MARGINAL FIT OF THE DIGIDENT CAD/CAM ZIRCONIA CERAMIC CROWNS

Yong-Sun Kim, D.D.S., Jae-Ho Yang, D.D.S., M.S.D., Ph.D.
Department of Prosthodontics, Graduate School, Seoul National University

Statement of problem. There have been many studies about marginal discrepancy of single restorations made by various systems and materials. However most of the statistical inferences are not definite because of sample size, measurement number, measuring instruments, etc, and there have been few studies about the marginal fit of the Digident CAD/CAM zirconia ceramic crowns.

Purpose. The purpose of this study was to compare the marginal fit of the anterior single restorations made by using the Digident CAD/CAM zirconia ceramic crowns with metal-ceramic restorations and to obtain more accurate information by using a large enough sample size and by making sufficient measurements per specimen.

Material and Methods. The crowns were made from one extracted maxillary central incisor prepared with a 1mm shoulder margin and 6° taper walls by milling machine.

The in vitro marginal discrepancies of the digident CAD/CAM zirconia ceramic crowns and control groups(metal ceramic crowns) were evaluated and compared. Twenty crowns per each system were fabricated. Measurements of a crown were recorded at 50 points that were randomly selected for marginal gap evaluation. Parametric statistical analysis was performed for the results.

Conclusion. Within the limitations of this in vitro study, the following conclusions were drawn:

1. Mean gap dimensions and standard deviations at the marginal opening for maxillary incisal crowns were $88 \pm 10\mu m$ for the control (metal-ceramic crowns), $92 \pm 4\mu m$ for Digident CAD/CAM zirconia ceramic crowns.
2. Marginal gap between Digident CAD/CAM zirconia ceramic crowns and metal ceramic crowns did not show significant difference ($P>.05$).
3. The Digident CAD/CAM zirconia ceramic crowns and metal ceramic crowns showed clinically acceptable marginal discrepancy.

Key Words
Marginal fit, Digident CAD/CAM zirconia ceramic crown, Metal ceramic crown

All ceramic crowns offer excellent esthetics and biocompatibility. It has been used successfully for restoring anterior teeth. The demand for esthetic dental restorations has made the all ceramic crown a popular restoration. The use of all ceramic materials for fixed restorations has become more and more important in esthetically oriented dentistry.

If all ceramic restorations are to be successful, they must satisfy strength and marginal fit. Especially,

marginal fit is valued as one of the most important criteria in fixed restorations because large marginal gap shows more plaque accumulation, more cement leakage, and higher secondary caries occurrence, etc. Although there have been many studies about marginal fit of single restorations fabricated by various systems, their statistical inferences were not so definite because of the relatively small sample size, and insufficient measurement number per sample, etc.

Digident CAD/CAM(computer aided design/computer aided manufacturing) zirconia ceramic crowns are the CAD/CAM all ceramic system which their framework material consists of zirconium oxide. It is biocompatible, esthetic and accurately fitting all-ceramic restorations for the anterior and posterior tooth region.

Digident CAD/CAM system uses a scanning, design and machining process to custom-shape copings from industrially pre-fabricated zirconia ceramic blocks. One of the significant advantages in using CAD/CAM technology lies in the fact that room-temperature milling of ceramic materials processed under high-quality processes will yield homogeneous material structures, where voids, flaws and cracks are reduced to a minimum. Therefore, CAD/CAM manufacturing of all-ceramic restorations from an industrially prepared ceramic block can be seen as an alternative techniqure for the fabrication of dental restoration. In addition, this technology also promises highly accurate results. In order to produce milled restorations with an accurate fit, it is necessary to mechanically or optically scan the prepared tooth surface and convert the data into control signals for computer-assisted milling. In Digident CAD/CAM system, optical 3D-Digitizer enables very precise measurements of single tooth and complete arches. Design unit is possible to program the manufacture of copings with a predetermined space. It has a controlled and constant quality and standardized fabrication conditions without material fault. During milling, the CAM method enables total control of the design and orientation to the master model by individual and manual carving of the restoration.

