accuracy
of veneers fabricated using the casting glass and CAD/CAM techniques with the
conventional refractory die technique.

5.1        Experimental Methods

5.1.1        Teeth

The single master die technique from which working models are made is a common method
used for studying marginal adaptation (Sim and Ibbetson, 1993). However, 48 teeth were
used in this experiment because the second part of this investigation involved the study of
microleakage in relation to marginal discrepancy. It was, therefore, necessary to bond the
individual veneer to the tooth structure. By selecting 48 different teeth, this study also aimed
to simulate the clinical situation where a variety of tooth anatomy would be encountered. An
ideal preparation, such as that performed on a manufactured Ivorine tooth with perfect
anatomy, would be impractical to achieve under clinical situations. All the teeth chosen were
non-curious, had intact enamel and no restorations where the margins were likely to end.
This was to ensure an optimal marginal seal at the veneer-tooth interface.

5.1.2        Tooth preparation

A depth cutting diamond bur of 0.5 millimetre was used to allow a uniform intra-enamel
reduction of tooth surface. This was a desirable clinical requirement for successful bonding
with composite resin luting cement and protection against microleakage. The gingivo-incisal
and mesio-distal templates were created with a curvature and radial dimension consistent
with that of the diamond milling wheel for tooth reduction in group C specimens. This was
to ensure uniform tooth reduction consistent with the milling capability of the diamond wheel.

5.1.3 Fabrication of veneers

The manufacturer's instructions were followed for the fabrication of the veneers in each technique. Only one operator was involved in the fabrication of these veneers and the observations of marginal discrepancy and microleakage. This was to exclude any inter-operator variability.

5.1.4 Cementation and polishing

After the 48 veneers were cemented individually onto their respective tooth preparations, they were stored in distilled water at 37°C. The specimens were then polished a day after. This was to allow hygroscopic expansion of the luting resin. The aim of this was to reduce marginal gaps (Retief, 1987) and to allow maximum bond strength to develop (Czarkowski, 1985).

5.1.5 Thermocycling

These specimens were thermocycled one day after polishing. This was to simulate the clinical situation whereby the restorations are usually subjected to the harsh environment of the oral cavity soon after they are placed.

The purpose of thermocycling was to simulate temperature fluctuations occurring in the oral environment at an accelerated rate in-vitro. Thermocycling was necessary to correlate laboratory findings with clinical performance (Crim and Mattingly, 1981). The number of thermocycles used in different studies of microleakage in porcelain veneer has ranged from 100 to 1000 (Tjan et al., 1989; Zaimoglu and Karaagacioglu, 1991; Lacy et al., 1992; Sorensen et al., 1992). A median of 550 cycles was therefore chosen in this study. The upper and lower temperature limits of 5°C and 55°C were selected, based on previous studies, and the temperature tolerated by the oral cavity (Nelsen et al., 1952; Peterson et al., 1966).

5.1.6 Sectioning

Reference points and planes of sectioning perpendicular to the margins were drawn on all the specimens. Each specimen was secured tightly in the mounting chuck and the planes of

162
sectioning aligned parallel with the wafering blade. A more scientific and reproducible method of sectioning needs to be established to ensure a consistent and correct interpretation of marginal discrepancy.

5.1.7 Study of marginal adaptation

It was important that specimens cemented with tooth-coloured luting cement were sectioned for the accurate assessment of marginal accuracy. This was because evaluating marginal fidelity of an overcontoured and apically overextended veneer margin by the direct technique often under-reported the dimension of the marginal gap (Sorensen, 1992).

5.2 Experiment Results

5.2.1 Marginal adaptation of veneers fabricated by the refractory die technique, castable glass Dicor® technique and CAD/CAM Cerec® technique

The results showed that there was a significant difference in the marginal adaptation of the veneers fabricated by the three different techniques.

