J Indian Prosthodont Soc (July-Sept 2013) 13(3):247–253
DOI 10.1007/s13191-012-0178-x

ORIGINAL ARTICLE

A Comparative Study of the Effect of Four Consecutive Firing Cycles on the Marginal Fit of All: Ceramic Crown System and Metal Ceramic Crown System

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Received: 24 May 2011 / Accepted: 21 September 2012 / Published online: 28 September 2012

Abstract The marginal fit of new all ceramic crown system. To know the marginal adaptability of new all ceramic systems. Finesse all ceramic system and traditional metal ceramic system total 15 samples of all ceramic (test group) and 15 samples of metal ceramic crown system (control group) were fabricated and tested for marginal distortion at four firing cycles using image analyzer and special software (Leco Version La 32) in which instead of measuring at points an area was measured that gives a computed mean measured thickness of marginal distortion. Value obtained were evaluated for significance using two tailed, unpaired, student *t* test and Tukeys-Kramer multiple comparison test. Finesse all ceramic crown system showed continued clinically acceptable marginal distortion through all firing cycles (12.84 μm). Greatest distortion of metal ceramic system occurred during degassing cycle(16.90 μm). In respect of marginal fit all ceramic (finesse) crowns is better choice when esthetics is more concern.

Keywords All ceramic crown system · Firing cycles · Marginal fit · Image analyzer

Introduction

Since 1950s refinement in metal ceramic systems dominated dental ceramic research to overcome limitation like high thermal conductivity of metal which may sometimes results in adverse pulpal response, radiopaque nature of metal, increase devitrification, microscopic corrosion which reduces longevity of restoration, patient's sensitivity to metal element and most important limited transmission of light [1].

When in 1886 Land [2] made the first porcelain jacket crown, introduction of advanced ceramics with innovative processing methods stimulated a renewed interest in all ceramic restorations with added advantages like low thermal conductivity, Radio density similar to enamel, more resistance to devitrification and corrosion, biocompatible and fulfills the specific demanding esthetic need of the patient.

Irrespective of the type of restoration the margin is one of the components of the tooth restoration most susceptible to failure, both biologically and mechanically [3]. A well adapted and finished crown margins will reduces bacterial accumulation and subsequent recurrent caries and periodontal diseases. However, deterioration of crown margins can lead to microleakage of bacteria and their toxic products can cause severe pulpal damage. Use of all ceramic restoration markedly diminishes the incidence of subgingival margin for esthetics [4].

The fit of all ceramic crowns has been a concern to the dentist despite the manufacturer's claim of their superior fit. Hence, this study was aimed to evaluate and compare the effect of four consecutive porcelain firing cycles on the marginal fit of an all: ceramic system and a traditional porcelain fused to metal crown system and obtain clinically relevant information about use of such crown systems.

Materials and Method

The groups were as follows:

Group A: All ceramic crown system.

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(Finesse all ceramic core and finesse low fusing veneer ceramic).

Group B: Traditional PFM crowns system.

(Ni–Cr alloy, Bellabond—N-coping and ceramco3 veneer ceramic).

For convenience the method of study was divided into following phases.

For Group A

Phase 1: Preparation of metal coping.
Phase 2: Ceramic build up for metal restoration.

For Group B

Phase 3: Preparation of ceramic core (All ceramic).
Phase 4: Ceramic build up for all ceramic restoration.
Phase 5: Experimental measurements.

The wax patterns for specimens were fabricated by using a special assembly machined to avoid variations in shape and thickness of porcelain or in the contours of tooth preparation based on previous studies by Dario Castellani [5] and Deniz–Gemalmaz [6] as shown (Fig. 1). The special assembly machined consists of the stainless steel master die and split mould. The stainless steel master die machined to approximate dimensions of premolar tooth preparation with 7 mm high, 5 mm in diameter at the centre of the tooth core, 1.3 mm rounded shoulder margin, 12 degree of total taper as shown (Fig. 2). Two split mould were machined to get 0.5 mm and 0.8 mm uniform thickness as shown (Fig. 2).

