TECHNICAL REPORT

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Dentistry — Test methods for machining accuracy of computer-aided milling machines

Médecine bucco-dentaire — Méthodes d'essai pour l'exactitude d'usinage des fraiseuses à commande numérique

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Foreword

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The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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For an explanation on the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT) see the following URL: www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 106, *Dentistry*, Subcommittee SC 9, *Dental CAD/CAD systems*.

Introduction

Dental CAD/CAM systems have been successfully used for the fabrication of indirect dental restorations such as inlays, crowns and bridges. The accuracy of these restorations is one of the most important factors for their clinical success. This document provides standardized test methods to evaluate the machining accuracy of computer-aided milling machines which are used as a part of dental CAD/CAM systems and the information to be provided by the manufacturer. A flow chart of test method is shown in Annex A.

There is another method to evaluate accuracy of the target restoration(s) using coordinate measuring machine (CMM) and software. Test methods using CMM are shown in Annex B.

Dentistry — Test methods for machining accuracy of computer-aided milling machines

1 Scope

This document specifies the test methods to evaluate the machining accuracy of computer-aided milling machines as a part of dental CAD/CAM systems, which fabricate dental restorations, e.g. inlays, crowns and bridges.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements 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 18739, *Dentistry — Vocabulary of process chain for CAD/CAM systems*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 1942, ISO 18739 and the following apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— IEC Electropedia: available at http://www.electropedia.org/

— ISO Online browsing platform: available at http://www.iso.org/obp

3.1
computer-aided milling machine
computer-aided machining device designed for subtractive manufacturing of dental prostheses using rotary instruments for cutting and grinding

4 Recommendations

The accuracy of target restoration(s) should be evaluated using the test methods described in Clause 5. The test method and its results should be provided in the instruction for use, the technical manual or other means. When the machining accuracy is affected by the material, appropriate material(s) should be tested. Testing should be performed on each material type that the manufacturer indicates for use by the device.

5 Test methods

5.1 Target restorations

Three types of restorations, a) Class II inlay, b) crown and c) four-unit bridge, are the targets of this document. Choose the type(s) following the applicable restoration(s) specified by the manufacturer. If any of the three restorations is not specified as applicable by the manufacturer, this restoration is eliminated from the target. In other words, the fabrication of the restoration(s) and the accuracy evaluation are carried out only for the applicable restoration(s) specified by the manufacturer.

NOTE This test method is designed adopting the same principle as the examination method of clinical marginal adaptation. The clinical adaptation is examined checking the discrepancy between the restoration and the cavity margin or between it and the shoulder margin of abutment. The metal die for crown and four-unit bridge is used as same as ISO 12836.

5.2 Apparatus

Two types of metal dies given in Figure 1 (Class II inlay) and Figure 2 (crown and four-unit bridge dies) are used both for the preparation of three-dimensional data (manufacturing data set) and the evaluation of the accuracy of restorations. As shown in Figure 1 and Figure 2, these dies consist of a non-malleable metal die and one or more removable structure(s) used for the evaluation of accuracy. Each die should be measured using a measuring device with accuracy of ±2 µm to confirm the specified shape and dimensions. The measured data are used to prepare the three-dimensional data (see 5.3).

The diameter of the removable occlusal part should be not less than the diameter of abutment and the difference of diameter should be not more than 10 µm.

The surface roughness (Sa) of the die, excepting the surfaces which do not come in contact with the test specimens/machined restorations, should be less than 2 µm. Refer to ISO 25178-2 and other parts for test methods.

If a mark for reference point is necessary, a groove and/or a ridge may be placed on the part, but should be placed so as to not influence the evaluation of the results according to 5.5.

The shapes and sizes of test specimen of the crown and the bridge should conform to Figure 3 (crown) and Figure 4 (bridge). One proximal-side of crown and bridge should have a flat plane to orient their position.

NOTE 1 An example of the machining device to fabricate the dies is Vertical Center NEXUS 410B[1].

NOTE 2 Coordinate measuring machine (CMM) can be useful to measure the size of die. An example of a CMM is America Strato-Apex 574[2].

5.3 Preparation of three-dimensional data

To fabricate the target restorations, a design data set (STL data) for each of the restorations should be prepared. This design data set should then be processed by the CAM software to prepare the manufacturing data set. The design data set should not be modified by the CAM software.

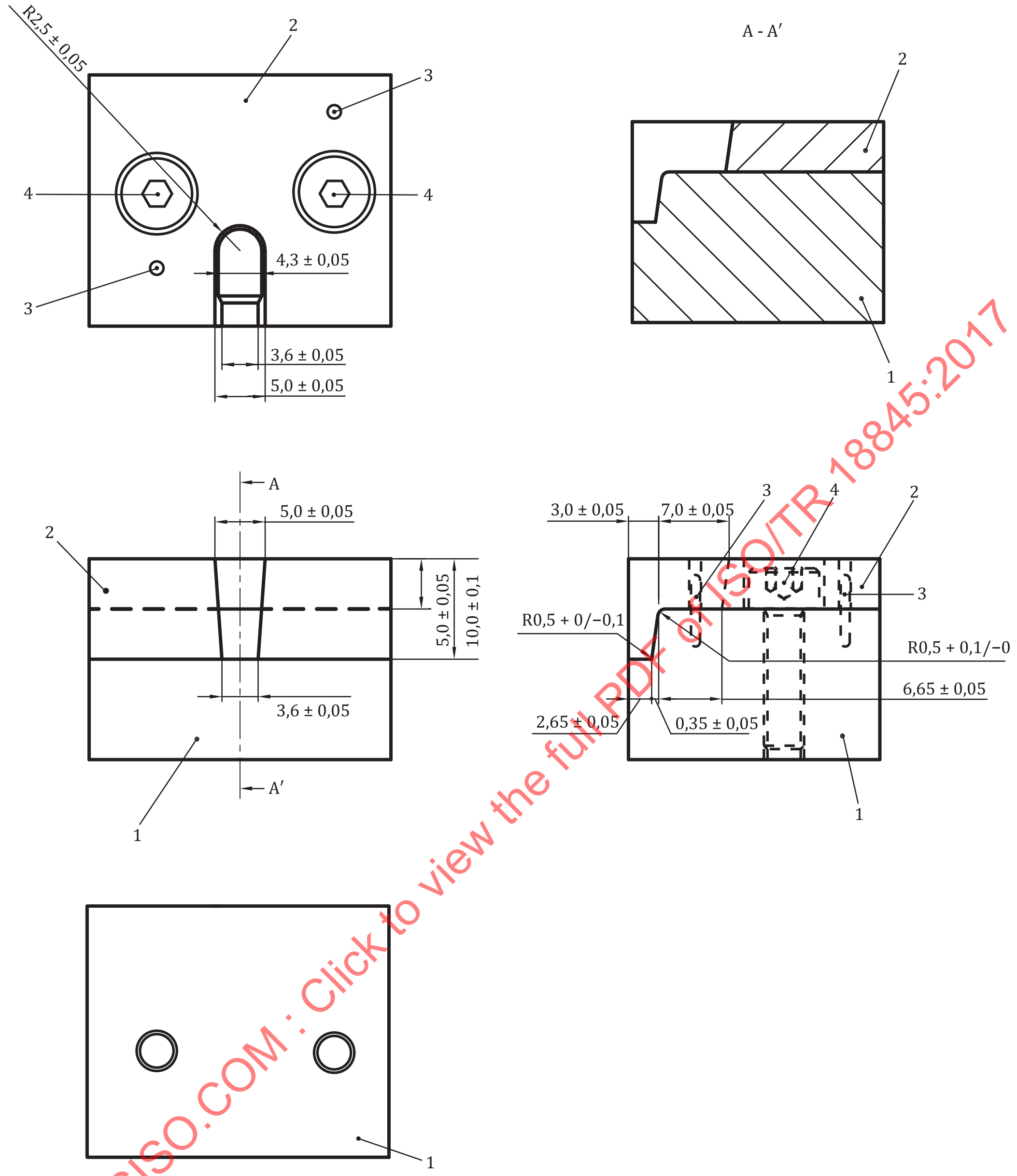
The dimensions of any surfaces in contact with the die surfaces are obtained from the measuring process in 5.2. Other dimensions are determined from Figure 3 and Figure 4.

