Specific Problems occurred in Dental Materials

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Abstract: High hardness of metallic materials in order to increase sustainability in exploitation must be associated with strength to satisfactory dynamic stresses with shock. In the case of mastication with high contact tensions, the contact area of the superficial layers is under a state of special-complex voltage.

Key words: fatigue strength, implant, plane distortion, plane tension.

1 Introduction

Internal tensions of appreciable values (400-600) MPa influence negatively the durability of metallic and nonmetallic materials. Detailed research of the tension state in the area of contact has been undertaken by many researchers [2], Fig.1.

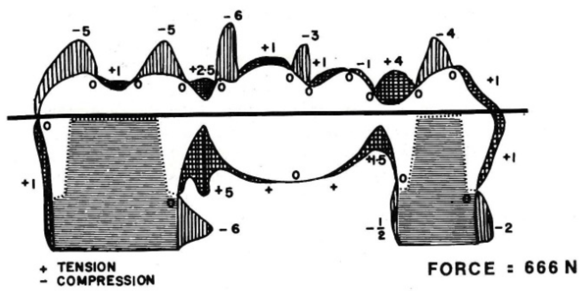

Fig.1 The fringe order or a measure of the magnitude of the stress at the periphery.

Elastic testing at a macro-scale has effects of plastic distortion started at the micro scale, which then transforms at the macro scale, with the increasing number of cyclical stresses, producing cracks that represent the fusing of the breaking phenomenon under fatigue circumstances.

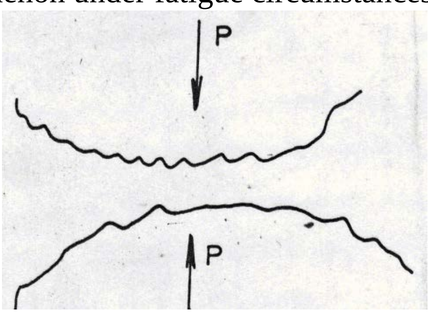

Fig.2 Microirregularities of the contact area.

Plastic strains of small value occur even at light loadings due to micro irregularities of the areas of contact (Fig.2). Elastic distortion or Δ proximity between areas of contact varies linearly with the load $F^2/3$ (Fig.3).

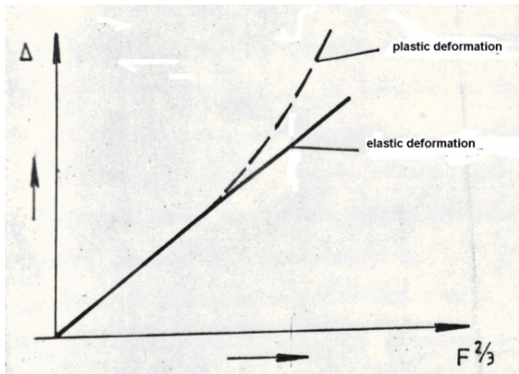

Fig.3 Graphic representation of the elastic distortion between the areas of contact

2Theoretical and Experimental Aspects

Also, the deformability variation of a material with temperature must be studied in order to be chosen the field of distortion temperature at which the deformability is maximum to obtain the desired structure and the hardness, by controlling the deformability being obtained the required form and properties. The material's deformability is expressed by several reports:

$$\varepsilon_l = \frac{l - l_0}{l_0} \quad ; \qquad \varepsilon_d = \frac{d_0 - d}{d_0} \quad ;$$

$$\psi = \frac{A_0 - A}{A_0} \quad ; \qquad \varphi = l_a \frac{l}{l_0} \qquad (1)$$

where l_o = the length, d_o = the diameter and A_0=the area of the tube's section before distortion and l = the length, d = the diameter and A = the area of the minimum section after the breaking.
On repeated stresses occurred after mastication, the materials are destroyed, sometimes without prior arise of remaining strains. The initial crack starts from a defect within the material or processing the surface. In the case of jaws' contacts it can not be reached a limit of tensions at which not to occur fatigue damage. Materials break at a number of stress cycles, behaving according to curve type 2 from Fig. 4.

