RESEARCH LABORATORY FOR DENTAL BIOMATERIALS

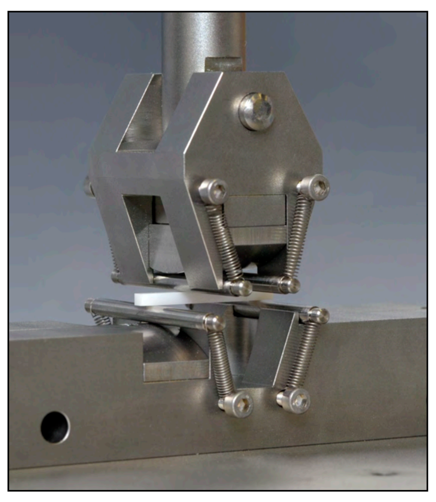
Friedrich-Alexander-Universität
Faculty of Medicine

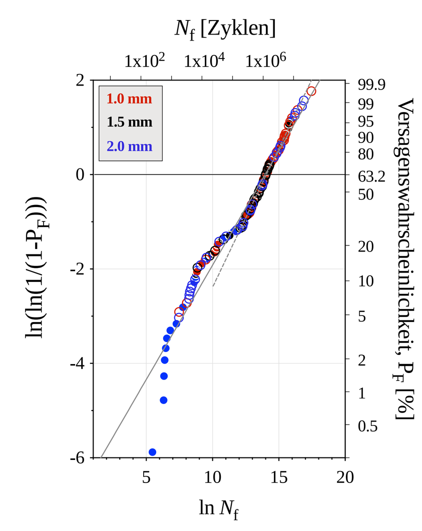
Uniklinikum Erlangen

Mechanical Testing

Flexural Strength

- It measures the critical outer fibre stress in bending necessary for the largest defect in a specimen volume and surface to reach the critical stress intensity factor.
- A test series contain preferably >30 specimens in order to sample the defect size distribution of the parent defect population, resulting in a distribution of strength.
- Whether in uniaxial or biaxial stress, the distribution of strength values is analysed using Weibull statistics to obtain the Weibull modulus and the characteristic strength.

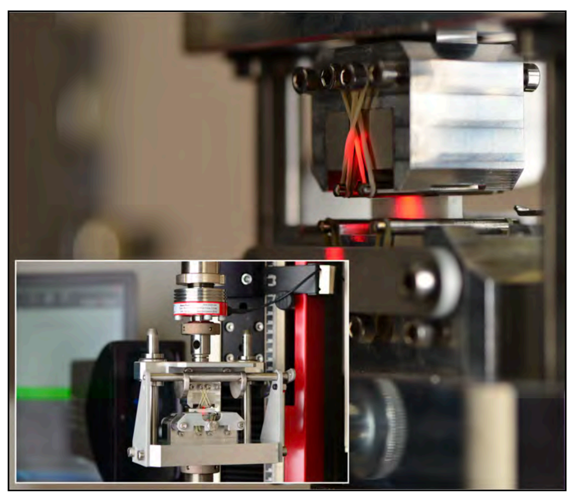


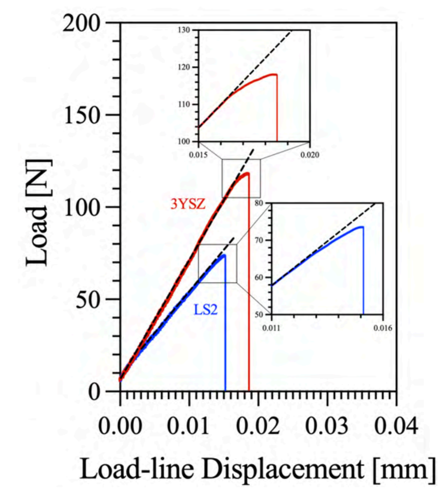


- (Left): Strength of a ceramic beam being tested under 4-point bending in a universal testing machine (quasi-static).
- (Right): Weibull plot showing the failure probability distribution of strength values in specimens with different volumes and surface areas.

