Journal of Oral Rehabilitation 2008 **35**; 116–122

Clinical evaluation of the marginal fit of cast crowns – validation of the silicone replica method

M. LAURENT, P. SCHEER, J. DEJOU & G. LABORDE *Université de la Méditerranée, UFR Odontologie Marseille, Marseille France*

SUMMARY Replication of the space between a tooth and its cast crown, using a light-body silicone supported by a heavy-body silicone, is a recognized technique to evaluate the quality of a restoration. This study validates a similar method that is of great clinical and experimental interest. Whatever the type of silicone used, comparison is possible between different technical procedures of crown elaboration (type of impression, type of material, method of spacing, etc.). If an appropriate silicone is used, the cement space may be reproduced and its thickness measured, whatever the localization (cervical, axial, occlusal).

KEYWORDS: marginal fit, silicone replica, spacing, methodology, quality control

Accepted for publication 10 July 2002

Introduction

Quality control is extremely important in fixed prosthetics as the evolution of materials and techniques is rapid and the industry regularly proposes new methods (i.e. the recently proposed complete-ceramic crown systems). An excellent marginal adaptation of the restoration is a pre-requisite for treatment but the evaluation methods of marginal and internal adaptation are generally empirical and non-validated. Some values have been collected however, and the consensus seems to be, that a marginal joint of <100 μm is clinically acceptable (1–4).

Amongst the techniques for measuring the marginal fit, those that may be used *in vivo* must be distinguished from those that can only be used *in vitro*. *In vivo* methods test the adaptation directly between the tooth and the cast restoration to be cemented. *In vitro* methods are used to measure experimental crowns or to measure the adaptation of real crowns on plaster models (5–8). *In vitro* methods generally over-estimate the quality of the fit as it is easier to obtain a small gat between resaturation and tooth in laboratory as opposed to in clinical dentistry.

Different methods have been proposed for clinical studies:

– Intra-oral radiographs (bitewings) (9).
– Tactile evaluation with a probe (10, 11).
– Prospective study of crowned, extracted teeth (following experimental restoration of teeth programmed to be extracted) (12).
– Retrospective study of crowned, extracted teeth (teeth extracted for medical reasons after several years in oral environment) (13).
– Impression of the buccal adaptation of the restoration, pored with another impression material or an epoxy resin and measured under the microscope (2).
– A three dimensional replica of the space between the tooth and the crown using light-bodied silicone impression material supported by a heavy bodied silicone, measured under the microscope (1, 3, 14, 15).

The aim of our study is to test the reliability of the silicone replica technique in a clinical evaluation of the fit of cast restorations and to evaluate:

1. The ability of a light-body silicone film to reproduce the cement thickness.
2. The ability of a heavy-body silicone to support and to avoid any distortions of a light-body silicone film.
3. The reliability of the measurements in a cervical, axial and occlusal position.

doi: 10.1111/j.1365-2842.2003.01203.x

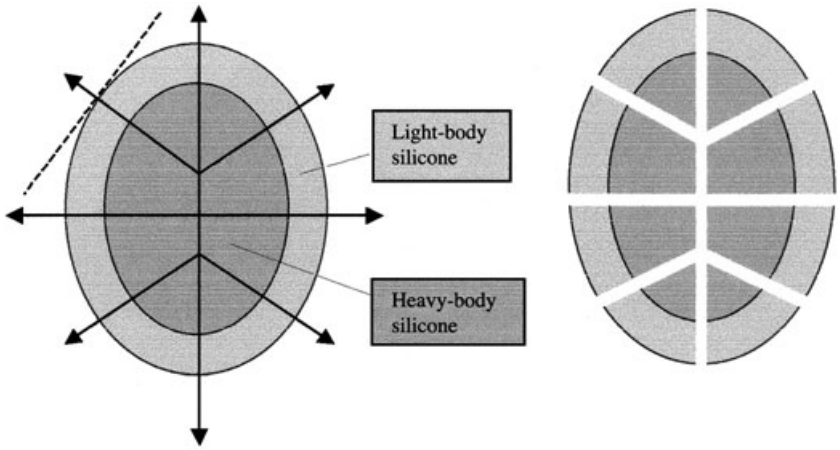

Fig. 1. Occlusal view of the perpendicular section through the surface of the silicone impression, in eight sections.

