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Biomechanical planning for minimally invasive indirect restorations

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Contents

Introduction

Increasingly, a worldwide consensus exists towards minimally invasive approaches for managing dental caries (1); which for non-cavitated carious lesions often involves non-invasive or micro-invasive management (2). In contrast, no such consensus yet exists for the prescription, design and preparation of indirect restorations. The majority of the half-a-billion dental restorations placed worldwide every year are direct composite-resin restorations (which are more conservative than amalgam restorations), whereas, in contrast, the majority of indirect restorations placed are still full coverage crowns, which are less conservative than biomimetic partial coverage indirect restorations (3).

This suggests that biomechanical preparations which allow for a more conservative biomimetic approach to planning restorations are still not popular when it comes to indirect restorations. Indeed, in the United States 95% of indirect restorations are still full coverage crowns rather than partial coverage indirect restorations (4). Moreover, surveys of UK General Dental Practice reveal that the most commonly used methods for planning and designing tooth preparation are the dimensions of the preparation burs and the form of the opposing/adjacent teeth (5), as opposed to minimally invasive partial coverage designs. This is a missed opportunity, given the technological advances for planning restorative treatments, including the ability for digital planning of minimally invasive endodontic access cavities and digital diagnostic wax ups having potential to be more precise than conventional wax ups.

This paper will review the principles behind biomechanical planning for minimally invasive indirect restorations such as the case shown in Figure 3, and consider the with many different variables influencing their outcome as shown in Figure 1 (6-8). This paper will also explore the planning and executing of indirect partial coverage restorations and will outline practical recommendations for maximizing the outcomes for minimally invasive approaches to indirect restorations, with a special focus on vital teeth, endodontically treated teeth and worn dentitions. Throughout the paper, the supporting

evidence for each rationale for partial coverage restorations will be considered, as well as the risks and benefits of adopting a minimally invasive approach to indirect restorations.

Planning Indirect Restorations in vital teeth, non-vital teeth and worn dentitions.

What does the evidence say on direct vs. indirect restorations for vital teeth?

The most important consideration regarding minimally invasive indirect dentistry is to consider whether to provide a direct restoration as opposed to an indirect restoration. Each clinician reading this article will have developed a personal threshold for provision of indirect restorations. This is based on the clinician's own expertise, personal protocols and practice setting, balanced by the available scientific literature, on one hand, and patient values and expectations, on the other (9). Provision of indirect restorations sacrifices more healthy tooth tissue than direct restorations and moreover full coverage crown restorations require more tooth tissue removal than partial coverage restorations (10).

Online evidence-based syntheses algorithms are emerging to help resolve this dilemma. To date more than 10 systemic reviews with meta-analyses (11-20), provide data from prospective clinical outcome studies looking into indirect restorations which are summarized by online clinical-decision supporting applications, e.g. *'Crown-or-fill©'* www.Crownorfill.com (21). As shown in Figure 2, the *Crown-or-fill* app summarizes the evidence regarding indirect or direct restoration of teeth, depending on specific pre-existing factors (i.e. location of tooth in dentition, pulpal status, amount of coronal tooth tissue remaining and quality of pre-existing root canal treatment). The algorithm includes the fixed

prosthodontic replacement options in terms of bridges and implant supported restorations, which is particularly helpful for discussions of all possible options with patients.

Once the clinical features are entered, prospective outcome data is presented (5-year % failure rate) for each restorative option, in terms of either direct (amalgam / composite resin) or indirect (crown) restoration (with or without a post for non-vital teeth), as well as the fixed prosthodontic replacement options (implant crown /bridge). There is no doubt that this type of evidence synthesis will increasingly guide the decision-making process, when considering whether to directly restore, crown, root fill or extract and replace. This will help consent and communication with patients and potentially save clinicians time and money whilst improving patient outcomes. The main key benefits for dentists using the algorithm are listed in

Table 1 Key benefits to dentists for using the Crown-of-Fill Evidence Based Algorithm

Decision making Topic	Options appraisal	Strengths	Limitations
Direct or indirect restoration?	Crown vs. direct restoration? If direct restoration; amalgam vs. composite?	Especially helpful given number of dentine walls available and location of tooth in dental arch. Can be combined with measurements taken from a restorability assessment or intra-oral scan of tooth with restorations removed	Doesn't explicitly mention the ferrule effect Doesn't take into consideration of periodontal health
Core with or without a	Core plus post?	Very useful to help	Doesn't consider

post?		justify added time and expense of post placement	indirect vs/ direct posts or other factors (e..g cement, which root etc.)
Extraction and replacement vs. restoration	Whether to endo treat or extract? Whether to replace with a bridge or dental Implant?	Ensures that patients are aware of annual failure rates especially when a tooth is heavily broken down and requires endo plus crown. Helps consider whether an implant/bridge maybe more cost-effective than a endo/crown	Doesn't' factor in costs and cost-effectiveness, would be good to be able to input financial aspects of care. Doesn't factor in risk factors for development of peri-implantitis.

However, one of the key drawbacks of this application for general dental practice is that although this provides highly standardized data, there are many modifying dentist and patient factors (e.g. case selection, bruxism and caries risk) have a major influence on restoration survival. In addition, the above evidence doesn't discriminate between choice of material or restoration design (partial or full coverage). Factors such as practice setting, patient cohort, renumeration arrangements and clinicians' experience, also make generalisation about indirect restoration outcomes very difficult and therefore we must consider practice-based data which is more applicable to the general dental practitioner (22, 23).

Full vs. Partial coverage restorations long term outcome data in general dental practice

Many readers of this series on minimally invasive (MI) dentistry may already have a preference towards more MI adhesive strategies for teeth that were previously deemed as requiring full coverage crowns. However, full coverage crowns remain a popular choice amongst dentists, with long term practice-based outcome data supporting their use.

Outcome data from single operators, caring for highly motivated cohorts of patients, have 5 decades of follow-up data of indirect restorations following traditional principles. These data reveal that, in patients with regular recall intervals, including strict control of oral hygiene and meticulous occlusal management, the mean survival of metal-ceramic crowns can be up to 47.53 years in a general practice cohort (24) and 25-year survival of 85.40% for a cohort of tooth wear cases in a specialist prosthodontic practice (25). Whilst not generalizable to all UK General Dental Practices, it does reinforce that experienced operators and case selection play an important role in survival of restorations.

Minimally Invasive Restoration of Vital Teeth – why shift towards partial coverage indirect restorations for vital teeth?

