A STUDY ON THE MARGINAL FIT OF COLLARLESS METAL CERAMIC FIXED PARTIAL DENTURES

Jong-Wook Yoon, D.D.S., M.S.D., Jae-Ho Yang, D.D.S., M.S.D., Ph.D., Jung-Seok Han, D.D.S., M.S.D, Ph.D., Jae-Bong Lee, D.D.S., M.S.D., PhD.
Department of Prosthodontics, Graduate School, Seoul National University

Statement of problem. Collarless metal ceramic fixed partial dentures(FPDs) had an esthetic problem such as opaque reflection in cervical region. To overcome this, modified coping which removed its facial cervical metal could be used. The marginal quality could be worsen according to the amount of its facial metal reduction.

Purpose. The purpose of this study was to evaluate marginal fits of collarless metal ceramic FPDs with retainers of modified copings.

Material and method. Dentoform maxillary left central incisor and right lateral incisor were prepared for 3-unit collarless metal ceramic FPD and fixed in yellow stone. This model was duplicated to PBT resin dies via CAD/CAM and injection molding. Four different facial margin design groups were investigated. Group A was a coping with a thin facial metal collar, group B was a collarless coping with its facial metal to the shoulder, group C was a collarless coping with its facial metal 1 mm short of the shoulder, and group D was a collarless coping with its facial metal 2 mm short of the shoulder. Seven collarless metal ceramic FPDs per group were fabricated. They were cemented to PBT resin dies with resin cement. After removal of pontics, each retainers were separated and observed under Accura 2000 optical microscope. Then, retainers were embeded in orthodontic resin and cross sectioned faciopalatally. Internal marginal fits of midfacial porcelain margins were observed under FE-SEM.

Result and conclusion. Within the limitations of this in vitro study. The following conclusions were drawn.

1. Mean marginal gaps of collarless FPDs were in the 50-60 μm range.
2. In midfacial margin, marginal discrepancies were greater in group A than in the experimental groups($p<0.05$).
3. In midpalatal margin, marginal gaps were greater in group C and D than in group A and B($p<0.05$).
4. Marginal fits of porcelain margins were better than those of metal margins in collarless metal ceramic FPDs.
5. In both teeth, internal marginal gaps of group C and D were greater than those of group A and B($p<0.05$).

Key Words

Marginal fit, Collarless metal ceramic fixed partial denture, Modified coping

The metal ceramic crown system has been used successfully for a long time. It has become the most popular complete veneer restoration which could be used in the anterior esthetic zone. Many dentists still use metal ceramic crown system for anterior restoration in spite that a lot of esthetic all-ceramic crown systems have been introduced to dentistry, but it had a fatal problem, which was unesthetic cervical configuration. Collarless metal ceramic crown could be used instead of it, but it did not solve the problem such as cervical opaque reflection of facial porcelain veneer.

Recently, metal copings which were designed to terminate its faciocervical end on the axial walls 1-2 mm coronal from the shoulder have been used to solve this esthetic problem. This type of coping design could be used for the purpose of enhancing cervical esthetics.

There are several techniques that make facial porcelain margin. These include direct lift technique[1], wax porcelain technique[2], platinum foil technique[3], refractory ceramic die technique[4], light curing porcelain margin technique.[5] Some in vitro and in vivo studies showed that collarless metal ceramic crowns had acceptable marginal fits irrespective of their fabrication techniques.[6-10] Among these, direct lift technique became the most popular method. Generally the porcelain margin had some problems when the direct lift technique was used. The internal marginal gap became greater than the external marginal gap at porcelain margin. Mesial and distal interproximal marginal gaps became greater during porcelain margin correction.[6] External portion of porcelain margin could be shortly rounded or overhanged.[11] These phenomena occurred during fabrication of single crown, and the fabrication of collarless metal ceramic FPD was much more challenging task. It was doubtful that the marginal fits of collarless metal ceramic FPDs were in acceptable range, especially when modified copings were applied.

The purpose of this study was to evaluate marginal fits of collarless metal ceramic FPDs with modified copings.