Theoretically, the castable glass technique, which employs the lost wax technique, should yield the most accurate marginal adaptation. In addition, both the cast glass ceramic and the investment mould contain silica. This would allow the cast glass ceramic to wet the investment more readily than cast gold and therefore, yield a more accurate margin (Adair and Grossman, 1984). This was, however, not the finding. Problems with the material, such as increased thickness, damaged margins (Schaerer et al., 1988) and the technique sensitive nature of this method might explain the discrepancy. The 1.6% expansion following casting was compensated for after ceramming by the same percentage of shrinkage (Malament, 1988), so that marginal discrepancies caused by this factor were quite unlikely. Sim and Ibbetson (1993) also reported that the fit of refractory veneers was better than the Dicor® veneers.

The CAD/CAM technique yielded the largest marginal discrepancy. This is because the technique involves a number of variable factors which are highly dependent on the skill and accuracy of the operator. Such factors include oxide coating of the preparation, the capture
of optical impression and the mapping of a smooth preparation outline. There was also a limitation of the milling disc to mill a smooth fitting surface, according to the contour of the tooth without grooves. The fitting surfaces of the veneers required adjustment to provide a better fit (Essig et al., 1991).

Ibsen (1985) feels that a marginal integrity of 25 micrometres is no longer required in porcelain veneers. This is because the cementing medium used is composite resin, which is less soluble than zinc phosphate cement (Ibsen, 1985; Harasani et al., 1991). However, a large marginal discrepancy filled with composite resin could increase the chances of plaque accumulation and discolouration of the luting material (Harasani et al., 1991).

The final criteria for an acceptable interfacial marginal gap with a bonded restoration are still being evaluated. The current concept, relative to bonded porcelain inlays and onlays, is that the interfacial gap should not exceed 100 micrometres at occluding and stress bearing areas and approximately 150 micrometres at non-occluding and non stress bearing interfaces (Leinfelder et al., 1989; Essig et al., 1991). The results obtained in this experiment were within the limits reported in other studies (Table 5.1).
Table 5.1  Comparison of marginal discrepancy in porcelain veneers fabricated by different techniques

<table>
<thead>
<tr>
<th>Investigator</th>
<th>Type of marginal discrepancy studied</th>
<th>Refractory die technique</th>
<th>Dicor® technique</th>
<th>Cerec® technique</th>
<th>Platinum foil technique</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tay et al. (1987)</td>
<td>Cemented; SEM direct view of replica cervical margin</td>
<td></td>
<td></td>
<td></td>
<td>160-400 μm</td>
</tr>
<tr>
<td>Cerutti (1991)</td>
<td>Mean marginal width</td>
<td></td>
<td></td>
<td></td>
<td>95-225 μm</td>
</tr>
<tr>
<td>Essig et al. (1991)</td>
<td>Pre-cementation; direct view pre and post adjustment</td>
<td></td>
<td></td>
<td></td>
<td>248±26.7 μm</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>128±12.5 μm</td>
</tr>
<tr>
<td>Harasani et al. (1991)</td>
<td>Cemented, sectioned; Absolute marginal discrepancy</td>
<td></td>
<td></td>
<td></td>
<td>88-193 μm</td>
</tr>
<tr>
<td>Sorensen et al. (1992)</td>
<td>Cemented, sectioned; Vertical marginal discrepancy</td>
<td></td>
<td></td>
<td></td>
<td>242 μm</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>187 μm</td>
</tr>
<tr>
<td>Liu et al. (1993)</td>
<td>Pre-cementation; direct view of replica gingivally, incisally and proximally</td>
<td></td>
<td></td>
<td></td>
<td>66 μm</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>68 μm; 103-117 μm incisally</td>
</tr>
<tr>
<td>Sim and Ibbetson (1993)</td>
<td>Pre-cementation, sectioned; mid-labially, gingivally and incisally</td>
<td>80±40 μm</td>
<td>0.5 mm: 140±60 μm; 1 mm: 180±80 μm</td>
<td></td>
<td>60±40 μm</td>
</tr>
</tbody>
</table>

mean±standard deviation (S.D) in micrometres (μm)
5.2.2 Marginal adaptation of pre and post-cementation veneers

The purpose of studying the marginal adaptation before and after cementation was to investigate any difference in marginal adaptation which might arise between the two due to the luting cement or seating discrepancies. The fit on the tooth may not accurately reflect the fit after cementation in the mouth, as evident in the results obtained. This could be a result of the resin cement film thickness, polymerization shrinkage of the resin cement, or seating inaccuracies.

