INTERNATIONAL STANDARD

ISO 28319

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Dentistry — Laser welding

Médecine bucco-dentaire — Soudage par laser

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Foreword

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International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO 28319 was prepared by Technical Committee ISO/TC 106, *Dentistry*, Subcommittee SC 2, *Prosthodontic materials*.

Dentistry — Laser welding

1 Scope

This International Standard specifies requirements and test methods for laser welding, in the dental laboratory, of materials suitable for use in metallic restorations and appliances.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 1942, *Dentistry — Vocabulary*

ISO 3585, *Borosilicate glass 3.3 — Properties*

ISO 3696, *Water for analytical laboratory use — Specification and test methods*

ISO 6344-1, *Coated abrasives — Grain size analysis — Part 1: Grain size distribution test*

ISO 10271, *Dental metallic materials — Corrosion test methods*

ISO 22674:2006, *Dentistry — Metallic materials for fixed and removable dental restorations and appliances*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 1942, ISO 22674 and the following apply.

3.1
laser welding
method for joining similar or dissimilar metallic materials, using a laser beam as heat source, with or without a metallic filler material (welding rod), which produces coalescence by melting the metallic materials in order to join them by creating a fusion zone

3.2
brazing
method for joining similar or dissimilar metallic materials by applying heat and using a metallic brazing material as filler

NOTE 1 The brazing materials used have liquidus temperatures above 450 °C, but below the melting range of the metallic materials being joined. They flow by capillary action into the gap between the metallic base materials and join them by creating a metallurgical bond.

NOTE 2 Brazing differs from welding in that brazing does not melt the metallic base materials.

4 Requirements

4.1 Chemical composition

4.1.1 Metallic materials to be joined

The metallic materials to be joined shall comply with ISO 22674:2006, 5.1 and 5.2.

4.1.2 Filler material

4.1.2.1 Chemical composition

For all elements that are present in excess of 1,0 % (mass fraction), the percentage by mass of each of the constituent elements shall be declared by the manufacturer and shall be reported to a precision of 0,1 % (mass fraction). Any element that is present in a concentration in excess of 0,1 % (mass fraction), but not in excess of 1,0 % (mass fraction), shall be identified either by name or symbol.

4.1.2.2 Permitted deviation from the reported composition

For silver-based or noble-metal-based filler materials, the percentage of each of the constituents shall not deviate by more than 0,5 % (mass fraction) from the values stated in the manufacturer's instructions for use.

For base-metal-based filler materials, all elements present with more than 20 % (mass fraction) shall not deviate from the value stated in the manufacturer's instructions for use by more than 2 % (mass fraction). Those present in excess of 1 % (mass fraction) but not in excess of 20 % (mass fraction) shall not deviate from the value stated in the manufacturer's instructions for use by more than 1 % (mass fraction).

Testing shall be carried out in accordance with 7.2.

4.1.3 Hazardous elements in filler material

4.1.3.1 Recognised hazardous elements

For the purposes of this International Standard, the elements nickel, cadmium, beryllium and lead are designated to be hazardous elements.

4.1.3.2 Permitted limits for hazardous elements

The filler material shall not contain more than 0,02 % (mass fraction) of cadmium or beryllium or lead. If the filler material contains more than 0,1 % (mass fraction) of nickel, the percentage shall not exceed the amount indicated on the package or label or insert.

Testing shall be carried out in accordance with 7.2.

4.2 Biocompatibility

Specific qualitative and quantitative requirements for freedom from biological hazard are not included in this International Standard, but it is recommended that, in assessing possible biological hazards, reference should be made to ISO 10993-1 and ISO 7405.

4.3 Mechanical strength of laser-welded joint (tensile strength)

The tensile strength of laser-welded specimens shall exceed 350 MPa. If the 0,2 % proof strength of either one or both of the metallic materials to be joined by laser welding is below 350 MPa, the tensile strength shall exceed the lower 0,2 % proof strength of the two.

Testing shall be carried out in accordance with 7.3.