MATERIAL AND METHODS

A resin maxillary left central incisor and a maxillary right lateral incisor analogue (Nissin dental products Inc., Kyoto, Japan) were prepared for a collarless metal ceramic FPD. The preparation followed the protocol of Shillingburg et al., except for the proximal wing.[12] The preparation finish lines were the shoulder at the facial margin and the chamfer at the palatal margin. Two finish lines were blended continuously at interproximal margins. These resin teeth were fixed in yellow stone with their axis parallel to each other and vertical to the earth. The distance between the two teeth was as wide as a maxillary central incisor. Two teeth were copied to the same dimension copper anodes by a CAD/CAM procedure. Then, the fabricated copper anodes were used to make a negative mold of the die specimen via electric erosion. The negative mold was used as an injection mold. Polybutylene terephthalate (PBT) resin was selected as the master die material. The PBT resin (SPESIN®, Kolon Chemical Co., Kumi, Korea) was melted and injected into the prepared negative mold of the specimen(Fig. 1).

One metal coping of a three-unit FPD was made in advance and used to confirm that the duplicated dies had same sizes in all three dimensions. The metal coping fitted on almost all of the duplicated dies accurately. These dies were used as respective master dies. Four different facial margin design groups were investigated. Group A was a coping with a thin facial metal collar, group B was a collarless coping with its facial metal to the

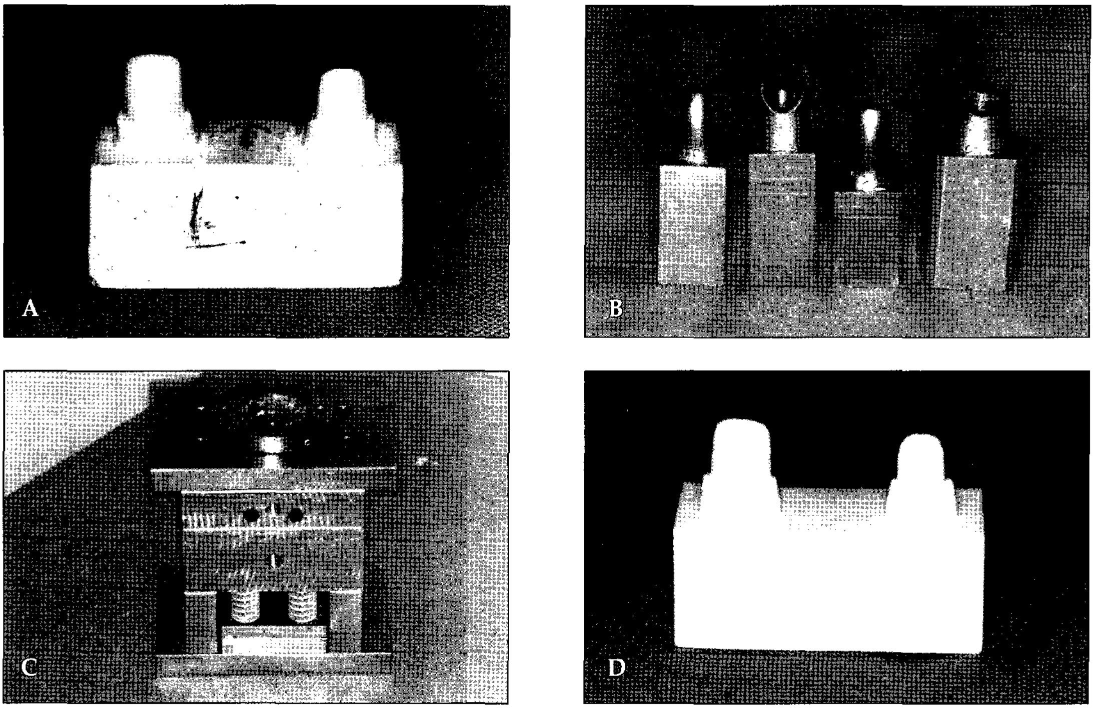

Fig. 1. A, Prepared resin teeth fixed in stone. B, Copper anodes. C, Fabricated injection mold. D, PBT resin die.

shoulder, group C was a collarless coping with its facial metal 1 mm short of the shoulder, and group D was a collarless coping with its facial metal 2 mm short of the shoulder (Fig. 2). Each group had 7 specimens.

First, a full contour wax-up of the three-unit FPD was carried out on the resin die, and indexes for wax coping and porcelain build-up were prepared. The wax-up of copings was done by the dipping method and adjusted by indexes and wax gauge. All of the wax copings were sprued and invested in phosphate-bonded investment (Ceramvest, Protechno, Girona, Spain). Castings were made in Ni-Cr-Be alloy (Rexillium Ⅲ, Jeneric/Pentron Industries, Wallingford, Conn., USA) with a centrifugal casting machine. After divesting, copings were adjusted again to confirm their size and thickness.