Few studies have been conducted upon the marginal discrepancies of Digident CAD/CAM zirconia ceramic crowns. Coli et al.[1] made a study about marginal fit of zirconia dioxide ceramic copings manufactured using a recently introduced CAD/CAM based technique (Denzir), but the number of specimens used for the statistics of marginal gap in each group was five.

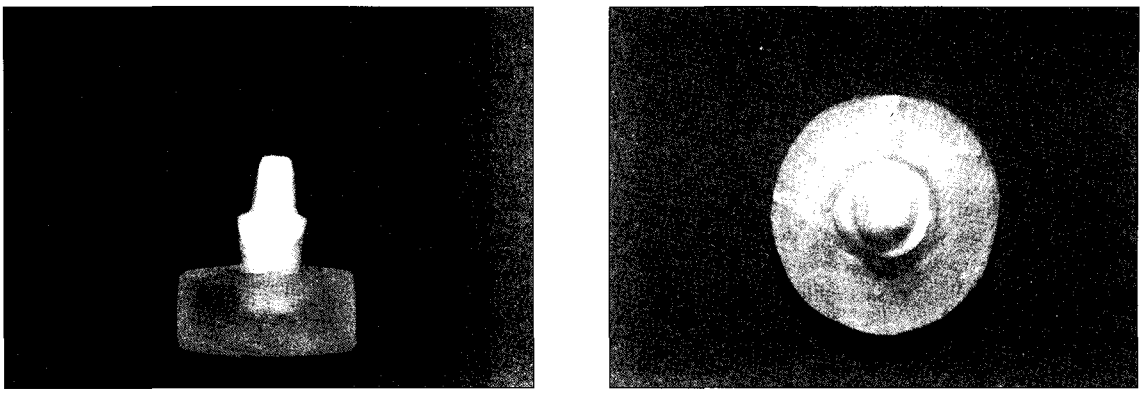
The purpose of this study was to compare the marginal fits of the anterior single restorations made by using Digident CAD/CAM zirconia ceramic crowns with metal ceramic restorations. This study was also intended to obtain more definite statistical inference and analysis by enough sample size, sufficient measurements and proper variable control.

MATERIALS AND METHODS

One extracted maxillary central incisor without caries was cleaned and embedded in an autopolymerizing resin-manufactured block (Orthodontic resin, Dentsply International Inc., Milford, DE). The long axis of the tooth was set perpendicular to the surface of the block.

The tooth was prepared for all-ceramic crown fabrication. Using a high-speed handpiece, incisal reduction of 2-3mm and axial reduction of approximately 1mm were prepared. The tooth was finished by milling (F2, Degussa Korea Inc., Seoul, Korea), which resulted in about a 1mm shoulder margin with 6° tapered angles and an approximate height of 7mm (Fig. 1).

A preliminary impression using a stock tray was made using irreversible hydrocolloid impression material (Aroma fine, GC Co., Tokyo, Japan), and a plaster (Samwoo plaster, Samwoo CO., Ulsan, Korea) cast was made. After obtaining the relief of two sheets of baseplate wax on the plaster cast, the 40 custom-made



A B

Fig. 1. The prepared maxillary central incisor without caries was cleaned and embedded in an autopolymerizing resin-manufactured block. The long axis of the tooth was set perpendicular to the surface of the block. A. Labial view, B. Incislal view.

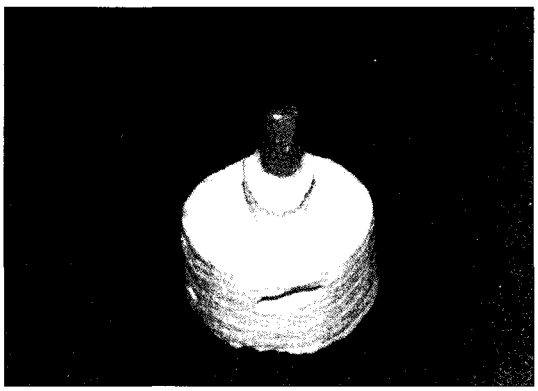


Fig. 2. The master die for final restoration.

