Choosing the Right Dental Material and Making Sense of the Options: Evidence and Clinical Recommendations

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ABSTRACT

Decision-making is a fundamental aspect of clinical dentistry. Advances in technology and trends towards more conservative technologies have broadened the options available to patients and dentists, increasing the range of choices and opportunities to restore teeth. With such a broad range of dental materials, there are a number of factors to consider in making an appropriate choice.

We present several decision-making dilemmas. Namely; how to restore worn lower anterior teeth, what to consider when replacing crowns, materials to consider when providing cuspal protection for posterior teeth, and finally the issues to consider when selecting a luting cement. The evidence supporting different clinical choices is considered in a discussion of the various dilemmas faced.

INTRODUCTION

Dentists are often confronted with decisions regarding the choice of appropriate materials and techniques to use in the restoration of teeth. Decisions regarding the best choice of material or restoration may be based upon clinical experience, familiarity with a material or technique, the evidence base, financial considerations and/or patient preferences. Many clinicians base their choices on their own clinical experience. Some are early adopters of newer materials and techniques; others fail to move on from their initial teachings as undergraduates.[1] However, it is important to consider dental materials in the context of the effect on clinical outcomes, rather than personal preference alone.

This article uses a clinical case to discuss a few common decision making dilemmas faced by the dental practitioner involved in selecting the most appropriate dental materials and techniques.

CLINICAL CASE

In order to contextualise this discussion a previously restored toothwear case has been chosen. A 60-year-old female concerned about worn teeth and spaces. Images of the dentition at presentation are shown in Figures 1a-g. She was diagnosed with:

1. Toothwear, of a primarily erosive aetiology with an attritional element.
2. Chronic apical periodontitis to UL3 and UL2
3. Fractured restorations to UR2, UR1, UL1 and UL2

4. Poor marginal adaptation of crowns at UL1 and UL3

Figure 1a: Intra-oral anterior view, patient in ICP

Figure 1b: Intra-oral anterior view, teeth apart

Figure 1c: Occlusal view, maxillary teeth

Figure 1d: Occlusal view, mandibular teeth

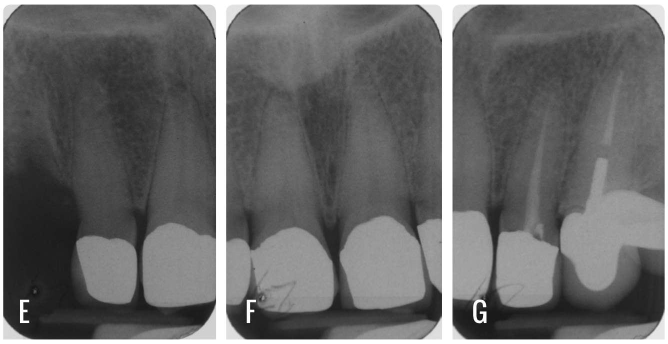

Figure 1e: Peri-apical radiograph of UR1 and UR2
Figure 1f: Peri-apical radiograph of UR1 and UL1
Figure 1g: Peri-apical radiograph of UL2 and UL3

Following primary disease control, a variety of treatment approaches were considered and discussed with the patient. In the end treatment involved the use of the Dahl concept to build up the worn teeth with direct composite, replacement of the crowns in the upper anterior region, protection of the posterior teeth with indirect cuspal coverage restorations and provision of a tooth supported cobalt chrome framework removable partial denture to replace the upper missing teeth. Several areas in this case represent common decision-making dilemmas. We present a discussion of the evidence, which may help practitioners make treatment-planning decisions when faced with similar situations in their own practice.

LOWER ANTERIOR TEETH

The lower anterior teeth show significant toothwear and require restoration to prevent further toothwear, improve appearance and alleviate any associated sensitivity. However, their restoration is complicated by dentoalveolar compensation, which limits the restorative space, and by the reduction in the available tooth tissue by wear. How then can we predictably restore these teeth? Traditional options for the creation of restorative space have included surgical crown lengthening followed by preparation for full coverage restorations, preparation as overdenture abutments or extraction of the lower anterior teeth and prosthetic replacement. Surgical crown lengthening of the lower anterior teeth increases the clinical crown height for retention of crowns to improve resistance and retention form. However, it involves a surgical procedure with the associated morbidity, reduces periodontal support and alters the emergence profile of the crowns. Furthermore surgical crown lengthening does not change the occlusal vertical dimension or increase restorative space, which means that preparation of the teeth is still required, which would involve significant removal of tooth structure on already small teeth.

