

Porcelain-veneered computer-generated partial crowns

Harry W. Denissen, DDS, PhD¹/Ahmed A. El-Zohairy, DDS²/
Marinus A. J. van Waas, DDS, PhD³/Albert J. Feilzer, DDS, PhD⁴

Objective: It would be advantageous to be able to use computer-aided design and manufacturing to fabricate a restoration that can be layered with a conventional porcelain veneer in the occlusal region, thus optimizing esthetics, function, and strength. This case study reports the laboratory technique and the clinical performance of 38 partial crowns fabricated with computer technology and veneered with porcelain.

Method and materials: Twenty-one mandibular and 17 maxillary molars in 27 patients were prepared for partial crowns. The occlusal surfaces were lowered (1.5 to 2.0 mm), deep shoulders (1.5 mm) were prepared around the functional cusps, and 1.0-mm-deep shoulders were prepared in the proximal gingival regions. The nonfunctional cusps were prepared with an occlusal shoulder at approximately a right angle with the axial surfaces of the seat. In the computer-aided design procedure, the occlusal table was reduced to 1.4 mm above the preparation surface. The marginal ridge points, the marginal ridge line, the equator line, and the fissure line heights were adjusted accordingly. **Results:** The lowest occlusal table thickness was 1.1 mm in six partial crowns, 1.2 mm in 26 partial crowns, and 1.3 mm in six partial crowns. The lowest occlusal table thickness of the porcelain veneers varied between 0.4 and 0.6 mm. The total occlusal table thickness thus was 1.5 mm or more. Clinically, no fractures occurred during an observation period varying between 1 and 4 years after placement. **Conclusion:** Computer-aided design and manufacturing technology is also convenient for partial crown preparation design with shoulder finish lines.

(*Quintessence Int* 2002;33:723–730)

Key words: computer-aided design–computer-aided machining (CAD-CAM), partial crown, porcelain veneer

CLINICAL RELEVANCE: The described fabrication technique aids the dentist and the dental technician in combining modern computer technology with proven conventional craftsmanship, creating layered esthetic, functional, and strong partial crowns.

Computer-aided design–computer-aided machining (CAD-CAM) technology is capable of fabricating a

partial crown from a uniformly colored, monolayered block of ceramic. The restoration is cemented with a light-curing posterior resin composite, and the centric occlusion is adjusted in the mouth of the patient by grinding. Articulation is checked, and grinding adjustments are made as required.¹

However, only a layered, lifelike ceramic can match the esthetics of natural teeth. Moreover, designing the occlusion and articulation in the mouth of the patient by grinding is a cumbersome procedure. Occlusal contacts can vary from complex tripod contacts with an ideal opposing tooth to simple centric contacts with a less-defined opposing occlusal table. The occlusal surface should allow cusps to escape and return to their fossae without interferences during articulation.²

Against this background, it would be advantageous to use CAD-CAM technology to fabricate a partial crown with a reduced occlusal table that can be layered with a conventional porcelain veneer, thus optimizing esthetics, function, and strength. This case study reports the laboratory technique and the clinical performance of porcelain-veneered partial crowns that were fabricated with CAD-CAM technology.

¹Mentor, CAD-CAM Research, Department of Oral Function and Prosthetic Dentistry, Academic Center for Dentistry, Amsterdam, the Netherlands.

²Assistant Lecturer, Department of Operative Dentistry, Faculty of Oral and Dental Medicine, Cairo University, Cairo, Egypt; Research Associate, Department of Materials Science, Academic Center for Dentistry, Amsterdam, the Netherlands.

³Professor and Head, Department of Oral Function and Prosthetic Dentistry, Academic Center for Dentistry, Amsterdam, the Netherlands.

⁴Professor and Head, Department of Materials Science, Academic Center for Dentistry, Amsterdam, the Netherlands.

Reprint requests: Dr Harry W. Denissen, Academic Center for Dentistry Amsterdam (ACTA), Louwesweg 1, 1066 EA Amsterdam, the Netherlands. E-mail: H.Denissen@acta.nl

Figs 1 and 2 Clinical cases selected for porcelain veneered CAD-CAM partial crowns. Conservative prosthetic preparation of the buccal and palatal/lingual surfaces of the molars will result in partial crowns.

