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CLINICAL EVALUATION OF PREFABRICATED CAD/CAM POLYMETHYL METHACRYLATE CROWNS FOR RESTORING PRIMARY ANTERIOR TEETH

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Abstract

Background: Children's anterior teeth restorations present a difficult challenge since they require high standards of strength, longevity, aesthetics, and less restoration microleakage. This study was performed on primary maxillary anterior teeth, comparing prefabricated aesthetically pleasing and cost-effective CAD/CAM Polymethyl Methacrylate crowns (PMMA) and resin composite strips. **Materials and methods**: A total of 60 teeth anterior maxillary were treated in 22 children aged 3-5.5. Group-I included 30 primary anterior teeth covered by PMMA crowns while group-II included 30 primary anterior teeth covered by strip crowns. Crowns were assessed regarding color match crown contour, gingival and plaque indices, restoration failure, and marginal integrity over three, six, and nine months. **Results**: PMMA crowns showed a significantly good color match with adjacent teeth at 6, and 9-month follow-up periods (p=0.0102, and 0.0016, respectively) also, significantly adequate marginal integrity was observed at 6, and 9-month follow-up periods (p=0.0837, 0.0700, respectively). There were losses of 3 lateral incisors and 1 more lateral incisor at 6 and 9 months respectively in the PMMA group. Moreover, less gingival bleeding, and less plaque accumulation at the 6- and 9-month follow-up visits in the PMMA group. **Conclusion:** It was concluded that teeth covered with prefabricated CAD/CAM-PMMA crowns exhibit improved gingival health, marginal integrity, crown shape, color match, and decreased bleeding, plaque accumulation, and material loss over time. CAD/CAM Polymethyl Methacrylate crowns (PMMA) could be used as a cost-effective aesthetic crown restoration for anterior primary teeth.

Keywords: CAD/CAM, Polymethyl Methacrylate, Crowns, Primary Anterior Teeth.

1. INTRODUCTION

Primary teeth are vital for children's growth, keeping space for their successors, assisting with phonation and mastication, and maintaining aesthetic qualities [1]. As a result, there is a greater interest in treating and repairing primary teeth than in extracting them [2]. Primary teeth with significant and multisurface caries lesions, endodontic therapy, and developmental abnormalities should be repaired with full-coverage crowns due to their

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lifespan and greater sealing ability [3]. Stainless steel crowns (SSC) are the most commonly used crowns in pediatric dentistry because of their convenience of use and mechanical characteristics [4]. Whereas SSCs are durable and cost-effective, their silver metal color is unappealing to both children and their parents [5]. Pre-veneered SSCs are a treatment option for improving the aesthetic properties of SSCs. Nevertheless, they possess various limitations that limit their use, such as expensive costs, longer work time, requiring additional preparation, and being unable to bend their edges and create a desired look [6]. Resin composite strip crowns are used to restore primary anterior teeth by combining celluloid crowns and resin composite [7]. Strip crowns were widely considered to be the most aesthetically pleasing alternative for mutilated primary anterior teeth until the introduction of ready-made pediatric zirconia crowns. They are very technique-sensitive, requiring adequate moisture management during bonding and crown configuration [8].

Ready-made zirconia crowns (ZCs) were designed for the primary teeth that offer various advantages, including biocompatibility, aesthetic, longevity, plaque accumulation reduction, gingiva-friendliness, fracture resistance, less antagonist wear, and parental acceptance [9].

Their varied sizes for the primary teeth also give significant ease to the dental practitioner [4]. Nevertheless, ZCs are bulkier, can't be crimped, and need more rigorous tooth preparation, resulting in higher pulp exposure risk. Additionally, their expensive cost restricts their application in clinical practice [10]. Restorations developed by computer-aided design/computer-aided manufacturing (CAD/CAM) technology are increasingly common in clinical practice [1]. It is a cost-effective and accurate method for creating unique and complicated designs [11]. This technology is now accessible immediately in dental clinics, and its software can fabricate full ceramic crowns, inlays, onlays, and veneers for permanent teeth in a single session [12]. Furthermore, they may be utilized for primary teeth restoration and may substitute SSCs, affording greater aesthetics, superior marginal adaptability, and parental approval [13]. There is more demand for a suitable economical aesthetic paediatric crown that can give long-term and high failure resistance therapy. The purpose of this study was to clinically assess esthetic and economical CAD-CAM crowns as a final restoration for primary anterior teeth. The null hypothesis (H0) assumed that there was no difference between CAD-CAM crowns and celluloid crowns as an esthetic restoration in primary anterior teeth.