4.4 Corrosion resistance

4.4.1 Static immersion test

The corrosion resistance of laser welded specimens shall be in the same range as that of the metallic materials to be joined. The ion release shall not exceed twice that of the metallic material. If two different metallic materials are joined, the ion release shall not exceed twice that of the metallic material with the lesser corrosion resistance. The metallic materials to be joined and the laser-welded specimens shall comply with ISO 22674:2006, 5.6.

Testing shall be carried out in accordance with 7.4.

4.4.2 Appearance after corrosion exposure

Magnified visual comparison prior to and after corrosion testing shall not reveal any visible selective corrosion in the vicinity of the laser weld.

Testing shall be carried out in accordance with 7.4.

5 Sampling

The metallic filler material and the metallic material shall each be from one lot and shall be sufficient to prepare the specimens as required in 6.1 and 6.2, including provision for a second set for tensile testing. Further samples and packaging materials shall be made available for inspection in accordance with 9.2.

If the proof strength values of 0,2 % non-proportional extension of the one or two metallic materials to be joined by laser welding are available from a test report in accordance with ISO 22674, these data can be used. If not, perform the tests in accordance with ISO 22674 to determine the required proof strength values of 0,2 % non-proportional extension.

6 Preparation of specimens

6.1 General

The specimens consist of the metallic materials joined by laser welding either with or without using a filler material according to the manufacturer's instructions. Prepare casating alloy specimens by the "lost wax process" of investment casting. If the manufacturer recommends a forming method other than casting, use this method to assess the suitability of the metallic material for laser welding. Follow the manufacturer's instructions relating to the processing of the metallic material(s) and, if applicable, the filler material, including as regards the use of necessary aids and casting and welding equipment.

Specimens with visible defects shall be discarded and replaced. Specimens shall be separated from sprues, casting beads/runners, fins and other projections. Surface contaminations shall be removed.

The specimens shall be in the metallurgical state appropriate to their intended application.

If heat-treatment is recommended by the manufacturer, perform the tests in the heat-treated state in accordance with the manufacturer's instructions.

If laser welding is recommended following ceramic firing, the simulated ceramic firing of the specimens shall be in accordance with ISO 22674:2006, 7.2.3, and shall be applied before laser welding.

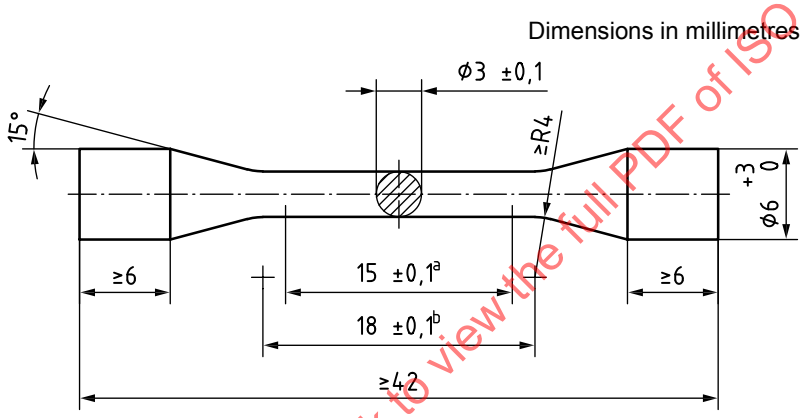
6.2 Specimens for tensile testing

Prepare six specimens of the metallic material(s) to be laser-welded, which comply with either Figure 1 or Figure 2. Cut the specimens of the set at right angles to their long axis at the midpoint of the gauge length using a fine saw.

Replace specimens that have visible shrinkage, defects or porosities.

Prepare the ends of the specimens to the recommended seam geometry. See A.7 for guidance on seam geometry. Support the two halves of the specimens and align them in an investment or a rigid jig. If two different metallic materials are to be laser-welded, use one of each for the two halves. If a recommended filler material is used, follow the manufacturer's instructions (see Clause 8).