In the last few decades, 3 major drivers are changing clinician's attitudes towards design of indirect restorations, away from full coverage conventional mechanical preparations and towards provision of indirect tooth colored restorations for vital teeth.

Firstly, indirect restorative dentistry is benefitting from the adhesive bonding protocols pioneered in direct adhesive dentistry, whilst also benefitting from more aesthetic translucent etchable/sandblasted/silanated indirect materials. This is allowing a profound shift away from mechanical preparation designs (26) towards adhesive approaches focusing on preservation of enamel and dentine (27).

The second major shift is adoption of biomimetic additive approaches, which refers to the use of digital or analogue wax-ups. The use of digital wax ups have evolved from simple additive approaches based on digital smile design and intra-oral try-in to more extensive full-arch restorative cases as shown in , where digital superimposition of a subtractive wax up is used to guide tooth structure removal. This allows for a more precise plan of different preparations for each specific surface of each individual tooth based on the final proposed contour rather than a standardized tooth removal for all teeth.

Finally, the third profound transformation driving partial coverage indirect restorations is the use of digital dentistry and both additive and subtractive in-surgery computer aided manufacturing, as shown in Figure 3.

However, whilst these technological advances have brought benefits, the introduction of novel hybrid ceramic-polymer materials also has brought some challenges. Early practice-based data shows clinically concerning outcomes in certain situations, namely premature de-bonding or terminal fracture of the material when used as a full coverage crown in load bearing situations. Indeed some practice-based data is finding almost a third of novel ceramic-polymer hybrid restorations experienced debonding after 1 year and a quarter novel non-crystallized lithium disilicate restorations experienced terminal fracture after 1 year, indeed the same data showed almost 60% of Zirconia crowns causing greater than expected wear of the opposing dentition after 1 year (28). This clinically concerning data led to some manufactures withdrawing indications for their novel ceramic-polymer hybrid materials as a full coverage crown (29). The poor performance of these materials as full coverage restorations is thought to be due to the hoop stress concentration at the occlusal/axial transition when used as a conventional full coverage crown, as highlighted by Finite Element Analysis which resulted in the fracture at the transition from occlusal to axial (30). Therefore, these practice-based data of novel indirect materials show clinically concerning results –So, where does this leave us? Should we be changing our preparation

design away from full coverage restorations and towards partial coverage tooth-coloured materials and if so how to maximize the success of these restorations?

Preservation of tooth structure has always been the first key principle of all indirect restorations and there have been several recent major changes which are increasing the predictability of minimally invasive indirect restorations. When the survival of partial coverage ceramic restorations is considered, the largest practice based research data is the Ceramic Survival Analysis (CSA) project (mostly Germany and US). Analysis of 5791 ceramic inlay or onlays in 5523 patients shows that inlays and onlays constructed from many glass ceramic materials (mostly lithium disilicate) have good outcomes for a large number of dentists (167) working in different settings over two decades (22). The CSA reported annual failure rates (AFR) of 1.6 % at 10 years regardless of type of glass ceramic and or whether CAD/CAM or pressed techniques. However, perhaps predictably, restorations with a deep marginal extension into dentine showed an increased failure rate of 78 % compared to restorations in enamel. Unsurprisingly, use of glass-ionomer cement as a core material and use of simplified adhesive protocols (single or dual step dentine bonding agents) also presented a 142 % increased risk of failure as opposed to gold standard 3-step etch/prime/bond protocols.

Therefore any clinician considering a change to their clinical practice, such as adopting a novel CAD/CAM material with a minimally invasive approach, is encouraged to enroll onto the open-source CSA (www.csa-online.net) and enter as a minimum, data on their first 50 consecutive cases using the new material, with full details of their entire protocol. On subsequent review of every case, clinicians determine as soon as possible they are experiencing any issues with their cases, which may require modification of case selection, preparation design or bonding protocol for example.

Minimally Invasive Restoration of the Endodontically treated teeth

Root canal treatment is needed when pulpal health is irreversibly damaged by caries, cracks, restorations and trauma. Timely restoration back to form, function and aesthetics is as important as the quality of the root canal treatment, in order to protect endodontically treated teeth from future fracture or loss of coronal seal and re-infection (ETT). (15, 31). Many clinical studies are now available to support cuspal coverage of ETT in order to improve outcomes for ETT.

Even prior to the restoration, a key aim during endodontic treatment is the preservation of tooth structure with multiple prospective clinical studies correlating increased tooth structure with improved outcomes (32). Provision of cuspal coverage for ETT has specific benefits for premolars and molars, with a non-functional cusp sparing approach advocated to preserve tooth tissue, as opposed to full coverage crowns (4). However, this approach, whilst showing promise in finite element analyses (33), has not been widely adopted. It is also perhaps surprising that more clinical research has not been carried out towards direct cuspal coverage restoration of ETT, even when extensively broken down (34).

In terms of which cusps to cover, as shown in Figure 4, a key parameter to consider is the thickness of the remaining dentine walls. Krifka et al (2009) investigated the influence of remaining cusp wall thickness on the marginal integrity and enamel crack formation and concluded that if non fuctional cusps are to be left uncovered they should be of at least 2 mm thickness (35). As shown in Figure 4, this measurement maybe carried out simply using Iwanson calipers or alternatively by scanning the remaining tooth structure once all the old restorations and caries has been removed and using cross sectional measurement tools provided within chairside CAD/CAM software.

Minimally Invasive Restoration of Erosive Tooth Wear

Clearly, when managing a disease process which involves gradual loss of hard tooth tissue, a minimally invasive approach aimed at preservation of tooth tissue is required. In the first instance, a thorough diagnostic phase is required to ascertain whether indeed a non-operative strategy can be employed, in order to avoid restorations (36). Once it has been decided to provide restorations, initial prescription of direct adhesive restorations, in addition with other minimally invasive methods such as tooth whitening is the recommended course of action, especially for mild erosive tooth wear cases where most of the enamel has been retained.

However, the long-term outcome of minimally invasive direct restorations for patients with moderate to severe tooth wear with extensive dentine exposure coupled with reduced surface area for bonding and parafunctional habits is uncertain and reported annual failure rates vary widely (37), from 0.4-26.3% for direct resin composite, 0-14.9% for indirect resin composite and 2.7% for indirect ceramic restorations.

This leads to the conclusion that choice of a direct or indirect approach is largely operator and patient dependent, therefore it seems sensible to try to avoid indirect restorations until direct restorations have been tried (38). Recent prospective clinical trials of direct restorations for tooth wear have found that a key factor influencing success of anterior composite restorations for tooth wear cases is ensuring that the anterior restorations are provided at a single visit, thus maximizing control of both the adhesive bonding to a fresh substrate and also provision of an appropriate occlusal scheme (39).