2. MATERIALS & METHODS

2.1. Study Setting and Ethical Consideration:

A controlled, randomized clinical trial was carried out within the Pediatric Dentistry Department Outpatient Clinic of Tanta University's Faculty of Dentistry. The Helsinki Declaration of 1964 and its subsequently amended versions were complied with by the ethical commission of Tanta University's Faculty of Dentistry, with code #R-PED-8-20-2. Parents signed a documented informed consent form before beginning clinical therapy.

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2.2. Sample Size Calculation

Using the Epi-Info software statistical tool, which was developed in 2002 by the World Health Organization and the Centres for Disease Control and Prevention in Atlanta, Georgia, USA, the sample size and power analysis were determined. Twenty-three teeth in each group, and it was increased to thirty, met the criteria needed to calculate the sample size with a 95% confidence limit and 80% study power.

2.3. Eligibility criteria

Using the study's inclusion and exclusion criteria, a total of sixty-five children with 120 primary anterior teeth between the ages (3 and 5.5) had their anterior primary teeth assessed. The children who met the inclusion criteria were cooperative and apparently healthy, with at least two surfaces of multi-surface caries, anterior primary teeth that had undergone vital pulpal treatment, surface developmental abnormalities, root resorption of less than or equal to one-third, and sufficient coronal structure to support a full-coverage crown. Children who were uncooperative or had systemic ailments were not allowed to participate in this study. Non-vital teeth with an abscess or fistula, mobile primary teeth that could not be restored, and/or significant internal or external pathological root resorption were excluded as well. Also, children who have an oral habit, bruxism, or a deep overbite were not included. Thus, sixty primary molars that were not repairable were taken out, resulting in 60 primary anterior teeth out of 22 children in the final study samples.

2.4. Group assignment and randomization

Sixty primary anterior teeth including primary centrals, laterals, and canines were included in this study. These teeth were divided randomly into two groups according to the types of crowns used:

- **Group-I (Study group)**: 30 primary anterior teeth were crowned with PMMA-based crowns fabricated using CAD/CAM.
- **Group-II (Control group)**: 30 primary anterior teeth were crowned using resin composite strip crowns.

Concealment was used to randomly assign children in each group to receive CAD-CAM PMMA-based crowns or resin composite strip crowns. Version 20.0 of the SPSS program (IBM Corp., Armonk, NY) was used for randomization. By presenting the attending candidate with opaque sealed envelopes numbered consecutively, allocation concealment was ensured. An envelope was opened at the moment the crown was applied, and the child was assigned to the written restorative material within.

2.5. Clinical procedures:

Preoperative radiographs were obtained in order to look for any signs of periapical or pulpal pathology. Following the clinical and radiographic evaluation of the chosen teeth, the following stages should be followed to finish all treatment procedures:

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2.5.1. CAD-CAM PMMA Crowns:

After administering 1.8 ml of 2% mepivacaine-based local anesthetic, rubber dam isolation was carried out. Sterile carbide burs (number 330 round) were used at high speed to remove all carious lesions. If necessary, pulp treatment was administered before glass ionomer cement was used to restore the remaining tooth structure.

The teeth preparation was done using a round-end tapered diamond bur (TF-12, Mani, Germany) for the occlusal surface reduction, leaving a 1.5 mm gap with the opposing tooth. Next, a chamfer finish line was placed circumferentially after the round-end tapered diamond bur was used for the buccal, lingual, mesial, and distal surfaces (0.8 to 1.0 mm). Impression of teeth preparation was done using a polyvinyl siloxane impression material (zhermack elite hd+, VOCOGmbH, Germany) within a stock tray, and for the opposing jaw, an alginate impression (zhermack hydrogum, Germany) was made as well.

Provisional composite material (pro temp 4, 3M ESPE, USA) was used to create a temporary crown that covered the prepared tooth until crown cementation. After the construction of the working cast, a desktop scanner (DOF Freedom HD) was used for digital scanning. Crowns for full coronal restoration were designed using Exocad GmbH software (GmbH, Darmstadt, Germany) to create STL files and fabricate the PMMA crowns.