Porcelain build-up was carried out on all the prepared copings with feldspathic porcelain powder (Noritake Dental Supplies, Nagoya, Japan). The direct lift technique was used to make the facial porcelain margin. The overall contour and thickness of FPDs were checked with prepared index and metal gauge. Every FPD was adapted to a spare PBT resin die to avoid scratches and deformation of the PBT resin master dies. The adjusted FPDs were finally adapted on the respective master dies.

The prepared resin dies were cleaned with rubber cup and pumice. The inner portion of the facial unsupported porcelain veneer was etched with 37% phosphoric acid (Panavia etching agent Ⅴ, Kuraray Medical Inc., Tokyo, Japan) for 60 seconds and treated with silane agent. Then, all of the FPDs were cemented to their original dies with dual curable composite resin cement (Panavia F, Kuraray Medical Inc., Tokyo,

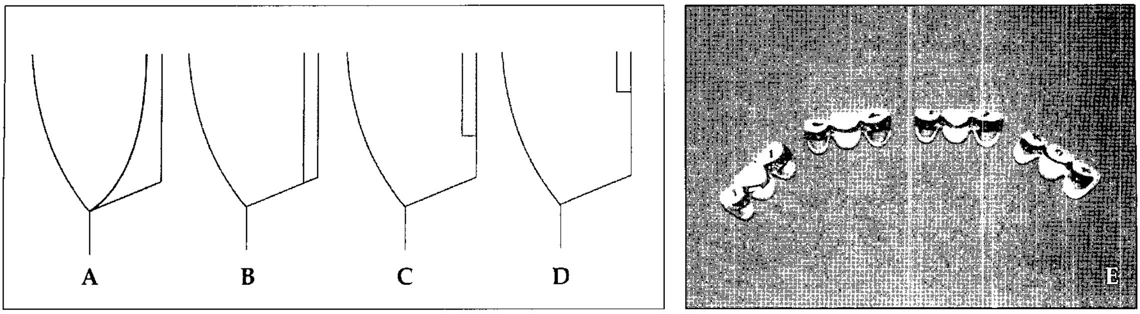

Fig. 2. A, group A. B, group B. C, group C. D, group D. E, 4 groups of metal ceramic FPDs.

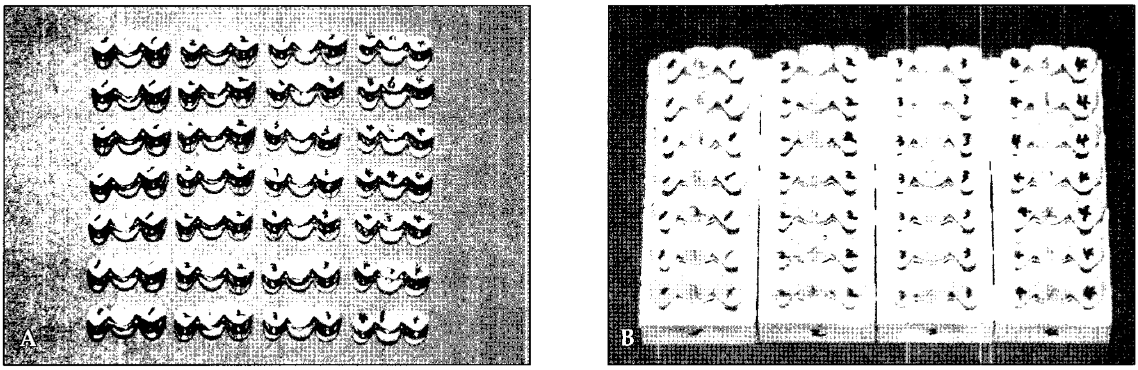

Fig. 3. A, Fabricated metal ceramic FPDs. B, FPDs cemented to respective dies.

Japan). Immediately after the FPDs were seated onto their respective dies with resin cement in them, finger pressure was applied, and light cured for 20 seconds. The excess of resin cement was removed and an air-blocking gel (Oxyguard Ⅱ, Kuraray Medical Inc., Tokyo, Japan) was applied (Fig. 3). The pontics and respective portions of resin dies were removed and each central incisor and lateral incisor specimens were acquired.

