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Review

Tooth–PDL–bone complex: Response to compressive loads encountered during mastication – A review

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ABSTRACT

The components of the tooth–periodontal ligament (PDL)–alveolar bone complex act in a synergistic manner to dissipate the loads incurred during mastication. The complex incorporates a diverse array of structural features for this purpose. These include the non-mineralized and hence soft PDL that absorbs much of the initial loads. The internal structure of the tooth also includes soft interphases that essentially surround the dentine core. These interphases, although stiffer than the PDL, still are more compliant than the dentine core, and are thus key components that allow the tooth itself to deform and hence help dissipate the compressive loads. There is also direct evidence that even under moderate compressive loads, when the tooth moves in the alveolar bone socket, this movement is guided by specific locations where the tooth comes into contact with the bone surface. The combination of all these responses to load is that each tooth type appears to move and deform in a specific manner when loaded. Much, however, still remains to be learned about these three-dimensional responses to load and the factors that control them. Such an understanding will have major implications for dentistry, that include a better understanding of phenomena such as abfraction, the manner in which tooth implants function even in the absence of a PDL-like tissue and the implications to bone remodelling of the movements imposed during orthodontic interventions.

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1. Introduction

Teeth residing in the jaw socket incorporate many structural features and a range of materials. These all function in a synergistic manner not only to fulfil the key function of food particle breakdown (comminution), but also to prevent or minimize damage to the tooth.[1] Teeth may incur mechanical damage by overload, by abrading each other and by wear due to interactions with hard food particles.[1] Some of this irreversible micro-damage occurs when tooth deformation exceeds the elastic limit. One strategy to minimize or prevent damage is the built-in capability of teeth to move and deform in response to load, such that the deformation remains within the reversible elastic range. This is achieved by the incorporation of relatively soft components that can act as shock absorbers.[2] By moving and deforming, teeth dissipate the loads encountered in a way that reduces stress concentration and minimizes the chance of irreversible damage.[3] This review focuses on ways in which the tooth-periodontal ligament bone complex responds to short term loads encountered during routine mastication.

Mastication in humans involves the cyclic loading of teeth by forces of usually tens of Newtons, or occasionally even as much as hundreds of Newtons.[4–6] The thrust time during mastication can be less than a second.[2,7] Teeth also encounter forces due to clenching that can even last for minutes,[5] and in orthodontic treatments for days and weeks.[8] During each chewing cycle, teeth may move as much as tens of microns.[2,7] The upward movement of the mandible and the resistance to this movement by the maxillary teeth while crushing intervening food particles, results in teeth being loaded in compression both on the crown and on the root. In addition, the mandible can also move horizontally and may cause a lateral movement of teeth. As a result, an individual tooth may be loaded in a complex, three-dimensional manner. To facilitate withstanding loads without failure, each tooth incorporates several structural features, known as interphases. These are three-dimensional interfaces between the dentine and enamel in the tooth crown[9–11] and between dentine and cementum in the tooth root[12] (Fig. 1a). Both crown and root interphases are composed of a relatively soft layer that acts as a cushion between two harder materials in the tooth itself.[11,13,14] The presence of this soft layer with a relatively low elastic modulus as compared to that of the materials flanking it,[15] reduces the stiffness of the whole tooth and minimizes irreversible damage during mastication.[11]

There is however another much softer component in the complex, namely the periodontal ligament (PDL). The PDL is unmineralized and hence it is at least an order of magnitude

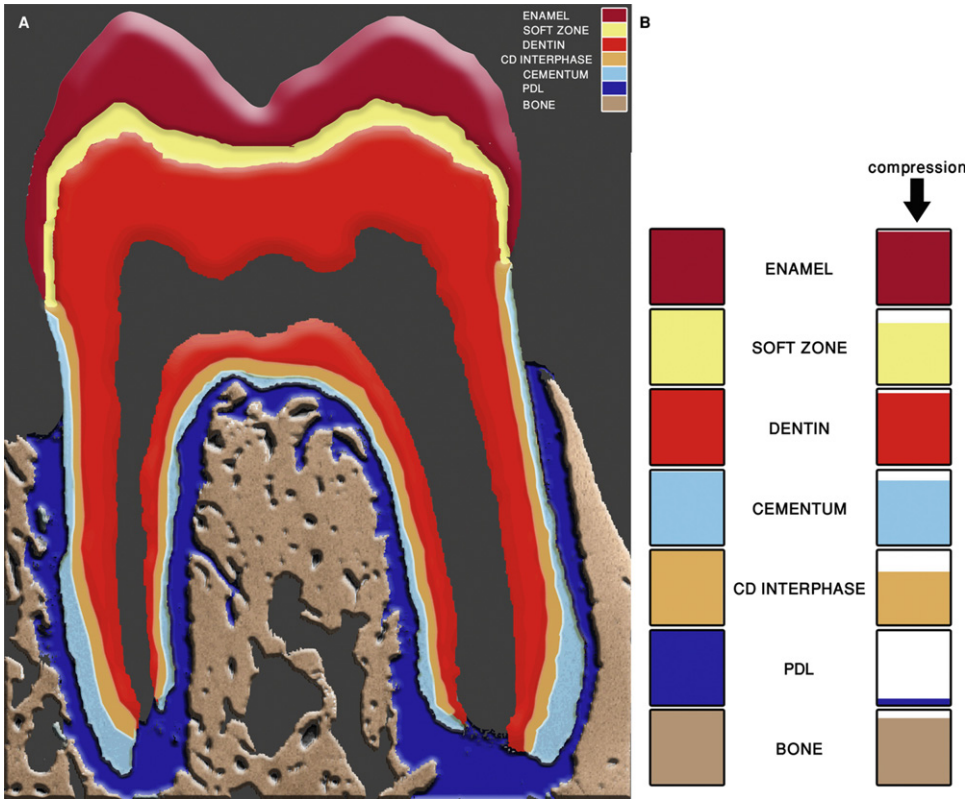

Fig. 1 – (A) Schematic illustration of a mesial-distal longitudinal section of a rat mandibular first molar (M1) showing the different components of the tooth–PDL–alveolar bone complex. Note that the light yellow band (the sub-DEJ soft zone) in the crown and the dark yellow band (the cementum–dentine junction) in the root form an almost continuous soft interphase over the entire dentine core. (B) Schematic illustration, drawn approximately to scale, showing the relative extents to which the various components of the tooth–PDL–bone complex will contract (strain) under an axial stress of 100 N/mm^2 based on the elastic moduli cited in the text. Note that the PDL compresses a lot, the enamel very little, and the interphases somewhere in between.

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