

Fracture toughness of 3Y-TZP ceramics – measured with the CNB method

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Various standardized mechanical measurement methods are used to characterize the fracture toughness (K_{Ic}) of fine-grained zirconia polycrystals, e.g. the Single-Edged Precracked Beam (SEPB), Single Edge V-Notched Beam (SEVNB), Surface Crack in Flexure (SCF) and Chevron-Notch Beam (CNB) methods. Literature data show that the fracture toughness of 3Y-TZP (3 mol % Y_2O_3 -doped tetragonal polycrystalline zirconia) has been measured in the range of 4.4 to 6.6 (13.6) $MPa\sqrt{m}$, with the differences in standard deviation and variance being too large [1].

So far, there has been no robust test method for determining the fracture toughness of the fine-grained dental ceramic 3Y-TZP. For this reason, Fraunhofer IKTS was one of ten test laboratories to take part in a round robin test to investigate the robustness of the CNB method and the effect of processing and test variations on the fracture toughness of a 3Y-TZP ceramic. In the CNB method, the test specimen is notched to produce the fracture to be analyzed as the load increases. The interlaboratory test was carried out in accordance with ISO 24370:2005 using standardized 3Y-TZP test specimens measuring $3 \times 4 \times 45 \text{ mm}^3$. The participating laboratories established a standard operating procedure with narrow processing tolerances and the data was analyzed using one-way ANOVA followed by the Tukey HSD test. 95 % confidence intervals (CI) were calculated ($p < 0.05$). A previous round robin test, in which IKTS was also involved, had already considered further variations in the test conditions with regard to CNB notching, storage conditions and the test medium.

The fracture toughness of 3Y-TZP was measured as $K_{Ic} = 4.48 \pm 0.11 \text{ MPa}\sqrt{m}$ for the standard processing tolerance in all laboratories. The application of the standard operating procedure increased the number of valid tests and reduced the standard deviation. Preparation parameters such as notch offset and geometry had a significant influence on the results. The test medium used also influenced the K_{Ic} value. A reduced fracture toughness of $3.71 \pm 0.52 \text{ MPa}\sqrt{m}$ was measured under water.

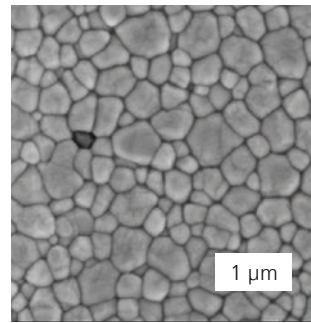


Figure 1: SEM image of a 3Y-TZP ceramic.

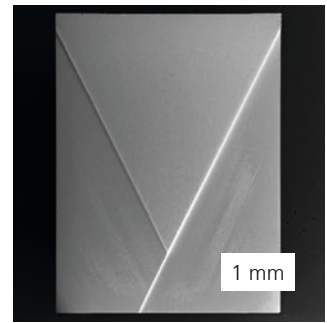


Figure 2: SEM image of a broken chevron notch.

The defined tolerances during preparation and testing and the close adherence to the procedure according to ISO 24370:2005 enable a highly precise evaluation of the fracture toughness of 3Y-TZP with low data fluctuations. The tests also show that a standardized notch shape with defined preload is important and that oil should be specified as the test medium in order to avoid any influence of foreign substances. The consistent results of the laboratories in the round robin test show that the CNB procedure is a reliable method for testing the fracture toughness of 3Y-TZP if the test parameters are adhered to. [2]

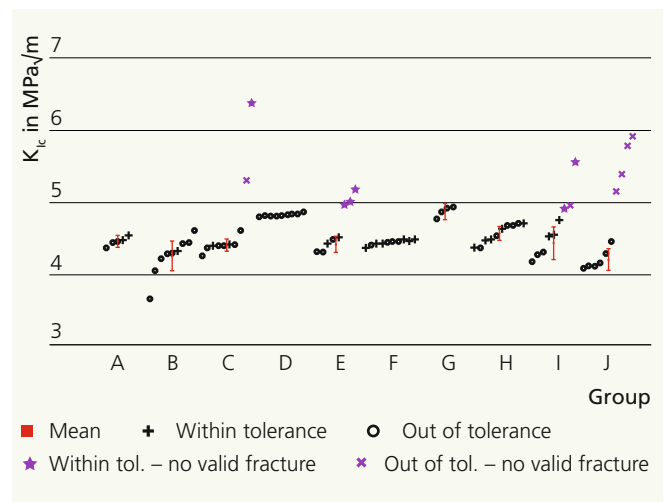


Figure 3: K_{Ic} in oil, individual values, mean value.

Literature

- [1] R. Belli et al. (2018): Fracture toughness testing of biomedical ceramic-based materials using beams, plates and discs, 10.1016/j.jeurceramsoc.2018.08.012.
- [2] S. Begand et al. (2022): Fracture toughness of 3Y-TZP ceramic measured by the Chevron-Notch Beam method: A round-robin study, 10.1016/j.dental.2022.05.001.