Stress Analysis on All-Ceramic Specimens of Different Geometries During Thermalcycling Tests

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Abstract

The oral cavity can present sharp temperature changes due to eating of hot or cold liquids and foods. These changes create residual stresses in dental restorations due to their continuous contraction and expansion. Restorations are usually made of two different materials coupled, creating thermal stress, mainly at the interface between them.

A thermocycler can be used to predict the behavior of the restoration, specifically the bonding between the materials. The thermocycle simulates the oral cavity, considering the temperature changes and the chemical environment. On this work, the software COMSOL Multiphysics® was used to simulate the thermocycler test, predict the generated stresses by the temperature changes and compare two different sample geometries. The test consists into diving the samples into a high temperature liquid for certain time, then transfer it to a low temperature bath, where it will stay for certain time. This cycle can be repeated several times.

COMSOL Multiphysics was used to simulate the test described above. The thermal stress physics interface was used to calculate the residual thermal stress. A 2D axisymmetric model was used to simulate a cylinder made by two materials: alumina on the bottom half and porcelain on the top half. A 3D model was used to simulate a sample for a three points bending test, which has alumina at the top and porcelain at the bottom. The initial temperature was considered 310K, as well as the strain reference temperature. A heat flux was considered on all of the external walls. The samples stayed in an environment with 328K for 15 seconds, and then they were transferred to a 278K environment, where they stayed for other 15 seconds. The transfer time is considered 5 seconds. A finer triangular element size was used to mesh the cylinder and a finer tetragonal element size was used for the other geometry.

Figure 1 shows the maximum stress at the cylinder as function of time and the stress state at 15 seconds, 20 seconds and 35 seconds. At the end of the cycle, the porcelain region is under tension and the alumina region is under compression. However, just after the samples leave the hot liquid, it is the other way around. (Figure 2) shows the same stress evaluation for the three-point bending test sample. The maximum stress increases just after it was dived into the hot liquid, then it decreases during the transferring. However, when it was dived into the cold environment, the maximum stress rapidly increases, but after a peak, it comes back to decrease until the end of

the cycle.
For the cylinder, the maximum stress is always at the interface between the materials. However, in the second case, during the heating the stresses are concentrated throughout the part, and just during the cooling, the stress concentrates at the interface. In only one cycle, the stresses are small, due to the small temperature change and similar properties between alumina and porcelain. However, theses stresses can be expressive if one consider that the restoration will undergo several cycles during its lifetime.

Figures used in the abstract

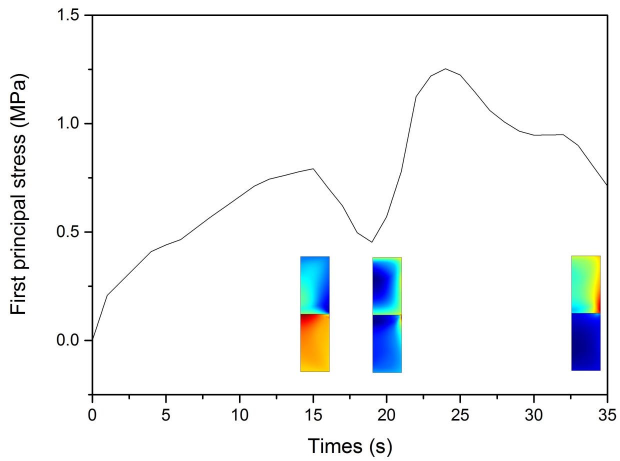

Figure 1: Evolution of maximum stress at the cylinder through the time. The stress state at 15, 20 and 35 seconds is also shown at the graph.

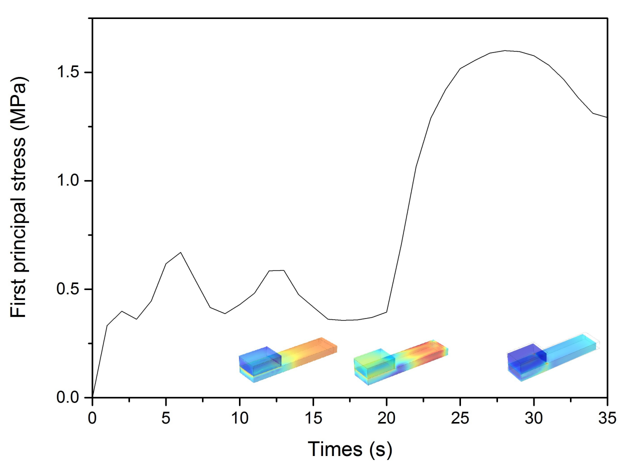

Figure 2: Evolution of maximum stress at the three-point bending test sample through the time. The stress state at 15, 20 and 35 seconds is also shown at the graph.