The fit of Procera titanium crowns

An in vitro and clinical study

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In contrast to conventional casting methods for the production of a metallic crown the Procera process is based on precision machine duplication of models combined with spark erosion of the metal frame. Some of the steps in the manual handling procedure are thereby excluded. The present study evaluated, by means of a replica technique, the fit or adaptation of Procera titanium crowns to the stone die and in vivo to the tooth before cementation. For any combination, the marginal adaptation was superior to and significantly better than the occlusal areas and axial surfaces, respectively. In addition, the crowns had a significantly better fit to the stone die than to the tooth. The marginal discrepancy was approximately 60 μm in vitro and 70 μm in vivo, with a range of 3–205 μm. □ *Accuracy; clinical examination; crowns; titanium*

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A frequently discussed issue among dentists has been the marginal fit and/or the congruence of the inner surface of an artificial crown and the corresponding surface of the prepared tooth. Likewise, the discussion has concerned the range of an acceptable marginal discrepancy, or gap, not resulting in deleterious effects to the tooth structure or the surrounding tissue. Previous investigators have reported a marginal gap ranging from 10 to 500 μm with mean values of 50–100 μm (1, 2). Considerably higher values have been found when measuring the incisal/occlusal discrepancies. The clinical significance of a definite value is difficult to establish, and the literature in this field is scarce. In a previous study intra-oral roentgenographs were examined, and defects at the margin of crowns were noted (3). A marginal discrepancy of more than 200 μm was associated with a reduced periodontal bone level. Clinical experience and empirical data, however, seem to advocate a discrepancy of less than 100 μm (1).

Although some manufacturers claim that their system or material will result in no marginal gap and an excellent fit, this is perhaps not always clinically desirable. There must always be a space for the luting agent, and it should be possible to perform a try-in without too much discomfort to both the patient and the dentist. Therefore it seems more likely that other factors, like the viscosity and the grain size of the luting agent, with resulting film thickness, the mode of preparation, and variations in clinical performance are of greater importance with regard to the final result (4, 6).

To exclude the inherent errors in the 'lost wax' technique and investment and casting of a metallic crown, other methods have been developed to produce metal crowns. One of these methods is the Procera technique, based on a precision machine duplication of the model combined with spark erosion of the inner surface of the metal frame and machining of the outer surface. In this manner a metal coping is produced. In addition, an enlargement procedure of the spark electrode will result in a larger coping, to compensate for the luting medium.

To fabricate metal crowns, a solid piece of commercially pure titanium is used as the base. Titanium has been the choice mainly for two reasons: first, the rising price of gold and the subsequent demand to replace it with other metals, and second, a wish to find a metal that is highly biocompatible and has sufficient inherent mechanical properties compared with gold alloys. This method of producing non-cast titanium crowns has been used for a few years, and clinical evaluations have reported acceptable results after 2 years in function (7, 8).

This study was undertaken to evaluate the fit of Procera titanium crowns in vitro and in vivo by a replica technique.

Materials and methods

This study included 12 crowns—8 seated on premolars, 3 on incisors, and 1 on a canine. The patients had been referred to the Department of Prosthetic Dentistry, University of Göteborg, for treatment. The tooth preparation procedure was performed in accordance with the principles issued by Procera, Göteborg, Sweden (9). Consequently, a chamfer finishing line preparation with no sharp edges and smooth contours with no inner and outer right-angle corners was performed. As the technique is sensitive to irregularities like remnants from old fillings, such defects were filled out before final impression. If possible, a supragingival finishing line was preferred. All clinical handling procedures were performed by the author. Full arch impressions were taken in an A-silicon material (President, Coltene). Stone dies (Bayer Moldastone) were poured within 2 h. The complete technical procedure, from stone dies to ceramic veneering, was performed by the Procera Laboratory, Göteborg. All personnel engaged in the production was informed about the purpose of the study.

The crowns were fabricated in accordance with the standard procedure for Procera titanium crowns, meaning duplication of the die and spark erosion of the inner surface and precision milling of the outside of the metal base. A solid block of commercially pure titanium is used in the process. This procedure is followed by porcelain veneering. The veneering material used was Procera Ceramics. There was no clinical try-in of the metal framework before porcelain veneering.

When the crowns came back from the laboratory, replicas of the intermediate space between the inner surface of the crown and the stone die surface were taken. This was achieved by filling, with the help of a syringe, about half of the crown with a light-bodied A-silicon material (President, Coltene). The crown was then placed onto the stone die and a maximal finger pressure was applied. After setting of the impression material the crown was removed, resulting in a thin film of light-body material representing the discrepancy between crown and stone die. In most cases the film dressed the inside of the crown, and for purposes of stabilization a heavy-body material (President, Coltene) was injected into the crown, joining with the light-body film to form one piece. By this procedure it was possible to remove and handle the intermediate replica of light-body material. The same method and procedures were applied for the clinical replica production of the crown versus the prepared tooth. No adjustments were performed of either the prepared tooth or the crown before replica-taking.

