

Comparison of volume loss of tooth structure between traditional and conservative FPD designs



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Abstract

Objectives: The purpose of this study is to evaluate the amount of tooth structure that is sacrificed with the conventional preparation of a 3-unit bridge and compare this with a variety of more conservative 3-unit bridge designs.

Materials and methods: Fifty typodont Frasco teeth were used to prepare five 3-unit FPD preparation designs (25 lower right first premolar teeth and 25 lower right first molar teeth). One conventional full coverage crown retainer, two different innovative partial coverage crown retainer and two different Inlay design retainer. The volume of tooth structure lost was measured for each design and statistically analyzed.

Results: One-way ANOVA with Tukey's test statistical analysis of the results at ($p < 0.001$), revealed that there was a highly significant effect of the preparation design on the volume loss of tooth structure. Volume tooth structure saved design IV and V was about twice that saved with the partial coverage crown in design II and III.

Conclusion: The amount of tooth structure sacrificed in the proposed conservative FPD designs is significantly less than that calculated for the traditional design.

Keywords: Bridge design, Conservative, Resin bonded ceramic, Tooth structure.

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Introduction

Natural tooth morphology has a robust relation to original needs. The wide occlusal table of posterior teeth needs to withstand a maximum occlusal bite force of up to 750 N during maximum intercuspation and preserve tooth vitality⁽¹⁻³⁾.

The introduction of an all-ceramic FPD as an alternative to metal-ceramic FPD exhibits an exceptional aesthetic appearance and a high level of biological compatibility⁽⁴⁾. However, their brittleness required an adequate amount of tooth structure to be removed, to provide enough space to be occupied by restoration thickness that can withstand the occlusal bite forces. This has an impact on the loss of tooth structure, vitality and strength of the abutment tooth. The introduction of resin bonded ceramic, has facilitated innovative, conservative preparation designs for single crown and FPD restorations⁽⁵⁾.

Conservation of tooth structure can be maintained by decreasing the cutting depth and surface area that can potentially preserve more enamel structure, which will enhance the bond strength of resin-bonded restorations⁽⁶⁻⁹⁾. Adherence to the minimal preparation design guidelines and using self-limiting burs for

preparation prevents both over-reduction and under-reduction that may compromise the results⁽¹⁰⁾. Introduction of small-diameter non-cross-cutting burs and non-concentric hand pieces help to reduce over cutting of tooth structure during preparation⁽⁸⁾.

Tooth structure loss measured by weighed the tooth or scanned using a laser profilometer and the volume of remaining tooth structure calculated before preparation and after preparation^(9,11).

The purpose of this study is to evaluate the volume of tooth structure that is sacrificed with the conventional preparation of a 3-unit bridge and compare this to a variety of more conservative 3-unit bridge designs.

Materials and Methods

1. Preparation of the abutment teeth

Fifty typodont Frasco teeth were used for this study consisting of five teeth in each group (25 lower right first premolar teeth and 25 lower right first molar teeth).

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All the teeth had been weighed before preparation and 24 hours after preparation under dry conditions by using air pressure and a high Precision balance (Kern, d= 0.001g Kern and Sohn GMBH, Baliongen, Germany) as shown in Figure 1. Five 3-unit FPD preparation designs were applied according to the Ivoclar Vivadent Company guidelines for preparation of posterior teeth to receive resin bonded all ceramic IPS e.max restorations ⁽¹²⁻¹³⁾ and the preparation guidelines for each group are given in Table 1 and Table 2.

Each set of teeth was fixed on a Frasco standard working lower jaw model A-3 (GMBH, Tettngang, Germany). The socket of the lower second premolar was blocked with wax. A high speed handpiece and contra angle handpiece



Figure 1: Precision balance, d=0.001g

(W&H, Burmoss, Austria) were used for the preparation with a cooling water jet. A new set of diamond burs was used for every 10 abutment tooth preparations. A paralleling device (Nesor product LTD, Britain) was used during the



Figure 2: Paralleling device

preparation to enhance reproducibility of the preparations as shown in Figure 2. The primary preparation for designs I, II, III were started by cutting three guiding grooves following the tooth contour on each surface. The depth of guiding grooves was 1.5 mm on the occlusal surface and 1 mm on the buccal, lingual and proximal wall adjacent to the edentulous area. The grooves were joined together with diamond burs (847RH 016, Meisinger, Germany). The depth of the preparation on the occlusal surface was controlled using guide depth bur (828G, FG, 314, L 1.5 mm, Meisinger, Germany) and a periodontal pocket measuring probe (Williams probe). For the axial wall, a tapered bur was used (847RH 016, Meisinger, Germany). The convergence angle of the wall was prepared to be $\approx 6^\circ$.