A total of 30 wax patterns, 15 for metal with 0.5 mm thickness and 15 for ceramic with 0.8 mm thickness, were made by injecting melted wax into the warmed assembly chamber (Fig. 3). These 15 wax patterns were cast in non precious(Ni–Cr) metal ceramic alloy (Bellabond-N, Bego, Germany) and 15 wax pattern were pressed in Finesse ceramic ingots (Dentsply USA).

All the metal copings were degassed according to the manufacturer's recommended firing program for ceramco3 material. After degassing the copings were cooled in open air the same cooling method was then followed for all subsequent firing cycles. Opaquer (ceramco3) was applied to each coping with help of stiff brush and firing was completed. Maximum care was taken to get an even opaque layer of 0.3 mm thickness after firing. Body ceramic was then applied to build up each coping. The dentin ceramic was condensed by mechanical vibration so that the excess water could be removed with a tissue paper and third firing was completed. A steel template was repeatedly used to control uniformity of thickness of veneered specimens that had a final baked thickness of 0.4 mm. Enamel ceramic was then applied, condensed in similar manner as for dentin layer and fourth firing was completed. A steel template was used to contour and maintain the uniform thickness of completed crown with 0.5 mm of metal coping, 0.3 mm of opaque, 0.4 mm of dentin and 0.3 mm of enamel layer and a total 1.5 mm of resultant thickness. (Fig. 4).

During veneering of all ceramic core with low fusing ceramic firing all programmed cycles were followed given by manufacturer's for Finesse low fusing ceramic. Care was taken to produce an even layer that had a final baked thickness of 0.4 mm. Enamel was then condensed similarly and second firing was completed. Third firing was used to compensate for shrinkage so that final baked thickness of enamel was 0.3 mm and template was used to contour the surface. This produced a uniform thickness of completed crown with 0.8 mm ceramic core. 0.3 mm dentine and 0.4 mm enamel layer and total 1.5 mm of total thickness. (Fig. 4) Fourth firing was used to naturally glaze the restoration.

Experimental Measurement

To validate the reliability of placing and removing the copings on the prepared steel tooth models every time, orientation groove was made on master tooth model and

