

# Cementation of Indirect Restorations

A Clinical Guide

Presented by

**KURARAY**  
**DENTAL**



# Cementation of Indirect Restorations

## A Clinical Guide

**This booklet was compiled with scientific input from Markus B. Blatz, DMD, Dr Med Dent and Ulrike Blatz, DMD, Dr Med Dent**

The plethora of indirect restorative dental materials resulted in numerous treatment options, each requiring a different approach for predictable clinical longevity. The selection and proper application of dental cements and luting agents for final insertion of indirect restorations are as crucial as the restorative material itself for pleasing esthetics and long-term functional success.

This article provides clinical guidelines for final cementation of the various indirect restorations based on currently available data and luting agents. The first part lists current indirect restorations and preferred luting agents for their definitive insertion. Part two includes an illustrated step-by-step flowchart for the easy implementation of these recommendations using a current adhesive composite resin cement. Rationale and scientific background are discussed in the third part of this “Cementation Guide”.

# 1.0

## Quick Reference Chart

**Table 1:**  
 Type of restorations and their preferred luting agents.  
 The following abbreviations are used:  
 PFM = Porcelain-Fused-to-Metal  
 FPD = Fixed Partial Denture  
 Composite Resin = Conventional Bis-GMA Composite Resin Luting Agent  
 Adhesive Resin = Composite Resin Luting Agent Containing Adhesive Monomers  
 RM Glass Ionomer = Resin-Modified Glass Ionomer Cement

TYPE OF RESTORATION	RESTORATIVE MATERIAL	POSSIBLE LUTING AGENTS	PREFERRED CHOICE
Cast Metal and PFM Crown, FPD, Cast Metal Inlay/Onlay	PFM - Noble Alloys, Base Alloys	<ul style="list-style-type: none"> <li>• <b>Adhesive Resin</b></li> <li>• Composite Resin</li> <li>• RM Glass Ionomer</li> <li>• Glass Ionomer</li> <li>• Zinc Phosphate</li> <li>• Polycarboxylate</li> </ul>	<ul style="list-style-type: none"> <li>• <b>Adhesive Resin</b></li> <li>• RM Glass Ionomer</li> <li>• Glass Ionomer</li> <li>• Zinc Phosphate</li> </ul>
Resin-Bonded FPD (Maryland Bridge)	PFM - Base Alloys	<ul style="list-style-type: none"> <li>• <b>Adhesive Resin</b></li> <li>• Composite Resin</li> </ul>	<ul style="list-style-type: none"> <li>• Opaque <b>Adhesive Resin</b></li> </ul>
Tooth-Colored Inlay/Onlay	Composite Resin or Silica-based Ceramic	<ul style="list-style-type: none"> <li>• <b>Adhesive Resin</b></li> <li>• Composite Resin</li> </ul>	<ul style="list-style-type: none"> <li>• <b>Adhesive Resin</b></li> <li>• Dual-Cure Composite Resin</li> </ul>
Laminate Veneer	Composite Resin or Silica-based Ceramics	<ul style="list-style-type: none"> <li>• <b>Adhesive Resin</b></li> <li>• Composite Resin</li> </ul>	<ul style="list-style-type: none"> <li>• <b>Adhesive Resin</b></li> <li>• Light-cure or Dual-Cure Composite Resin</li> </ul>
Silica-Based All-Ceramic Crown	Silica-based Ceramics (e.g. IPS Empress 1 or Eris, Ivoclar Vivadent)	<ul style="list-style-type: none"> <li>• <b>Adhesive Resin</b></li> <li>• Composite Resin</li> </ul>	<ul style="list-style-type: none"> <li>• <b>Adhesive Resin</b></li> <li>• Dual-cure or Self-Cure Composite Resin</li> </ul>
High-Strength All-Ceramic Crown/FPD	Glass-infiltrated Aluminum and Zirconium Oxide (e.g., InCeram, Vita Zahnfabrik)	<ul style="list-style-type: none"> <li>• <b>Adhesive Resin</b></li> <li>• RM Glass Ionomer</li> <li>• Glass Ionomer</li> </ul>	<ul style="list-style-type: none"> <li>• <b>Adhesive Resin</b></li> <li>• RM Glass Ionomer</li> <li>• Glass Ionomer</li> </ul>
	Densely-sintered Aluminum Oxide (e.g., Procera AllCeram, Nobelbiocare)	<ul style="list-style-type: none"> <li>• <b>Adhesive Resin</b></li> <li>• RM Glass Ionomer</li> <li>• Glass Ionomer</li> </ul>	<ul style="list-style-type: none"> <li>• <b>Adhesive Resin</b></li> <li>• RM Glass Ionomer</li> <li>• Glass Ionomer</li> </ul>
	Zirconium Oxide (e.g., Procera AllZirkon, Nobelbiocare; Lava, 3M ESPE; Cercon, Dentsply)	<ul style="list-style-type: none"> <li>• <b>Adhesive Resin</b></li> <li>• RM Glass Ionomer</li> <li>• Glass Ionomer</li> </ul>	<ul style="list-style-type: none"> <li>• <b>Adhesive Resin</b></li> <li>• RM Glass Ionomer</li> <li>• Glass Ionomer</li> </ul>

# 2.0

## Cementation Step-By-Step Procedures

### General Considerations

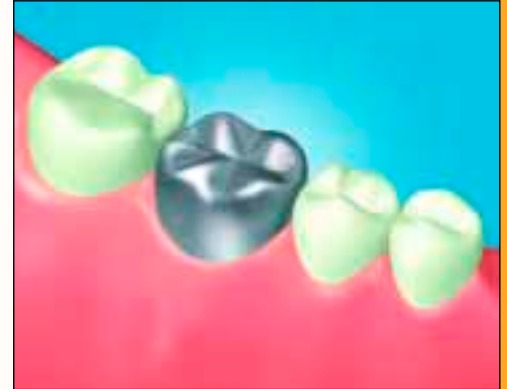
A clean and dry working field is recommended for all cementation procedures and mandatory for predictable and successful application of adhesive bonding techniques. The use of a rubber dam is therefore recommended whenever adhesive bonding techniques are applied.

