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Dentistry — Determination of tarnish and corrosion of metals and alloys

*Art dentaire — Détermination du ternissement et de la corrosion des
métaux et alliages*



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Foreword

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The main task of technical committees is to prepare International Standards, but in exceptional circumstances a technical committee may propose the publication of a Technical Report of one of the following types:

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Technical Reports of types 1 and 2 are subject to review within three years of publication, to decide whether they can be transformed into International Standards. Technical Reports of type 3 do not necessarily have to be reviewed until the data they provide are considered to be no longer valid or useful.

ISO/TR 10271, which is a Technical Report of type 2, was prepared by Technical Committee ISO/TC 106, *Dentistry*, Sub-Committee SC 2, *Prosthetic materials*.

Annex A of this Technical Report is for information only.

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Dentistry — Determination of tarnish and corrosion of metals and alloys

1 Scope

This Technical Report indicates currently available test methods for the tarnish and corrosion behaviour of metals and alloys used in dentistry. It applies to all metals and alloys introduced to the oral cavity such as:

- direct filling metals and alloys;
- cast metals and alloys (including implants);
- wrought metals and alloys (including implants);
- solder/braze filler metals and alloys;
- deposited metals and alloys;
- combinations of the above.

2 Normative references

The following standards contain provisions which, through reference in this text, constitute provisions of this Technical Report. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this Technical Report are encouraged to investigate the possibility of applying the most recent editions of the standards indicated below. Members of IEC and ISO maintain registers of currently valid International Standards.

ISO 1559:1986, *Dentistry — Alloys for dental amalgam*.

ISO/TR 7405:1984, *Biological evaluation of dental materials*.

3 Definitions

For the purposes of this Technical Report, the following definitions apply.

3.1 corrosion: Physico-chemical interaction between a metal or an alloy and its environment resulting in a partial or total destruction of the metal or in a change of its properties.

3.2 tarnish: Type of corrosion as (surface change) characterized by surface discoloration.

3.3 loss of substance: Reduction of mass of the specimen by corrosion.

3.4 pitting corrosion: Corrosion resulting in pits; i.e. cavities extending from the surface into the metal.

3.5 crevice corrosion: Corrosion associated with, and taking place in, or immediately around, a narrow aperture or clearance.

3.6 corrosion product: Substance formed as a result of corrosion.

3.7 accelerated test: Corrosion test carried out under more severe conditions to yield results in a shorter time than in service.

3.8 in vitro test: Test which predicts service or clinical performance using physical, chemical and/or electrical systems in the test laboratory.

3.9 extraction product: Product soluble in an extraction vehicle, obtained from a material.

3.10 extraction vehicle: Liquid selected specifically to obtain extraction products from a material, and simulating human body fluids.

3.11 animal test: Test which relates to clinical performance preliminary to use in humans.

3.12 clinical trial: Test designed for and used in the human oral cavity.

3.13 artificial saliva: Test medium which simulates natural saliva for the performance of a specific test.

4 Requirements for tests

4.1 Test specimens

The materials shall be processed according to the manufacturer's instructions.

4.1.1 General test specimens

Test specimens applicable to the tarnish test, loss of substance, pitting corrosion and crevice corrosion are described in the relevant tests. See table 1.

4.1.2 Test specimens for filling material

The test specimens for filling materials shall be prepared in accordance with ISO 1559, table 1 or applicable national standards.

4.1.3 Specimens for tensile testing

Tensile specimens shall be prepared as shown in the applicable standard with reference to the test method.

4.2 Tests

4.2.1 Static immersion test

This test requires placement in a test solution for a specified period of time.

4.2.2 Rotating immersion test

The apparatus usually consists of a vertical wheel, driven by an electric motor at a specified speed. The wheel consists of a material that neither is attacked by the test solution nor can interfere with the test result in any other way. The wheel shall be provided with fittings so that the specimens can be attached to it. The test solution is placed in such a manner that the specimens are immersed in the solution for each revolution of the wheel.

4.2.3 Loss of substance test

Immersion, electrochemical, nuclear and photometric tests are described in table 1.

4.2.4 Potentiodynamic polarization test

See table 1.

4.2.5 Potentiostatic polarization

See table 1.

4.2.6 Pitting corrosion test

See table 1.

4.2.7 Crevice corrosion test

See table 1.

4.2.8 Corrosion cracking test

See table 1.

4.2.9 Tarnish test

See table 1.

5 Deleterious effects

The deleterious effects of tarnish and corrosion may be defined in three areas.