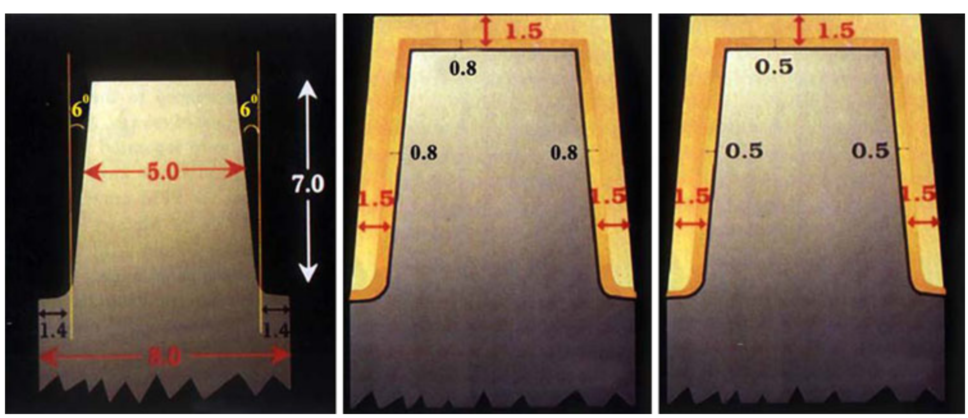

Fig. 1 Schematic representation of dimensions of master die

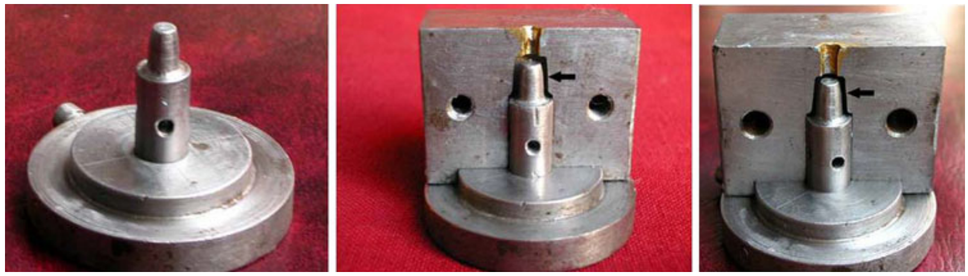

Fig. 2 Machined assembly with master die and two split mould

Fig. 3 Molten wax injected into the warmed assembly chamber and prepared wax pattern

corresponding triangular elevation was cast in each coping (Fig. 5) Easily identifiable reference marks (Fig. 5) on the steel tooth models on four surface were used so that measurements could be made on either side of mark. A total of eight measurements were recorded for each coping after every firing cycle. The measurements were made by direct view image analyzer and software made by Leco Version La 32 (Fig. 6) in which instead of measuring at points an area was measured that gives a computed mean measured thickness thus giving more accuracy in marginal gap measurement.

Results

To compare both tested groups with each other at different firing cycles *two tailed, unpaired, student t test* was performed and 't' valued were evaluated for significance as shown in Table 1–3 and Fig. 6. To compare the marginal distortion within the group at different firing cycles a repeated measurements analysis of variance, *Tukeys-Kramer multiple comparison test* was performed as shown in Table 2, 4.

The mean marginal openings for all ceramic and metal-ceramic group was 26.03 μm and 38.83 μm respectively.

Discussion

In this study shoulder with rounded internal line angle configuration was used for finish line as it is well documented that this type of finish line shows the least stress concentration and significantly less distortion compare to other type of finish lines and is mostly recommended [7]. In this study die replica were not used to minimize the seating error as a result of replication and cementation process stated by previous studies [8]. Previous researchers recommended the use of non-precious alloys due to their

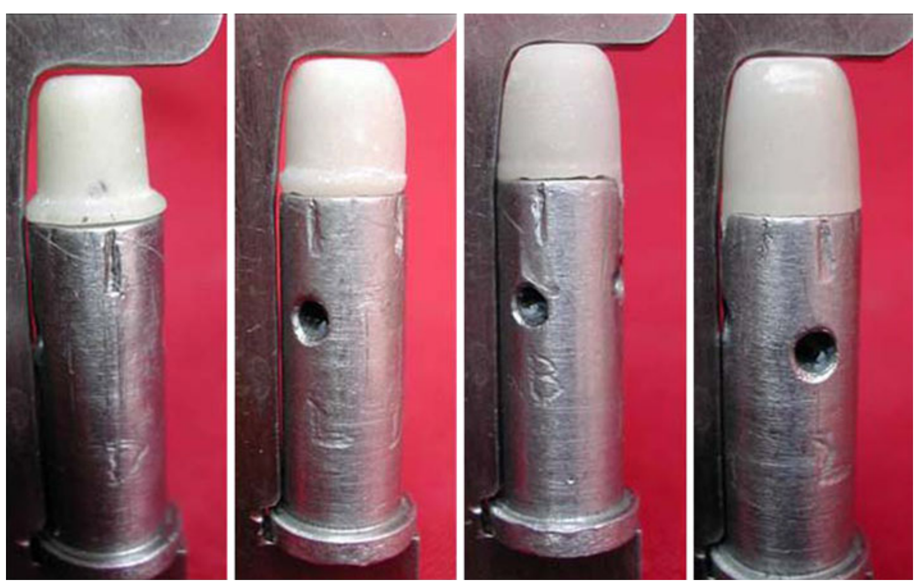

Fig. 4 Stainless steel template used to control uniform thickness of veneered ceramic

