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Effect of Taper Angle and Luting cement on the Retention and Marginal Accuracy of All-Ceramic Crowns

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ABSTRACT

Marginal accuracy and retention of all-ceramic crowns are crucial prerequisites for their long-term survival. Meanwhile, the innovative revolution of adhesive cementation has led to uncountable number of recent brands through which the dentist has to choose.

The aim of the present study was to evaluate the effect of two different tapering angles [10°& 26°] and two different luting cements [Self-etching adhesive & Self adhesive resin cement] on the retention and marginal accuracy of single unit crowns, constructed from three types of ceramics: IPS e-max Press, IPS e-max CAD and Zirconia CAD/CAM.

Seventy two recently extracted sound human molars were used in this study. The teeth were mounted on acrylic blocks and randomly divided into two equal main groups (n = 36) according to the degree of tapering angles10˚ and 26˚. Every group was subdivided into three subgroups according to the type of ceramic used (n= 12) IPS e-max Press, IPS e-max CAD and Zirconia CAD/CAM. The occlusal surface of each specimen was reduced to a flat plane perpendicular to the Long axis and all the resulting preparations had the same coronal height 4mm. The crowns of each subgroup were fabricated according to the manufacturer's instruction. The crowns of each subgroup were further subdivided into two subdivisions (n=6) according to the type of luting cement used; Multilink N and Multilink Speed. Marginal accuracy was detected before and after cementation of all specimens by stereomicroscope. All samples were subjected to retention testing using the universal testing machine. Data was collected and statistically analyzed. Heat Press fabrication technique resulted in a superior marginal fit, and higher retention of crowns as compared to the CAD/CAM technique. The self etch resin cement improved the marginal fit and retention of single unit crowns more than the self adhesive resin cement.

KEYWORDS

Taper angle,
Retention,
Marginal accuracy,
All-ceramic crowns.

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INTRODUCTION

There has been a growing interest in the use of all-ceramic restorations as replacements for traditional porcelain-fused-to-metal restorations because of their improved esthetic appearance. Developments in ceramic material science have resulted in improvements in the physical properties of modern ceramics, leading to a substantial increase in the clinical use of all-ceramic restorations [1-4].

Lithium disilicate glass ceramic material was introduced for use in all ceramic restorations which is available as an ingot that can be press-fit (IPS e.max Press) or as a block that can be milled with computer-aided design/computer-aided manufacturing (CAD/CAM) technology (IPS e.max CAD). Zirconia is a ceramic of high flexural strength exceeding 1000 Mpa, which is about six times stronger than feldspathic porcelains [2].

The retention of FPDs has been shown to depend on the taper angle: the smaller the taper angle, the higher the retention. Longevity of all-ceramic FPDs mainly relies on adequate adhesion of the resin-based luting cements both to the tooth tissues and the ceramic surface. Adhesion of luting cements increases the fracture resistance of the tooth and the restoration itself. It also increases the retention of the restoration and minimizes microleakage that may play a role in the biological success of the restoration. Marginal fit is one of the most important criteria for the long-term success of all-ceramic crowns. Increased marginal discrepancies expose the luting material to the oral environment, thus leading to cement dissolution and microleakage [5].

The objective of this study, therefore, was to evaluate the effect of two taper angles (10º & 26º) and two different luting cements, on the retention and marginal accuracy of IPS e.max Press, IPS e.max CAD and Zirconia CAD/CAM single unit crowns. The research hypothesis was that increasing taper angles would result in decreased retention and marginal accuracy, regardless of the luting cement type [6].

MATERIALS AND METHODS

Table 1. *Materials, Description of material, Composition, Manufacturers:*

Materials	Description of material	Composition	Technique	Manufacturer
IPS e.max CAD (C 14)	Lithium disilicate glass ceramic (partially crystallized)		Machinable CAD/CAM (Cerec inLab)	Ivoclare Vivadent Schaan, Liechtenstein Germany
IPS e.max Press	Lithium disilicate glass ceramic ingot		Press technique	Ivoclare Vivadent Schaan, Liechtenstein Germany
GC Initial Zirconia Disk HT(High Translucency)	Yttria Stabilized tetragonal zirconia polycrystals		Machinable CAD/CAM (Roland)	CG American Inc.