Consider the use of retraction cords, especially when preparation margins are located subgingivally.

### Precementation Procedures

After removal of the provisional restoration verify all clinically important parameters such as esthetics, fit, interproximal contacts, and static/dynamic occlusion with appropriate instruments and adjust when necessary. Then, follow the flowcharts for the different kinds of materials and types of restorations and the use of a current adhesive composite resin cement. Whenever sandblasting is recommended, it is in reference to the internal surface and should be done with 30-50  $\mu\text{m}$   $\text{Al}_2\text{O}_3$  powder at an air pressure of 60-100 psi for 2-3 seconds per  $\text{cm}^2$ .

2.0.1



# 2.1

## Basic Cementation Technique

Luting Agent:  
Adhesive Composite Resin (Panavia F 2.0)

### Step 1

Preparation of the  
restoration

- 1 Sandblast intaglio surface of the restoration.



- 2 Apply a thin coat of ALLOY PRIMER if noble/high-noble alloys are used.



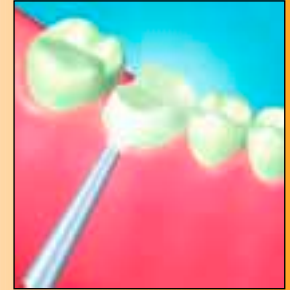
# Step 2

## Preparation of the abutment tooth

- 1** Clean the prepared tooth structure with fluoride-free pumice.



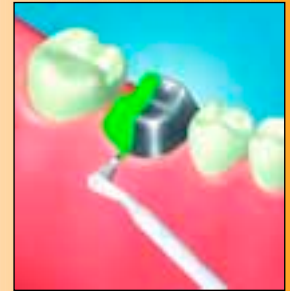
- 2** Rinse tooth with water & dry gently.



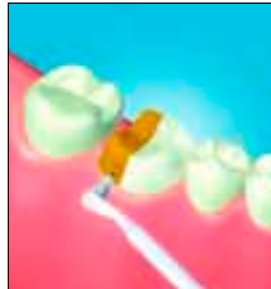
- 3** Isolate & dry working field.



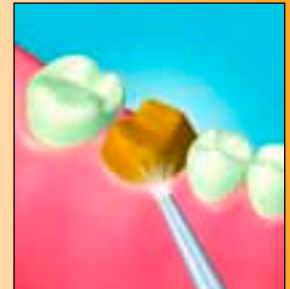
- 4** Apply ALLOY PRIMER if tooth structure is replaced with noble alloy cast post & core.



- 5** Mix one drop of each ED PRIMER II Liquid A & Liquid B, apply to both enamel & dentin tooth structures, leave for 30 seconds.



- 6** Dry with gentle air stream - surface will appear glossy.



# Step 3

## Mix Cement

# Step 4

## Insertion of Restoration

20 sec. for each surface (conventional halogen or LED light); 5 sec. for each surface (Plasma arc or fast halogen light)

- 1 Dispense & mix cement: dispense equal amounts of PANAVIA F 2.0 A PASTE and B PASTE.



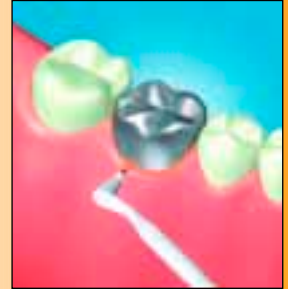
- 2 Mix pastes for 20 seconds & apply a thin & even layer of cement to the intaglio surface of the restoration.



- 1 Seat restoration & hold in place with finger pressure.



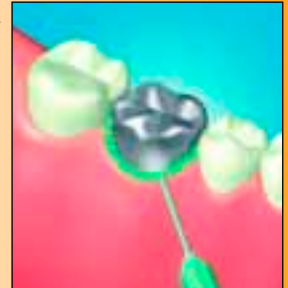
- 2 Excess cement may be removed by partially light curing the cement at the margins for 2-3 seconds then removing the excess with a hand instrument.



- 3 Cure cement margins with a curing light; 20 sec. for each surface (conventional halogen or LED light); 5 sec. for each surface (Plasma arc or fast halogen light).

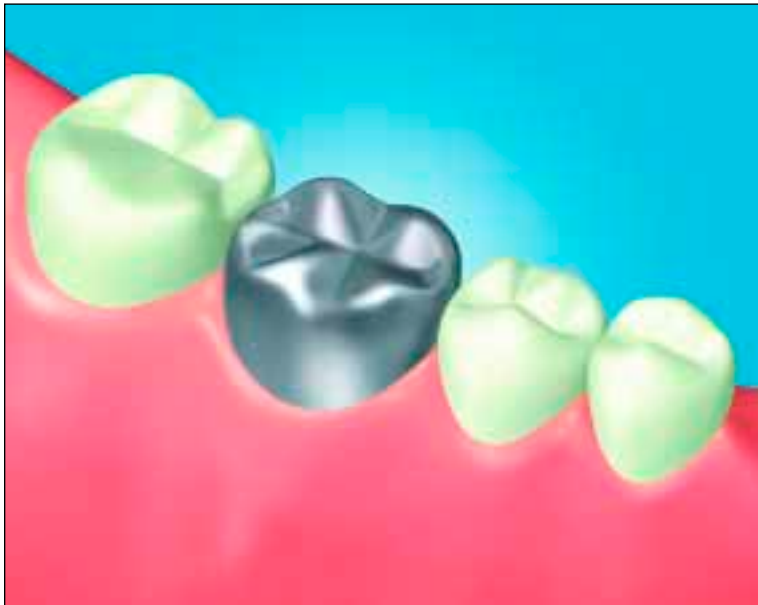


- Or apply PANAVIA F OXYGUARD II on the margins & leave for 3 minutes.
- If OXYGUARD II was used, clean after 3 minutes with water spray & cotton rolls.

