THE WEDGE EFFECT: Structural Design Weakness of Class II Amalgam

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ABSTRACT

Historically, amalgam has served dentistry well as a restorative material. Unfortunately, it does present shortcomings. Typical G.V. Black direct amalgam restorations for posterior interproximal cavities (Class II) may compromise structural integrity. The restoration design acts as a keyway wedge, risking cuspal fracture and insult to pulpal or periodontal tissue.

This article simplifies complex mechanical engineering concepts. Cuspal fracture is often seen in teeth with Class II conventional direct amalgam restorations. Alternative methods and materials are addressed to reduce risk of fractures.

INTRODUCTION

There are several contributing factors to tooth fractures in teeth restored with Class II amalgam. Three structural design problems involve *wedge function, constant versus repeated loading, and diametral tensile force.* These complex mechanical engineering principles have been simplified. It is as easy as splitting firewood.

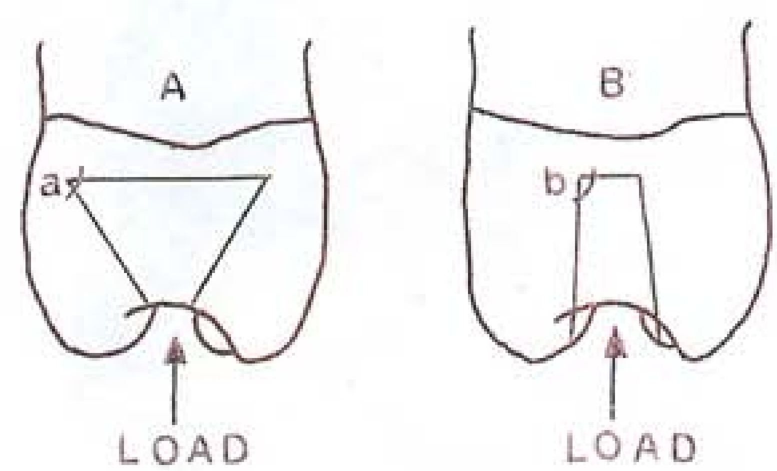

Figure 1: Cross section of Class II amalgam restorations Compression load will concentrate at the acute line angle "a". Horizontal tensile stress direction at the narrowest site risking cuspal fracture. Stress will be dissipated over a greater area at obtuse line angle "b". Force will be directed more vertically (apically), potentially risking insult to pulpal tissue or periodontal ligament.

WEDGE FUNCTION

A stick of firewood is stood on end, with the grain lined vertically. This is similar to dentinal tubules. Also, like tooth structure, the lower the moisture content in wood, the easier it splits.

Ax blades and splitting wedges are first given a thin coat of lubrication. Wedge lubrication in dentistry is generated by microleakage. Microleakage on dentino bonded direct amalgams has also been reported.[1] Both saliva and dentinal tubules supply this fluid. Formulas prove greatly increased penetration and force for lubricated wedges.[2]

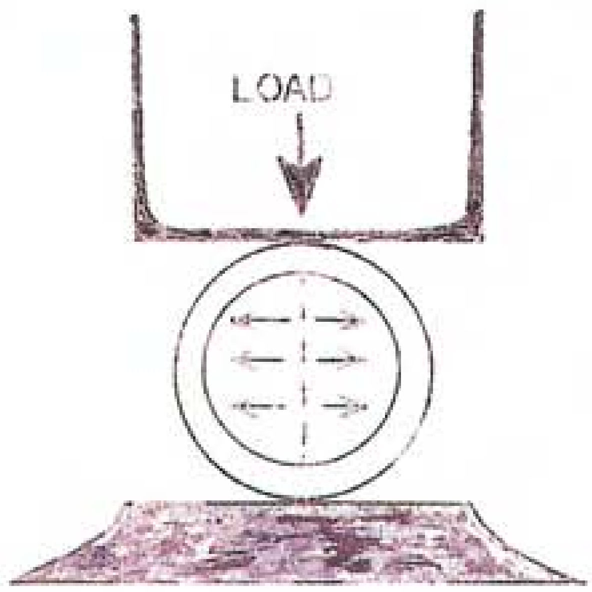

Figure 2: Diametral Tensile Test
Compression load applied to a cylindrical specimen. Horizontal arrows indicate direction of destructive tensile stress.

Figure 3: Buccal cusp fracture of maxillary first bicuspid. Note angulation of fracture towards axiopulpal line angle.

A wedge is an inclined plane set into motion. For example, a narrow bladed ax is driven into the wood. The downward force is called compression load. Force concentrates on the sharp edge and is continued vertically, deep into the wood. This crack will rarely separate wood. Similarly, a narrow Class II amalgam may pound into a tooth creating a progressive vertical fracture.

Compare a nutcracker (second class lever) to the dentition.[3] The closer to the hinge (center of rotation), the greater is compression load. Understandably, the most frequent teeth to exhibit cracked tooth syndrome are second molars.