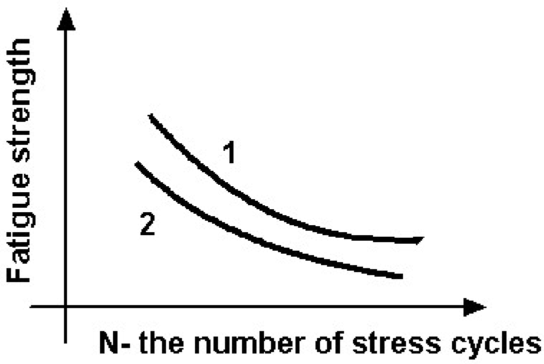

Fig. 4 Materials´ behavior in case of jaws´ contacts

Both imperfections and surface defects are weaknesses. In the vicinity of these weaknesses, because of repeated stresses, strong local concentration of tensions with local modifications occurs, due to which are initiated the first micro cracks. Localization of plastic distortion in a small volume of crystals in the cyclical stresses and not its development over most of the crystals in the static stresses radically distinguishes phenomenological variables in time, from the static ones. Generally for metals, the fatigue endurance σ-1 is contained in the interval (0.40-0.55) σ_r
Titanium and its alloys are ideal materials for implants performance under variable stresses, even under unfavorable environmental conditions. The elements of alloys as molybdenum, chromium, vanadium and wolfram increasing fatigue strength and also decreasing the sensitivity to tension concentrators. Negative influence of scratches and the amount of inclusions may lead to premature destruction of the implant even after a low number of mastication cycles (Fig.5). Chemical and dimensional homogeneity of networks guarantees obtaining high limits of strength to fatigue.

Fig.5 Premature destruction of the implant

Experimental studies have shown that initiation of crack in areas where tangential tensions are maximum coincides with material's discontinuities. Cracks are propagated towards surface through the effects of indent. Generally, the state of tensions at the crack's extremity is spatial (Fig.6). Using finite element modeling, it is shown that in areas of the material located towards surface, the state of tensions becomes smooth and distortions occur after the second direction, manifested by contraction phenomena.

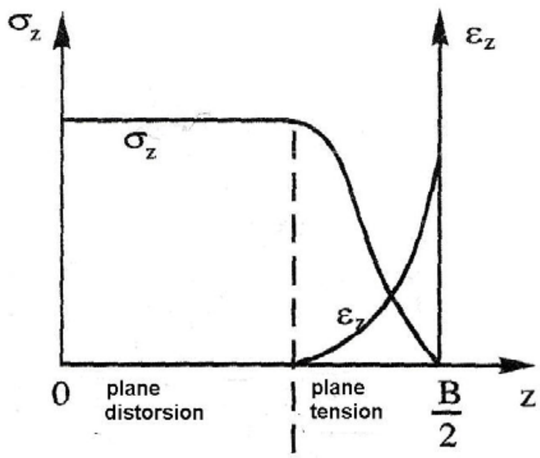

Fig.6 Numerical modeling of the state of tension depending on the thickness of the material

To obtain complete information on the propagation of cracks, is needed the examination of the curves of strength to breakage Y_r. But the initiation of stable propagation of the crack is practically impossible to be defined with precision, being estimated in the same way as the conventional limit of the elastic field is. The parameter that provides information on stability of the crack's growth is the tangent of the angle to the curve Y_r to a given point. (Fig.7).

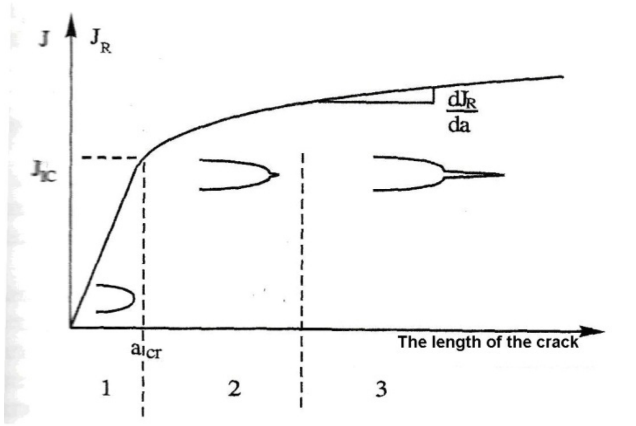

Fig.7 The shape of J curves for ductile materials. (1) Rounding phenomena at the crack´s extremity; (2) Crack´s extension-stable propagation; (3) Instable propagation of the crack.