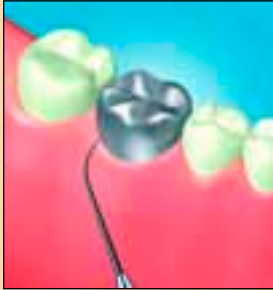


# Step 5

Removal of Excess Cement and Final Adjustments



**1** Remove cured excess cement with explorer, scaler, or blade & polish restoration if necessary.





# 2.2

## Resin-Bonded Fixed Partial Denture ("Maryland Bridge")

Opaque adhesive composite resin luting agents (e.g., PANAVIA F 2.0) should be used for cementation of resin-bonded FPDs with a metal frame, since metal parts of the retainers may reflect through the abutment teeth and cause discolorations.

**Luting Agent:**  
**Adhesive Composite Resin (Panavia F 2.0)**

### Step 1

Preparation of  
the Restoration

- 1 Sandblast bonding surface of the restoration.



2.2.1

# Step 2

## Preparation of the Abutment Tooth

- 1** Clean the prepared tooth structure with fluoride-free pumice.



- 2** Rinse tooth with water and dry gently.



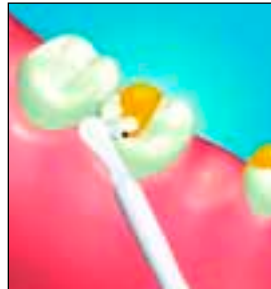
- 3** Isolate and dry working field.



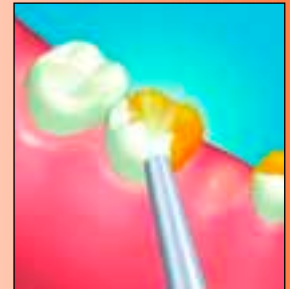
- 4** Condition enamel tooth structure with K ETCHANT GEL for 10 seconds. Then, rinse with water and air-dry.



- 5** Mix one drop of each ED PRIMER II Liquid A & Liquid B & apply to both enamel & dentin tooth structures & leave for 30 seconds.



- 6** Dry with gentle air stream - surface will appear glossy.



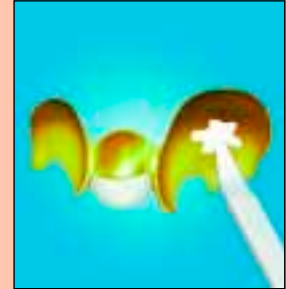
# Step 3

## Mix Cement

- 1 Dispense & mix cement: dispense equal amounts of PANAVIA F 2.0 A PASTE & B PASTE.



- 2 Mix pastes for 20 seconds & apply a thin & even layer of cement to the intaglio surface of the restoration.



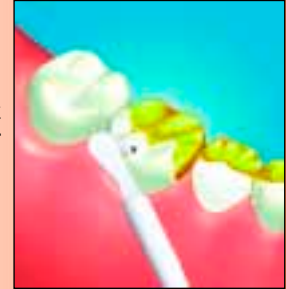
# Step 4

## Insertion of Restoration

- 1 Seat restoration & hold in place with finger pressure.



- 2 Excess cement may be removed by partially light curing the cement at the margins for 2-3 seconds then removing the excess with a hand instrument.



- 3 Cure cement margins with a curing light; 20 sec. for each surface (conventional halogen or LED light); 5 sec. for each surface (Plasma arc or fast halogen light).



Or apply PANAVIA F OXYGUARD II on the margins & leave for 3 minutes.

- If OXYGUARD II was used, clean after 3 minutes with water spray & cotton rolls.



## Step 5

Removal of Excess  
Cement and Final  
Adjustments



- 1 Remove cured excess cement with explorer, scaler, or blade & polish restoration if necessary.



# 2.3

## Tooth-colored Inlay/Onlay (Composite Resin or Silica-based Ceramic)

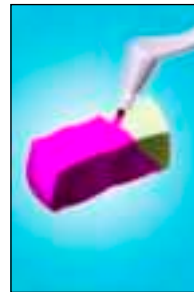
In addition to the preliminary try-in procedures described above, esthetic appearance of the restoration seated on the natural tooth should be verified with water, glycerin, and/or try-in pastes. A special applicator (e.g., explorer with sticky wax) may be used to simplify trial insertion and removal of the restoration and to prevent damage to marginal areas. Type, shade, and viscosity of the resin cement have to be selected before the actual cementation procedure. The bonding surfaces of the restoration should be pretreated (sandblasting or acid etching) after try-in procedures and necessary adjustments. Cured composite resin restorations should be sandblasted with 30-50  $\mu\text{m}$   $\text{Al}_2\text{O}_3$  powder at an air pressure of 60-100 psi for 2-3 seconds per  $\text{cm}^2$ . Clean and decontaminate the surface with K ETCHANT GEL, leave for 5 seconds and then rinse with water.

**Luting Agent:**  
**Adhesive Composite Resin (Panavia F 2.0)**

### Step 1

Preparation of the Restoration

- 1 Sandblast (composite resin) and acid etch (silica-based ceramic) bonding surfaces of the restoration with K ETCHANT GEL.



- 2 Apply silane coupling agent (mix equal amounts of CLEARFIL SE BOND PRIMER with CLEARFIL PORCELAIN BOND ACTIVATOR) & leave for 5 seconds. Dry gently with air.



