Design Principles For Class II Preparations

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This article follows a previous article, published in Oral Health Journal, December 2011, concerning preparation and instrumentation for Class V and Incisal Attrition restorations.

INTRODUCTION

A sound restoration cannot begin with a flawed preparation. Amalgam preparations reached consensus more than a century ago. However, after 30 years, posterior composite preparations have not been formulated into a definitive textbook. No one method is accepted by university circles, dental communities, or the majority of the profession. Without consensus on fundamentals, how can a standard of care be defined or measured?

Studies of posterior composite longevity show variable results. Some indicate only a 7 year life span for Class II composite resin restorations.[1–3] Others show annual failure rates of 1 to 3 percent.[4,5] Some studies correlate success with number of surfaces.[2] While some branches of the profession claim near-epidemic premature failure in Class II composite restorations, some studies show better survival rates for resins than amalgam.[6] The variability of findings suggest that technique variation is responsible for disparities in outcome.

Preparation design is seldom detailed in these studies, yet it is describable, measurable, amenable to scientific exploration, and simple enough to develop consensus. This article explores the clinical and scientific evidence for preparation axioms for simple to extensive Class II direct composites. These concepts and methods have been developed by the writer for study clubs mentored in British Columbia since 2004.

The goal of this article is to foster professional debate to potentially resolve current points of dispute.

ENAMEL AND DENTIN AXIOMS

All our data on enamel adhesion is laboratory-based on fresh cut facial bovine enamel. To achieve the megapascals promised by these tests, we need to duplicate these conditions clinically. Five enamel axioms, if applied, create optimum enamel adhesion (Fig 1). Similarly, five dentin axioms drive preparation internal form (Fig 2). These axioms and resulting methods unify clinical, histological, and adhesive driving forces, and require us to modify and supplement the GV Black cavity design. Successfully applied, properly matrixed, well-cured, with correct materials, a long-lasting restoration of almost any size can be delivered.

ENAMEL AXIOM #1: ALWAYS FRESH CUT ENAMEL

Optimum rod-end enamel etching increases surface area ten to 20 fold and penetrates up to 20 microns. Stable, cohesive adhesion grips rod-ends. The surface of mature teeth is an amorphous layer of highly fluoridated, remineralized enamel averaging 10 microns in thickness, as seen in Fig 3. This layer resists etching, particularly in populations where fluoridated toothpaste is commonly used.

It is important, but perhaps less widely understood, that the outer layer of remineralized enamel crystals lack rod structure. Being generated from salivary constituents, this layer is disorganized and not cohesive with underlying enamel rods. When bonded to remineralized enamel, the restoration disconnects from deeper rod-ends. "Prep-less restorations", where enamel is untouched by the operator, are hence categorically inferior in retention and seal not just due to the lack of penetration into this etch-resistance enamel, but also due to underlying structural disconnection from the cohesive rod structure of the tooth. Preserving ten microns of tooth structure in the name of conservatism is a misplaced and erroneous design. True conservatism revolves around restoration lifespan, and the desire to avoid premature re-treatment.

ENAMEL AXIOMS
1. Always fresh cut
2. Always rod ends
3. Always a bevel
4. Thickness for wear
5. Thickness for contraction

FIGURE 1

DENTIN AXIOMS
1. Always fresh cut
2. Rounded internal form
3. Consistent depth for esthetics
4. Sufficient depth for loads
5. Form to spare the bond

FIGURE 2

FIGURE 3—Amorphous enamel overlying rods.
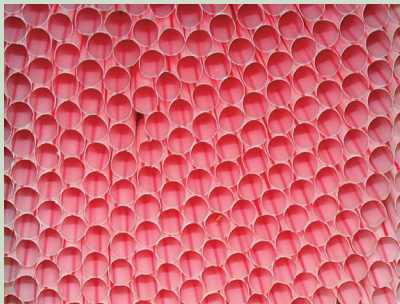
FIGURE 4—Schematic of rod ends on an enamel surface.

