Influence of silica and alumina doping on the microstructure and the mechanical properties of zirconia ceramics used for Joint Prostheses applications.

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Abstract.
Yttria-stabilized zirconia is a surgical grade zirconia ceramic, which exhibits a phase transformation toughening. This toughening is at the origin of the excellent mechanical properties (toughness and strength) of zirconia ceramics, particularly in comparison to alumina ceramics. Zirconia ceramics thus appear today to be an excellent choice for the new generation of ceramic - ceramic joint prostheses. For these couples, ageing in vivo must be reduced to the minimum, in the perspective of long term prostheses on young patients. This was the aim of this work to control the doping of a surgical grade zirconia ceramic, with small amount of silica and alumina, in order to obtain ageing resistant materials. It is shown that, by adding a vitreous phase at triple grain boundaries, ageing resistance is enhanced but zirconia keeps its outstanding mechanical properties.

Introduction.
Yttria-stabilized Zirconia ceramics were introduced in orthopaedy in 1985, for Total Hip Replacement as hip joint heads. Zirconia exhibits phase transformation toughening, which acts to resist crack propagation. This toughening is at the origin of zirconia’s excellent mechanical properties (toughness and strength), particularly in comparison to alumina ceramics. The use of zirconia ceramics has allowed the development of a large variety of femoral heads designs down to 22.22 mm and opens the way to reliable ceramic - ceramic couples or knee prostheses. Moreover, zirconia femoral heads are shown to induce the lowest amount of wear debris against polyethylene or another ceramic.

In the past few years, the issue of the stability of zirconia in water has been widely discussed. Many studies have shown that zirconia ceramics were prone to Low Temperature Degradation (LTD) in water vapor, in the range of 200°C-300°C. Thus, the question of the stability of zirconia in-vivo was raised, especially by the competitors to zirconia. However, it was clearly shown recently that LTD was not a concern for femoral heads articulating against polyethylene, if a control of the density and grain size was systematically done. Approximately 25 years are required at 37°C to induce detectable transformation at the surface.

However, considering an aging population and a growing demand for implants with a lifetime of more than 30 years, LTD needs to be delayed for the new generation of prostheses (for example ceramic-ceramic couples). Our goal was then to increase the resistance of zirconia ceramics to isothermal transformation without affecting their good crack resistance. Increasing only the grain size is not appropriate, since it plays a contradictory role on crack...