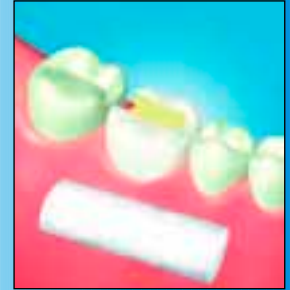
# Step 2

## Preparation of the Abutment Tooth

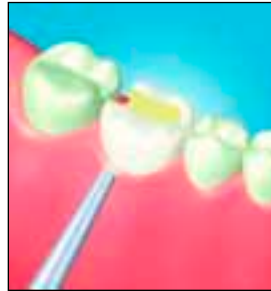
- 1** Clean the prepared tooth structure with fluoride-free pumice.



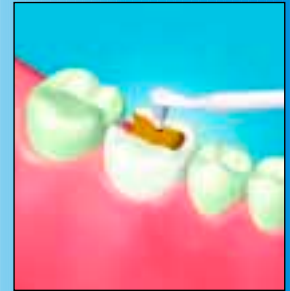
- 2** Rinse tooth with water & dry gently.



- 3** Isolate & dry working field.



- 4** Mix one drop of each ED PRIMER II Liquid A & Liquid B & apply to both enamel & dentin tooth structures & leave for 30 seconds.



- 5** Dry with gentle air stream - surface will appear glossy.



# Step 3

## Mix Cement

- 1 Dispense & mix cement: dispense equal amounts of PANAVIA F 2.0 A PASTE & B PASTE.



- 2 Mix pastes for 20 seconds & apply a thin & even layer of cement to the intaglio surface of the restoration.



# Step 4

## Insertion of restoration

- 1 Seat restoration & hold in place with finger pressure.



- 2 Excess cement may be removed by partially light curing the cement at the margins for 2-3 seconds then removing the excess with a hand instrument.

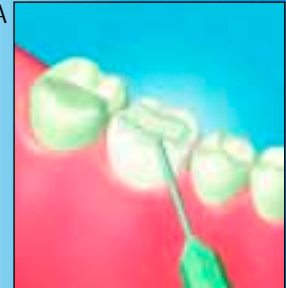


- 3 Cure cement margins with a curing light; 20 sec. for each surface (conventional halogen or LED light); 5 sec. for each surface (Plasma arc or fast halogen light).



Or apply PANAVIA F OXYGUARD II on the margins & leave for 3 minutes.

- If OXYGUARD II was used, clean after 3 minutes with water spray & cotton rolls.



# Step 5

Removal of Excess Cement and Final Adjustments



- 1 Remove cured excess cement with explorer, scaler, or blade & polish restoration if necessary.





# 2.4

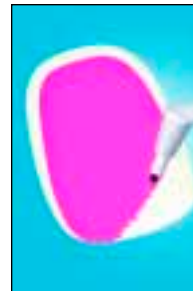
## Laminate Veneer (Composite Resin or Silica-based Ceramic)

In addition to the preliminary try-in procedures described previously, esthetic appearance of the restoration seated on the natural tooth should be verified with water, glycerin, and/or try-in pastes. Type, shade, and viscosity of the resin cement should be selected before the actual cementation procedure. The bonding surfaces of the restoration should be pretreated after try-in procedures and necessary adjustments. Cured composite resin restorations should be sandblasted with 30-50  $\mu\text{m}$   $\text{Al}_2\text{O}_3$  powder at an air pressure of 60-100 psi for 2-3 seconds per  $\text{cm}^2$ . Clean and decontaminate the surface with K ETCHANT GEL, leave for 5 seconds and then rinse with water.

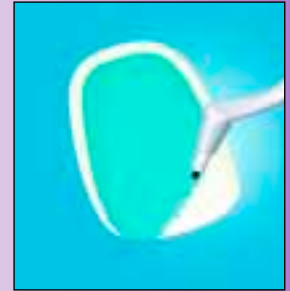
**Luting Agent:**  
**Adhesive Composite Resin (Panavia F 2.0)**

### Step 1 Preparation of the Restoration

- 1 Sandblast (composite resin) and acid etch (silica-based ceramic) bonding surfaces of the restoration with K ETCHANT GEL.



- 2 Apply silane coupling agent (mix equal amounts of CLEARFIL SE BOND PRIMER with CLEARFIL PORCELAIN BOND ACTIVATOR) & leave for 5 seconds. Dry gently with air.



2.4.1

# Step 2

## Preparation of the Abutment Tooth

- 1** Clean the prepared tooth structure with fluoride-free pumice.



- 2** Rinse tooth with water & dry gently.



- 3** Isolate & dry working field.



- 4** Condition enamel tooth structure with K ETCHANT GEL for 10 seconds. Then, rinse with water & air-dry.



- 5** Mix one drop of each ED PRIMER II Liquid A & Liquid B, apply to both enamel & dentin tooth structures, leave for 30 seconds.



- 6** Dry with gentle air stream - surface will appear glossy.



# Step 3

## Mix Cement

- 1 Dispense & mix cement: dispense equal amounts of PANAVIA F 2.0 A PASTE & B PASTE.



- 2 Mix pastes for 20 seconds & apply a thin & even layer of cement to the intaglio surface of the restoration.



# Step 4

## Insertion of Restoration

- 1 Seat restoration & hold restoration in place with finger pressure.



- 2 Excess cement may be removed by partially light curing the cement at the margins for 2-3 seconds then removing the excess with a hand instrument.



- 3 Cure cement margins with a curing light; 20 sec. for each surface (conventional halogen or LED light); 5 sec. for each surface (Plasma arc or fast halogen light).



