Original Article

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Impact of Preparation Design on Marginal Adaptation and Fracture Resistance of Overlay Restorations

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Abstract:

Objective: To assess the impact of different preparation designs on marginal adaptation (MA) and fracture resistance (FR) of indirect overlay restorations for maxillary premolars fabricated using two types of hybrid ceramics. **Materials and Methods:** 48 sound human maxillary first premolars with homogenous dimensions were divided into three equal groups (16 each) based on the overlay preparation design; Group (1): 16 teeth with conventional design, Group (2): 16 teeth with shoulder palatal design, and Group (3): 16 teeth with circumferential shoulder design. Based on the hybrid ceramic material utilized for overlay fabrication, each group was subdivided into 2subgroups (8each); Subgroup (V): 8 teeth restored using Vita Enamic and Subgroup (C): 8 teeth restored using Cerasmart 270. Marginal adaptation testing was made before overlays cementation using a stereomicroscope. After cementation and thermal cycling aging, marginal adaptation was tested again followed by fracture resistance testing. The statistical significance of resultswas setat $p \leq 0.05$. **Results:** The marginal gap values decreased for the five groups after overlays cementation. Cerasmart overlays using shoulder palatal design recorded the highest value before (36.33 µm) and after (27.81 µm) cementation. Comparing fracture resistance between all tested groups, significant difference was found ($p=0.002$). Vita Enamic overlays using conventional design recorded the lowest value of fracture resistance (609.565 N), while Cerasmart overlays using circumferential shoulder design recorded the highest value (1458.796 N). **Conclusions:** The preparation design and the restorative material significantly influence both the MA and the FR of hybrid ceramic overlay restorations for maxillary premolars.

KEYWORDS: Marginal adaptation, Fracture resistance, Vita Enamic, Cerasmart, Overlay

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1. Introduction

Over the previous 4 decades, there have been significant advances in adhesives, composites, and ceramics that enabled clinicians to segue from a mechanical restorative goal to a biological one. Such materials also enabled the minimally-invasive restoration of tooth in a manner close to its original biomechanical function.[1,2]

When cusp coverage is indicated, the traditional complete-coverage crown preparations are still the most commonly utilized indirect restorative method. Incomplete-coverage crown preparations, about 70-75% of the tooth structure are removed compared to only 32-47% for overlay preparations depending on the used preparation design.[1]Overlayshaveseveral advantages as an alternative to the conventional complete-coverage crown preparations. The overlay conserves more tooth structure, harmonizes with the biomechanics of natural teeth, increases the longevity of the restoration, and increase the FR of ceramic material.[2]

Various materials like ceramics, composites, and metallic alloys can be used to fabricate partial-coverage restorations. Biocompatible ceramics and composites are materials of choice for definitive machinable restorations as they can match the tooth color.[3,4] Hybrid ceramics can simulate mechanical and optical characteristic of natural teeth. They are composed of polymer-infiltrated ceramic-network (PICN) material called “Vita Enamic (Vita Zahnfabrik)” and resin nano-ceramic (RNC) materials including Cerasmart (GC).[5,6]

The quality of marginal fit is an essential factor affecting the longevity of indirect posterior restorations.[5] In addition, testing for the FR is fundamental when assessing the long-term viability of materials used for fabrication of dental restorations. Fracture resistance can be affected by the physical characteristics of restorative materials, the luting agent utilized, and the preparation technique.[7]

With the advancements of dental practice, the emergence of new materials has added complexity to the clinical choice. Although glass ceramics, in particular those based on lithium disilicate and leucite-reinforced variants, have been widely investigated and are favored due to their properties, hybrid ceramics are less studied as they are stilla relatively recent area in research.[8] In addition, there is little evidence on overlay ceramic adhesive replacement in the posterior teeth regarding the preparation design, and whether the design affects the

MA.[9] Therefore, this study aimed at determination how 3 different preparation designs for overlays (conventional, shoulder palatal, and circumferential shoulder) influence the marginal fit of hybrid ceramic blocks (Vita Enamic and Cerasmart) both pre- and post-cementation.

Currently, clear recommendations for conservative preparation of teeth before ceramic overlays are scarce, particularly when it comes with the need to conserve as much as possible from the tooth structure and achieving high FR to chewing forces.[10] Consequently, our study aimed at investigation the FR of different overlay preparation designs.

The null hypotheses of this study were that preparation designs do not affect the MA and FR of bondable hybrid ceramic overlay restorations.

2. Materials and Methods

2.1. Ethical approval:

This study followed all guidelines of the Local Research Ethics Committee of the Faculty of Dentistry, Mansoura University, and received approval no. A0201024FP.

2.2. Sample size calculation:

Based on Vianna et al.,[11] sample size was calculated by the G power program V 3.1.9.4. Based on effect size of 1.59 using 2-tailed test, α error = 0.05 and power = 80.0%, the sample size in our study was 48 in total, which wasallocated into 3 main groups (n=16) with 8 samples at least for each subgroup.