FIGURE 5—A rod-end facial surface.
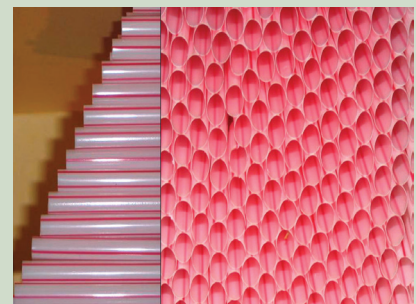
FIGURE 6—Schematic of a bevel.

Therefore this outer layer should be removed by either light air abrasion, rotary carbides (not diamond burs),[7] or ultrasonic instrumentation during preparation. Operator preference, morphology, and clinical contingencies guide the choice. All are effective in removing this 10 micron layer of amorphous enamel.

ENAMEL AXIOM #2: ALWAYS BOND ROD-ENDS

The natural resistance of the sides of the rod sheath (rod side) to acid dissolution by virtue of the arrangement of the hydroxyapatite crystal lattice is nature's way of limiting lateral spread of caries. Resin technique must adapt to this biological given.

According to Munichika et al,[8] "When the transverse section or face of the crystal, rather than its side, is exposed to acid, the central core of the crystal is most susceptible to acid dissolution.

Resin bond strengths are twice as high when adhering to the acid-etched ends of the crystals as compared to the sides of the crystals". Therefore, the most tenacious adhesion will be achieved when the enamel surface presents rod ends intrinsically (Fig. 4, Fig 5) or when the rod ends are exposed by a bevel (Fig 6).

ENAMEL AXIOM #3: ALWAYS A BEVEL

Bevel options are represented schematically in Fig 7. Besides increasing adhesion, bevels also decrease microleakage.[9]

In the G.V. Black (GVB) amalgam Class I and II technique, occlusal margins in preparations are intrinsically obliquely transected, namely bevelled, because occlusal anatomy itself is inclined. This generates an automatic enamel bevel in the occlusal preparation. But the proximal box walls feature butt margins that are 90 degrees to the cavosurface.

Relative to this axiom, the occlusal portion is correct, but the box is not.

Therefore, while occlusal portions might deliver a full 30MPa with a high-performance adhesive, only 15 MPa will be expected in the proximal box. This weak link jeopardizes the restoration because 15MPa approaches the threshold for de-bond under contraction forces.

To compound the issue, many popular adhesives, both etch-and-rinse or self-etch, deliver less than 30 MPa to enamel, the range being from 17.4 to 32.8.[10,11] Adhesion in the box can be expected to be half of these figures, therefore dangerously low.

In a GVB box, the enamel on the gingival floor inclines apically, following the orientation of enamel rods as they approach the CEJ. Cold steel margin trimmers
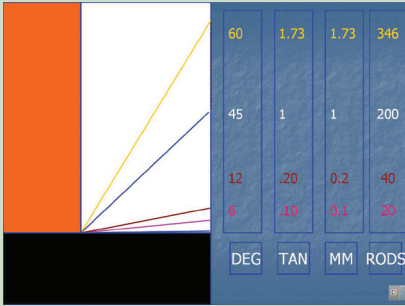
FIGURE 7—Bevels and respective tangents, cavosurface footprint and rods consumed.

FIGURE 8—Enamel "peel". Red = side-bonded rods cohesively separating.

FIGURE 9—Clinical appearance of adhesive separation or cohesive "peel".

FIGURE 10—Typical stress-riser following cusp fracture.

FIGURE 11

FIGURE 12—A complex composite restoration restored according to these axioms.

are not capable of transecting enamel rods. All they do is fracture out weak and unsupported rods. True bevelling of the gingival floor requires cutting rods obliquely with a carbide or diamond instrument.

From the summary of the above points, it can be seen that without bevelling box margins, the floor and walls of GVB boxes hover in the danger zone. Failure in two modes can occur during cure and polymerization:

1. ADHESIVE FAILURE: "RESIN SEPARATION"
If an overly large increment, generating excessive contractility is placed, the restoration can separate from an under-etched butt margin during polymerization. The resin is sound, the enamel is sound, but a void develops because the adhesive limit is exceeded. A white line may be visible. Failure ensues.

