RESEARCH ARTICLE

Radiographic evaluation of the margins of clinically acceptable metal-ceramic crowns

Sheikh Bilal Badar, Kamil Zafar, Robia Ghafoor, Farhan Raza Khan

Abstract

Objective: To radiographically evaluate the proximal marginal fit of the clinically acceptable metal-ceramic crowns.

Method: The prospective study was conducted at the dental clinics of Aga Khan University, Karachi, from July to December 2018, and comprised metal-ceramic crowns that were evaluated prior to the cementation. Clinical examinations were conducted by seating the crown on the tooth preparation and visual assessment was done using sharp explorer along the margins. Clinically acceptable crowns were then evaluated on the bite-wing radiograph. Any horizontal or vertical inaccuracy of >0.5mm at the proximal margins was recorded as 'discrepancy'. Data was analysed using SPSS 22.

Results: Of the 230 interproximal margins of 115 crowns evaluated, 113(49.1%) sites had marginal discrepancies; 44(19.1%) horizontal discrepancies, 58(25.2%) vertical discrepancies, and 11(4.8%) having both horizontal and vertical discrepancies. Horizontal crown margin discrepancies were most associated with the mesial site of the maxillary crowns, while vertical discrepancies were commonly associated with the distal aspect of all crowns ($p<0.050$).

Conclusions: Almost half of the crowns that were considered clinically acceptable had some vertical or horizontal marginal discrepancy on radiographic evaluation.

Keywords: Crown, Margins, Dental radiography, Metal ceramic crowns. (JPMA 72: S-35 [Suppl. 1]; 2022)

DOI:https://doi.org/10.47391/JPMA.AKU-08

Introduction

Prosthetic crowns are indirect restorations that are placed to repair teeth, maintain occlusion and improve the aesthetics.[1,2] Endodontically treated teeth are commonly subjected to crown placement to prevent any future fracture. The margins of a crown mark the transition between the crown material and the finishing line at the recipient tooth surface. The integrity of the margins is critical for the long-term health and survival of the crowned teeth.[3,4] Crown margins should be blended and confluent with the tooth structure without having any positive or negative ledges or gaps.[5] In clinical practice, it is not uncommon to encounter crowns with faulty and imprecise margins.

Marginal discrepancies in the crown are mostly observed in scenarios where tooth preparation margins are irregular or missing. Defects in impression-taking, and pouring or laboratory errors, such as distortion in the pattern or casting shrinkage, are responsible for incorrect positioning of the crown margins.[6] Regardless of the cause, the marginal discrepancy, if left unnoticed at the trial and cementation stages, may lead to poor survival of the fixed prosthesis. The gap between the prosthesis margin and tooth-preparation margins exposes the luting cement to the oral environment, leading to an increased rate of cement dissolution. This could ultimately lead to percolation of bacteria, resulting in compromised longevity of the tooth due to caries.[7] Studies have also shown the association between margin discrepancies and the presence of caries in adjacent teeth.[8-10] Before cementing any crown, the try-in step offers an opportunity to the clinician to ensure that the margins of the fixed prosthesis, especially at the proximal sites, are satisfactory.[3]

Marginal fit of the crowns can be evaluated either qualitatively or quantitatively.[11] Qualitative evaluation is done by employing clinical or radiological methods whereas quantitative evaluation involves use of microscope at high magnification.[12] However, the use of such microscope is neither logistically possible nor clinically practical in routine dental practice.[13] Therefore, clinical methods involving visual inspection and use of sharp explorer are commonly employed in clinical practice. The assessment of margins is a relatively straightforward exercise on the buccal and lingual aspects. However, evaluation of interproximal and subgingival margins poses a clinical challege.[14,15] The detection of the marginal discrepancy of crowns largely depends on the skills and experience of the dentist.[4] The use of appropriate radiographs can overcome this limitation. Fattahi et al.[12] showed that upon radiographic examination, 75.5%

Department of Surgery, Aga Khan University, Karachi, Pakistan.