Fracture Toughness

- Is the *critical stress intensity factor*, or K_{Ic}, relating the strength to the critical crack size, through the Griffith-Irwin relation.
- It is obtained through the strength testing of a specimen containing a crack with a defined size and geometry.
- The crack geometry function is particular to each specific test configuration, loading condition, crack shape and size relative to the thickness of the specimen.

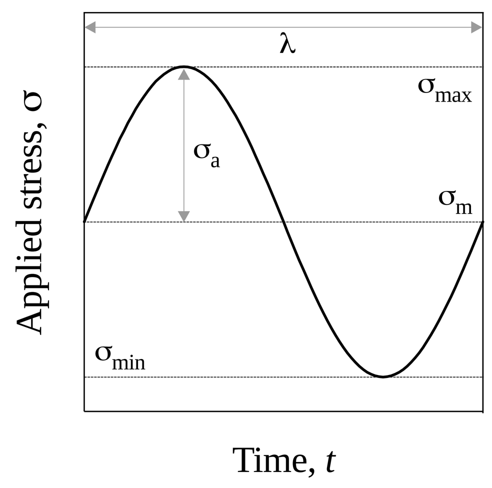




- (Left): Fracture toughness testing of a ceramic specimen containing a sharp precrack in a bending jig.
- (Right): Load-displacement diagram traced by optical speckle tracking formed by laser illumination.

Subcritical Crack Growth (Fatigue)

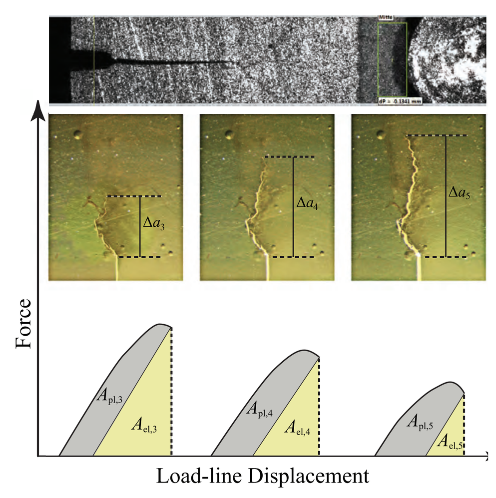
- It characterizes the susceptibility of a material to undergo crack growth when subjected to a stress level below the critical stress for quasi-static fracture.
- It can have a chemical nature, such as through the corrosive action of water on oxide bonds, or purely mechanical, by the degradation of toughening mechanisms.
- It is tested using strength tests under different conditions: dynamic, static or cyclic loading, yielding the fatigue exponent *n and* crack velocity relations.

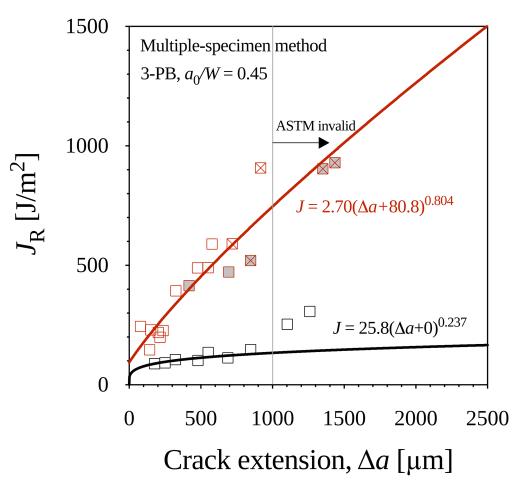


- (Left): Ball-on-3-Balls configuration in round discs and square plate configurations for the mechanical testing of quasi-static and fatigue of dental ceramics.
- (Right): Sinusoidal stress profile utilised for fatigue cyclic experiments in bending mode.

R-Curve Behavior

- Occurs in materials where the fracture toughness is not a single material property, but it rather increases during the extension of a crack.
- It is mostly induced by microstructural features as opposed to amorphous materials, in which crystals, particles, fibers, etc. induce shielding mechanisms.
- It is tested using fracture toughness tests by tracking the crack extension during loading, using optical or compliance techniques.