2. COHESIVE FAILURE: ENAMEL "PEEL"
The restoration adheres to the immediate enamel sides. But because contraction is not dissipated into multiple rods, as it does when a bevel is engaged, stress concentrates along a single plane of rods. When this tug-of-war exceeds the inherent inter-sheath cohesion of enamel, rods 'peel' apart and enamel self-destructs between contiguous rod sheaths (Fig 8). This damage may also be visible as a white line, but the intrinsic mode is different from separation.

Both modes of failure fail aesthetically (Fig 9) developing brown lines and marginal stain. Clinical collapse through leakage, dentin bond hydrolysis, restoration loss, and recurrent decay ensues.

BEVELS DEFINED
Bevels are defined as oblique cuts through enamel extending without interruption from DEJ to cavosurface. Four incrementally increasing bevels are shown in Fig 7.

1. Bevel of 6 degrees: indicated for enamel 1 mm thick

2. Bevel of 12 degrees: indicated for thinner enamel or to resist large resin mass contraction

3. Bevel of 45 degrees: indicated in thin enamel near the CEJ

4. Bevel of 60 degrees: indicated for cosmetic blending

GEOMETRY MEETS HISTOLOGY

Enamel is composed of 30,000 to 40,000 enamel rods per square millimetre of tooth.[12] The number of rods in one linear millimetre of enamel is found by taking the square root of these figures, namely, 173 to 200 rods per millimetre. When a bevel transects rods from DEJ to a point bevelled one-tenth of a millimetre past a butt margin, 17 to 20 rods (one-tenth the above number) are transected. To calculate the angle of the bevel, the tangent function of the bevel is required. A bevel of 6 degrees, tangent = 0.10, cuts 0.10 of a millimetre at the cavosurface (assuming an enamel thickness of 1 mm.), transecting 20 rods. A twelve degree bevel, tangent = 0.20, incurs a cavosurface loss of two-tenths of a millimetre, transecting 40 rods. This is summarized in Fig. 7.

In this author's study clubs, stable, functional results with excellent cosmetics over nearly a decade have been clinically achieved using bevels between 6 and 12 degrees. This is a cavosurface increase in footprint of only one to two-tenths of a millimeter, assuming enamel 1mm thick. A 45 degree bevel was considered ideal for composite margins at the start of the composite era.[12] The tangent of 45 degrees, an isosceles triangle, is 1.0. This entails an increase in the enamel footprint of 1 millimeter, transecting 200 rods. At ten times greater enamel loss, this is clearly not conservative and is clinically unnecessary.

Generally, 6 to 12-degree bevels are imparted to surfaces accessible by a FG 7406 carbide, held at ninety degrees to the cavosurface. The tapered bullet form of this bur, mated to the operator's choice of handpiece angulation, imparts the desired bevel.[13] Due the 12-bladed design and low rake angle, a smooth, consistently bevelled, and easily finished margin is defined. However, the Class II box does not permit this instrumentation.

A 60 degree bevel is voracious, committing the patient to a facial loss of 1.73 mm, transecting 346 rods. It is rarely necessary except for ultra-critical aesthetic applications, and far exceeds the structural requirement.

THE IMPORTANCE OF ETCH:

Etched enamel, properly accomplished, is the principal driver of increased surface area and hence adhesion. Etching increases area by 1000 to 2000 percent.[12] However, proprietary etchants are vastly dissimilar. A range of 1000% in efficacy is noted between etchants in Table 1. Observe that 37% liquid phosphoric acid is superior to most gels.
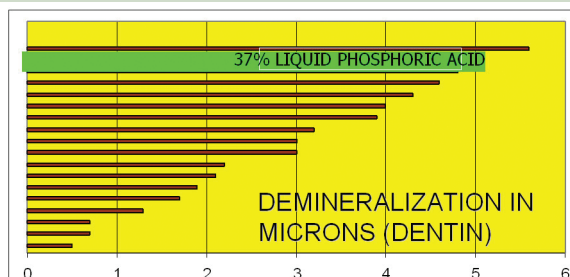
Confirming the importance of etch as a factor, a recent study by Reality reveals that enamel shear bond strength varied nearly 25%, from 22 to 27 MPa, using five popular gel etchants with the same bonding agent (Table 2).