5.1 Safety: generation of harmful corrosion products

Corrosion and tarnish denote the formation of metal compounds, whether formed by simple oxidation-type reactions or by the release of metal or metal ions. The harmful effects of these metals or metal compounds, such as oxides, sulfides, chlorides, metal organics or other species need evaluation for their effect on the soft and hard tissues and other parts of the body, in accordance with ISO/TR 7405.

Harmful effects may include, for instance, inflammatory, allergenic, cariogenic, mutagenic, carcinogenic, toxic, cytotoxic, teratogenic, or distasteful effects.

Electrical currents and pain can occur due to the use of dissimilar metals and alloys, and galvanic action.

5.2 Efficacy

5.2.1 Loss of substance

If the loss is sufficient to reduce section thickness significantly, it is conceivable that enough mechanical strength will be lost that failure will occur by bending or fracture. Where the loss of material occurs by pitting or roughening, sites can be formed for plaque deposition and growth. Pitting may initiate fatigue fracture.

5.2.2 Metal/non-metal interface

Where corrosion occurs at the interface of metal with ceramic, plastic, cement, etc., the bond or adhesion between the two materials may be weakened or destroyed, or a crevice can be created or enlarged. The result may be loss of the non-metal, discoloration of the non-metal or increased corrosion within the crevice. At the interface between metal and hard or soft tissue, corrosion is more likely because of oxygen depletion.

5.2.3 Stress corrosion cracking

Failure may occur with the combined action of corrosion and stress.

5.2.4 Corrosion fatigue

Service life may be reduced from repeated or fluctuating load when occurring in a corrosive environment.

5.3 Aesthetics

Corrosion may result in loss of lustre since reflected light is diffused, giving the appearance of a discoloration. Actual discoloration results from coloured reaction products which are tenacious enough to remain on the surface. Such coloured or uncoloured reaction products might even protect against further reaction. Well known coloured reaction products are silver and copper sulfides. With many other elements being tested for use in dental alloys, other coloured compounds are possibilities in future alloys. Discoloration in itself, where the coloured film is not a part of another corrosion reaction, does not affect safety or efficacy. Therefore this aspect can be ignored in this context and the market will be the determining factor as to whether a discolouring metal is acceptable.

6 Proposal for future testing

It is well established that no single test can give a complete indication of the reaction between metal or alloy, and the oral environment. This Report therefore, suggests only types of tests and the type of information to be gathered which will lead to an International Standard.

6.1 Testing regarding safety

- a) immersion tests (including depleted oxygen tests);
- b) electrochemical tests (including galvanic coupling);
- c) identify and quantify corrosion products:
 - identify harmful corrosion products and rate of release,
 - establish acceptable limits of concentration of harmful products based on release ratio in the oral cavity.
- d) correlate *in vitro* with *in vivo*. From identification of corrosion products, it may be inferred that such products will be produced *in vivo*. Such products should be evaluated for biocompatibility. The simple conclusion that harmful species can be formed and that injury to the patient can be expected may be the basis for rejection of a metal or alloy.

6.2 Testing regarding efficacy

6.2.1 From 6.1 a) to c), determine rate of loss of substance *in vitro*.

Test for loss of substance *in vivo* (providing that reaction products are not found harmful).

Translate this loss of thickness to millimetres per year. Compare with average lifespan of restoration and with normal thicknesses found in restorations of the type for which the metal or alloy would be used.

6.2.2 Pitting corrosion is tested as follows.

Determine density and dimension of pits on samples tested in 6.1 a) to c).

Check *in vivo* results on samples from 6.2.1.

6.2.3 Interface corrosion (including crevice and reduced oxygen corrosion) is tested on specially designed specimens *in vitro* for corrosion in an experimental crevice.

Repeat *in vivo* tests and correlate between *in vitro* and *in vivo* values. Relate the rate of penetration to normal restorations and estimate lifespan.

6.2.4 Stress corrosion cracking is assessed by formation and propagation of cracks when subject to a corrosive environment under stress and dynamic load.

6.2.5 Alloy combinations are assessed by similar tests to 6.2.1, 6.2.2 and 6.2.3, run on soldered samples where a solder is recommended for a particular alloy.

6.3 Testing regarding aesthetics

6.3.1 Test by the methods of 6.1 a) and b).

The acceptance of discoloration may vary considerably depending on the standards required by peoples of differing social origin. The specification shall be set in such a manner that it can be varied according to local circumstances and in a voluntary form so acceptable alloys will not be ruled out.

6.3.2 Tenacity of film is assessed by a toothbrush test as prepared by several researchers (see annex A).