The over-extended margins of the veneer and any excess composite resin cements were all removed during the finishing stage. This procedure tends to reflect the efficiency of the finishing technique, rather than the accuracy of the fabrication technique. Therefore, under normal circumstances, when comparing the marginal fidelity of restorations by different techniques, the margins would not be finished. However, as this investigation also involved a microleakage study, the margins had to be finished.

There was an overall improvement of marginal discrepancies after cementation in all the three techniques. The improvement in marginal adaptation was most obvious in group R (21.7%), followed by group D (12.3%) and group C (6.9%). This could, in part, be explained by the additional labial-incisal step incorporated in the tooth preparation in groups R and D which helped in the accurate seating of the veneer during cementation. This preparation could not be used on the specimens in group C because the optical impression could not register the depth of the additional step.

Four main factors could explain the overall improvement in the marginal adaptation of the veneers after cementation. Firstly, the use of uncured bonding resin placed on both the veneer and the tooth during cementation could have decreased the resin's viscosity and made it more compressible. This improvement in the flow of the composite luting resin underneath the veneer would have allowed any excess resin cement to escape. This would have resulted in a thinner cement thickness and therefore, complete seating. Secondly, the use of a minimal amount of composite resin to tack the veneer on to the preparation without any bonding agent in the study of the pre-cementation marginal adaptation could have resulted in a rather viscous cement. This might have interfered with the complete seating of the veneer when the impressions of the margins were taken. Thirdly, curing from the palatal aspect of the restoration to direct polymerization shrinkage towards the light source may also have contributed to the decrease in the marginal gap. Polymerization shrinkage of resin in thin layers has been shown to have three times the shrinkage applicable to a thicker layer, such as a direct composite restoration (Feilzer et al., 1989). Lastly, the "swelling" or
hygroscopic expansion of the luting resin due to water sorption during storage after polymerization (Lambrechts et al., 1991), could have resulted in a decrease in the marginal gap (Retief, 1987).

5.2.3 Marginal adaptation of veneers with and without sandblasting

Sandblasting has been implicated in causing marginal discrepancies in the refractory die veneer techniques (Sorensen, 1992; Sim and Ibbetson, 1993). A constant pressure of 1.5 bar was used intermittently over one minute to sandblast the investment materials from the refractory and castable glass veneers. The difference in the vertical marginal discrepancy with and without sandblasting was greater for the castable glass Dicor® technique (group D) than the refractory die technique (group R). This indicates that sandblasting seems to have a greater effect on the marginal accuracy of the castable glass veneers than the refractory veneers.

The difference could be due to the fact that twice the amount of sandblasting was required by the castable glass technique compared to the refractory die technique. This was because sandblasting was first used to remove the investment materials after casting, and a second time after ceramming. This subjected the margins to abrasion from the glass beads twice as often as the refractory technique.

The result could also be an indication that the fracture toughness (K_{IC}) of the Dicor® material might not be as high as it was thought to be. The K_{IC} value of feldspathic porcelain was reported to be 0.9-1.06 MPa.m^{1/2} (Morena et al., 1986), while that of the Dicor® machinable glass ceramic (MGC) was reported to be 1.4-1.5 MPa.m^{1/2} (Grossman, 1991). The K_{IC} value of castable Dicor® was not available. However, the mean fracture load for castable Dicor® has been reported to be greater than feldspathic porcelain (Rodrigues et al., 1987). As the sample size used in this additional study of veneers without sandblasting was relatively small, further investigations in this area are necessary. However, a significant difference in the marginal discrepancies with and without sandblasting of Dicor® veneers might indicate the future use of something less abrasive for removing the investment materials around the veneer margins. For example, the veneers could be immersed ultrasonically in a 10% sodium citrate solution for ten minutes.
5.2.4 Microleakage