For cases whose tooth wear is primarily of an erosive component, such as the case highlighted in Figure 5 who presented with amelogenesis imperfecta, hypodontia and erosive tooth wear primarily related to acid erosion, partial coverage ceramic or resin restorations are likely to have a good prognosis and be the first choice of restorative treatment. However for cases with parafunctional bruxism, whose tooth wear is so severe that all the enamel has been lost for adhesive bonding, full coverage conventional

crowns provided with traditional retention and resistance form are the more appropriate treatment choice.

Conclusion

This paper has considered the benefits of adopting a minimally invasive approach when considering the design and execution of indirect restorations. Although we are now in an era whereby prescription of high-gold content partial coverage restorations are declining, new technologies using to preserve tooth structure are arising due to increased availability of bondable aesthetic indirect materials and modern imaging and CAD/CAM for a more bespoke approach to cuspal coverage restorations.

However, more research is needed for long term prospective clinical trials of these novel materials to ensure that clinicians are aware of the correct case selection, design and bonding protocols so that patient outcomes are optimized.

Figures and tables

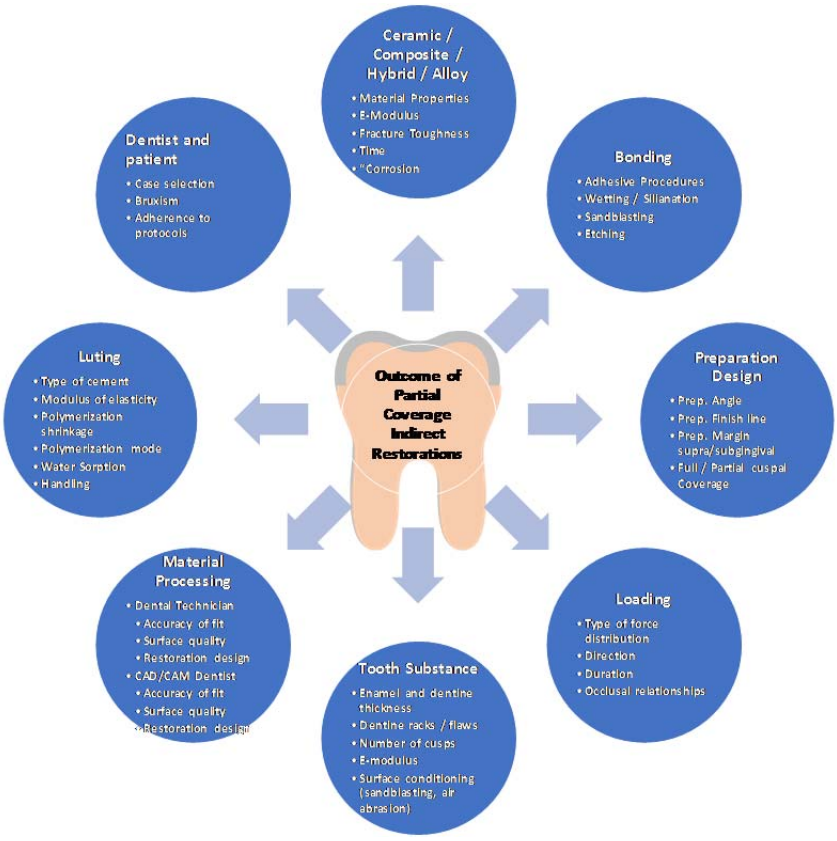

Figure 1 Variables which influence the outcome of partial coverage indirect restorations

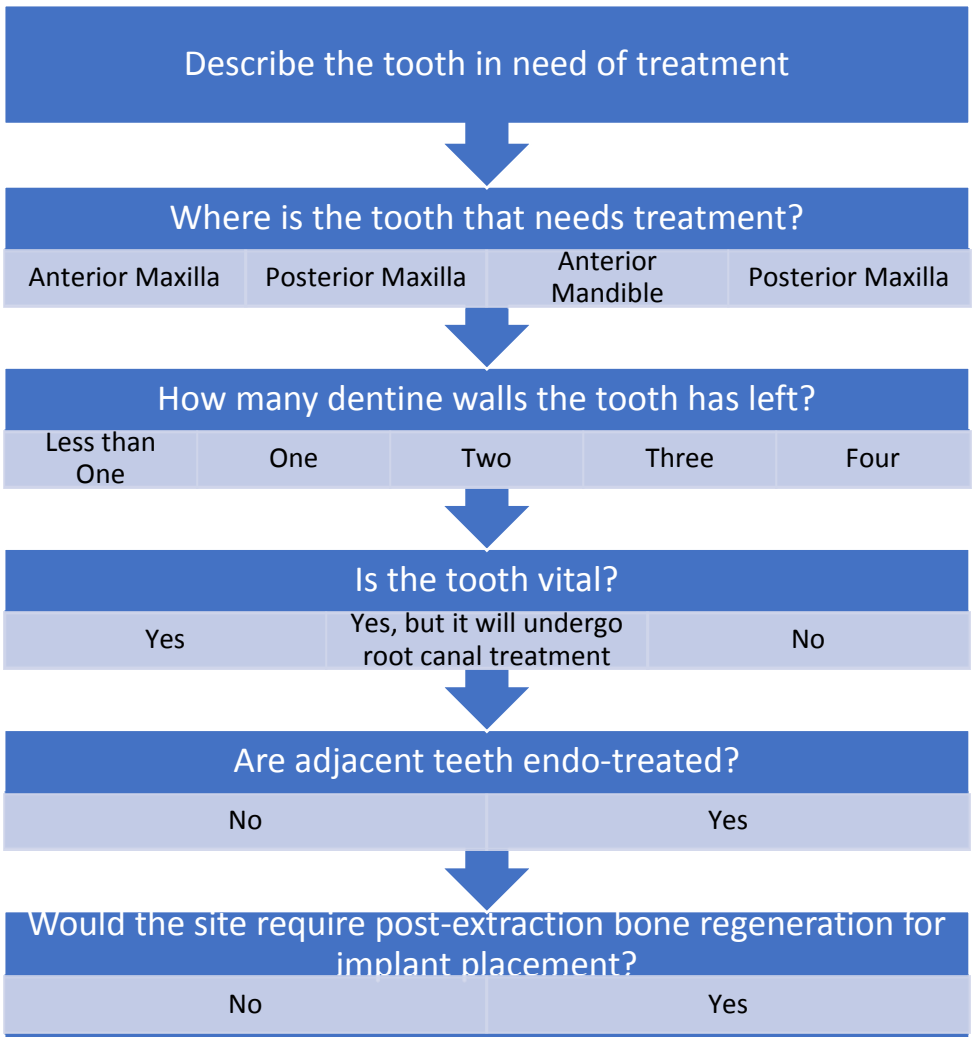

Figure 2 Algorithm for case selection – reproduced from www.crownorfill.com (21)