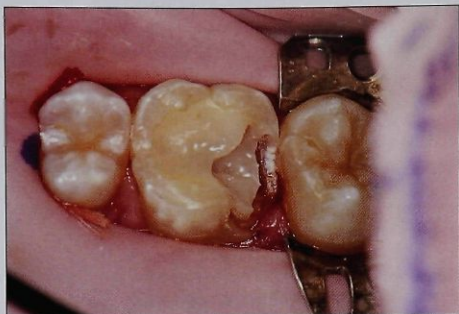


Fig 1 Maxillary first molar with a large, broken-down resin composite restoration and caries lesion.



Fig 2 Mandibular first molar with an extensive, leaking amalgam restoration. The buccal cusps are discolored (bluish) with fractured enamel edges.

METHOD AND MATERIALS

Patients

An experimental group of 27 patients (18 women and 9 men) with large defective resin composite or amalgam restorations in maxillary or mandibular molars was selected for partial crown therapy. Endodontic treatment was not a contraindication for selection.

Figures 1 and 2 show a maxillary case and a mandibular case. Of the 17 maxillary teeth selected for partial crowns, 11 were first molars, three were second molars, and three were third molars. Of the 21 mandibular teeth, 15 were first molars, four were second molars, and two were third molars.

Preparation design

The partial crown preparation design for molars was experimental. The occlusal surfaces were lowered (1.5 to 2.0 mm) with cylindrical diamond burs (Horico 111-014 or 111-018). A seat was prepared over the whole occlusal surface from mesial to distal with cylindrical diamond burs (Horico 111-018 or 111-025). Internal shoulders were thus created at approximately a right angle to the axial surfaces of the seat.

The shoulder finish lines were also prepared with the cylindrical diamond burs (Horico 111-014 and 111-018). Deep shoulders (1.5 mm) were prepared around the functional cusps, ie, in the buccal aspect of the mandibular molars and the palatal aspect of the maxillary molars. The functional cusps were thus enclosed. In the proximal gingival regions, 1.0-mm-deep shoulders were prepared. If possible, these gingival shoulders were level with or just below the proximal gingiva.

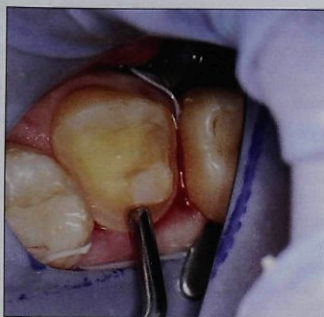
The nonfunctional cusps were prepared with an occlusal shoulder at approximately a right angle to the axial surfaces of the seat. The width of the occlusal surface of the shoulder was 1.5 to 3.0 mm. The nonfunctional cusps were thus covered. The transitions from the proximal shoulders to the occlusal shoulder on the nonfunctional cusps and the shoulder around the functional cusps were rounded and smoothed with a fine cylindrical diamond bur (Komet 8881-016). Figures 3 and 4 show maxillary and mandibular preparations for partial crowns.

After preparation, a complete-arch hydrocolloid impression (Van R Dental) was taken and poured in white stone (New Fuji Rock, GC). The master stone cast and stone cast of the opposing arch were mounted in an articulator (Dentatus). The master stone cast was used to obtain a partial hydrocolloid impression of the prepared molar and the adjacent dentition. This duplicate impression was poured in a brown reflective type of stone (CAM-base, Dentona). The partial stone cast was mounted on a model holder so that the surface of the prepared molar and the adjacent teeth could be drawn with computer surface digitization technology (Fig 5).

Color matching

Color guides with CAD-CAM partial crown samples were used to color match the porcelain with the adjacent teeth. The CAD-CAM samples were fabricated of ProCAD Esthetic ceramic blocks (Ivoclar/Vivadent) or Vitapan 3D ceramic blocks (Vita Zahnfabrik).

For ProCAD Esthetic block matching, a color guide was made of five CAD-CAM partial crowns fabricated of blocks E100, E200, and E300. The E100, E200, and



Figs 3 and 4 Experimental preparation designs for CAD-CAM partial crowns on a maxillary first molar (Fig 3) and mandibular molar (Fig 4). The nonfunctional (buccal maxillary and lingual mandibular) cusps have broad occlusal shoulders of approximately 2.0 mm. The shoulder depth around the functional cusps (palatal aspect of the maxillary cusps and buccal aspect of the mandibular cusps) is 1.5 mm (indicated by the gauge on the maxillary cusps) and 1.0 mm (indicated by the gauge on the mandibular molar). The proximal shoulders have a depth of 1.0 mm (indicated by the gauge on the mandibular molar). There are smooth transitions from the shoulder around the functional cusps to the shoulders in the proximal gingival margins. The proximal gingival shoulders continue smoothly into the occlusal shoulder on the non-functional cusps.