The inlay cavity was prepared by cutting the central groove to prepare the occlusal cavity and then the proximal box by bur (838G 014, L 4.0 mm, Meisinger, Germany). A butt joint margin was prepared for the inlay cavity without bevels. The buccal and lingual walls were tapered to

Table 1: Preparation guidelines for FPD design I, II, and III

Full and partial crown retained FPD designs	Occlusal reduction in mm	Axial wall reduction in mm	Finishing line	Convergence angle
Design I, II, and III	1.5	1.2-1.5	Deep rounded shoulder 1 mm	6°

Table 2: Preparation guidelines for FPD design IV and V

Inlay retained FPD designs	Pulpal depth in mm	Gingival floor depth in mm	Width buccal-lingual in mm	Divergence angle
Design IV molar tooth MO inlay	1.5-2.0	1	4	6°
Design IV and V box inlay	4	1	4	6°

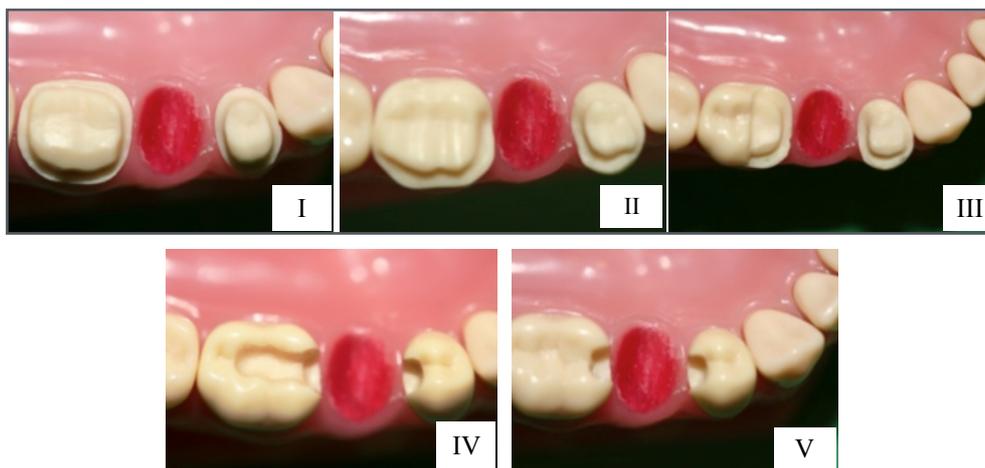


Figure 3: Prepared abutments teeth I) traditional full coverage crown retainer, II) partial coverage crown retainer includes all occlusal surfaces, III) partial coverage crown retainer includes all half occlusal surfaces of molar, IV) Class II inlay on molar and box inlay on the premolar. V) Inlay box for both abutments saved with partial coverage crown in design II and III.

approximately 6 degrees from the pulpal floor to the occlusal surface with rounded internal line angles. A finishing bur (HM 212L FG 016, Meisinger, Germany) was used for smoothing all preparation walls. Figure 3 shows the final appearance of the five FPD designs.

II. Calculating Volume of Tooth Structure Loss

After the preparation had been complete, all prepared teeth were dried with air pressure and left on the laboratory bench for the next 24 hours before weighing them. The volume loss of the tooth structure with different designs was calculated using Equation 1.

$$V = \frac{(W_0 - W_1)}{D} \quad (1)$$

Where the V= volume of tooth structure loss, W0= the weight of unprepared teeth, and W1= the weight of the prepared teeth and D= density of typodont tooth, which is made of poly methyl methacrylate (PMMA) =1.2 g/cm³ (14).

The % Volume of the tooth structure loss in the four conservative designs relative to the volume of tooth structure lost with traditional design was calculated using Equation 2.

$$\%V \text{ loss} = V_1 / V_0 \times 100 \quad (2)$$

V1 is the volume of the tooth structure loss in design II, III, IV or V whereas the V0 is the volume of the tooth structure loss in the design I.

Data analysis

The statistical package Minitab 13 was used for the statistical analysis of the results. Basic statistics and One-way ANOVA with Tukey’s test statistical analysis was used to measure the mean, standard deviations (SD) and any other significant differences between the volumes of the tooth structure removed.

Results

For the lower first molar and lower first premolar the volume of tooth structure loss (n=5) mean and

Table 3: Volume of tooth structure loss according to the preparation design

FPD designs	Lower first molar		Lower first premolar	
	Mean volume removed cm ³	% Volume saved	Mean volume removed cm ³	% Volume saved
Design I	0.253 ± 0.02 (A)		0.126 ± 0.013 (A1)	
Design II	0.158 ± 0.008 (B)	37%	0.071 ± 0.007 (B1)	44%
Design III	0.075 ± 0.009 (C)	70%	0.070 ± 0.009 (B1)	45%
Design IV	0.048 ± 0.005 (D)	80%	0.016 ± 0.002 (D1)	87%
Design V	0.033 ± 0.002 (D)	86%	0.017 ± 0.006 (D1)	86%

Mean with different letters are significantly different.