The imes-icore milling machine was activated and PMMA-blocks (Aidit, Development Zone, Qinhuangdao City, Hebei Province, China) were fixed successively in the spindle of the milling machine and the door was closed then the milling icon was clicked to start the milling process using 2.5 mm, 1mm, and 0.6 mm diamond imes-icore burs to cut the blocks. After a while, the milling process was completed. Then the excess material at the site of connection with blocks and blanks was removed using a slow-speed diamond disk (eve copper disk).

2.5.2. Strip Crowns:

Strip crowns were prepared and altered before treatment appointments. Sharp explorers were used to create escape venting holes in the crowns by puncturing the mesial or distal incisal angles. This created a core vent that allowed excess air bubbles trapped inside the crown to escape with ease. The dentinal tissues were protected by covering the glass ionomer base with resin before the strip crowns were placed and filed. After filling with composite resin, each crown was cured separately to ensure that the proper distance between crowns was maintained when the neighboring strip crowns were mounted on their respective teeth. Peeling the strip crown shell from the lingual side was done with a knife or discoid carver. Occlusion was then examined.

2.6. Clinical evaluation:

An evaluation rating system was devised similar to the US Public Health Service (USPHS) [14] and Kupietzky et al., [15] criteria rating system at 3, 6, and 9-month follow-up periods (Figure-1,2).

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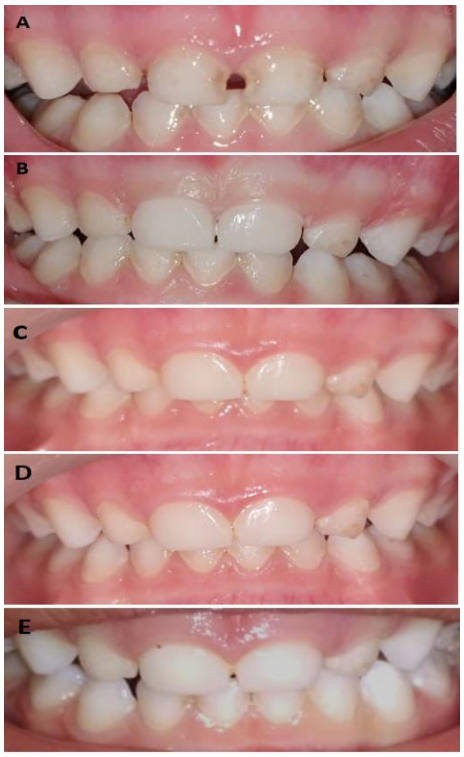

Figure 1: A, Preoperative photo showing bilateral carious upper primary central incisors; B, Post-operative photo after insertion of PMMA crowns; C, three-month follow-up; D, six-month follow-up; E, , Nine-month follow-up

Figure 2: A, Preoperative photo showing bilateral carious upper primary central incisors and canines; B, PMMA crowns were designed for full coronal restoration; C, Post-operative photo after insertion of PMMA crowns

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The definitions and criteria for the rating system are detailed in Table 1. Briefly, the examination included an evaluation of the color, contour, marginal integrity, and restoration failure of the crowns. The health of gingival tissue and plaque index were evaluated by dental probe according to Löe criteria [16].

Table 1: A list of the parameters that were assessed for this investigation

Criteria	Description	Score
Color match	A	Not noticeable difference from adjacent teeth
	B	Slide shade mismatch
	C	Obvious shade mismatch
Crown contour	A	Crown appears cosmetic, nicely contoured, and natural-looking
	B	Crown appears acceptable but could be contoured better
	C	Crown not aesthetics detracts from the appearance of the mouth
	D	Crown not present
Restoration failure	A	The crown appears normal, with no cracks, chips, or fracture
	B	Small but noticeable area of loss of material
	C	Large loss of crown material
	D	Complete loss of the crown
Marginal integrity	A	Close marginal adaptation
	B	No detectable margin
	C	Detectable margin
Gingival Health	0	No gingival bleeding
	1	Bleeding with probe
	2	Spontaneous bleeding
	3	Severe gingivitis- tissue is swollen, spontaneous bleeding
Plaque index	0	No plaque
	1	A film of plaque adhering to the free gingival margin cannot be seen with the naked eye. But only by disclosing solution or by using a probe
	2	Moderate accumulation of deposits within the gingival pocket, on the gingival margin and/ or adjacent tooth surface, seen by the naked eye
	3	Abundance of soft matter within the gingival pocket and/or on the tooth and gingival margin

2.7. Statistical Analysis:

Data were gathered, tabulated, and statistically analyzed with GraphPad Prism 9 Software. The range, mean, and standard deviations of numerical variables were computed. The differences between the observations were tested using Fisher's exact test. variance. The significance level was set at $p<0.05$.