The lower anterior teeth can be conservatively restored with direct composite restorations placed using the Dahl concept, which involves restoration to the normal anatomical form at an increased vertical dimension and allowing posterior contacts to be re-established over time. Several studies have demonstrated success with this approach. Poyser *et al*[2] described the use of the 'composite Dahl' for the restoration of the lower anterior teeth using a bulk build up technique. Investigating both performance over 2.5 years and the effect of preparing the teeth before build up the authors found that this procedure improves patient's perceptions about their dental appearance, the complete failure at 2.5 years was only 6% and that the mean time taken to re-establish posterior tooth contacts was 6.2 months.[2] These patients were subsequently reviewed seven years after initial placement. Investigators reported an approximate survival at 7 years of 85%, with 53% of patients having survival of all restorations.[3] In a ten-year evaluation of the performance of composite Dahl restorations for the restoration of localised anterior toothwear, Gulmali *et al*[4] found a median survival of 5.8 years.[4]

Collectively the studies by Poyser *et al*, Al-Khayatt *et al* and Gulamali *et al* demonstrate that this method works well in the medium term over 5-7 years. Composite has low biological cost and is easy to polish, repair and replace.[4] The authors consider composite to be the treatment of choice for localised anterior toothwear due to the relatively small size of mandibular incisor teeth and the space requirements for even the most conservative of full-coverage restorations being unnecessarily destructive. Patients need to be aware that it may take up to two years for the posterior occlusion to re-establish and of the maintenance requirements associated with this approach.[5] A few key steps will achieve good outcomes with composite restorations when the Dahl concept is used to restore worn teeth.

Achieving a Predictable Bond with Resin Composite

In the authors' experiences many dentists express concerns about the predictability of composite restorations placed in the treatment of toothwear. However, these restorations are predictable if moisture is controlled, the remaining enamel is preserved for bonding rather than being removed by 'bevelling', and if the bonding procedure is fully understood and the importance of the various steps respected.

Enamel bonding involves dissolution of enamel rods by acid etching to create a surface rich in microporosities into which a bonding agent penetrates to create, upon polymerisation, a tough micromechanical retentive interface with superior retentive properties than the bond achieved to dentine.[6,7] Bonding to dentine involves dissolution of inter-tubular hydroxyapatite to leave a mesh of collagen fibres, which when primed with a hydrophilic monomer, dissolved in an organic solvent, can then be penetrated by a hydrophobic resin, which infiltrates into the dentinal tubules as well as around the collagen mesh, resulting in the hybrid layer interface.[6,8] A stronger bond is achieved to enamel (30-50MPa) than with dentine (20 MPa).[6,7] The bond to dentine is more variable and reduces significantly in-vivo after a few months.[70] It is essential that the remaining enamel on the labial, lingual and interproximal surfaces is utilised i.e. the restoration wraps around on to these surfaces. It is also essential to ensure good moisture control to maximise bond strength and the authors find that use of rubber dam is the best method to prevent moisture contamination.

The variety of bonding systems available can be confusing. Bonding systems can be broadly grouped as:

a. 3-step systems (etch, prime, bond)
b. 2-step systems (etch, combined prime and bond)
c. self-etching adhesives (1-step or 2-step)

Three-step bonding systems have been considered the 'gold standard' in *in-vitro* studies. However, they are technique sensitive and good clinical outcomes can be difficult to achieve.[6,9] A common mistake is to over-dry the dentine and collapse the collagen network which is critical in formation of the hybrid layer and thus reduce bond strength. Current advice is to dry the tooth until the enamel appears 'frosted' and the dentine loses its 'shine'.[10] One step systems are not advocated as they do not remove the smear layer in the traditional sense and they demonstrate a propensity for nanoleakage and hydrolytic degradation.[4] The authors favour the use of a three-step bonding system such as Optibond FL (Kerr, CA). However, we acknowledge that two-step self-etching systems have shown comparable results when assessed by similar criteria in clinical situations.[10]

Choosing the appropriate composite

Resin composites consist principally of filler particles within a resin matrix. Composites are usually classified according to the size and shape of the filler particles, leading to descriptive terms such as macrofilled, microfilled, hybrid and nanohybrid composites.[11,12] Increasing filler content reduces polymerisation shrinkage and improves the materials handling properties, wear resistance and aesthetics.[11] Composites with smaller filler size demonstrate more impressive aesthetic properties including polishability, opalescence and translucence.[11]

Choosing the type of composite clearly depends on the clinical situation. In anterior teeth aesthetics is often more important, but posteriorly the physical properties such as compressive strength (CS), flexural strength (FS), fracture toughness and wear resistance may have greater importance. Physical properties may assume greater importance in anterior teeth when increased loads are expected, e.g. in class IV restorations and attrition toothwear cases. The properties of the different composite types are summarised with advantages, disadvantages and clinical indications of each in Table 1.[11,13,14] The authors favour the use of a multi-purpose microhybrid composite for the treatment of toothwear cases as these were the materials used in a number of clinical studies into the use of resin composite for the treatment of toothwear.[2,3]

