

Current concepts on the management of tooth wear: part 4. An overview of the restorative techniques and dental materials commonly applied for the management of tooth wear

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VERIFIABLE CPD PAPER

This final article of the four part series on the current concepts of tooth wear will provide the reader with an evaluation of the data available in the contemporary literature with regards to the survival analysis of differing restorative materials, and their respective methods of application to treat tooth wear. It is vital that the dental operator is familiar with the role of differing materials which may be used to restore the worn dentition, some of which may prove to be more suitable for the management of particular patterns of tooth wear than others. The active management of tooth wear unfortunately commits the patient to a lifelong need for considerable maintenance, and it is imperative that this is understood from the outset.

RESTORATIVE MATERIALS/ RESTORATIONS COMMONLY USED IN THE MANAGEMENT OF TOOTH WEAR

A number of materials/restorations are commonly used for the treatment of cases presenting with tooth wear (TW).

CURRENT CONCEPTS ON THE MANAGEMENT OF TOOTH WEAR

1. Assessment, treatment planning and strategies for the prevention and the passive management of tooth wear
2. Active restorative care 1: the management of localised tooth wear
3. Active restorative care 2: the management of generalised tooth wear
4. **An overview of the restorative techniques and dental materials commonly applied for the management of tooth wear**

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According to Poyser *et al.*¹ the position within the dental arch of each worn tooth and the quantity of remaining tooth tissue will determine the most appropriate form of restoration. While conventional restorations have been used historically, such as conventional cast gold onlays, partial and full veneer crowns or metal-ceramic crowns, with advances in adhesive dentistry a number of other options have become available, including:

- Direct composite resin restorations
- Indirect composite resin restorations
- Cast adhesive alloys (metal palatal veneers and metal adhesive onlays)
- Adhesive ceramic restorations.

These will be considered in more detail below.

Direct composite resin restorations

Composite resin has been used for the restoration of anterior teeth for the past 30 years. The use of resin composite to treat cases of tooth wear was first described by Bevenius *et al.*²

According to Briggs *et al.*³ a rim of enamel is usually present at the gingival margins of severely eroded teeth. The latter, commonly termed the 'gingival ring', as shown by Figure 1, will improve the predictability of bonding hard tissue to resin composites

IN BRIEF

- Provides an overview of the available restorations commonly used for the management of pathological tooth wear.
- Illustrates some of the techniques currently used to restore worn dentitions.
- Stresses the role of contingency planning, as often the quantity and quality of available tooth tissue has already been severely compromised by the process of wear.



Fig. 1 Gingival enamel 'ring', commonly seen among worn teeth, which is vital to the successful outcome of resin-retained/resin bonded restorations

(rather than relying solely on dentine bonding), and concomitantly help to control marginal microleakage. The exact reason for the presence of the gingival ring of enamel is unclear, but the neutralising effect of the presence of gingival crevicular fluid is thought to play an important role. It has also been suggested that the presence of plaque at the gingival margin may act as a barrier to prevent the diffusion of erosive acidic substrates.

Direct composite resin when used in the management of cases of tooth wear offers the advantages of:⁴

- An acceptable aesthetic outcome
- A non-invasive procedure
- May be used as a diagnostic tool
- Well tolerated by pulpal tissues
- Minimally abrasive to antagonistic surfaces

- Being easy to repair and adjust
- Cost-effective material
- Restorations may be applied within a single visit.⁴

The disadvantages of direct resin composite restorations for the above purpose include:⁴

- Polymerisation shrinkage, which may culminate in marginal leakage and staining
- Accelerated wear rate (when compared to metals/ceramics) and possible inadequate wear resistance for posterior use⁵
- Bulk fracture(s)
- Discoloration
- Need for optimal moisture control
- Need for good quality/quantity of dental enamel
- Complexity of application, particularly for palatal veneers. Limited control over occlusal and inter-proximal contours.

Briggs *et al.*³ have described the use of direct composite resin restorations as an intermediate restorative option among cases with tooth wear ('intermediate composite restoration'; ICR). The use of an ICR with complementary routine preventative measures to manage 'at risk sites' (to reduce long term catastrophic damage, particularly where future sporadic bursts of aggressive wear may take place with changes in lifestyle or personal circumstances), has been an advocated approach.³ It has been proposed that an ICR would help to protect vulnerable teeth during the so called 'danger years'.