2.3. Teeth selection:

A total of 48 sound human maxillary first premolars with completely-formed roots, with homogenous dimensions and morphology were selected.[9] All teeth were freshly extracted due to periodontal or orthodontic reason and were collected after obtaining consents from patients at the Oral and Maxillofacial Surgery Department, Faculty of Dentistry, Mansoura University.

2.4. Teeth cleaning, disinfection and storage:

Initially, an ultrasonic scaler was used todebride and clean the teeth from any superficial stain, calculus, and adherent soft tissues. Subsequent low speed polishing with polishing paste was made.As recommended by the Centers for Disease Control and Prevention (CDC, 1993), all teeth underwent disinfection for 7 days using 1:10 diluted 5.25% sodium hypochlorite bleach (Clorox Bleach, Clorox Co., Cairo, Egypt).[12] To avoid dehydration, teeth were stored in 0.9% saline at room temperature during all testing period.

2.5. Teeth mounting:

For proper dealing with the selected teeth during the following steps including preparation, impression recording, and during overlay cementation procedures, their roots were embedded vertically along their long axes in epoxy resin blocks. Selected teeth were individually mounted in a cylindrical plastic ring filled with self-curing epoxy resin material (KEMAPOXY 150, CMB International, Egypt) using a 1- arm dental laboratory parallelometer device (Delineador B2, Bio-Art Co., SP, Brazil). The level representing the simulated alveolar bone was defined 1 mm below the CEJ level.[9,13] Periodontal ligament was simulated around roots following "Transitional Wax Technique" using a light-body of vinyl polysiloxane (VPS) impression material (Perfit Light-body, Huge Dent, China).[13,14] All the steps were performed by the same operator.

2.6. Samples grouping:

The resulted 48 epoxy resin blocks with their mounted teeth were numbered and divided into three equal groups (16 each) based on the overlay preparation design for each tooth; Group (1): 16 teeth with conventional preparation design, Group (2): 16 teeth with shoulder palatal preparation design, and Group (3): 16 teeth with circumferential shoulder preparation design. Each group was subdivided into two subgroups (8 each) based on the hybrid ceramic material utilized for overlay construction; Subgroup (V): 8 teeth restored using Vita Enamic PICN material and Subgroup (C): 8 teeth restored using Cerasmart 270 RNC material.

2.7. Teeth preparation:

The selected teeth were prepared occlusally through a freehand technique using a high-speed handpiece under constant copious water coolant.[9,13] A standard-grit tapered diamond bur with round end (TR-16, AZDENT, Zhengzhou, China) was used for preparation following the occlusal anatomic configuration (1.3 mm for functional palatal cusps and 0.8 mm for non-functional buccal cusps). A putty index was utilized to assess the uniformity and degree of tooth reduction using a periodontal probe.[13]

Axially, a standardized overlay preparation for the selected natural teeth was performed using a dental surveyor (Milling unit BF 2, Bredent GmbH & Co., Germany). For Group (1) samples, the conventional design was made.[9] This preparation procedure included using a standard-grit tapered diamond bur with flat end (TF-12, AZDENT, Zhengzhou, China) producing a central cavity with 2.5 mm width, 1.5 mm depth and 6°-tapered axial walls. Proximally, this cavity level was extended more cervically forming a proximal box mesially and distally, extended 1 mm cervically (1 mm above CEJ level) and 1 mm axially with 1.5 mm buccopalatal width and the same 6°-tapered axial walls.[9](Figure 1A)

For Group (2) samples, the shoulder palatal preparation design was made.[10] This preparation procedure included using the tapered diamond bur with flat end producing two proximal boxes mesially and distally that were extended 2 mm cervically and 1 mm axially with 3 mm buccopalatal width and 6°-tapered axial walls. Besides, palatal surface preparation was made following the tooth contour connecting both proximal boxes, forming 1 mm shoulder finish line.[10](Figure 1B)

For Group (3) samples, the circumferential shoulder preparation design was made.[15] It included using the tapered diamond bur with flat end producing a circumferential 1 mm shoulder finish line. This preparation level was defined with marker at a level 4 mm occlusal to the CEJ level. This preparation design was made following the tooth contour and oriented along the major axis of the tooth forming 6°-tapered axial walls.[15](Figure1C) The periodontal probe was used to check preparation dimensions at different points of all types of preparation.

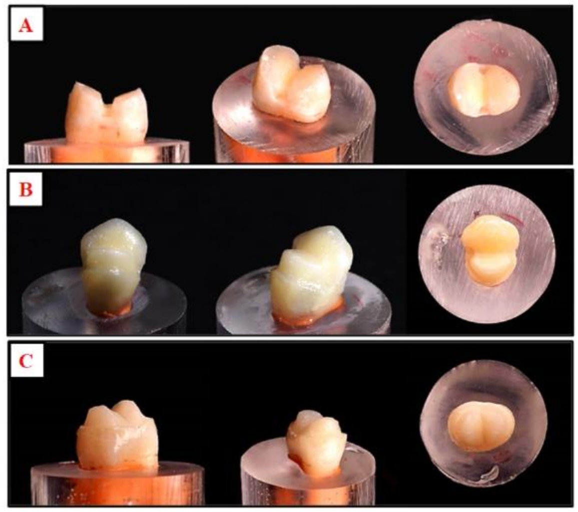

Figure 1. The finished preparation designs for all studied groups; (A) the conventional design for group (1), (B) the shoulder palatal design for group (2), and (C) the circumferential shoulder design for group (3).