Correspondence: Farhan Raza Khan. Email: farhan.raza@aku.edu

crowns had vertical discrepancy at the margins and recommended the use of parallel radiography as an adjunct to the clinical examination for evaluation of proximal marginal adaptation. Libby et al.[16] evaluated the longevity of fixed partial dentures and suggested that periapical or bite-wings radiographs provided additional information regarding the marginal fit of restoration. Moreover, bite-wing radiographs were more valuable in the detection of proximal lesion compared to the periapical radiography.[17] It is not uncommon to observe that the margins of otherwise clinically acceptable crowns turned out to be inadequate when assessed radiographically. This led the current hypothesis that there is a difference in the radiographic and clinical acceptability of the crown margins. The current study was planned to radiographically evaluate the proximal margins of the metal-ceramic crowns that were otherwise clinically acceptable.

Materials and Methods

The prospective study was conducted at the dental clinics of Aga Khan University (AKU), Karachi, from July to December 2018. After approval from the institutional ethics review committee, the sample size was calculated using the World Health Organisation (WHO) calculator[18] with absolute precision 0.08, level of significance 0.05 and confidence level 0.95.

The sample was raised using non-probability convenience sampling technique from among metal-ceramic crowns of patients who had presented for single-unit crown placement in maxillary or mandibular arch. The patients were included after taking informed consent. Those who had lost their provisional crowns or had gingival inflammation or overgrowth around the prepared teeth were excluded.

All crown preparations were performed by restorative dentistry residents, with clinical experience of more than three years, under the supervision of consultants. A pre-cutting putty matrix composed of silicon rubber (Aquasil, Dentsply) was used to ensure appropriate tooth reduction in each case. Crown preparations were done for the metal-ceramic crowns with shoulder on buccal aspect, while rest of the margins were chamfer. The uniformity of margins and depth of preparation were ensured by using previously taken putty matrix for each preparation. Impressions of the prepared teeth were made with addition type silicone impression material in putty and light-body consistencies (Aquasil, Dentsply) using the single-step technique. These impressions were poured within 30 minutes with type IV high-strength dental stone using vacuum mixer (Bego stone plus, BEGO). Metal-ceramic crowns were fabricated with lost-wax technique using nickel-chromium alloy (Starloy N, Dentsply) as metal core followed by layering with ceramic (Ceramco 3, Dentsply). All crowns were fabricated by a single technician with experience of >15 years. Each crown was visually evaluated for marginal adaptation using its respective die by the restorative dentistry residents. The laboratory acceptable crown was taken to the clinic and was seated on the tooth preparation and was clinically evaluated using a sharp explorer along the margins of the preparation. The crowns that exhibited satisfactory marginal fits were deemed as clinically acceptable crowns. Once the clinical test was satisfied and no discrepancy was detected on clinical examination, radiographic assessment was done using the bite-wings. Digital image was obtained using complementary metal oxide semiconductor (CMOS) size 2 plate (XIOS XG, Sirona) with a help of a bite-wing film holder (XIOS holder system) and cone positioning guide to get the uniform bite-wing radiograph. This plate was then exposed at 70KVp, 7mAs, focus to distance 23cm for 0.10 seconds, using an X-ray unit (CS 2200, Carestream). The image acquired was transferred to imaging software Sidexis XG (Version 2.61, Sirona). Any discrepancy observed in the radiographic marginal adaptation was measured using a digital caliper on the imaging software Sidexis XG. A marginal discrepancy >0.05mm on the proximal sites was labelled as a "deficiency" on radiographic examination. The radiographic outcome of the crown margins was divided into four categories;no discrepancy, horizontal discrepancy (which may be a positive or a negative ledge), vertical discrepancy and a combination of horizontal and vertical discrepancy (Figure).

All radiographic evaluations were independently carried out by two calibrated examiners. Both examiners were trained for one week before the initiation of the project for the identification of marginal discrepancies on the bite-wing radiographs and the use of digital caliper on Sidexis XG (Version 2.61, Sirona) for the quantification of the discrepancy, if present.