The replica adhering to the heavy-body material was cut with a scalpel in two axial directions: buccolingually and mesiodistally. In this manner the replica was divided into four pieces. Care was taken to equalize the portions as much as possible. For purpose of measurement, a microscope (Nikon Profile Projector) was used at 50× magnification. All registrations were made to the nearest 1/1000 mm. Measurements of the film thickness were performed at three different locations: the margin, the axial wall, and the occlusal surface, resulting in four measurements of each location and two measurements of each point, totaling 24 measurements for each replica (Fig. 1). At the margin the film thickness was recorded as the shortest distance from the edge of the crown to the closest tooth structure. Measurements along the axial wall were per-

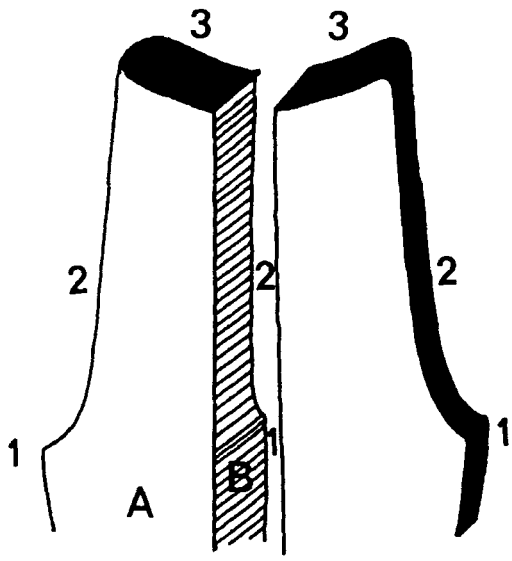

Fig. 1. Points of measurement for tooth and die, buccolingual (A) and approximal (B) views.

formed approximately halfway between the margin and the occlusal border, perpendicular to the surface and in an area representative for the surface. In total, 576 measurements were made.

Student's paired *t* test was applied to find statistically significant differences between film thicknesses recorded for the tooth and the die stone.

Results

The recorded adaptation of the Procera crowns to the individual tooth and die stone (means and standard deviations) is presented in Tables 1 and 2. For any combination, the marginal adaptation was superior to and significantly better than the axial and occlusal ones. Examples of the discrepancies seen are visualized by the photomicrographs in Fig. 2.

Seen in the buccolingual view, the analyses showed a significant difference in mean film thickness between the combinations crown/tooth and crown/die for the measuring points at the axial (2) and occlusal (3) surfaces (Table 1). In general, a thinner film was recorded for the crown/stone die combination. Similar results were achieved for the approximal view (Table 2).

A large range and coefficient of variation (CV) were found for all measuring points, irrespective of location (Tables 1 and 2).

Table 1. Discrepancy (mean, standard deviation (SD), coefficient of variation (CV), and range, in μm) between prepared tooth/stone die and inner surface of the crown. Buccolingual view. Measuring points in accordance with Fig. 1

	Tooth					Stone die			
Measurement	Mean	SD	CV	Range	*P*	Mean	SD	CV	Range
1	70	39	56	4–175	NS	61	37	61	3–186
2	127	55	43	38–302	0.05	92	49	53	27–301
3	161	96	60	55–575	0.01	115	67	58	29–319

Table 2. Discrepancy (mean, standard deviation (SD), coefficient of variation (CV), and range, in μm) between prepared tooth/stone die and inner surface of the crown. Approximal view. Measuring points in accordance with Fig. 1

	Tooth					Stone die			
Measurement	Mean	SD	CV	Range	*P*	Mean	SD	CV	Range
1	73	42	58	15–205	0.01	58	36	62	3–152
2	93	43	46	27–230	NS	82	45	55	32–300
3	177	124	70	37–556	0.001	107	68	64	53–311