However, it has also been argued that the placement of intermediate composite resin restorations will undoubtedly commit the patient to long-term restorative maintenance care, which may ultimately culminate in the need for subtractive, conventional indirect restorations.⁶

While a number of different restorative placement techniques have been described in the literature, it is generally accepted that resin composite restorations when applied to areas of high loading should be placed in the thickness range of 1.5-2.0 mm.¹ The techniques for applying this material directly can be considered under three broad categories, hence:

- Freehand application

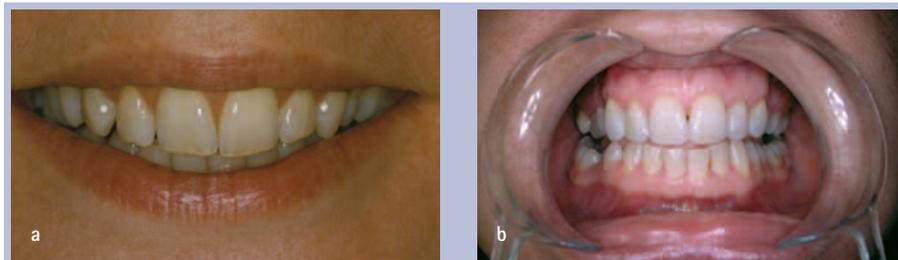


Fig. 2 Clinical case 1. Tooth wear has been restored by the 'freehand' application of resin composite, with zero tooth reduction. a) Pre-operative case of mild attrition that has just started to involve the dentine layer. Intervention advised to prevent further wear, in particular differential wear. b) The post-operative view at 12 years



Fig. 3 Clinical case 2. The direct application of resin composite to treat a case of tooth wear, with the aid of a silicone matrix derived from a diagnostic wax up. Figures show pre-op (a and b), a diagnostic model (c), palatal putty matrix (d), and restored teeth with Gradia Direct (GC) (e and f)

- Use of a customised polyvinylsiloxane (PVS) matrix
- Use of a customised vacuum formed matrix.

The application of direct composite resin 'freehand' has the potential to offer excellent aesthetic results, as shown by clinical case 1, Figure 2.

With the use of the freehand technique restorations may be placed within a single visit, without the need for taking impressions. However, this method of material application is considerably dependent on operator skill (to achieve

aesthetically acceptable and occlusally stable/functional restorations). For cases of anterior maxillary wear, where a re-organised approach is adopted, it has been suggested that composite resin is added initially to the cingular areas of the maxillary canines, and the mandible subsequently manipulated into its retruded arc of closure (before curing). The patient is then guided to close into the uncured resin until the desired space is achieved to place material to restore the remaining anterior teeth.⁷ The remaining teeth are then 'built up' by the incremental application of resin composite using the occlusal stops



Figs 4a-c The use of a transparent silicone index to facilitate the application of resin composite to treat a case of lower anterior tooth wear

ascertained initially as a reference guide. This technique does, however, require the operator to be very familiar with average mesio-distal tooth widths and relative tooth proportions respectively.

The use of a stable, rigid 'polyvinylsiloxane - PVS matrix guide' formed from the palatal or lingual aspect a diagnostic wax up (or a duplicate cast of a wax up), where the desired occlusal prescription and aesthetic form have been established indirectly has the potential for providing excellent results by facilitating the use of an incremental build up technique, which in turn will allow aesthetic layering and the application of increments to permit optimal light polymerisation, as depicted by clinical case 2, Figure 3. The accuracy of the wax up and a well adapted matrix are, however, critical to a successful outcome.