Composite resin shrinks by 2-4% upon polymerisation. In intra-coronal restorations an incremental layering technique bonding to only one tooth surface at a time is advocated to ensure bonding at all margins.[15] In toothwear cases composite can be cured in bulk, as the configuration (C) factor is favourable and any polymerisation shrinkage will pull the mate-

Table 1. Summary of advantages, disadvantages and clinical indications of currently available composite materials

Category (Size & % volume filler particles)	Trade examples	Advantages	Disadvantages	Clinical Indications
Multipurpose/ Microhybrid **Filler sizes: 2-4μm and 0.04-0.2μm** **Filler volume: 60-70%**	TPH Spectrum and Esthet-X (Dentsply) Herculite XRV (Kerr) Venus and Charisma (Heraeus Kulzer) EnamelPlus HFO (GDF) Z250 and Z100 (3M ESPE) Miris (Coltene-Whaledent) Gradia Direct (GC)	Mechanical properties: FS (80-160MPa), DTS (30-55MPa), FM (8-13GPa), CS (240-290MPa). Low polymerisation shrinkage (0.7-1.4%) Low opacity therefore no multi-layering with opaque and enamel shades required. Good handling properties, easy to use in difficult areas to access. Ease of shade matching, due to metamerism (chameleon-like properties)	Limited scope to create character to restorations including incisal translucency, fluorotic patches and craze lines. Loss of surface polish and roughening of surface in time	Universal direct composite for both anterior and posterior teeth.
Nanocomposite **Filler sizes: 0.002-0.075μm** **Filler volume: 76-84%**	Filtek Supreme (3M ESPE) CeramX Duo and CeramX Mono (Dentsply) Premise Enamel (Kerr) Tetric Evo Ceram (Ivoclar-Vivadent)	Best mechanical properties: DTS (81MPa), FS (180MPa), CS (460MPa) High polishability and wide ranges of shade and opacity. Aesthetic properties similar to those of microfilled composites No bevelling required in aesthetic areas Opaque shades may hide discolouration of underlying substrate	Increased evidence of the potential for water degradation	Universal direct composite for both anterior and posterior teeth. Suitable for areas of high aesthetic demand e.g. direct composite veneers and high character restorations.
Packable **Filler sizes: 0.04 μm and 0.2-20μm** **Filler volume: 59-80%**	Filtek P60 (3M ESPE) Soltaire 2 (Heraeus Kulzer) Prodigy Condensible (Kerr) Tetric Ceram Condensible (Ivoclar-Vivadent)	Good mechanical properties: CS (220-300MPa), FM (9-12GPa), DTS (34MPa), FS (85-110MPa) Packable material, easy to use in areas of difficult access	Limited aesthetics, should not be used in aesthetically important areas	Posterior direct composite restorations (Class I, II, and MOD style cavities) and core build ups
Microfilled **Filler size: 0.04 μm** **Filler volume: 32-50%**	Durafill (Heraeus Kulzer) Heliomolar radiopaque (Ivoclar-Vivadent) Silux Plus (3M) EcuSphere Shine (DMG)	Artificially aged material outperforms nano-hybrid composites despite inferior initial mechanical properties Wide ranges of shade and opacity Opaque shades may hide discolouration of underlying substrate. Best aesthetics and polishability	Lowest mechanical properties: FS (73MPa), flexural modulus (4GPa), CS (61MPa), DTS (24MPa) Bevelling required in aesthetic areas	High aesthetic demand restorations e.g. direct composite veneers and high character restorations.

FS: Flexural strength, DTS: Diametral Tensile Strength, FM: Flexural Modulus, CS: Compressive Strength rial towards the bonded tooth surface and enhance marginal integrity.[2] A bulk build up may be facilitated by the use of an index created from a diagnostic wax up.

UPPER ANTERIOR TEETH

The upper anterior teeth were restored with metal ceramic crowns at initial presentation. Replacement crowns were indicated due to fracture of ceramic, marginal deficiencies and following endodontic re-treatment of the UL2 and UL3. Replacement of the crowns involved three phases:

1. Dismantling and assessment of restorability of the remaining tooth structure
2. Provisional restorations
3. Crown replacement

Dismantling

In this case it was only possible to assess the restorability of the upper anterior teeth by dismantling the existing restorations. Often, where multiple units require dismantling it is helpful to construct a clear suck down matrix beforehand. This simplifies the construction of chairside temporary crowns. Where bridged teeth are being dismantled and the prognosis for abutments is uncertain the production of a partial denture as a fallback option is advocated. Alternatively a rigid clear splint e.g. an Essix retainer may be useful both in the fabrication of chairside temporary crowns and, by adding direct composite into a pontic site, as an unconventional temporary removable denture until such time as a more permanent solution can be achieved. It is important that patients are informed of the potential consequences of finding teeth unrestorable and that they are involved in the planning of care in the short, medium and long term.