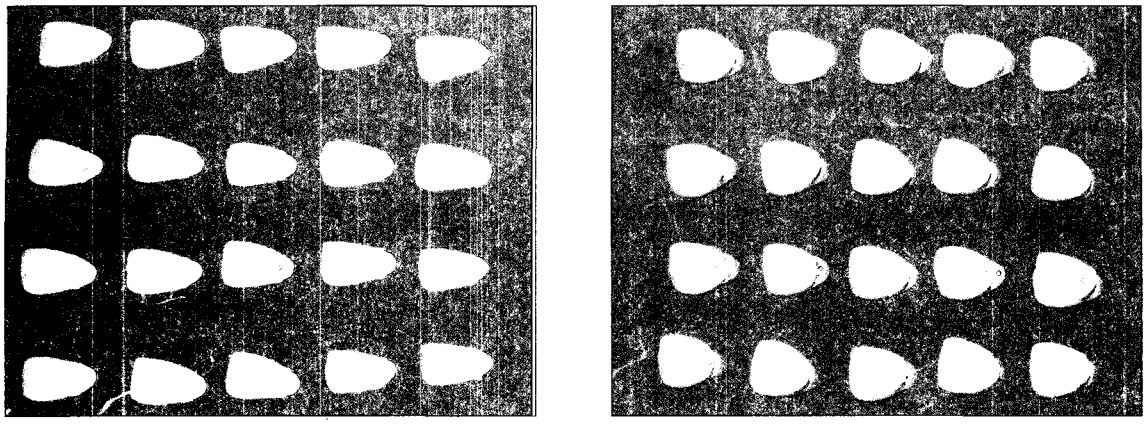
trays were fabricated using acrylic resin (Quicky, Nissan Dental Products Inc., Kyoto, Japan). Final impressions were made with polyvinyl siloxane (Examix, GC Korea Inc., Seoul, Korea) using custom trays, and 40 master stone dies were fabricated (Rhombrock, Mitsubishi, Tokyo, Japan) (Fig. 2). Forty veneered crowns (20 crowns per group) were fabricated : 20 metal ceramic (Rexillium III, Jeneric/Pentron Inc., Wallingford, Conn. and VMK 95, VITA Zahnfabrik, Bad Sakingen, Germany) crowns and 20 Digident CAD/CAM zirconia ceramic crowns (Girrbach Dental, Pforzheim, Germany) were made (Fig. 3).

Each group was fabricated by an experienced dental technician who was accustomed to the specific system. Digident CAD/CAM zirconia ceramic crowns were fabricated by scanning device, design unit and milling unit (Fig. 4).

The marginal fit was evaluated by measuring the gap between the edge of the crown and the prepared tooth margin in a light microscope with image processing (Acura 2000, INTEK PLUS, Daejon, Korea) at X240 magnification (Fig. 5).

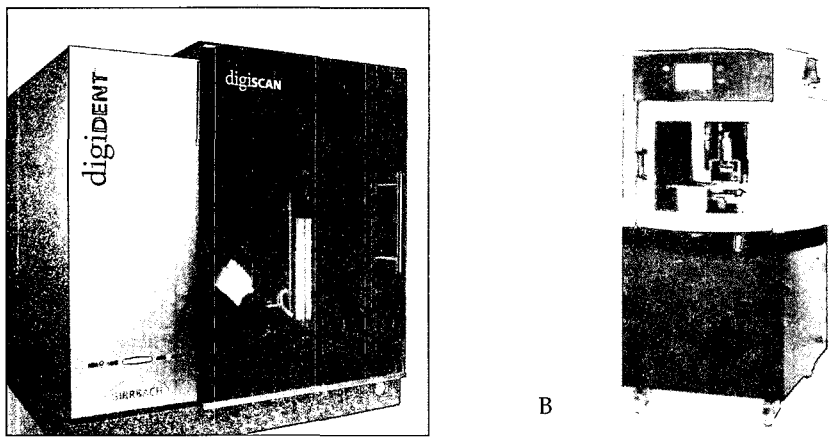
The accuracy of this light microscope was $\pm 0.1\mu$m. The gap was measured as the minimum distance from one point of the crown edge to a line determined by least squares of points at the tooth margin (Fig. 6).