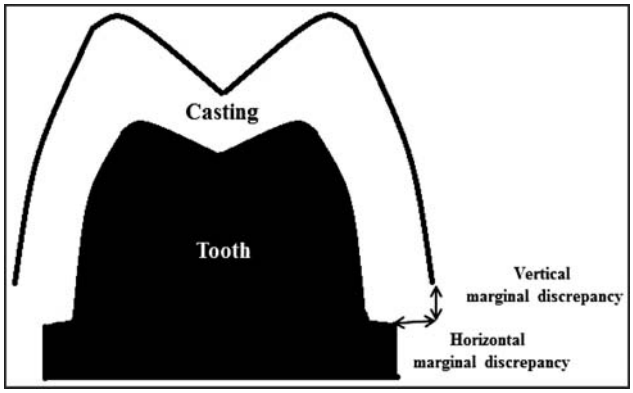

Figure: Vertical and horizontal marginal discrepancy between metal-ceramic crown and the tooth preparation.

Data was analysed using SPSS 22. Frequencies and percentages were calculated for tooth maxillary and mandibular teeth, mesial and distal tooth surfaces, clinical and radiographic assessment. Chi-square test was used to determine the association of marginal discrepancy of the crown with tooth type and tooth surface. Odds ratio (OR)was used to measure the association between the horizontal and vertical discrepancy categories of marginal discrepancy, and between the type of and site of tooth. Inter-examiner reliability was determined using intra-class correlation (ICC) coefficient. P<0.05 was taken as statistically significant.

Results

Of the 115 metal-ceramic crowns, 38(33%) belonged to mandibular teeth and 77(67%) were in the maxillary arch. Out of 230 mesial and distal sites assessed on the radiograph, 113(49.1%) had some form of crown marginal discrepancies (Table-1). The mean horizontal discrepancy was 0.08+0.35mm, while mean vertical discrepancy was 0.19+0.34mm. The vertical marginal discrepancies were mainly observed on the distal aspects of the crowns (OR: 8.2) whereas horizontal discrepancies were mainly seen on the mesial side of the maxillary crowns (OR: 3.0). These associations were statistically significant (Tables-2, 3). The inter-examiner reliability was excellent with ICC coefficient 0.93.

Table-1: Crowns and discrepancies (n=115 crowns).

Type of defect	Frequency (surfaces)	%
No discrepancy	117	50.9
Horizontal discrepancy	44	19.1
Vertical discrepancy	58	25.2
Both horizontal and vertical discrepancy	11	4.8
Total sites	230	100

Discussion

The null hypothesis was refuted in the present study. The radiographic examination exhibited horizontal and vertical marginal discrepancies in a large proportion of clinically acceptable crowns. This indicates significant difference in the two assessment methods. Ideally, there should be no difference in the clinical and radiographic assessments of the crown margins.[19] The presence of marginal discrepancy became a potential source for cement dissolution, microleakage and plaque accumulation which attract potential pathogens responsible for the development of carious lesions.[5,14,20-22] It is not only associated with the dental caries beneath the crown margins, but also with the caries in the adjacent teeth, leading to the failure of the fixed prosthesis.[8,23] For this reason, bite-wing radiographic technique was used to evaluate crown margins on the proximal surfaces in the present study.

Direct viewing technique is commonly employed at the chair-side that involves the use of dental explorer to evaluate the marginal fit of the crowns.[11] It provides valuable information regarding the presence of defects on the buccal and lingual surfaces, but it was not a suitable modality to detect any marginal defect on the proximal aspects of crown-tooth interface.[8,12]

The present study showed that clinical examination alone is not sufficient to label a crown as adequate. The radiographic assessment is superior in terms of deterring the marginal discrepancies, especially on the proximal sites. Relying solely on the clinical examination for the detection of marginal

Table-2: Association between tooth location and marginal discrepancy of metal-ceramic crowns observed on the bite-wing radiograph.

Tooth location	Radiographic Assessment				p-value
	No discrepancy	Horizontal discrepancy	Vertical Discrepancy	Both horizontal and vertical discrepancy	
Maxillary sites (n=154)	88	33	29	4	
Mandibular sites (n=76)	29	11	29	7	0.001
Total sites (n=230)	117	44	58	11	

*Chi square test was applied.
**Odds ratio between horizontal/vertical discrepancy and maxillary/mandibular teeth location turned out to be 3.0.

Table-3: Association between tooth surface and marginal discrepancy of metal-ceramic crowns observed on bite-wing radiograph.