Self-etching adhesives show equally wide variation in pH,[15] from 1.2 to 2.7, with commensurate variability in enamel etching efficacy.

Thus, even ideal preparations may under-perform if acid etching falls below criteria, whether embedded in adhesive chemistry, or whether a separate etch-and-rinse protocol is followed.

Being an invisible parameter, the importance of etchants to longevity is often overlooked. Sadly, resin technique refuses to be simple. It is inherently complex and exacting.

ENAMEL AXIOM #4: SUFFICIENT DEPTH FOR SERVICE LIFE

Class II occlusal extension, beyond considerations of cariology, is driven by the need to provide longevity. Normal teeth wear at approximately 30 microns per year.[16] Many worn adult dentitions have thinned enamel. Occlusal finish lines placed in thin enamel may wear through to dentin prematurely, necessitating re-restoration. Therefore, enamel thicknesses on the occlusal surface should be thick enough to meet the patient's life expectancy, factored from the above, at an average of 0.3 mm wear per decade. Extension of the occlusal outline into thicker cusp structure may be indicated to achieve adequate service life.

ENAMEL AXIOM #5: PROPORTIONALITY OF RESIN MASS TO ENAMEL MASS

Meshing with the above is the requirement that a large resin mass

TABLE 1—Efficacy of 37% liquid phosphoric acid. From Summitt and Robbins pg 214.

must be met with an equally robust enamel mass. When enamel is thin, it cannot accept large contraction loads. If thin, finish lines should be moved to a coronal location that has robust remaining enamel. This may require cusp shoeing if no appropriate mass of enamel presents on the occlusal table. If enamel mass is nearly sufficient, bevelling increases effective area and may be all that is needed to preserve enamel cohesion against contraction. When proportionality cannot be attained, a low-contraction resin placement protocol is indicated to reinforce fragile enamel before contraction by a large contiguous resin mass, or, alternatively, indirect restoration may be indicated.

DIAMONDS VS CARBIDES: THE CONFUSION BETWEEN MACRO-ADHESION AND MICRO-ADHESION.

Many practitioners believe that adhesion for resin restorations is increased by "roughening" the bonding surface with diamond burs. The intuitive sense that a rough surface is more tenacious than a smooth one is misguided. While bondability of a diamond-abraded surface is increased, it is no better than air-abrasion in removing amorphous surface enamel.[17] The gain in area is insignificant compared to the gain of 1000 to 2000 percent attained through acid etching.[12]

Most importantly, the gain in surface area by diamond roughening is obtained at the expense of the integrity of the enamel layer. The spinning diamond projections of rotary diamond burs shatter, undercut and damage enamel thus breaking the cohesion of the enamel rods.[18] A sound restoration cannot ensue from a tooth broken by the preparation process. A diamond-abraded margin is less cohesive and weaker as a bonding substrate than one prepared with a spiral-cut, non-crosscut carbide bur, or air-abraded.

DENTIN AXIOMS:

Factors governing the dentin in preparation are more concise than enamel.

DENTIN AXIOM #1: ALWAYS FRESH CUT OR AIR – ABRADE

This step removes biofilm, etch-resistant fluoridated dentin, and hyper-mineralized sclerotic dentin surfaces. As with enamel, removal of only microns is required.

DENTIN AXIOM #2: ROUNDED FORM, STRESS RISERS

Rounded internal line angles:

Transitions from one plane to another should be rounded. Stress travelling within the resin, like flowing water, should not abruptly change direction over sharp internal form. This compares to the turbulence of a stream flowing over and around rocks. Smooth, laminar flow is preferable.

ELIMINATION OF STRESS RISERS:

Sharp internal form, such as seen after tooth fracture (Fig 10) must be eliminated. This structural principle is widely honoured in diverse engineering applications, from utility knives to airplane wings. Where does a scored utility knife blade break? It breaks where intended, at the scored lines. Equally, in the structurally imperative world of aircraft safety, a tiny nick in a wing surface mandates panel replacement. This recognizes the fact that any flaw in a continuous surface can become an axis around which repeat flexure takes place, leading to localized fatigue and material failure. Resin is the more fluid element in tooth/resin interactions since the flexural modulus of most current resins ranges from 8 to 10 gigapascals (GPa). This compares to the flexural modulus of dentin at 12 to 14 GPa and enamel at 80GPa.