3. RESULTS

3.1. Demographic data distribution

Full coronal restorations were applied to 60 primary maxillary anterior primary teeth including thirty-eight central incisors, fourteen lateral incisors, and eight canines, throughout 22 patients (10 males and 12 females).

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The age ranged from 3 to 5.5 years with a mean value (±SD) of 4 (±0.66) years. In the PMMA group, one patient with two teeth was dropped out at three months. Furthermore, another patient with three teeth was dropped out at 6 and 9 months. While, in the strip crown group, one patient with three teeth was dropped out at 3, 6, and 9 months.

3.2. Clinical Evaluation

Every restoration was assessed using the modified Ryge criteria [14] developed by the US Public Health Service (USPHS), Kupietsky et al., [15] and Löe criteria [16].

Table 2: The demographics of the study participants

Sex (n= 22)	**Male**		**Female**	
	N	%	N	%
	10	45	12	55
	Min	Max	Mean ±SD	
Age (n= 22)	3	5.5	4	±0.66

3.2.1 Color match:

In the PMMA group, there was no discernible difference from neighboring teeth at the three-, six-, and nine-month follow-up. At three, six, and nine months, respectively, the percentage of the strip group with a “slide shade mismatch” was 7.4%, 25.9%, and 33.3%. Furthermore, two strip crowns exhibited “an apparent shade mismatch” at the nine-month follow-up (Table-3).

Table 3: Comparison of color match at different follow-up periods in both groups.

Color match		**3 months**		**6 months**		**9 months**	
		N	**%**	**N**	**%**	**N**	**%**
PMMA crown	A	28	100%	25	100%	25	100%
	B	0	0	0	0	0	0
	C	0	0	0	0	0	0
Strip crown	A	25	92.6%	20	74.1%	16	59.3%
	B	2	7.4 %	7	25.9%	9	33.3%
	C	0	0	0	0	2	7.4 %
P-value		0.2364		0.0102*		0.0016*	
***Statistically Significant (*p*<0.05)**							

3.2.2 Crown contour:

The PMMA crown appeared “cosmetic, nicely contoured, and natural-looking” at three, six-month follow-ups while one crown was not present at the nine-month follow-up. At three, six, and nine months, the percentage of the strip crowns appearing with an “acceptable but could be contoured better” were 7.4%, 22.2%, and 18.5 respectively while two crowns (7.4%) were” not aesthetics detracts from the appearance of the mouth “at the nine-month follow-up (Table-4). There were statistically significant differences between the tested groups at six- and nine-month follow-ups (p=0.0232, p= 0.0272).

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Table 4: Comparison of crown contour at different follow-up periods in both groups

Crown Contour		3 months		6 months		9 months	
		N	%	N	%	N	%
PMMA crown	A	28	100%	25	89.3%	24	96%
	B	0	0	0	0	0	0
	C	0	0	0	0	0	0
	D	0	0	3	10.7%	1	4%
Strip crown	A	25	92.6%	21	77.8%	20	74.1%
	B	2	7.4%	6	22.2 %	5	18.5%
	C	0	0	0	0	2	7.4%
	D	0	0	0	0	0	0
P-value		0.2364		0.0232*		0.0272*	
*Statistically Significant (p<0.05)							

3.2.3 Marginal integrity:

The marginal integrity of the two groups at various follow-up periods is illustrated in Table 5. At 3 months follow-up, there was 100% close marginal adaptation in the PMMA group. While in the strip crown group, only 96.6% showed close marginal adaptation and 7.4 % displayed no detectable margins (p= 0.2364). At six months follow-up, the PMMA group showed close marginal adaptation in 96% of cases. Whereas, in the strip crown group only 74.1% showed close marginal adaptation and 7.4% displayed detectable margin (p=0.0837). At the end of the research, 92% and 66.7% showed close marginal adaptation in PMMA and strip crown groups respectively (p= 0.0700).

