Thermal properties of dental ceramics strongly influence their clinical success

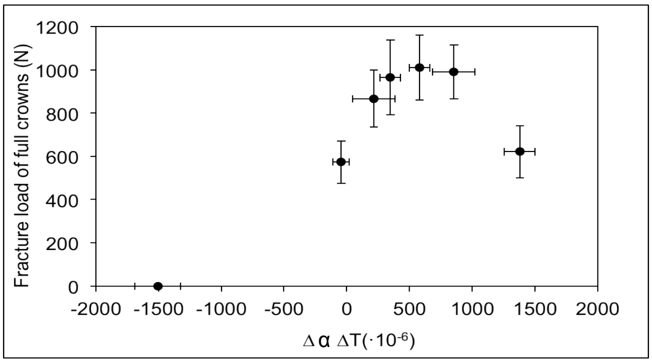
Jens Fischer

Institute for Materials Science and Engineering,
University Hospital of Dental Medicine, University of Basel
jens.fischer@unibas.ch

Ceramics are the materials of choice for dental restorations such as crowns and bridges in esthetically demanding regions. However, their brittleness and their susceptibility to fracture are challenging and require careful handling. To reinforce ceramic materials, frameworks of stronger materials like precious metal alloys or zirconia are used. To achieve a tooth like color and translucency these frameworks are veneered with a ceramic layer by a sintering process. Framework material and veneering ceramic form a bilayer and during cooling after the sintering process interfacial stress is established. Ceramics are susceptible to tensile stress but tolerant to compressive load. Due to their brittle behavior intrinsic stress has to be controlled in purpose to avoid any tensile stress. A slight compressive stress however reinforces the bilayer. Therefore, coefficient of thermal expansion and glass transition temperature are crucial parameters when developing dental ceramics.

In laboratory studies with standardized single crowns, where zirconia frameworks were veneered with ceramics of different thermal expansion, a correlation was found between the difference in thermal expansion between veneering ceramic and framework material ($\Delta\alpha$) on the one hand and the fracture load of these crowns on the other hand.

The intrinsic stress is generated during cooling at temperatures below the glass transition temperature. Hence, the temperature interval between glass transition temperature and room temperature (ΔT) also has an impact on the stress development. A coefficient of thermal compatibility was defined as the product $\Delta\alpha\Delta T$, which is a valuable parameter for improving and accelerating the development of dental materials and for predicting the clinical performance of layered crowns (cf. Fig.).



Fracture load of veneered zirconia single crown frameworks plotted against $\Delta\alpha\Delta T$.

Recently, glass ceramics based on lithium silicates were developed, which exhibit a flexural strength superior to traditional monolithic ceramic materials, which are based on feldspathic compositions. The advantage of stronger materials is not only a major clinical reliability but also the option to prepare the natural tooth less extensive because restorative materials with higher strength require less wall thickness.

These materials are delivered in blanks and processed by grinding with CAD/CAM units. The best condition to machine these glass ceramics is in an initially crystallized state. After the grinding process the work piece has to be fully crystallized. That procedure has to work in different technical laboratories under quite different terms. Hence, during industrial production of the blanks there are narrow tolerances in the temperature profile for crystallization. Thermal analysis is essential to understand the mechanism of crystallization in respect to quality assurance.