Materials and methods

Thirty metal crowns were made for 30 posterior teeth (premolars and molars) extracted for therapeutic reasons. Preparations for ceramic fused to metal crowns were made. Following extraction, the teeth were stored in a 1% Chloramine solution before preparation. A cone shaped bur with a rounded tip (1·6 mm) and coarse grit was used (Komet 6856 016). The teeth were polished with a fine grit bur (Komet 8856 016). Two layers of spacer varnish were applied directly to the tooth surface, apart from the cervical limits. The dipped wax model was cast in a Ni–Cr–Mo alloy (Réxilium III v®)*.

For each tooth, a replica of the tooth/crown space was made. The crown was filled with a light-body silicone impression material, and seated over the crown preparation. After polymerization, the cast crown was removed along with the silicone. In most cases the silicone stayed fixed to the crown without any specific precaution. If it unstuck, the recording was repeated dampening slightly the dental surface. A heavy body silicone was then introduced into the cast crown to support the film of light body silicone. The silicone replica was sectioned perpendicular to its surface with a scalpel into eight parts (a bucco-lingual section, a mesio-distal section and one through each corner) (Fig. 1).

The light body silicone film thickness was measured under a microscope. Magnification was 59·5 × (Fig. 2). Measurements were noted (i) at the most external margin of the film, (ii) in the centre of the axial wall and (iii) at the occlusal surface (Fig. 3). Both sides of the section, which should logically have been identical, were measured to reduce error by calculation of the mean. A total of 48 measurements were taken for each silicone replica.

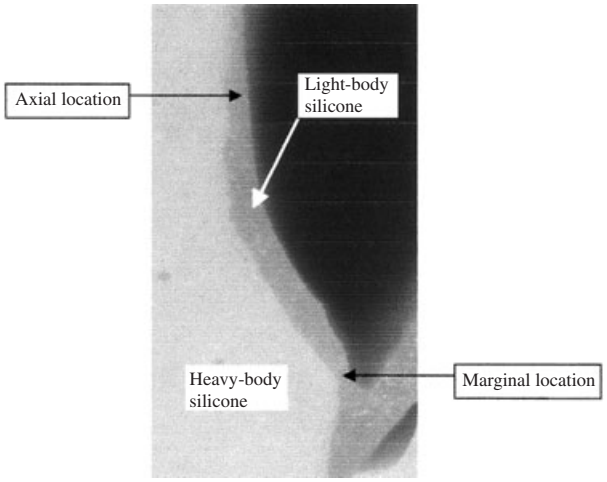

Fig. 2. A silicone replica: the light body silicone, supported by a similar heavy body silicone, reproduces the cement space between the tooth and the cast restoration (detail of the margin of the preparation).

At the cervical limit, it was important to define the exact location of measurement in order to allow comparison. It was taken perpendicularly through the joint and gave information about vertical adaptation but not horizontal (Fig. 4) (16, 17).

For 15 of the replica, S4i† Bisico light and S1®† heavy body silicone were used and for the other

*Jeneric Pentron.

†Bielefeld, Germany.