The design data set should be prepared to ensure that the restoration comes in contact with the die without an allowance for cement space.

1) Vertical Center NEXUS 410B is an example of a suitable product available commercially. This information is given for the convenience of users of this document and does not constitute an endorsement by ISO of this product.

2) America Strato-Apex 574 is an example of a suitable product available commercially. This information is given for the convenience of users of this document and does not constitute an endorsement by ISO of this product.

Dimensions in millimetres



Key

1 metal die

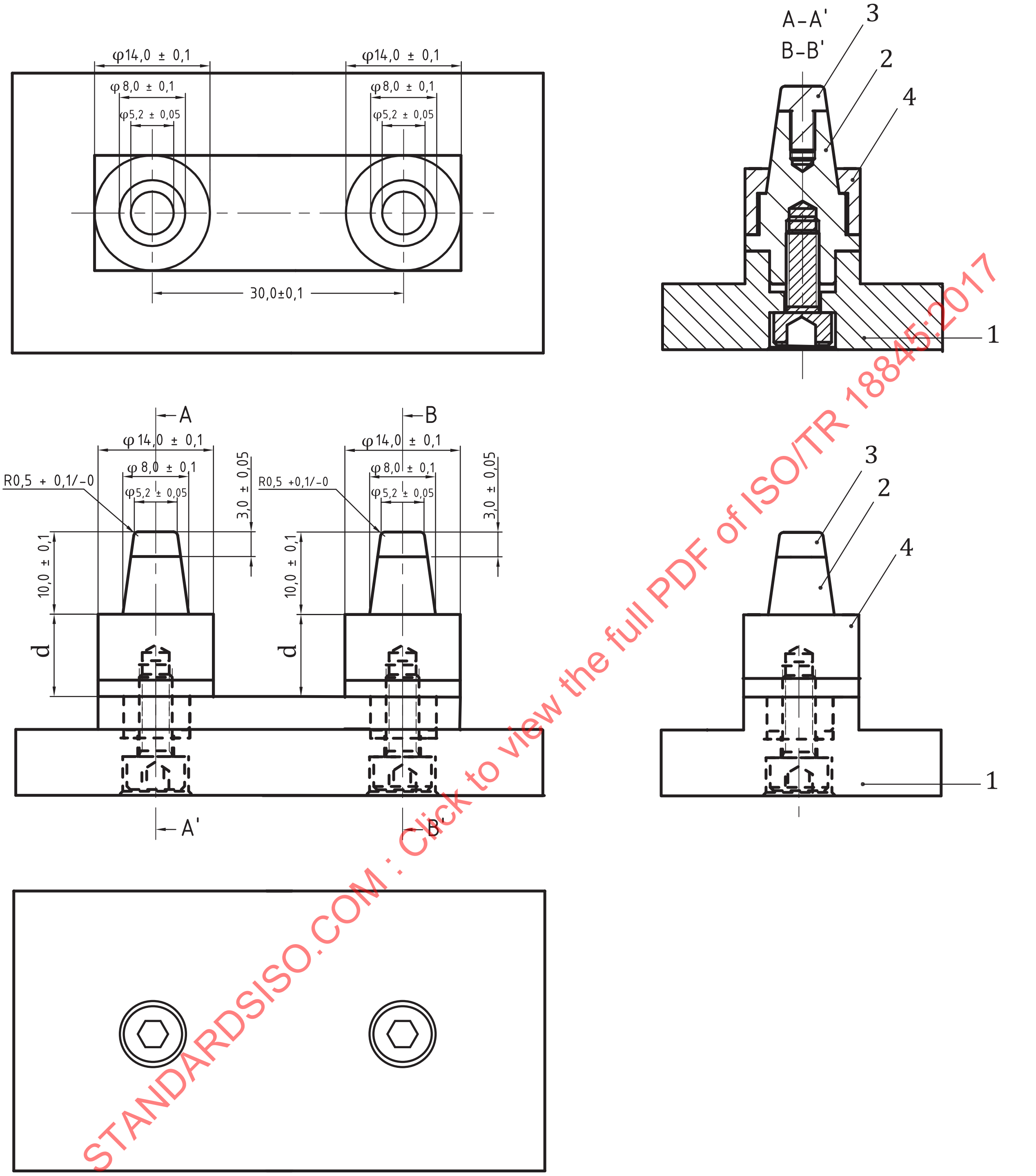
2 removable part

3 positioning pin

4 fixing screw

Figure 1 — Die for class II inlay specimen

Dimensions in millimetres



Key

1 metal die

2 abutment

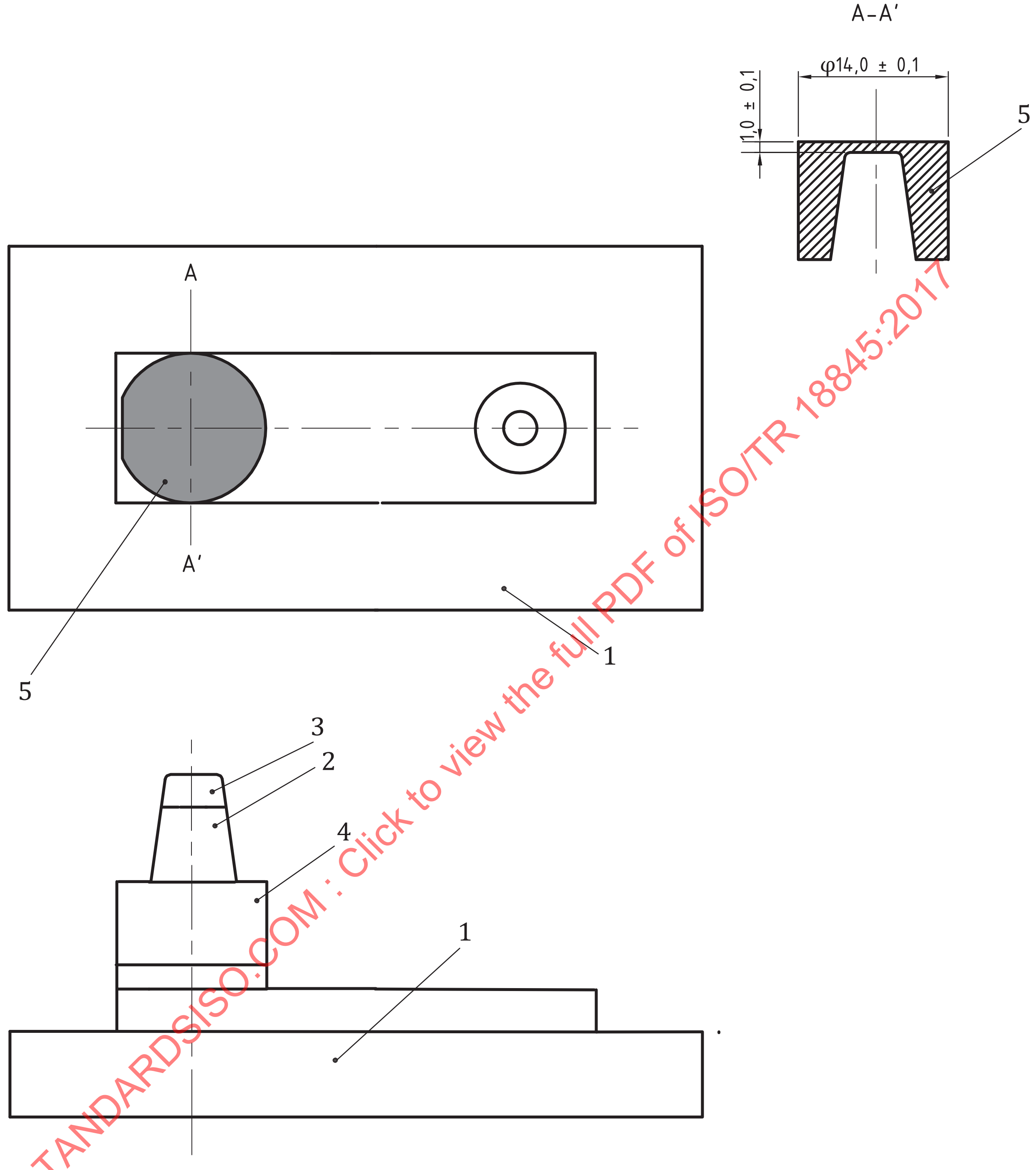
3 removable occlusal part

4 removable shoulder

d height of removable shoulder

Figure 2 — Die for crown and bridge specimen

Dimensions in millimetres



Key

1 metal die

2 abutment

3 removable occlusal part

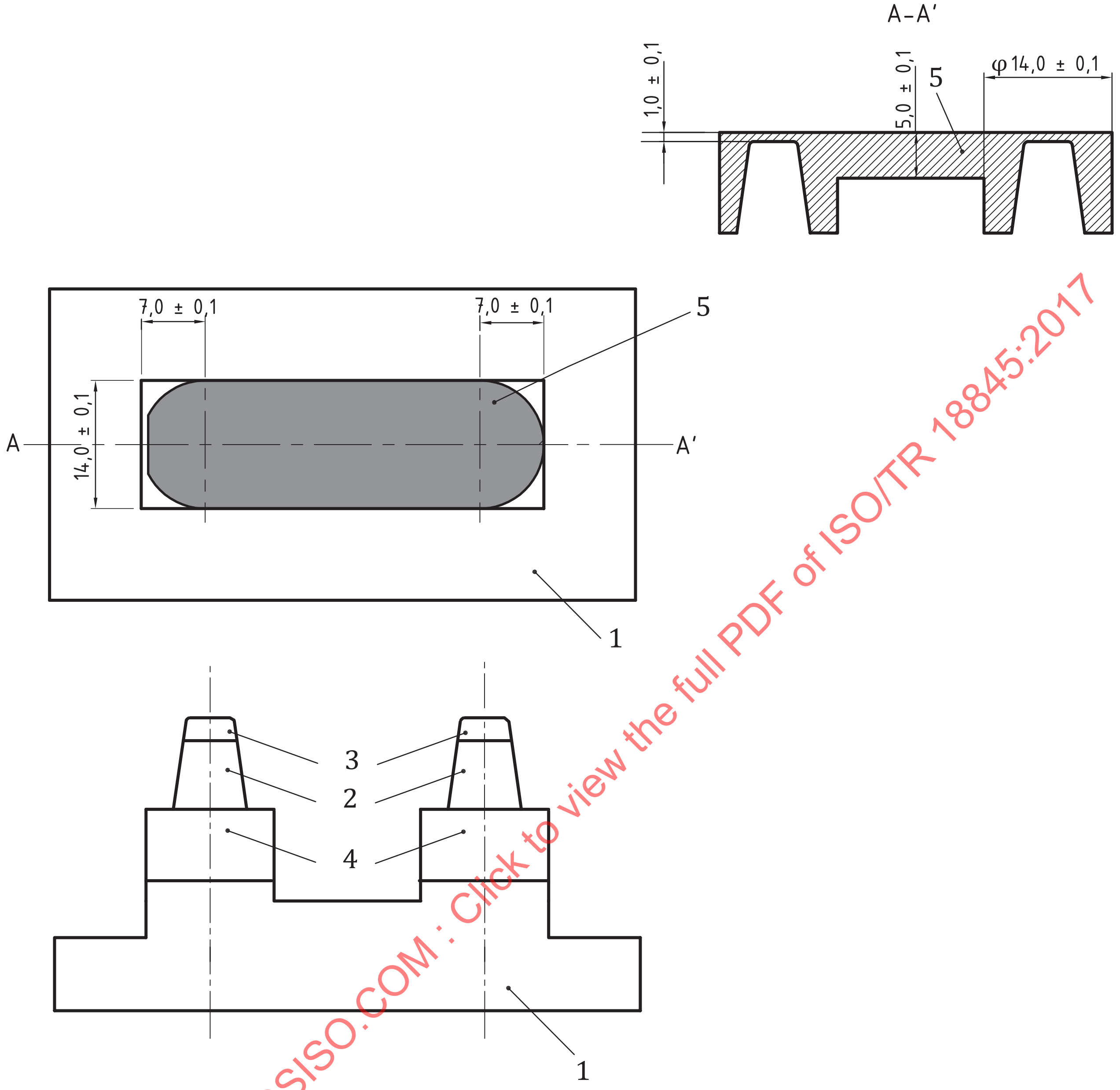
4 removable shoulder

5 test specimen

NOTE The unspecified dimensions are determined using the measured data specified in the first paragraph of 5.2.

Figure 3 — Test specimen of crown

Dimensions in millimetres



Key

1 metal die

2 abutment

3 removable occlusal part

4 removable shoulder

5 test specimen

NOTE The unspecified dimensions are determined using the measured data specified in the first paragraph of 5.2.

Figure 4 — Test specimen of bridge

5.4 Machining of restorations

The prepared manufacturing data set should be input into the computer-aided milling machine following the manufacturer's instruction. The CAM software should use the same configuration and parameters as is usually delivered. The target restoration should be machined using the material specimen (blank) following the manufacturer's instruction.

NOTE A manufacturer means a natural or legal person actually manufacturing a computer-aided milling machine or a natural or legal person supplying necessary information to use the computer-aided milling machine.

This test is carried out using a computer-aided milling machine maintained according to the manufacturer's instruction.

The evaluation of accuracy (see 5.5) is carried out using the restoration without any after treatment such as a sintering process. If any support structures are necessary for fabrication, they should not be positioned on the surface contacting the die and should be removed before the measurement.

