Mechanical & Physical Properties of Dental Ceramics
Introduction

What is important about dental ceramics is how closely their various properties have been designed to fit their purpose, and how these properties can be altered by the manufacturing techniques of the technician.

To examine this, we have to look a bit more closely at how such properties are controlled by the material structure
Dental ceramics have the mechanical properties of a typical glass. They have a much higher compressive strength than tensile strength. In fact, their properties are usually not quoted as compressive or tensile strengths, but as a flexural test and as we have said, they are brittle.
Mechanical Properties

Probably the best way to understand these properties is to do a *simple experiment*.

Take two of sticks of chalk.
- Pick up one and break it.
- Note how hard, or how easy it was.
- How did you break it?
Mechanical Properties

- You probably took the stick at each end, put your thumbs under the middle, and bent the stick until it broke.
- Take another stick and grip it at both ends
- Pull it in a straight line until it breaks.
Mechanical Properties
The second test is a tensile test, unlike your first experiment, which broke the chalk by applying a bending load. You will almost certainly find that it is much harder to break the chalk under direct tension.
Mechanical Properties

As you can see from the diagrams, bending a test piece puts the outside of the bend in tension, (you are making it stretch) and the inside of the bend under compression (you are trying to make shorter).
Mechanical Properties
The third test: take one of the broken half sticks of chalk, put it vertically on the palm of one hand, and then try to break it by compressing it, pushing downwards. It is very difficult to break it this way.
Mechanical Properties

What does this prove?

✓ That chalk, like any other brittle material, is many times stronger in compression than in tension.

✓ That a bending force will cause much higher tensile stresses in the outside of a bent object than can be found in direct tension; that is why it is easier to break brittle materials by bending them than by pulling them.
Join these two facts together, and you understand why dental ceramics must be made so as to avoid bending stresses in their application. Think of a multiple-unit restoration. If it doesn’t fit perfectly at either end or is periodontally compromised, the chances of creating a destructive flexural load in use are high.
Mechanical Properties

Think of a single crown. If it is a tight fit on the preparation pushing it into place forces the bottom perimeter, at the margins, apart. This places the crown under an “opening” bending stress and this demonstrates the need for great accuracy in manufacturing ceramic restorations.
Mechanical Properties

The reason that ceramics fail this way puzzled science for a while; the strength of the covalent bonds in them should have produced much greater strength. Only the presence of many minute cracks, called “Griffith’s Microcracks” after their discoverer could explain the low tensile strengths.
In fact it was discovered shortly after Griffith’s suggestion, that almost all ceramics contain a lot of such tiny cracks as a result of how they are made. Small cracks, with a sharp radius at the tip, create very much larger tensile stresses at their tips, and lead to early tensile failure.
How do such cracks get there?

When you **cool a ceramic too rapidly** (as technicians can) or by **slight tensile stresses** (compressive stresses tend to close up cracks, not open them). There is also **porosity** in many ceramics, a set of small cracks, in effect. The less porosity in a dental ceramic restoration, the stronger it is.
Mechanical Properties
This can be proved in a simple test:

The flexural strength of a typical fired dental ceramic is about 70Mpa.
If the test piece is glazed there will be no microcracks or porosity in the surface region where the tensile stresses caused by bending are greatest, and where a crack will almost certainly start under a bending force.

After being glazed, the component will have more than doubled its flexural strength, to 150Mpa!
Mechanical Properties

A hardness comparison: (Vickers Hardness Scale)

1. Human teeth have at best a hardness of about 300 VHN

2. Cobalt/Chromium alloys, have a hardness of about 450 VHN.

3. Dental ceramics can be as hard as 800 VHN
Physical Properties

The **softening temperature** of many ceramics is well above the melting point of most metals. That is why we use ceramics as refractories, or heat resistant material in furnaces. In fact, such **ceramics do not melt**, as we know it for metals, they behave more like thermoplastic polymers.
Physical Properties

As the temperature is raised, they undergo a gradual change from a rigid solid to a **viscous liquid**. This change in viscosity with temperature is called the **glass transition**. This ability of ceramics to soften at high temperatures is why the particles of glass in a dental ceramic will **flow slightly and fuse together** at their firing temperature.
Physical Properties

The coefficient of linear expansion is vitally important to dental ceramics. Ceramics generally expand slightly less than metals, and much less than polymers over any given temperature range.
Physical Properties

Typical coefficients: (CTE)

- metals are about $15 \times 10^{-6}/^\circ\text{C}$
- ceramics are about $11 \times 10^{-6}/^\circ\text{C}$
- polymers are about $300 \times 10^{-6}/^\circ\text{C}$

This means that a ceramic crown will not work its way free of a human tooth preparation with continued expansion and contraction, whereas some polymer restorations will.
Physical Properties

As it is so important to avoid cracking the ceramic, the coefficient of expansion of ceramics used for the PFM technique must be very accurately designed to match that of the metal they are being bonded to.