Multilink N (MN) **&** **Primer A/B**	Self-curing Resin Cement dual-curing Self-curing and Self-etching primer	The monomer matrix is composed of dimethacrylate and HEMA. The inorganic fillers include barium trifluorid and spheroid mixed oxide. Aqueous solution of initiators. Composed of HEMA, phosphoric acid and methacrylate monomers.		Ivoclare Vivadent Schaan, Liechtenstein Germany
Multilink Speed (MS)	Self adhesive Self-curing Resin Cement dual-curing	The monomer matrix is composed of dimethacrylate and acidic monomers. The inorganic fillers are barium glass, ytterbium trifluorid, co-polymer and highly dispersed silicon dioxide. Additional contents are initiators, stabilizers and colour pigments (<1%)		Ivoclare Vivadent Schaan, Liechtenstein Germany
Monobond N		Alcohol solution of saline methacrylate. Phosphoric acid methacrylate and sulphide methacrylate.		Ivoclare Vivadent Schaan, Liechtenstein Germany

METHODOLOGY

Seventy two recently extracted sound human lower first molars were used in this study. The teeth were disinfected then debrided from calculus and soft tissue. The molars were embedded in plastic cylinders (2cm height& 1.5cm diameter) filled with self-cure acrylic resin using a dental surveyor. Teeth were randomly divided into two main groups (n=36) according to the taper angle (10˚ and 26˚). The preparation was achieved using an industrial lathe machine with high speed. The occlusal surface of each tooth was reduced to a flat plane perpendicular to the long axis of the tooth. All the resulting preparations had the same occlusal height (4mm) and the finishing line was 1mm shoulder. An anti-rotational occlusal groove was made using a high speed diamond stone to prevent rotation of the crowns on the teeth, also to insure the exact reproducibility of placement of the crowns.

Crowns construction:

Teeth of each group were further subdivided into three subgroups (n=12) according to the type of ceramic used.

Subgroup A: IPS e.max CAD all ceramic crowns:

A CAD/CAM (CEREC inLab) was used for the construction of crowns using IPS e.max CAD blocks. Every tooth was sprayed with light reflecting powder and then it was secured on the tray of the inEos scanner for taking optical impression. The restoration design was created then checked and the restoration dimensions were adjusted according to the manufacturer's instructions. Final design was stored on the hard desk and the machine was ready for milling procedure.

To start the milling procedure, the ceramic block was selected from ''select blocks'' box. The milling chamber door was closed and the "mill" icon was clicked. The milling process started automatically in which the two diamond stones were milling the block simultaneously with copious water cooled spray from two directions. The crowns were then inserted into the furnace in which Sintering process took place at temperature of 865º C according to manufacturer instructions. After Sintering process, the crowns were seated on their corresponding teeth with the help of anti rotational groove and checked for complete seating.

Subgroup B: Zirconia CAD / CAM all ceramic crowns:

A CAD/CAM (Roland machine) was used for crowns construction using CG Intial zirconia disk High translucency (HT). The tooth was sprayed with light reflecting powder and then it was secured on the tray of the scanner for taking optical impression. The restoration design was created and the restoration dimensions were adjusted according to the manufacturer's instructions. After finishing the design process, the zirconia disk was fixed to its place in the milling machine and the preview window was activated to start the milling process. AS CG Initial zirconia disks are initially manufactured in partially sintered state, so the Roland CAD/CAM milling machine is programmed to produce an enlarged restoration with a percentage equal to that of the shrinkage percent during sintering process. The crowns were then placed on their occlusal surface inside the ceramic sintering tray, which was filled with sintering beads and then sintered in the HTC furnace (High-temperature Furnace with program control unit) according to the manufacturer instructions. After Sintering process, the crowns were seated on their corresponding teeth with the help of anti rotational groove and checked for complete seating.