With the advent of clear or transparent silicones such as Memosil (Heraeus Kulzer, Newbury, Bucks, UK), it is possible to ensure that adequate quantities of material are applied onto worn palatal surfaces (without the inclusion of major voids) and subsequently light cured (through the matrix), which is an obvious drawback associated with the use of non-transparent materials. The lack of rigidity offered by available transparent silicones can make the accurate positioning of such indices difficult, which may culminate in the need for copious adjustments. Furthermore, the removal of 'flash' from the material may prove challenging (by virtue of its transparent nature), which will also increase the need for further alteration of the resin composite restorations post light-curing. For further details on how to fabricate and apply a PVS matrix guide the reader is referred to an article by Nixon *et al.* from 2008.⁷ Figure 4 provides an example of a transparent silicone index to treat a case of lower anterior tooth wear by the application of resin composite.



Figs 5a-e The use of a sectioned thermoplastic template where a 'labial window' has been cut away to permit resin application to manage a case of multiple diastemata

The use of a 'vacuum formed matrix guide' has been well described by Daoudi and Radford.⁸ They suggest that a duplicate cast poured in dental stone is formed from a diagnostic wax up, and a vacuum formed transparent matrix is formed in a material of choice. Mizrahi⁹ has advocated that the matrix should be formed from a rigid material (to permit accurate seating) and be of approximately 1 mm in thickness. The matrix should be extended over sound teeth that do not require restoration to provide positioning stops for the matrix to remain in place when resin is applied. Small relief holes can be cut into the matrix to avoid air entrapment.⁸

To avoid bonding of resin material to interproximal surfaces, Daoudi and Radford⁸ have described the interproximal placement of wedge shaped cellulose acetate strips of approximately 4 mm in

length retained by the means of customised wedges trimmed so that they do not interfere with the placement of the matrix. Resin is applied into the matrix (following the appropriate conditioning of the affected teeth for the purposes of adhesive bonding) and firmly seated into place and resin light cured.

The management of interproximal excess, and the inability to apply resin incrementally or indeed in layers, are obvious drawbacks with this approach. Other commonly encountered problems with the use of a vacuum formed guide include:

- Sensitivity that may occur during the curing process due to heat build up
- Poorly fitting matrices
- Overfilling of matrices, which will culminate in gross excess
- Air entrapment.

The use of this method has been suggested to be unsuitable in cases of advanced severe tooth wear.⁸ To overcome the problem of interproximal excess, Daoudi and Radford⁸ have described an approach involving the restoration of alternative teeth or 'every other tooth' to permit the complete establishment of individual tooth anatomy with emphasis on the interproximal areas.

It may also be possible to 'modify' a thermoplastic template to permit the more accurate placement of resin composite to treat cases of anterior tooth wear.⁹ Shown in Figure 5 is a case of diastema closure, attained by resin application. A thermoplastic template has been formed from a duplicate cast of a diagnostic wax up. Following clinical evaluation of the fit of the template, a labial window has been cut away so that resin has been applied to the approximal surfaces, initially just short of the inter-proximal contact area. The contact areas have been formed subsequently, aided by the placement of a Teflon coated dead soft sectional matrix (Garrison Solutions), which provides control of this key area, and avoids the creation of overhanging restorations. The use of the clear thermoplastic template permits light curing from a palatal direction. This approach can be extended to include the management of the worn dentition, where direct resin composite has been prescribed to treat affected surfaces, as described by Mizrahi in 2004.⁹ Please note the omission of rubber dam isolation in this case, as the patient was unable to tolerate the presence of a dam.

An alternative means of applying a vacuum formed matrix to treat cases of tooth wear to overcome some of the problems listed above is shown by clinical case 3, Figure 6 for the management of worn lower anterior teeth. The latter clinical condition is further complicated by the diminutive nature of these teeth and often less than optimal visual access. Figure 6 depicts an example of a 'modified vacuum formed template', whereby warmed resin composite has been injected into a modified (sectioned) matrix. It is a case of a 79-year-old male patient whose presenting complaint related to the poor appearance of his lower anterior dentition and poor aesthetics of his partial dentures. The patient has an FWS of 6 mm. It was decided to adopt a minimally invasive