Because the flexural strength of most hybrids ranges from 85 to 170 megapascals (MPa), compared to dentin at 220 MPa, resin is the element moving the most in the restoration. Being the weakest in load-carrying capacity, and flexing the most, it is likely to fail first, and fracture will most likely start around sharp internal projections which concentrate stress.

DENTIN AXIOM #3: CONSISTENT AND SUFFICIENT DEPTH FOR AESTHETICS

When treating visible surfaces, consistent axial depth on the facial surface leads to consistent aesthetics. Just as in laboratory ceramics, direct materials need room to develop aesthetics. In outer dentin, pulpal encroachment is of no concern, but stained tooth structure needs depth of overlying resin to be effectively hidden. Fig 11 shows a failure to cover stained tooth structure in tooth #15 due to insufficient depth.

DENTIN AXIOM #4: SUFFICIENT DEPTH TO ACCEPT LOADS

Strength increases as the square of the depth in most load-carrying structures, such as beams. The application of this axiom in prep design is pre-emptive. Shallow restorations exposed to point loads, such as the distal marginal ridge of the mandibular first bicuspids, may fail at the fossa if the pulpal floor is too shallow. The fossa is the location where the strain between marginal ridge (which is strained in compression) meets the isthmus (which is strained in tension). A material path in the prep must be provided, of sufficient depth and volume, through which these strains can travel and resolve.

Clinical experience and judgment are used to determine the spatial need from case to case. This is also specific to the resin selected. Because performance var-

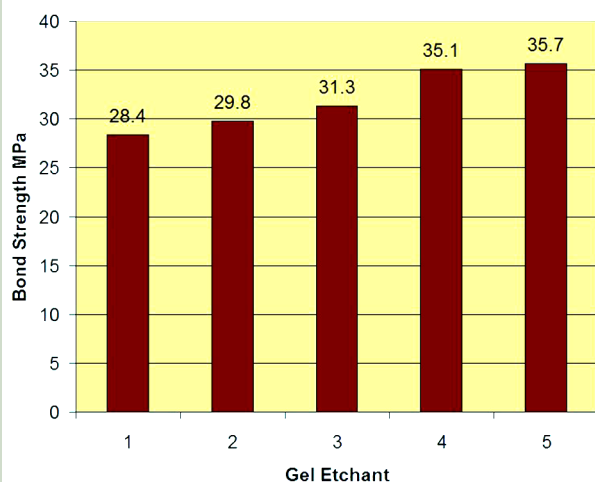### Table 2: Bond Strength with different etchants; Reality Research

TABLE 2—Shear Bond Strength with five different etchants using the same adhesive.[14]

ies as the square of depth, small increases in size can pay large dividends. The flexural strength of hybrid and nano-hybrid resins determines the outcome, and varies from 85 to 166 Megapascals (200%) while Flexural Modulus varies from 3.8 to 22GPa (700%). Therefore, different outcomes will be seen in similar preparations when different resins are placed.

DENTIN AXIOM #5: MECHANICALLY EFFICIENT INTERLOCKS

Adhesion to dentin generally declines over time, so that efficient macro-retentive features such as dovetails and parallel or convergent walls can supplement adhesion and improve durability. Conventional GVB resistance form (like gingival and pulpal floors) relieve adhesives of shear loading. Mechanical interlocks and reciprocal retention improve stress transfer from tooth structure to the restoration and reduce the cyclic fatigue at the adhesive interface that occurs over time. This axiom is concisely expressed as "Form Spares the Bond".

CONCLUSION

These ten axioms apply to preparation design and drive the operator in the choice of burs and the development of the internal form of a composite Class II preparation. In an upcoming issue of Oral Health, this article will be continued, detailing instrumentation and outcomes, to illustrate the application of this theoretical framework to daily practice. **OH**

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