Subgroup C: IPS e.max Press all ceramic crowns:

Impression making:

1- A custom made Teflon base was fabricated to hold the teeth during impression making. (Figure 1)

2- Six acrylic trays with handle, perforations, 4 mm spacer were fabricated over the base with the 4 acrylic blocks in place and impression was taken.

3- Impressions were poured immediately using type IV dental stone.

4- Two layers of spacer of total thickness [18-22μm] were applied on the stone dies by the aid of painting brush up to maximum 1mm from the preparation margin according to the manufacturer's instructions.

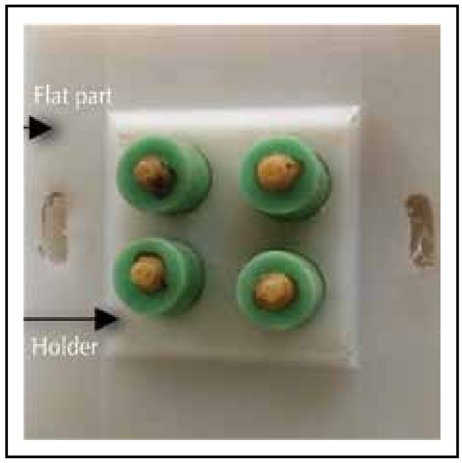

Fig. (1) Acrylic blocks fitted in the Teflon base

Wax pattern construction:

For the purpose of crown samples standardization, the same external shape and size of the milled crowns of zirconia and e-max CAD were obtained by an index using the Teflon base and the special tray. Spruing of the wax patterns, Investing and Preheating following the manufacturer's instructions.

Pressing:

The investment ring was removed from preheating furnace then the corresponding ingot for IPS e-max press was placed followed by the AIOX plunger. The investment ring with the ingot and AIOX plunger was placed in the center of EP600 furnace. The program was selected and activated according to manufacturer instructions. The pressing process started at the 1100 °C when the ceramic ingot became plasticized, it was pressed inside the investment mold at 3.5 bars. The investment ring was allowed to cool at room temperature for about 60 minutes on a wide-meshed grid (IPS e-max cooling rack) which insured quick and even cooling of the investment ring. After cooling of the investment, the length of the ALOX plunger was marked on the investment ring. The investment was then separated at the predetermined mark using a separating disk. The investment ring was broken using a plaster knife at the predetermined breaking point. Rough divestment was carried out with polishing jet medium using polishing alumina beads (type 100μ) at 4 bar (60 psi) pressure according to manufacturer's instructions. The crowns were seated on their corresponding teeth with the help of anti rotational groove and checked for complete seating.

Cementation

Each subgroup was further subdivided into two divisions according to the cement type.

- **Division 1:** were cemented with Multilink N cement.
- **Division 2:** were cemented with Multilink speed cement.

I. Surface treatment of the restorations

1. The fitting surface of IPS e.max Press and CAD crowns was etched using 5% Hydrofluoric acid for 20 seconds according to manufacturer's instructions, Crowns were rinsed thoroughly with water for 15 seconds and then dried with water and oil free air stream.
2. The fitting surfaces of the zirconia crowns were sand blasted with 100μm AL_2O_3 at a maximum pressure of 4 bars for 30 seconds at an approximate distance of 2 cm according to manufacturer's instructions. The fitting surface was not touched after that until cementation to avoid contamination with impurities.
3. Monobond N was applied on the fitting surface of all crowns with a microbrush, allowing the material to react for 1 minute and then dispersed with water and oil free air stream.

II. Surface treatment of the tooth

Only with Multilink N primer A/B liquids were mixed in a 1:1 ratio, the mixed primer A/B is solely self-curing and no need to be protected from light. However it must be applied within10 minutes.

The tooth surface was rinsed, dried and painted with primer A/B for 30 seconds using a microbrush. Dispersing the excess with blown air until the mobile liquid film is no longer visible.