All the prepared single tooth specimens were observed under the optical microscope with image processing software (Accura 2000; INTEK PLUS, Taejon City, Korea) at original magnification X240. The external marginal gaps of 8 points of each retainer were measured. The measured points were midfacial, midpalatal, midmesial, middistal, 1.5 mm facial and palatal from midmesial points, 1.5 mm facial and palatal from middistal points. 1.5 mm facial points from midproximal margins meant the start of porcelain margins. 1.5 mm palatal points from midproximal margins meant the start of metal margins. Measurements were done three times per observation point, and averages were defined as final data.

Then each retainer specimens were embeded in orthodontic clear resin (Lang Dental Manufacturing Co. USA) and sectioned faciopalatally into two halves(Fig. 4). The cross section surfaces were finished by fine sand papers and gold coated for FE-SEM observation. Finally, the overall configurations of facial internal margins were observed under FE-SEM (Hitachi, S-4700, Japan). Internal gaps were measured from internal angles of shoulder margin to the nearest points of internal

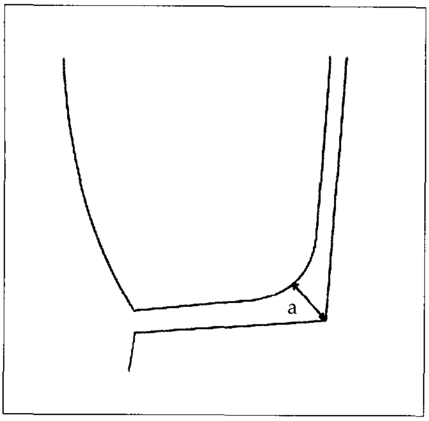

Fig. 4. Measuring point of internal marginal gap (a).

surfaces of facial veneers. This method generated consistent results (Fig. 4).

RESULTS

Marginal fit by Accura 2000

The result of external marginal fits measured under Accura 2000 optical microscope is shown in Table Ⅰ and Fig. 5. The result was analyzed by Kruskal-Wallis test using SPSS statistics program. Overall marginal gaps of collarless FPDs(mean of P, F, M, D) existed between 50 ㎛ and 60 ㎛(Table Ⅱ). These results were similar to that of control group A. In control group A, marginal gaps at each measuring points were similar except for proximal margins. In collarless FPD groups, marginal gaps of palatal metal margins (P, MP, DP) were greater than those of porcelain margins (F, MF, DF).

* Midfacial margins: In both teeth, marginal discrepancies were greater in group A than in the experimental groups($p<0.05$). There were not significant differences among experimental groups($p>0.05$).
* Midpalatal margins: In both teeth, marginal gaps were greater in group C and D than in group A and B. Group A had similar marginal fits at midfacial and midpalatal margins. Experimental groups had greater marginal gaps at midpalatal margins than at midfacial margins.
* Midmesial margins: Midmesial marginal fits were poor irrespective of groups. No statistical differences existed among groups in both teeth($p>0.05$). They had greater marginal gaps compared to distal marginal gaps in all groups.
* 1.5mm palatal margins from midmesial margins: marginal gaps at this points were similar to midmesial margins in group A. In the experimental groups, the marginal gaps at this point were similar to or a little bit smaller than midmesial marginal gaps. In central teeth, there were no statistical differences among groups. In lateral teeth, statistically significant differences existed between group A and group B, C.
* 1.5mm facial margins from midmesial margins: Marginal fits were better in the experimental groups than in group A($p<0.05$). In the experimental groups, the marginal gaps at this point were smaller than midmesial marginal gaps.
* Middistal, 1.5mm facial and palatal margins from middistal margins: Generally the pattern of marginal gaps at these points was similar to that of mesial margin, but the marginal fit was better at distal margins.

Observations of facial porcelain margins by FE-SEM

The result of internal marginal fits measured under FE-SEM is shown in Table Ⅲ and Fig. 6. One way ANOVA and Student-Newman-Keuls test detected significant differences of results between groups. In both teeth, the internal marginal gaps of group C and D were significantly greater than those of group A and B($p<0.05$).