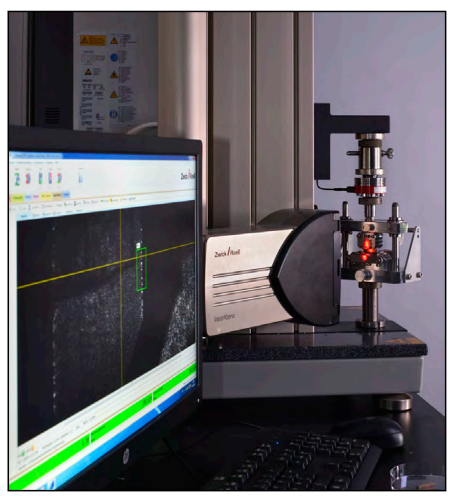


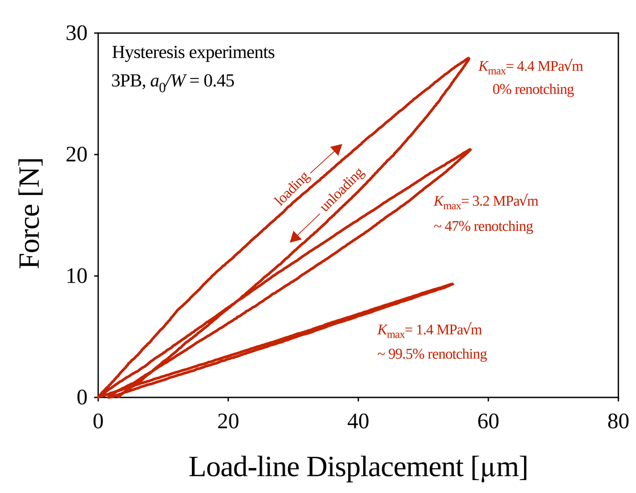


- (Left): Optical tracking and measurement of different crack lengths on the specimen following interrupted measurements.
- (Right): Elastic-plastic R-curve plot for two fiber-reinforced composites.

Hysteresis

- Is a mechanical behaviour characterised by its time-dependency on the strain, when the elastic recovery has a time delay.
- It is mostly present in viscoelastic materials, but can also be induced in ceramics by the action of frictional elements that oppose crack closing.
- It is tested using typical tension or bending tests below the critical stress by loading and unloading, needing an accurate measurement of the specimen's compliance.

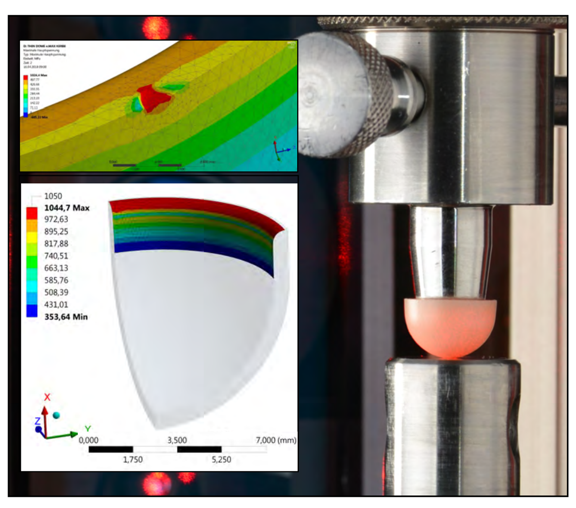




- (Left): Optical tracking of specimen compliance using a laser.
- (Right): Hysteresis plots showing the time-dependency of load recovery.

Bench-Testing

- Are non-standardised mechanical tests that incorporate aspects relevant to the real-life application, by modifying loading configurations, test parameters and geometry.
- They deliver behaviors that may be easier to relate to application scenarios, but tend to be more phenomenological and less formalized.
- Most bench-tests in dental materials take the form of chewing simulation or strength tests using specimens with geometries analogous to dental prostheses.



- (Left): Testing and simulation of the hoop-strength test using Finite Element Analysis.
- (Right): Chewing simulation in thermo-tempered chambers of dental crowns.