Precision of a CAD/CAM Technique for the Production of Zirconium Dioxide Copings

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Purpose: The precision of a computer-aided design/manufacturing (CAD/CAM) system to manufacture zirconium dioxide copings with a predetermined internal space was investigated. ***Materials and Methods:*** Two master models were produced in acrylic resin. One was directly scanned by the Decim Reader. The Decim Producer then manufactured 10 copings from prefabricated zirconium dioxide blocks. Five copings were prepared, aiming for an internal space to the master of 45 µm. The other five copings were prepared for an internal space of 90 µm. The second test model was used to try in the copings produced. The obtained internal space of the ceramic copings was evaluated by separate measurements of the master models and inner surfaces of the copings. The master models were measured at predetermined points with an optical instrument. The zirconium dioxide copings were measured with a contact instrument at the corresponding sites measured in the masters. ***Results:*** The first group of copings had a mean internal space to the scanned master of 41 µm and of 53 µm to the try-in master. In general, the internal space along the axial walls of the masters was smaller than that along the occlusal walls. The second group had a mean internal space of 82 µm to the scanned master and of 90 µm to the try-in master. ***Conclusion:*** The aimed-for internal space of the copings was achieved by the manufacturer. The CAD/CAM technique tested provided high precision in the manufacture of zirconium dioxide copings. *Int J Prosthodont 2004;17:577–580.*

Denzir (Dentronic) is a new restorative material in the field of dentistry. This material is pressure-sintered zirconium dioxide, an advantage of which is claimed to be its unique crystal structure preventing fracture formation along the crystals.[1] With a computer-aided design/manufacturing (CAD/CAM)–based technique, the prefabricated yttrium oxide–partially stabilized zirconium ceramic is handled with precision machines for the production of tooth restorations.[2]

One aspect to be investigated is the fit and/or congruence of the inner surface of a Denzir coping and the corresponding surface of the prepared tooth, defined as discrepancy or gap. An interface discrepancy can be internal and/or marginal. An internal discrepancy is the misfit of the coping at the occlusal/incisal and axial surfaces. Marginal discrepancy can be defined as a vertical dimension from the finish line of the preparation to the cervical margin of the restoration. This type of gap is caused by too-short crowns or improper seating of the crowns. Marginal gap can also be defined as a horizontal discrepancy, perpendicular to the tooth axis, caused by too-wide crowns.[3]

In dentistry, the discussion has long concerned the range of acceptable marginal discrepancy not resulting in deleterious effects to the tooth structure or surrounding tissue. A marginal gap ranging from 10 to 500 µm, with mean values from 50 to 100 µm, has been

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Fig 1 Cibatool master model and one of the copings.

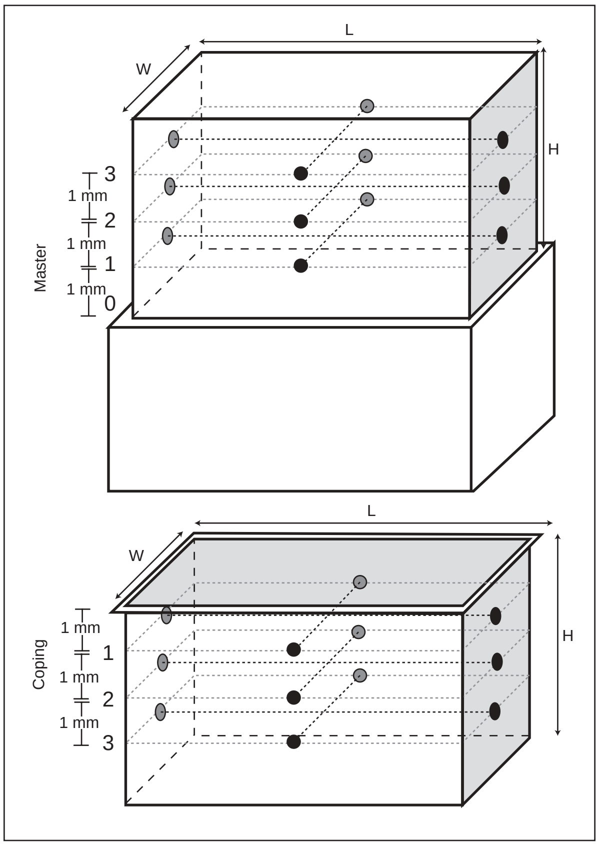

Fig 2 Measurement points on master model. Height of the master is measured, and other measurements are taken at the midpoints of the width and length dimensions at three levels along the height of the master: 1, 2, and 3 mm.

