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Biologic Consideration of Dentin and its Clinical Significance of Operative Dentistry

Dentin is a mineralized connective tissue that is covered by enamel in the crown and cementum in the root, as well as enclosing the innermost pulp.

Mature dentin is a crystalline material that is less hard than enamel but slightly harder than bone. Mature dentin is 45%- 50% inorganic or mineralized material, 30% organic material, and 25% water. This crystalline formation of mature dentin mainly consists of calcium hydroxyapatite with the chemical formula of $Ca_{10}(PO_4)_6(OH)_2$. The calcium hydroxyapatite found in dentin is similar to that found in a higher percentage in enamel and in lower percentages in both cementum and bone tissue, such as the alveolar process. In addition, the crystals in dentin are plate like in shape and 30% smaller in size than those in enamel. Small amount of other minerals, such as carbonate and fluoride, are also present.

Function

1. Dentin forms the bulk of the tooth (both in the crown and root).
2. The coronal dentin (crown) provides color for the overlying enamel Because of the translucency of overlying enamel, the dentin of the tooth gives the white enamel crown its underlying yellow hue, which is a deeper tone in permanent teeth. When the pulp undergoes infection or even dies, there is discoloration of the dentin, which causes darkening of the clinical crown.
3. Dentin also has great tensile strength, providing an elastic basis for the more brittle enamel.
4. Tooth strength and rigidity are provided by intact dentinal substrate. Resistance of tooth to fracture is significantly lowered with increasing depth and width of cavity preparation. Therefore a conservative initial approach that combines localized removal of carious tooth structure, placement of a bonded restoration, and placement of sealant is recommended. If large preparations are required, the dentist should consider placement of onlay or crown.
5. Protective encasement for the pulp. As a vital tissue without vascular supply or innervation, it is nevertheless able to respond to thermal, chemical or tactile external stimuli.

Dentin can be distinguished from enamel (during tooth preparation) by:

1. **Color:** dentin is normally yellow-white and slightly darker than enamel, in older patients dentin is darker and become brown or black in cases in which it

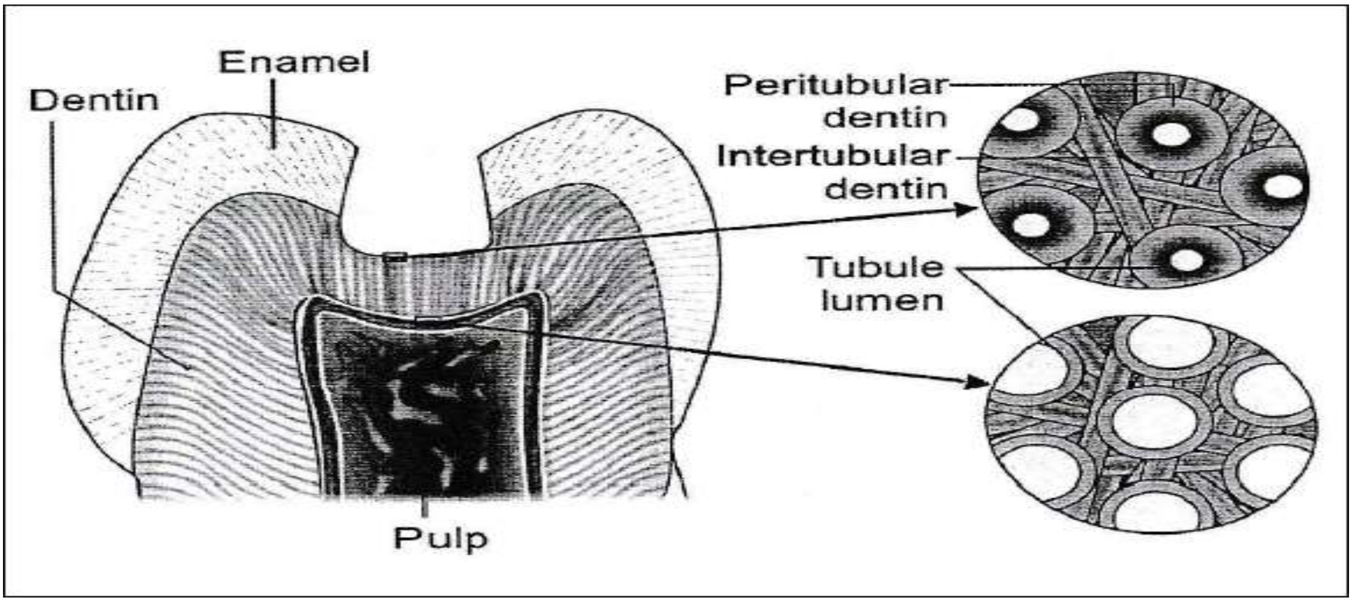
has been exposed to oral fluids, old restorative materials or slowly advancing caries.

2. **Reflectance:** dentin surfaces are more opaque and dull, being less reflective to light than enamel surfaces, which appear shiny.
3. **Hardness:** dentin is softer than enamel, sharp explorer tends to catch and hold in dentin.
4. **Sound:** when moving an explorer tip over the tooth, enamel surfaces provide a sharper, higher pitched sound than dentin surfaces.

	Enamel	Dentin
Color	Whitish blue or white gray	Yellowish white or slightly darker than enamel
Sound	Sharp, high-pitched sound on moving fine explorer tip	Dull or low-pitched sound on moving fine explorer tip
Hardness	Hardest structure of the tooth	Softer than enamel
Reflectance	More shiny surface and reflective to light than dentin	Dull and reflects less light than enamel

There are two main types of dentin which are:

1. **Intertubular dentin:** the primary structural component of the hydroxyapatite-embedded collagen matrix between tubules.
2. **Peritubular dentin:** the hypermineralized tubular walls. These component ratios vary according to depth of dentin, age and traumatic history of the tooth.