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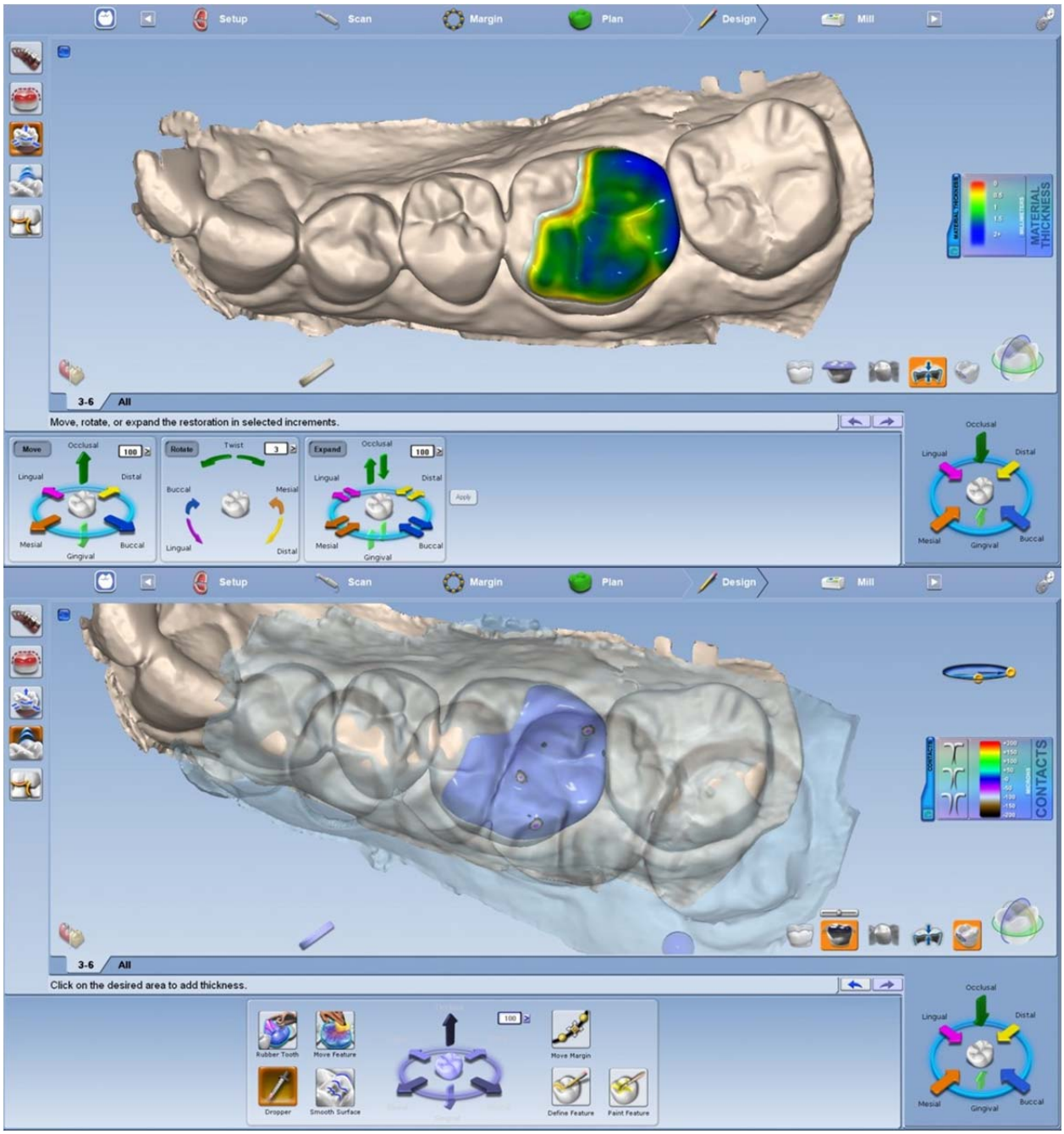
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Move, rotate, or expand the restoration in selected increments.
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Expand
Occlusal
Lingual
Distal
Mesial
Buccal
Gingival
Twist
Apply
Setup
Scan
Margin
Plan
Design
Mill
CONTACTS
3-6
All
Click on the desired area to add thickness.
Rubber Tooth
Move Feature
Dropper
Smooth Surface
Move Margin
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Paint Feature
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Lingual
Distal
Mesial