For all groups, all prepared surfaces were properly finished and smoothed with fine grit diamond burs. The prepared teeth for all groups were finally featured with 1.5 mm and 1 mm occlusal reductions for functional palatal cusps and non-functional buccal cusps, respectively. All the teeth were prepared by the same operator using a magnification dental loupe.[9]

2.8. Fabrication of overlay restorations:

A total of 48 hybrid ceramic overlay restorations were CAD/CAM-constructed;

24 fabricated using Vita Enamic PICN material (2M2-T/EM-14, Vita Zahnfabrik, BadSackingen, Germany) and 24 fabricated using Cerasmart 270 RNC material (A2 LT/14, GC Corp, Tokyo, Japan). The CAD/CAM process chain consisted of scanning, designing (Figure 2) and milling phases was followed. All milled overlay restorations were checked using a digital caliper to check and confirm the uniform dimensions for each design group.[13] Finishing and high-gloss polishing for milled restorations were completed using the suitable manufacturer- recommended finishing/ polishing tools.

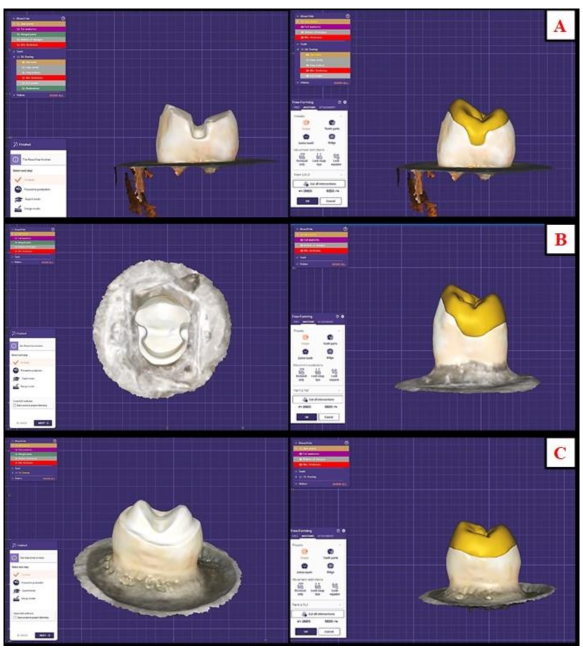

Figure 2. Designing phase for fabrication of overlay restorations; (A) for group (1) samples, (B) for group (2) samples, and (C) for group (3) samples.

2.9. Pre-cementation marginal adaptation testing:

A calibrated stereomicroscope (SZ61TR, Model SZ2-ILST, Olympus Co., Tokyo, Japan) was used to examinethe samples of all studied groups up to 40x magnification to evaluate the level of marginal adaptation or fit before cementation procedure. A special software (IS Capture 4.1, Informer Technologies, Inc., CA, US) was used to determine the amount of MG at 3 different points of each overlay surface to estimate the mean MG before cementation.[9]

2.10. Cementation of overlay restorations:

Each overlay was cemented to its corresponding prepared tooth following the manufacturer-recommended cementation protocol. All prepared teeth were first etched with a 37% phosphoric acid etching gel (DENU Etch-37, HDI Inc, Seoul, Korea) for 15 sec followed by proper washing under running water for 30 sec and finally were air-dried for 15 sec. Second, a light-curing bonding agent (Tetric N Bond Universal, Ivoclar Vivadent, Schaan, Liechtenstein) was applied with brush, gently oil-free air blown for 5 sec and finally a LED light-curing unit (Elipar Deep Cure-S, 3M ESPE Dental, MN, US) was used for 10 second-light-curing.

The fitting surfaces of all overlays were treated with 5% hydrofluoric acid etching gel (IPS Ceramic Etching Gel, Ivoclar Vivadent, Schaan, Liechtenstein) for one minute followed by proper rinsing off under running water for one minute and finally were air-dried for 20 sec. Then, a thin coat of a silane coupling agent (Porcelain Primer, Bisco Inc., Schaumburg, IL, US) was applied for 30 sec followed by light streaming with air for 5 seconds, based on manufacturer's guidelines. A dual-cured, self-adhesive resin luting cement (Breeze Translucent, Pentron Clinical, CA, US) was utilized for cementation of overlays on their respective prepared teeth using a custom-made cementation loading device.[9] All cemented samples were stored and preserved in the saline solution for 24 hours at room temperature prior to testing.[15,16]

2.11. Thermal cycling:

An accelerated artificial aging process was performed for all samples using a thermocycler (SD Mechatronik, Feldkirchen- Westerham, Germany). In this study, thermal cycling was performed for 5000 cycles altering between 5 ± 1°C and 55 ± 1°C with a dwell time of 30 sec in each water bath and 5 sec of transfer time.[10,13,16]