Table I. External marginal gaps (㎛)

	F	P	MF	M	MP	DF	D	DP
Central A	52.7	55.5	57.4	74.5	77.5	56.4	56.4	49.3
Central B	23.0	46.1	27.6	79.6	64.8	33.2	60.3	41.4
Central C	19.4	74.3	37.3	73.6	74.8	42.0	61.2	48.9
Central D	23.4	82.4	24.6	69.9	54.5	21.3	62.0	40.9
Lateral A	49.9	64.2	87.6	97.2	90.1	53.5	62.7	52.4
Lateral B	25.7	59.4	31.4	67.7	63.5	29.7	72.2	64.8
Lateral C	14.9	84.0	37.2	74.0	57.2	29.2	56.3	37.0
Lateral D	27.2	84.6	26.7	90.0	69.3	23.0	41.7	38.3

F=midfacial, P=midpalatal MF=1.5 mm facial from midmesial, M=midmesial, MP=1.5 mm palatal from midmesial, DF=1.5 mm facial from middistal, D=middistal, DP=1.5 mm palatal from middistal

Table II. *Overall external marginal gap (㎛)

	Central	Lateral
Group A	60	69
Group B	52	56
Group C	57	57
Group D	59	61

* average of midfacial, midpalatal, midmesial, middistal marginal gaps

Typical appearances of internal margins are shown in Fig. 7. A few changes could occur in specimens during preparing of specimens. Metal could be burnished, porcelain could be chipped out or cracked. These could act as errors in reading the marginal gap. External end of metal collars looked like distorted. Ends of metal collars were bent to orient to shoulder finish line. This might have been produced during wax up phase or adaptation of copings. Almost all of external margins of group A showed roundness. It could be explained by the result of tries to cover the metal collar. To make the collar invisible, technicians had to put more porcelain on that area. As a result, actual external marginal recess would be increased.

On the other hand, external margins of facial porcelain margin groups were relatively sharper than that of group A. This could be because there were no need to put more porcelain on that area. Another explain might be improved qualities of margin porcelain which have high fusing temperature, low sintering shrinkage. The quality of external characteristics of porcelain margin looked superior to that of metal collar margin unless porcelain margins were chipped out.

Inner angles of facial porcelain veneers were round, so internal marginal gaps became greater than external marginal gaps. Majority of internal marginal gaps were more than 100㎛ in the experimental groups. Internal marginal gaps were less than 100㎛ in control group A.

DISCUSSION

In vivo studies, marginal gaps were measured by indirect method. Impressions of intraoral natural teeth treated with metal ceramic crown were taken. Then duplicated models were observed by microscope. Belser et al studied with this method and reported the marginal gap of collarless metal ceramic crown after cementation was acceptable(46 ㎛).[7]