Tooth surface	Radiographical Assessment				p-value
	No discrepancy	Horizontal discrepancy	Vertical Discrepancy	Both horizontal and vertical discrepancy	
Mesial	62	34	17	2	
Distal	55	10	41	9	<0.001
Total sites n=230	117	44	58	11	

*Chi square test was applied.
**Odds ratio between horizontal/vertical discrepancy and mesial/distal site of teeth turned out to be 8.2.

discrepancy resulted in the loss of marginal fit information in the proximal area of 50% sites.[12] Studies suggest that disparity exists among clinicians for the detection of marginal gap and the disagreement is there even within the subject assessed at two different times.[19,24,25]

Multiple studies proposed the use of radiographic aid in addition to the clinical examination for the detection of proximal marginal fit of fixed dental restorations.[12,16,26] Fattahi et al. recommended the use of periapical radiographs in addition to the clinical examination and proposed that the evaluation of marginal adaptation just with the use of explorer or even with the use of impression material was not sufficient.[12] Libby et al. advocated the use of radiography as a mandatory step in the crown and bridge cementation.[16] Durre and Ahmad had proposed the use of radiographs both before and after cementation for the detection of marginal discrepancies and presence of residual cement.[8] Such marginal discrepancies, when present, could lead to exposure of margins to oral environment, cement dissolution and plaque accumulation, which had adverse effects on both tooth and periodontal tissues.[8,27,28] Bite-wing radiographs were taken in the present study for the evaluation of the proximal marginal fit because it provided a near-parallel image of the abutment tooth.[29] This helped in obtaining practical information regarding adaptation of crown margins, its location and its relation to the crestal bone, thus, resulted in better treatment prognosis.[12] Although pre-cementation radiographs are not universally practised, data in the present study strongly suggests a case in its favour. For the present study, no unnecessary radiations were exposed to the patients as pre-cementation radiographic examination of fixed prosthesis is a standard operating procedure. Several studies have reported marginal gaps among crowns (detected radiographically or microscopically) that were earlier considered acceptable on visual examination.[23,30]

What constitutes a marginal discrepancy is debatable in literature.[11] According to Mclean et al.[31] marginal discrepancy <0.08mm was difficult to be detected under clinical examination. Another study showed that marginal opening of 0.1mm was detectable with dental explorer and was considered the borderline of acceptability.[24] Schaefer et al. described 0.05-0.15mm gap as acceptable marginal discrepancies.[32] Fattahi et al.[12] had considered the marginal gap >0.05mm to be an open margin. In the present study, a marginal gap of >0.05mm on bite-wing radiograph was treated as marginal discrepancy. However, there remains a lack of consensus on what constitutes a clinically acceptable marginal gap.

Does any configuration of the tooth preparation margin lead to inadequate margins in the definitive crown? The answer is not definitive. Although the present study has not evaluated the effect of marginal configuration on the marginal fit of dental restoration, as it was beyond the study's scope, literature suggests that large chamfer and tilted chamfer configuration are associated with higher marginal discrepancies compared to the shoulder preparation.[33] However, Tsitrous et al. were unable to detect any association between different marginal designs and marginal fit of dental restorations.[34]

The overall marginal discrepancies detected among clinically acceptable crown in the present study turned out to be 49.1% of the cases. This was better than reported by Fattahi et al. which showed marginal discrepancies in 85% of the cases when examined radiographically.[12] These discrepancies could be due to inaccuracy in the impression-taking by the clinician or improper handling of the dental casts by the dental technician. Durre and Ahmad evaluated patients with cemented crowns and bridges on periapical radiograph and found marginal discrepancies in 13-18% cases.[8] They attributed these discrepancies to improper tooth preparation technique, impression errors or casting defects.[6,8]

In the present study, out of around 50% sites of the defected margins, the horizontal discrepancy comprised nearly 20% of the sites, while 25% of the discrepancies were in the vertical plane. Only 11(5%) crowns had discrepancy in both dimensions. In contrast, Fattahi et al. detected horizontal discrepancies in 60% of the crowns, while vertical discrepancies were in 75.5% of the examined crowns.[12] The presence of vertical and horizontal discrepancies could be attributed to incomplete seating of crowns due to tight proximal contact or the presence of premature contact surface at tooth surface or fitting surface of the crown. It could also be due to inaccurate impression of prepared tooth because of the presence of blood and poor access of impression material to the prepared surface. The presence of subgingival margins could also be ascribed to the presence of crown marginal discrepancies.[12] Evidence suggests that marginal discrepancy is more common on the distal sites of the crown. This probably is due to difficulty in gaining access to the distal surfaces during tooth preparation.[8]

In terms of limitations, the present study was done at a single centre study and only metal-ceramic crowns on posterior teeth were evaluated, limiting the generalisability of the findings. Furthermore, bite-wing radiographs were not taken after the final cementation of the crowns, and, therefore, the effect of cementation could not be determined. The use of bite-wing dental radiographs should be used as an adjunct to the clinical assessment prior to the permanent cementation of the metal ceramic crowns on posterior teeth.