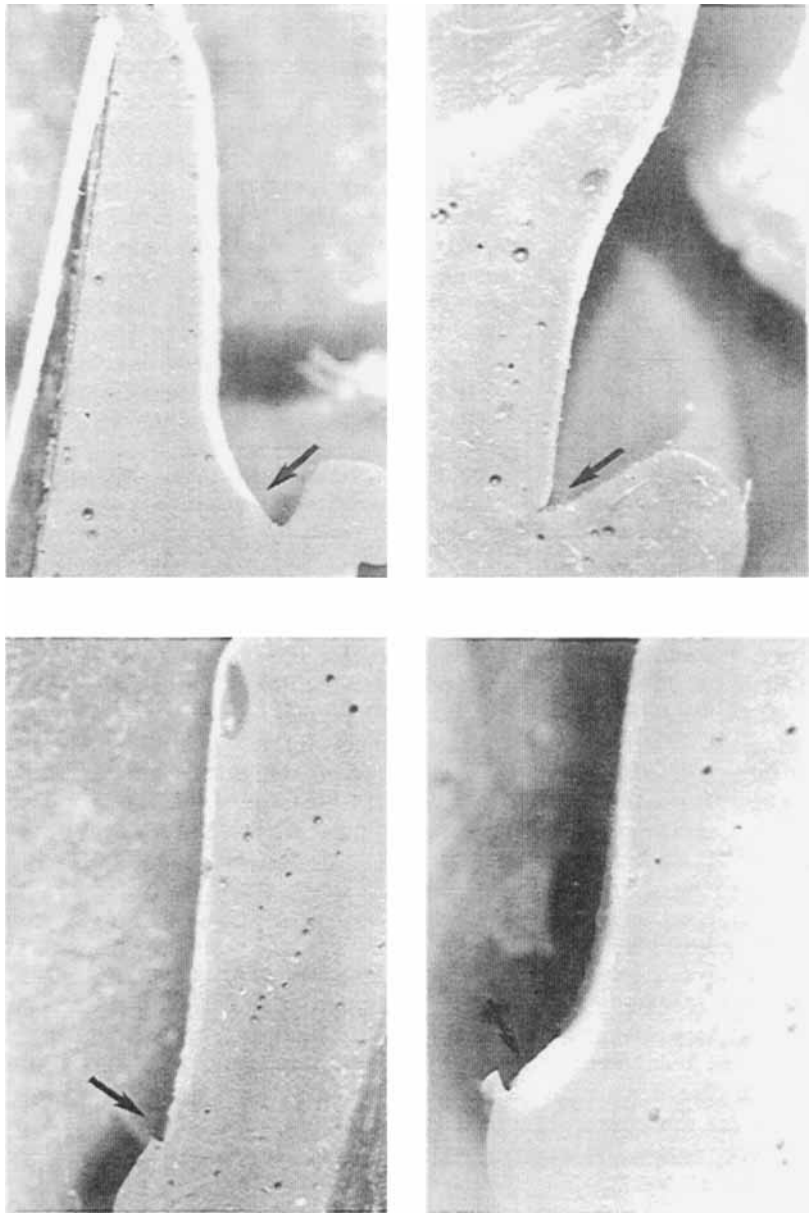

Fig. 2.
Photomicrographs of some representative replicas of the recorded discrepancies (magnification, 15–20×). Note the white replica film and differences in marginal adaptation (arrows).

Discussion

An in vivo evaluation of crown-tooth discrepancy certainly has its limitations and inherent errors. One of them, the seating force, has been reported to be non-significant for the magnitude of the marginal gap in in vivo investigations (10). Furthermore, there is a limited number of non-invasive techniques available to measure the fit, and the replica technique has by previous examiners been proved to be reliable and valid for this purpose. Likewise, the problems related to the replica material used and

methodologic errors have been thoroughly examined and discussed earlier (2). One of the problems has been related to the search for a replica material with a flow close to that of the cementing medium. Different silicone impression materials have been found to fulfill these criteria (1).

The production of a cast crown involves several compensatory factors to meet the dimensional changes occurring during the process. By the Procera method the technical steps involved in the casting process are excluded, and a final product with higher precision than that produced by conventional methods should therefore be anticipated.

When making a survey of the present literature, one frequently finds controversial opinions on the clinical relevance of the size of the marginal gap and/or crown discrepancies. Most authors agree, however, that a marginal gap or inaccuracies in the order of 100 μm seem to be in the range of clinical acceptance with regard to longevity (1, 2, 11). Others are of the opinion that 'excess or deficiency of material amounting to 0.2 mm still means a fairly good fit' (3). Clinically, the width of the cement film is related to several factors, but the dentist has to accept the inevitability of a cement film between the tooth and the crown. This should, however, be kept to a minimum, as poor marginal fit will increase the dissolution of the cementing medium and possibly predispose for subsequent failures. However, there are indications that factors other than a reasonably good marginal fit are of greater clinical relevance and importance for the longevity of a fixed denture and possible damage to the adjacent tissue (3, 12, 13).

For technical reasons and machining limitations, a chamfer mode of preparation is advocated by the Procera Laboratories (9). A chamfer finishing line predisposes, geometrically, for a magnitude of the marginal gap of a size in between that for a horizontal shoulder and a bevel or feather-edge preparation. The marginal gap recorded in the present study is in accordance with, or smaller than, what has been reported for conventional techniques investigated in vivo (2). In the present study a recognized common feature was an occlusal/incisal discrepancy significantly greater than the axial and marginal ones. This is in line with previous studies and other techniques (2, 11). The geometric relationship between angle of convergence and marginal/axial adaptation will influence the occlusal discrepancy and is probably one reason for the great values and ranges recorded. Another contributing factor could be the process of manufacturing the Procera crowns, in particular the method for tracing of the model.

The Procera method will exclude some of the steps and errors in the production of a metallic crown with a controlled enlargement of the metallic coping. There are still, however, several clinical handling procedures, such as impression technique and die production, predisposing for discrepancies in the final product. Some of them can be overcome, like the impression technique, and others not. A better fit of the crown onto the stone die compared with the tooth is an indication for the validity of this statement. The recorded values for the marginal fit were less than those for the axial wall and occlusal surface. This might be explained by a deformation of the metal related to the porcelain veneering and the fact that the marginal zone of the crown was manually corrected.

A CV in the range of 58–70% is somewhat surprising but is probably just a reflection of the clinical variation recognized for all in vivo studies. Nevertheless, it can be concluded from the results of this study that the accuracy achieved by the Procera technique is well within the range of clinical acceptance.

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