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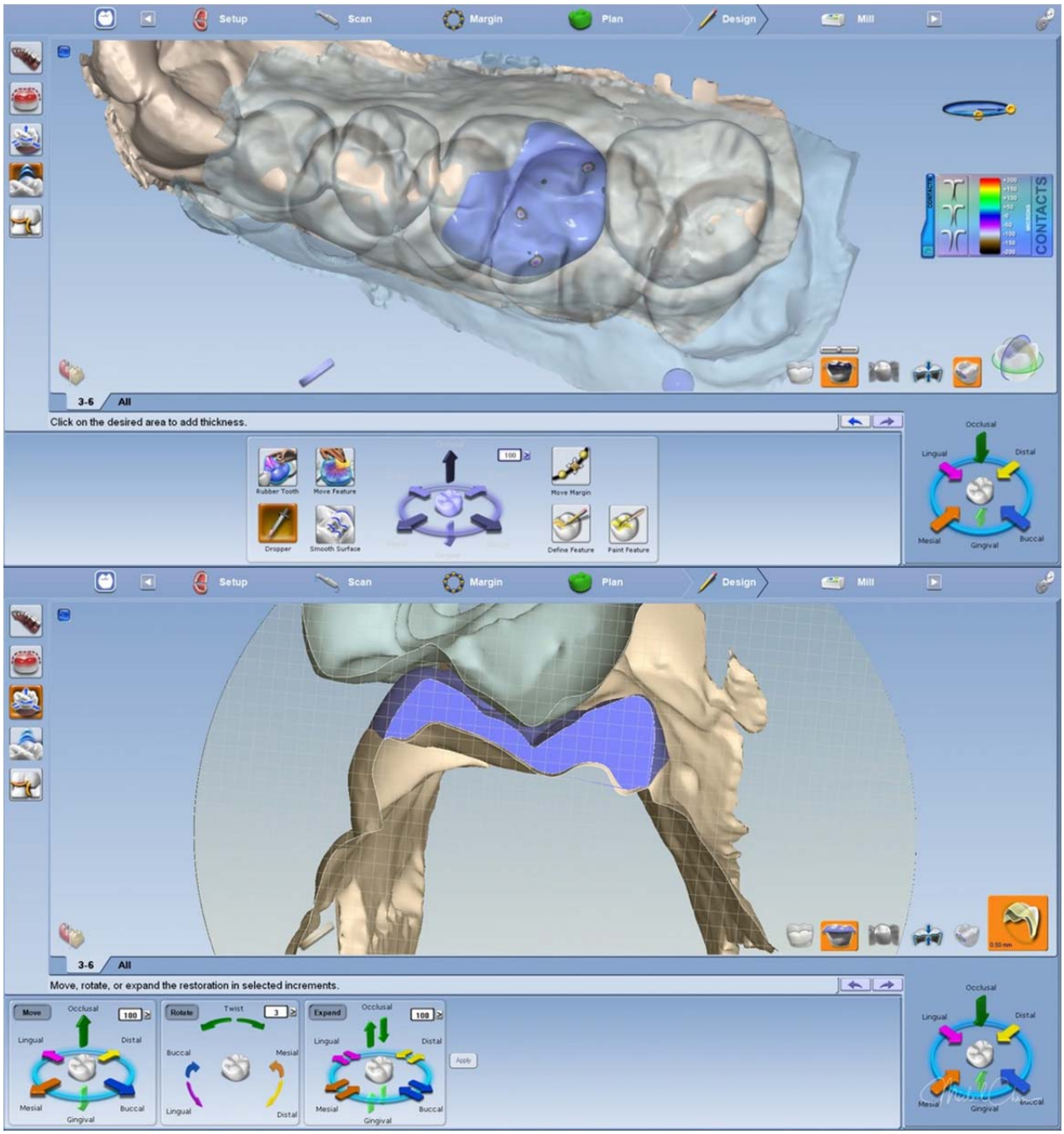
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Move Margin
Define Feature
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Gingival
Buccal
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Design
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3-6
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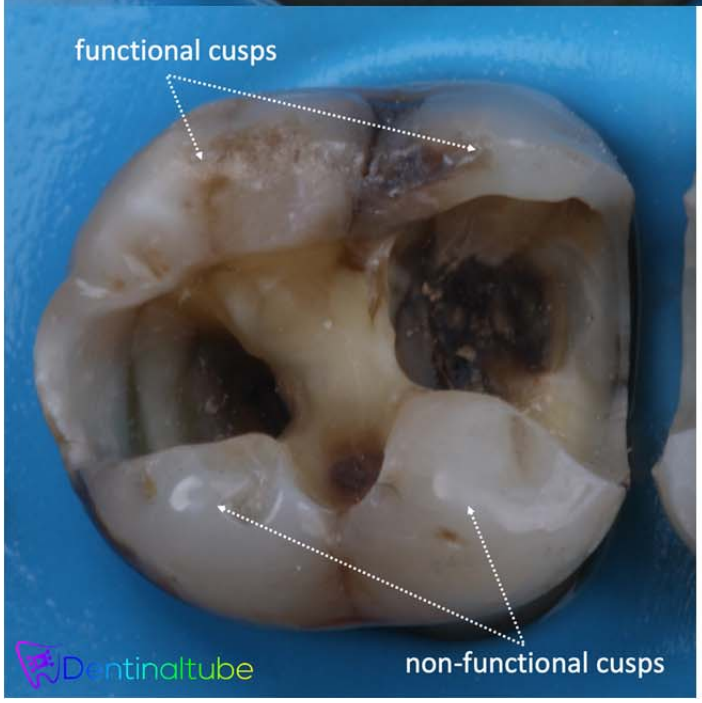
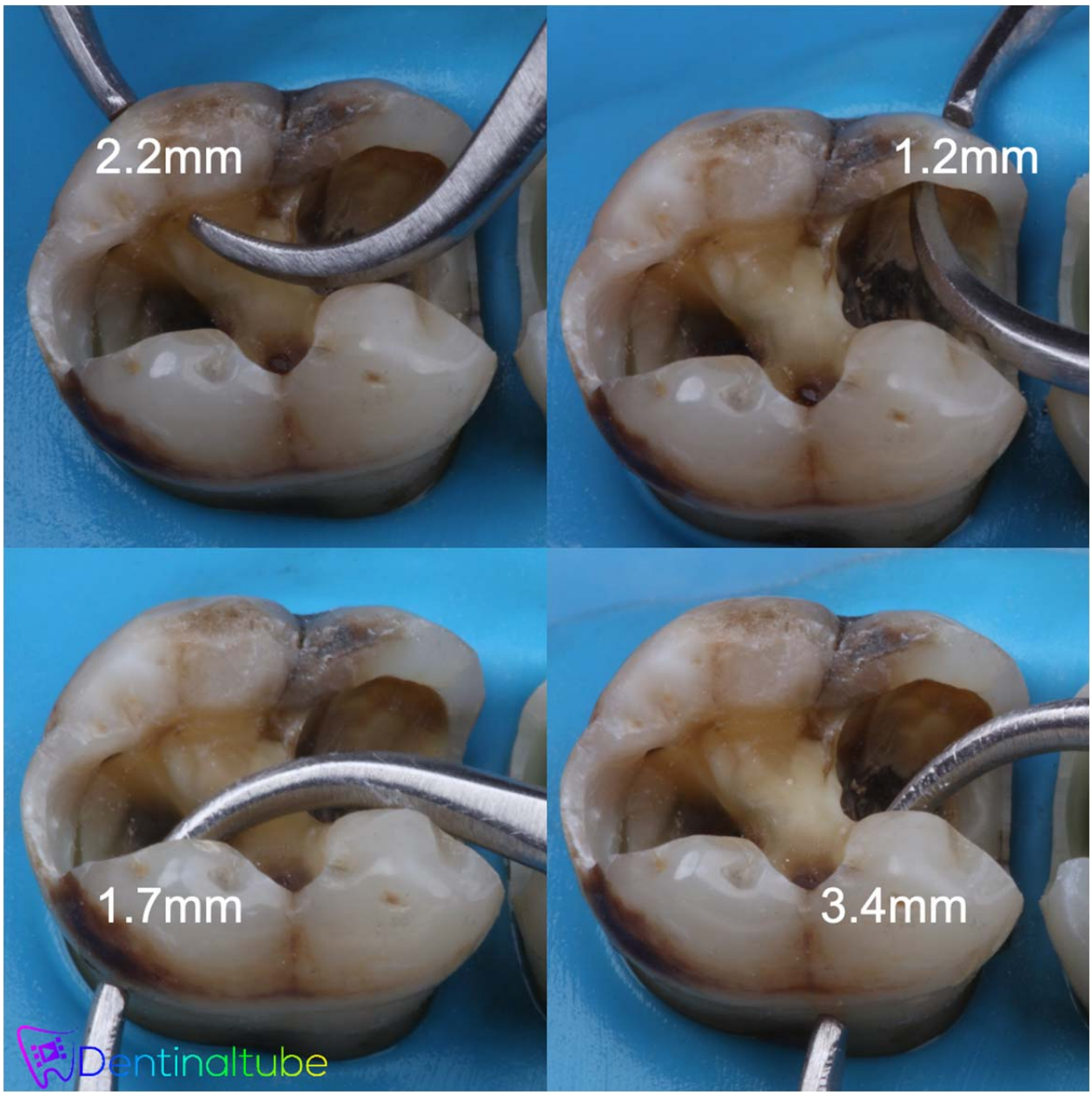
Move, rotate, or expand the restoration in selected increments.
Move
Rotate
Twist
Expand
Apply
Occlusal
Lingual
Distal
Mesial
Gingival
Buccal