The dentinal tubules in the outer dentin which is near the DEJ are relatively far apart and the Intertubular dentin makes up 96% of the surface area. In the inner dentin, the tubules diameters are larger and the distance between tubule centers is half that of tubules at DEJ. Thus the intertubular matrix area is only 12% of the surface area, and the permeability of inner dentin is about eight times more permeable than the dentin near DEJ.

Permeability of Dentin

The permeability of dentin is directly related to its protective function. When the external cap of enamel and cementum is lost from the periphery of the dentinal tubules through caries, preparation with burs or abrasion and erosion, the exposed tubules become conduits between the pulp and the external oral environment. Restored teeth are also at risk of toxic seepage through the phenomenon of microleakage between the restorative material and the cavity wall, through capillary action differential thermal expansion, and diffusion, fluids containing various acidic and bacterial products can penetrate the gap between the tooth and restoration and initiate secondary caries of the internal cavity walls. Bacterial substances can continue diffusion through permeable dentinal tubules to reach the pulp, putting the tooth at risk for pulpal inflammation and sensitivity. So restorative techniques with varnishes, liners or dentin bonding resin adhesives are effective to provide reliably sealed margins and sealed dentinal surface.

The remaining dentin thickness is the key determinant of the diffusion of gradient

Sensitivity of Dentin

Although; dentin is sensitive to thermal, tactile and osmotic stimuli across its (3-3.5mm) thickness. Dentin is neither vascularized nor innervated, except for about 20% of tubules that have nerve fibers penetrating inner dentin by few microns. Therefore odontoblast and its process is the possible stimulus receptor.

Theories of thermal sensitivity

1. Theory of thermal shock: This states the sensitivity is the result of direct thermal shock to the pulp via temperature changes transferred from the oral cavity through the restorative material, especially when the remaining dentin is thin. Protection from this insult would then be provided by an adequate thickness of an insulating material.
2. A hydrodynamic theory: This theory based on the capillary flow dynamics of the fluid-filled dentinal tubule. In a vital tooth with exposed dentin there is a constant slow movement of fluid outward through the dentinal tubules. The hydrodynamic theory proposed that when a stimulus such as air evaporation, cold or heat (i.e. generated from dental bur) or tactile pressure these stimuli causes the slow fluid movement to become

more rapid causing displacement of odonoblast bodies and the nerve endings in the pulp are deformed, a response that is interpreted as pain.

As dentin near the pulp, tubule density and diameter increase also the permeability increase, thus increasing both the volume and flow of fluid. This explains why deeper restorations are associated with more problems of sensitivity.

According to this theory, if the tubules can be occluded, fluid flow is prevented and temperatures do not induce pain. So the operative factor in reducing sensitivity to thermal changes is by effective sealing of the dentinal tubules rather than placement of an insulating material.

This theory has gained general acceptance in recent years and has changed the direction of restorative procedures away from thermal insulation and toward dentinal sealing. Thus there is increasing emphasis on the integrity of the interface between restorative material and cavity preparation.

Physiologic and Tertiary Dentin

Physiologic dentin

1. Primary dentin: formed relatively quickly until root formation is completed by odontoblasts.

2. Secondary dentin: this is slowly formed dentin that continues to constrict the dimensions of the pulp chamber. In response to mild occlusal stimulus, secondary dentin is mainly deposited in the pulp horns and on the roof and floor of the pulp chamber so after many decades the chamber becomes quite narrow occluso-gingivally. The dentist must pay attention for the size and location of the pulp chamber to decide the design of the preparation and placement of retentive features such as pins.

Sclerotic dentin (transparent or peritubular dentin)

Results from aging or mild irritation (such as slow caries) and causes a change in the composition of the primary dentin. The tubular content appears to be replaced by calcified material that obliterates the tubules, progressing from the DEJ pulpaly. These areas are harder, denser, less sensitive and more protective of the pulp against subsequent irritation. Sclerosis resulting from aging is (physiological dentin sclerosis) and that resulting from mild irritation called (reactive dentine sclerosis).

Reparative dentin (tertiary dentin)

Intense traumatic insult (injury) to the tooth, whether caused by bacterial penetration associated with caries, or heat and trauma from a dental bur, may be severe enough to destroy the supporting odontoblasts in the affected location. Within 3 weeks, fibroblasts or mesenchymal cells of the pulp are converted or differentiated to stimulate the activities of original odontoblast, and form irregularly organized tubules

The rate of formation and the thickness and organization of reparative dentin depend on the intensity and duration of the stimulus. The barrier of reparative dentin is superior because there is no continuity between the affected permeable tubules of the regular primary dentin and those within the reparative dentin.

The tooth will be able to compensate for the traumatic or carious loss of peripheral dentin with deposition of new dentin substrate and reduction of pulpal irritation from tubule permeability. Unless the lesion is either arrested or removed and a restoration placed, the diffusion of bacterial toxins reaching the pulp and initiate strong inflammatory response and result in pulpal necrosis.

	Primary	Secondary	Tertiary
Definition	Dentin formed before root completion	Formed after root completion	Formed as a response to any external stimuli such as dental caries, attrition and trauma
Type of cells	Usually formed by primary odontoblasts	Formed by primary odontoblasts	Secondary odontoblasts or undifferentiated mesenchymal cells of pulps
Location	Found in all areas of dentin	It is not uniform, mainly present over roof and floor of pulp chamber	Localized to only area of external stimulus
Orientation of tubules	Regular	Irregular	Atubular
Rate of formation	Rapid	Slow	Rapid between 1.5 and 3.5 μm/day depending on the stimuli
Permeability	More	Less	Least