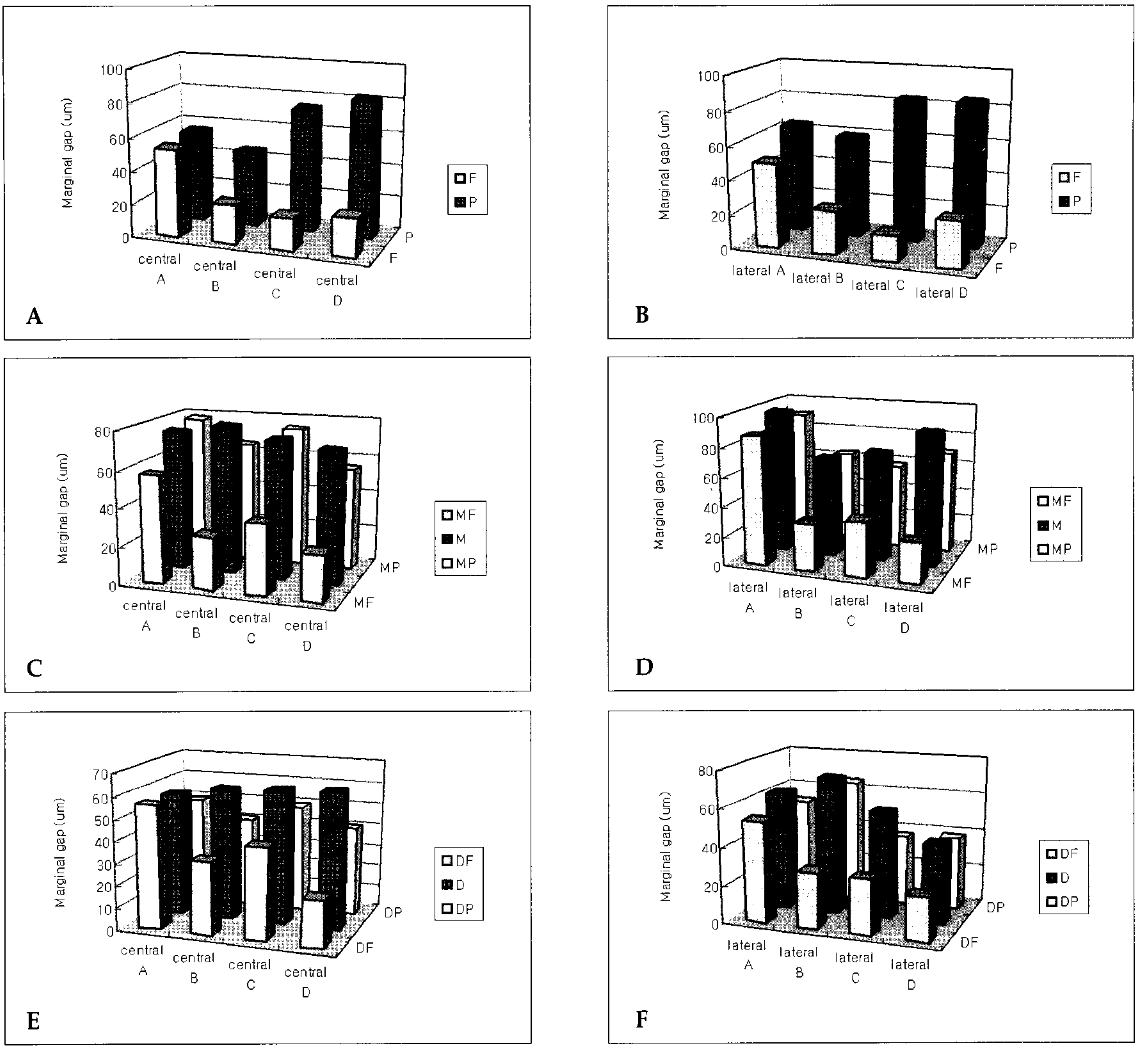

Fig. 5. A, Midpalatal and midfacial marginal gaps of central teeth. B, Midpalatal and midfacial marginal gaps of lateral teeth. C, Mesial gaps of central teeth. D, Mesial gaps of lateral teeth. E, Distal gaps of central teeth. F, Distal gaps of lateral teeth.

Table III. Internal marginal gaps by FESEM

(㎛)

	Group A	Group B	Group C	Group D
Central incisor	93	105	152	140
Lateral incisor	86	124	166	150

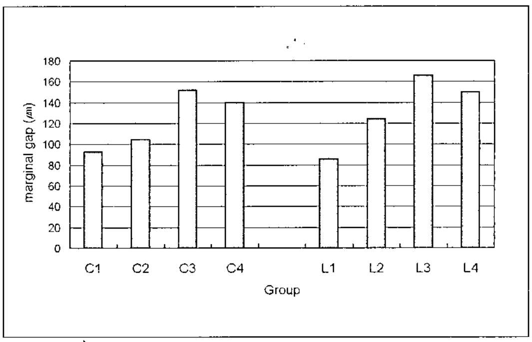

Fig. 6. Internal marginal gaps by FE-SEM.

Fig. 7. FE-SEM observation. (× 60) A, Group A. B, Group B. C, Group C. D, Group D.

Belle et al reported that conventional collarless crowns have similar marginal fit with modified coping designs. It was said that the internal marginal fits were generally poorer than external facial marginal fit.[11]

Wanserski studied the changes of marginal gap of collarless metal ceramic crowns during the fabrication procedures. The marginal gap increased while fabrication and marginal gaps were greater in completed crowns than in metal copings.[9]

Marginal fit of metal ceramic crown can be influenced by several factors. The dimension of metal ceramic restoration is determined right after casting, but minor changes occur during each porcelain baking stages.[13] Changes of marginal fit are mainly due to the distortion of metal framework. In the collarless metal ceramicd restoration, another factors involve in the change of marginal fit. Correction build up and distortion of porcelain margin during firing also influence on the changes of marginal gap. Shrinkage of porcelain and gravity become the cause of distortions. In addition, direct lift technique requires more firing schedules because of margin porcelain correction. Increased firings can also make an influence on the marginal fit. Several authors have reported that porcelain could flow inside the metal coping during the formation of the all porcelain margin with a direct lift technique. This could prevent the crown from seating completely on the die after firing.[14,15] Furthermore, complex metal ceramic prosthesis like a modified collarless metal ceramic FPD could have unacceptable marginal fitness.