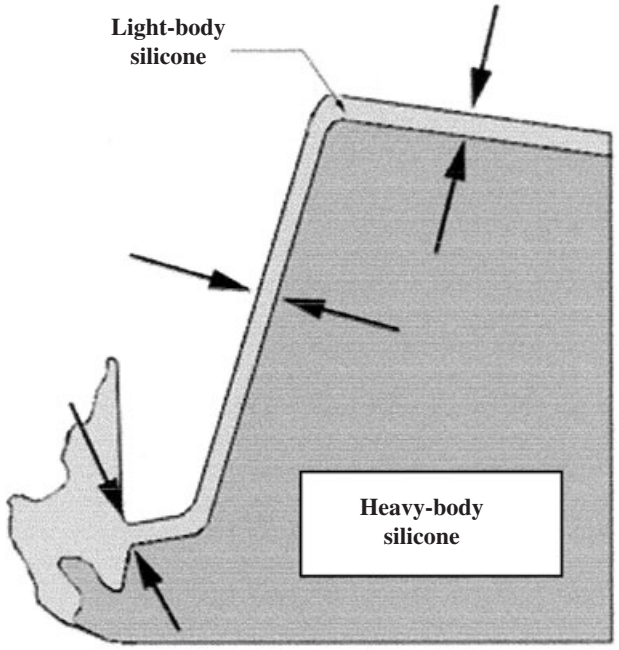

Fig. 3. Measurement of the thickness of the film of light body silicone was undertaken in three places: cervical (external), axial (middle of the axial wall) and occlusal (middle of the half of the occlusal surface studied).

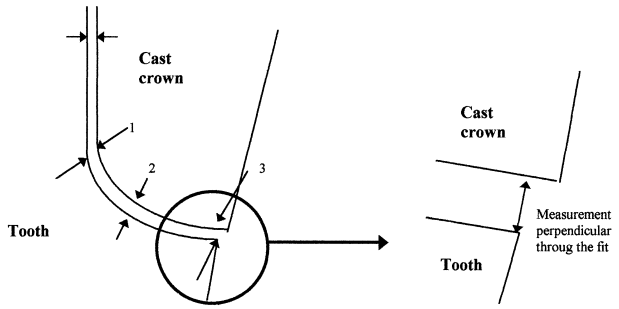

Fig. 4. Cervically, the adaptation was measured at the most external angle (i) internal angle of the margin, (ii) intermediate zone of the margin and (iii) external angle of the margin. The horizontal defect was not taken into account, only the thickness of the joint exposed to the oral cavity was considered.

15 Président®‡ Coltene light and heavy body silicone were used. Two different silicones were used to increase the probability of finding a material able to reproduce the cement thickness. Indeed, some variations however slight of the viscosity from one brand to another can modify the silicone flow and thus the residual thickness and the ability to simulate the cement thickness.

‡Altstätten, Switzerland.

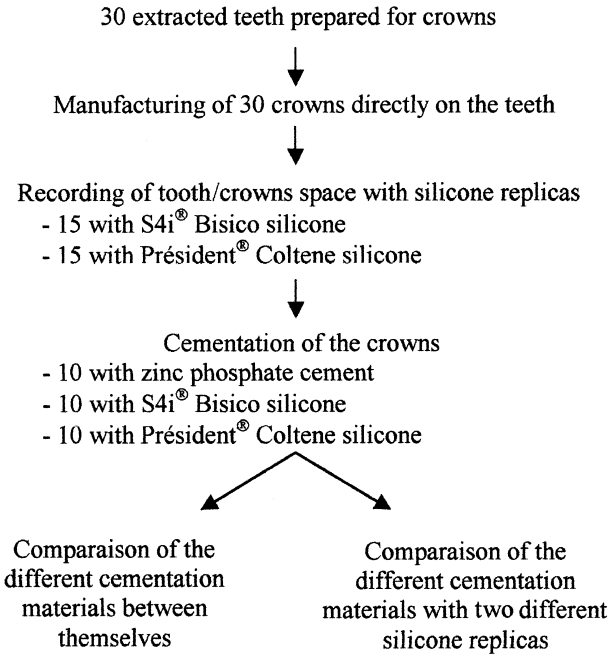

Fig. 5. Summary of the experimental method.

The spacing varnish was removed from the 30 test teeth. Ten of the crowns were cemented onto the tooth using light body Président® Coltene silicone, 10 were cemented with S4i® Bisico light body silicone, and 10 were cemented with zinc phosphate cement (Crown & Bridge® Dentsply – manual mix). The crowns were cemented using manual pressure. These conditions were used to reproduce the clinical situation as closely as possible. Each tooth and its crown were embedded in Epoxy resin (Epon)§ and sectioned in a bucco-lingual plane with a water-cooled diamond saw (Histo saw DDM P 216 RUA)¶. Four sections (300 μm apart) (thickness 1 mm) were made. The sections were polished with an abrasive disc (600 grit), immersed in a methylene blue solution, and rinsed in tap water in order to clearly identify the cement or silicone film, even in narrow thickness. The film thickness was measured at cervical, axial and occlusal locations. For each tooth we obtained a total of 36 measurements.