reported; even higher values have been found for incisal/occlusal discrepancies.[3–10]

With the Dentronic CAD/CAM technique, it is theoretically possible to program the manufacture of copings with a predetermined space. In a previous investigation, the fit of Denzir copings was shown to be in the range of what is considered to be clinically acceptable.[11] Although the Denzir method will exclude some of the steps and errors in a standard production line, a number of clinical handling procedures (eg, impression technique and die production) still predispose discrepancies in the final product. Thus, the real precision of the CAD/CAM system could not be evaluated. Recently, new software for the Dentronic system has been introduced; therefore, it is of interest to investigate the precision of the new software system by excluding the error induced by the impression and stone die steps.

The aim of this study was to investigate the precision of the new Dentronic software to manufacture zirconium dioxide copings with a predetermined inner space to the master model. The hypothesis tested was that there would be no significant difference between the inner space aimed for by the manufacturer and the actual measured inner space.

Materials and Methods

Two test models in acrylic resin (Cibatool BM5460) were produced at the Dentronic Laboratory, Skellefteå, Sweden. The models were rectangular and slightly convergent (convergence angle 5 degrees). At the base, the long side measured 6.9 mm; the short side measured 4.9 mm. The axial dimension of the models (height) was 4.0 mm. All of the edges of the rectangle were rounded (Fig 1). One of the two test models was used as a master; to avoid the steps of impression taking and stone die production, one of the two master models was scanned by the Decim Reader.

The Decim Producer then manufactured 10 copings by grinding on prefabricated zirconium dioxide blocks. The grinding software was programmed to produce two groups of copings. The first group of five copings was predetermined to have an internal space to the master of 45 µm. The second group of five copings was predetermined to have an internal space to the master of 90 µm. The second acrylic resin test model was used to try in the copings produced. Thus, the first model, master 1, was scanned and remained untouched, whereas the second model, master 2, was used for manually testing the fit of the copings and was therefore possibly abraded by this procedure.

The fit of the ceramic copings was measured at the Measuring Center, Laboratory Service, SKF Service, Göteborg, Sweden. The two master models were

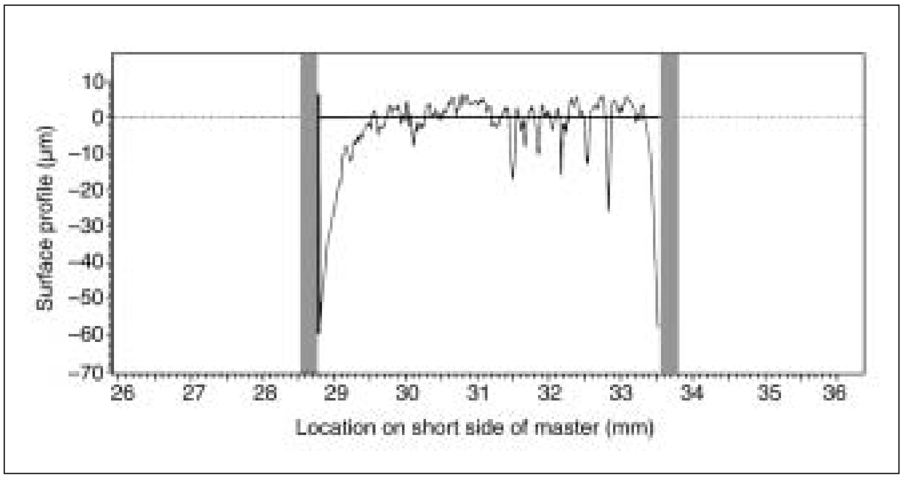

Fig 3 Profilometric analysis of short side of master 1. Surface shows a few grooves 10 to 20 µm deep, but in general no major alteration in shape.