It could be possible to measure marginal gaps without cementation. This was not destructive but inaccurate because the fixation of specimen was unstable. The experiment data could not be consistent. Sorensen[16] said in his report that if porcelain labial margin crowns were not cemented, researcher could not record the fracturing or chipping of ceramic margins that occur when porcelain margins were overextended and fractured from seating pressure. These chips in the porcelain margin could significantly increase the standard deviation in marginal fidelity measurement.

Accura 2000 optical microscope support computer assisted measurement. Marginal gap was defined as distance between one point of restoration margin and the least squared line of the tooth margin.[17] In direct view with Accura 2000, it was important that the specimens were examined at right angle. The measurement of marginal gap could be changed according to the angle of examination.[18] Like other studies, it was difficult to observe the margin at right angle. Because the contour of porcelain disguised the margin differently.

* Midfacial margin: Generally porcelain facial margin had better marginal adaptation than metal collar margin. It might be because that the marginal fit of metal collar margin was determined right after casting procedure, but the porcelain margin could be corrected through the stages of fabrication. The greater bulk of unsupported margin porcelain could affect on the marginal quality of the restorations. It could be expected that the group D had higher marginal gap than group B and C, but statistical significant differences among the experimental groups were not found in both teeth.
* Midpalatal margin: Marginal gaps were poorer in group C and D than in group A and B. This meant that the palatal margin was lifted up during adaptation of porcelain margin. In group A, midpalatal marginal gaps were similar to that of midfacial margin. On the other hand, the experimental groups had greater marginal gap at midpalatal points than at midfacial points. The midpalatal marginal gap became greater as the bulk of facial shoulder porcelain increased. The palatal marginal gap increased because corrections of facial porcelain raised the palatal side of coping.
* Midmesial margin: Generally, 3-unit FPD have poor marginal quality at the interproximal margin near the pontic and these points should be observed. In present study, all groups showed poor marginal fit at the midmesial margins. Group A seemed to be affected by the poor marginal gap of coping itself. Other groups seemed to be affected by the raising effect or tilting effect of casting body during porcelain build up procedures. Midmesial marginal gaps were greater than middistal marginal gaps. The accessibility could have caused this phenomenon.
* 1.5 mm facial margin from midmesial margin: It showed good fit in the experimental groups, because it was the start of porcelain margin. Group A showed similar fit to other points, because they were all metal margins.
* 1.5 mm palatal margin from midmesial margin: It showed similar marginal fit at midmesial margins in all group. The experimental groups showed a little bit better marginal fit than midmesial point. This point meant the start of palatal metal margin. The coping would be lifted from this point at the experimental groups.
* Middistal margin and 1.5 mm facial and palatal margin from middistal margin: They showed similar pattern to mesial side. But general marginal fits were better than mesial ones.

Overall mean marginal gaps of collarless FPDs were 50-60 ㎛. Clinically acceptable marginal fit values for casting restorations, including metal ceramic crowns, have been reported in the literature to be up to 70 ㎛[19-24] After clinical study of 1000 restorations over a 5-year period, Mclean and von Fraunhofer concluded that 120 ㎛ represented the maximum clinically acceptable marginal opening.[25] The marginal fit of collarless metal ceramic FPD with modified copings in our present study could be acceptable compared to the previous studies.

CONCLUSIONS

Within the limitations of this in vitro study. The following conclusions were drawn.

1. Mean marginal gaps of collarless FPDs were in the 50-60 ㎛ range.
2. In midfacial margin, marginal discrepancies were greater in group A than experimental groups($p<0.05$).
3. In midpalatal margin, marginal gaps were

greater in group C and D than group A and B($p<0.05$).

4. Marginal fits of porcelain margins were better than those of metal margins in collarless metal ceramic FPDs.
5. In both teeth, internal marginal gaps of group C and D were greater than those of group A and B($p<0.05$).

