Biomaterials Journal
http://www.biomatj.com
Online ISSN: 2812-5045

Type of the Paper (Review Article)

Assessment of chemical degradation in dentistry :a review

Layla Mahmoud bakir [1,*] and Hebatallah Fathy [1]

Citation: *Layla Mahmoud bakir and **Hebatallah Fathy** . **Assessment of chemical degradation in dentistry :a review** . Biomat. J., 2 (5),30 – 36 (2023)*

https://doi.org/10.5281/znodo.5829408

Received: 20 May 2023
Accepted: 30 May 2023
Published: 31 May 2023

[1] *Department of* Biomaterials Faculty of Dentistry, Cairo University

* Corresponding author e-mail: layla.mahmoud@dentistry.cu.edu.eg

Abstract:. Analysis of the reasons for structural degradation and failure of the employed materials is crucial in order to forecast how well the clinical performance of the dental materials will perform in the patient's mouth. The oral cavity is a challenging environment with pH and temperature variations, various stressors, and bacteria. The most frequent causes of dental material failure are poor material selection, poor design, or overuse. Damage might also happen while being repaired. It's crucial to prepare for failure, identify its causes, and take the appropriate precautions to avoid material failure**.**

Keywords: *Chemical degradation, dentistry, degrdation and aging.*

Introduction

It's important to predict the clinical performance of the dental materials used in the patient's mouth; therefore, it's essential to analyse the causes of structural degradation and failure of the materials used. The oral cavity is a harsh environment with fluctuations in pH and temperature, different stresses, and bacteria. Improper material selection, inadequate design, or misuse are the most common reasons for the failure of dental materials. Also, damage can occur during service. It's important to plan to avoid failure, assess the causes, and take the necessary preventive measures to prevent material failure.[1]

Dental material failure assessment can be classified into

1) Chemical degradation.
2) Biological degradation.
3) Mechanical degradation.
4) Optical degradation.
5) Thermal degradation.

1) Assessment of chemical degradation

A. Metal degradation

Tarnish is a staining of the surface caused by the production of hard and soft deposits. It doesn't cause material deterioration, but it is unpleasant and may be simply removed by polishing the metal. While, corrosion is a chemical interaction between the material (usually metals) and its surroundings, causing material degradation, so it's a far more significant problem. The corrosion process for metals in the oral environment is usually electrochemical, with the removal of electrons in an oxidation (anodic) reaction at the anode, converting the metal to a positively charged ion:

$M \rightarrow M^{n+} + ne^-$

Depending on the environment, a variety of reduction (cathodic) reactions at the cathode can occur. Metal ions take the electrons to produce metal atoms:

$M^{n+} + ne^- \rightarrow M$

When the environment is hostile; has strong temperature and pH fluctuations, all metals are susceptible to corrosive attack, which is a problem because it weakens materials, can cause fractures, and may also react negatively with the biological environment.[1]

Methods of testing metal degradation

Identification and quantification of degradation products from metals and alloys", there are 2 methods. Test solutions (electrolytes) to be used are either saline, artificial saliva, or artificial plasma. It's selected according to the environment to be surrounding the material in vivo. The sample shape can be circular or bar with a rectangular cross-section, but it is usually preferred to resemble the final shape to be used in vivo. The surface condition of the sample also should match that to be used in vivo.

1. Electrochemical test:

It is used to know the overall electrochemical behavior of the metal or alloy.

Procedure:

• Clean the specimen ultrasonically for 10 to 15 minutes in ethanol, then rinse with water and immediately transfer it to the test cell.

• Only the test surface should be in touch with the electrolyte, thus place it in a waterproof electrode holder. The sample is known as the working electrode. The counter electrode is either platinum in the shape of a grid, plate, or wire, or crystalline carbon of area 10 times or more than that of the sample.

Note: This difference in area is to ensure that there is continuous uptake of the ions from the solution at the cathode, so that ion saturation of the electrolyte does not occur, which leads to the termination of the corrosion reaction process.

• Avoid creating conditions (e.g. scratches) that could lead to crevice corrosion due to the formation of a crevice between the holder and the sample.

• Set up the test apparatus, and then fill the test container with the electrolyte. Temperature of the water bath should be maintained at 37°C.

• Oxygen level within the electrolyte is decreased before the beginning of the test by pumping nitrogen or argon.

• During the test period, continuous stirring of the electrolyte is done either by gas agitation or magnetic stirrers, to avoid concentration gradient.