III. Cementation steps of Multi link N & Multi link Speed

- The cement was dispensed from the automix syringe; the desired quantity was applied directly onto the fitting surface of the crown.
- The crowns were then seated on their corresponding teeth using finger pressure. The excess was removed immediately with a micro-brush. Application of 3 kg load for 5 minutes was performed using load applicator device and then light curing for 40 seconds.

Testing procedures:

A. Marginal accuracy:

Vertical marginal gap (the gap distance starting from the finishing line to the external surface of the crown margin) was tested before and after cementation using a stereomicroscope (Carl Zeiss stereomicroscope, Germany). Crowns were held in place over their corresponding teeth. Shots of the margins were taken for each crown using digital camera (Olympus Camedia C-5060 digital Camera, Japan) fitted on the stereomicroscope at a fixed magnification of 30X. Shots were taken at 4 landmarks along the cervical circumference for each crown (mid-buccal, mid-proximal 1, mid-lingual and mid-proximal 2). Morphometric measurements were done using a special image analysis software on an IBM compatible personal computer.

For each shot, readings were taken at ten equidistant pre-selected points along the margin of the crown with a total of 40 readings along the circumferential margin of each crown. The mean score of different readings per-sample was used for statistical analysis of linear vertical gap distances for different groups.

B. Retention test:

Before starting the test and in order to prevent fracture of ceramic crowns, vertical epoxy resin blocks were built around the crowns (Figure 2 a,b,c &d) in order to hold to the attachment device, which is a metal rod consisting of two ends (solid end and split end) (Figure 2 e).

Retention was measured using universal testing machine (Model LRXpPlus, Lloyd Instruments, Fareham, UK) with a load cell of 5 kN. The attachment device was attached to the upper member of the machine and the samples were individually mounted in the lower fixed compartment of a computer controlled universal testing machine. The device was subjected to a slowly increasing vertical tensile load (5mm/min) until the crown was totally out of place. The load at dislodgment manifested by total vertical dislodgment of crown and confirmed by a sharp drop at load-deflection curve was recorded using computer software (Nexygen-MT-4.6; Lloyd Instruments) and this value was recorded in Newtons.

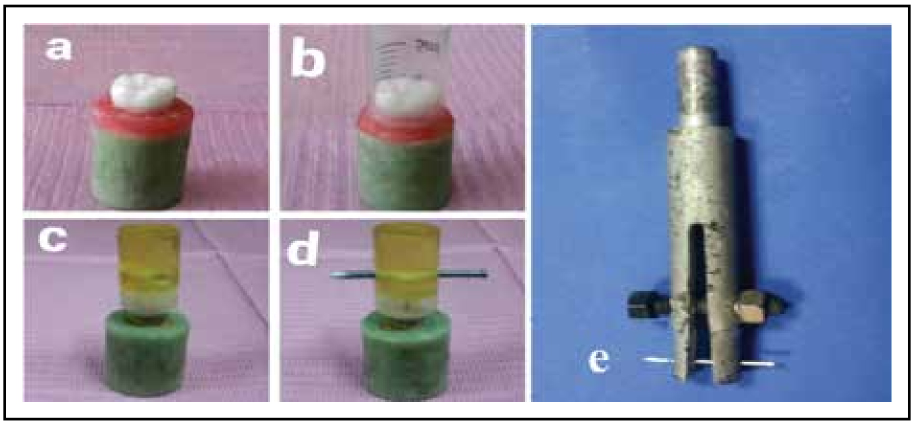

Fig. (2) Steps of building epoxy resin blocks around the crowns and the attachment device.

RESULTS

Data analysis was performed in several steps. Initially, descriptive statistics for each group results. Three factorial analysis of variance ANOVA test of significance was used for comparing variables affecting retention and gap mean values (ceramic, convergence angle and cementation). One way ANOVA followed by pair-wise Student Newman-Keuls (SNK) post-hoc tests were performed to detect significance between ceramic groups. Paired t-test was performed to detect significance between convergence subgroups. Statistical analysis was performed using Aasistat 7.6 statistics software for Windows (Campina Grande, Paraiba state, Brazil). P values ≤0.05 are considered to be statistically significant in all tests.