Table 1 Discrepancy Between Master Models and Inner Surface of Copings (µm)

Model	Coping group 1 (45-µm internal space) Mean	SD	CV	Range	Coping group 2 (90-µm internal space) Mean	SD	CV	Range
Master 1	41	20	49	10–115	82	11	14	62–103
Master 2	53	29	55	12–101	90	13	15	64–115

SD = standard deviation; CV = coefficient of variation.

measured with an optical instrument (Universal Measuring Microscope, Zeiss). The height of the masters was measured. The other measuring points were located at three levels along the long axis (height) of the master, at 1-, 2-, and 3-mm heights. The measurements were made at the middle of both the long and short sides of the master, along two lines perpendicular to each other. In this way, three measurements of the length, three measurements of the width, and one measurement of the height were obtained for each master model (Fig 2). To ensure that the selection of the measuring points at the middle of the long and short sides was representative of the whole surface, a profilometer (Form Talisurf, Serie 2, Taylor Hobson) was used to control the form of the master. The contact measurements along the surface, at a height of about 1 mm from the preparation margins, were made with a measuring tip of 1.5-mm diameter.

The inner surface of the 10 zirconium dioxide copings was measured with a contact instrument (Trioptic 9, SIP), with a measuring tip of 0.25-mm diameter, at the corresponding sites measured in the masters. Their inner form was also controlled with the same instrument to make sure that the selected measurement points were representative of the whole surface.

According to the respective manufacturers, the measurement resolution for the Universal Measuring Microscope and Trioptic 9 instruments is 0.5 µm, and 12 nm for the Form Talisurf. From previous measurements and calibration procedures at the Measuring Center, the measurement uncertainty was calculated to be less than 5 µm for the Universal Measuring Microscope and Trioptic 9 instruments, and less than 3 µm for the Form Talisurf.

Results

The profilometry of the master surfaces detected a few grooves (Fig 3), but in general there were no major alterations in form that could induce serious measurement errors. The same pattern was seen for the inner surface of the Denzir copings.

The first group of copings (predetermined internal space of 45 µm) showed a mean internal space of 41 µm to master 1 and 53 µm to master 2 (Table 1). In general, the internal space along the axial walls of the masters was smaller than the internal space along the occlusal wall. The second group of copings (predetermined internal space of 90 µm) showed a mean internal space of 82 µm to master 1 and 90 µm to master 2.

Discussion

Few techniques have been used for the in vitro examination of crown fit to the master. Often, an impression material is used instead of a luting cement, and the obtained replica of the discrepancy between crown and master is used to measure the misfit between crown and master.[3,6,10–13] Other authors have cemented the crown to the master with a luting cement and, after sectioning the whole crown-cement-master complex, measured the thickness of the cement.[8,14–17] This kind of in vitro evaluation of crown-master discrepancy certainly has inherent errors, one of which may be the seating force. Another source of error can be inaccurate placement of the crown to the master. A crown is produced for a unique preparation; consequently, only one position gives an optimal fit. A minimal rotation of the crown on the stone die–master may result in an increased discrepancy at one side and a smaller one at another site.[18] Likewise, the problems related to the replica material used and methodologic errors have been discussed earlier.[3] Measurement errors may occur because of instrument and/or observer errors. The observer error has been reported to be about 8 µm.[11,17] Two different observers may not choose exactly the same measuring points, and they may differ in the interpretation of the starting and ending points of the discrepancies.[18] Furthermore, the replicas must be cut perpendicular to the surface to measure the correct thickness of the impression film. This technique cannot exclude that in some cases the cut is oblique, and the measurement may overestimate the discrepancy between crown and master.

With the measuring technique used in the present investigation, most of the above errors have been avoided. Nevertheless, measurement errors of other kinds may have occurred. Imprecision in the correlation between the measuring points at the inner surface of the copings and the measuring points at the surface of the masters may have affected the results. However, even if the measuring points did not exactly correspond, the form of the masters and the profilometric control of the surface warrant only small changes in dimension along the whole surface of the masters and copings, provided that the same height is maintained.

Considering the measurement error to be around 5 µm, the results of this investigation suggest that the predetermined internal space of the copings was actually obtained by the manufacturer. It appears, though, that the copings predetermined with a 90-µm internal space showed less variation compared to the copings with a 45-µm predetermined internal space. Within the limitations of this in vitro study, it may be concluded that the CAD/CAM technique tested provided high precision in the manufacture of zirconium dioxide copings.

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