Table 5: Comparison of marginal integrity at different follow-up periods in both groups

Marginal integrity		3 months		6 months		9 months	
		N	%	N	%	N	%
PMMA crown	A	28	100%	24	96%	23	92%
	B	0	0	1	4%	2	8%
	C	0	0	0	0	0	0
Strip crown	A	25	92.6%	20	74.1%	18	66.7%
	B	2	7.4 %	5	18.5%	7	25.9%
	C	0	0	2	7.4 %	2	7.4 %
P-value		0.2364		0.0837		0.0700	
*Statistically Significant (p<0.05)							

3.2.4 Restoration failure:

Crown failure at follow-up intervals (Table 6) was clinically assessed by visual examination. No failures were observed in the PMMA group at the three-month follow-up. While Two crowns in the strip crown group displayed a" discernible area of material loss" (p=0.2364). Three primary lateral incisor crowns (10.7%) were completely lost at the 6-month follow-up in PMMA crowns. Only five strip crowns at the 6-month follow-up displayed a" discernible area of material loss", and one crown displayed a "significant loss of crown material" (p= 0.0252). At nine months follow-up, another lateral incisor crown

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(4%) was lost in the PMMA group while in the strip crown group, four crowns (14.8%) showed a “small noticeable loss “and three crowns (11.1%) showed “large material loss” (p=0.0402).

Table 6: Comparison of restoration failure at different follow-up periods in both groups

Restoration failure		3 months		6 months		9 months	
		N	%	N	%	N	%
PMMA crown	A	28	100%	25	89.3%	24	96%
	B	0	0	0	0	0	0
	C	0	0	0	0	0	0
	D	0	0	3	10.7%	1	4%
Strip crown	A	25	92.6%	21	77.8%	20	74.1%
	B	2	7.4 %	5	18.5%	4	14.8%
	C	0	0	1	3.7 %	3	11.1%
	D	0	0	0	0	0	0
P-value		0.2364		0.0252*		0.0402*	
*Statistically Significant (p<0.05)							

3.2.5 Gingival index evaluation

Table 7 shows the gingival index as determined by bleeding with probing. Neither group experienced any bleeding at the 3-month follow-up. In the strip crown group, there were 22.2% and 18.5% of teeth had bleeding on probing at the 6- and 9-month follow-up respectively. In addition, only 8% in the PMMA group had bleeding on probing, and 7.4% in the strip crown group had bleeding on probing and spontaneous bleeding at the 9-follow-up with no statistically significant differences.

Table 7: Comparison of gingival index at different follow-up periods in both groups

Gingival Index		3 months		6 months		9 months	
		N	%	N	%	N	%
PMMA crown	0	28	100%	25	100%	23	92%
	1	0	0	0	0	2	8%
	2	0	0	0	0	0	0
	3	0	0	0	0	0	0
Strip crown	0	27	100%	21	77.8%	20	74.1%
	1	0	0	6	22.2 %	5	18.5%
	2	0	0	0	0	2	7.4%
	3	0	0	0	0	0	0
P-value		NA		0.0232		0.1806	
*Statistically Significant (p<0.05)				NA: not applicable			

3.2.6 Plaque index evaluation

All patients received dental prophylaxis at the start of the trial, and patients and their parents also received information on oral hygiene. Plaque indices at the follow-up visits are displayed in Table 8. There was no plaque buildup in either group throughout the three-month follow-up (p >0.05).

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A film of plaque adhering to the free gingival border was observed on 7.4% of the strip crown group at the 6-month follow-up, but PMMA-covered teeth did not exhibit any plaque accumulation (p=0.490).

At the end of the study, only 4% of teeth with PMMA crowns had a plaque film, whereas 11.1% and 7.4% of teeth had " a film of plaque at the gingival margin and moderate film of plaque around the free gingival edge and neighboring teeth" in the strip crown group, respectively.

Table 8: Comparison of plaque index at different follow-up periods in both groups

Plaque Index		3 months		6 months		9 months	
		N	%	N	%	N	%
PMMA crown	0	28	100%	25	89.3%	24	96%
	1	0	0	0	0	1	4%
	2	0	0	0	0	0	0
	3	0	0	0	0	0	0
Strip crown	0	27	100%	25	92.6%	22	81.5%
	1	0	0	2	7.4 %	3	11.1%
	2	0	0	0	0	2	7.4%
	3	0	0	0	0	0	0
P-value		NA		0.4910		0.2541	
NA: not applicable		*Statistically Significant (p<0.05)					

4. DISCUSSION

Aesthetic restoration of primary maxillary anterior teeth which seriously decayed by caries or trauma remains tricky for pediatric dentists for multiple causes, like missing tooth structure, insufficient bonding of the adhesive to primary teeth, and uncooperative children who require these treatment [17].

