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Elastic constants estimation of dentin by using micromechanical analysis

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Dentin is a subunit of a tooth and its mechanical properties are similar to bone. Dentin has a hierarchical structures, such as the mantle dentin (MD), the circumpupal dentin (CD), the dentin tubule (DT), and the peritubular dentin (PTD). We develop four steps of micromechanical analysis to estimate anisotropic elastic constants of dentin. Step 1, we calculate the collagen and hydroxyapatite mineral crystals associated with water by using the Voigt and Reuss bounds. Step 2, we calculate the effective elastic constants of intertubular dentin by using the periodic distribution assumption in micromechanics. Step 3, we estimate the effective elastic constants of the peritubular dentin (PD) containing a dentin tubule (DT) by using the micromechanical dilute distribution assumption. Finally in Step 4, we estimate the effective elastic constants of the circumpupal dentin (CD) by using periodic distribution assumption.

Based on the finding that the shape of mineral crystals is different on the location of mineral crystals, two types of mineral crystals are reported and used in the calculation; platelet shaped and needle shaped mineral crystals. It is reported that the platelet shaped mineral crystals are observed near enamel and the needle shaped mineral crystals are observed near pulp.

By following the four steps illustrated in the first paragraph and two types of mineral crystals illustrated in the second paragraph, we estimate the anisotropic elastic constants to be E_{11}=21.0GPa, E_{22}=23.4GPa,E_{33}=23.1GPa,ν_{12}=0.257, ν_{13}=0.336, ν_{21}=0.287, ν_{23}=0.293, ν_{31}=0.369, ν_{32}=0.289, G_{12}=9.5GPa, G_{13}=9.6GPa, G_{23}=9.6 GPa for needle shaped mineral crystals and E_{11}=20.7GPa, E_{22}=23.2GPa,E_{33}=25.3GPa,ν_{12}=0.264, ν_{13}=0.283, ν_{21}=0.296, ν_{23}=0.286, ν_{31}=0.345, ν_{32}=0.211, G_{12}=9.0GPa, G_{13}=9.1GPa, G_{23}=9.8 GPa for platelet shaped mineral crystals, respectively. These estimated elastic constants are close to the experimentally measured elastic constants by using the ultrasound techniques.

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