Title: **CAD/CAM techniques for the conservative and efficient management of toothwear**

In Brief:

1) Discusses the benefits that digital dentistry offers for the management of toothwear.

2) Discusses how CAD/CAM techniques can reduce tooth preparation and improve cost-effectiveness.

3) Discusses the available materials for restoring toothwear.

Abstract: The prevalence of toothwear has increased significantly in recent decades. Whilst many treatment approaches are available, there is no consensus on the best materials or techniques. Advances in digital workflows have the potential to reduce the biological cost of treatment, improve treatment outcomes and reduce costs. This article describes CAD/CAM techniques which preserve tooth tissue and improve cost-effectiveness.

Introduction

Over the last decade, the United Kingdom has experienced a significant increase in the prevalence of toothwear.[1,2] Therefore, dentists must be well equipped to manage this condition. Prevention is key but restorative interventions, when indicated, are often complex.

In recent years, restorative techniques have altered towards more conservative treatment approaches. There is currently no consensus regarding the best technique or material for restoring the worn dentition. This is likely to be dependent on many different factors.[3-4] For example, the presence of parafunction may contra-indicate the use of weaker materials such as feldspathic porcelain. A lack of tooth tissue may contra-indicate conventional crowns and favour conservative restoration designs and cementation choices in order to optimise bonding and minimise tissue reduction. Much of the current research is focused on finding the optimal techniques and materials for the management of the worn dentition.

The digital age has revolutionised many aspects of our lives, ranging from entertainment to healthcare. One would hope that technological advances in dentistry will provide both dentists and patients with simpler and more affordable options. This paper aims to review the existing literature surrounding the use of modern CAD/CAM materials in the treatment of toothwear. The clinical application of these materials is outlined, with several cases used to illustrate the techniques involved. There is a particular focus on how a digital workflow can be used to reduce the biological cost of restorations. We discuss design choices and specific milling/cementing techniques which preserve tooth tissue and improve efficiency.

Current approaches to the management of toothwear

The role of direct composites

In the UK, direct composites are a popular method of restoring toothwear.[5-6] Their conservative, additive-only nature makes them an attractive option. In addition, they are repairable, relatively inexpensive, and require minimal laboratory input.[3]

With that said, direct application is time consuming and tiring, particularly for generalised toothwear cases where multiple prolonged visits are required. Manipulation of the composite can be technique sensitive and dependent on the operator's skill. Consequently, many general practitioners are not confident in providing this treatment. This has contributed to an ever-increasing number of referrals to secondary care centres.

In addition, direct composite build-ups require maintenance due to chipping, wearing and staining over time.[4] It will be important to follow-up cases carefully to ensure that wear of the composite does not adversely alter guidance patterns. Despite this, high patient satisfaction has been reported with this treatment approach.[7]

Many still view composite build-ups as a medium-term solution, as there have been few long-term studies.[3] Studies examining medium term survival have reported survival rates between 50% and 95% up to 10 years.[7-10] These studies are limited by small sample sizes and short follow-up.

A recent large scale prospective 8-year evaluation of 1010 composites reported a survival of 93% over a mean follow-up of 33.8 months.[9] The longest follow-up reported 50% survival of 283 composites at seven years.[6] At ten years, 90% experienced a major or minor failure, illustrating the maintenance burden.

Ultimately, whilst direct composites are a suitable treatment option, there are many reasons to consider indirect restorations. Repeated failure, excessive maintenance burden and the skill level required are all factors which may influence the treatment plan. Regardless of the reason, the clinician then has to consider what the best material and preparation design is.

The role of indirect restorations in the management of toothwear

There is a long history of using all ceramic restorations for the management of toothwear. Whilst they may be durable, they have the potential to be highly destructive.[11]

Indirect composites are also a viable option. Short and medium term studies have been favourable, although there is a lack of long-term outcomes. Recent studies with follow-up periods between 2 to 5 years have reported survival rates of 87.2%-97.4%.[12-16] Longer term studies are required to clarify which approaches are most appropriate.

To successfully manage the increasing prevalence of toothwear, simplified solutions are required in order to overcome the limitations of traditional direct and indirect approaches.

The next paradigm shift - What can digital dentistry offer in the management of toothwear?

Major advancements in digital dentistry and material science allow clinicians to develop novel treatment approaches. With the help of technology, time and cost can be decreased. Recently, a European agreement was published advocating an additive adhesive approach.[4] CAD/CAM adhesive restorations satisfy this as they require minimal to no preparation and can be reliably bonded.