Computerized dentistry advancements and novel adhesive materials have helped to propel ultraconservative dentistry forward. It enables the creation of ultra-thin aesthetic crowns that are both aesthetically pleasing and conservative [18]. CAD/CAM technology is a revolutionary method for primary tooth restoration. Unlike readymade zirconia crowns, which need extensive tooth preparation for a passive fit of the crown, CAD/CAM primary crowns may not need extra tooth preparation and may fit well on the prepared tooth [19]. Consequently, when full-coverage restoration is needed for pediatric patients, CAD/CAM primary crowns might be regarded as an aesthetic and conservative option [1].

The current study used PMMA-based crowns created using CAD/CAM technology, which is a novel approach to generating indirect restorations in primary teeth. The clinician can also use the designing program to create optimum occlusal and proximal contact points as well as a superior marginal fit along the gingival wall [12]. Furthermore, it results in a shorter clinical working time, reduced wear on the opposing teeth, and the use of more biocompatible materials [20]. The composite strip crown was selected as a control in this study since it requires little effort to fit and trim, has quick and simple removal,

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effectively matches with natural dentition, offers a smooth shining surface, has excellent shade control with composite, and is superior aesthetically and financially [21].

The present study evaluated clinical performance by a modified USPHS criterion since it is widely used and a well-accepted tool for clinical evaluation [22]. Furthermore, plaque condition was measured using GI and PI indices, which have been verified to be reliable and consistent techniques in a clinical study [23].

To minimize the error, all color match and shade evaluations were completed by a single operator (first author). Concerning color match in the present study, there was no significant difference between the two studied groups at a 3-month follow-up; these results coincided with Ram and Fuks [24] who reported that the color of resin-bonded composite strip crowns remained either good or acceptable with no pitting or discoloration that compromised the aesthetic results in 96% of the central incisors and 98% of the lateral incisors. While there was a statistically significant higher color match in the CAD/CAM group compared to the strip crown group at six- and nine-month follow-up. ($p=0.0102$ and $p=0.0016$, respectively). This agreed with Kupietzky et al. [15], who found that the esthetic components of the color of strip crowns had fewer ideal ratings (74%) than their retention (88%). Also, this was in line with Vaghela et al., [21] who reported that among all the samples of strip crowns, 2 crowns (3.6%) showed “slight shade mismatch” at 3 months, and 15 crowns (29.4%) showed color mismatch at 9 months follow-up. Moreover, the present study results were concurred with Sharma et al. [8] who revealed that in the strip crowns group, 52.9% of crowns found a “slight shade mismatch” and 11.7% of crowns showed obvious shade mismatch at one-year follow-up. This color mismatch may be ascribed to inadequate light curing of resin composite, microleakage owing to chipping or loss of material, or contamination by blood during the treatment, which can influence the shade of the resin composite material.

Regarding the crown contour, there were statistically significant differences between the tested groups at six- and nine-month follow-ups ($p=0.0232$, $p= 0.0272$). Also, two crowns (7.4%) of the strip crown group were” not aesthetics detracts from the appearance of the mouth “at the nine-month follow-up; this agreed with Kupietzky et al. [15] who reported that the crown contour of composite strip crowns had fewer ideal ratings (63%). On the other hand, these study results disagreed with Vaghela et al., [21] who revealed a 100% success rate in crown contour in both composite strip crowns and prefabricated zirconia crowns in primary anterior teeth.

The present study results revealed that there was no statistically significant difference in the marginal integrity in both groups through all follow-up periods with a higher marginal integrity reported in the PMMA-based CAD-CAM group. This may be attributed to superior marginal fit and adaptation achieved by CAD-CAM technology due to accurate milling and software design. This agreed with Al-Halabi et al. [25] who revealed no statistically significant differences between CAD/CAM -PMMA crowns and 3D-printed composite crowns. Also, these study results coincided with Vaghela et al., [21] who revealed a 100% success rate in marginal integrity in composite strip crown and prefabricated zirconia crown in primary anterior teeth.