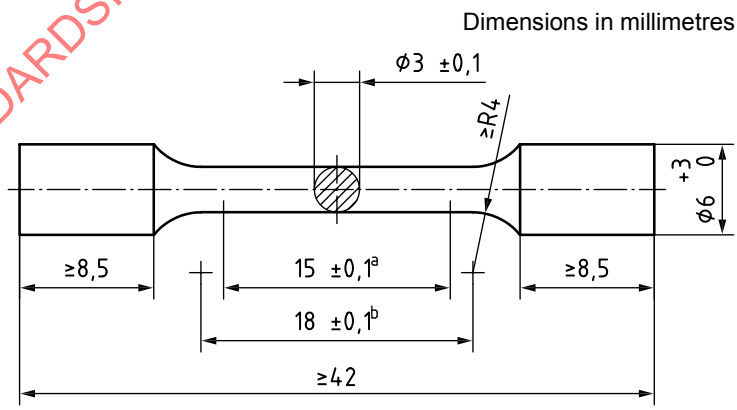
After laser welding, ensure that the diameter of each tensile specimen is within the tolerances given in Figure 1 or Figure 2, and does not show visual evidence of radial run-out when rotated.



a Gauge length of (15 ± 0,1) mm.

b Parallel section of test specimen of (18 ± 0,1) mm.

Figure 1 — Test specimen with conical shoulders



a Gauge length of (15 ± 0,1) mm.

b Parallel section of test specimen of (18 ± 0,1) mm.

Figure 2 — Test specimen with radial shoulders

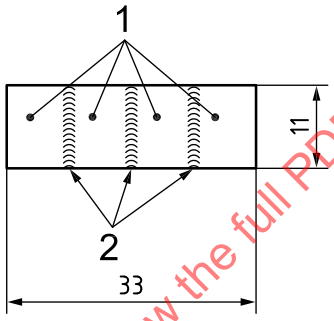
6.3 Specimens for corrosion testing

Platelets for the preparation of specimens are prepared in accordance with ISO 10271.

For corrosion testing of a laser-welded joint, two test specimens measuring 33 mm × 11 mm × 1 mm shall be prepared (see Figure 3).

Platelets of each metallic material to be joined are cut to create four parts (of 11 mm × 8,25 mm each). Once the platelets have been cut, the parts shall be laser-welded in the combination to be tested following the specifications of the metallic materials supplier [either AAAA or ABAB, where (in the latter specimen) A and B are parts from different plates]. Following laser welding, remove at least 0,1 mm from all surfaces of the samples using standard metallographic procedures ending with wet silicon carbide paper of grade P 1200 in accordance with ISO 6344-1. Use a new grinding paper for the preparation of each specimen.

Dimensions in millimetres
All tolerances: ±2 mm



Key

1 metallic plate
2 laser-welded seam

Figure 3 — Specimen for corrosion testing, consisting of four laser-welded platelets

7 Testing

7.1 Visual inspection

Visually inspect to check that requirements specified in Clauses 8 and 9 have been met.

7.2 Chemical composition

Determine the composition of the filler material using analytical procedures with sensitivities appropriate to the concentration of each element and its permitted deviation from the stated value or permitted limit.

7.3 Tensile testing

7.3.1 General

Determine the tensile strength in accordance with ISO 22674 on six test specimens prepared in accordance with 6.2. Load the test specimens in tension in a mechanical testing instrument at a cross-head speed of (1,5 ± 0,5) mm · min^{-1} until the specimens fracture.

Calculate the fracture stress on the basis of the original cross-sectional area, using the “force for elongation at fracture” derived from the force/elongation diagram.

7.3.2 Evaluation of tensile testing results

If four, five or six test specimens are found to exceed the minimum requirements given in 4.3, the laser-welded joint satisfies the tensile strength requirements of this International Standard.

If two or fewer test specimens are found to comply with the minimum requirements given in 4.3, the laser-welded joint fails the tensile strength requirements of this International Standard.

If three test specimens are found to comply with the minimum requirements given in 4.3, repeat the test with a second set of six test specimens.

If, in the second test, five or six test specimens are found to exceed the minimum requirements given in 4.3, the laser-welded joint satisfies the tensile strength requirements of this International Standard.

