Evaluation of marginal fidelity of copy-milled and CAD/CAM all ceramic crowns

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Statement of the problem. The interest in all-ceramic restorations has increased as more techniques have become available. With the introduction of machinable dental ceramics and CAD/CAM systems or Copy-milling systems there is a need for evaluating the quality levels of these new fabrication techniques.

Purpose. This study was to evaluate the fitting accuracy of machined all-ceramic crowns made out of an industrially prefabricated feldspathic porcelain.

Material and Methods. Three master models with different cutting depth (0.8mm/1.0mm/1.2mm)were produced using a palladium-silver alloy. A total of 36 working dies, 12 of each form, was used for the modellation of prototype resin copings and 36 additional crowns, 12 of each cutting depth, were produced by using the CEREC®2 system for all crowns. The maginal fit of all 72 crowns was then evaluated on their respective master die at 54 circularly staggered points of measurement per crown under a fixation pressure of 30 N by using a computerized video image system.

Results. The medians of the copy-milled CELAY® crowns ranged from 29 to 36μm. The highest value for the marginal gap was found in group B (cutting depth 1.0mm) at 107μm. The median for the CEREC®2 crowns was found between 43.5 and 70μm. The maximum values for all three groups ranged from 181μm to 286μm. With 286μm, the highest value for marginal gap was found in group C. the Kruskal-Wallis test and multiple comparisons analysis procedure revealed a significant influence of the production technique on the marginal fit in all three groups ($p<0,02$).

Conclusion. 1. The CELAY® system is capable to produce all-ceramic crowns with a significantly better marginal fit than the CEREC®2 system.

2. As far as premolar crowns produced with the CEREC®2 system are concerned, the cutting depth has a significant influence on fitting accuracy. 3. The production of crowns with an acceptable marginal fit is possible with both systems. However, adhesive luting is recommended for milled feldspathic porcelain crowns.

Key Words
All-ceramic crown, CAD/CAM-system, CELAY® system, Copy-milled, Marginal fidelity

INTRODUCTION

The interest in all-ceramic restorations has increased as more techniques have become available.[1] With the introduction of machinable dental ceramics and CAD/CAM systems (CEREC®2, Sirona Dental, Munich, Germany)[2-8] or Copy-milling systems(CELAY®, Mikrona AG, Spreitenbach, Switzerland)[9-13] there is a need for evaluating the quality levels of these new fabrication techniques. Previous studies have shown that the production of all-ceramic crowns based on industrially sintered alumina blanks is possible by using the CEREC®2 (CAD-CAM) and the CELAY® system. The CAD-CAM(computer-aided design and computer-adided manufacturing) system use a 3 dimensional probe system, serface modeling, and screen display, an automatic milling machine.[14]

The CELAY® system produced by a manually guided copy-milling process. A resin modell of the coping is used as a pattern.[9] The aim of the present study was to evaluate the fitting accuracy of machined all-ceramic crowns made out of an industrially prefabricated feldspathic porcelain (VITA CELAY® and Vita MK II®, Vita Zahnfabrik, Bad Saecking, Germany). The crowns were produced with the CEREC®2 and the CELAY® system, their marginal fit was determined for crowns with different preparation depths.

MATERIAL AND METHODS

Preparation of teeth

For this study three models of idealized prepared upper premolar with different cutting depths (0,8mm/ 1,0mm/1,2mm) were produced using a palladium-silver alloy (Palliag®, Degussa AG, Germany) (Fig. 1). Each model was prepared with a shoulder and a rounded axiogingival internal line angle.

Fabrication of test speciments

Then 12 impressions of each master die were taken by using addition silicone material (Provil®, Heraeus Kulzer, Germany) to from the working dies. After 2 hours, the impressions were poured into a type IV dental stone(Silky Rock, Whip Mix, Louisville, KY). Die spacer was applied until an adequate layer of die spacing appeared to have been produced.