Once an opening in the wood has been made, a series of wedges are hammered into the opening. First, smaller V-shaped wedges are used, which progress the vertical crack. Next, larger, blunt-ended wedges are used. These resemble teeth on a gear cog and are called "keyway wedges." [4]

Larger keyway wedges are the most effective in sectioning wood. They redirect compression load horizontally. Minimal compression load provided by the hammering maul is required to generated a more destructive horizontal force *(diametral tensile force)*. Stress will concentrate and be raised on any sharp angles of the keyway wedge (Figure 1).[4,5]

Daily in restorative dentistry, keyway wedge designed Class II amalgam results in cuspal fracture. Retention pins and sharp internal line angles may act as stress concentrators.[6,7] Compression load on the occlusal of an alloy may result in *diametral tensile force* fracturing the cusp. Often the restoration remains intact.

Constant vs. Repeated Loading

Imagine a gas powered log splitter with a conveyor belt design. The log ends are driven into a fixed V-wedge with a constant amount of force *(constant loading)*. Often, the machine jams. Power must be turned off and the log and/or wedge repositioned. This change in direction and amount of force *(repeated loading)* is much more effective in splitting wood.

Likewise, repeated loading on amalgam restorations is more effective than *constant loading* in crack formation and progression.[8,9] Habitual bruxers are thus more at risk for fractures on their amalgam restored teeth.

Diametral Tensile Force

Diametral tensile force may be demonstrated with a can of tomatoes (Figure 2). The cylinder is secured in a bench vise by its sides. Tightening the vise arm, the can eventually ruptures. Force from the vise (compression load) is redirected at right angles and splits the sides of the can *(diametral tensile force)*. Importantly, tensile force damage almost always occurs at lesser magnitudes than compressive force. Also, it is significantly more destructive.[8]

$$\text{Tensile Stress (MPa)} = \frac{2P}{\pi \times D \times T}$$

Where P =Load (compressive force) (N)

D= Diameter (mm)

T= Thickness (mm)

π = 3.14...

Tensile stress on teeth restored with Class II amalgam may be amplified by increasing P (load). This is seen in patients with a clenching habit. Tensile stress also may be elevated by decreasing D (diameter) or T (thickness). An increase in the buccal/lingual width of a preparation's isthmus often leaves only a thin shell of cusp. This reduction in thickness of tooth structure lowers the value of T. D is lowered in teeth that have exhibited occlusal attrition or abrasion.

Case Reports

1. A patient fractured the buccal cusp of a maxillary first bicuspid during

Figure 4: In centric occlusion, note position of keyway wedge (amalgam) in relation to compression load applied by opposing bicuspids.

Figure 5: Occlusal view demonstrates clinical abuse of amalgam. Note moderate size of alloy wedge generating loss of tooth structure.

normal mastication (Figure 3). The tooth was noncarious and asymptomatic. At least seven years earlier, a Class II amalgam was placed.

The patient was asked to close into centric occlusion (Figure 4). Mandibular bicuspids were positioned to generate compression load. The Class II amalgam acted as a keyway wedge and horizontal forces contributed to buccal cusp fracture. Note the location of the cervical fracture which removed the cusp and its angle of incidence directly towards the axiopulpal line angle.

This patient had a history of overcarved cusp onlay amalgam molar restorations (Figure 5). These restorations were in minimal occlusal function to increase longevity potential. Correspondingly, added forces of masticatory function were moved to bicuspids. This included compression load, as well as shear and flexural forces.

2. A patient's cracked tooth syndrome was investigated (Figure 6). A relatively conservative amalgam was partially removed. The mandibular second molar had a midline fracture traveling parallel to compressive force, mesial to distal in a vertical axis. The crack visibly extended from the mesiomarginal ridge to the mesioaxial wall and onto the pulpal floor. Restorative options were dictated by the extent of fatigue and fracture of tooth structure. This tooth may be non-restorable. Despite damage sustained on the tooth, the alloy restoration showed no visible signs of fracture.

Discussion

The design feature of a keyway wedge for Class II amalgam potentially compromises sound tooth structure. Dimensional structure of a restoration, buccal to lingual and occlusal to pulpal floor, influences internal stress. The larger the wedge (amalgam), the greater is its potential to fracture teeth. Pulp is more susceptible to insult with a vertical fracture from a narrow wedge.