7.3.3 Calculation of tensile strength

Calculate the tensile strength as the mean of the values of the four, five or six test specimens of the first test, or, if applicable, of the three test specimens of the first test plus the five or six test specimens of the second test, that are found to comply with 4.3, and report to the nearest 5 MPa.

7.4 Corrosion testing by static immersion

7.4.1 Reagents

7.4.1.1 Lactic acid ($C_3H_6O_3$), 90 %, chemically pure.

7.4.1.2 Sodium chloride (NaCl), analytical grade.

7.4.1.3 Water, conforming to grade 2 of ISO 3696.

7.4.1.4 Ethanol or methanol (C_2H_5OH or CH_3OH), analytical grade.

7.4.2 Apparatus

7.4.2.1 Borosilicate glass container, of approximately 16 mm in diameter and 160 mm in depth in accordance with ISO 3585.

7.4.2.2 pH-meter, with a precision of ± 0,1 pH units.

7.4.2.3 Analytical instrumentation, for example AAS or ICP.

7.4.2.4 Micrometer, with a precision of 0,01 mm.

7.4.3 Test solution

Prepare a fresh immersion solution for each test. Dissolve (10,0 ± 0,1) g of 90 % lactic acid (7.4.1.1) and (5,85 ± 0,05) g sodium chloride (7.4.1.2) in approximately 300 ml of water (7.4.1.3). Dilute to (1 000 ± 10) ml with water. The pH value shall be 2,3 ± 0,1. If not the batch should be discarded and suitable reagents chosen to produce a solution with the correct pH.

7.4.4 Procedure

Determine the surface area of each test specimen to the nearest 0,1 cm^2. Using an ultrasonic bath, clean the specimens in ethanol or methanol (7.4.1.4) for 2 min. Rinse them in water (7.4.1.3).

Place each specimen in a separate borosilicate glass container (7.4.2.1).

Record the pH value of the solution. Add the solution to each container sufficient to produce a ratio of 1 ml of solution per 1 cm^2 of specimen surface area and to fully immerse it. Record the volume of solution to an accuracy of 0,1 ml. Close the container and prevent evaporation of the solution. Maintain at (37 ± 1) °C for 7 d ± 1 h. Remove the samples and record the pH value of the solution.

7.4.5 Analysis

Analyse each test solution quantitatively for constituents of the metallic filler materials as specified in 8 a) and the constituents of the metallic material to be joined, as specified in ISO 22674. In addition, analyse for nickel, cadmium, beryllium and lead.

7.4.6 Microscopic inspection

Perform microscopic inspection of the laser-welded joints with a magnification of ×10 prior to and after corrosion testing in accordance with 7.4.4. Record images of the surface of the laser-welded joints during this inspection.

7.4.7 Report

State the analytical method used, and give the detection limits for the elements under investigation. For all elements found in each test solution, record the values separately in micrograms per square centimetre specimen surface area. Calculate the total amount of leached ions for each test solution and report the mean.

8 Information and instructions

The manufacturer's instructions regarding the use of a metallic filler material (welding rod) for laser welding shall contain at least the following information about applications and processing of laser welding:

a) all alloying elements, present in concentrations greater than 1% (mass fraction), shall be stated quantitatively and all other alloying elements, present in concentrations between 0,1 % and 1 %, shall be mentioned either by name or by symbol;

b) if the metallic filler material contains more than 0,1 % by mass of nickel, adequate detailed instructions regarding precautions shall be given in the package or in the accompanying literature;

c) a general warning regarding the potential health hazards associated with the inhalation of metallic dust;

d) instructions for fabrication and processing;

e) metallic materials and/or the combinations, recommended for use with the filler material.

9 Marking and labelling

9.1 Marking

The direct packaging of metallic filler material shall be clearly marked to identify the manufacturer and the material.