2.12. Post-cementation marginal adaptation testing:

After overlays cementation to corresponding teeth and exposure to thermal cycling protocol, the samples of all studied groups were re-examined using the calibrated stereomicroscope to evaluate the level of marginal adaptation or fit after cementation procedure. The MG was measured at the same 3 points of each overlay surface that were selected before cementation.[9]

2.13. Testing for the FR:

All specimens were tested for the FR (Figure 3) using a computer-controlled, dual-column, tabletop universal testing machine (model 3365, Instron Industrial Products, Norwood, MA, US). The compressive load was axially and centrally-applied using a 5 mm-diameter, stainless steel, round-end antagonist stylus at a crosshead speed of 1 mm/minute until fracture of the sample. The maximum load that produced was recorded in newton (N) while separating tin foil was used [13,15]

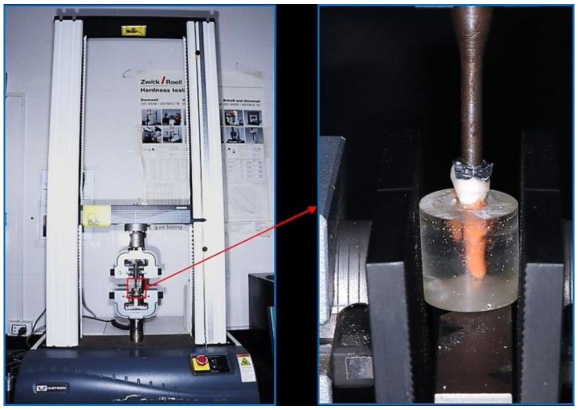

Figure 3. Fracture resistance testing; the sample was secured in its position in the universal testing machine with axially and centrally-applied compressive load while separating tin foil was used.

2.14. Statistical analysis:

Data obtained were analyzed by SPSS (Statistical Package for Social Sciences) statistical software (V 22, IBM Co., Armonk, NY, US). Qualitative data were expressed as numbers and percents. Quantitative data were tested for normality by Shapiro-Wilk test then expressed in means and SDs for normally distributed data and medians and ranges for non-normally distributed. Statistical significance of the obtained results judged at $p \leq 0.05$ level.

3. Results:

3.1. Effect of preparation design and restorative material on marginal adaptation of indirect overlay restorations:

The Wilcoxon Signed Ranks' test was performed to test the difference betweenthe pre-cementation and post-cementation MG. Before cementation, samples restored with Cerasmart overlays using circumferential shoulder preparation design (CD3) recorded the lowest value of MG (32.10 ± 1.72 µm), while samples restored with Cerasmart overlays using shoulder palatal preparation design (CD2) recorded the highest value (36.33 ± 2.65 µm). After cementation and aging, samples restored with Vita Enamic overlays using shoulder palatal preparation design (VD2) recorded the lowest value of MG (22.33 ± 1.58 µm), while samples restored with Cerasmart overlays using shoulder palatal preparation design (CD2) recorded the highest value (27.81 ± 2.82 µm). (Table 1)

Individually regarding to restorative material, Vita Enamic material was found lower than Cerasmart in MG both before (33.21 ± 2.96 µm for Vita Enamic and 34.68 ± 2.65 µm for Cerasmart) and after (24.16 ± 3.32 µm for Vita Enamic and 26.01 ± 3.12 µm for Cerasmart) cementation, therefore Vita Enamic is individually better than Cerasmart in marginal adaptation. When preparation design is considered, circumferential shoulder design exhibited the lowest MG value both before (32.10 ± 1.98 µm) and after (22.93 ± 1.95 µm) cementation. On contrary, conventional design showed the highest value of MG before and after cementation (35.39 ± 2.71 µm and 27.25 ± 2.83 µm, respectively). (Table 1)

The MG value was decreased in all tested groups following overlays cementation. Wilcoxon Signed Ranks' test indicateda significant difference ($p<0.05$) between pre- and post-cementation MG values in all tested groups. (Table 1)

Kruskal-Wallis and Mann-Whitney U tests were conducted to detect whether there is significant difference between levels of each factor regarding applied MG. Comparing marginal adaptation between all tested groups, significant differences were found among groups before ($p=0.001$) and after ($p=0.000$) cementation. When preparation designs were compared, statistically significant differences were found among all designs except between conventional and palatal shoulder designs with p value of 0.283 before cementation and between palatal shoulder and circumferential shoulder designs with p value of 0.092 after cementation. In terms of material, a significant difference existedamong both tested materials ($p=0.028$). (Table 2)

3.2. Effect of preparation design and restorative material on fracture resistance of indirect overlay restorations:

After cementation and aging, samples restored with Vita Enamic overlays using conventional preparation design (VD1) recorded the lowest value of fracture resistance (609.565 ± 178.128 N), while samples restored with Cerasmart overlays using circumferential shoulder preparation design (CD3) recorded the highest value (1458.796 ± 544.311 N). Individually regarding to restorative material, samples restored with Vita Enamic overlays had fracture resistance mean value (971.035 ± 491.806 N) significantly lower than samples restored with Cerasmart overlays (1296.051 ± 435.651 N). When preparation design is considered, circumferential shoulder design exhibited the highest fracture resistance mean value (1444.211 ± 517.915 N), while conventional design showed the lowest value of fracture resistance after cementation and aging (822.014 ± 323.689 N). (Table 3)