Provisional crowns

The use of provisional restorations allows assessment of aesthetics, occlusion, anterior guidance, phonetics, pulpal status of compromised teeth, and gingival margin position following any adjunctive surgery. A number of materials are available and material selection is often dependent upon how long the restorations are expected to remain in place. Often the ease of fabrication, aesthetics and strength are important considerations. Table 2 provides a summary of the currently available tooth coloured materials that can be used in the provisionalisation of teeth requiring indirect restorations.[16-26] The ability to form a good provisional crown margin will enhance the soft tissue quality, thereby making impression making for definitive crowns more predictable. Once the ideal form of the provisional crowns has been established this can be transferred to definitive restorations using silicone indices or a customised incisal guidance table.[27]

Crown replacement

When crowns are being placed in the aesthetic zone the dentist and patient usually must decide between metal-ceramic and all-ceramic restorations. Traditionally indirect resin composite materials have mainly been used for the construction of provisional restorations in the aesthetic zone, however, indirect resin composite is a widely used definitive indirect material for onlays, inlays and even full coverage crowns.

Metal-Ceramic Crowns

Metal-ceramic crowns can provide metal palatal surfaces and have the advantage of being strong with minimal palatal reduction, however achieving excellent aesthetics can be demanding. Metal-ceramic crowns may be constructed with a precious or non-precious metal alloy core. Veneering ceramics contract onto this core during the firing process and bond to metal oxides within the alloy. Precious metal alloys have greater accuracy of marginal fit, a lower propensity for the development of casting porosities, are easier to finish and are less susceptible to corrosion.[28-32] There is, however, an increasing tendency to use non-precious metal alloy cores on cost grounds. The metal areas of these restorations should be adjusted with great care and copious irrigation to prevent excessive heat build up and porcelain fracture.

Precious and non-precious metal alloys are strong in thin section; 0.7-1.5mm thickness depending on the functional requirements, permitting more conservative preparation in non-aesthetic areas.[33] Where possible, surfaces in occlusal contact are better constructed in metal, not ceramic, to reduce wear on the opposing dentition. Silicone putty indices can be useful to ensure adequate tooth preparation.[34] Metal-ceramic crowns can provide excellent aesthetics where adequate space is created for a sufficient thickness of ceramic (1.5mm labial reduction and 2-2.5mm incisal reduction).[35-37] If insufficient space is prepared, restorations can appear opaque because of insufficient veneering ceramic or over-contoured as the technician may have tried to compensate for an under-prepared tooth, which can compromise gingival health. Various margin designs have been proposed for metal ceramic restorations including a porcelain labial margin, finishing the metal coping margin up the axial wall, however such modifications introduce compromises to the strength of the restoration in the unsupported region and to the accuracy of fit which can be achieved.[38-42] A shoulder or heavy chamfer margin is recommended.[43]

5-year survival rates of 95.6% have been reported for metal-ceramic crowns.[44] Failures and complications for such restorations were found to be due to biological complications including recurrent caries (0.7% per year), loss of pulp vitality (2.1% per year), periodontal disease (0.6% per year) and tooth fracture (0.9% per year).[44] A prospective long term survival analysis demonstrated a median survival time of 14.6 years for crowned teeth, though this study grouped full metal crowns with metal ceramic crowns in their Kaplan Meier analysis of 89 crowned teeth, the majority of failures being due to endodontic problems and secondary caries.[45]

In conclusion metal ceramic crowns can provide excellent aesthetics and demonstrate high survival rates, but tooth preparation can be destructive.

All-ceramic Crowns

All ceramic crowns can achieve excellent aesthetics. Ceramics may be classified according to their microstructure from veneering ceramics to polycrystalline ceramics *(Figure 2 & Table 3)*.[46,47] The main weakness of ceramics is that they are brittle and fail due to fracture propagation, caused by the presence of surface flaws on the intaglio surface of the ceramic restoration, therefore values for fracture toughness, a materials ability to resist crack propagation, should be considered.[46,76-78] Veneering ceramics have excellent aesthetics and can be etched and micromechanically bonded to enamel and dentine for laminate veneers and full or partial coverage resin bonded crowns also known as 'dentine bonded crowns'.[9,46,47] However, they have relatively low flexural strengths (66-71 MPa), fracture strength and toughness and need to be supported by a metal or high strength ceramic core unless the forces applied to them are very carefully controlled.[46]