• The breakdown potential (Ep) of the sample is determined by cyclic polarization. It's the electrode potential above which localized corrosion occurs.[2] (Figure 1)

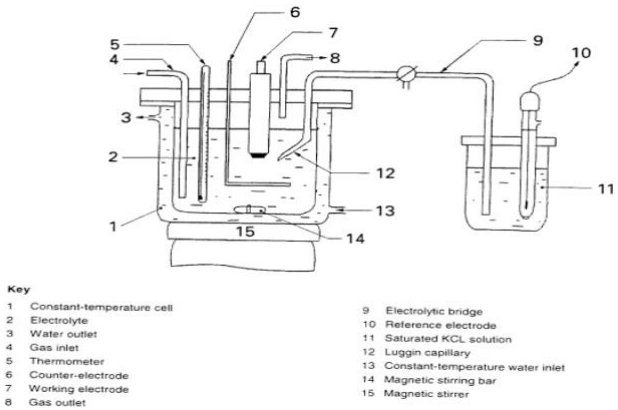

Fig. 1 A diagram of electrolytic test cell

2. <u>Immersion test:</u>

It is utilized to degrade the test material chemically in order to generate degradation products that can be analyzed.

Procedure:

• Calculated volume of the electrolyte of choice is poured in a glass container, which is placed in a water bath.

• Immerse the sample in the electrolyte, make sure it does not touch the walls of the glass container or touch each other if more than one sample is placed in the same container.

• The size of the glass container, as well as the number of samples to be used in one container, is determined so that less than 1 ml of the electrolyte is covering 1cm2 of the sample surface.

- Measure the initial pH value of the electrolyte at the start of the test.
- Close the container tightly, and keep at 37°C for 7 days.
- At the end of the test, remove the sample, then measure the pH value of the electrolyte again.
- Examine the surface of the samples under microscope of either low or high magnification, depending on the extent of details needed.
- The electrolyte undergoes qualitative and quantitative analysis using mass spectroscopy, atomic absorption spectroscopy, etc. Note: Both sample surface analysis and electrolyte analysis must be done together, as some corrosion products deposit on the sample surface and don't dissolve.[2]

B. Polymer degradation

Many polymers used in dentistry are sensitive to solvent absorption (mainly water), pushing the polymer chains apart and inducing swelling and slippage of chains, loss of soluble components, as well as affecting the matrix-fillers interface. Water acts as a plasticizer where it neutralizes the secondary bonds between the chains that prevent the slippage of the chains against each other. The end result is that the polymer gets softer, the glass transition temperature lowers, and the strength may be reduced. In dental materials based on polymers, unbound monomers and degradation products infiltrate into the pulp and other adjacent tissues, ultimately entering the circulation, giving possible biological risks as: being potential carcinogens and inducing immunological responses. Mastication forces result in increased material sensitivity to abrasive wear due to the softening of the polymer.[3]

Methods of testing polymer degradation

Identification and quantification of degradation products from polymeric medical devices", there are 2 tests.

The procedure is common; the difference lies in the temperature used and period of testing.

1. **Accelerated degradation test:**

- Temperature: higher than 37 °C but below the polymer's melting or softening range. Usually, 70±2 °C is employed.
- Test periods: 2 to 60 days for devices of more than 30 days usage. 2 to 7 days for devices of less than 30 days usage. Time can last until the material loses integrity if it is made of resorbable polymers. N.B.: the term Usage refers to the intended time the device should be serving in the intended environment (e.g the oral cavity). [3]

2. **Real time degradation test in simulated environment:**

- Temperature: 37±1 °C

• Test periods: 1,3,6 and 12 months for devices of more than 30 days usage. 4 time intervals within 30 days for devices of less than 30 days usage. Time can last until the material loses integrity if it is made of resorbable polymers.

These tests are to be done in order, where the accelerated test is done first, and if the analysis of the degradation products doesn't help in their risk assessment, real time test is to be done subsequently. Procedure:

• Sample is prepared. It should be taken in consideration to minimize or eliminate the parts that will not be in contact with the environment in in vivo conditions.

• The initial mass of the sample is recorded.

• The test solution to be used should be nearly the same as the in vivo environment of interest (e.g. artificial saliva).

• The sample is immersed in the test solution.

• Time and temperature of test depend on the selected test (accelerated or real-time). The pH value is selected to simulate the in vivo environment.

• The sample is then removed from the solution, rinsed, dried, and its final mass is measured.

