Anisotropic local physical properties of dental fillings in comparison to dental enamel

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A major aspect in evaluating the quality of dental materials is their physical properties. Their properties should be a best fit of the ones of dental hard tissues. Manufacturers give data sheets for each material. The properties listed are characterized by a specific value (cf. table 1). This assumes (but does not prove) that there is no direction dependence of the properties. However, dental enamel has direction dependent properties which additionally vary with location in the tooth. The aim of our research is to show the local direction dependence of physical properties like the elastic modulus or the thermal expansion in dental hard tissues. With this knowledge the "perfect filling / dental material" could be characterized.

Table 1: Compilation of typical physical bulk properties for different dental material classes.

dental material class	(overall) elastic modulus [GPa]	(overall) thermal expansion [10^{-6}/°C]
composites	~ 16	~ 27
glass ionomer cements	~ 20	~ 13
framework ceramics	~ 80	~ 10
dental metals / alloys	~ 220	~ 15

Enamel sections of ~400-500µm thickness have been cut with a diamond saw from labial/buccal to palatal/lingual (canine, premolar and molar) and parallel to labial (incisor). Crystallite orientations have been measured in over 400 data points on all types of teeth with synchrotron transmission step measurements at beam-line P02.1 (wavelength: ~0.207 Angström, beam-diameter: 0.2mm, sample detector distance: 1200mm, Perkin Elmer 1621 XRD detector, measuring time per image. 20 seconds).

X-ray measurements show impressively that dental enamel has a strong direction dependence of its crystallites which also varies with location within the tooth [1,2]. Since a general strong relationship exists between crystallographic orientations and the resulting mechanical and functional anisotropy of crystalline materials one can calculate the direction dependence directly from texture measurements [3,4].

The results of the local anisotropy calculations are shown following, presented by means of the stereographic projection in figure 1 and 2.

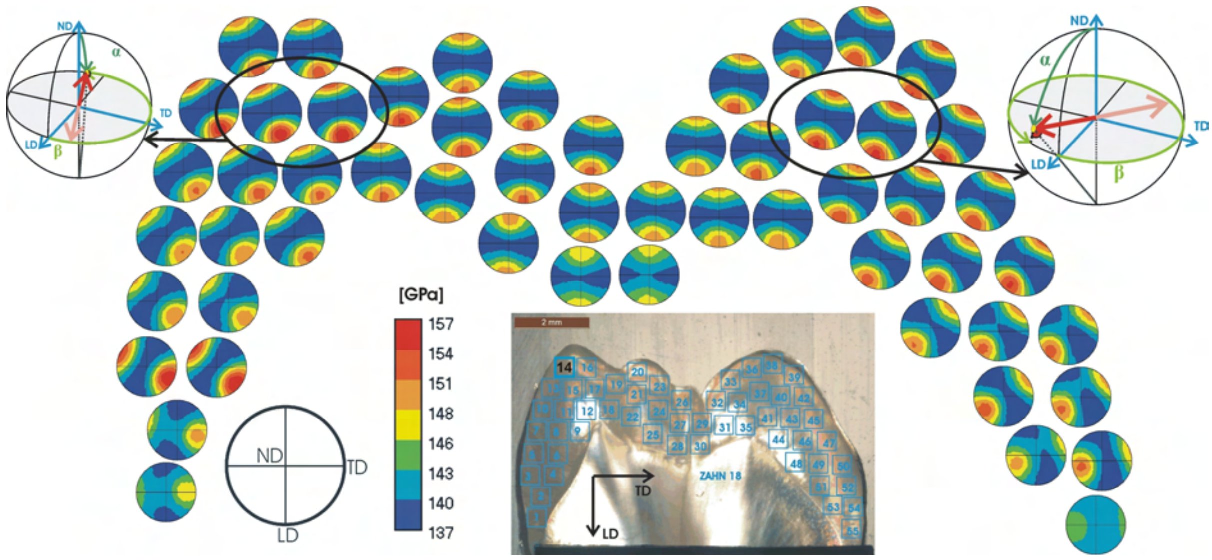

Figure 1: Local map of the direction dependence of the elastic modulus for a molar tooth (FDI 18) with equal scaling. The sample can be seen in the middle. The coordinate system is given by ND (normal direction), LD (longitudinal

direction) and TD (transversal direction). Orientations of maximum values of the stereographic projections in the black ellipses are also illustrated by 3-dimensional drawings on the left and right side.