Kruskal-Wallis and Mann-Whitney U tests were conducted to detect whether there is significant difference between levels of each factor regarding fracture resistance. Comparing fracture resistance between all tested groups, significant difference was found (p=0.002). When preparation designs were compared, a significant difference existed between conventional and circumferential shoulder designs with p value of 0.001. In terms of material, a significant difference existed between both tested materials (p=0.011). Furthermore, the interaction effect between preparation design and used materials were studied for FR. No significant interaction effect was found between overlay material and preparation design regarding FR (p value = 0.220). (Table 3)

Table 1. Descriptive statistics with Wilcoxon Signed Ranks' test for comparison of marginal gaps (μm) before and after cementation.

Factor Level	N	Before Cementation			After Cementation			Mean Differ	Wilcoxon test
		Mean	Med	SD	Mean	Med	SD		***p***
Group									
VD1	8	35.17	34.07	3.78	26.99	26.45	3.74	8.18	**0.012***
CD1	8	35.61	35.75	1.18	27.51	28.05	1.76	8.10	**0.012***
VD2	8	32.35	32.85	1.55	22.33	22.13	1.58	10.02	**0.012***
CD2	8	36.33	36.48	2.65	27.81	28.00	2.82	8.52	**0.012***
VD3	8	32.11	31.17	2.33	23.15	22.03	2.37	8.96	**0.012***
CD3	8	32.10	32.05	1.72	22.72	22.84	1.55	9.38	**0.012***
Design									
D1	16	35.39	35.42	2.71	27.25	27.58	2.83	8.14	**0.000***
D2	16	34.34	34.07	2.94	25.07	24.32	3.59	9.27	**0.000***
D3	16	32.10	31.68	1.98	22.93	22.43	1.95	9.17	**0.000***
Material									
V	24	33.21	32.87	2.96	24.16	22.78	3.32	9.05	**0.000***
C	24	34.68	34.85	2.65	26.01	26.94	3.12	8.67	**0.000***

*significance at p-value ≤ 0.05.
SD: Standard Deviation
(V): Vita Enamic
(C): Cerasmart
(D1):Conventional preparation design
(D2):Shoulder palatal preparation design
(D3):Circumferential shoulder preparation design

Table 2. Kruskal-Wallis & Mann-Whitney U tests for comparison of marginal gaps (µm) among tested groups before and after cementation.

Factor Level	Marginal Gap					
	Before Cementation			After Cementation		
	Mean ± SD	p_p *(pairwise)*	p_o *(Omnibus)*	Mean ± SD	p_p *(pairwise)*	p_o *(Omnibus)*
Group						
VD1	35.17 ±3.78	0.386	**0.001***	26.99 ± 3.74	0.562	**0.000***
CD1	35.61 ± 1.18			27.51 ± 1.76		
VD1	35.17 ±3.78	0.080		26.99 ± 3.74	**0.005***	
VD2	32.35 ± 1.55			22.33 ± 1.58		
VD1	35.17 ±3.78	0.272		26.99 ± 3.74	0.688	
CD2	36.33 ± 2.65			27.81 ± 2.82		
VD1	35.17 ±3.78	**0.045***		26.99 ± 3.74	**0.017***	
VD3	32.11 ± 2.33			23.15 ± 2.37		
VD1	35.17 ±3.78	0.056		26.99 ± 3.74	**0.017***	
CD3	32.10 ± 1.72			22.72 ± 1.55		
CD1	35.61 ± 1.18	**0.009***		27.51 ± 1.76	**0.001***	
VD2	32.35 ± 1.55			22.33 ± 1.58		
CD1	35.61 ± 1.18	0.816		27.51 ± 1.76	0.858	
CD2	36.33 ± 2.65			27.81 ± 2.82		
CD1	35.61 ± 1.18	**0.004***		27.51 ± 1.76	**0.003***	
VD3	32.11 ± 2.33			23.15 ± 2.37		
CD1	35.61 ± 1.18	**0.005***		27.51 ± 1.76	**0.003***	
CD3	32.10 ± 1.72			22.72 ± 1.55		
VD2	32.35 ± 1.55	**0.004***		22.33 ± 1.58	**0.001***	
CD2	36.33 ± 2.65			27.81 ± 2.82		
VD2	32.35 ± 1.55	0.803		22.33 ± 1.58	0.681	
VD3	32.11 ± 2.33			23.15 ± 2.37		
VD2	32.35 ± 1.55	0.872		22.33 ± 1.58	0.688	
CD3	32.10 ± 1.72			22.72 ± 1.55		
CD2	36.33 ± 2.65	**0.002***		27.81 ± 2.82	**0.005***	
VD3	32.11 ± 2.33			23.15 ± 2.37		
CD2	36.33 ± 2.65	**0.003***		27.81 ± 2.82	**0.005***	
CD3	32.10 ± 1.72			22.72 ± 1.55		
VD3	32.11 ± 2.33	0.929		23.15 ± 2.37	0.993	
CD3	32.10 ± 1.72			22.72 ± 1.55		
Design						
D1	35.39 ± 2.71	0.283	**0.003***	27.25 ± 2.83	**0.036***	**0.001***
D2	34.34 ± 2.94			25.07 ± 3.59		
D1	35.39 ± 2.71	**0.001***		27.25 ± 2.83	**0.000***	
D3	32.10 ± 1.98			22.93 ± 1.95		
D2	34.34 ± 2.94	**0.021***		25.07 ± 3.59	0.092	
D3	32.10 ± 1.98			22.93 ± 1.95		
Material						
V	33.21 ± 2.96	**0.028***	**0.028***	24.16 ± 3.32	**0.030***	**0.030***
C	34.68 ± 2.65			26.01 ± 3.12		