- Or apply PANAVIA F OXYGUARD II on the margins & leave for 3 minutes.
- If OXYGUARD II was used, clean after 3 minutes with water spray & cotton rolls.



## Step 5

### Removal of Excess Cement and Final Adjustments



- 1 Remove cured excess cement with explorer, scaler, or blade & polish restoration if necessary.



# 2.5

## Silica-based All-Ceramic Crown

In addition to the preliminary try-in procedures described previously, esthetic appearance of the restoration seated on the natural tooth should be verified. Type, shade, and viscosity of the resin cement should be selected before the actual cementation procedure. The intaglio of silica-based ceramic crowns (e.g., leucite-reinforced feldspathic porcelain) should be acid etched after try-in procedures and necessary adjustments.

**Luting Agent:**  
**Adhesive Composite Resin (Panavia F 2.0)**

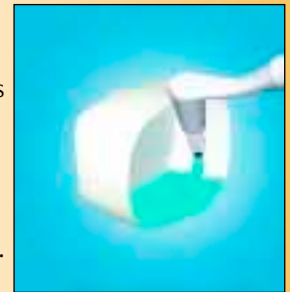
### Step 1

Preparation of the Restoration

- 1 Acid etch intaglio surface of restoration.



- 2 Apply silane coupling agent (mix equal amounts of CLEARFIL SE BOND PRIMER with CLEARFIL PORCELAIN BOND ACTIVATOR) & leave for 5 seconds. Dry gently with air.



2.5.1

SILICA  
CERAMIC  
CROWN

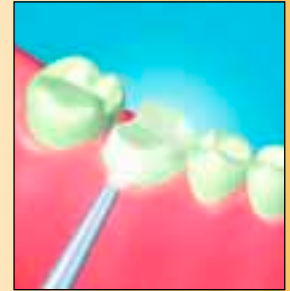
# Step 2

## Preparation of the Abutment Tooth

- 1** Clean the prepared tooth structure with fluoride-free pumice.



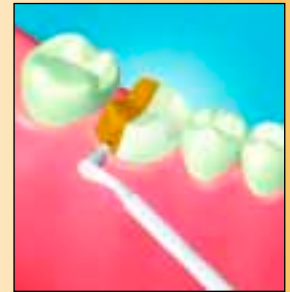
- 2** Rinse tooth with water & dry gently.



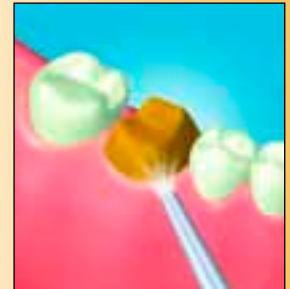
- 3** Isolate & dry working field.



- 4** Mix one drop of each ED PRIMER II Liquid A & Liquid B, apply to both enamel & dentin tooth structures, leave for 30 seconds.



- 5** Dry with gentle air stream - surface will appear glossy.



# Step 3

## Mix Cement

- 1 Dispense and mix cement: dispense equal amounts of PANAVIA F 2.0 A PASTE and B PASTE.



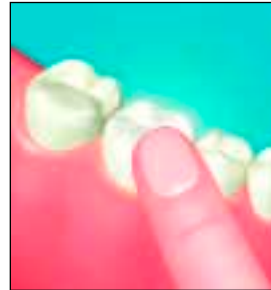
- 2 Mix pastes for 20 seconds & apply a thin & even layer of cement to the intaglio surface of the restoration.



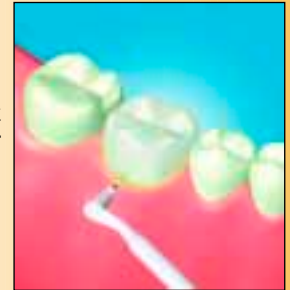
# Step 4

## Insertion of Restoration

- 1 Seat restoration & hold in place with finger pressure.



- 2 Excess cement may be removed by partially light curing the cement at the margins for 2-3 seconds then removing the excess with a hand instrument.



- 3 Cure cement margins with a curing light; 20 sec. for each surface (conventional halogen or LED light); 5 sec. for each surface (Plasma arc or fast halogen light).



- Or apply PANAVIA F OXYGUARD II on the margins & leave for 3 minutes.
- If OXYGUARD II was used, clean after 3 minutes with water spray & cotton rolls.



# Step 5

Removal of Excess Cement and Final Adjustments



- 1 Remove cured excess cement with explorer, scaler, or blade & polish restoration if necessary.





# 2.6

## High-Strength All-Ceramic Crown (aluminum-oxide or zirconium-oxide ceramic)

### Step 1

Preparation of the Restoration

The intaglio surface of high-strength ceramic crowns (e.g., glass-infiltrated or densely-sintered aluminum-oxide ceramic, zirconium-oxide ceramic) should be sandblasted after try-in procedures and necessary adjustments. Sandblast with 50-110  $\mu\text{m}$   $\text{Al}_2\text{O}_3$  at 60-100 psi pressure for 2-3 seconds per  $\text{cm}^2$ . If restoration was already pretreated in the laboratory, clean and decontaminate the surface with K ETCHANT GEL, leave for 5 seconds and then rinse with water.

**Luting Agent:**  
**Adhesive Composite Resin (Panavia F 2.0)**

- 1 Sandblast the intaglio surface of the high-strength ceramic crown.



2.6.1

HIGH STRENGTH  
ALL-CERAMIC  
CROWN

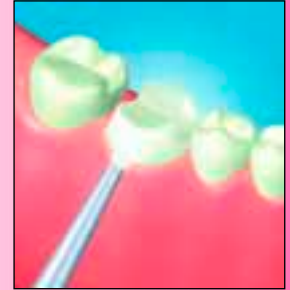
# Step 2

## Preparation of the Abutment Tooth

- 1** Clean the prepared tooth structure with fluoride-free pumice.