Cracks develop starting from interatomic dimensions. The way of occurrence and development of micro crack is determined mainly by the crystallographic nature of the material. There are several ways of breakings at the micro structural level:

-fragile transgranular breaking;
-fragile intergranular breaking;
-fragile shearing breaking;
-ductile breaking;

3 The breaking of ceramic materials

Ceramic materials have a structure based on covalent or ionic link types. Tensions' values of breaking are lower than the theoretical values, due to defects located at grains limit. Ceramics present a type of intergranular breaking. Impurities in the initial powders with additional substances lead to the formation of segregations at the limit of the grains.

In practice sometimes occur breakings of ceramic materials because of the static fatigue as consequence of progressive development of superficial microcracks, phenomenon accelerated by the presence of saliva (in fact, there is an erosion phenomenon under tension).

4 The breaking of composite materials

There is not a general valid pattern of breaking, the aspect and mechanisms that occur are dependent on the internal composition, the components' nature and execution technologies. Frequently encountered causes of damage and breaking are residual tensions arising from differences in coefficients of thermal expansion among constituents.

In case of short fibers composites used as restorative materials, breaking mechanisms are similar to those of metal alloys, through the appearance of the cavities, their growth and union in macro cracks.

5 The propagation of the cracks under fatigue circumstances

The phenomenon of destruction caused by variable repeating stresses that occur for a number of times constitutes the overwhelming cause of destruction of materials used in restorative dental technique.

Cycles represented in Fig.8 have approximately the same effect in terms of the fatigue strength In general, in mastication process appear random requests such as those in Fig.9. Materials' fatigue studies the changes that occur in mechanical properties of a material subjected to cyclic applications.

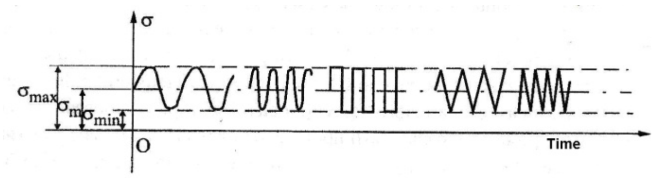

Fig.8 Cycles of fatigue strength

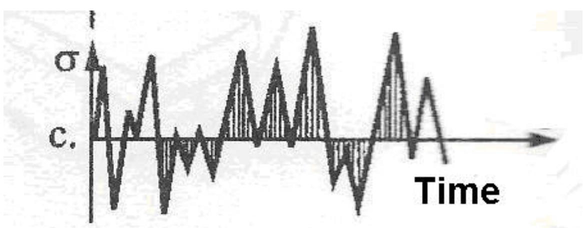

Fig. 9 Random stresses occuring in mastication.

Fatigue strength depends on material composition and structure. Fixed and uniform structure leads to a greater strength than the structure with large granulation.

Area's state and technical treatments also influence fatigue strength (Fig.10).

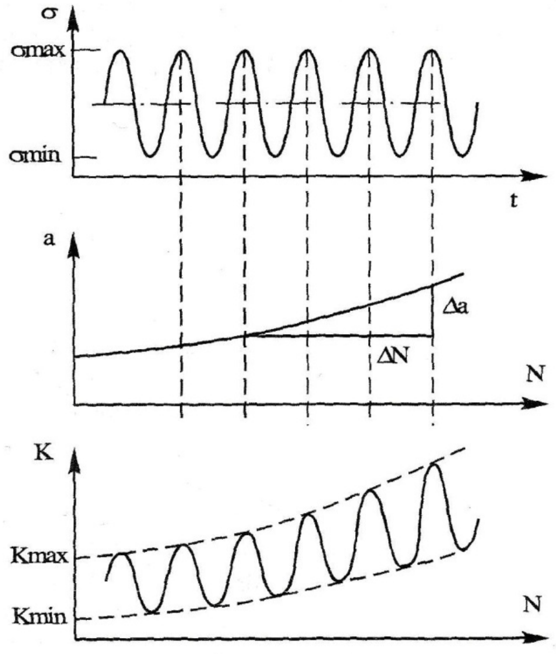

Fig. 10 The growth of crack´s length produces a variation of Kmin size.

The increasing length of Δa crack to fatigue will be dependent on:

-the value of maximum factor of intensity of $K_{\max}$ tensions

-the value of intensity factor's variation of ΔK tensions

-the value of asymmetry rapport of R cycles ($R = \frac{\sigma_{\min}}{\sigma_{\max}} = \frac{K_{\min}}{K_{\max}}$)

The propagation speed of the crack at fatigue depends on at least two parameters; as a general expression, it may be write:

$$v = \frac{da}{dN} = f\left(K_{\max}, \Delta K\right) \quad \text{or} \quad v = \frac{da}{dN} = f\left(\Delta K, R\right) \qquad (2)$$

The study of fatigue phenomena of materials seen in the perspective of exploitation lies in determining the propagation speed of cracks in a certain quality of material. The occurrence of fatigue cracks takes place from the surface through the material phenomena of intrusion-extrusion along slip bands generated by the cyclical application (Fig.11).