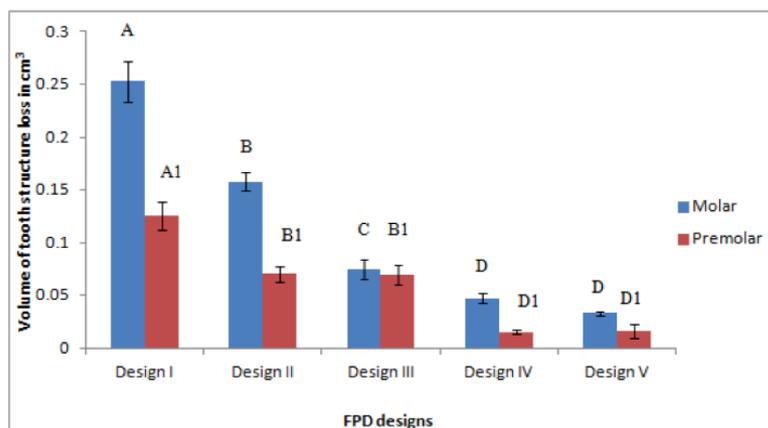


Figure 4: Mean volume, \pm SD of tooth structure loss according to the preparation design, teeth n=5. Mean with different letters are significantly different (ANOVA one way with Tukey's test, $p < 0.001$).

SD was shown in Table 3 for designs I, II, III, IV, and V respectively. One-way ANOVA with Tukey's test statistical analysis of the results at ($p < 0.001$), revealed that there was a highly significant effect of the preparation design on the volume loss of tooth structure respectively for molar and premolar teeth.

The tooth structure saved with designs II, III, IV and V were 37%, 70%, 80% and 86% for lower first molar respectively. For lower first premolar 44%, 45%, 87% and 86% for design II, III, IV and V were saved compared with design I as illustrated in Table 3 and Figure 4.

Volume tooth structure saved for both MO inlay and box inlay in the molar design IV and V was about twice that saved with partial coverage crown in design II and little more compared with design III. For lower first premolar with the box inlay design IV and V was about twice that.

Discussion

Although preparation of one tooth is enough to represent each design, five teeth were used for each design to confirm the reproducibility. The method used for calculating the relative tooth structure loss for each design was remarkably consistent as indicated by the low standard deviation. Thus the use of only 5 specimens for each group was adequate to prove statistically significant differences. The teeth had been weighed before preparation and after 24 hours in dry fields. The amount of water absorbed by resin materials after preparation with turbine/spray application affect the weight measurement of resin teeth⁽¹⁵⁾. The measured weight was changed to volume in cm^3 using Equation 1. The choice of the density of the resin was based on the assumption that all resins have a very similar

density, being in the region of 1.2 g/cm^3 ⁽¹⁴⁾. Although the value used may not be strictly correct it is unlikely to result in any significant difference and will not affect the percentage change in calculating volume loss. The typodont teeth used in this study were selected to avoid individual differences such as tooth morphology and extension of the pulp.

The results of the present study suggest that minimising the prepared surface area of the abutment crown to receive all-ceramic resin bonded FPD, offers a tremendous advantage over conventional abutment crown preparations. In this study three main FPD designs were applied, which included a traditional all-ceramic FPD abutments design, two innovative partial coverage crowns retained FPD designs, with less coverage area and a similar depth to the traditional design depth, and two different designs for inlay retained FPDs.

The results showed that the amount of tooth structure loss was influenced significantly by the preparation design. It should be pointed out that a decrease in the prepared surface area increases the volume percentage of tooth structure saved. Design I showed highly significant tooth structure loss compared with the other four more conservative designs. The results also revealed a significant difference between the conservative designs themselves.

It was difficult to compare the results from this study with those from other studies as there are a limited number of papers in the literature covering similar aspects. The methods used to calculate the tooth structure removal for different preparation designs also varied tremendously. Edelhoff et al (2002) measured the loss of tooth structure by weighing but the root was excluded from the weight so it is difficult to compare his

results with this study in terms of numbers. However, in general, the conclusions were consistent with this study. The Edelhoff et al study showed that 39%, 27% and 5.5% tooth structure were lost, versus 37%, 80% and 86% of the tooth structure volume saved in this study, in partial coverage crown, MO inlay inclusion transverse ridge and proximal inlay box designs respectively in both studies.

Location of the finishing line mesially for the premolar and distally for the molar in designs II and III made access for the preparation easier and avoided disruption of the contact point with the adjacent tooth. Losing this contact point would have made it difficult to re-establish the original position. Moving the finishing line location for design II and III above the highest contour of tooth structure buccally and lingually left more enamel surface area compared with traditional design and decreased the potential for irritation to the gingival tissue. Retaining the preparation within the enamel structure enhanced the bonding action⁽¹³⁾.

Conservative designs II and III provided convenient access during preparation particularly at the contact area. These results are in agreement with the hypothesis that states that “the new designs will significantly reduce invasiveness of the FPDs abutment tooth preparations”. Although the results of the minimal preparation design in this study showed conservation in the volume of tooth structure, what has not yet been considered is whether or not the extension of the designs provides a benign stress distribution. Further work is needed to establish if the proposed designs produce a sufficient benign stress distribution under occlusal loading, to be clinically acceptable.

Conclusion

The amount of tooth structure sacrificed in the proposed conservative FPD designs is significantly less than that calculated for the traditional design.

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