Conclusions

Almost 50% of the clinically acceptable crowns had some form of marginal discrepancy when evaluated on the radiograph. Vertical discrepancies were mainly noticed on the distal surfaces of the crowns irrespective of the arch, and horizontal discrepancies were mainly observed on the mesial margins of the maxillary crowns.

Disclaimer: None.

Conflict of Interest: None.

Source of Funding: None.

References

1. Donovan TE. Factors essential for successful all-ceramic restorations. J Am Dent Assoc 2008;139(Suppl 4):s14-8. doi: 10.14219/jada.archive.2008.0360.
2. McCracken MS, Louis DR, Litaker MS, Minyé HM, Mungia R, Gordan VV, et al. Treatment recommendations for single-unit crowns: Findings from The National Dental Practice-Based Research Network. J Am Dent Assoc 2016;147:882-90. doi: 10.1016/j.adaj.2016.06.012.
3. Wassell RW, Barker D, Steele JG. Crowns and other extra-coronal restorations: try-in and cementation of crowns. Br Dent J 2002;193:17-20, 23-8. doi: 10.1038/sj.bdj.4801473.
4. Bronson MR, Lindquist TJ, Dawson DV. Clinical acceptability of crown margins versus marginal gaps as determined by pre-doctoral students and prosthodontists. J Prosthodont 2005;14:226-32. doi: 10.1111/j.1532-849X.2005.00048.x.
5. Goodacre CJ, Bernal G, Rungcharassaeng K, Kan JY. Clinical complications in fixed prosthodontics. J Prosthet Dent 2003;90:31-41. doi: 10.1016/s0022-3913(03)00214-2.
6. Bishop K, Briggs P, Kelleher M. Margin design for porcelain fused to metal restorations which extend onto the root. Br Dent J 1996;180:177-84. doi: 10.1038/sj.bdj.4809011.
7. Beschnidt SM, Strub JR. Evaluation of the marginal accuracy of different all-ceramic crown systems after simulation in the artificial mouth. J Oral Rehabil 1999;26:582-93. doi: 10.1046/j.1365-2842.1999.00449.x.
8. Durr-E-Sadaf, Ahmad Z. Porcelain fused to metal (PFM) crowns and caries in adjacent teeth. J Coll Physicians Surg Pak 2011;21:134-7.
9. Zoellner A, Heuermann M, Weber HP, Gaengler P. Secondary caries in crowned teeth: correlation of clinical and radiographic findings. J Prosthet Dent 2002;88:314-9. doi: 10.1067/mpr.2002.128122.
10. Smukler H, Chaibi M. Periodontal and dental considerations in clinical crown extension: a rational basis for treatment. Int J Periodontics Restorative Dent 1997;17:464-77.
11. Nawafleh NA, Mack F, Evans J, Mackay J, Hatamleh MM. Accuracy and reliability of methods to measure marginal adaptation of crowns and FDPs: a literature review. J Prosthodont 2013;22:419-28. doi: 10.1111/jopr.12006.
12. Fattahi F, Giti R, Torabi K. Marginal Assessment of Crowns by the Aid of Parallel Radiography. J Dent Mater Tech 2015;4:29-36.
13. Rastogi A, Kamble V. Comparative analysis of the clinical techniques used in evaluation of marginal accuracy of cast restoration using stereomicroscopy as gold standard. J Adv Prosthodont 2011;3:69-75. doi: 10.4047/jap.2011.3.2.69.
14. Mjör IA. Clinical diagnosis of recurrent caries. J Am Dent Assoc 2005;136:1426-33. doi: 10.14219/jada.archive.2005.0057.
15. Larson TD. The clinical significance of marginal fit. Northwest Dent 2012;91:22-9.
16. Libby G, Arcuri MR, LaVelle WE, Hebl L. Longevity of fixed partial dentures. J Prosthet Dent 1997;78:127-31. doi: 10.1016/s0022-3913(97)70115-x.