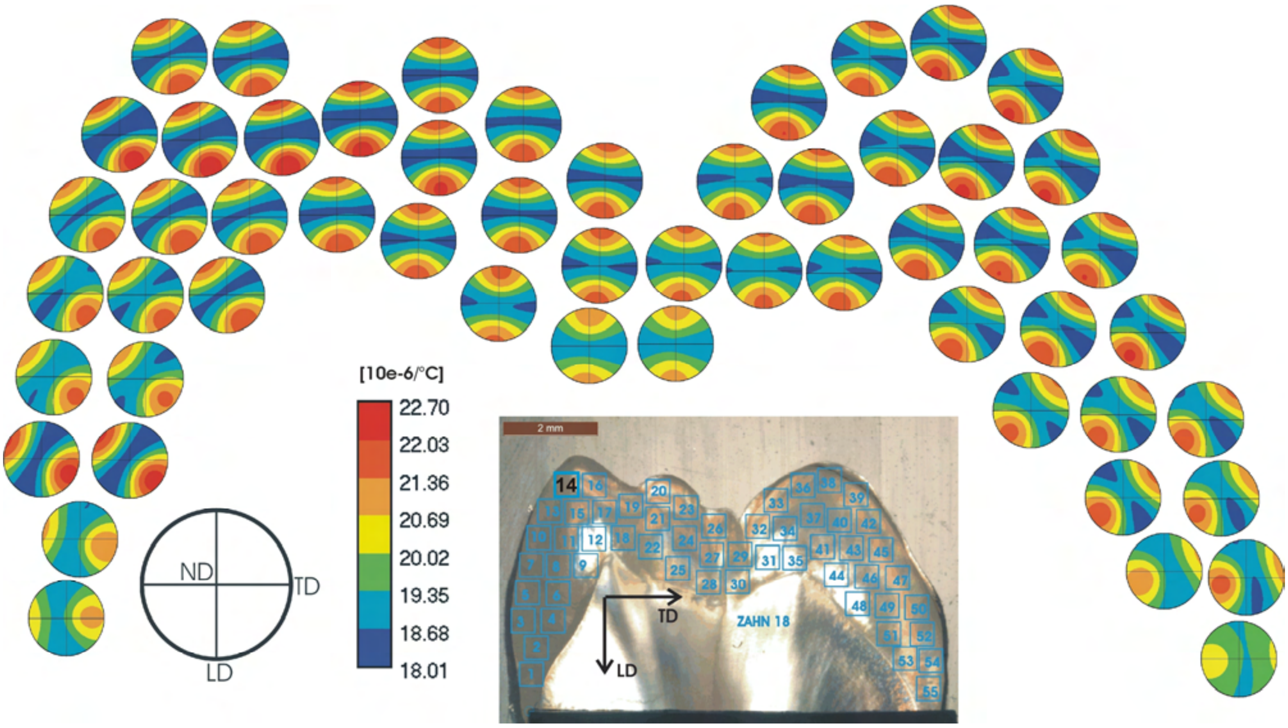

Figure 2: Local map of the direction dependence of the thermal expansion for a molar tooth (FDI 18) with equal scaling. The sample can be seen in the middle. The coordinate system is given by ND (normal direction), LD (longitudinal direction) and TD (transversal direction). Directions are presented by the stereographic projection.

Former texture measurements on dental materials showed that they possess only little or no property direction dependence. Therefore, comparing the results from anisotropic properties calculations (cf. fig. 1 & 2) with the given properties of dental materials (cf. tab. 1) a mismatch was found between enamel and dental materials properties.

Since dental materials should possess equal (direction depending) properties, worthwhile properties could be characterised by transferring the directional properties of enamel into a property "wish list" which future dental materials should fulfil. Hereby the "perfect dental material" can be characterised.

References

[1] Simmons, L, Al-Jawad, M, Kilcoyne SH, Wood, D (2011). Distribution of enamel crystallite orientation through an entire tooth crown studied using synchrotron X-ray diffraction. *Eur J Oral Sci*; **119**:19-24.

[2] Raue L, Gersdorff N, Rödiger M, Klein H (2012). New insights in prism orientation within human enamel. *Arch Oral Biol*; **7**:271-6.

[3] Nye JF (1985). Physical Properties of Crystals. Oxford: Oxford University Press; p. 93-148.

[4] Raue L, Klein H (2011). Calculation of anisotropic properties of dental enamel from synchrotron data. *J Synchr Rad*; **18**:550-6.