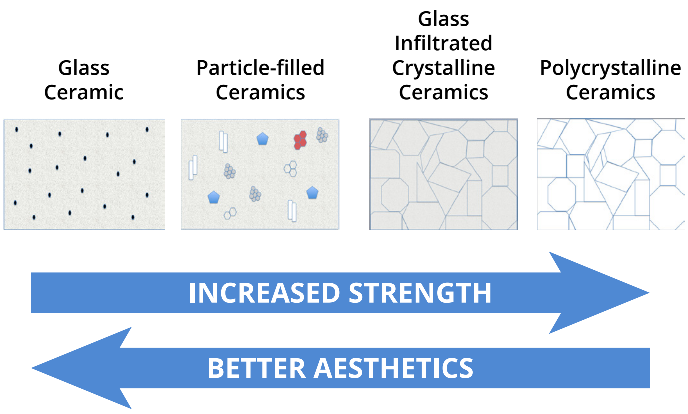

Figure 2: Graphical representation of the microstructure of various dental ceramic materials

Particle-filled glass ceramics have a higher flexural strength than veneering ceramics (182MPa for leucite) but they are less translucent. Whilst the incorporation of filler particles has yielded higher flexural strengths, improvements in the fracture toughness is still limited by the inherent weakness of the glassy phase of these materials which allows crack propagation.[76] Fracture toughness of approximately 1MPa $m^{1/2}$ are reported for these materials.[77] Fillers available include fluorapatite, leucite and lithium disilicate. Lithium disilicate is a patented subcategory of particle filled glass ceramics (e.maxPress™ or e.maxCAD™, Ivoclar Vivadent, Amherst N.Y), which has a crystalline structure of plate-like crystals that interlock to prevent the propagation of fractures through the material.[46-49] This ceramic can be heat pressed and has flexural strength properties (350-450MPa) approaching the next strongest category; glass-infiltrated crystalline ceramics.[49]

Table 2. Summary of the advantages and disadvantages of indirect chair-side provisional materials

	Material	Advantages	Disadvantages
Methacrylates	Methyl Methacrylate (PMMA) Ethyl Methacrylates (PEMA) Vinyl Methacrylates (PVMA)	Good fracture resistance (PMMA) Polishability Good stain resistance (PEMA/PVMA) Ability to add to material. This allows customisation of aesthetics and correction of marginal discrepancies Available in different shades	High polymerisation shrinkage (PMMA) Exothermic setting reaction may compromise pulp health if large volumes needed (PMMA) Need for remargination Less aesthetic than composite materials Low abrasion resistance (PMMA) Reduced fracture resistance (PEMA) Tissue reactions or pulp toxicity due to free monomer[87,88]
Composites	Bis-acryl composite BisGMA composite Urethane Dimethacrylate	Low exothermic reaction Low shrinkage Good strength and abrasion resistance Good marginal fit Good aesthetics (BisBMA and lab made Urethane Dimethacrylate superior) Chairside Urethane Dimethacrylate resins can be adapted intra-orally for temporisation of inlay/onlay preparations	Less polishable than filled resins More brittle than Methacrylate materials (Bis-acryl) Low stain resistance due to oxygen inhibition layer (less problematic with BisGMA composites) Repair or re-margination difficult (Bis-acryl) Chairside Urethane Dimethacrylate has poor aesthetics relative to other tooth coloured temporary materials

Table 3. Characteristics of ceramics in dentistry and indications for their use clinically

Increased strength ↓ / Increased Aesthetics ↑

Category	Subcategory	Trade Examples	Manufacture	Indications
Glass Ceramics (Veneering Ceramics)	Veneering over ceramic (feldspathic porcelain with 4-5% colourant/opacifier)	Vita VM7	Powder	Veneering over high strength ceramic core e.g. In-Ceram alumina
	Veneering on zirconia (feldspathic porcelain with 5-10% leucite and other modifiers)	Vita VM9, IPS e.maxCeram	Powder	Veneering over zirconia core e.g. In-Ceram zirconia or e.max ZirCAD Laminate veneers
		IPS e.max ZirPress	Heat pressed	
	Veneering on metals (fedspathic porcelain with 17-25% leucite)	Vita VM13	Powder	Veneering over metal in metal ceramic restorations
		Vita PM9	Heat pressed	
Glass Ceramics with Fillers	Leucite (40-50%)	IPS Empress	Heat pressed	Onlays, veneers and partial or full coverage crowns
		IPS ProCAD	Milled	
		Optec	Powder	
	Lithium Disilicate	e.max CAD	Milled	Anterior and posterior crowns Anterior bridgework
		e.max Press	Heat pressed	
Crystalline Ceramics infiltrated with Glass	Alumina	In-Ceram alumina	Slip-cast and milled	Anterior and posterior crowns Anterior bridgework
	Alumina-magnesia	In-Ceram spinel	Milled	Anterior crowns
	Alumina-zirconia	In-Ceram zirconia	Slip-cast and milled	Anterior and posterior crowns Anterior and posterior bridgework
Polycrystalline Ceramics	Polycrystalline partially stabilised (with 3-5% yttrium) zirconia	Lava,	Milled	Anterior crown and bridgework Posterior crown and bridgework
		e.max ZirCAD	Milled	
		Procera,	Milled	As above plus implant abutments
	Polycrystalline alumina	Procera, Vita AL-Cubes	Milled	Anterior and posterior crowns Anterior bridgework