A total of 36 working dies, 12 of each form, was used for the modellation of prototype resin copings (CELAY®-Tech, ESPE, Seefeld, Germany). After the pattern was formed it was subjected to an initial light polymerization for 20 seconds, after which it was removed from the die (Optilux®, Demetron, Danbury, CT). To reduce possible errors, both sets of restorations were milled by the same individual. The CELAY®

Unit consists of two integrated but separate components: the copying bur and milling instrument. The bur and the milling cutter are able to translate on three planes (X, Y, and Z) and on two additional rotational planes(X and Z). The coupling of all these movements confers 8 degrees of freedom to the system.[13] The structures were scanned using a modified CELAY® system and simultaneously milled from an industrially milled felds-

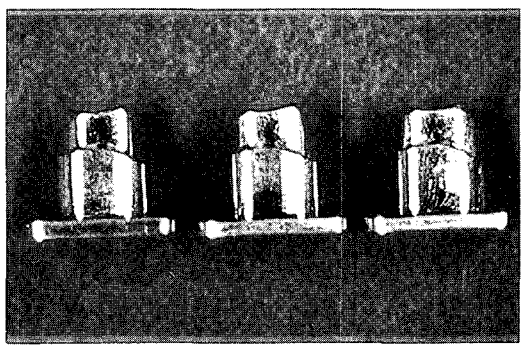

Fig. 1. Manufacture of the three master models(a maxillary premolar): were produced using a palladium-silveralloy[cutting depth; 0.8mm/ 1.0mm/ 1.2mm].

CEREC®2 In-Ceram crowns	CELAY® In-Ceram crowns
Manufacture of the master model	Manufacture of the master model
↓	↓
Application of die spacer	Application of die spacer
↓	↓
Optical impression	**Modeling of prototype resin coping as a pattern**
↓	↓
Computer-aided design and computer-aided manufacture	**Copy-milling of the structure from an industrially sintered blank**
↓	↓
Trimming of the milled substructure	Trimming of the milled substructure
↓	↓
Glass infiltration (35 min)	Glass infiltration (35 min)
↓	↓
Removal of excess glass	Removal of excess glass
↓	↓
Veneering with aluminous porcelain	Veneering with aluminous porcelain

Fig. 2. Process of two fabrication techniques

pathic ceramic blank (Vita MK 11, Vita Zahnfabrik).

36 additional crowns, 12 of each cutting depth, were produced by using the CEREC®2 system with the CEREC®-crown 1.1. Software for all crowns. The CEREC system uses an optical topographic scanningprocedure and an electronically controlled milling machine. The "optical impression" was taken with the CEREC®2 camera directly from the metallic master die. All crowns were produced from industrially prefabricated feldspathic porcelain (Vita MK II) (Fig. 2).

In-Ceram CECEC®2 crowns and In-Ceram CELAY® crowns were constructed on the master dies, in accordance with the manufacture' s instructions.[15] The size of the speciments corresponded to that of natural maxillary second premolars.

Measurements

The maginal fit of all 72 crowns was then evaluated on their respective master die at 54 circularly staggered points of measurement per crown under a fixation pressure of 30 N by using a computerized video image system (180-fold magnification)(Fig. 3-5).

The vertical marginal discrepancy between the outer edge of the crowns and the preparation limit was examined. A total of 3,888 measurements was taken, additional quality control was performed by SEM analysis.

For the statistical analysis non-parametric procedures of descriptive and analytic statistics were used. Kruskal-Wallis tests were performed as overall-tests, multiple comparisons were made by the Wilcoxon test adjusted according to Bonferroni.

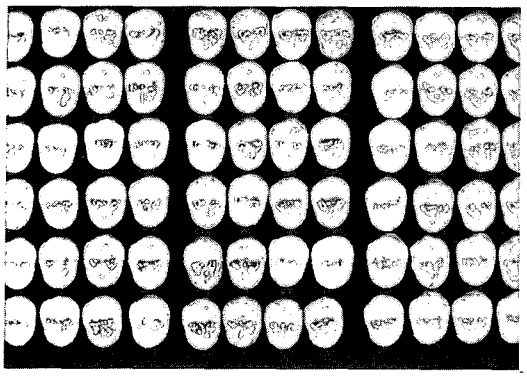

Fig. 3. A total 72 specimen of In-Ceram® crowns.

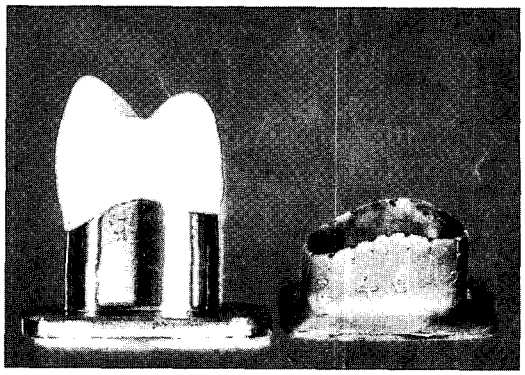

Fig. 4. Metal ring for the marginal measurement.