There is a distinction between microleakage and dye penetration. Microleakage refers to the ingress of oral bacteria, fluids, molecules or ions which have diameters of 0.5 micrometres or less. However, the tracers and dyes used to assess microleakage are much smaller than 0.5 micrometres. This therefore makes dye penetration a severe test of microleakage (Douglas, 1989).

Microleakage occurs when a microscopic gap exits between two bonded phases. The bonding of the ceramic veneer to the tooth structure with composite resin produces two interfaces, one between the cement and the veneer (c-v) and the other, between the cement and the tooth (c-t). Polymerization shrinkage of the resin can cause marginal gaps to form either between the the cement and the veneer or between the cement and the tooth. The gap formation depends on which interface has a stronger bond strength to resist polymerization shrinkage. If the bond strength between either interface is strong enough to resist the polymerization shrinkage, gap formation can then be prevented (Tjian et al., 1989). The weaker of the adhesive forces between the two bonding interfaces usually fails, allowing dye molecules to penetrate the interface and displace the forces of attraction uniting the phases.

The results showed that there was no significant difference in the extent of microleakage amongst groups R, D and C. Overall, there was minimal microleakage along the cement-tooth and veneer-cement interfaces in the specimens. This was not unusual as the preparation margins were intra-enamel and acid etched, and the fitting surfaces of the veneers were also acid etched and silane treated. The reliable bond strength of etched enamel to composite resin is very well established (Jassem et al., 1981; Wiltshire et al., 1987). Therefore, little or no microleakage would be expected with composite resin due to the acid etched enamel (Lacy et al., 1992). The range of microleakage at each interface in each group was comparable, except in group R at the cement-tooth interface. The large value (1625 micrometres) was caused by exposed dentine margin in the gingival area of one specimen.

The microleakage pattern observed was greater along the cement-tooth interface compared to the cement-veneer interface. This corresponds to studies by Sorensen (1992), Harasani et al. (1991) and Tjian et al. (1989). This observation can be explained by the fact that the bond strength between the resin and etched silane treated porcelain was much higher (22.4-24 MPa) (Ibsen et al., 1987; Hsu et al., 1985) than the bond strength between the resin and etched enamel (13.8-20 MPa) (Bowen, 1983). The high bond strength between the luting resin and the porcelain was achieved mainly via acid etching and, to a lesser extent, silane treatment (Calamia and Simonsen, 1984). Occasional microleakage along the cement-veneer
interface has been attributed to an inadequate etching of the lateral border of the veneer as the etchant gel slumps away from the veneer margin (Jones et al., 1986).

Where microleakage was present along the cement-tooth interface, it was greatest in the gingival margins, similar to findings by Sorensen (1992). This could be explained by the thinness of the enamel and the deviation in enamel rod orientation, especially at the cervical area, affecting the bond strength between the resin cement and the acid-etched enamel (Tjian et al., 1989).

5.2.5 Correlation between marginal adaptation and microleakage

No correlation was found between the amount of marginal discrepancy and the extent of microleakage in this study. This was also similar to a finding by Sorensen (1992). The extent of microleakage was more likely to be associated with bond strength than marginal discrepancy, as explained in section 5.2.4. Microleakage was believed to be caused by the poor bonding qualities of the materials or to the disruptive effect of water immersion thermocycling and dye penetration (Buonocone, 1981). If the attraction between water molecules and either of the bonded interfaces was stronger than the attraction between the bonded surfaces, water molecules may penetrate the interface and displace the forces of attraction uniting the phases.