Digital scans can be obtained through direct intra-oral scanning or by scanning a conventional cast. Restorations can be designed using software or after scanning a diagnostic wax-up. Software can also accept digital (and analogue) facebows and facial scans. Models can be virtually articulated in both static and dynamic occlusion. More commercial labs are now adopting computer designed wax-ups due to their efficiency in terms of reduced design and fabrication time and reduced running costs. Indeed, it could be argued that the skillset of the modern dental technician is migrating away from traditional methods and towards CAD CAM design. When compared to traditional indirect restorations, these improved efficiencies lend themselves to cost effective production, particularly in cases requiring multiple units. Automatic wax-up proposals are becoming increasingly accurate, reducing the time spent on digital design. Furthermore, as the use of intraoral scanners increases, the availability of, and need for, physical models will reduce. Finally, the manufacturing processes for CAD CAM materials lead to reliable material properties such as lack of voids and a high degree of polymerisation. By contrast, traditional methods can introduce undesirable errors such as contamination within feldspathic porcelain, voids in wax patterns or casting defects.

A meta-analysis of in-vitro studies reported superior marginal and internal fit of digitally manufactured restorations compared to conventional restorations.[17] Several studies have reported good accuracy of intraoral scanners,[18-20] although full-arch conventional impressions may still be more precise.[21] Digital scans can be acquired in several ways. In the cases demonstrated in this paper, conventional impressions and casts were digitised to provide optimal precision over the full arch in line with current best evidence[21-22]. The prostheses were milled, the advantages and disadvantages of which are discussed in table 1.

(Anticipated position of table 1).

A conservative CAD/CAM approach to the management of toothwear

In this paper, we describe a CAD/CAM based approach to conservatively manage toothwear. The principles discussed are demonstrated by three clinical cases (figures 1-26). We highlight specific design choices and cementation techniques. Finally, we discuss the reasoning behind how this approach can improve treatment efficiency whilst reducing biological costs.

Tooth preparation and restoration design:

Traditional all-ceramic and metal-ceramic crowns are associated with over 60% coronal tissue loss.[11] Although the reduction required in the worn dentition would be less, notable preparation is often still needed.

As illustrated by figures 1-6, it is possible to use indirect milled composite restorations without tooth preparation. This is due to milling design, material selection and cementation technique.

We compensate for the lack of margins and the lack of tooth reduction during the stages of restoration design and cementation. The milled restorations may be intentionally overcontoured for several reasons. Firstly, this achieves an adequate thickness for the milling process. It also gives the restorations enough strength to withstand the cementation process. Finally, overcontouring allows us to ignore undercuts, thus preserving valuable tooth tissue. Inevitably, this may result in larger and poorer fitting restorations. Unlike with conventional crowns, this can be simply offset by the choice of cement material. Cementation with a composite resin fills any voids and forms a homogenous unit with the restoration. This is then adjusted to remove any overhangs and create smooth margins.

[Anticipated position of Figures 1-6. Description: With no preparation being carried out, conventional impressions were taken with D-code silicone putty/wash impression material (Coltene Whaledent). D-code silicone has been formulated to have a matt surface when set, making it optimal for scanning. The impressions and casts were scanned along with a wax-up. These were used to create CAD designs (inLab, Dentsply Sirona) and restorations were milled from Crios blocks (Coltene Whaledent) in an MCXL machine (Denstply Sirona). The restorations were sandblasted on the fitting surfaces and cemented with One-coat 7 Universal and Duo-cem (Coltene Whaledent). The occlusion was re-organised with a slight posterior disclusion and posterior re-positioning of the mandible into the retruded arc of closure. The posterior teeth settled back into occlusion within a few weeks.

(Case by P. Nixon)

A crucial component to this technique is cementation with a composite resin. Unlike with traditional crowns, where the cement is a weak point, in this technique the composite cement fills any voids/overhangs that may be present. A key concept to appreciate is that the restoration and the cement form a homogenous unit. This is then easily adjustable, allowing the clinician to manage any overhangs, over contouring or occlusal issues by simply adjusting the restorations.

As illustrated by figures 7-15, minimal preparation can be carried out to create a finish line for the restorations. This preparation makes it easier to define the edge of the restoration for the milling process.

[Anticipated position of Figures 7-20. Description: Minimal preparation was used to create a finish line for each restoration. Conventional impressions were taken using D-code silicone impression material (putty and wash). The impressions and casts were scanned. A wax-up was carried out to increase the occlusal vertical dimension and restore normal dental contours. This was subsequently scanned. The specific CAD design allowed for undercuts in the preparations and overcontoured margins (to ensure correct milling). The final restorations were milled from high translucency Crios blocks (Coltene Whaledent). After polishing, the restorations were sandblasted on the fitting surfaces and cemented with One-coat 7 Universal and Everglow hybrid composite (Coltene Whaledent). A specific technique is required when cementing with composite to ensure correct seating. As illustrated by figures 16-20, the restoration is firmly seated for one minute to encourage the composite to flow out. The excess is then easily removed. The restorations need to be translucent enough for light to penetrate. With this cementation technique the ‘cement’ is a resin composite. As a result, any voids, undercuts or deficient margins are restored with conventional filling material, becoming a cohesive part of the restoration. The clinician then adjusts and polishes it into the desired shape and occlusal configuration.