Fabricate six specimens for each of the target restorations.

5.5 Evaluation of accuracy

5.5.1 General

The accuracy of the restorations is expressed by the discrepancy between the margin of a restoration and baseline (cavity margin for inlays and abutment shoulder for crown and bridge).

The measurement is carried out using a measuring device with an accuracy of ≤5 µm, e.g. three-dimensional measuring microscope. The measured value should be expressed in millimetre to two decimal places.

When two or more dies for each restoration type are prepared, the restoration should be fabricated using three-dimensional data based on the actual dimension of the die used for accuracy measurement.

5.5.2 Class II inlay

Place the inlay in the cavity of a metal die and apply a load of 50 N on the centres of occlusal and proximal surfaces simultaneously and remove it after 30 s. Remove the load and examine where the margin of the inlay is located.

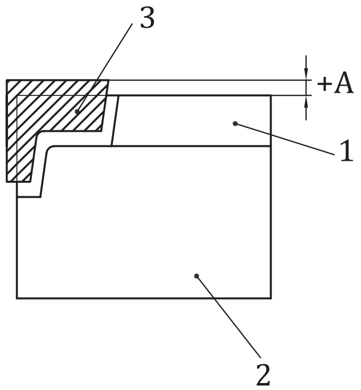
When the occlusal margin of the inlay is located higher than the occlusal baseline (occlusal margin of the die cavity), measure the discrepancy between the inlay margin and the baseline [+A in Figure 5 a)]. Similarly, when the proximal margin of the inlay extends past the proximal baseline (proximal margin of the die cavity), measure the discrepancy between the inlay margin and baseline [+B in Figure 5 b)]. The measured values for both occlusal and proximal discrepancies are expressed as positive values.

When the occlusal and proximal margins of the inlay are located at the same level of the baseline or beneath the baseline, remove the cavity base and place the inlay in the die cavity. Apply a load of 50 N on the occlusal and proximal surfaces simultaneously and remove it after 30 s. Measure the N on the occlusal and proximal surfaces simultaneously and remove it after 30 s. Measure the discrepancies between the occlusal inlay margin and the occlusal baseline [−A in Figure 5 c)] and between the occlusal inlay margin and the proximal baseline [−B in Figure 4 d)]. The measured values are expressed as negative values. If the inlay margin is located at the same level of the baseline, the discrepancy is 0,00 mm.

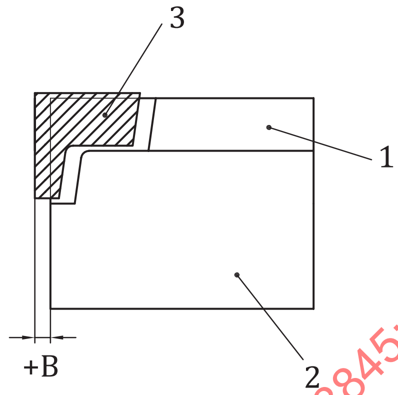
For both cases, measurements with and without metal die, the measurement should be carried out at three points for the occlusal discrepancy [see Figure 5 e)] and at four points for the proximal discrepancy [see Figure 5 f)]. A discrepancy should be measured as horizontal discrepancy judging from the top.

NOTE When a measuring microscope is used, the discrepancy in the Z-direction cannot be precisely measured because of its poor focusing accuracy.

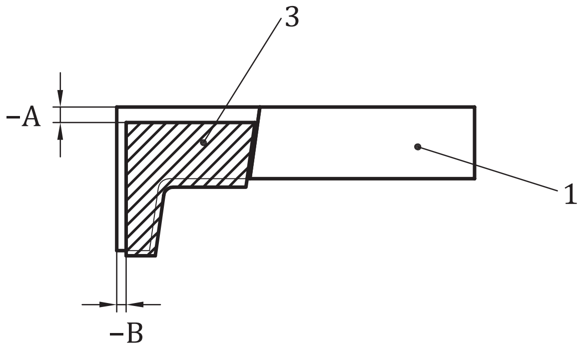
The measured discrepancy data (three points for the occlusal discrepancy and four points for the proximal discrepancy) of one inlay are averaged to represent the discrepancy of that inlay. Calculate the average of the six representative discrepancy values and the standard deviations to express the accuracy of the inlay.



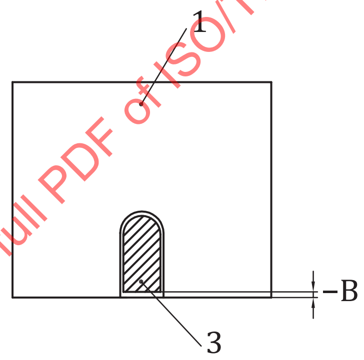
a) Occlusal discrepancy with metal die



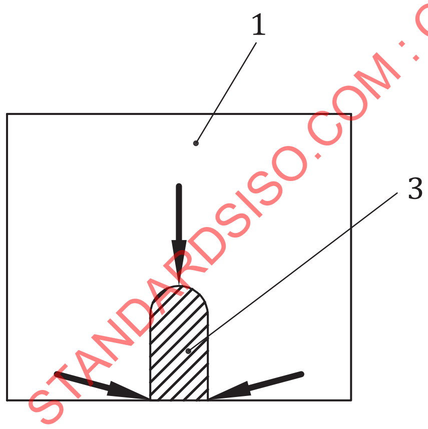
b) Proximal discrepancy with metal die



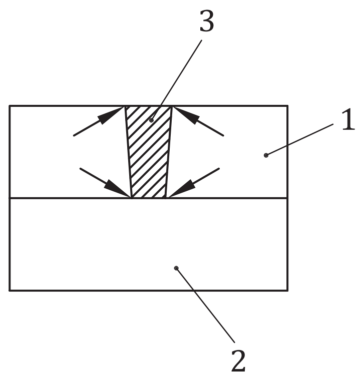
c) Occlusal and proximal discrepancy measurements without metal die



d) Proximal discrepancy measurements without metal die



e) Measurement points for occlusal discrepancy



f) Measurement points for proximal discrepancy

Key

1 removable part

2 metal die

3 inlay

Figure 5 — Discrepancy measurement of class II inlay

5.5.3 Crown

Place the crown on the abutment of a metal die and apply a load of 50 N for 30 s on the centre of the occlusal surface of a crown. Remove the load and measure the discrepancy where the margin of the crown (margin at the centre of medial, distal, buccal and lingual surfaces) is located.

When the crown margin is located higher than the baseline (abutment shoulder), measure the discrepancy between the crown margin and the baseline (abutment shoulder) [+Ay in Figure 6 a)]. The measured value is expressed as a positive value.

When the crown margin meets the baseline, remove the removable occlusal part and the removable shoulder. Place the crown on the abutment without the two removable parts. Apply a load of 50 N and remove it after 30 s. Measure the discrepancy between the crown margin and the second baseline which is lower from the original baseline [By in Figure 6 b)]. Subtract the height of removable shoulder from the measured value and obtain the discrepancy between the crown margin and the original baseline [By in Figure 6 b)]. The obtained discrepancy value is expressed as a negative value.

When the crown margin is located higher than the baseline, calculate the lateral accuracy (+La) using Formula (1).