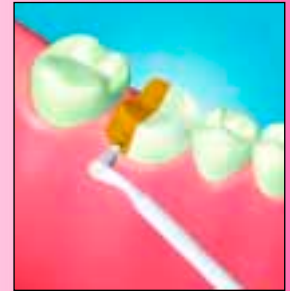
- 2** Rinse tooth with water & dry gently.



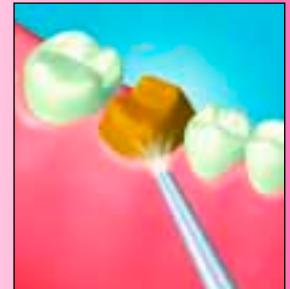
- 3** Isolate & dry working field.



- 4** Mix one drop of each ED Primer II Liquid A & Liquid B, apply to both enamel & dentin tooth structures, leave for 30 seconds.



- 5** Dry with gentle air stream - surface will appear glossy.



# Step 3

## Mix Cement

- 1 Dispense & mix cement: dispense equal amounts of PANAVIA F 2.0 A PASTE and B PASTE.



- 2 Mix pastes for 20 seconds & apply a thin & even layer of cement to the intaglio surface of the restoration.



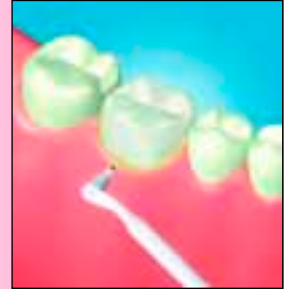
# Step 4

## Insertion of Restoration

- 1 Seat restoration & hold in place with finger pressure.



- 2 Excess cement may be removed by partially light curing the cement at the margins for 2-3 seconds then removing the excess with a hand instrument.

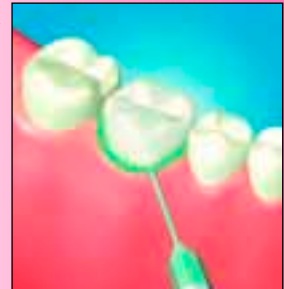


- 3 Cure cement margins with a curing light; 20 sec. for each surface (conventional halogen or LED light); 5 sec. for each surface (Plasma arc or fast halogen light).



Or apply PANAVIA F OXYGUARD II on the margins & leave for 3 minutes.

- If OXYGUARD II was used, clean after 3 minutes with water spray & cotton rolls.



# Step 5

Removal of Excess Cement and Final Adjustments



- 1 Remove cured excess cement with explorer, scaler, or blade & polish restoration if necessary.



# 3.0

## Background

Dental luting agents retain a laboratory-made (indirect) fixed restoration on the supporting tooth.<sup>1</sup> The selection and proper application of luting agents for definitive insertion of indirect restorations are fundamental for long-term functional success and pleasing esthetics. The variety of current treatment modalities and new indirect restorative dental materials may require different luting materials and insertion procedures.

The background and recommendations given are based on the currently available data and manufacturers' information. They are prone to adaptations as new knowledge evolves and new materials are developed. Controlled clinical trials will be necessary to verify some of the in-vitro data presented.

### 3.0.1

**BACKGROUND/  
SUMMARY/  
REFERENCES**

# 3.1

## Cast metal and PFM crown, FPD, cast metal inlay/onlay

Zinc phosphate cements have traditionally been the most popular luting materials<sup>1</sup> and their reliability is documented by the excellent clinical long-term survival rates of cast metal crowns, cast inlays/onlays, and porcelain-fused-to-metal (PFM) restorations.<sup>2-6</sup> Some advantages of zinc-phosphate cements are easy handling, sufficient compressive strength, and low cost. However, these cements have some major disadvantages such as brittleness, high solubility, and lack of antibacterial and - most important - adhesive properties. Retention of an indirect restoration cemented with traditional luting agents depends mostly on geometric form (surface, height, angulation) of the tooth preparation. Consequently, such cements have rather space-filling than retentive functions, which is important in light of the reportedly high number of prosthetic failures due to lack of retention.<sup>1,7</sup> Some of those drawbacks have been solved with the development of glass ionomers<sup>8</sup>, which offer some adhesion to tooth structures and various restorative materials, and they also release fluoride.<sup>1</sup> Latest additions to this material group are resin-modified glass ionomers, which combine some of the advantages of glass ionomer and resin luting agents.<sup>9</sup>

Cast metal and PFM restorations yield tremendous clinical success with the afore-

mentioned luting agents. However, adhesive bonding techniques are beneficial in various clinical situations, such as excessive dislodging forces, compromised mechanical retention, limited space for adequate tooth preparation, and occlusal contacts in excursions on short posterior restorations. Resin luting agents containing special adhesive monomers (e.g., 10-methacryloyloxydecyl dihydrogen phosphate (MDP)) that provide chemical bonds to metal oxides<sup>10</sup> have shown a significant increase in retention of cast restorations when compared with zinc phosphate, glass ionomer, or conventional resin cements.<sup>1,11-14</sup> Noble and high-noble alloys must be pretreated with special alloy primers, tin plated, or silica-/silane-coated.

Microleakage and the possible development of hypersensitivity and/or secondary caries are clinically important factors that can be reduced by the use of adhesive resin systems.<sup>15-17</sup> Filled resin luting agents also exhibit superior mechanical properties, such as increases in flexural strength, fracture toughness, modulus of elasticity, and hardness.<sup>1</sup>

Autopolymerizing or dual-cure resin cements are recommended for insertion of cast and PFM restorations.