(Case by P. Nixon)

Material Choices

There are a plethora of materials that can be utilised in a CAD/CAM approach for the management of toothwear. These include ceramics, composites and relatively new materials such as resin-ceramics. Composite resins and resin-ceramics are the materials of choice for this technique for several key reasons.

Resin-ceramics were designed to combine the beneficial properties of ceramics and composites.[23] Traditional ceramics have excellent chemical stability, aesthetics and generally superior mechanical properties. Compared to resins, their flexural modulus, flexural strength and hardness are greater.[24-25] However, ceramics are brittle and repairing them is difficult. Conversely, composites wear faster, lose their polish quicker and generally have inferior mechanical properties.

To overcome the brittle nature of ceramics, hybridisation with a resin successfully increased the material's flexibility.[26] Their elastic modulus is similar to that of both dentine and adhesive cements, allowing for a uniform stress distribution.[26-27] This has resulted in superior fatigue resistance to ceramics.[28-30] This is a particularly important property when managing cases of attrition, where an element of pathological bruxism may still be present.

They have lower hardness values than ceramics, meaning they are less likely to cause pathological wear. It does however also mean that they wear out faster than ceramics.[31-32]

Polishing them is simpler, requiring only regular composite polishing equipment. In contrast, ceramics require specialised equipment, and if left unpolished, are overly abrasive.[33] Furthermore, the milling and polishing processes are simpler than ceramics, with no post-milling stages required except sprue removal and sandblasting (or acid etching).

These materials can be milled thinner than ceramics, with less chipping of the fine edges. This is an important property for our technique, where the lack of preparation may leave the restoration with thin margins.[34-35]

They form a strong adhesive bond to composite, meaning it is easy to make adjustments and additions. This allows clinicians to characterise and repair restorations intra-orally.[36-37] When compared to resins, resin-ceramics have shown a greater degree of resistance to degradation in stimulated oral environments.[36,38]

Cerasmart™ (GC Europe) is a resin-ceramic. It was the choice of material for the case illustrated by figures 21-26 because the uniform nano-filler dispersal aids predictable milling in thin sections while maintaining strength. Cerasmart™ has outperformed several ceramics and resins during in-vitro flexural testing. It was also found to have the smoothest and most accurate post-milling margin. This is likely due to its less brittle nature.[34]

It should be emphasised that because of their relative novelty, there is currently limited data on the clinical performance of resin-ceramics. One would expect this to change as their use increases following the positive findings from in-vitro studies.

[Anticipated position of figures 21-27. Description: Upper incisor and canine build-ups were planned to protect the teeth and restore form and function. Gross approximal undercuts were removed with minimal preparation (figure 23-the central incisors had spacing pre-treatment). No labial or palatal reduction was performed. Silicone impressions were poured and scanned along with a scan of the wax-ups designed to increase the vertical dimension by 3mm in the retruded arc of closure. CAD designs were heavily overcontoured labially to ensure a good mill and to strengthen the material during cementation (figures 24-25). Cerasmart™ (GC Europe) restorations were sandblasted on the fitting surfaces and cemented using Scotchbond Universal Adhesive and Rely-X Ultimate following sandblasting of the fitting surfaces. Labial recontouring and polishing could subsequently take place (not shown).

(Case by A. Keeling)

Key advantages of the proposed technique:

1) More conservative. We propose accepting undercuts and avoiding or minimising margins. This lowers the biological cost and makes the procedure technically simpler.

2) Less concern about margin precision and thickness. The composite cement compensates for this by filling in voids and forming a homogenous unit with the restoration. After cutting back and polishing, the restoration-tooth margin should be imperceptible.

3) Simpler chairside occlusal refinement: Accurate articulation of the models is very difficult to achieve, particularly in cases where the OVD is being altered. Despite the use of best practices, such as the facebow, some occlusal adjustment is likely to be required due to inherent operator variability and technique inaccuracies. Milled composite restorations can be easily adjusted post-cementation. This can save a significant amount of chairside time compared to conventional indirect restorations.

4) Greater clinician control. The final restoration's shape and occlusal surfaces are easily adjusted as desired. In the case of a chairside system, the clinician controls the full design.

5) Reduced costs. Reduced chairside time leads to a cost saving. The blocks from which these prostheses are milled typically cost around £15-20 and design software is improving in its usability (negating the need for physical wax-ups). A large upfront investment is required

for a fully chairside system, but the techniques can equally be applied with no change to the chairside impression technique.

It should be noted that there is a lack of long-term data available to support this technique. Due to rapidly changing technology and materials, it is challenging to conduct long term clinical studies.

Conclusions:

The technique described in this paper demonstrates good aesthetic and functional outcomes, whilst also preserving tooth tissue. Moreover, it has the potential to be much more time-efficient and cost-effective than traditional methods. The attractive features of this technique are its low biological cost and simplicity. Clinicians need not be overly concerned about an accurate preparation, precise restoration fit or even occlusion. As digital dentistry evolves and becomes more widely available, it has the potential to offer clinicians efficient and simplified treatment options for the management of toothwear in general practice.

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