The fits evaluated with the two silicone replicas (Président® Coltene silicone and S4i® Bisico silicone) and with the sections of restored teeth (cemented either with the ZnO phosphate cement or the two silicone

§Fluca Chemica AG, Buchs, Switzerland.
¶Torcy, France.

impression materials) were compared. Besides the thickness of the three different materials used to seal the crowns on the prepared teeth (Président® Coltene silicone, S4i® Bisico silicone and Crown & Bridge® Dentsply ZnO phosphate cement) were also compared. The values were analysed according to their position (cervical, axial or occlusal) (Fig. 5).

Statistical analysis

The three groups of teeth were compared using the non-parametric Kruskall–Wallis test and modified Mann–Whitney tests for multiples comparisons ($P \leq 0{\cdot}05$). Comparison between the three groups of teeth and the two types of silicone impression was carried out using the non-parametric Wilcoxon *t*-test for paired groups ($P \leq 0{\cdot}05$).

Results

Comparison of the adaptation of cemented crowns with zinc phosphate cement, Président® Coltène silicone or S4i® Bisico silicone (tooth and cemented crowns embedded in resin and sectioned)

At the cervical level, the mean thickness of the tooth/crown space is 66·4 μm for the crowns cemented with zinc phosphate, 38·9 μm for those cemented with Président® Coltène silicone and 80·3 μm for those cemented with the S4i Bisico® silicone. Only the cementing with the Président® Coltène silicone differs significantly from the two other materials.

At the axial level, the averages do not differ significantly and are respectively 71·2 μm for the zinc phosphate cement, 83·9 μm for the S4i Bisico® silicone and 76·6 μm for the Président® Coltène silicone.

Lastly, at the occlusal level, the averages do not differ significantly and are respectively 121 μm for the zinc phosphate cement, 127·5 μm for the S4i Bisico® silicone and 140·3 μm for the Président® Coltène silicone.

So there was no significant difference between the adaptation of crowns cemented either with zinc phosphate cement or with light bodied S4i Bisico silicone, whatever the location of measurement.

There was a significant difference between the marginal opening of those crowns cemented with zinc phosphate cement and those cemented with Président Coltène light bodied silicone. There was also a significant difference between the two silicones (see Table 1).

Comparison between the fit of the crowns cemented with Président® Coltène silicone and their Président® Coltène silicone replica

Whatever the location (cervical, axial or occlusal), no significant difference has been shown between the tooth/crown space cemented with the Président® Coltène silicone and its replica with the same material (see Table 2).

Table 1. Mean values and standard deviations expressed in μm of the cervical, axial and occlusal gap of crowns cemented with zinc phosphate cement, Président® Coltene silicone and S4i® Bisico silicone

	Cemented with zinc phosphate [mean (s.d.)]	Cemented with Président® Coltène [mean (s.d.)]	Cemented with S4I® Bisico [mean (s.d.)]	*P*-value
Cervical mean	66·4 (31·6) b	38·9 (17·3) a	80·3 (34·7) b	0·003
Axial mean	71·2 (13·4)	83·9 (26·7)	74·6 (16) b	NS
Occlusal mean	121 (43·6)	127·5 (43·4)	140·3 (36·5)	NS

For cervical line, those with the same key letter (b) do not differ significantly.
NS, not significant.

Table 2. Mean values and standard deviations expressed in μm of the cervical, axial and occlusal space by direct reading on the crowns cemented with Président® Coltene silicone then sectioned, or by indirect reading on the Président® Coltene silicone replicas

Coltène Président	Cemented with Président® [mean (s.d.)]	Replica with Président® [mean (s.d.)]	*P*-value
Cervical mean	38·8 (17·3)	54·3 (18·8)	NS
Axial mean	83·8 (26·7)	98·2 (17·5)	NS
Occlusal mean	127·6 (43·4)	141·5 (23·2)	NS

NS, not significant.