9.2 Labelling

The label or the insert in the package shall be marked at least with the following information:

a) manufacturer's or distributor's name or trademark and address;

b) trade or brand name of the filler material;

c) the three principal constituents of the filler material and their percentage by mass;

d) lot number;

e) minimum net mass, expressed in grams;

f) a warning, if the filler material contains nickel [see 8 b)], and the percentage by mass in which it is present.

10 Test report

In order to document the suitability of metallic materials for laser welding in the context of this International Standard, a test report shall be prepared. The test report shall contain at least the following information:

a) seam geometry used for testing tensile strength and corrosion;

b) filler material, if used;

c) laser welding equipment used;

d) parameter settings for laser welding (pulse energy, current, pulse length, frequency, focal settings, protection gas);

e) reported results for the tensile strength and corrosion resistance in accordance with Clause 7.

Annex A
(informative)

Quality assurance of laser welding

A.1 General

This annex lists recommendations on how to conduct laser welding to ensure appropriate and reproducible joining of metals and alloys for the purpose of this International Standard.

It covers the following aspects:

a) training of operator of a laser welding unit, in accordance with A.2;

b) apparatus and devices, in accordance with A.3;

c) selection of materials, in accordance with A.6;

d) joining technique, in accordance with A.7;

e) preparation of laser welding unit, in accordance with A.9.1;

f) performance of laser welding, in accordance with A.9.1;

g) inspection of welding result, in accordance with A.8, A.9.2 and A.9.3.

A.2 Training of operator of a laser welding unit

The operator of laser welding equipment should have adequate knowledge and experience in the following topics:

a) weld preparation;

b) compatibility of materials;

c) quality requirements;

d) quality testing;

e) workstation and equipment.

A.3 Workstation and equipment

The laser welding unit available should be suitable for the welding job at hand.

Welding should be conducted with argon as shielding gas [Group I argon, Code No. 1 (purity $\geqslant$ 99,99 %), in accordance with ISO 14175].

Both welding energy and performance should be controllable through appropriate settings on the laser welding unit (e.g. pulse voltage and pulse duration).

A microscope is needed and should provide not less than 15-power magnification.

A.4 Protective device and safety measures

A.4.1 General

All prescribed protective devices have to be in place during the welding procedure, and any protective measures required have to be observed.

A.4.2 Personal protection against laser radiation

Functionality and effectiveness of laser radiation shielding (e.g. shutter) have to be checked at regular intervals.

A.4.3 Personal protection against dust and fumes

An operational exhaust system has to be in place and adequately maintained.

A.5 Maintenance and operational state

A.5.1 Maintenance of welding equipment

Welding equipment should be maintained at regular intervals in accordance with the laser supplier's instructions for use. Maintenance should be documented.

A.5.2 Operational state

The operational state of a laser welding unit should be adequately checked prior to welding, in accordance with A.9.1.

A.6 Selection of materials

The combination of materials used, including additives, should meet the suitability requirements for laser welding, as specified in this International Standard.

A.7 Joining technique

For the intended application, appropriate joint geometries should be used (e.g. V-seam, I-seam, X-seam, Y-seam). See Figure A.1 for guidance.

Laser welding should be avoided in regions exposed to high mechanical stress.

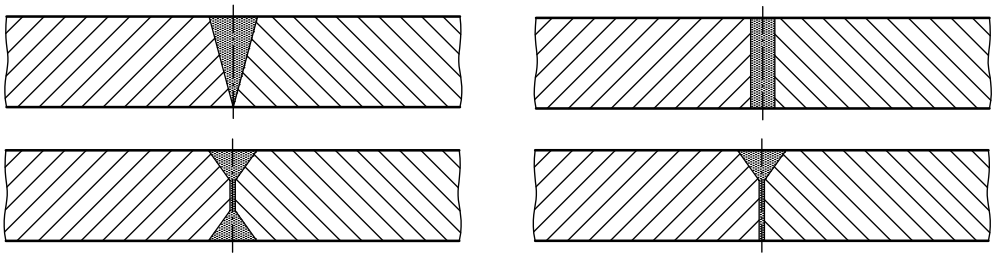


Figure A.1 — Seam geometries (V-, I-, X-, Y-shapes)