Figs 6a-j Clinical case 3. Use of a modified vacuum formed template for management of worn lower anterior teeth

approach, whereby the vertical dimension was increased by 3 mm by the addition of direct resin composite (Gradia Direct, GC) to the worn lower anterior teeth (LL1, 2; LR2, 1). A sectioned 0.5 mm thickness thermoplastic template (Acorn Plastic) was used to apply resin composite, formed from a duplicate cast of an accurately prescribed diagnostic wax up, fabricated to provide an even anterior guidance on protrusion and canine guided occlusion during lateral and protrusive mandibular movements. Metal matrix strips of 0.05 mm thickness (Polydentia, Mezzovico, Switzerland) were

placed interproximally through slits cut into the template. Resin was inserted into the template by means of holes cut into the template of a suitable size to accommodate a resin composite ampoule. Composite resin was applied, after being warmed in a composite resin warmer, Ena Heat Micerium, Italy. The worn teeth were restored on an individual basis. PTFE tape was placed interproximally while etching teeth, to prevent resin adhering to undesired areas interproximally. The existing dentures were modified by the application of a light cured composite resin (Revotek, GC) to achieve

stable occlusal contacts, while the definitive dentures were being constructed.

The above technique of 'injection moulding' has the potential to permit the application of resin in incremental layers, whereby a cone of dentine shade could be applied centrally before applying the desired enamel shade of appropriate resin with the template then *in situ*.

Direct composite resin restorations are frequently used as 'medium term restorations' for cases of TSL, often before the application of conventional restorations (especially where there is a need to create space inter-occlusally by controlled tooth movement), hence in a 'diagnostic' manner.³ The use of resin composite for the latter application will help with the design of the correct horizontal and vertical occlusal scheme, thereby simplifying the fabrication of longer term definitive restorations which are often made from more costly materials such as cast gold alloys, as discussed in further detail below.

A number of studies have evaluated the efficacy of resin composite to treat wear of the anterior dentition. A success rate of 86% for labial direct composite veneers was reported over a period of three years by Welbury in 1991.¹⁰ Hemmings *et al.* elucidated a success rate of 90% with direct resin composite restorations placed in maxillary anterior teeth (at an increased vertical dimension), with a mean follow up period of 30 months.¹¹ Similar results have been published by Redman *et al.*¹² and Poyser *et al.*¹ over a similar evaluation periods (two to five years). Interestingly, the study by Poyser *et al.*¹ involved the application of direct resin composite restorations to worn mandibular anterior teeth to increase the anterior occlusal vertical dimension between 0.5 and 5.0 mm.

The study by Hemmings *et al.*¹¹ reported a higher success rate for hybrid resins *versus* microfilled composites, possibly related to a slightly superior rigidity offered by the former variety, making them less vulnerable to flexure and fracture upon tensile loading; the primary cause of failure was bulk fracture.

Data for the prognosis of direct resin composite restorations to manage worn posterior teeth are very limited. Bartlett and Sundaram¹³ reported a relatively poor prognosis of direct composite resin restorations when used to restore worn posterior

occluding surfaces among patients with parafunctional tooth grinding/clenching habits. A failure rate of 28% was determined over an observation period of three years. Failures among posterior teeth may be accounted for by the fact that material is commonly inadvertently applied to certain areas in thin sections, which may fracture, flex, crack or chip.¹ The choice of resin (hybrid *versus* micro-filled) may also be influential to prognostic outcome, as a study by Schmidlin *et al.*¹⁴ has reported a very favourable outcome for the role of direct hybrid composite resin restorations to treat posterior segmental wear over a medium term evaluation period.

It is important to note the conclusions of a long term study which has compared the survival of direct and indirect restorations for the treatment of advanced tooth wear.¹⁵ Over a ten-year assessment period, a survival rate of 62.0% was reported for direct resin bonded composite restorations (RBCs) and 74.5% for indirectly retained restorations respectively. Bulk fracture was noted as the most common mode of failure for RBCs, which were readily addressed conservatively by either repair or replacement, while failures for the indirect category of restorations were generally of a catastrophic nature, frequently involving the complete loss of restorations, which often required subsequent root canal therapy or indeed extraction. Interestingly, a promising survival rate of 78% was described for RBCs placed in the anterior region.

In conclusion, direct resin restorations may serve as acceptable medium term (or intermediate) definitive restorations particularly for the management of anterior tooth wear. However, patients must be advised of the need for potential regular need for polishing, repair and occasional replacement respectively. Their use for the management of worn posterior teeth however requires careful consideration.