All measurements and the least squared lines were computed by the programmed macro provided by Acura 2000 software system. Measurements were made without cementation. The marginal gap of one crown was measured at 50 points along the margin that were randomly selected in distances of about 400μm. The marginal fit of one crown was defined as a mean value of these 50 measurements.



A. Metal ceramic crowns (n=20) B. Digident CAD/CAM zirconia ceramic crowns (n=20)

Fig. 3. Forty crowns fabricated.



A B

Fig. 4. A. Digident digiscan (Girrbach Dental, Pforzheim, Germany), B. Digident milling unit (Girrbach Dental, Pforzheim, Germany).

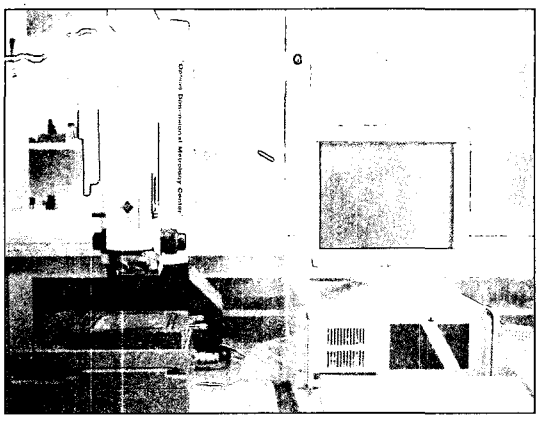


Fig. 5. The light microscope with image processing (Acura 2000).

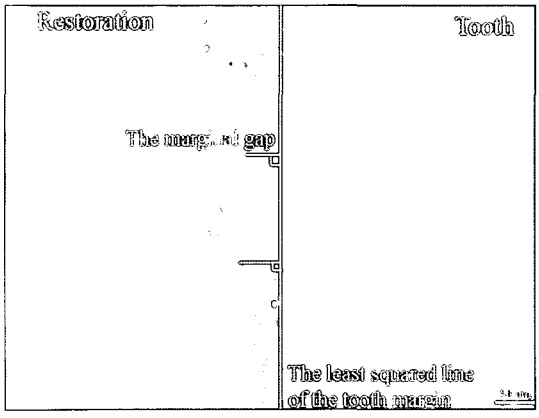


Fig. 6. Demonstration of computer aided measurement of marginal fit.

The means and standard deviations per group were calculated and statistical inferences among the groups were made using t-test at .05 level of significance.

RESULTS

Table I showed the means and the standard deviations of the average gap dimensions of the crown groups.

The means and standard deviations of the marginal fit were 88±10㎛ for the control group, 92±4㎛ for the Digident CAD/CAM zirconia ceramic crowns. The t-test of the marginal discrepancies between Digident CAD/CAM zirconia ceramic crowns and metal-ceramic crowns were perfomed (Table II). Significant differences were not found between groups (P=0.193>.05).

Table III presents the normal distribution of the data around the mean value in each group.

Based on the criterion of 120㎛ as the lim- it of clinical acceptability, the mean marginal fits of Digident CAD/CAM zirconia ceramic crowns and metal-ceramic crowns were acceptable.

DISCUSSION

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. According to Beschnidt et al.[3] the evaluation of the marginal discrepancy of crowns depends on several factors in general: measurements of cemented or not-cemented crowns, storage time and treatment (such as aging procedures) after cementation, kind of abutment used for measurement, kind of microscope and enlargement factor used for measurements, location and quantity of single measurements.