Bisico S4i	Cemented with S4i® [mean (s.d.)]	Replica with S4i® [mean (s.d.)]	*P*-value
Cervical mean	80·3 (34·7)	73·9 (11·6)	NS
Axial mean	74·6 (16)	64·6 (6·9)	NS
Occlusal mean	140·4 (36·5)	129·5 (33·9)	NS

NS, not significant.

Table 3. Mean values and standard deviations expressed in μm of the cervical, axial and occlusal space by direct reading on the crowns cemented with S4i® Bisico silicone then sectioned, or by indirect reading on the S4i® Bisico silicone replicas

	Cemented with zinc phosphate [mean (s.d.)]	Replica with Président® [mean (s.d.)]	*P*-value
Cervical mean	58·4 (27·21)	90·03 (23·2)	0·01
Axial mean	76·8 (17·5)	74·1 (17·9)	NS
Occlusal mean	134·5 (37·3)	155 (36·9)	NS

NS, not significant.

Table 4. Mean values and standard deviations expressed in μm of the cervical, axial and occlusal space by direct reading on the crowns cemented with zinc phosphate cement then sectioned, or by indirect reading on the Président® Coltene silicone replicas

Comparison between the fit of the crowns cemented with S4i® Bisico silicone and their S4i® Bisico silicone replica

Whatever the location (cervical, axial or occlusal), no significant difference has been shown between the tooth/crown space cemented with the S4i Bisico® silicone and its replica with the same material (see Table 3).

Comparison between the fit of the crowns cemented with zinc phosphate cement and the Président® Coltène silicone replica

A significant difference has been food between the zinc phosphate cement thickness and its replica by Président® Coltène silicone (see Table 4).

Comparison between the fit of the crowns cemented with zinc phosphate cement and the S4i® Bisico silicone replica

Whatever the location (cervical, axial or occlusal), no significant difference has been shown between the zinc phosphate cement thickness and its replica with S4i Bisico® silicone (see Table 5).

To sum up no significant difference was found between the fit obtained by cemented the crown with a light body silicone and the replica using thickness of an impression of the same silicone, whatever the location of measurement. The film of a light body silicone material does not seem to be distorted by the introduction of a heavy body silicone support or by sectioning.

No significant difference was found between the fit of crowns cemented with zinc phosphate cement and their replicas made with S4i® Bisico silicone impression, whatever location measurement. There was a significant difference, however, between the cervical measurements of the crowns cemented with zinc phosphate cement and their replicas made with Président® Coltène silicone impression.

Discussion

The aim of this study was to test the efficiency of silicone replicas in the evaluation of tooth /crown space. Two different brands of silicone were tested to find the most appropriate material to simulate the cementing with a zinc phosphate cement. The accuracy of the replication relies upon the use of a silicone that is adapted to the type of cement employed for cementing (in this study S4i Bisico silicone was the best related material to zinc phosphate cement in the conditions

	Cemented with oxyphosphate [mean (s.d.)]	Replica with S4I® [mean (s.d.)]	*P*-value
Cervical mean	73 (35·9)	74·2 (16·7)	NS
Axial mean	66·5 (7·5)	66·7 (10·1)	NS
Occlusal mean	109·8 (48·6)	114·3 (23·6)	NS

NS, not significant.

Table 5. Mean values and standard deviations expressed in μm of the cervical, axial and occlusal space by direct reading on the crowns cemented with zinc phosphate cement then sectioned, or by indirect reading on the S4i® Bisico silicone replicas

described). Nevertheless, in using two different silicones, the volume of samples was reduced. The section of the crowns cemented to the teeth using a diamond saw, whatever the material used, could only be performed in the bucco-lingual sense, whereas the measure of the replicas was performed by eight points over the whole circumference. The precision of the method is thus evaluated globally and not surface by surface. Nevertheless the lack of a significant difference between the thicknesses of light silicone on the different sides of the replicas was verified.