Figure 3a: Post-operative intra-oral image, patient in ICP

Figure 3b: Post-operative intra-oral image, teeth apart

Figure 3c: Post-operative occlusal view of maxillary teeth

Figure 3d: Post-operative occlusal view of mandibular teeth

Glass infiltrated crystalline ceramics (InCeram™, Vita Zahnfabrik, Bad Säckingen) have much higher flexural strength than particle-filled glass ceramics and are generally used for higher strength cores with a veneer of traditional glass ceramic for increased translucency and aesthetics.[47,49] The crystalline phase in these systems may be spinell (350MPa), alumina (450MPa) and zirconia (600MPa).[46,49] In-Ceram Alumina shows improved fracture toughness over the particle filled glass ceramics with values of 3.6-4.4 MPa $m^{1/2}$, compared to 4.8 MPa $m^{1/2}$ for In-Ceram Zirconia.[77-78]

Polycrystalline ceramics have no glass content but they contain crystals in an arrangement that prevents fracture propagation. This category includes polycrystalline alumina (Procera™, Nobel Biocare, Zurich), and polycrystalline zirconia (Procera™, Nobel Biocare, Zurich; Lava™, 3M ESPE, St. Paul, Minn.; e.max ZirCAD™, Ivoclar Vivadent, Amherst N.Y.). Zirconia ceramics have demonstrated the highest fracture toughness properties of the all-ceramic materials, at between 8-10MPa $m^{1/2}$ they are roughly twice as strong as polycrystalline alumina materials.[76] The disadvantages of the polycrystalline ceramics include the difficulty of processing, hence the need for CAD-CAM to produce well-fitting margins, and the aesthetics, with the opacity of the material requiring significant thickness of veneering ceramic to overcome.[47] There are quite significant aesthetic limitations with the use of such materials as they are often milled from monochromatic blocks and thus require the addition of veneering ceramics and unpredictable surface stains to achieve optimal aesthetic outcomes. To overcome this problem some manufacturers have begun manufacturing layered blanks with different degrees of translucency e.g. Lava™ Plus High Translucency (3M ESPE) .

Veneering ceramics have good translucency and an aesthetic result can be achieved with relatively minimal preparation. However these ceramics have poor mechanical properties. Polycrystalline ceramics and high strength core ceramics require more aggressive preparations, similar to that of metal-ceramic crowns, (1.5-2.0mm incisally, and 1.0-1.5mm proximal with a taper of 3-5°).[50-52] Readers are directed to the preparation guidelines of their chosen all-ceramic system for guidance on tooth preparation dimensions.[51-53]

All-ceramic restorations provided in ideal situations have demonstrated excellent survival data in the medium term showing 5-year survival data of between 94.5 to 96.4% with different systems.[44] In this case metal-ceramic restorations were chosen as they have a proven long-term track record, they enabled the use of a more conservative tooth preparation without over-contouring of the palatal aspect of the upper incisors and avoided the reduced the risk of wear to the lower anterior teeth by using metal palatal surfaces.

UPPER AND LOWER POSTERIOR TEETH

When posterior teeth are heavily restored with direct restorations or have been endodontically treated the need for cuspal coverage and protection may be considered necessary. Materials such as gold, ceramics or indirect composite may be used for this purpose. It is important to keep in mind that whilst cuspal coverage may be desirable to protect against further damage to tooth tissue, the preparation involved when providing indirect restorations to posterior teeth is in itself destructive. One should always consider whether a full coverage indirect restoration is really necessary, as it is often the case that the incorporation of preparation features such as slots and grooves, and the use of adhesive techniques enables the use of a more conservative preparation design such as onlays or partial coverage crowns.[54-56] The use of directly bonded resin composite onlays with minimal preparation has also been described as a conservative option for cuspal protection restorations and has demonstrated excellent (100%) survival in clinical studies at 6-7 years with minimal preparation and moderate results when considering success, 73%, at 11 years.[71-73]

Gold, Composite or Ceramic?