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Regarding restoration failure, the present study results reported that there was no statistically significant difference between the two studied groups at 3 months of follow-up. However, the CAD/CAM group showed statistically significant better results than the strip crown group in the six and nine-month follow-up. This could be clarified through the fact that the lifetime of the crown is likely to be endangered if a significant portion of tooth structure is lost, as the composite crown depends on dentin and enamel adhesion for retention [26]. This disagreed with Vaghela et al., [21] who reported a 100% success rate in crown retention of composite strip crowns. Additionally, Nor et al. [27] found that the dentine of primary teeth is more reactive to acid than that of the permanent teeth. These authors also discovered reduced bond strength in primary teeth, which they blamed to a thicker hybrid layer that the bonding agent did not entirely penetrate. They suggested employing a shorter etching period for primary dentine to replicate the hybrid layer observed in the etched permanent dentine.

Concerning the gingival health evaluation, in the strip crown group, there were 22.2% and 18.5% of teeth had bleeding on probing at the 6- and 9-month follow-up respectively in addition, only 8% in the PMMA group had bleeding on probing at the 9- follow-up with no statistically significant differences. This agreed with Walia et al., [28] who found that the mean gingival health scores were increased in the strip crown group at the 6-month follow-up compared to pre-veneered stainless steel crowns and pre-fabricated primary zirconia crowns. Also, it was in line with Alaki et al., [29] who reported that at the 3-month follow-up, significantly more teeth in the strip crown group were bleeding compared to the zirconia groups also, at the 6-month follow-up more teeth in the strip crown group were bleeding ($p < 0.001$). Moreover, these study results coincided with Kupietzky et al., [15] who found that 43% of the restored teeth with composite resin strip crowns showed gingival irritations. These findings could be explained as the gingival health of teeth restored with composite strip crowns can be affected by tooth preparation and finishing [30]. Padbury et al., [31] proposed placing the strip crown margin supragingivally to minimize gingival irritation. Despite being clinically logical, this prescription is deemed inapplicable in the majority of cases since it results in poor aesthetics and appearance. On the other hand, the current study results disagreed with Al-Halabi et al., [25] who found that the CAD/CAM fabricated crowns showed more gingival inflammation than 3D-printable crowns in all follow-up periods with a statistically significant difference in the 12th month. In this study, there was no statistically significant difference in the plaque index between both groups at all follow-up periods with two cases of strip crown group reported with moderate accumulation of deposits within the gingival pocket. This may be attributed to the rough surfaces of resin crowns that encourage biofilm development. This agreed with Sharma et al., [8] who found that the plaque accumulation was significantly higher in the strip crowns group.

Furthermore, Eidelman et al. [32] reported that improved results for strip crowns were found in cases done under general anesthesia than those done under sedation also, general anesthesia permits treatment to be provided under theoretically ideal conditions, indicating outcomes that are more successful. Also, Kupietzky et al. [15] and Ram and Fuks [24] reported success rates ranging from 80 to 88%. In addition, Tate et al. [33]

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found a significant failure rate of 51% over two years when strip crowns were fitted under general anesthesia with endodontically treated teeth included.

The limitation of this study was the inclusion criteria of choosing patients with positive behavior, in a few cases children became uncooperative due to prolonged procedures. Also, PMMA-based CAD-CAM crowns need other means of retention for longer periods, especially in small retentive areas in lateral incisors. Longer follow-up studies on PMMA-based CAD-CAM crowns are recommended with the inclusion of more evaluation parameters such as patients' satisfaction.

5. CONCLUSION

Based on the present study findings, teeth with CAD/CAM-PMMA crowns exhibited improved color match, crown shape, gingival health, marginal integrity, and decreased bleeding and plaque build-up and material loss over time. It may be applied to anterior primary teeth as an affordable cosmetic crown restoration.

Declarations

Ethical approval and consent to participate

Ethical Approval for this study was obtained from the ethical committee, Faculty of Dentistry, Tanta University; code (#R-PED-8-20-2) complying with the Helsinki Declaration of 1964 and its subsequent amendments. The study purpose was explained to the Patients' parents and informed written consent was acquired from parents at the extraction time.

Consent for publication: Not applicable

Availability of Data and Materials

On reasonable request, the datasets utilized and/or analyzed during the present study are accessible from the corresponding author.

Competing interests

The authors declared no conflict of interest relevant to this article.

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