Fig. 5 Stainless steel master die with orientation notch and reference mark

excellent physical properties and low costs for metal ceramic restorations [9]. Also measurements were taken by seating the crown specimen without cementation as difference in accuracy of measurements for marginal gap was independent of whether the crown were cemented or not. Final seating position of each crown specimen on the master die was stabilized by a specially made crown die assemble holding device (Fig. 7) to avoid displacement or seating error. As this study attempt to measure marginal opening to obtain the clinical relevant information about tested crown systems, the definition of marginal fit varies from one study to another with each study drawing a conclusion based on their own definition. Therefore it is important to define the term used. In this study we *defined marginal opening* as a perpendicular measurement at the margin from the internal surface of casting to the axial wall of the preparation". The measurement from the margin of the casting to the cavosurface angle of the preparation was defined as an absolute marginal discrepancy (Fig. 8) that can be measured only on sections of cemented [10] crowns and hence not used in this study. As both types of crowns had both well-adopted and illfitting areas at the margins. The marginal fit of a single crown varied to such an extent that single measurement of the marginal opening give a misleading concept of the marginal integrity. Even withing a short distance along the margin of single crown there can be extemely large deviations. Fig. 9 illustrates this problem. at ×100 magnification, such findings are common in both types of crowns investigated in this study. Because of these large deviations, a more realistic concept of the marginal fit was gained by measuring the *entire margin* of the focused area. Measuring marginal opening of sectioned specimen can be misleading as it gives the impression that the marginal openings are the same along the entire distance of the cervix as stated by Chan C [11], Groten M et al. [12] stated at least *50 randomly selected measurements per crown* was essential to obtain clinical relevant information. Hence in this investigation measurements were taken at total eight areas than at any specific point which shows general magnitude of the marginal openings for the entire margin of each specimen. A.D.A specification No. 8 and Christensen GJ [13] reported 25–39 µm as maximally allowed marginal opening. In this study mean marginal openings for all: ceramic and metal ceramic group was 26.03 µm and 38.83 µm respectively. Metal ceramic group shows significantly greater deformation compared to all ceramic group and maximum distortion shown was after degassing cycle. As in this study maximum distortion occurred before any ceramic application ceramic firing shrinkage as a causative factor in the marginal distortion was questionable and is in agreement with

Fig. 6 Graphical representation of measurement at one area

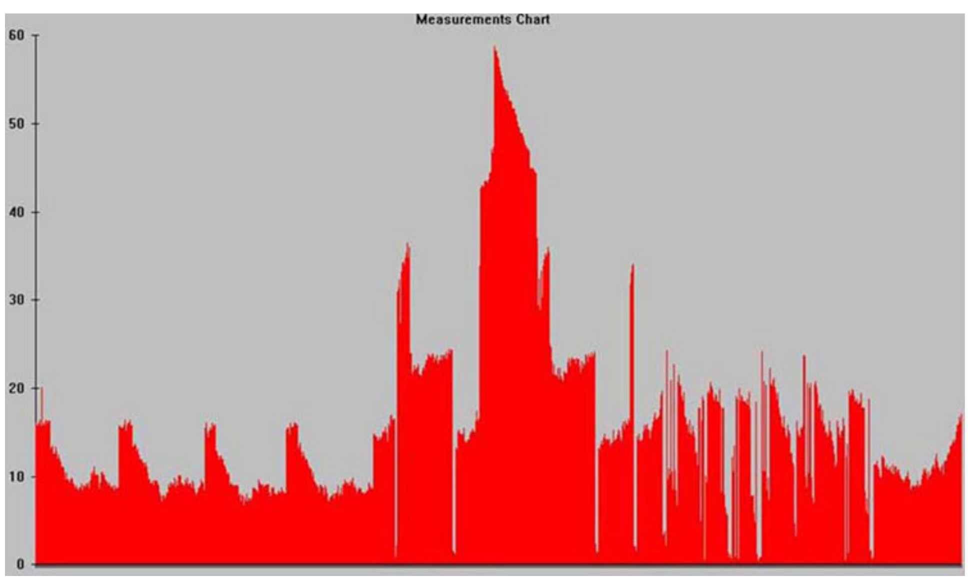

Table 1 Marginal distortion of metal ceramic group at various stages of ceramic firing