The use of glass fibre re-enforced composite resins as described in a case report by Akar and Dundar¹⁶ or the development of composites with better wear resistance and minimal/no shrinkage may hold a future promising potential.

Indirect composite resin restorations

The use of indirect composite resin restorations was first described in the mid-1970s;

however, only in recent times have material formulations been introduced into the marketplace which possess the desired mechanical properties and aesthetic values to provide an alternative to the use of dental ceramics.

Most contemporary indirect composite resin products are based on hybrid resins which offer a superior level of fracture resistance when compared to micro-filled resins. Indirect resin restorations offer two primary advantages over direct counterparts, hence a reduced level of polymerisation shrinkage (as this takes place extra-orally) and the ability to apply further treatment after the initial curing phase.

According to Wendt¹⁷ the hardness and wear resistance of certain composite resins can in theory be further enhanced by dry heating 'post-light curing'. Specifically, the properties of hardness and abrasion resistance could hypothetically be increased by up to 60 to 70% by dry heating at a temperature of 125°C (258°F) for a period of five minutes after first light curing.¹⁷ A slow rate of heating has also been postulated to cause continued or 'extended' polymerisation, culminating in a greater molecular size as well as annealing of polymer chains, which has been suggested to reduce the potential for residual strain formation within the polymer matrix and a concomitantly increased ability to flex with the tissue when an occlusal load is applied (a feature which ceramics do not display, and is indeed thought to account for their increased level of brittleness).¹⁸

Alternative approaches to heat treatment include the application of a slower rate of polymerisation (which has been suggested to improve the potential for a greater level of movement of molecular chains and thereby increase the potential for energising activation sites) and the elimination of internal porosities within the resin matrix (which may occur during conventional light curing).¹⁸ It is thought that oxygen entrapment in the resin may lead to partial polymerisation (due to the well documented 'air inhibition effect'), thus curing can be carried out in a chamber where normal environmental oxygen is exchanged for a non-reactive gas such as nitrogen or argon.¹⁸

However, medium (five years¹⁹) and long term (11 years²⁰) clinical comparison studies

respectively on the performance of indirect composite resins have shown that the clinical performance of indirect resin restorations to not be significantly superior when compared to direct materials (where criteria such as occlusal wear, fracture or secondary caries have been assessed).²⁰ However, the wear resistance on approximal surfaces has been described to be improved by the application of heat treatment.^{21,22}

According to Kilpatrick and Mahoney,⁴ the advantages of indirect composite resin restorations when used in the management of cases of TW include:

- Improved control over occlusal contour and vertical dimension, when compared to direct restorations, particularly in the case of a larger number of multiple restorations
- Perhaps less time involved chairside
- Can be added to and repaired relatively simply intra-orally
- Aesthetically superior to cast metal restorations
- Less abrasive than indirect ceramic restorations
- Superior strength and wear resistance when compared to direct materials
- Polymerisation shrinkage negated intra-orally, other than at the level of the resin luting agent.

The disadvantages include:

- Inferior marginal fit (*versus* metal and ceramic)⁴
- Restorations may be bulky
- Require at least two appointments
- Laboratory costs
- May require the removal of hard tissue undercuts
- Cementation line may require masking with direct materials
- Wear and leakage of the resin based luting agent
- Possible inadequate wear resistance for posterior use.

In 2002, a promising short to medium term success rate of 96% was reported by Gow and Hemmings,²³ where 75 teeth displaying signs of palatal TW had been restored with indirect resin composite palatal veneers (Artglass), over an observation period of two years. Thirteen cases required minor repairs, which were readily achieved intra-orally with the use of direct materials. Many of the latter cases were of



Fig. 7 Clinical case 4. Pre-operative views (a and b); indirect composite palatal veneers made on articulated casts (c) were bonded to upper 321/123 to increase OVD, protect the eroded surface from further wear, reduce the palatal dentine sensitivity, restore the aesthetics (d), provide a 'bonded Lucia jig' effect and encourage mandibular repositioning from CO to CR. These were bonded on and left for four months for the occlusion to stabilise at increased OVD. Posterior contact was formed (though combination of intrusion, extrusion and mandibular repositioning). Lower labial indirect veneers were also fabricated and bonded on. A further four months allowed the occlusion to stabilise (e). Then to complete the aesthetics a labial set of composite veneers were placed (f and g). This case was completed without any tooth reduction, in a completely additive manner.

the variety of 'fixed Dahl appliances'.