Table 3. Descriptive statistics withKruskal-Wallis & Mann-Whitney U tests for comparison of fracture resistance (N) among tested groups.

Factor level	Fracture Resistance		
	Mean ± SD	p_p *(pairwise)*	p_o *(Omnibus)*
Group			
VD1	609.565 ± 178.128	**0.032***	**0.002***
CD1	1064.812 ± 280.180		
VD1	609.565 ± 178.128	0.177	
VD2	873.914 ± 290.704		
VD1	609.565 ± 178.128	**0.001***	
CD2	1335.639 ± 383.920		
VD1	609.565 ± 178.128	**0.001***	
VD3	1429.626 ± 527.287		
VD1	609.565 ± 178.128	**0.000***	
CD3	1458.796 ± 544.311		
CD1	1064.812 ± 280.180	0.402	
VD2	873.914 ± 290.704		
CD1	1064.812 ± 280.180	0.303	
CD2	1335.639 ± 383.920		
CD1	1064.812 ± 280.180	0.287	
VD3	1429.626 ± 527.287		
CD1	1064.812 ± 280.180	0.215	
CD3	1458.796 ± 544.311		
VD2	873.914 ± 290.704	0.053	
CD2	1335.639 ± 383.920		
VD2	873.914 ± 290.704	**0.049***	
VD3	1429.626 ± 527.287		
VD2	873.914 ± 290.704	**0.031***	
CD3	1458.796 ± 544.311		
CD2	1335.639 ± 383.920	0.971	
VD3	1429.626 ± 527.287		
CD2	1335.639 ± 383.920	0.827	
CD3	1458.796 ± 544.311		
VD3	1429.626 ± 527.287	0.855	
CD3	1458.796 ± 544.311		
Design			
D1	822.014 ± 323.689	0.075	**0.004***
D2	1104.777 ± 406.291		
D1	822.014 ± 323.689	**0.001***	
D3	1444.211 ± 517.915		
D2	1104.777 ± 406.291	0.122	
D3	1444.211 ± 517.915		
Material			
V	971.035 ± 491.806	**0.011***	**0.011***
C	1296.051 ± 435.651		

4. Discussion:

This study determined the impact of three distinct preparation designs (conventional, shoulder palatal, and circumferential shoulder) on the marginal fit of hybrid ceramic overlays fabricated from Vita Enamic and Cerasmart both pre- and post-cementation. The null hypotheses of the study were rejected since significant differences were observed in MG values and in the FR among all tested groups (p=0.000). Maxillary first premolars were selected in our study due to their high fracture susceptibility which is related to their anatomic morphology, including steep cuspal inclines and narrow cervical areas. In addition, they endure high occlusal loads (particularly in persons with parafunctional habits),making them an ideal model for the evaluation of FR and MA of restorative materials.[10]**Vianna et al. (2018)**[11]stated that the preparation design and the type of material have significant effects on the stress distribution in premolar teeth, further validating their use in comparative restorative studies.

Vita Enamic and Cerasmart 270 were selected in this study to represent two distinct classes of hybrid ceramics with promising clinical applications. Vita Enamic is a type of PICN material composed of a dominant ceramic network infused with a polymer matrix, designed to replicate the elastic modulus and biomechanical properties of natural dentin.[17]In contrast, Cerasmart 270 is a resin nanoceramic (RNC) that integrates nano-sized ceramic fillers into a resin matrix, providing superior flexural strength and resistance to chipping. These two materials were chosen to allow direct comparison of their behavior under identical testing conditions, offering insight into their suitability for adhesive overlay restorations. Their selection also reflects a shift in restorative dentistry toward minimally invasive, biomimetic materials that enhance tooth preservation and clinical longevity.[18]

In our study, artificial thermal aging was performed for all samples to imitate the oral environment and gain more understanding of how the studied materials perform in oral conditions. In 2015, the latest specifications issued by International Organization for Standardization (ISO/TS11405) recommended that thermocycling protocol between 5 ± 1°C and 55 ± 1°C with a dwell time of 30 sec in each water bath and 5 sec of transfer time is as an accelerated aging test. This simulates the physiological range of temperatures in the mouth caused by hot or cold drinks.[10,13,16] It was proposed and accepted that one year of oral life can be represented by 10000 cycles based on the hypothesis that such thermal cycles might occur 20-50 times daily.[19] Therefore, to simulate six months of clinical service, 5000 thermal cycles were applied in this study.