Marginal gap

The mean values and standard deviation of marginal gap (μm) for all ceramic groups as function of convergence angle and cementation procedure are summarized in table (2):

Table 2. *Marginal gap results (Mean values± SDs) for all ceramic groups as function of convergence angle and cementation:*

Variables		Before cementation	After cementation with	
			Multi link N (ML N)	Multilink Speed (ML speed)
IPS e.max Press	26º	69.5±11.8	81.71±17.2	104.21±15.6
	10º	77.36±14.8	103.76±15.7	99.29±20.2
IPS e.max CAD	26º	70±6.3	84.14±19.1	120.43±12.4
	10º	82.25±26.3	105.38±20.9	99.38±19.7
Zr CAD	26º	94.63±21.4	122.5±1.1	155±9.6
	10º	86.43±16.3	95.43±23.2	113±10.1

Effect of ceramic materials

Irrespective of convergence angle or cementation, totally it was found that Zr CAD group recorded statistically significant ($P<0.05$) highest marginal gap mean value (111.16 ± 4.79 μm) followed by IPS e.max CAD group (93.6± 7.82μm) while IPS e.max Press group recorded statistically significant ($P<0.05$) lowest marginal gap mean value (89.31± 5.44 μm) as indicated by three way ANOVA test. Pair-wise SNK post-hoc test showed non-significant ($p>0.05$) difference between IPS e.max CAD and e.max Press groups.

Table 3. *Comparison between total marginal gap results (Mean values± SDs) as function of ceramic:*

Variables		*Mean*	*SD*	*Rank*	*Statistics (p value)*
Ceramic	*IPS e.max Press*	89.31	5.44	B	<0.0001*
	IPS e.max CAD	93.6	7.82	B	
	Zr CAD	111.16	4.79	A	

*Different letter in the same column indicating statistically significant difference (p < 0.05) *; significant (p < 0.05) ns; non-significant (p>0.05)*

Effect of convergence angle

Regardless to ceramic or cementation, totally it was found that 26° convergence angle subgroup recorded statistically non-significant ($P>0.05$) higher marginal gap mean value (100.24± 22.49 μm) than 10° convergence angle subgroup (95.81± 9.28 μm) as indicated by three way ANOVA followed by pair-wise SNK post-hoc tests.

Table 4. *Comparison between total marginal gap results (Mean values± SDs) as function of convergence angle:*

Variables		*Mean*	*SD*	*Rank*	*Statistics (p value)*
Convergence angle	*26º*	100.24	22.49	A	0.2754 ns
	10º	95.81	9.28	A	

*Different letter in the same column indicating statistically significant difference (p < 0.05) *; significant (p < 0.05) ns; non-significant (p>0.05)*

Effect of cementation

Irrespective of ceramic or convergence angle, totally it was found that Multi link Speed (ML Speed) subgroup recorded statistically significant ($P<0.05$) highest marginal gap mean value (115.22±

22.33μm) followed by Multi link N (ML N) subgroup (96.47± 22.78 μm) while non-cemented subgroup recorded statistically significant (P<0.05) lowest marginal gap mean value (82.38 ± 19.91 μm) as indicated by three way ANOVA. Pair-wise SNK post-hoc test showed non-significant (p>0.05) difference between ML Speed and ML N subgroup.

Table 5. *Comparison between total marginal gap results (Mean values± SDs) as function of cementation:*

Variables		*Mean*	*SD*	*Rank*	*Statistics (p value)*
Before cementation		82.38	19.91	*B*	0.0064*
After cementation with	*ML N*	96.47	22.78	*A*	
	ML Speed	115.22	22.33	*A*	

Different letter in the same column indicating statistically significant difference (p < 0.05)
**; significant (p < 0.05) ns; non-significant (p>0.05)*

Retention

The mean values and standard deviation of retention (N) for all ceramic groups as function of convergence angle and cementation procedure are summarized in table (6).