# 3.2

## Resin-Bonded Fixed Partial Denture ("Maryland Bridge")

Since the preparation for PFM resin-bonded fixed partial dentures (FPD) is not designed to facilitate mechanical retention, clinical success relies on the adhesive bond of the metal framework to the supporting tooth structure.<sup>18-21</sup> If the tooth preparation is primarily confined to the enamel structures and adhesive bonding techniques are performed appropriately (acid etching, bonding agent application), a predictable resin bond to the metal can be established with the use of composite resin luting agents containing adhesive monomers that can bond directly to the metal. Base metal alloys should be typically used for PFM

resin-bonded FPDs due to their stiffness and susceptibility to form a surface oxide layer. Adhesive resin luting agents provide strong resin bonds to this oxide layer without pretreatment of the base-metal framework other than sand-blasting with  $Al_2O_3$ . Noble and high-noble alloys must be pretreated with special alloy primers, tin plated, or silica/silane-coated. Since the metal retainer wing may reflect through thin abutment teeth and result in a grayish appearance, dual- or self-cure resin cements of high opacity can be used to minimize this phenomenon and optimize the esthetic outcome.

# 3.3

## Tooth-colored Inlay/Onlay (Composite Resin or Silica-based Ceramic)

Ceramic inlays and onlays offer optimal esthetics, biocompatibility, and durability.<sup>2,22-24</sup> Adhesive bonding techniques, composite resin luting agents, and proper treatment of the ceramic and tooth surfaces are fundamental for clinical success and increased fracture resistance of silica-based (e.g., feldspathic porcelain, leucite-reinforced feldspathic porcelain) all-ceramic restorations.<sup>2,25-27</sup>

A sufficient resin bond to silicate ceramic materials relies on chemical bonding and micromechanical interlocking and can be achieved through surface roughening and application of a silane coupling agent. Grinding and air abrasion (e.g., aluminum-oxide particles) may increase bond strength<sup>28-31</sup> but are not suitable for final insertion of all-ceramic restorations due to possible marginal damage.<sup>32</sup> Most studies recommend acid etching of the ceramic surface with 4% to 9.8% hydrofluoric acid (HF) for 2-3 minutes to achieve preferable surface texture and roughness.<sup>33-39</sup> HF acid gels are user friendly and allow for chairside etching of the ceramic bonding surface after the completion of all try-in procedures and alterations.

Silane coupling agents provide a chemical covalent bond and micromechanical interlocking to silica-based ceramics.<sup>40-44</sup> Contamination of an etched and silanated restoration should be avoided since it may negatively

affect etching patterns and decrease bond strengths. If the restoration is contaminated during clinical try in with organic contaminants, such as saliva, blood or a silicone fit-checking medium, phosphoric-acid etching can remove organic contaminants prior to HF acid etching and is more effective than solvents such as acetone or alcohol.<sup>45</sup>

Silane coupling agents may have different chemical compositions that must be compatible with the bonding agent and the resin cement.<sup>46</sup> Therefore, it is of paramount importance to stay within one bonding system and to closely follow the manufacturer's instructions for application procedures and timing. Silane coupling agents are dispensed in single-bottle or multiple-bottle applications.

Composite-resin inlays and onlays experience an increased popularity.<sup>47,48</sup> Cured composite resins as used for indirect restorations lack an uncured resinous, oxygen inhibition layer, which is typical for freshly cured composite and offers excellent resin-to-resin bonds. Therefore, an indirect composite restoration must be pretreated (e.g., sandblasting and application of a silane coupling agent).

The dentin and enamel tooth structures are pretreated with the respective bonding agents. Dual- or chemical-activated resin cements are recommended for insertion of ceramic and composite resin inlays/onlays.<sup>49</sup>



# 3.4

## Laminate Veneer (composite resin or silica-based ceramic)

Ceramic laminate veneers offer excellent long-term clinical success.<sup>50-57</sup> The non-invasive nature of this treatment modality and the inherent brittleness of the typically-used feldspathic porcelain make resin bonding an absolute must. Silica-based ceramics are treated with HF acid and a silane coupling agent for predictable and long-term durable resin bonds as described above (3.3). High bond strengths can also be achieved to the supporting tooth structure if the preparation design is kept to the required minimum and mainly confined

to enamel. The esthetic appearance of the definitive restoration seated on the natural tooth should be verified with water, glycerin, and/or try-in pastes. Type, shade, and viscosity of the resin cement should be selected before the actual cementation procedure. The dentin and enamel tooth structures are pretreated with the respective bonding agents.

Indirect laminate veneers may also be fabricated of composite resins, which must be pretreated (e.g., sandblasting and application of a silane coupling agent).

# 3.5

## **Silica-based All-Ceramic Crown**

All-ceramic, especially silica-based ceramic restorations need support through adhesive technologies and composite resin luting agents,<sup>2,25</sup> which is also true for full-coverage crowns.<sup>2,26</sup> Pretreatment and bonding methods of tooth and restoration surfaces are the same as for ceramic inlays/onlays (3.3) and ceramic laminate veneers (3.4).

# 3.6

## High-strength All-Ceramic Crown (aluminum-oxide or zirconium-oxide ceramic)

All-ceramic systems using non-silicate, high-strength ceramic materials (aluminium-oxide and zirconium-oxide ceramics) become increasingly popular due to their esthetic characteristics, mechanical properties, and biocompatibility.<sup>2</sup> Indications include full-coverage crowns and multiple-unit FPDs<sup>2</sup>, while some systems even offer laminate veneers<sup>58</sup>, resin-bonded fixed partial dentures (FPDs)<sup>59</sup>, and implant abutments. Long-term clinical studies revealed high success rates of densely-sintered alumina crowns cemented with conventional luting agents.<sup>60, 61</sup> However, a recent literature review<sup>25</sup> suggests the use of adhesive bonding techniques for ceramic restorations, especially in clinical situations of compromised retention and high occlusal loads.<sup>62</sup> Adhesive luting is mandatory for resin-bonded FPDs and laminate veneers independent from the restorative material.