When the crown margin meets or extends beyond the baseline, remove the removable occlusal part and the removable shoulder, calculate the lateral accuracy (−La) using Formula (2).

$$g = \frac{\mathrm{f}(\mathrm{a}-\mathrm{b})}{\mathrm{ac}} \times 100 \quad (1)$$

$$g = \frac{(\mathrm{d}-\mathrm{e})(\mathrm{a}-\mathrm{b})}{\mathrm{ac}} \times 100 \quad (2)$$

where

a is the diameter of abutment at the baseline [see Figure 6 c) and d)];

b is the diameter of abutment at the top line [see Figure 6 c) and d)];

c is the height of abutment [see Figure 6 c) and d)];

d is the height of removable shoulder [see Figure 2 a) and Figure 6 d)];

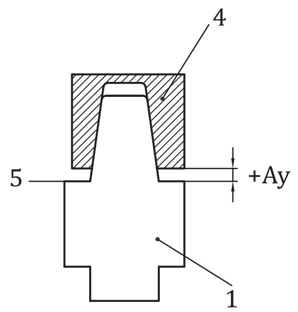
e is the vertical discrepancy without removable shoulder [By in Figure 6 d)];

f is the vertical discrepancy [+Ay in Figure 6 c)];

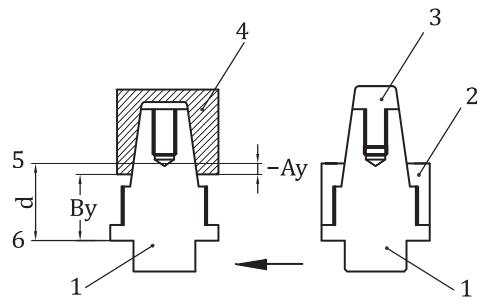
g is the lateral accuracy (+LLy or −LLy) (%).

For both cases (measurement with or without removable parts), the measurement should be carried out at four points [see Figure 6 e)] for each of the six fabricated crowns and the four measured data of one crown are averaged to represent the discrepancy of that crown.

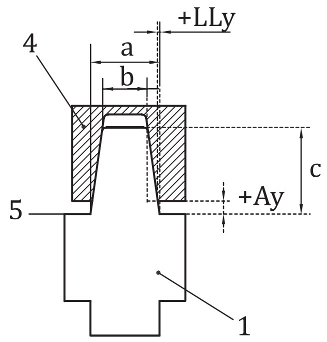
Calculate the average of the six representative lateral accuracies (%) and the standard deviation to express the accuracy of the crown.



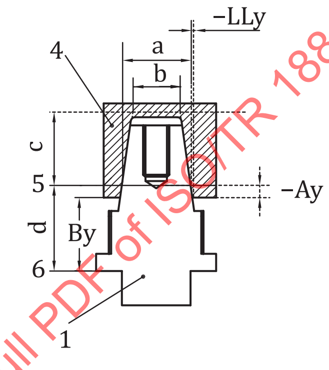
a) Vertical discrepancy (+Ay) measurement of crown with removable parts



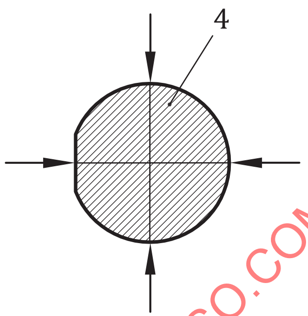
b) Vertical discrepancy (−Ay) measurement of crown without removable parts



c) Lateral discrepancy (+LLy) of crown with removable parts



d) Proximal discrepancy measurements without metal die



e) Measurement points (margin at the centre of medial, distal, buccal and lingual surfaces)

Key

1	metal die	d	height of shoulder which is the distance between the baseline and the second baseline
2	removable shoulder	+Ay	vertical discrepancy of crown with removable parts
3	removable occlusal part	−Ay	vertical discrepancy of crown without removable parts
4	crown	By	measured vertical discrepancy of crown without removable parts
5	baseline (shoulder)	+LLy	lateral discrepancy with removable parts
6	second baseline	−LLy	lateral discrepancy without removable parts
a	diameter of abutment at the baseline		
b	diameter of abutment at the top line		
c	height of abutment		

Figure 6 — Discrepancy measurement of crown

5.5.4 Four-unit bridge

Fix the removable abutments to the bridge die and place the bridge on the bridge die. Apply a load of 25 N at the centre of the occlusal surface of the two crowns for 30 s. The total load is 50 N.

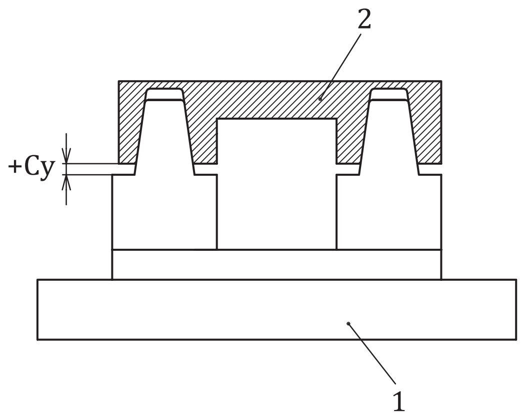
Remove the load and examine if the bridge margin meets the baseline (abutment shoulder).

When the bridge margin is located higher than the baseline, measure the discrepancy between the bridge margin and the baseline [+Cy in Figure 7 a)]. The measured value is expressed as a positive value.

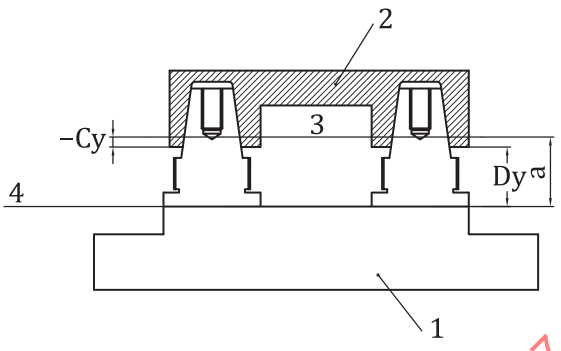
When the bridge margin meets the baseline, remove the removable occlusal part and the removable shoulder of two abutments. Place the bridge on the abutments without the two removable parts. Apply a load of 25 N at the centre of the occlusal surface of the two crowns for 30 s. The total load is 50 N. Measure the discrepancy between the bridge margin and the second baseline which is lower from the original baseline [Dy in Figure 7 b)]. Subtract the height of removable shoulder from the measured value (Dy) and obtain the discrepancy between the bridge margin and the original baseline [−Cy in Figure 7 b)]. The obtained discrepancy value is expressed as a negative value.

For both cases, measurement with or without removable parts, the measurement should be carried out at three points for each of two crowns [see Figure 7 c)] of one bridge and obtain the average of the six measured values in total to represent the discrepancy of that bridge.