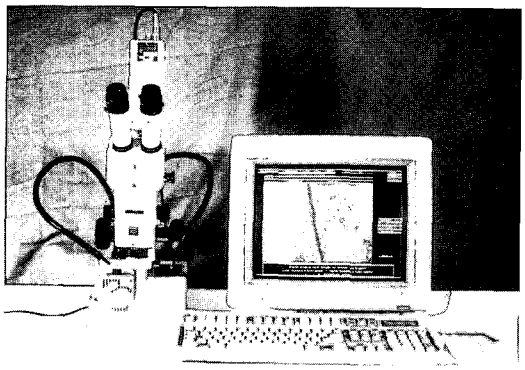

Fig. 5. Analysis of the marginal fit with light microscope and PC.

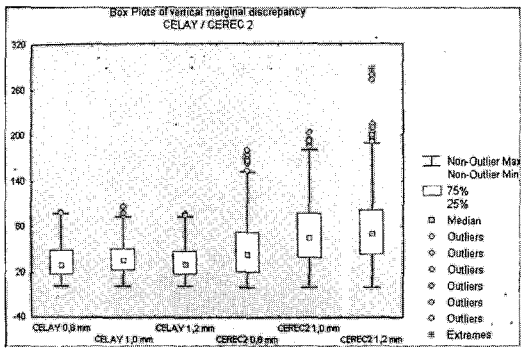

Fig. 6. box-plots of marginal discripancies (CELAY ® / CEREC® 2).

RESULTS

The medians of the copy-milled CELAY® crowns ranged from 29 to 36μm (group A: 29μm , grcup B: 36μm, group C; 30μm). The highest value for the marginal gap was found in group B (cutting depth 1.0mm) at 107μm (group A: 99μm, group C: 97μm).

The median for the CEREC®2 crowns was found between 43.5 and 70μm(group A: 43.5μm, group B: 65μm and group C: 70μm). The maximum values for all three groups ranged from 181μm to 286μm (group A : 181μm, group B : 193μm). With 286μm, the highest value for marginal gap was found in group C(Fig. 6). For the CEREC®2 crowns, the Kruskal-Wallis test revealed a significant influence of the cutting depth on the achievable marginal accuracy.

Moreover the two-stage analysis procedure (Kruskal-Wallis test and multiple comparisons) revealed a significant influence of the production technique on the marginal fit in all three groups ($p<0,02$).

DISCUSSION

The results prove that it is possible to produce copy-milled feldspathic crowns, with signifi-

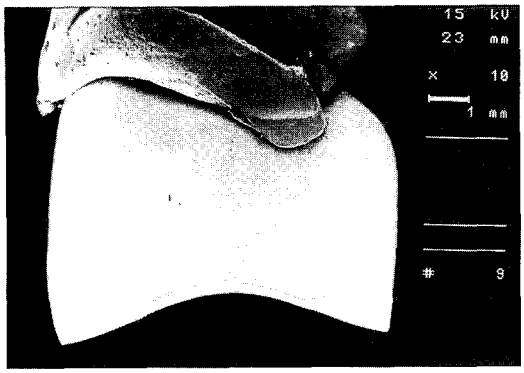

Fig. 7. SEM of better marginal fit by the CELAY ® In-Ceram crown (10x).

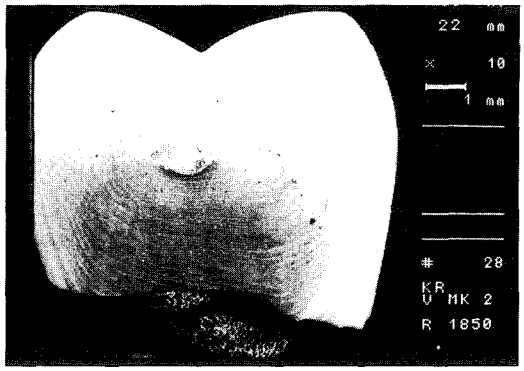

Fig. 8. SEM of poorer marginal fit by the CECEC® In-Ceram crown (10x).