Reviews of the literature indicate that bonding procedures used for silica-based ceramics are not efficient for high-strength ceramic materials.<sup>27,63</sup> It is important to differentiate between studies that test only short-term bond strengths and studies that include simulated aging parameters such as long-term water storage and thermocycling for clinical relevance.<sup>27,63,64</sup> The intaglio surfaces of restorations made from different all-ceramic systems are unique due to the

use of different material compositions and fabrication procedures. Therefore, it is necessary to apply bonding protocols that were tested on specimens that possess the actual intaglio surface of a certain system.<sup>27,63</sup>

### Glass-infiltrated aluminum-oxide or zirconium oxide ceramic

Glass-infiltrated aluminum-oxide ceramic (e.g., In-Ceram Alumina, Vita Zahnfabrik, Bad Säckingen, Germany) offers a flexural strength of 450 MPa.<sup>65</sup> HF acid does not sufficiently roughen aluminum-oxide ceramics.<sup>66</sup> Air-particle abrasion with a microetcher and Al<sub>2</sub>O<sub>3</sub> abrasive particles is a practical method to successfully roughen the surface of aluminum-oxide ceramics for enhanced mechanical bonds.<sup>63</sup> Some silica-coating methods also achieve reliable and durable resin bonds to glass-infiltrated alumina.<sup>67-69</sup>

A resin luting agent containing an adhesive phosphate monomer provided reliable and long-term durable resin bonds to air-particle-abraded glass-infiltrated alumina ceramic in several in-vitro<sup>68,70,71</sup> as well as in-vivo studies.<sup>72</sup> The adhesive functional phosphate monomer MDP chemically bonds to metal oxides, including aluminum and zirconium oxides.<sup>10</sup>

There are no bonding studies to glass-infiltrated zirconium-oxide ceramics (e.g., Inceram Zirconia) available, but their composition suggests bonding procedures and materials as used for other high-strength ceramics.

### **Densely-Sintered Aluminum-Oxide Ceramic**

Procera AllCeram<sup>73</sup> (Nobel Biocare, Goteborg, Sweden) uses CAD/CAM technology for the fabrication of high-alumina (>99.9%) copings and frameworks that offer a flexural strength of 610 MPa.<sup>73,74</sup> While densely-sintered alumina restorations yield high clinical success with conventional cements,<sup>60,61</sup> adhesive luting may be beneficial and offers some advantages.<sup>25</sup> Air-particle abrasion with a microetcher (50 m Al<sub>2</sub>O<sub>3</sub> at 2.5 bar) has produced higher resin bonds than other surface roughening methods including grinding and HF acid etching.<sup>66</sup> One study revealed that conventional silane coupling agents and tribochemical silica coating fail to enhance the long-term resin bond to densely-sintered alumina.<sup>76</sup> Only air-particle abrasion and a composite resin containing an adhesive phosphate monomer provided high and long-term durable bond strengths.<sup>76</sup> Studies evaluating bond strength to the unique intaglio surface of Procera AllCeram restorations recommend air-particle abrasion and the use of a resin luting agent containing a phosphate monomer in combination with a corresponding silane coupling/bonding agent (Clearfil New Bond and Clearfil Porcelain Bond Activator).<sup>77,78</sup>

### **Zirconium-oxide ceramics**

Zirconium-oxide ceramics have a very high flexural strength (over 1000 MPa)<sup>79</sup> Contemporary CAD/CAM systems (e.g. Procera AllZirkon, obel Biocare, Lava, 3M ESPE, Cercon, Dentsply) use zirconium-oxide ceramics for fabricating copings, frameworks, and implant abutments. The high strength of densely-sintered zirconia restorations may allow inserted with traditional luting agents. However, resin bonding may become necessary in some clinical situations and may offer some additional advantages.<sup>27</sup> One study revealed that air particle abrasion, silane application, and a conventional Bis-GMA resin cement provided high initial bonds that failed spontaneously after simulated aging.<sup>80</sup> Tribochemical silica-coating was equally ineffective. Only air-particle abrasion and a phosphate-modified resin cement provided long-term durable resin bonds, which was confirmed by another long-term study in which specimens were subject to two years of water storage and repeated thermocycling.<sup>81</sup> The use of silane/bonding agents and resin cements containing special adhesive monomers was found to be the protocol of choice for Procera AllCeram restorations.<sup>77</sup> The same protocol was successful for the intaglio surface of Procera AllZirkon densely sintered zirconia restorations, and have also demonstrated that, potentially, the significant ingredient is the silane/bonding agent, which contains special adhesive monomers.<sup>82</sup> These findings have been verified using Lava Zirconia specimens. However, silica-/silane coating provided similar results.<sup>83</sup>

# 3.7

## Summary

Conventional luting agents have a long history of excellent clinical success and their use is relatively simple and commonly known. Some clinical situations and treatment modalities, however, may require resin bonding. If resin bonding is selected for final insertion, the following conclusions may be drawn in respect to the specific restorative material:

- Resin luting agents containing adhesive monomers provide high bond strengths to various, especially base metal alloys. Noble alloys should be specially pretreated (e.g., alloy primers).
- Cured composite resins used for indirect restorations should be adhesively luted after adequate surface treatment.
- Clinical success of silica-based ceramics relies on resin bonding. Preferred surface treatment methods are acid etching with HF acid solutions and subsequent application of a silane coupling agent.
- The preferred surface treatment for alumina and zirconia frameworks is air particle abrasion. A silane/bonding agent containing adhesive monomers employed with a modified resin cement provide predictable and durable bond to densely-sintered alumina- and zirconia-based restorations.

## 3.8

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