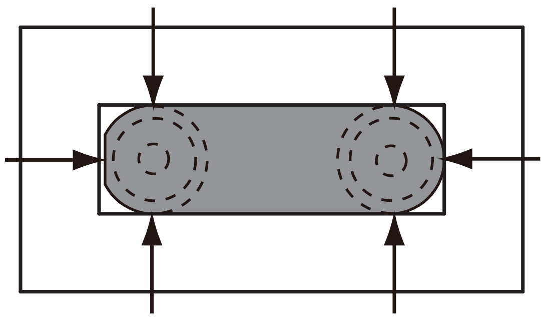
Calculate the average of the six representative discrepancy values and the standard deviation to express the accuracy of the four-unit bridge.



a) Discrepancy measurement with removable parts



b) Discrepancy measurement without removable parts



c) Measurement points

Key

1 metal die

2 bridge

3 baseline (shoulder)

4 second baseline

a Height of removable shoulder (see Figure 2)

Figure 7 — Discrepancy measurement of four-unit bridge

6 Test report

A test report should contain at least the following information:

a) name of computer-aided milling machine (include serial number of the machine) and CAM software (include version number and machining template version details);

b) intended target restoration, e.g. inlay, crown, bridge;

c) dimension of the die used and device for die dimensional measurement;

d) tested material and its lot number (batch designation);

e) type of milling bur/tool and its condition (e.g. period of service);

f) device for evaluating accuracy of restoration;

g) mean and standard deviation of occlusal and proximal accuracies for inlay (see 5.5.2), lateral accuracy for crown (see 5.5.3) or accuracy for four-unit bridge (see 5.5.4).

h) date of test;

i) date, name and signature of the test inspector.

7 Information

A manufacturer should provide the following information in an instructions for use, a technical manual or other means:

a) name of computer-aided milling machine (include serial number of the machine) and CAM software (include version number and machining template version details);

b) intended target restoration, e.g. inlay, crown, bridge;

c) tested material;

d) mean and standard deviation of occlusal and proximal accuracies for inlay (see 5.5.2), lateral accuracy for crown (see 5.5.3) or accuracy for four-unit bridge (see 5.5.4).

Annex A
(informative)

Flow chart of test method

Subclauses of test method	Steps of test method	Remarks
5.1 Target restorations	Selection of types of restorations ↓	
5.2 Apparatus	Preparation of die ↓	a) A die consists of a metal die and removable part(s). b) Each die should be prepared based on the shape and dimensions of applicable figure.
	Measurement of dimensions and surface roughness of die ↓	a) The dimensions of each die should be measured using a measuring device with an accuracy of ±2 µm. b) The surface roughness (Sa) of die is less than 2 µm.
5.3 Preparation of three-dimensional data	Preparation of three-dimensional data of restoration ↓	a) Three-dimensional data should be prepared using the dimensions measured in the “Measurement of dimensions and surface roughness of die” step.
5.4 Machining of restorations	Machining of restoration ↓	a) The prepared three-dimensional data are input into the computer-aided milling machine. b) Target restorations should be machined.
5.5 Evaluation of accuracy	Evaluation of accuracy	a) Each restoration should be evaluated using the same die used for the preparation of three-dimensional data.

Annex B
(informative)

Test methods using coordinate measuring machine (CMM)

B.1 General

This annex provides an alternate test method using CMM to evaluate the machining accuracy of a computer-aided milling used to fabricate dental restorations.

The manufacturer of the computer-aided milling machine should provide product-specific information including instructions for use. The manufacturer should identify the primary direction of travel for each primary axis (X, Y, Z) in the instructions for use document.

The accuracy of target restoration(s) and the test results should be provided in the instructions for use or the technical manual supplied with the computer-aided milling machine. If the computer-aided milling machine is indicated for use with multiple materials, the accuracy and the results for each indicated material should be provided.

NOTE Coordinate measuring machine (CMM) is a device defined ISO 10360-1.

B.2 Test methods

B.2.1 General

There is a single crown test specimen with similar dimensions and shape as a molar crown restoration (see Figure B.1). There are three additional test specimens (see Figure B.2, Figure B.3 and Figure B.4) which are representative of short-span, long-span and cross-arch bridge restorations. Computer-aided milling machines may have restrictions on stock material dimensions and may not be capable of milling all of the bridge restoration specimens.

The specimen fabrication and accuracy evaluation are carried out for the restoration types: crown and bridge, as indicated by the manufacturer. If indicated by the manufacturer, the crown and only the largest bridge specimen that fits within the computer-aided milling machine's allowable stock material dimensions are tested. For example, if a computer-aided milling machine only accepts small blocks for machining, and only the crown specimen fits in the block, then the crown specimen is the only specimen milled and measured for accuracy. If the three-unit bridge fits in a block compatible with the computer-aided milling machine and is indicated by the manufacturer, then the crown and three-unit bridge specimens (short-span bridge) are milled and measured for accuracy. If a computer-aided milling machine accepts large stock material for machining crowns and cross-arch bridges, then the crown specimen and only the cross-arch bridge specimens will be milled and measured for accuracy.

The single crown specimen has a diameter of about 12 mm and a height of about 10 mm. The design is shaped like a sphere with a cylindrical section. The cylinder walls are conical with a wall angle of 6° from vertical. The wall thickness of the specimen is 1 mm overall.

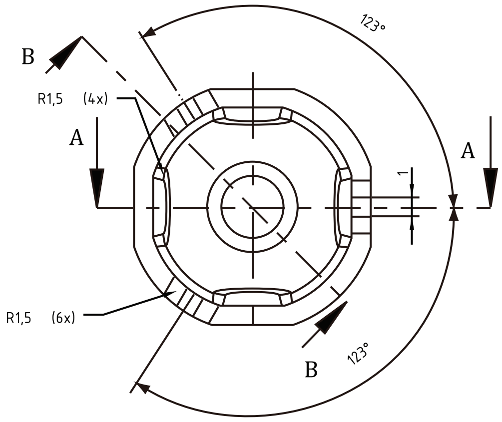
The design has planes or flats, for measurement in X, Y and Z-axes. Furthermore, three pins are added to the cervical surface to allow the specimen to be placed on a platform to measure the overall Z-axis dimension. In addition, a marker is included on the top to identify X+ axis of the computer-aided milling machine to allow correlation of measurement values and machine axes.

Except for the X+ marker and the three pins, the specimen is rotationally symmetric around the Z-axis.

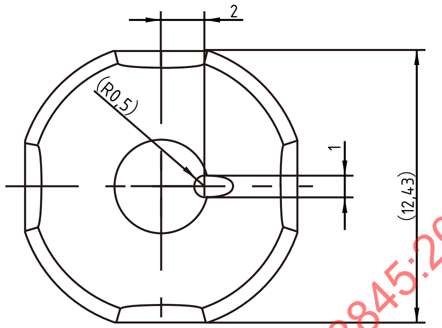
B.2.2 Crown accuracy

To determine crown accuracy, the single crown test specimen should be used. See Figure B.1.