Apart from the high reliability of the method described in this study, the silicone impression technique has several other advantages that make it a method of choice for the evaluation of the marginal fit of a cast restoration, either in experimental conditions or in clinical practice (assessment by direct vision):

– The technique allows accurate, *in vivo* measurement of the adaptation of cast restorations just before sealing and thus reflects a clinical reality. This is important because many clinical situations (subgingival margins, posterior teeth…) may create difficult working conditions that compromise the quality of the final restoration. Experimental preparation of extracted teeth may allow to obtain good marginal fit but does not reflect clinical practice. Measurements taken from cast restorations on their models have also shown to have a better marginal fit than those taken *in vivo* (3).

– The technique allows measurements to be repeated following clinical modification, for example following grinding of areas of friction, or before and after placement of the cosmetic ceramic layer in ceramic fused to metal restorations.

– The technique allows three dimensional study of the entire cement thickness, not just the cervical margin.

– The technique is ethically acceptable as the data collected is of direct clinical benefit to the patient without deleterious effects (quality control).

– The technique is easy to carry out, not time consuming and relatively not expensive.

However, to avoid the risk of contamination of the operators, because of an eventual impregnation of blood and saliva in the replicas, a decontamination treatment must be used (Carbizine® ATO Zizine for example).

Despite these advantages, it must be recognized that certain difficulties can arise on measuring the thickness of the silicone film. This is particularly true cervically, because of deterioration of the silicone film and to limits of the preparation and/or of the cast crown poorly defined. This study was undertaken *in vitro* and thus these difficulties were not encountered [only 22 measurements were eliminated overall (1·5%)].

This study was undertaken to validate a technique and not to give absolute values, however the values found are comparable with those reported in other *in vitro* studies. The cast restorations cemented with zinc phosphate cement had a cement thickness similar to those of other studies (3, 7, 18–22). The mean variations observed between the cervical, axial and occlusal measurements can probably be related to the use of spacer varnish destined to increase the gap for the cement at the axial and occlusal level in order to reduce the marginal opening. The standard deviation, sometimes significant, translate probably the hazards linked to the fabrication of personalized prosthesis by craftsmen methods.

This technique may allow evaluation of the influence on the final quality of the cast restoration with different methods of fabrication. Many of these factors (the shape of the preparation, the type of impression, the spacing method or the choice of materials used) led to different, sometimes contradictory, results between authors (8, 23–26).

Conclusion

Within the limits of this study, the following conclusions were drawn:

– Measurement of a silicone replica of the cement space between tooth and cast restoration allows comparison of adaptation whatever the silicone used.

– The use of this technique with appropriate materials, such as zinc phosphate cement and S4i® Bisico silicone, allows accurate prediction of the actual size of the cement thickness *in vivo*, after cementation.

– The method is valid whatever the measurement location (cervical, axial or occlusal).

References

1. Mclean JW, Von Fraunhofer JA. The estimation of cement film thickness by an *in vivo* technique. *British Dental Journal*. 1971;131:107–111.
2. Belser U, Mac Entee M, Richter W. Fit of three porcelain-fused-to-metal marginal designs *in vivo* : A scanning electron microscope study. *Journal of Prosthetic Dentistry*. 1985;53:24–33.
3. Karlsson S. The fit of procera titanium crowns. An in vitro and clinical study. *Acta Odontologica Scandinavica*. 1993;51:129–134.