Ideally, for measuring the marginal gap after cementation, the same number of teeth or steel dies as that of restoration sample is needed because of the control of variables. On the contrary, only one tooth or steel die is needed if we measure without cementation. Some authors[3-5] found that a significant increase in the marginal discrepancy was observed after cementation. They showed, however, considerable different results according to the kinds of ce-

Table I. The mean and standard deviations of marginal fit in each of the groups (unit: ㎛)

	N	Mean	Standard Deviation
Metal ceramic	20	88	10
Digident CAD/CAM	20	92	4

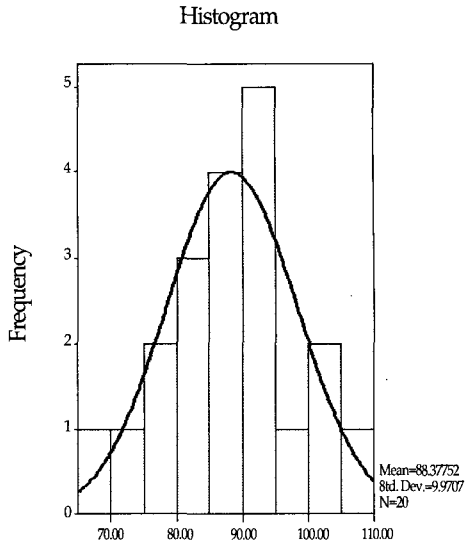
Table II. The result of independent sample test

	Levene's test for equality of variances		t-test for equality of means						
	F	Sig.	t	df	Sig(2-Tailed)	Mean Dif.	Standard Error difference	95% confidence interval of the difference	
								Lower	Upper
Equal Variances Assumed	9.512	.004	-1.326	38	.193	-3.19	2.40	-8.05	1.68
Equal Variances not assumed			-1.326	25	.197	-3.19	2.40	-8.13	1.76

Table III. Distribution of the data.

A. metal ceramic crown.

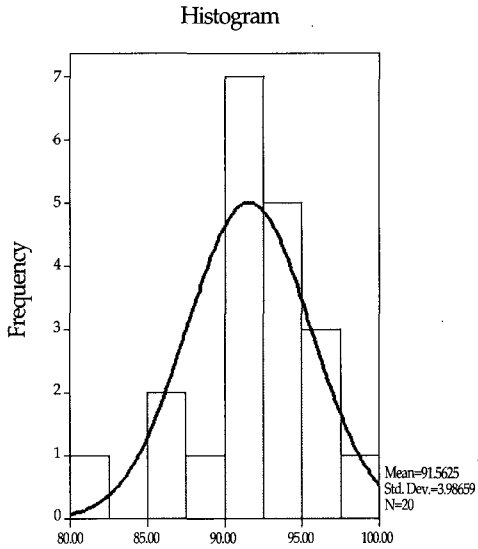
N	Valid	20
	Missing	0
Mean		88.3775
Standard error of mean		2.2295
Median		88.8550
Mode		66.51
Standard deviation		9.9707
Variance		99.415
Skewness		-.446
Standard error of skewness		.512
Kurtosis		.167
Standard error of kurtosis		.992
Range		38.54
Minimum		66.51
Maximum		105.05
Sum		1767.55



METAL-CERAMIC
(X= marginal gap, Y= number)

B. Digident CAD/CAM zirconia ceramic crown

N	Valid	20
	Missing	0
Mean		91.5625
Standard error of mean		.8914
Median		91.1300
Mode		80.99
Standard deviation		3.9865
Variance		15.893
Skewness		-.809
Standard error of skewness		.512
Kurtosis		1.391
Standard error of kurtosis		.992
Range		17.57
Minimum		80.99
Maximum		98.56
Sum		1831.25



Digident CAD/CAM zirconia ceramic
(X= marginal gap, Y= number)

menting measured without cementation for more sophisticated variable control in this study. The marginal discrepancies found in this study were all within clinically acceptable standards.[9]

Variation exists regarding what constitutes a clinically acceptable margin. McLean and von

Fraunhofer[10] proposed that a successful restoration was possible if restorations could be constructed so that marginal gaps and cement films of less than 120μm were achieved. This criterion has been cited in some articles. The value of 120μm was, therefore, used as the maximum clinically acceptable marginal opening in this study.