Advantages of gold or metal restorations for posterior teeth include conservation of tooth structure, maintenance of good marginal integrity and the ability to build in rest seats, guide planes and undercuts for RPD retention. The use of posterior gold onlays has shown clinical success rates of up to 89% at 5 years when using adhesive techniques for cementation.[57]

Ceramic and indirect composite onlays have good aesthetics and demonstrate comparable survival rates to metal onlays in clinical studies.[58,59] However, tooth preparation is more destructive and marginal adaptation is poorer than metal onlays. Ceramic occlusal surfaces can lead to wear of opposing teeth particularly if the surface is not polished and re-glazed following adjustment. Indirect composite is kinder to opposing

Table 4. Surface treatment protocols for various indirect materials prior to cementation

Indirect material	Restoration Surface Treatment
Veneering Ceramics & Filled Glass Ceramics	Etch restoration for 15 seconds with 5-9% hydrofluoric acid, Wash & dry Silanate using product recommended by cement manufacturer of choice Appropriate isolation and moisture control e.g. use of rubber dam
Alumina based high strength ceramics	Sandblast restoration with 50-75µm aluminium oxide Etch for 15 seconds with 5-9% hydrofluoric acid, Wash & dry Silanate using product recommended by cement manufacturer of choice Appropriate Isolation and Moisture control e.g. use of rubber dam
Polycrystalline zirconia ceramics	No surface treatment required
Indirect Composite	Sandblast with 50µm aluminium oxide Wash & dry Appropriate Isolation and Moisture control e.g. use of rubber dam
Gold/Palladium	Sandblast with 50-75µm aluminium oxide AND/OR Consider heat treatment to 350-400ºC for 4 minutes Wash & dry Use product recommended by cement manufacturer of choice to treat restoration fit surface Appropriate Isolation and Moisture control e.g. use of rubber dam N.B. The use of a bi-functional resin cement is essential for the bonding of metal restorations
Base Metals (NiCr, CoCr)	Sandblast with 50-75µm aluminium oxide Wash & dry Silanate using product recommended by cement manufacturer of choice Appropriate Isolation and Moisture control e.g. use of rubber dam N.B. The use of a bi-functional resing cement is essential for the bonding of metal restorations e.g. Panavia F 2.0™ (Kuraray, Japan)

teeth although it may itself wear with continued parafunction. This may be less of a problem with newer indirect composites e.g. belleGlass HP® (Kerr, Orange, CA), which have greater filler density and are thought to have better marginal adaptation than ceramics.[59-61]

In this case the posterior teeth were restored with cast metal restorations as the posterior occlusion failed to re-establish. The use of cast metal restorations is conservative and provides occlusal stability. Rest seats were incorporated within these restorations to facilitate final rehabilitation with a RPD.

Selecting a Luting Cement

A variety of different luting cements are available for the cementation of indirect restorations. Selection of an appropriate cement and cementation technique is essential to the success of an indirect restoration. Conventional full coverage gold crowns and metal-ceramic crowns can be cemented with any cement including the traditional zinc phosphate (ZnPh), zinc polycarboxylate (ZnPx), or glass ionomer cements (GIC). Some authors suggest that a resin-modified glass-ionomer cement (RMGIC) is the cement of choice for definitive cementation due to superior mechanical properties and its ability to seal dentinal tubules and protect the pulp.[9] This statement is perhaps to simplistic and it is important to remember that conventional restorations gain resistance from the preparation shape and do not require a strong cement. Restorations need to be retrievable so that replacement is possible and in the 19% of crowned teeth develop peri-radicular pathology, they can removed to facilitate endodontics.[74]

Resin cements have the best aesthetic properties, excellent compressive and tensile strength, low solubility and enhance the retention of a restoration.[62] They are essential in 'resin bonded' restorations such as adhesive bridges, adhesive onlays, resin bonded crowns, ceramic restorations, and conventional restorations on teeth with insufficient resistance form. It is important to carefully follow the bonding protocols set out by manufacturers and to prepare the restoration fit surface appropriately, *(Table 4)*.

If using an alumina ceramic the fitting surface should be prepared by sandblasting/air abrasion with 50-75µm alumina (Coejet™, 3M ESPE, St. Paul, Minn) particles, followed by etching with hydrofluoric acid, and silanation[7,63] Indirect composite restorations should be sand-blasted with 50µm alumina for 10 seconds followed by application of a silane as a linking molecule (3M Sil™, 3M ESPE, St. Paul, Minn). Non-alumina ceramics should not be air abraded as this may cause microfracture and increase the potential for ceramic fracture.[64,65] Veneering ceramics and lithium disilicate ceramics should be etched for 15 seconds with 5-9% hydrofluoric acid to create a roughened surface amenable to micromechanical retention. It is important to appreciate that ceramic can be over-etched resulting in reduced bonding strengths to the adhesive cement.[66] It is possible, with the use of low-pressure alumina blasting and the use of a zirconia-compatible primer, which improves the adherence of phosphate monomers in self-adhesive cements to terminal end groups within the zirconia surface.[75] The cement should provide sufficient strength to support the overlying restoration and not expand due to water sorption, thus a resin cement is recommended.