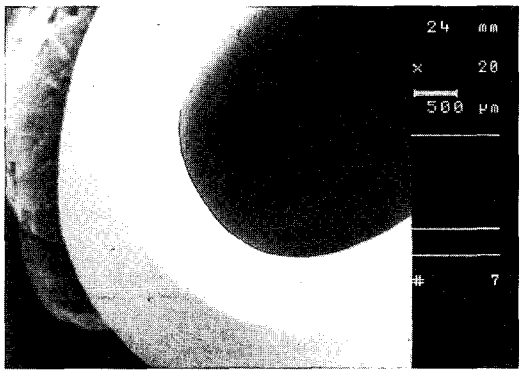

Fig. 9. SEM of better marginal fit by the CELAY In-Ceram crown(10x).

Fig. 10. SEM of poorer marginal fit by the CECEC® In-Ceram crown (10x).

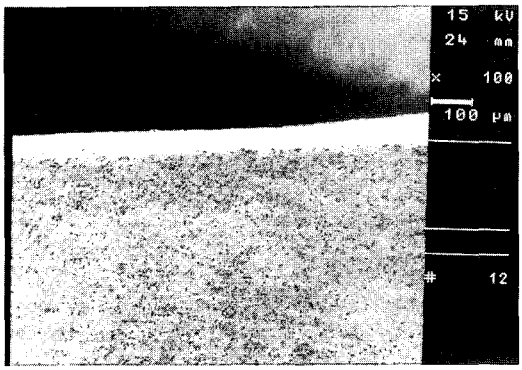

Fig. 11. SEM of better marginal fit by the CELAY® In-Ceram crown (10x).

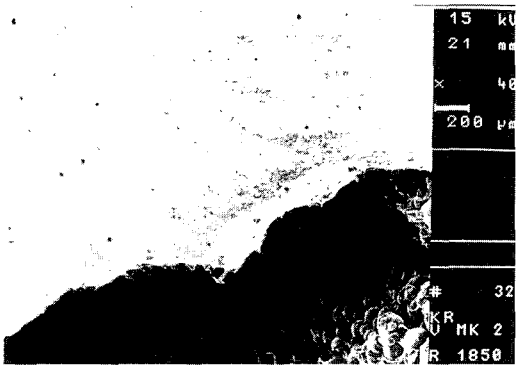

Fig. 12. SEM of poorer marginal fit by the CECEC® In-Ceram crown (10x).

cantly smaller marginal gaps than with the CEREC®2 system. SEM analysis revealed that the process with the CAD/CAM system led to increased chip-outs in the marginal areas. These cllip-outs are responsible for theses poorer marginal fit of the CEREC®2 crowns (Fig. 8, 10, and 12).

Kappert and Altervater[16] found an average marginal gap of 38μm CEREC®2 crowns. Rinke, Huels and Leon[11] found mean values of 38μm for the marginal adaptation of CELAY® crowns and 33.5μm with conventional In-Ceram technique.

At present, it is not clear whether these marginal defects can be sealed by using a high viscosity resin cement.

A possible source of error in the CEREC®2 procedure is related to the milling process with only six axes of freedom and a constant working pressure. Moreover, the milling instruments are only available in a standard grit size. All these facts can promote the formation of chip-outs.

The CELAY® system works in eight axes of freedom. The marginal areas can be scanned and milled with an individually working pressure. Moreover, the milling instruments are available in two grit sizes (standard and fine). As the results of this study show, marginal chip-outs can be reduced by using fine diamond instruments at a reduced working pressure (Fig. 7, 9, and 11).

The results of this study lead to the conclusion that the marginal integrity of CEREC®2 crowns is influenced by their preparation design: The deeper the cut, the poorer the marginal fit. Nevertheless, the recommendation of a minimal cutting depth of 1.0mm is still valid. It is based on the knowledge gained from the working of other all-ceramic systems and from the mechanical properties of the feldspathic porcelain.

CONCLUSIONS

1. The CELAY® system is capable to produce all-ceramic crowns with a significantly better marginal fit than the CEREC®2 system.
2. As far as premolar crowns produced with the CEREC®2 system are concerned, the cutting depth has a significant influence on fitting accuracy.
3. The production of crowns with an acceptable marginal fit is possible with both systems. However, adhesive luting is recommended for milled feldspathic porcelain crowns.

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