A three year retrospective study by Redman *et al.*¹² where 73 cases of localised anterior maxillary tooth wear were treated by the application of Artglass (an indirect ceromer), a very favourable outcome was reported, although a high incidence of minor wear was described to occur on these restorations.

While the application of indirect composite restorations with cuspal coverage on posterior teeth has been reported to be very successful, with an 'excellent level of clinical performance' over an evaluation period of 30 months²⁴ among teeth

not necessarily displaying signs of tooth wear, the results of a study by Bartlett and Sundaram¹³ have provided less promising levels of clinical performance, where indirect cuspal coverage (micro-filled) composite resin restorations were used to treat cases of posterior tooth wear among patients with tooth wear. A failure rate of 21% over an evaluation period of three years was described by the latter group; fracture and complete loss were the most common modes of failure. The authors concluded that the use of resin composites (of either direct or indirect variety) to restore worn posterior teeth should be contraindicated,

according to the results of their randomised clinical study.¹³

An interesting approach is to combine the application of indirect and direct composite resins, as shown by the example of clinical case 4, Figure 7.

Cast adhesive alloys

Traditionally conventionally retained indirect restorations fabricated from cast alloys have been used to restore worn teeth/tooth surfaces where the aesthetic requirements are not of paramount importance. Smales and Bereckally¹⁵ have reported a relatively good long term prognosis for full veneer gold crown restorations when used to manage worn posterior teeth.

With the advent of chemically active resin luting cements containing agents such as 4-META or dimethacrylate (whereby phosphate ester groups are incorporated into the BisGMA resin), such as Superbond (Sun Medical, Kyoto Japan) and the Panavia based cements (Kuraray, Japan) respectively, it has been possible to form a bond between 'cast adhesive restorations' and the dental hard tissues with a high level of predictability. The latter has reduced the need for aggressive tooth preparations, thereby lessening the 'biological damage' inflicted upon already compromised tooth tissue (which would be necessary to attain adequate retention and resistance form to insure longevity with conventional indirect restorations).

Type III gold alloy and alloys based on nickel-chromium (Ni-Cr) are the most commonly used alloys for the fabrication of fixed metallic adhesive restorations, as shown by clinical cases 2 and 3 in paper 1²⁵ and by clinical case 3 above. While Ni-Cr alloys offer improved bond strengths to resin luting agents, and a higher modulus of elasticity (thereby enabling application in thinner sections, in conjunction with more conservative tooth preparation[s] than Type III gold alloys). Type III gold alloys offer easier working properties and superior polish ability (on account of a higher relative value of elongation and lower hardness respectively) and superior wear characteristics.²⁶ Examples of adhesive onlay restorations fabricated from the two materials described above are shown in Figures 8 and 9 respectively.

The addition of beryllium has been described in the literature to improve the

castability Ni-Cr alloys; however, the biological hazard associated with the inhalation of alloy dust containing beryllium generated during the finishing and polishing stages has culminated in a decline in its use. However, concerns remain over the use of Ni-Cr alloys among patients who may display hypersensitivity to nickel.

The advantages of adhesive cast restorations when applied to worn occluding surfaces include:⁴

- They may be fabricated in thin sections (0.5 mm)
- Very accurate, predictable fit attainable
- Minimal wear of antagonistic surfaces
- Protective of residual tooth structure
- Suitable for posterior restorations among parafunctional patients
- Placed supra-gingivally, therefore conducive to good periodontal health, and offer simplification of technique with regards to tooth preparation and impression making
- Minimal tooth preparation required.