E300 partial crowns were shaded with shading pastes 100, 200, and 300, respectively. Shading an E200 sample with paste 400 and an E300 sample with paste 500 provided partial crown samples E400 and E500. The shaded CAD-CAM partial crowns were layered with ProCAD Add-on porcelain and polished and glazed with the ProCAD universal glazing paste.

For Vitapan 3D color matching, the value (brightness of color) of the adjacent teeth was compared with three partial crown samples made of blocks 2M, 3M, and 4M. These CAD-CAM partial crowns were only polished and glazed. The chroma (saturation of color) of the adjacent teeth was compared with four partial crown samples. These samples were fabricated of blocks 2M2, 2M3, 3M2, and 4M2 and layered with porcelain, polished, and glazed.

Digital drawing of the preparation surface

Before June 2000, the Cerec 2 (Sirona Dental) with the light beam was used for the digital drawing of the preparation surface. Thereafter, the Cerec 3 scanner was used with the laser beam.

The model holder with the stone cast of the prepared molar and the adjacent teeth was fastened in the spindle that is positioned in the middle of the unit chamber. The stone cast was measured three dimensionally, line by line, in approximately 8 minutes. The measurement procedure was performed in two steps with different angulations. The measurements resulted in a digital drawing and, after it was accepted, it was optimized by rotation. The height of the preparation surface was checked with the level mode of the sys-

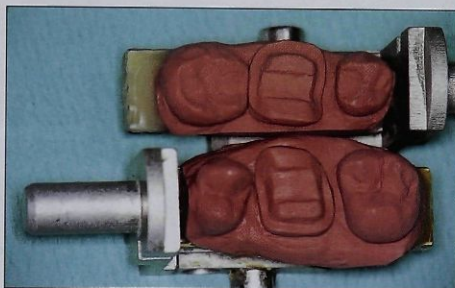


Fig 5 Mounted stone casts of prepared molars and adjacent teeth. The stone casts can be waxed on the model holder. The position of the stone cast can be adjusted by the ball-joint in the middle of the holder. The extension of the holder fits into the spindle of the Cerec 3 scanning unit.

tem. The mesial and/or distal contact lines of the adjacent teeth and the finish line of the partial crown preparation were drawn. The finish line was optimized in the x-y axis in the computer surface digitization image and in the z axis in projection and in section.

Digital drawing of the partial crown

The Cerec Crown software and the dental database of the system were used. The system suggested sites and calculated heights for the cusps as well as for the construction lines of the equator, marginal ridge, and main fissure of the partial crown. The digital drawing of the occlusal table of the partial crown by the software was modified. The heights of the cusps were reduced to only

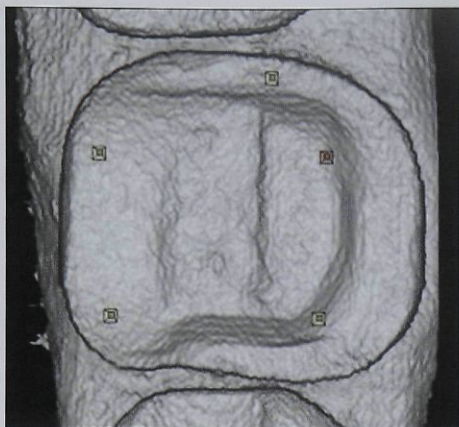


Fig 6 (left) Digital drawing of a partial crown preparation on a first molar with proximal parts of the adjacent teeth. The drawing was made with Cerec 3 laser beam technology. The sites of the cusps for the partial crown are indicated by the colored squares. The height of the cusp, indicated by the red square and calculated by the system (19.98 mm), was reduced to 1.4 mm above the preparation surface. The height of the preparation surface was 17.88 mm; consequently the cusp height was adjusted to 19.28 mm, to allow for porcelain veneering.