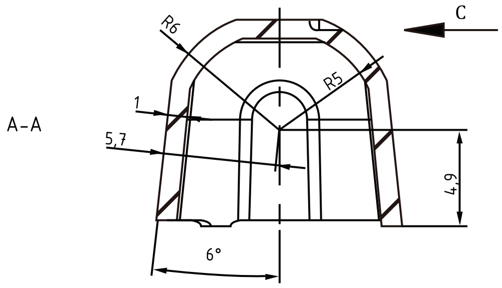
Dimensions in millimetres



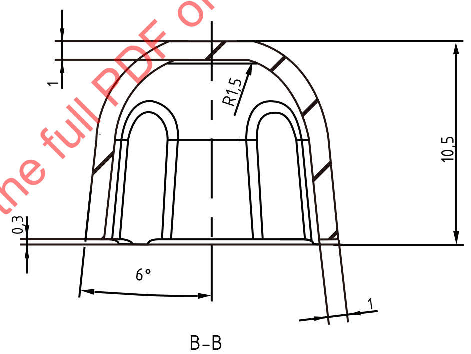
a) Bottom view



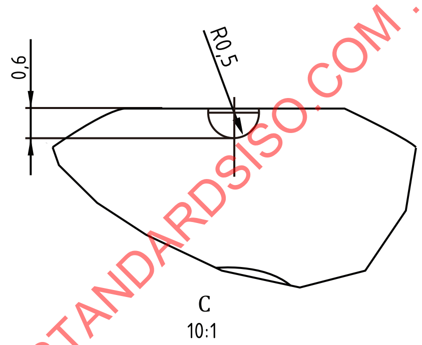
b) Top view



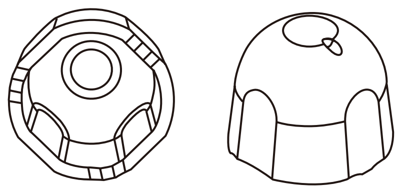
c) Section A—A



d) Section B—B



e) Partial view from the right (direction C)



f) Frog's and bird's eye perspectives

Key

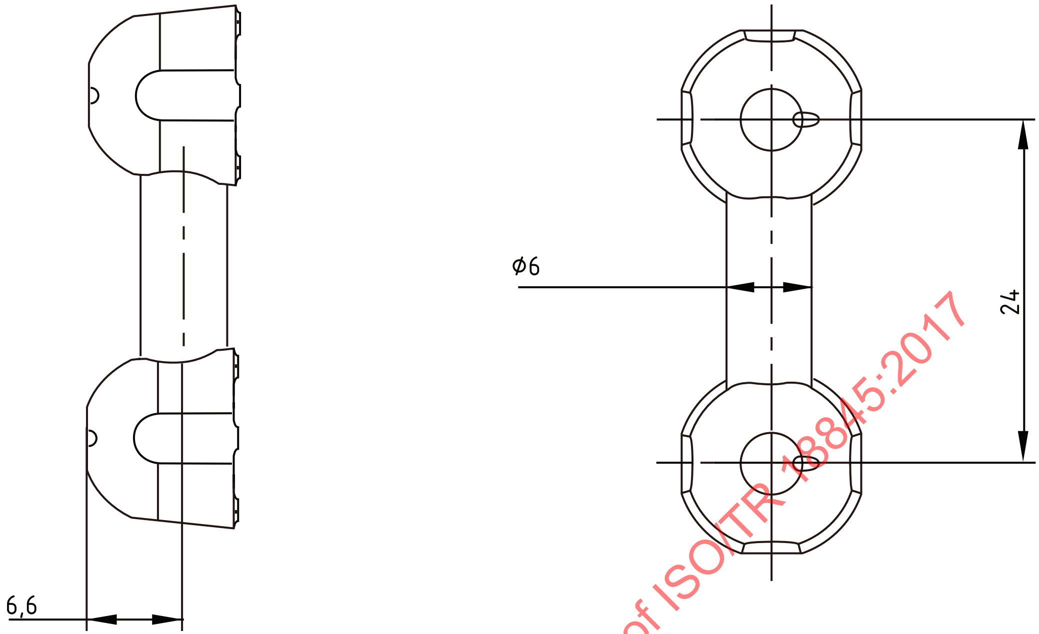
C direction of groove

Figure B.1 — Crown specimen

B.2.3 Short-span accuracy

To determine the short-span accuracy, the short-span bridge model is used for small milling stock-computer-aided milling machines. Two single-crown specimens are connected with a bar and simulate a three-unit bridge. See Figure B.2.

Dimensions in millimetres



a) Side view　　　b) Bottom view

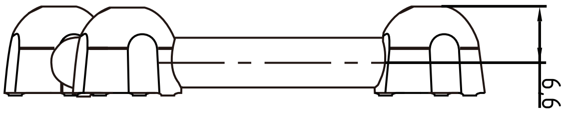
NOTE　Shapes and dimensions of crown part are indicated in Figure B.1.

Figure B.2 — Short-span bridge model for small block

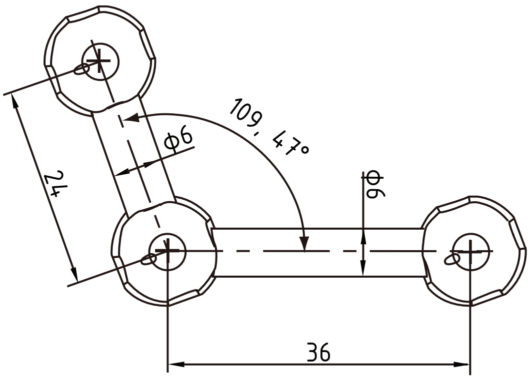
B.2.4 Medium-span accuracy

To determine the medium-span accuracy, the medium-span bridge model is used for computer-aided milling machines that accommodate medium blocks as stock material. The three single-crown specimens are connected with two bars and simulate a six-unit bridge. See Figure B.3.

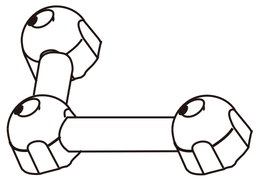
Dimensions in millimetres



a) Side view



b) Bottom view



c) Bird's eye view

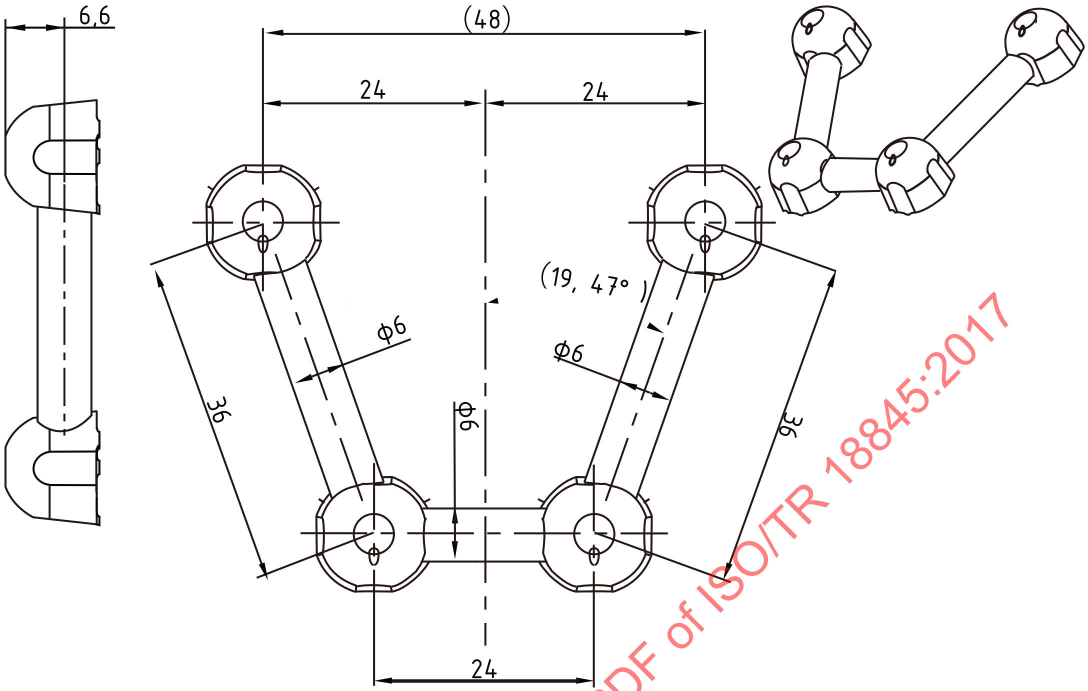
NOTE Shapes and dimensions of crown part are indicated in Figure B.1.