In tooth preparation, some forms of the margin are possible: shoulder, heavy chamfer, etc. It was said that the type of finishing line did not affect the marginal gap. According to Goodacre et al.[7], the shoulder margin was recommended in all ceramic restorations and many authors usually agreed with such a marginal design In this study, therefore, this type of margin was chosen. In the control group, chamfer margin was selected at the lingual surface. But two teeth would have been required (one: all shoulder margin, the other: about 1/2 of shoulder, 1/2 of chamfer) in such a case. Then the two teeth could have different conditions in measuring the marginal opening and there could be a problem in the control of variables. For unification of conditions, all the surfaces of the tooth were prepared with the shoulder margin of about 1mm width and it was used as the only master model.

There have been few studies about marginal fit of Digident CAD/CAM zirconia ceramic crowns. Similar study has been done by Tinschert et al.[8] They reported marginal gap of alumina - and zirconia-based fixed partial dentures produced by a CAD/CAM system (Precident DCS system) and their marginal gap was smaller than these in this study. But their sample size was too small and they used a non-parametric analysis. Hertlein et al.[9] reported that CAD/CAM zirconia based all-ceramic system (3M Lava) had smaller marginal gap. But their sample size was also small. Coli et al. made a study about marginal fit of zirconia dioxide ceramic copings manufactured using a recently introduced CAD/CAM/ based technique (Denzir). The number of specimens used for the statistics of marginal gap in each group was small and 24 measurements per specimen were contributed to the variation

In recent studies, Bindl and mormann[15] compared marginal fit of the six different all ceramic systems (In-Ceram Zirconia, Empress II, Cerec In-lab, DCS, Decim, Procera). The fit of conventional and CAD/CAM all ceramic systems had the same range of marginal gap. Reish and wickmann[14] reported clinical fit of all ceramic fixed partial dentures, generated with three different CAD/CAM systems(The CEREC inlab system, The Digident CAD/CAM system, The LAVA system). The result suggest that the accuracy of CAD/CAM all ceramic system was satisfactory for clinical use.

There were no definite standards for the proper sample size and number of measurements for each sample. In many articles, nonparametric statistical analysis was used in evaluating the marginal opening because it was very difficult to obtain the normal distribution of the data. When the sample size was 10, non-parametric analysis was chosen in marginal gap measurement because standard deviations were relatively large compared with mean values, resulting in failure in acquiring normality

However, the parametric analysis is more reliable in evaluating the original population than the non-parametric one. Parametric tests are advocated if normality of the data of the samples can be obtained. When the sample size is high (at least 20), the distribution of data is usually normal. Table III showed that the distribution of data were normal. According to Groten et al.[2] approximately 50 measurements along the margin of a crown yield clinically relevant information and a consistent estimate for the gap size, and that error size for the calculation of measurement' s mean was about $\pm$5μm. It was of minor importance whether 50 measurements along the margin were randomly selected or systemically recorded in distances of about 500μm (strategic 50 measurements). On the contrary, Gassino et al.[11] reported that min-

imum number of measurements required to ensure relevant results for gap analysis was 18 for experimental crowns. In this study, 20 sample sizes and 50 measurements per sample in random manner were selected for more accurate result.

On the other hand, Groten et al.[16] compared light microscopic data with scanning-electron-microscopic data at measuring marginal fit. The evaluation of the external marginal gap was performed on the master steel die by using a light microscope and by using a scanning electron microscope. At result, there were no significant differences between these two methods.

It was considered that there were two variables that were distinguished between the groups in this experimental design: one was the difference between the systems and the other the difference between the skills of dental technicians who made the single restorations. It was assumed in this study that there was no difference in the technique of the dental technicians, because they had fabricated more than 500 crowns using each system, and they were considered experienced. It was, therefore, thought that the difference between the systems was the only significant variable and that the other conditions were identical. The present study showed clinically acceptable marginal discrepancy of all groups.

There were some limitations in this study. Marginal opening was measurable in this experimental design, but internal fit of the crowns was impossible to measure. In order to measure the inner fit of artificial crowns, cementing the crowns and sectioning the specimens are required. New experimental design to measure both the marginal and inner fit are required.

Digident CAD/CAM zirconia ceramic anterior fixed partial dentures as well as single crowns have been applied for esthetics. It requires more strength and dimensional stability that has resulted in clinically acceptable marginal fit. More studies are necessary about strength and marginal fit of Digident CAD/CAM zirconia ceramic fixed partial dentures.