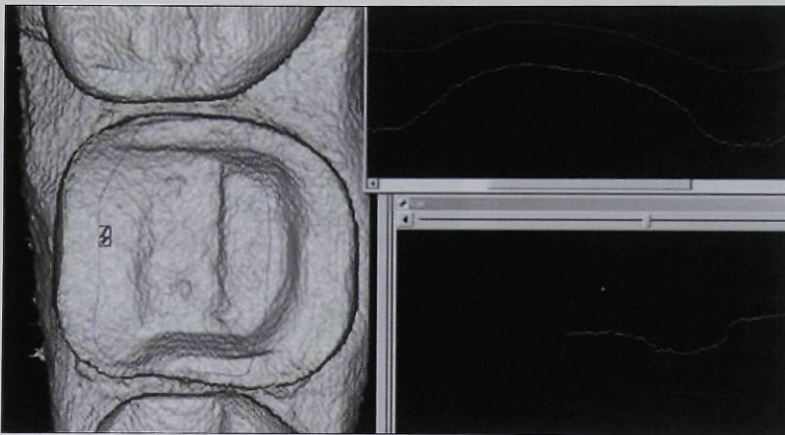


Fig 7 (below) (left) Digital drawing of Fig 6 with the constructions lines for the marginal ridge line (blue) and equator line (yellow) for the partial crown. Two icons on the marginal ridge line indicate the sites of the line in the projection window (upper right) and section window (lower right). The projection window shows the projection of the (blue) marginal ridge line and the (yellow) preparation line. The section window shows a red dot that indicates the section point through the marginal ridge line. The yellow line is the preparation line.



Fig 8 Buccal-lingual cross section of a partial crown on a mandibular molar using CAD technology. The preparation line (yellow) shows the nonfunctional cusp on the left. The seat portion is in the center, and the functional cusp with its buccal aspect is on the right. The blue line is the outer surface line of the partial crown. The red dots indicate section points through the finish line, equator line, marginal ridge line, and fissure line.

1.4 mm above the preparation surface. The heights of mesial and distal marginal ridge points were reduced to 0.5 mm below the value calculated by the system, and the fissure line height was adjusted to 1.4 mm above the preparation surface. Consequently a reduced occlusal table was drawn, leaving room for porcelain veneering.

The buccal and palatal/lingual equator lines were placed next to the finish line. At the mandibular buccal and the maxillary palatal sides, the equator lines were adjusted to the heights of the preparation surface at the sites of the functional cusps. At the mandibular lingual and maxillary buccal sides, the equator lines were adjusted to the heights of the nonfunctional cusps. The proximal equators were adjusted to the heights of the marginal ridge points minus 0.7 mm (Figs 6 to 8).

Partial crown fabrication

The selected Vitapan 3D or ProCAD Esthetic ceramic block was mounted in the spindle in the milling chamber of the Cerec unit. The drive motors of the tapered bur (1.6 mm in diameter) and the cylindrical bur (1.2 mm in diameter) milled the outer and the inner surfaces of the partial crown, respectively. All milling was done under water cooling and took approximately 12 minutes.

After milling was completed, the occlusal table thickness was measured at all sides with calipers. The lowest thickness and the particular site, which represented the weakest point of the restoration, were recorded before porcelain veneering.

Porcelain veneering

For Vitapan 3D partial crowns, enamel porcelain (Vitadur Alpha EN2) and translucent porcelain (Vitadur Alpha opal T2) were used. If a hue that was more yellowish or reddish than the used orange block was desired, the porcelains were stained to achieve the matching hue.

For ProCAD partial crowns, five shading pastes (100, 200, 300, 400, and 500) and ProCAD Add-on porcelains (100, 200, and neutral) were used.

The occlusal tables of the CAD-CAM partial crowns were veneered with porcelain, and cusp-fossa contact relations during occlusion and articulation were established. Function was thus optimized, and the layering provided a natural, toothlike appearance to the partial crown. Individual effects present in the adjacent teeth, such as decalcifications, enamel cracks, abrasion, fissure discoloration, proximal discoloration, restorations, surface structure, and surface glaze, were imitated by staining the partial crown.

Vitapan 3D partial crowns were glazed with Vita Akzent fluid and glaze powder (Akz25). ProCAD partial crowns were glazed with ProCAD universal glazing paste (Fig 9).

After porcelain veneering was completed, the occlusal thickness at the recorded thinnest site of the partial crown was measured with calipers. Subtraction of the recorded CAD-CAM thickness of the partial crown from the measured value revealed the thickness of the porcelain veneer at that particular site.

Partial crown cementation

The porcelain-veneered partial crown was placed in acetone and ultrasonically treated for 5 minutes. The internal surface of the partial crown was cleaned with phosphoric acid (37%), rinsed, and dried before placement.