Disadvantages include:

- May be cosmetically unacceptable due to the 'shine through' of metallic grey
- Limited use among anterior teeth which display wear of the incisal edge
- Adhesive cast restorations do not offer the ease of repair intra-orally
- There is a need for copious, good quality enamel to create acceptable bond interface
- Close proximal contacts with adjacent teeth among posterior teeth may pose a concern with the application of resin bonded onlay restorations (Yap)²⁷
- Difficulty with the placement of provisional restorations.

The terms 'gold hats' or 'gold bonnets' have been used synonymously with that of posterior adhesive onlays.¹ The preparation of a tooth to receive a metal adhesive onlay should include an occlusal clearance of 1.0-1.5 mm with a minimal chamfer of 0.7-1.0 mm finish line occlusally.^{26,27} Where the restoration is to be fabricated from Ni-Cr alloy, a more conservative preparation can be applied.²⁷

For anterior teeth, the preparation to receive a metal palatal veneer (also termed 'palatal shim(s)') should include the removal of any undercuts and cover all



Fig. 8 This cast gold overlay was used to restore tooth wear on 27 and shows the post-view at 24 years with no debonds over that period.



Fig. 9 An example of a Ni-Cr onlay

remaining peripheral margins and extend up to the incisal edge, so as to optimise adhesive retention, aid placement and improve resistance to shearing loads.²⁶ Margins may be finished with either a knife edge or chamfer finish. The preparation of cingulum rests may also be useful. The internal surfaces of all metallic restoration should be sandblasted with 50 µm alumina (in the case of Type III gold alloy restorations, oxidation must be completed before sandblasting). The inclusion of a metal tag or location lug is also helpful when cementing in metal palatal veneer restorations. The latter may be readily removed with diamond burs and finished with a set of abrasive discs, such as Sof-lex discs (3M, ESPE).

For either form of restoration (veneer or onlay), while an inter-occlusal clearance of between 0.5-1.5 mm is required, this may be attained (as is the case with any other material described in this section) through an ultra-conservative approach, whereby restorations are placed in supra-occlusion, and occlusal contacts established by the process of controlled tooth intrusion and extrusion. With metallic restorations, owing to their high fracture resistance, this can be undertaken with a higher level of confidence. A success rate of 89% for metal palatal veneers was reported by Nohl *et al.*²⁸ where 210 cast

metal palatal veneers and observed over a period of 56 months.

Type III gold restorations do, however, require either heat treatment of the fit surface (this may be carried out at 400°C for four minutes in an air furnace) to form an active oxide layer, or tin plating of the fit surface, to increase the surface energy to enhance bonding with resin cements. The combination of sandblasting and tin plating had been described by Wada²⁹ to maximise resin retention to gold alloys. Tin plating is thought to produce a roughened surface which will not only enable micro-mechanical retention but also chemical adhesion through the formation of hydrogen bonds with tin-oxide. The dulling effect of the metallic restoration also commonly referred to in the literature as 'grey-out' or 'shine through' may be partially masked by the use of opaque resins or by the covering of the labial surface with a tooth-coloured veneer.

Channa *et al.*³⁰ undertook a five-year analysis in 2000 of the clinical performance of gold adhesive onlays to restore posterior occlusal surfaces. A survival rate of 89% was reported. The prime cause of failure was wear of the metal alloy which resulted in cement exposure and subsequent de-bonding. According to Yap,²⁷ resin bonded onlays are most suitable for teeth where at least two walls are left intact (especially if there are no patent interproximal contacts), and more so for teeth where there is a plan to increase the occlusal vertical dimension. Where there may be a cosmetic concern with the display of metal from adhesive onlay, sandblasting intra-orally post-cementation may help to reduce the visible gleam associated with this form of the restoration.

Adhesive ceramic restorations

Ceramic restorations when used in the management of cases of TSL may provide:

- Superior aesthetics (however this is also depends on where the margin is located)
- Good abrasion resistance
- Lower relative surface free energy compared to resin composites, thus less susceptible to staining
- Higher level of gingival tissue tolerance.