Clinical implications of the study

Some investigators may feel that, with the improved physical properties of composite luting resins, marginal gaps in porcelain veneers are not as critical as those occurring in highly stressed areas, such as the occlusal surfaces. This is because the margin placements for porcelain veneers are not in occlusion with the opposing teeth and therefore, not under stress. However, recent findings regarding the phenomenon of abfraction, which causes stress in the cervical areas of teeth, may throw light on the placement of cervical margins and the maximal amount of gap permissible for the luting cement.

Abfraction is defined as the pathological loss of hard tissue tooth substance caused by biomechanical loading forces. These lesions are a result of flexure and ultimate fatigue of the enamel and dentine at a location away from the point of loading (Grippo, 1991). If the marginal discrepancy is large, the amount of composite resin exposed to the environment will similarly be large. This bulk of composite tends to retain plaque. Also, when the tooth
is subjected to unfavourable occlusal forces, stress around the cervical area may build up and cause cohesive failure within the thick cement and this can eventually result in the delamination of the restoration. It is, therefore, essential that the marginal discrepancies in porcelain veneers be kept to a minimum in order to ensure their longevity.
CHAPTER 6

CONCLUSION

The first part of this study investigated the marginal adaptation of veneers fabricated by three different techniques: namely, the refractory die technique, the castable glass Dicor® technique and the CAD/CAM Cerec® technique. The pre-cementation and post-cementation marginal discrepancies were studied by measuring the vertical marginal discrepancy between the cavosurface margins of the veneer and the tooth preparation. Some fractured and rounded margins were observed in the refractory and Dicor® group veneers. This was thought to have been caused by sandblasting abrading the margins. Therefore, an additional study was undertaken to investigate whether the marginal adaptation of veneers in both groups would improve without sandblasting.

The second part of the study investigated the extent of microleakage along the veneer-cement and cement-tooth interfaces in all three groups after thermocycling and dye penetration. An attempt was also made to correlate the amount of marginal discrepancy with microleakage.

The conclusions which can be drawn from this study are:

a. The pre-cementation and post-cementation marginal adaptation of veneers fabricated by the refractory die technique was superior to the castable glass Dicor® technique, followed by the CAD/CAM Cerec® technique.

b. The post-cementation marginal adaptation of veneers fabricated by the three techniques were all smaller than the pre-cementation marginal adaptation. However, a significant difference was only found in the refractory die technique group.

c. There was no significant difference in the marginal adaptation of veneers fabricated by the refractory die technique and castable glass Dicor® technique without sandblasting.

d. Sandblasting seemed to affect the marginal accuracy of veneers fabricated by the castable glass Dicor® technique more than the refractory die technique.

e. There was no significant difference in the extent of microleakage amongst the three groups.
The microleakage along the cement-tooth interface was generally greater than the cement-veneer interface, although statistical significance was only found in the veneers fabricated by the refractory die technique.

Where microleakage was present along the cement-tooth interface, it occurred more often at the gingival margin compared to the incisal or proximal margins.

There was no correlation between the amount of marginal discrepancy and microleakage.

The addition of porcelain veneers to the profession's armamentarium has provided the dentist with the ability to perform long lasting, aesthetic and reconstructive procedures without invading the sanctity of the dentine. Although porcelain veneers have had a long history, the science of this technique is still in its infancy.

The success of porcelain veneers depends very much on the method of fabrication and most importantly, case selection. As some of the research in this field has been based on personal preference and anecdotal information, more objective research is required so that the profession and public will view the technique with less scepticism, and eventually accept porcelain veneers as an alternate treatment in the field of conservative dentistry.
Bibliography


Davis DR. Comparison of fit of two types of all-ceramic crowns. J Prosthet Dent 1988;59:12-16.


177


178


Reeve D. An introduction to the 'IPS Empress System'. Int Society for Dental Ceramics Newsletter 1991 (Spring)


Waerhaug J. Histologic considerations which govern where the margins of restorations should be located in relation to the gingiva. Dent Clin North Am March 1960;161-76.