Non-precious metal restorations have a superficial oxide layer which can chemically bond with certain bi-functional resin cements e.g. MDP (Panavia F™, Kuraray, Tokyo) or 4-Meta (C & B Metabond™, Parkell, Edgewood, N.Y.). Precious metals such as gold or palladium do not readily form oxides. However, precious metals may be tin plated or alloyed with copper which becomes oxidised by heat treatment to 350-400ºC for 4 minutes.[9] The use of air abrasion enhances micromechanical retention by the creation of a roughened surface area and may yield clinical results as good as heat treatment.[67] These techniques may be extremely useful in situations where there is reduced resistance and retention form.[68]

Resin cements may be light-cured, chemically cured or dual cure preparations. Light cured cements are recommended for the cementation of porcelain laminate veneers and resin-bonded crowns as the curing light can penetrate through the restoration.[9] All ceramic crowns with more opaque cores, or resin bonded crowns where the primary bonding surface is onto dentine rather than enamel, should be cemented with a dual-curing resin cement.[9] Chemically cured resin cements can undergo a yellow discolouration with time and should be avoided in translucent restorations which could otherwise be cemented with light cured resin cements.[69]

SUMMARY

Dentists are frequently faced with dilemmas regarding selection of the most appropriate materials and techniques to restore the dentition. This case considers some of the factors that need to be considered when restoring worn lower incisors, replacing crowns, providing cuspal coverage for posterior teeth and selecting a luting cement *(Table 5)*.

This case was ultimately treated with composite 'Dahl' build-ups to the lower teeth using a multipurpose micro-hybriod composite EsthetX (Dentsply). Metal-ceramic crowns with a palladium based casting alloy (CerpallTM 2, Cendres + Métaux, Bienne) were placed on the anterior teeth and luted with a self-etching dual cure adhesive cement (Rely-X Unicem™ 3M ESPE, St Paul, Minn). The preparations of these restorations were adequate to enable the cementation with any conventional cement and the use of this cement was dictated by personal preference of the operator at the time. The crowns were constructed with metal palatal surfaces to avoid excessive wear of the opposing composite restorations. Posterior cuspal coverage restorations were provided because after 14 months posterior occlusion had not re-established restorations enabled re-establishment of posterior occlusion and incorporate additional support features for the removable partial denture design. Images 3a-d images demonstrate the final result.

Table 5. Top tips when dealing with common decision making dilemmas

Clinical Dilemma	Clinical Tips
Predictable Bonding with Composite	Enhance bond strength of composite restorations by preserving enamel i.e. no preparation[2] Avoid over-etching and over-drying of dentine when using etch-and-rinse adhesives Good moisture control – use of rubber dam, thick palatal/lingual stents and retraction cord help to prevent interface contamination from saliva or gingival crevicular fluid.
Choice of Direct Composite material	For anterior teeth the use of a nanocomposite will give most superior aesthetic properties For posterior teeth packable or microhybrid composites have superior properties for withstanding occlusal loading In aesthetically important areas where functional loads are high e.g. attrition toothwear cases, a microhybrid composite gives the best balance of aesthetics and physical properties
Provisional restorations	Good provisional restorations give control of aesthetics, occlusal scheme and can be used to develop healthy soft tissue Bis-acryl composite and PMMA acrylic materials for chairside provisional restorations are suitable in the short term (up to 3 months). PMMA materials may be re-marginated for improved marginal fit. Remairgination is also possible with Bis-acryl composite using flowable composite materials though this is more technique sensitive and less stable for longer term provisional. Where provisional restorations are needed for longer than 3 months the authors prefer to use laboratory made composite provisional restoration is preferred over PMMA materials due to the superior aesthetics and ease of repair/modification with chair-side composite resin. A metal core with lab-made provisional restorations allows easier removal and prevents chipping of the provisional material Ensure ideal crown margin for optimum soft tissue control
Choice of Definitive Crown Material	Fracture propagation is prevented by effective bonding to either a metal core, high strength ceramic core or the underlying tooth structure with an adhesive cement The veneering ceramic should have the same coefficient of thermal expansion as the core to prevent ceramic flexure and therefore fracture Any adjustment of ceramic should be carefully polished to prevent fracture propagation from external surface flaws
Luting	Etching Alumina core ceramics e.g. InCeram Alumina, after air abrasion improves bond strength to adhesives to a greater extent than air abrasion alone[75] Etching with hydrofluoric acid is not recommended for indirect composites as it causes dissolution of inorganic particles and damages the composite fitting surface[60] Non-alumina ceramics should not be air-abraded as it may cause microfracture and increase potential for ceramic fracture[64,65] When bonding metal indirect restorations to teeth with amalgam restorations, intra-oral sandblasting to roughen the surface, after appropriate isolation, will improve bond strength

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