Sample no.	Core	After first firing	After second firing	After third firing	After fourth firing
1	18.56	31.71	31.86	33.79	36.57
2	15.96	33.20	33.40	34.05	38.70
3	20.21	33.50	33.62	33.80	37.2
4	14.50	34.56	35.76	36.90	39.09
5	14.71	38.26	38.26	40.36	41.36
6	19.29	37.29	40.29	42.39	43.40
7	17.79	35.35	37.25	38.26	40.79
8	19.29	36.27	36.29	40.40	41.04
9	20.79	31.30	33.39	36.79	37.09
10	19.29	34.50	35.50	36.18	37.28
11	20.21	29.29	30.79	33.20	34.2
12	14.24	29.51	30.53	32.39	35.39
13	18.34	34.05	34.54	35.63	36.39
14	14.29	40.22	41.25	41.34	41.36
15	17.40	39.29	40.79	41.49	42.00
Mean	17.658	34.553	35.421	37.131	38.838
Std. deviation.	2.342	3.321	3.604	3.378	2.740
Std. error of mean	0.6046	0.8574	0.9305	0.8722	0.7076

Table 2 Marginal distortion of all ceramic group at various stages of ceramic firing

Sample no.	Core	After first firing	After second firing	After third firing	After fourth firing
1	7.94	8.29	15.49	17.59	20.98
2	8.10	9.1	13.09	24.28	25.28
3	11.24	12.24	18.29	20.82	26.27
4	15.79	16.78	19.39	24.56	29.29
5	14.78	15.76	20.58	20.86	25.39
6	13.28	15.09	18.74	24.2	26.87
7	9.29	11.29	13.67	15.19	20.28
8	10.28	13.38	19.47	20.56	23.49
9	14.89	19.29	20.68	22.9	28.74
10	16.28	18.2	22.12	25.22	27.56
11	18.19	20.19	22.2	23.09	25.67
12	15.25	15.35	29.28	30.49	33.42
13	14.56	16.79	18.83	20.7	25.32
14	13.29	18.24	20.36	23.43	25.32
15	14.72	20.43	22.62	24.38	26.59
Mean	13.192	15.361	19.654	22.551	26.031
Std.deviation.	3.119	3.822	3.929	3.55	3.197
Std.error.mean.	0.8052	0.9869	1.015	0.9167	0.8256

Table 3 Comparison for analysis of the effect of firing cycle on marginal distortion between groups at different stages of firing cycles

Stages of firing cycles	t value	df	p value	SI
First firing	$t = 12.916$	28	$p < 0.0001$	ES
Second firing	$t = 3.533$	28	$p < 0.0001$	Sig
Third firing	$t = 1.637$	28	$p < 0.05$	NS
Fourth firing	$t = 3.518$	28	$p < 0.05$	Sig
Total distortion	$t = 6.951$	28	$p < 0.0001$	ES

Two tailed unpaired student t test

Table 4 Analysis of marginal distortion of metal-ceramic system at various stages of firing cycles

Stages in comparison	Mean difference	q	p value	SI
Initial–first	16.895	30.57	$p < 0.001$	Sig
First–second	0.868	1.571	$p > 0.05$	NS
Second–third	1.71	3.094	$p > 0.05$	NS
Third–fourth	1.707	3.088	$p > 0.05$	NS