To assess the FR of restored premolars, a universal testing machine was utilized to create a compressive axial load to the samples using a metal stylus of 5 mm-diameter with crosshead speed of 1 mm/minute following ISO recommendation. For a homogenous stress distribution and to decrease the transmission of local force peaks during FR testing, a separating tin foil layer was placed as a buffer between the occlusal surface of the overlay restoration and the loading piston, thus achieving a homogenous stress distribution and minimizing the transmission of local force peaks during testing.[13,19]

At present, no consensus exists about the minimum clinically-accepted MG value. An MG value was suggested in some studies to be <100 µm, while otherstudies suggested anMG value <120 µm as the clinically-acceptable value.[9]All treatment groups in our study had MG values within these limits, irrespective of the significant difference among them. It might be linked to the mechanical properties of hybrid ceramics that are very similar to those found in natural tooth.[20] According to **Awada and Nathanson(2015)**[21], Vita Enamic and Cerasmart materials showed smoother, more defined margins and a better margin fitthan conventional ceramic materials.

According to our findings, the MG values significantly decreased for all tested groups post-cementation of overlays. There were significant differences in MG values in all tested groups between pre- and post-cementation. This finding is compatible with **El Mekkawi (2020)**[22]who evaluated the marginal accuracy of Vita Enamic hybrid ceramic with different machinable ceramic restorative materials. Vita Enamic restorations introduced MG mean value before cementation (29.50 µm) higher than the value measured after cementation (20.97 µm) with a significant difference.

On contrary, the post-cementation reduction in MG values in our study disagrees with some earlier studies in which the MG increased significantly after cementation. These studies assumed that the prostheses might not so complete seating post-cementation, which might be caused by the hydraulic pressure created during seating of restorations.[23]

The adhesion protocol plays crucial roles in the longevity of indirect partial prosthetic restorations. Studies have highlighted the significance of MA and joint integrity, both parameters are affected by the used adhesion protocol followed in this research Each overlay was cemented to its corresponding prepared tooth following the manufacturer-recommended cementation protocol. It included adequate surface treatment for both prepared tooth (etching and bonding) and overlay restoration (etching and silanization). **Peumans et al. (2013)**[24] found that the incorporation of etching and rinsing into the self-adhesive process of ceramic inlays/overlays enhances their marginal integrity over a clinical span of four years.

On comparing the impact of the 3 different preparation designs on the MG value, circumferential shoulder design exhibited the lowest MG value both before (32.10 µm) and after (22.93 µm) cementation. The shoulder palatal design came second while the conventional design showed the highest value of MG pre- and post-cementation (35.39 µm and 27.25 µm, respectively). This might be because circumferential shoulder design has simple preparation features, including flat smooth occlusal reduction, no retentive features, and few internal angles. These characteristics facilitate digital workflow procedures, including rapid scanning during digital impression recording, seamless software designing, and allowing milling burs to reproduce the details of overlays, and thus resulting in reduced MGvalue.[25]

After cementation, the circumferential shoulder design may allow for a better cement flow compared to other designs. This property is lacking for conventional and shoulder palatal designs leadingtoan increase in hydraulic pressure and discharge of excess cement, thus the MGvalue of their overlay restorationsis increased after self-adhesive resin cementation.[26]

Comparing shoulder palatal and conventional designs, the shoulder palatal design presents a better transition between proximal boxes and palatal finish lines. This causesan improved adaptation of partial ceramic restorations.[27]Moreover, the conventional design includes inter axial tooth structure reduction and formation of occlusal isthmuses. The latter increases the risk of increased friction during restoration insertion and thus has a negative impact on the marginal fit.[9]**Falahchai et al. (2020)**[23], stated that the most complex preparation design for overlay restorations yields the lowest marginal adaptation behavior.

In terms of overlay material, a significant difference was calculated between both tested Vita Enamic and Cerasmart. Vita

Enamic material was found significantly lower than Cerasmart in MGpre- and post-cementation, specifying a better adaptation to the tooth structure. This disagreeswith the findings of earlier studies, which reported improved performance of RNC materials like Cerasmart because of their higher resin content. However, in our study, Vita Enamic showed superior marginal fit irrespective of its lower resin content.[26,28]

It has been stated that the success of all-ceramic restorations to resist chewing forces is determined by their fracture loads.[7]After cementation and aging, samples restored with Vita Enamic overlays using conventional preparation design recorded the lowest value of fracture resistance (609.565 N), while samples restored with Cerasmart overlays using circumferential shoulder preparation design recorded the highest value (1458.796 N). This means all studied groups expressed significantly higher fracture load values than the normal biting force in the maxillary premolar region (450 N) supporting their clinical use..[29]