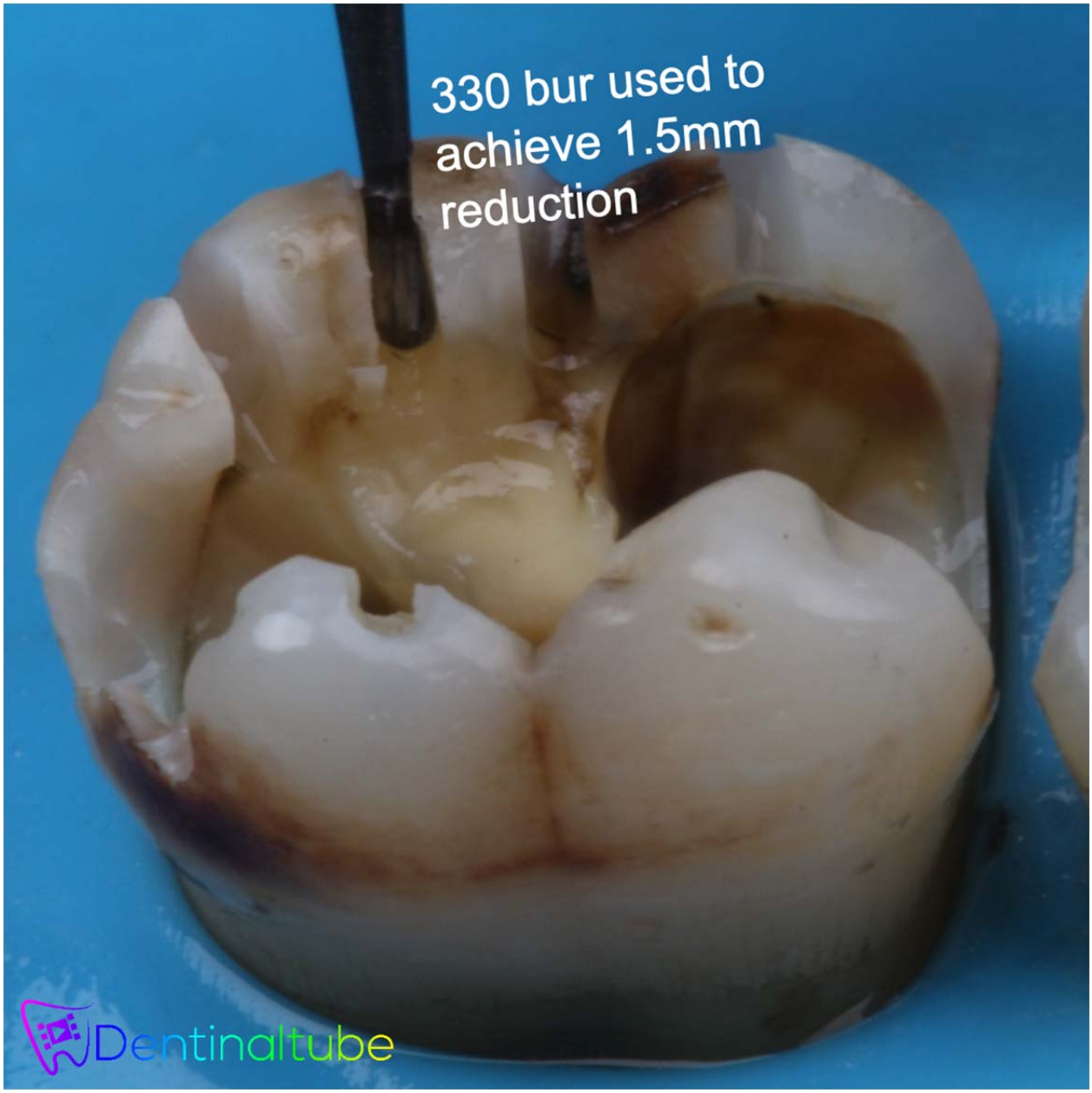
Figure 3 Case showing the benefits of a minimally invasive approach to indirect restorations.

