Micromorphology of dentin including peritubular cuffs: A first of its kind

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Abstract

Developing durable dental restorations requires mechanical characterization of dentin, the anchorage tissue of dental restorations. A 3D study of dentin micromorphology with all its components (lumen, peritubular and intertubular dentin) can help understanding the elastic and non-elastic properties of dentin. Here, we provide it in a small volume of ~ 9.0x9.3x4.9 µm^3 using FIB-SEM technique. The obtained stack of image is analyzed to quantify the microstructural parameters and then used to generate a mesh to be used to do Finite Element Modeling.

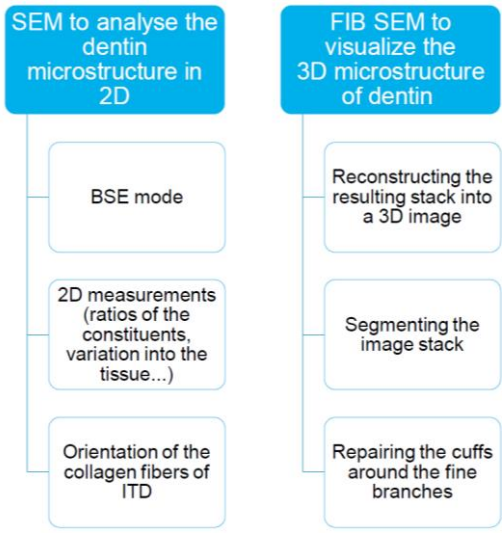
Keywords: Dentin; FIB-SEM; Micromorphology; Homogenization; FEM

1. What we know about dentin

Dentin:

- The main tissue of the tooth located under enamel
- A composite of irregular hollow cylinders (tubules) in a matrix.
- Made of lumen (also called tubules which are the natural porosity of dentin), peritubular and intertubular dentin – visualized in fig. 1-.
- The tubules have branches that occasionally link adjacent tubules.

2. Objectives



3. Results

3.1 2D analysis (SEM images)

The tubule branches have peritubular cuffs. We measured the ratio of their external to internal radii.

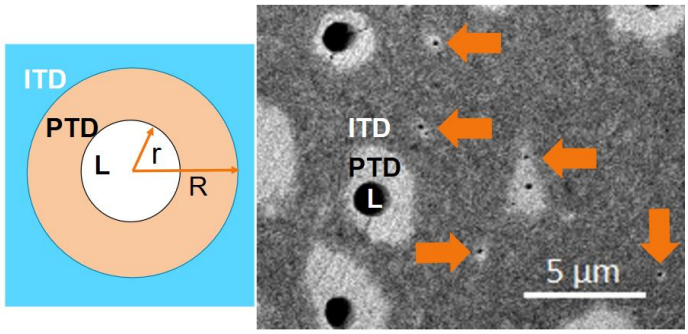


Figure 1. *Scheme of a fine branch beside a SEM image showing fine branches . The Lumen (tubule), peritubular dentin and intertubular dentin are marked by L, PTD and ITD. The peritubular dentin looks lighter because it has more minerals. Image taken at MSSMat.*

The mean R/r ratio of fine branches (n=95) is 2.8 (SD 1.1). We reconstructed the fine branch cuffs according to it in the following 3D image analysis.

3.2 3D analysis (FIB-SEM images)

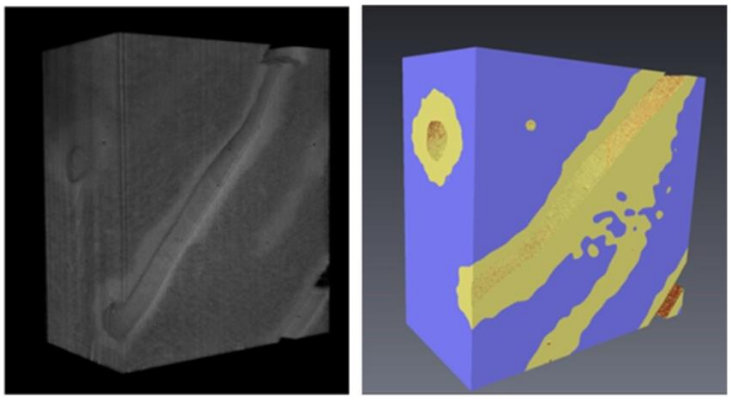


Figure 2.a (left) *The stack of images taken by FIB-SEM, 3D reconstruction by imageJ, (Image provided by MSSMat)* ***Figure 2.b (right)*** *The segmented stack of images. The peritubular cuff surrounding lumen are colored in yellow and the intertubular matrix in blue..*

Table 1. The volume percentage of different constituents of dentin at the microscale

Consituent	Volume percentage (%)
Lumen	3.7
PTD	15.6
ITD	80.7

3. Conclusion and perspectives

- The morphology we achieved can be used for a FEM simulation. It will be the first simulation of dentin microstructure with a realistic geometry. Previous FEM models simplified tubules into circular hollow cylinders with no branches [e.g. Misra et al. 2004], or considered branches with idealized geometry [Vennat et al. 2017].
- This FEM simulation will also reveal the patterns of stress concentration in dentin microstructure, which will help understanding the failure patterns of dentin.

References

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