Turkey–kramer multiple comparison test

number of authors, Bridger DV et al. [14], Campbell SD et al. [15], Dedrich DN et al. [16], Dehoff PH et al. [17], Papazoglou E et al. [18], Stein RS et al. [19]. Dehoff PH, Anusavice KJ and Carroll JE [20] under conditions designed to exaggerate distortion effect proved that thermal contraction mismatch were not primary factors in distortion. Richter–Snapp et al. [21] proved that there is no variation in distortion related to margin design. Metal coping of 0.5 mm thickness used in this study ruled out distortion due to inadequate substructure design as stated by Silver M. et al. [22]. Marginal distortion related to metal alloy used could account for the small amount of distortion that has been observed as stated by Buchanan WL et al. [23]. Release of stresses resulting from the solidification process of the casting technique and cold working of the surface preparation for ceramic application can adequately account for the observed distortion.

When metal is cold worked changes occur in almost all of its physical and mechanical properties. The annealing process of cold worked metals occurs at elevated temperature and grain growth of deformed crystals postulated to increase the marginal opening in cold worked ceramometal copings. All ceramic crown exhibited a continued marginal opening after every firing cycles although not of clinical significant amount proving that, these crown systems were sensitive to repeated number of porcelain firing cycles. Isgro G et al. [24] showed *thermal ceramic–ceramic incompatibility* introduces residual stresses and hypothesized that multiple firing of ceramics may influence the coefficient of thermal expansion and can affect the compatibility.

Fig. 7 The crown die assembly holding device

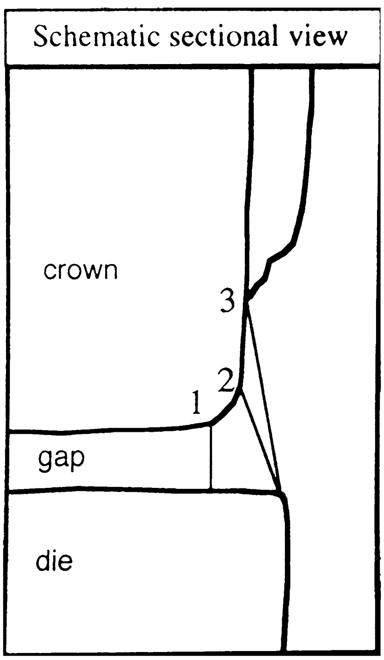

Fig. 8 Absolute marginal discrepancy

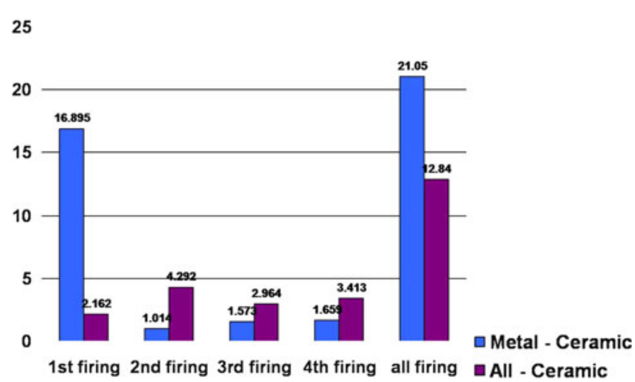

Fig. 9 Comparison of the effect of firing cycle on marginal distortion between groups at different stages of firing cycles

Further Mc Millan PW [25] stated that *changes in the volume fractions of crystal phases with crystal phases may begins to redissolve* as a cause of distortion. In an attempt to correlate the result of this study with published studies, there were wide variations in methods of measurements used in previous studies and also the materials tested were of different composition with different method of processing. Sulaiman F et al. [26] and number of other authors stated that all ceramic tested system met the criteria for acceptable marginal discrepancy. A comparison of the seat revealed that all ceramic crown system had even adaptation of the pressed ceramic, significant better seating compared with metal ceramic and uniform marginal opening.

Conclusion

1) Greatest distortion of metal ceramic system occurred during degassing cycle.
2) All ceramic system showed continued marginal distortion through all firing cycles.
3) All ceramic system showed significantly less distortion compared to metal ceramic systems.
4) Both tested systems showed clinically acceptable marginal fit.

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