Rubber dam was applied, and the prepared molar was cleaned with pumice. Panavia F TC dual-cure ce-



Fig 9 Three stages in the creation of the porcelain-veneered CAD-CAM partial crown. (left) A monochromatic partial crown has been fabricated of ProCAD Esthetic block using CAD-CAM technology. (center) Functional partial crown in which cusp-fossa relationships with the opposing tooth have been optimized by porcelain veneering. (right) The partial crown has been esthetically optimized by staining and glazing.

ment (Kuraray) was used for cementation. The self-etching primer (Panavia ED Primer) was applied to the preparation surface and left in place for 60 seconds. The volatile components were evaporated with a gentle flow of air until the surface was completely dry and glossy. Panavia F TC base paste and catalyst were mixed for 20 seconds, and the partial crown was seated within 40 seconds. Excess cement was removed with a brush, dental floss, and explorer. The cement was then cured along the margins in several sections by visible light for 20 seconds for each section. Final finishing of the margins was done with a tapered fine diamond bur (Horico 249 014).

RESULTS

Four Vitapan 3D partial crowns had a lowest occlusal ceramic thickness of 1.1 mm. Twelve partial crowns had a lowest thickness of 1.2 mm, and four partial crowns had a lowest thickness of 1.3 mm (Table 1). Two ProCAD partial crowns had a lowest occlusal thickness of 1.1 mm. Fourteen ProCAD partial crowns had a lowest thickness of 1.2 mm and two had a lowest thickness of 1.3 mm. The thickness of the porcelain veneer at the thinnest occlusal CAD-CAM sites varied between 0.4 and 0.6 mm.

The Vitapan 3D and ProCAD color guide samples developed for color matching were expedient for selection of the appropriate ceramic block. Optimization of hue, individual staining, and glazing of the partial crown represented creative and rewarding craftsmanship (Figs 10 to 12).

TABLE 1 Lowest occlusal table ceramic thickness (mm) of 38 CAD-CAM partial crowns

Thickness	Mandible			Maxilla		
	First molar	Second molar	Third molar	First molar	Second molar	Third molar
<i>Vitapan 3D</i>						
1.1 mm	0	1	0	0	1	2
1.2 mm	8	1	0	3	0	0
1.3 mm	2	0	0	2	0	0
<i>ProCAD</i>						
1.1 mm	0	0	1	0	0	1
1.2 mm	4	2	1	5	2	0
1.3 mm	1	0	0	1	0	0

Figs 10 and 11 Porcelain-veneered CAD-CAM partial crowns directly after placement on the maxillary first molar (Fig 1) and mandibular first molar (Fig 2).**Fig 10** Vitapan 3D crown.**Fig 11** ProCAD Esthetic crown.

The CAD-CAM partial crowns fabricated of ProCAD blocks were more translucent than were those made of Vitapan 3D blocks. Therefore, the Vitapan 3D partial crowns were veneered with translucent porcelain.

Optimization of occlusion and articulation in the articulator very much depended on the morphology of the occlusal tables of the opposing teeth. In 12 of the 38 cases, some selective grinding of restorations or superpositioned cusp tips of opposing teeth was necessary to achieve favorable cusp-fossa relations.

No fractures occurred during an observation period varying between 1 and 4 years.

DISCUSSION

The favorable periodontal aspects of partial crown preparation design are well known.³ Partial coverage design is a tissue-saving and conservative alternative

to rebuilding the bulk of the tooth with a core material and then providing it with a complete crown. The introduction of computer technology and strong ceramic blocks in dentistry offers prospects for all-ceramic CAD-CAM restorations with this preparation design.

This study showed that shoulder-type finishing lines, in which the gingival floor or occlusal surface met the external and internal axial surfaces at approximately a right angle, were feasible in all 38 cases. The depth of proximal gingival shoulders was 1.0 mm and buccal and palatal shoulders was 1.5 mm. This might suggest, from an anatomic point of view, that the shoulder design is the preparation of choice for well-supported all-ceramic CAD-CAM restorations milled with cylindrical burs.