All studied groups showed high fracture resistance values which recommend both tested hybrid ceramic materials as successful restorative overlay options for maxillary premolars in patients with normal occlusal profile. This is in accordance with other studies supporting their application for the conservative overlay restorations.[13,30,31] Moreover, they have all fracture load values exceeded the parafunctional bruxing force (660 N)[31] reported for this premolar region except Vita Enamic overlays using conventional preparation design, limiting their use for patients with normal chewing function, particularly those without parafunctional habits.[32]

The high fracture load values recorded for all groups may be attributed to multiple factors. It can be explained by application only axial loading with no oblique forces tested. Besides, the thickness of ceramic occlusal part of overlay restorations may affect the performance of the tooth/restoration complex that higher FR values were produced asthe occlusal thickness increases. The fracture load values behave as a function of specimen thickness, and this means that the FR increases as the occlusal thickness increases.[7,33]

Additionally, it was stated that the bonding mechanism of a restoration has more effect on its clinical success than the strength of the utilized restoration material.[10]It could be assumed that the greater the adhesion of the restoration, the better the stress distribution within the system, and accordingly a higher FR.[32]Advancements in adhesive systems and in restorative materials have resulted in restorations that are bondable to the natural tooth without the necessity for mechanical retention. In other words, the adhesive systems can compensate for the decreased axial wall height in the case of traditional techniques.[10] This may explain the high fracture resistance values even for the conventional design. The circumferential shoulder design with more axial preparation and hence more adhesive bond expressed the highest mean FR value.

With regard to effect of preparation design on fracture behavior, there was only significant difference found between conventional (822.014 N) and circumferential shoulder (1444.211 N) designs. This result agrees with **Hoopes et al. (2018)**[34]who found that preparations containing 2, 3, and 4 mm of axial wall height showed significantly higher FRcompared to groups with no axial wall height. Also, **Gad et al. (2023)**[13], described that overlays with no intra-coronal extension had higher FR values compared to overlays with intra-coronal extension, however the difference was non-significant.

On the other hand, this finding is not in accordance with **Channarong et al. (2022)**[10], outcomes. They concluded that overlay restorations were effective in strengthening damaged maxillary premolar teeth and imparting FR equal to sound teeth, but axial wall heights and margin types did not affect this result. They found overlay preparation with buccal and palatal walls had FR value higher than preparation with no axial walls on buccal and palatal surfaces, but with no significant difference.

Individually regarding to restorative material, samples restored with Vita Enamic (PICN) overlays had fracture resistance mean value (971.035 N) significantly lower than samples restored with Cerasmart (RNC) overlays (1296.051 N).Previous studies found RNC materials including Cerasmart expressed a higher flexural strength and resistance under flexural forces (230 MPa), and a lower flexural modulus than Vita Enamic material (150-160 MPa flexural strength).[18,21,35]This could be due to the high proportion of incorporated nano-ceramic particles in the resin matrix acting like "supporting bricks" that prevent elastic deformation at the load zone.[36]

As mentioned earlier, another explanation might be RNC materials including Cerasmart demonstrated superior performance for edge chipping resistance and lower CF compared to Vita Enamic material.[18,35] The material that chips more during milling has a smaller marginal fit because of increased damage to margins which might influence the resin cement integrity underneath the restoration due to its degradation, particularly after thermal cycling. As a result, this can be considered as discontinuity between restoration and underlying substrate that influence stress resolution, leading to fracture of the restoration.[13]

This in vitro study had some limitations. Despite the careful selection, it is difficult to ensure standardization as studied premolar teeth utilized as supporting dies might vary in morphological and hydroxyapatite structure. In this work, attempts were made to simulate standard clinical procedures. However, only axial load was applied to tested materials. The multi axial loading and lateral/oblique forces which occur in the mouth were not simulated. Moreover, the required tests were performed following only thermal aging without mechanical fatigue aging through cyclic loading apparatus.

Although the results obtained in this in vitro study provide valuable knowledge and comparison about both tested hybrid ceramic materials using different preparation designs to select the best, they are not sufficient to demonstrate their longevity in clinical performance. Additional studies are needed to assess if studied premolar overlays can exhibit sufficient marginal fit and fracture resistance following different aging protocols and using dynamic loading both axially and laterally. Future researches should explore clinical conditions to provide a better understanding of the behavior of different overlays and their associated preparation designs.

5. Conclusions:

Considering the conditions and outcomes of this in vitro study, the following conclusions were reached:

1. The preparation design and the restorative material have a significant effect on both the marginal adaptation and the fracture resistance of hybrid ceramic overlay restorations for maxillary premolars.
2. On analyzing the effect of the preparation design on both the MA before and after overlays cementation and the FR, circumferential shoulder design exhibited the best profiles while the conventional design exhibited the worst.
3. Regarding restorative material, Vita Enamic overlays expressed marginal adaptation better than Cerasmart overlays before and after cementation. On contrary, Cerasmart overlays showed better fracture behavior.
4. All studied groups expressed MG values within the clinically acceptable threshold

and fracture load values significantly surpassed the normal masticatory force in the maxillary premolar region, supporting their clinical use.

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