4. Sulaiman F, Chai J, Jamelson L, Wozniak W. A comparison of the marginal fit of In-Ceram, IPS Empress, and Procera crowns. *International Journal of Prosthodontics*. 1997;10:478–484.
5. Wang C, Millstein P, Nathanson D. Effects of cement, cement space, marginal design, seating aid materials, and seating force on crown cementation. *Journal of Prosthetic Dententistry*. 1992;67:786–790.
6. Nakamura Y, Anusavice K. Marginal distortion of thermally incompatible metal ceramic crowns with overextended margins. *International Journal of Prosthodontics*. 1998;11:325–332.
7. Cooney J, Richter W, Mac Entee M. Evolution of ceramic margins for metal-ceramic restorations. *Journal of Prosthetic Dentistry*. 1985;54:1–5.
8. Lin M, Sy-Munoz J, Munoz C, Goodacre C, Naylor W. The effect of tooth preparation form on the fit of Procera copings. *International Journal of Prosthodontics*. 1998;11:580–590.
9. Bjorn AL, Bjorn H, Grkovic B. Marginal fit of restorations and its relation to periodontal bond level. Part I: crowns. *Odontostomatology Revue*. 1970;21:337–346.
10. Karlsson S. A clinical evaluation of fixed bridges, 10 years following insertion. *Journal of Oral Rehabilitation*. 1986;13:423–432.
11. Krejci I, Krejci D, Lutz F. Clinical evaluation of a new pressed glass ceramic inlay material over 1,5 years. *Quintessence Internatinal*. 1992;23:181–186.
12. White SN, Yu Z, Tom J, Sangsurasak S. *In vivo* marginal adaptation of cast crowns luted with different cements. *Journal of Prosthetic Dententistry*. 1995;74:25–32.
13. Pilo R, Cardash HS. *In vivo* retrospective study of cement thickness under crowns. *Journal of Prosthetic Dententistry*. 1998;79:621–625.
14. Fransson B, Oilo G, Gjeitanger R. The fit of metal-ceramixc crowns, a clinical study. *Dental Matererials*. 1985;1:197–199.
15. Boening K, Wolf B, Schmidt A, Kastner K, Walter M. Clinical fit of Procera AllCeram crowns. *Journal of Prosthetic Dentistry*. 2000;84:419–424.
16. Holmes J, Bayne S, Holland G, Sulik W. Considerations in measurement of marginal fit. *Journal of Prosthetic Dentistry*. 1989;62:405–408.
17. Hung SH, Hung Ph. Marginal fit of porcelain-fused-to-metal and two types of ceramic crown. *Journal of Prosthetic Dentistry*. 1990;63:26–31.
18. Abbate M, Tjan A, Fox W. Comparison of the marginal fit of various ceramic crown systems. *Journal of Prosthetic Dentistry*. 1989;61:527–531.
19. Chan C, Haraszthy G, Geis-Gerstorfer J, Weber H, Huettemann H. Scanning electron microscopic studies of the marginal fit of three esthetic crowns. *Quintessence international*. 1989;20:189–193.
20. Holmes J, Pilcher E, Rivers J. Marginal fit of electroformed ceramo-metal crowns. *International Journal of Prosthodontics*. 1996;5:111–114.
21. Soumeire J, Dejou J. Comparaison *in vitro* de l'adaptation marginale de restaurations céramiques et céramo-métalliques. *Journal de biomatériaux dentaires*. 1997;12:5–11.
22. Weaver J, Johnson G, Bales D. Marginal adaptation of castable ceramic crowns. *Journal of Prosthetic Dententistry*. 1991;66:747–753.
23. Hoard R, Chiang P, Hewlett E, Caputo A. Marginal discrepancy as related to margin design in porcelain-fused-to-dicor restorations. *Oral health, Mars*. 1993;93:15–18.
24. Cagidiaco C, Ferrari M, Bertelli E, Mason P, Russo J. Epaisseur du ciment de scellement et microhiatus sous couronnes céramo-métalliques avec épaulement vestibulaire: étude in vitro. *Revue internationale de parodontie et dentisterie restauratrice*. 1992;12:325–332.
25. Campani W, Wright W, Martinoff T. Effect of die spacer on the seating of complete cast crowns with grooves. *Journal of Prosthetic Dentistry*. 1986;55:324–328.
26. Pera P, Gilodi S, Bassif F, Carossa S. *In vitro* marginal adaptation of alumina porcelain ceramic crowns. *Journal of Prosthetic Dententistry*. 1994;72:585–590.

Correspondence: Dr Michel Laurent, 307 Rue Paradis 13008 Marseille, France.
E-mail: laurent239@caramail.com