17. Akarslan ZZ, Akdevelio?lu M, Güngör K, Erten H. A comparison of the diagnostic accuracy of bitewing, periapical, unfiltered and filtered digital panoramic images for approximal caries detection in posterior teeth. Dentomaxillofac Radiol 2008;37:458-63. doi: 10.1259/dmfr/84698143.
18. Lwanga SK, Lemeshow S. Sample Size Determination in Health Studies: A Practical Manual. Geneva, Switzerland: WHO Press; 1991.
19. Holmes JR, Bayne SC, Holland GA, Sulik WD. Considerations in measurement of marginal fit. J Prosthet Dent 1989;62:405-8. doi: 10.1016/0022-3913(89)90170-4.
20. Reitemeier B, Hänsel K, Walter MH, Kastner C, Toutenburg H. Effect of posterior crown margin placement on gingival health. J Prosthet Dent 2002;87:167-72. doi: 10.1067/mpr.2002.121585.
21. Bader JD, Rozier RG, McFall WT Jr, Ramsey DL. Effect of crown margins on periodontal conditions in regularly attending patients. J Prosthet Dent 1991;65:75-9. doi: 10.1016/0022-3913(91)90053-y.
22. Goldman M, Laosonthorn P, White RR. Microleakage--full crowns and the dental pulp. J Endod 1992;18:473-5. doi: 10.1016/S0099-2399(06)81345-2.
23. Addy LD, Bartley A, Hayes SJ. Crown and bridge disassembly--when, why and how. Dent Update 2007;34:140-50. doi: 10.12968/denu.2007.34.3.140.
24. Christensen GJ. Marginal fit of gold inlay castings. J Prosthet Dent 1966;16:297-305. doi: 10.1016/0022-3913(66)90082-5.
25. Dedmon HW. Disparity in expert opinions on size of acceptable margin openings. Oper Dent 1982;7:97-101.
26. Sharaf AA, Farsi NM. A clinical and radiographic evaluation of stainless steel crowns for primary molars. J Dent 2004;32:27-33. doi: 10.1016/s0300-5712(03)00136-2.
27. Löe H. Reactions to marginal periodontal tissues to restorative procedures. Int Dent J 1968;18:759-78.
28. Silness J. Periodontal conditions in patients treated with dental bridges. J Periodontal Res 1970;5:60-8. doi: 10.1111/j.1600-0765.1970.tb01839.x.
29. Briggs P, Ray-Chaudhuri A, Shah K. Avoiding and managing the failure of conventional crowns and bridges. Dent Update 2012;39:78-80, 82-4. doi: 10.12968/denu.2012.39.2.78.
30. Lofstrom LH, Barakat MM. Scanning electron microscopic evaluation of clinically cemented cast gold restorations. J Prosthet Dent 1989;61:664-9. doi: 10.1016/s0022-3913(89)80038-1.
31. McLean JW, von Fraunhofer JA. The estimation of cement film thickness by an in vivo technique. Br Dent J 1971;131:107-11. doi: 10.1038/sj.bdj.4802708.
32. Schaefer O, Watts DC, Sigusch BW, Kuepper H, Guentsch A. Marginal and internal fit of pressed lithium disilicate partial crowns in vitro: a three-dimensional analysis of accuracy and reproducibility. Dent Mater 2012;28:320-6. doi: 10.1016/j.dental.2011.12.008.
33. Souza RO, Özcan M, Pavanelli CA, Buso L, Lombardo GH, Michida SM, et al. Marginal and internal discrepancies related to margin design of ceramic crowns fabricated by a CAD/CAM system. J Prosthodont 2012;21:94-100. doi: 10.1111/j.1532-849X.2011.00793.x.
34. Tsitrou EA, Northeast SE, van Noort R. Evaluation of the marginal fit of three margin designs of resin composite crowns using CAD/CAM. J Dent 2007;35:68-73. doi: 10.1016/j.jdent.2006.04.008.