CONCLUSIONS

Within the limitations of this in vitro study, the following conclusions were drawn:

1. Mean gap dimensions and standard deviations at the marginal opening for maxillary central incisor crowns were $88 \pm 10\mu m$ for the control (metal-ceramic crowns), $92 \pm 4\mu m$ for Digident CAD/CAM zirconia ceramic crowns.
2. Marginal gap between Digident CAD/CAM zirconia ceramic crowns and metal ceramic crowns did not show significant difference ($P>.05$)
3. The Digident CAD/CAM zirconia ceramic crowns and metal ceramic crowns showed clinically acceptable marginal discrepancy.

REFERENCES

1. Coli P, Karlsson S. Fit of a new pressure-sintered zirconium dioxide coping. Int J Prosthodont 2004;17:59-64.
2. Groten M, Axmann D, Proster L, Weber H. Determination of the minimum number of marginal gap measurements required for practical in vitro testing. J Prosthet Dent 2000;83:40-9.
3. Beschnidt SM, Strub JR. Evaluation of the marginal accuracy of different all-ceramic crown systems after simulation in the artificial mouth. J Oral Rehabil 1999; 26:582-93.
4. Hung SH, Hung KS, Eick DJ, Chappell RP. Marginal fit of porcelain-fused-to metal and two types of ceramic crown. J Prosthet Dent 1990;63:26-31.
5. Kern M, Schaller HG, Strub JR. Marginal fit of restorations before and after cementation in vivo. Int J Prosthodont 1993;6:5855-91.
6. Belser UC, MacEntee MI, Richter WA. Fit of there porecelain-fused-to metal marginal designs in vivo: A scanning electron microscope study. J Prosthet Dent 1985;53:24-9.
7. Goodacre CJ, Campagni WV. Aquilint SA Tooth preparation for complete crowns: An art form based on scientific principles. J Prosthet Dent 2001;85:363-76.
8. Tinschert J, Natt G, Mautsch W, Spickermann H, Anusavice KJ. Marginal fit of alumina-and zir-

conia-based fixed partial dentures produced by a CAD/CAM system. Oper Dent 2001;367-74.
9. Hertlein G, Hoscheler S, Frank S, Suttor D. Marginal fit of CAD/CAM manufactured all ceramic zirconia prosthesis. J Dent Res 2001;80:42.
10. McLean JW, von Fraunhofer JA. The estimationof cement film thickness by an in vivo technique. Br Dent J 1971;131:107-11.
11. Gasino G, Barone MS, Scanu M, Spina G, Preti G. Marginal adaptation of fixed prosthodontics: a new in vitro 360-degree external examination procedure. Int J Prosthodont 2004;17:218-23.
12. Yeo IS, Yang JH, Lee JB. In virto marginal fit of three all-ceramic crown systems. J Proshet Dent 2003; 90;459-64.
13. Coli P, Karlesson S. Precision of a CAD/CAM technique for the production of ziconium Dioxide Copings. Int J Prosthodont 2004;17:577-80.
14. Reich S, Wickmann M. Clinical fit of all-ceramic three-unit fixed partial dentures, generated with three different CAD/CAM Systems. Eur J Oral Sci 2005;113:174- 179.
15. Bindl A, Mormann WH. Marginal and internal fit of all-ceramic CAD/CAM crown-copings on chamfer preparations. J Oral Rehabil 2005;32:441-447.
16. Groten M, Proster L. Marginal fit consistency of copy-milled all-ceramic crowns during fabrication by light and scanning electron microscopic analysis in vitro. J Oral Rehabil 1997;24:871-881.

Reprint request to:
JAE-HO YANG, D.D.S.,M.S.D.,PH.D.
DEPARTMENT OF PROSTHODONTICS, GRADUATE SCHOOL,
SEOUL NATIONAL UNIVERSITY
28-1 YEONGUN-DONG, CHONGNO-GU, SEOUL, 110-768, KOREA
Jhoyang@snu.ac.kr