• Since the rinse water could contain debris loosened from the sample, it should be added to the test solution for analysis of residual monomers and leached elements.

• High-performance liquid chromatography and mass spectroscopy are used for identifying and quantifying residual monomers and leached elements.[3]

C. Ceramic degradation

Ceramics are more resistant to electrochemical corrosion than metals, yet they are still subject to chemical corrosion, which can have a significant impact on ceramic strength. Ceramic failure is usually caused by crack propagation. At the crack tip, chemical interactions between the ceramic and the environment can have a significant impact on the pace of crack propagation. E.g.: Water or water vapor at the crack tip can create hydroxides by reacting with the Si–O–Si bond at the crack tip in a silica-based glass.

When environmental factors are paired with high levels of stress in the ceramic, the crack's rate of propagation is significantly increased. In such cases, the failure can be attributed to stress corrosion cracking. Ceramics are prone to chemical corrosion in the range of oral fluid pH. The dissolving potentials of ceramics in acidic beverages such as soda (pH 2.5-4) vary depending on the patient's saliva and diet buffering ability. Glass-phase ceramics can also be dissolved by basic items like antacids (pH 10-14).[4]

Methods of testing ceramic degradation

Identification and quantification of degradation products from ceramics", there are 2 methods.

1. **Extreme solution test:**

Most ceramics can be screened for probable breakdown products using an extreme solution test performed at a low pH.

Procedure:

• Sample to be tested is grinded to a suitable particle size (i.e. sample is in powder form), where it should be between 400 and 315 μm.

• Depending on the solubility of the particles, the initial mass is determined. For high solubility, 10 g should be used, while for low solubility 5 g are enough.

• A plastic container (e.g. polypropylene) is used for the test. Glass containers are to be avoided because they may contaminate the test solution.

• Test solution is buffered citric acid of pH=3.

• The container is placed in water bath of 37˚C for 120 hours. If the specimen totally dissolves before 120 hours, time should be recorded.

• Continuous shaking of the container is done mechanically.

• At the end of test period, the container is left to cool to room temperature.

• A filter paper of known mass is used to filtrate the remaining undissolved particles from the solution.

• The filtered solution is analyzed using inductively coupled plasma spectroscopy, atomic absorption spectroscopy or mass spectroscopy.

Rinse the filter paper having the remaining particles with water to remove the citric acid, dry, and then weigh them.

• The difference between the mass of the filter paper before and after filtering is the mass of the remaining specimen.

• Subtracting this mass from the initial mass of the specimen gives value of the mass of the dissolved part. [4]

2. **Simulation solution test:**

It uses a pH that is more commonly observed in vivo. It follows the same procedure as the extreme solution test, with slight differences:

• The test solution is Tris (hydroxymethyl) aminomethane hydrochloride (TRIS-HCI) buffer of pH=7.4, this resembles the normal pH level within the body.

• The sample could be put as a coating on a disc of dimensions 36x2 mm or could be grinded as in the extreme solution test.[4] (Figure 2)

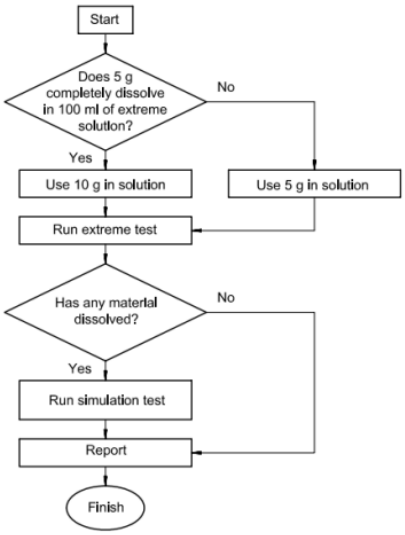

Fig. 2 Flowchart for testing sequence

References

1. Anusavice K., Shen C. and Rawls R.H, (2013): Phillips Science of dental materials: 12th ed. Saunders,.
2. ISO 10993-15 standards for " Biological evaluation of medical devices - Part 15: Identification and quantification of degradation products from metals and alloys" First edition 2000-12-01 Corrected and reprinted 2001-04-01.
3. ISO 10993-13 standards for " Biological evaluation of medical devices - Part 13: Identification and quantification of degradation products from polymeric medical devices" Second edition 2010-06-15.
4. ISO 10993-14 standards for " Biological evaluation of medical devices - Part 14: Identification and quantification of degradation products from ceramics" First edition 2001-11-15.