A drawback of a restoration fabricated from a monolithic block of material is the uniform color. The bonding cements cannot characterize restorations thicker than 1.5 mm. Ultimately, only porcelain layering can optimize the esthetics of restoration. It can be

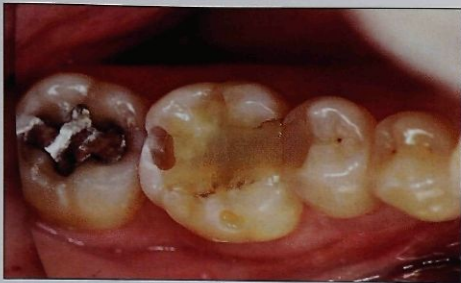


Fig 12a Mandibular first molar with large, leaking resin composite restoration with defective margins and buccal and lingual cavities.



Fig 12b Try-in of a monochromatic Vitapan 3D partial crown that was only polished and glazed.



Fig 12c Porcelain-veneered CAD-CAM partial crown, 6 months after placement. Note the esthetic effect of porcelain veneering.



Fig 12d Buccal aspect of the partial crown in the mouth of the patient.

argued that esthetic concerns are reserved for the anterior teeth. It has also been suggested that, ideally, a cosmetic restoration should be indistinguishable from the surrounding unrestored dentition.⁴ Between these extremes, a limited selection of ProCAD Esthetic and Vitapan 3D color samples were selected for partial crowns on molars.

Staining and glazing the porcelain layer, thus creating a more yellowish or more reddish hue, is a rewarding esthetic experience. Individual effects in the adjacent teeth, such as decalcifications and opalescent effects, can be imitated by stains and give a lifelike appearance to the restoration.

Apart from improving esthetics, oven glazing of CAD-CAM ceramic restorations results in significantly higher strength and higher resistance to loading than does surface polishing. Chen et al⁵ found that the fracture strength improved up to 2,254 N with oven glazing.

The CAD occlusal table was reduced in height to 1.4 mm above the preparation surface. Consequently,

the CAD-CAM partial crown had its net shape from the finish line up to the reduced occlusal table. The idea was that the occlusal ceramic thickness should be as high as possible to prevent fractures,^{6,7} but at the same time, should leave room for porcelain veneering of the occlusal table. A clinically realistic total occlusal thickness of 1.5 to 2.0 mm is hypothesized to be optimal for the longevity of the partial crown. These CAD-CAM partial crowns were produced with a lowest ceramic thickness of 1.1 to 1.3 mm. The lowest porcelain veneer thickness at the thinnest sites varied between 0.4 and 0.6 mm. The occlusal thickness of the porcelain-veneered partial crowns thus totaled 1.5 mm or more.

Clinically, no fractures occurred during an observation period varying between 1 and 4 years after placement.

CONCLUSION

The Cerec system is based on the concept of boxlike preparation design.¹ From the present short-term clinical results, it can be concluded that Cerec technology is also convenient for partial crown preparation design with shoulder finish lines. The described technique for porcelain-veneered CAD-CAM partial crowns aids the dentist and dental technician in combining modern computer technology with proven conventional craftsmanship, to create layered esthetic, functional, and strong partial crowns.

ACKNOWLEDGMENTS

The authors gratefully acknowledge Joke Denissen-Gruter for her help in preparing the manuscript.

REFERENCES

1. Mörmann WH, Bindl A. The Cerec 3—A quantum leap for computer-aided restorations: Initial clinical results. *Quintessence Int* 2000;31:699-712.
2. Zel van der JM, Vlaar S, Ruiter de WJ, Davidson CL. The CICERO system for CAD/CAM fabrication of full-ceramic crowns. *J Prosthet Dent* 2001;85:261-267.
3. Christensen GJ. The coming demise of the cast gold restoration? *J Am Dent Assoc* 1996;127:1233-1236.
4. Glick KL. Color management of cosmetic restorations. *Curr Opin Cosmet Dent* 1995;3:36-40.
5. Chen HY, Hickel R, Setcos JC, Kunzelmann K-H. Effects of surface finish and fatigue testing on the fracture strength of CAD-CAM and pressed-ceramic crowns. *J Prosthet Dent* 1999;82:468-475.
6. Doyle MG, Goodacre CJ, Munoz CA, Andres CJ. The effect of tooth preparation design on the breaking strength of Dicoor crowns. *Int J Prosthodont* 1990;3:327-340.
7. Scherrer SS, de Rijk WG. The effect of crown length on the fracture resistance of posterior porcelain and glass-ceramic crowns. *Int J Prosthodont* 1992;5:550-557.

HARVARD

survives
the test
of time

● Please ask for brochures



Richter & Hoffmann · Harvard Dental-Gesellschaft
Johannisberger Straße 24, 14197 Berlin, Germany