Figure B.3 — Medium-span bridge model for medium block

B.2.5 Cross-arch accuracy

To determine the cross-arch accuracy, the cross-arch bridge model is used for computer-aided milling machines that accommodate large blocks as stock material. The four single-crown specimens are connected with three bars and simulate a nine-unit bridge. See Figure B.4.

Dimensions in millimetres



a) Side view **b) Bottom view** **c) Bird's eye view**

NOTE Shapes and dimensions of crown part are indicated in Figure B.1.

Figure B.4 — Cross-arch bridge model for large block or disk

B.3 Machining of specimens

The prepared three-dimensional data (design data set) (STL) for each specimen should be imported or loaded into CAM software program for the computer-aided milling machine. Scaling of the stock material should be set to 1,0 for the purposes of this evaluation. The CAM software should use the same configuration and parameters as is usually delivered. The CAM software version and machining template version details should be recorded for each type of specimen machined and included in the test report.

B.3.1 Positioning in the blank

The test specimen should be positioned in the blank with the orientation of the X+ marker in X+ axis direction. The occlusal surface of the crown specimen should be oriented in the Z+ axis.

The computer-aided milling machine manufacturer's recommendation for the number of support pins and support pin size should be used. Support pins should not be placed on the plane surfaces of the test specimen as those surfaces are used for accuracy measurements. See Figure B.5.

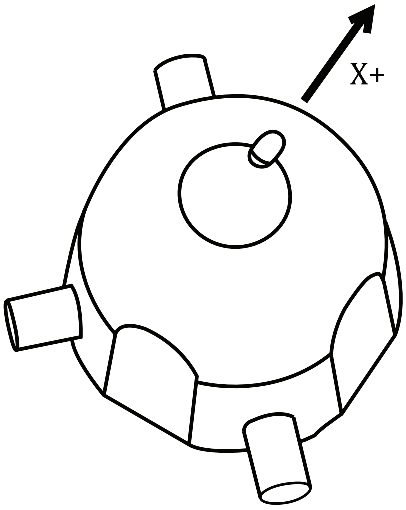


Figure B.5 — X+ marker oriented in the X+ direction

B.3.2 Milling

The manufacturing data set for the specimens should be calculated. The stock material (blank) should be placed in the computer-aided milling machine following the manufacturer's instructions. The CAM software version and machining template version number should be recorded for each type of specimen machined and included in the test report. Six specimens should be milled for accuracy measurements.

Tooling should be changed throughout the milling process according the computer-aided milling machine manufacturer's recommended practices as outlined in the device's instructions for use or operating manual.

B.4 Measurement

Each machined specimen should be measured using an appropriate optical scanner or a coordinate measuring machine (CMM). The measuring device should have an accuracy of ±5 µm or better.

Data collected should include all internal and external surfaces of the specimens.

The data resulting from the measurements should be converted to an STL format.

NOTE One commercially available CMM is America Strato-Apex574[3] or Leitz PMM-C[4].

B.5 Analysis

To measure the accuracy of the milled specimen, the STL produced from measuring should be compared with the reference specimen STL with appropriate analysis software. Prior to analysis, the scanned STL

3) America Strato-Apex 574 is an example of a suitable product available commercially. This information is given for the convenience of users of this document and does not constitute an endorsement by ISO of this product.

4) Leitz PMM-C is an example of a suitable product available commercially. This information is given for the convenience of users of this document and does not constitute an endorsement by ISO of this product.

should be aligned to the reference STL in the analysis software using an acceptable algorithm such as best fit least square error.

NOTE One commercially available program is Geomagic Control or Qualify[5] or GOM-Inspect[6].

B.5.1 Single-crown specimen

The hatched areas of surfaces indicated in Figure B.6 should be analysed and compared. For each surface, the maximum, minimum and standard deviation should be calculated by the analysis software.

Calculate the average and the standard deviation of the lateral discrepancy values to identify the lateral accuracy of the single crown.

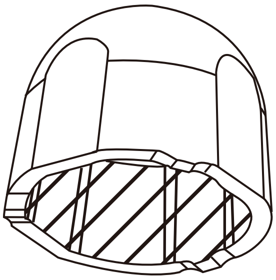
Calculate the average and the standard deviation of the Z-discrepancy value to identify the Z-direction accuracy of the single crown

Calculate the average and standard deviation of the prep-line surface to identify the prep-line accuracy of the single crown.

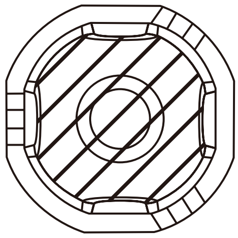
To achieve statistical relevance, a total of six crowns should be fabricated. The three characteristic values, lateral accuracy, Z-direction accuracy, prep-line accuracy, are averaged over the fabricated crowns.

5) Geomagic Control or Qualify is an example of a suitable product available commercially. This information is given for the convenience of users of this document and does not constitute an endorsement by ISO of this product.

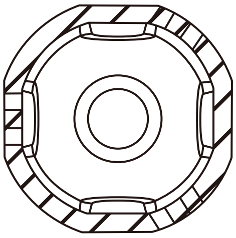
6) GOM-Inspect is an example of a suitable product available commercially. This information is given for the convenience of users of this document and does not constitute an endorsement by ISO of this product.



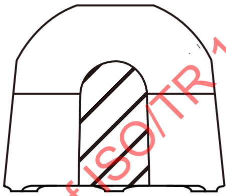
a) Specimen intaglio surface planes in the lateral direction



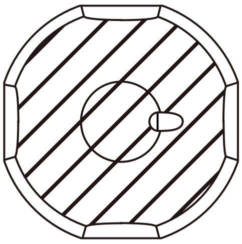
b) Specimen intaglio surface planes in the Z-direction



c) Specimen intaglio prep-line surface in the Z-direction



d) Specimen external surface planes the lateral direction



e) Specimen external surface planes in the occlusal Z-direction

NOTE 1 Only hatched areas are to be analysed.

NOTE 2 Only flat eternal surfaces are evaluated because pins are located at rounded surfaces.

NOTE 3 The X+ marker is excluded, as it is dependent on tool geometry and not relevant for accuracy.

Figure B.6 — Surfaces of single-crown specimen to be analysed

B.5.2 All bridge specimens

The following surfaces should be analysed and compared. For each surface, the maximum, minimum and standard deviation should be calculated by the analysis software.

— For each crown cap, the surfaces described in B.5.1.

— Excluded are the external surface planes in the lateral direction which are covered by the bar connecting the bridge units.

Calculate the average and the standard deviation of the lateral discrepancy values to identify the lateral accuracy of the bridge specimen.