Table 6. *Retention results (Mean values± SDs) for all ceramic groups as function of convergence angle and cement type:*

Variable ML N		*Cement*	
		ML speed	
IPS e.max CAD	*26°*	181.01±15.7	68.51±5.5
	10°	245.75±8.3	142.82±8.57
Zr CAD	*26°*	223.42±7.01	53.16±7.1
	10°	278.29±8.1	201.49±31.7
IPS e.max Press	*26°*	175.3±31.3	59.81±1.6
	10°	337.04±16.1	127.95±3.9

Effect of ceramic materials

Irrespective of convergence angle or cementation, totally it was found that Zr CAD group recorded statistically non-significant (P>0.05) highest retention mean value (189.09 ± 13.48 N) followed by IPS e.max Press group (175.03 ± 13.22 N) while IPS e.max CAD group recorded statistically significant (P<0.05) lowest retention mean value (159.52±9.44N) as indicated by three way ANOVA followed by pair-wise SNK post-hoc tests.

Table 7. *Comparison between total retention results (Mean values± SDs) as function of ceramic:*

Variables		*Mean*	*SD*	*Rank*	*Statistics (p value)*
Ceramic	*IPS e.max CAD*	159.52	9.44	A	0.0825 ns
	Zr CAD	189.09	13.48	A	
	IPS e.max Press	175.03	13.22	A	

Different letter in the same column indicating statistically significant difference (p < 0.05)
**; significant (p < 0.05) ns; non-significant (p>0.05)*

Effect of convergence angle

Regardless to scanning modes, totally it was found that 10°convergence angle subgroup recorded statistically significant (P<0.05) higher retention mean value (222.223± 18.62 N) than 26° convergence angle subgroup (126.87± 7.62 N) as indicated by three way ANOVA followed by pair-wise SNK post-hoc tests.

Table 8. *Comparison between total retention results (Mean values± SDs) as function of convergence angle:*

Variables		*Mean*	*SD*	*Rank*	*Statistics (p value)*
Convergence angle	*26°*	126.87	7.62	B	<0.0001*
	10°	222.223	18.62	A	

Different letter in the same column indicating statistically significant difference (p < 0.05)
**; significant (p < 0.05) ns; non-significant (p>0.05)*

Effect of cement

Regardless to ceramic or cementation, totally it was found that ML N cement group recorded statistically significant (P<0.05) higher retention mean value (240.14± 17.84 N) than ML Speed cement group (108.96± 12.25 N) as indicated by three way ANOVA followed by pair-wise SNK post-hoc tests.

Table 9. *Comparison between total retention results (Mean values± SDs) as function of cement:*

Variables		Mean	SD	Rank	Statistics (p value)
Cement	ML N	240.14	17.84	A	<0.0001*
	ML Speed	108.96	12.25	B	

*Different letter in the same column indicating statistically significant difference (p < 0.05) *; significant (p < 0.05) ns; non-significant (p>0.05)*

DISCUSSION

In the present study two different occlusal convergence angles were investigated in an attempt to clarify the most appropriate degree of convergence and its effect on the margin adaptation and retention of three all ceramic crown system. The two convergence angles used in our study were; group I with 10 ° degree convergence angle and group II with 26 ° degree convergence angle where the latter was reported, as the extreme occlusal tapering that could affect the retention of crowns. [1] On the other hand, a 10° taper angle was chosen because Weed et al found non-significant retention values between the preparations made with 3° to 16° taper angles. [1] The maximum retention is obtained between 6° and 12°, however other studies have reported mean taper angles ranging from 3° to 26°. [2],[3]

In the current study two types of resin cements having the same brand were used; Multilink N which is self-etching resin cement with light-curing option and Multilink Speed which is self adhesive resin cement with light-curing option.