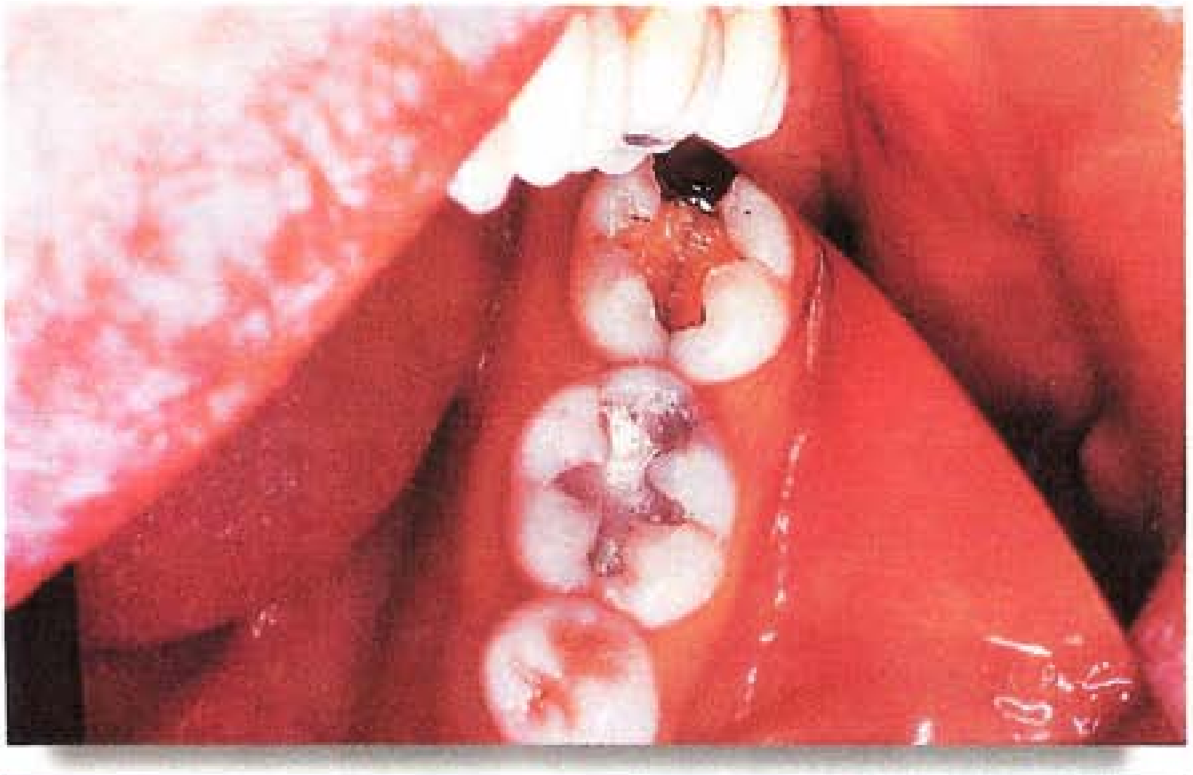

Figure 6: Conservative amalgam partially removed from mandibular second molar to investigate cracked tooth syndrome. Vertical fracture may extend to pulp chamber and/or the periodontal ligament.

Internal line angles for direct resin, indirect resin or ceramic preparations are highly rounded. Occlusal forces are dissipated over a greater surface area and are less concentrated. Risk of fracture is reduced.

Newer restorative materials primarily rely on micromechanical adhesion of hybridization for retention.[10] Microleakage is largely eliminated.[11] The intimate bond between restoration and tooth structure serves to spread compression load over a greater surface area and increases friction under compression load. Micro-fluids cannot act as a lubricant. Possibility of fracture is again lessened.

More ductile and less brittle materials are of benefit.[4] Stress of *constant loads* (i.e. clenching) should be transferred to the material and not immediately to the sharp angles in keyways.[9] Therefore, gold or composite resin, especially microfil, may be the optimal selection. Unfortunately, under *repeated loading*, material ductility or brittleness is of less significance to prevent fracture.

With our aging population keeping their teeth longer,[12,13] placing Class II amalgam restorations must be questioned. Does the structural design unnecessarily compromise the future of sound tooth structure? Is the initial low cost justified by potential cuspal loss, time and expense of indirect onlay, full crown coverage, or extraction?[14]

Academic investigators will continue to perform exhaustive in vitro compression strength tests on restorative materials. Amalgam has superior compressive strength compared with a multitude of restorative resins.[15] Unfortunately, due to the wedge effect, destructive forces are transferred to restored teeth.

Conclusion

Selection of optimal restorative materials and methods have future repercussions. The convention to choose amalgam for Class II cavity restoration may not be in the patient's best interest.

Ideal Class II restoration involves highly-rounded internal line angles, elimination of microleakage, material ductility, and intimate micromechanical adhesion. Future conservation of tooth structure and functional occlusion are best obtained with modern techniques and materials. The beneficial property of ductility in gold should not be overlooked.

A keyway wedge design potentially threatens sound tooth structure. Vertical compression load on Class II amalgam may transfer to more destructive horizontal diametral tensile force on teeth. Stress usually concentrates at the axiopulpal line angles and sites of thin, compromised tooth structure. Lubrication provided by microleakage increases wedge force.

An untimely fracture may occur within days, months, or years. These potentially destructive restorations must be viewed as "time bombs". Class II amalgams may threaten not only specific teeth, but possibly an entire dentition.

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Dedication

This article is dedicated to the memory of Dr. A. John Gwinnett. His years of inspired work did much to advance our understanding, application, and clinical success in the field of adhesive dentistry.