REFERENCES

1. Vryonis P. A simplified approach to the complete porcelain margin. J Prosthet Dent 1979;42: 592-3.
2. Prince J, Donovan TE, Presswood RG. The all-porcelain labial maragin for ceramometal restorations; A new concept. J Prosthet Dent 1983; 50:793-6.
3. Goodacre CJ, Van Loekel NB, Dykema RW, Ullmann RB. The collarless metal ceramic crown. J Prosthet Dent 1977;38:615-22.
4. Schneider DM, Levi MS, Mori DF. Porcelain shoulder adaptation using direct refractory dies. J Prosthet Dent 1976;36:583-7.
5. Pinnell DC, Latta GH Jr, Evans JG. Light-cured porcelain margins; A new concept. J Prosthet Dent 1987;58:50-2.
6. Strating H, Pameijer CH, Gildenhuys RR, Evaluation of the marginal integrity of ceramometal restorations. Part Ⅰ. J Prosthet Dent. 1981;46:59-65.
7. Belser UC, MacEntee MI, Richter WA. Fit of three porcelain-fused-to-metal marginal designs in vivo: A scanning electron microscope study. J Prosthet Dent 1985;53:24-9.
8. Boyle JJ Jr, Naylor WP, Blackman RB. Marginal accuracy of metal ceramic restorations with porcelain facial margins. J Prosthet Dent 1993;69:19-27.
9. Wanserski DJ, Sobczak KP, Monaco JG, McGivney GP. An analysis of margin adaptation of all-porcelain facial margin ceramometal crowns. J Prosthet Dent 1986;56:289-92.
10. Abbate MF, Tjan AH, Fox WM. Comparison of the marginal fit of various ceramic crown systems. J Prosthet Dent 1989;61:527-31.
11. Belles DM, Cronin RJ Jr, Duke ES. Effect of metal design and technique on the marginal characteristics of the collarless metal ceramic restoration. J Prosthet Dent 1991;65:611-9.
12. Shillingburg HT, Hobo S, Whitsett LD, Jacobi R, Brackett SE. Fundamentals of Fixed Prosthodontics. 3rd ed. Chicago: Quintessence Publishing; 1997. p.142-8.
13. Omar R. Scanning electroscopy of the marginal fit of ceramometal restorations with facially butted porcelain margins. J Prosthet Dent 1987;58:13-8.
14. Hunt JL, Cruickshanks-Boyd Dw, Davies EH. The marginal characteristics of collarless bonded porcelain crowns produced using a separating medium technique. Quintessence Dent Technol 1978;2:21-6.
15. Prince J, Donovan T. The esthetic metal-ceramic margin; A comparison of techniques. J Prosthet Dent 1983;50:185-92.
16. Sorensen JA. A standardized method for determination of crown margin fedelity. J Prosthet Dent 1990;64:18-24.
17. Yeo IS, Yang JH, Lee JB. In vitro marginal fit of three all-ceramic crown systems. J Prosthet Dent 2003; 90:459-64.
18. Groten M, Girthofer S, Probster L. Marginal fit consistency of copy-milled all- ceramic crowns during fabrication by light and scanning electron microscopic anaylsis in vitro. J Oral Rehabil 1997;24: 871-81.
19. Christensen GJ. Marginal fit of gold castings. J Prosthet Dent 1966;16:297-305.
20. Gavelis JR, Morency JD, Sozio RB. The effects of various finish line preparations of the marginal seal and occlusal seat of full crown preparations. J Prosthet Dent 1981;45:138-45.
21. Dedmon HW. Ability to evaluate nonvisible margins with an explorer. Oper Dent 1985;10:6-11.
22. Lofstrom LH, Barakat MM. Scanning electron microscopic evaluation of clinically cemented cast gold restorations. J Prosthet Dent 1989;61:664-9.
23. Fransson B, Øilo G, Gjeitanger R. The fit of metal ceramic crowns, A clinical study. Dent Mater 1985;1:197-9.
24. Valderrama S, Van Roekel N, Andersson M, Goodacre CJ, Munsoz CA. A comparison of the marginal and internal adaptation of titanium and gold-platinum-palladium metal ceramic crowns. Int J Prosthodont 1995;8:29-37.
25. Mclean JW, von Fraunhofer JA. The estimation of cement film thickness by an in vivo technique. Br Dent J 1971;131:107-11.

Reprint request to:

JAE-HO YANG, D.D.S., M.S.D., Ph.D.

DEPARTMENT OF PROSTHODONTICS, COLLEGE OF DENTISTRY,

SEOUL NATIONAL UNIVERSITY

28-1, YEONGUN-DONG, CHONGNO-GU, SEOUL, 110-749, KOREA

jhoyang@snu.ac.kr