The Tooth

Its Structure and Properties

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KEYWORDS

• Aging • Dentin • Durability • Enamel • Fatigue • Fracture • Tubules

KEY POINTS

- The tooth's durability is reduced by the introduction of damage in dentin or enamel, which can occur in the cutting of preparations and etching, and as a result of cyclic contact.
- There is a substantial reduction in the fatigue and fracture resistance of both dentin and enamel with increasing patient age, which should be considered in the treatment plan.
- Exposure of dentin to acidic environments reduces its fatigue strength and reduces the tooth's durability. Exposure to biofilm and aggressive or over-etching should be avoided.

INTRODUCTION

It seems appropriate to begin this review of the structure and properties of the tooth from the foundation provided by previous noteworthy reviews. For instance, Pashley[1] reviewed the microstructure of dentin, and the variations in tubule density and dimensions, from the deep to the peripheral regions. He discussed their influence on fluid movement within the lumens, that is, the fluid dynamics, as well as contributions of the smear layer developed during cutting to dentin permeability. Results from that body of work established the importance of the smear layer to adhesive dentistry and have guided the development of products to treat dentin sensitivity.

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Marshall and colleagues[2] also reviewed the structure and properties of dentin and placed emphasis on adhesive bonding due to the transition taking place in restorative materials. That review provided a comprehensive discussion of sclerotic and transparent dentin, as well as demineralized, remineralized, and hypermineralized forms. These altered forms exhibit distinct microstructures, which are important to acid etching and bonding.[3,4] The importance of location and tubule orientation to the mechanical behavior of dentin were also highlighted, as well as the need for adopting site-specific descriptions of properties that could be developed using instrumented indentation.

Kinney and colleagues,[5] presented a comprehensive review of the structure and mechanical behavior of dentin, the first after decades. That review serves as the bible on the mechanical behavior of dentin and now guides the way we think about the tooth as a loadbearing structure. More emphasis was placed on the importance of the collagen and its contribution to the elastic properties and viscoelastic behavior of dentin. This review also started the discussion of flaws in dentin, including their contributions to the strength and fatigue behavior. Kinney and colleagues[5] proposed that a fracture mechanics approach should be adopted to describe the strength of dentin, especially when considering the importance of changes in microstructure associated with the altered forms.

The last decade has brought greater interest in and understanding of the tooth's durability. Therefore, the objective of this article is to discuss the structure and properties most relevant to tooth durability, with an emphasis on their importance to clinical practice.

DAMAGE AND FLAWS

The mechanical forms of tooth failure originate at defects, which could be intrinsic or extrinsic, for example, as a result of treatment or induced during function. Defects within the tooth structure reduce its capacity to bear loads, thereby reducing its resistance to the forces of mastication.

Cracks in teeth facilitate tooth fracture[6,7]; but how do they develop? This question is being debated in the fields of endodontics and prosthodontics. In endodontics, the concern is whether flaws are introduced during instrumentation of the canal and if they are the cause of vertical root fractures. Some studies have reported that damage is introduced during instrumentation of the canal,[8–10] whereas others have shown there is no difference in the number of microcracks within instrumented teeth versus controls (ie, without instrumentation).[11–13] This debate is ongoing and has yet to address the residual strength of a tooth with defects.

Recent investigations have explored whether the introduction of cavity preparations and adhesive bonding reduce the tooth's durability. For instance, laser cutting preparations were shown to introduce cracks in dentin[14] that reduce the strength. However, Sehy and Drummond[15] could not identify visible or microscopic cracking in dentin after performing bur treatments. Majd and colleagues[16] evaluated the influence of bur cutting and an abrasive air jet treatment on the fatigue strength of coronal dentin. Despite an increase in surface roughness with respect to control surfaces and development of a smear layer, flaws or cracks were not evident in the prepared surfaces and there was no change to the static strength. However, both treatments caused a significant reduction in the fatigue strength of dentin, with bur cutting resulting in nearly 40% reduction in the fatigue limit.

More recently, Majd and colleagues[17] explored the influence of cutting direction on the fatigue strength of tooth structure. Treatments involved cutting of coronal dentin using a medium-grit diamond in parallel and transverse cutting directions with respect to the direction of cyclic tensile stress. A reduction in static strength of approximately