Regarding to the type of ceramic and irrespective of convergence angle or cementation, it was found that Zr CAD group recorded statistically significant (P<0.05) highest marginal gap mean value (111.16 ± 4.79 μm) followed by IPS e.max CAD group (93.6± 7.82μm) while IPS e.max Press group recorded statistically significant (P<0.05) lowest marginal gap mean value (89.31± 5.44 μm). This finding could be attributed to the differences in the heat press versus the CAD/CAM fabrication techniques. Where in the heat press technique, one single layer of die spacer material (20 μm) was applied on the prepared tooth, whereas the luting space and adhesive gap given by default for the CAD/CAM system was 50 μm. [4]

Moreover, software limitations in designing restorations and hardware limitations within scanning equipment and the milling machine are possible short-comings in the CAD/CAM technique. Also, a size discrepancy of the cutting tools and tooth preparation geometry may cause misfit and contribute to inferior marginal properties of the computer milled ceramic restorations. [5]

On the other hand IPS e.max CAD crowns gave better marginal fit than those of Zr CAD. This may be due to sintering shrinkage of zirconia. The CEREC InLab system provided greater balance between the enlarged machining of the presented ceramic block and shrinkage occurring during the sintering process compared with other CAD/CAM systems, thus creating frameworks with an overall improved internal and marginal fit.[6] Regarding to the convergence angle and regardless to ceramic or cementation, it was found that 26° convergence angle subgroup recorded statistically non-significant (P>0.05) higher marginal gap mean value (100.24± 22.49 μm) than 10° convergence angle subgroup (95.81± 9.28 μm). This could be explained by better seating of the crown when the taper of the preparation increased. There are two main factors that may affect the seating of crowns, the existence of hydraulic pressure resisting seating and escape of excess cement. Hydraulic pressure that is developed during cementation process is supposed to be higher if the taper of the preparation is lower. In addition, excess cement discharges better if the taper is higher. So with increased preparation taper, space for cement between side walls of the preparation and restoration increased, reducing stress areas created during cementation, and resulting in better fit of final restorations. Regarding CAD/CAM, the scanning accuracy of abutments could have been enhanced with a large convergence angles that allowed more data to be obtained from the axial walls, resulted in higher quality of data for milling process, and better internal fit. (6)

Regarding to the type of cement and irrespective of ceramic or convergence angle, totally it was found that Multi link Speed (ML Speed) subgroup recorded statistically significant (P<0.05) highest marginal gap mean value (115.22± 22.33μm) followed by Multi link N (ML N) subgroup (96.47± 22.78 μm) while non-cemented subgroup recorded statistically significant (P<0.05) lowest marginal gap mean value (82.38 ± 19.91 μm). The mean marginal fit values of the fabricated restorations increased significantly after cementation. Factors like the viscosity of the luting agent, filler particle size, as well as the preparation design may influence the marginal fit of restorations after their cementation. (7) The better marginal accuracy of the self etch over the self adhesive cement may be due to the better sealing of the multi step cement as it remove the smear layer of dentin and produce resin tags while the self adhesive cement only modifies the smear layer. (8)

Regardless to ceramic or cementation, it was found that 10°convergence angle subgroup recorded statistically significant (P<0.05) higher retention mean value (222.223± 18.62 N) than 26° convergence angle subgroup (126.87± 7.62 N). This coincide with that, the retention of the single-unit crowns and FPDs has been shown to depend on the taper angle; the smaller the taper angle, the higher the retention. (9)

Regardless to ceramic or convergence angle, totally it was found that the self etch adhesive cement group (Multilink N) cement group recorded statistically significant (P<0.05) higher retention mean value (240.14± 17.84 N) than (Multi link speed) cement group (108.96± 12.25 N). This observation can be attributed to the hydrophobic adhesive layer that can reduce permeability of dentinal fluids between dentin and the luting agent. In addition, direct light activation of the adhesive system probably resulted in a better monomer conversion within the hybrid and adhesive layers, resulting in higher bond strengths. (10)

CONCLUSIONS

Within the limitations of the present study, the following conclusions can be drawn:

1- Heat Press fabrication technique resulted in a superior marginal accuracy, and higher retention of crowns as compared to the CAD/CAM technique.

2- The self etch resin cement improved the marginal fit and retention of single unit crowns more than the self adhesive resin cement.

3- Decreasing the degree of convergence from 26° to 10°, improved the retention of the single unit crowns regardless of the type of ceramic.

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