However, such restorations are:

- Brittle and prone to fracture unless

applied in bulk, which may necessitate considerable tooth reduction, and be associated potentially with higher failure rates among patients who display signs of wear by parafunctional tooth clenching and grinding habits respectively

- Potentially abrasive to the opposing dentition (particularly in the case of feldspathic porcelains); glazed porcelain has been shown to be 40 times more abrasive to antagonistic surfaces than Type III gold²⁹
- Difficult to repair intra-orally
- Difficult to adjust
- Susceptible to degradation wear in acidic environments
- Costly.

Magne *et al.*³¹ have described an ultra-conservative approach to the management of worn palatal surfaces with the use of occlusal therapy combining centric relation and the use of the Dahl principle (with short term direct composite resin restorations) to create space for palatal ceramic veneers with the need for minimal tooth reduction.

A number of other studies such as Aristidis and Dimitris³² have described a success rate of 90% over a period of five years, for the management of TSL with ceramic restorations.

For the case of ceramic onlays, an interocclusal clearance of 2.0 mm is required. Preparations should be finished occlusally with a shouldered margin. Where a metal substructure is used, ideally the occlusal surface should be fabricated in metal to not only reduce the need for further inter-occlusal clearance but also to provide a less abrasive surface; the application of a metal collar at the margin may also help to reduce the levels of tooth reduction in this critical load bearing area.

Oh *et al.*³³ have suggested that an occlusal splint should be provided for nocturnal use (post-restoration placement) for all wear cases treated with ceramics to protect restorations from parafunctional habits associated which may be associated with premature degradation.

Dentine bonded crowns, as discussed in paper 2,³⁴ may also prove to be useful restorations for the management of wear cases.

In summary, the choice of a particular material and its respective method

of application will depend on a plethora of factors such as the preference of the operator (and patient), the relative skills of the operator, the mechanical demands required of the restorative material and undoubtedly the presence of any financial constraints.

When applied correctly, it would appear that most of the materials listed above provide relatively high (90%) medium term prognostic outcomes (with an evaluation period of approximately five years). Where possible, however, a reversible, adhesive, additive approach should be adopted, as discussed further below.

CONSENT AND CONTINGENCY PLANNING

The importance of gaining informed consent when contemplating the active restorative management of a patient presenting with tooth wear cannot be over-emphasised.

Such cases often require complex, extensive, time consuming and financially expensive treatment regimens. It is vital that the patient understands the eventual restorative outcome, the scope of occlusal changes being planned, the limitation of currently available restorative materials and techniques, as well as the adaptation required to adjust to a new occlusal prescription.

The risks of intolerance and restorative failure by means of restoration fracture, de-bonding, leakage, secondary caries, wear, discoloration and the high maintenance needs should be discussed at the outset. The possibility of initial speech and masticatory difficulty should also be raised, as well as the risks developing TMJ dysfunction and tooth mobility. Where conventional restorations are planned, the further loss of tooth tissue and the risks of pulpal damage or iatrogenic pulp tissue exposure should be explained.

As every practitioner will be aware, all restorations will ultimately fail. Often patients who have parafunctional tooth grinding/clenching habits may resume activity post-restoration. For the case of a worn dentition, where the availability of dental hard tissue is already compromised, treatment plans should where possible be minimally invasive, thus permitting contingency options, should they fail. It

is prudent to provide the restored patient with a post-operative splint, which should be monitored regularly.

Where removable appliances are involved, patients should be made aware of the increased risks of mucosal trauma (particularly in the case of mucosally supported dentures where an increase in the OVD is being planned). Other risks such as base/connector fracture and accelerated occlusal wear should be discussed. Where an overlay denture or overdenture is being considered, it is vital the patient is adequately consented, as these are often complex to construct and associated with poor tolerance in cases of TSL.

SUMMARY

There is no doubt that the prevalence of tooth wear is on the increase. The management of such cases is by no means always a simple matter. The successful management of a patient presenting with signs of pathological tooth wear is dependent on the dental operator having a good knowledge of the principles of occlusion, and the available materials and techniques for restoring such cases with a high level of predictability. Where possible, an adhesive, 'additive' approach is recommended, as the application of conventional restorations may be associated with a high risk of pulp injury and the copious loss of critical tooth tissue.

The importance of consent and contingency planning when providing complex restorative care cannot be over-emphasised.

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