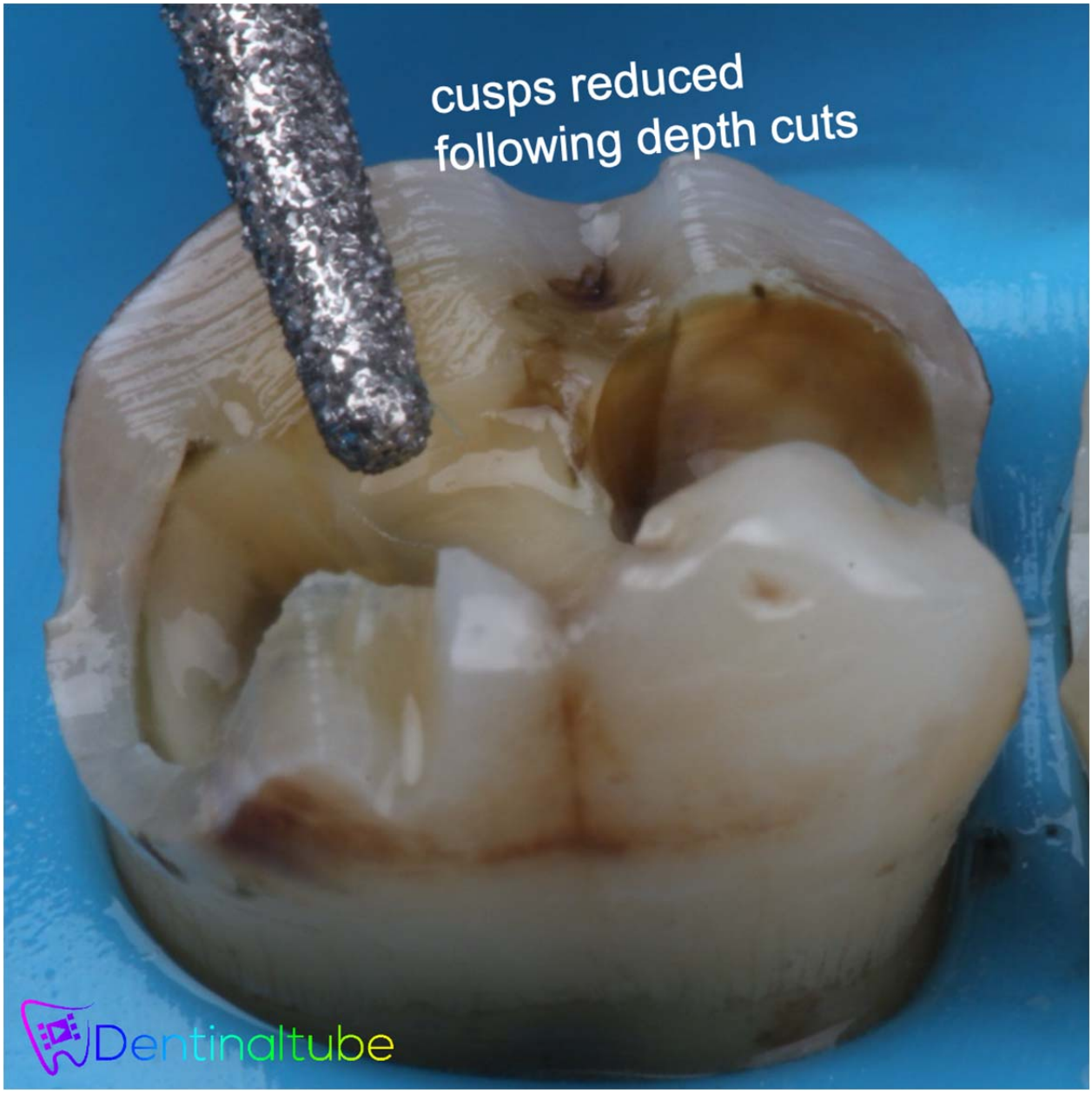
Figure 4 Step-by-step process for decision making regarding which cusps to cover, according to thickness of residual cusps. 'Courtesy of Dr. Nathaniel Lawson'