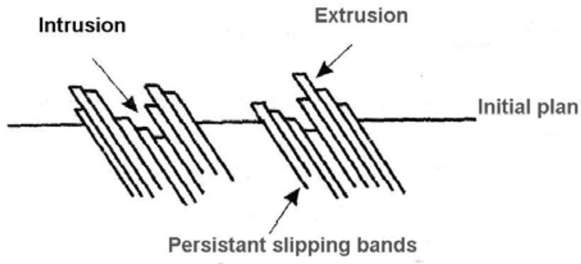

Fig.11 The development of microcracks starting from the material´s surface

As observation, it can be concluded that any structure of any material contains microcracks after the first cycle of operation. Studying the phenomena of fatigue, the number of cycles N is a reference value, uniquely determined and the crack's length is questionable value, as the front to propagate the fatigue cracks has an irregular, complex shape. The general shape of a phenomenology model is:

$$\frac{da}{dN} = C\left(\Delta K\right)^m \qquad (3)$$

where C and m are constants determined experimentally.

Of practical interest is to determine the life duration in the case of cyclical stresses from the law expression of cracks' propagation. For the general case of an exponential law:

$$N = \int_{ai}^{af} \frac{da}{C\left(\Delta K\right)^m} \qquad (4)$$

where a_i is the initial length and a_f represents the final length of the crack (a_f can be considered as critical length and is dependent on the material's ductility).

6 Conclusions

Resilience has particular importance in the evaluation of orthodontic wires because the amount of work expected from a particular spring in moving a tooth is of interest.

As with other mechanical properties, aging or storage in a simulated oral environment or at elevated temperatures can decrease the fracture toughness. Attempts to correlate fracture toughness with wear resistance have been mixed, and therefore it is not an unequivocal predictor of the wear of restorative materials. Also, numerical analysis rechnics have been applied to composites and the tooth-denture base joint to determine energy release rates in the presence of cracks.

A variety of brittle restorative materials, including dental amalgam, cements, ceramic materials, plaster and stone, and some impression materials, is important to dental practice.

The shear strength is the maximum stress that a material can withstand before failure in a shear mode of loading. It is very important in the study of interfaces between two materials, such as a porcelain fused to metal restoration or an implant tissue interface.

A variety of tests are recomandated to measure the bond strength between two materials such as porcelains to metal; cements to metal; and polymers, ceramics, resin composites, and adhesives to human enamel and dentin.

When the stress is frecquently repeated, the strength of the material may be drastically reduced and ultimately cause failure. Failure under repeated or cyclic loading is therefore dependent on the magnitude of the load and the number of loading repetitions.

The rate of loading is important in many materials, particularly polymers and soft tissues.

Tear strength is a measure of the resistance of a material to tearing forces. Tear strength is an important property of dental polymers used in thin sections, such as flexible impression materials in interproximal areas, maxillofacial materials, and soft liners for dentures. Specimens are usually crescent shaped and notched. Many materials used in dentistry are not homogeneous solids but consist of two or more essentially insoluble phases.

As a further illustration of the factors that effect the properties of a composite, consider the filled polymer resins used in dentistry.

For many of these dental composites a random arrangement of the dispersed phase is used, even though a random orientation results in about a sixfold lower strength compared to an oriented dispersed phase.

The property of hardness is of major importance in the comparison of restorative materials. Hardness represents the resistance to permanent surface indentation or penetration. Hardness is therefore a measure of the resistance to plastic deformation.

The importance of friction in dentistry lies in the concept of roughening the surface of a dental implant to reduce motion between the implant and adjacent tissue. It is perceived that a rough surface and resultant less motion will provide better osseointegration.

References:

[1] Bolfa T., Neamtu T.- Researches on plastic deformation capacity in correlation with macrostructural parameters. Research contract nr.89/85.

[2] Robert G. Craig - *Restorative dental materials*, 1996.

[3] Dimitriu St. - *Mecanica ruperii*, Brasov,2002.

[4] Bolfa T. - *Rezistenta materialelor*, Ed. Lux Libris, Brasov, 2000.