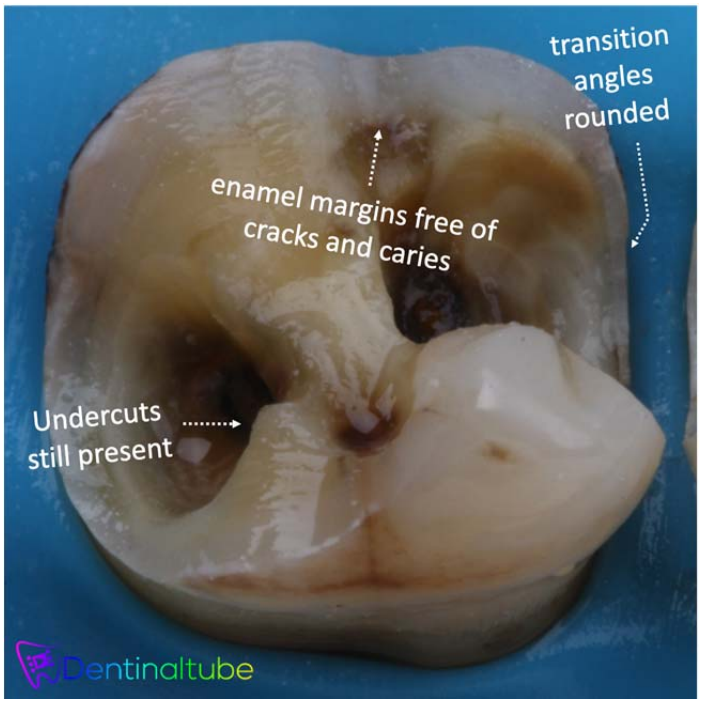

Dentinaltube


functional cusps
Dentinaltube
non-functional cusps

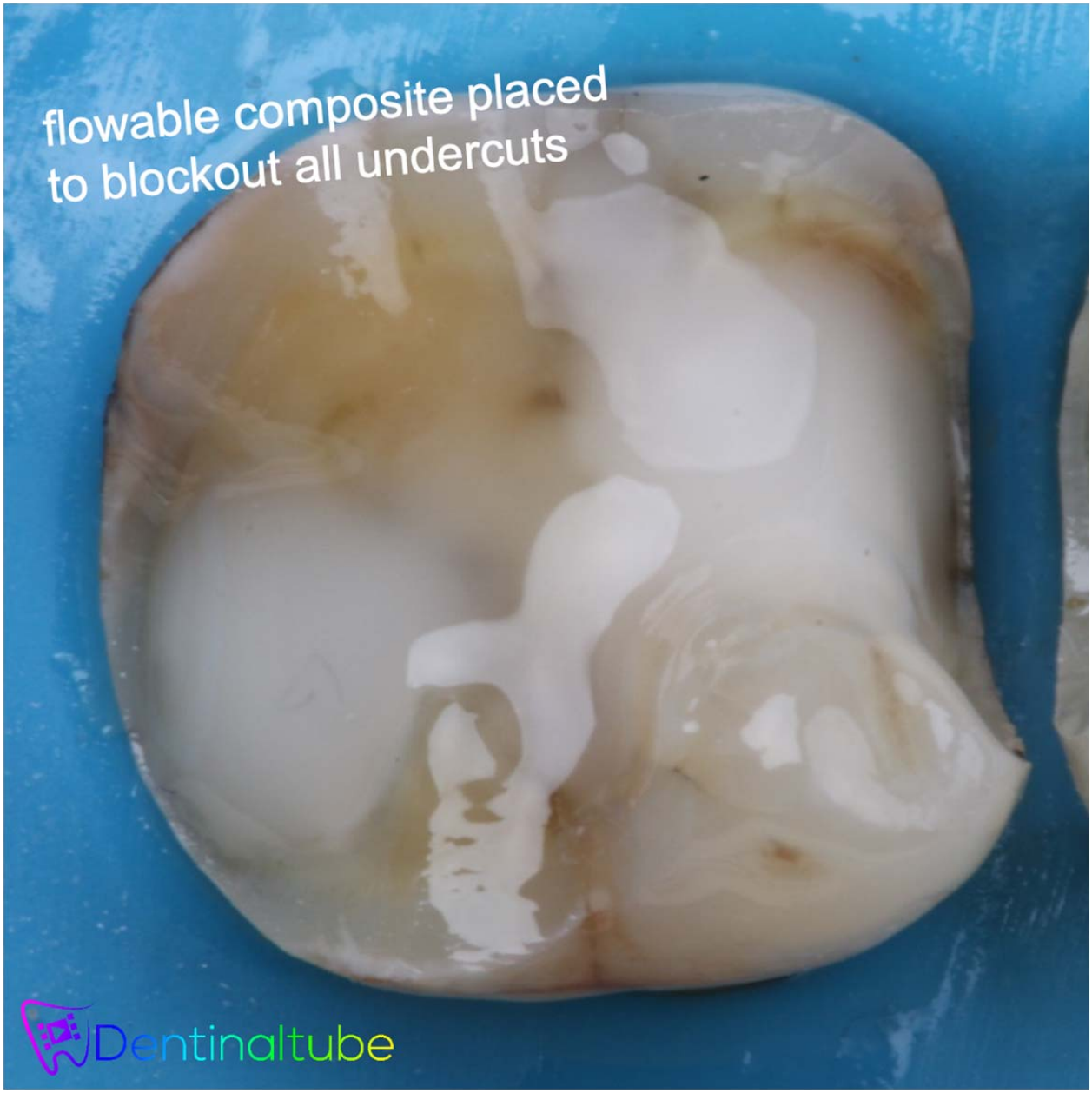

2.2mm
1.2mm
1.7mm
3.4mm
Dentinaltube


330 bur used to achieve 1.5mm reduction
Dentinaltube


cusps reduced
following depth cuts
Dentinaltube


transition angles rounded
enamel margins free of cracks and caries
Undercuts still present
Dentinaltube


bonding agent applied to
all freshly cut enamel &
dentin
Dentinaltube


flowable composite placed
to blockout all undercuts
Dentinaltube


outline form
Enamel
margins
cleaned
Dentinaltube


would
you keep
this cusp?
Dentinaltube

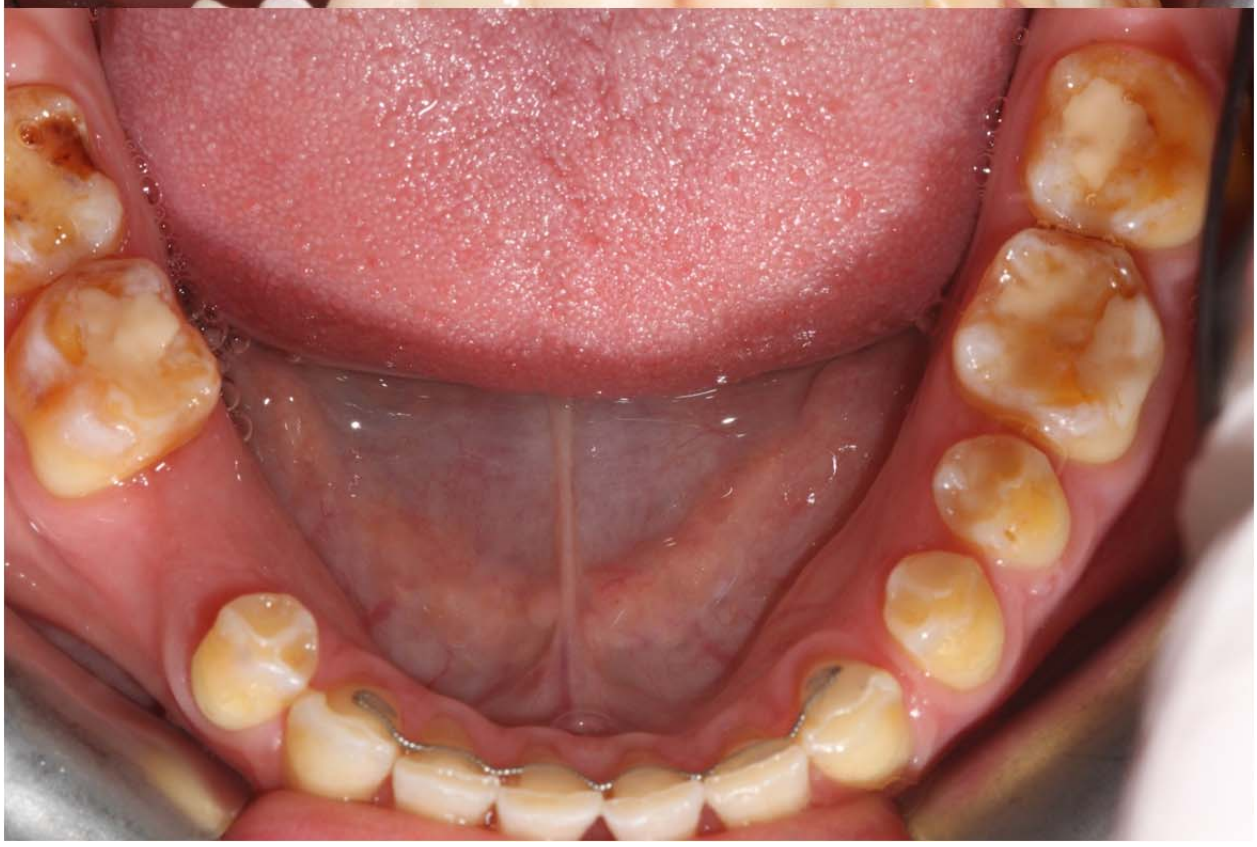


Figure 5 A case of amelogenesis imperfecta, hypodontia and erosive tooth wear of primarily erosive nature, treated with anterior direct composite resin restorations, posterior partial coverage lithium disilicate restorations and single unit implant supported crowns.

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