Marginal Integrity of Composite Restoration with and without Surface Pretreatment by Gold and Silver Nanoparticles vs Chlorhexidine: A Randomized Controlled Trial

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ABSTRACT

Aim: This study was conducted to evaluate the marginal adaptation, marginal staining, and postoperative sensitivity of resin composite restorations after disinfection of class II cavities with NanoCare Gold and chlorhexidine in class II cavities immediately, after 6 months, 1, and 2 years using World Dental Federation (FDI) criteria for assessment of dental restorations.

Materials and methods: In this study, 19 participants were recruited, 3 carious lesions in each one. After preparation of these lesions, they were randomly allocated into three parallel groups according to the disinfection protocol. The first group was for NanoCare Gold, the second was for chlorhexidine, and the third was for the control. The three groups were evaluated clinically and radiographically using (FDI) criteria at different intervals till 2 years of clinical service.

Results: There was no statistically significant difference in age, gender, arch, and tooth type distribution among study groups. Regarding marginal adaptation, there was no statistically significant difference among the different groups but the difference was only statistically significant within each group after 2 years. Regarding the marginal staining, the difference was only significant between the NanoCare and the other groups after 2 years. In case of postoperative sensitivity, there was no statistically significant difference among the different groups and within each one at different intervals.

Conclusion: NanoCare Gold could be promising in durability preservation of direct tooth-colored restorations. Marginal staining and postoperative sensitivity are regulated by other factors than surface pretreatment.

Clinical significance: As long as restorations are inserted under rubber dam isolation, proper application steps, proper filling, and adequate finishing and polishing, the performance of the restorations would be satisfactory up to 1 year without any surface disinfection. However, after a longer follow-up, some changes may be noticed. NanoCare Gold and chlorhexidine are accepted as a cavity disinfectant without any negative effect on marginal adaptation of resin composite restorations.

Keywords: Chlorhexidine, Marginal adaptation, Marginal staining, NanoCare Gold, Postoperative sensitivity.

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INTRODUCTION

Histological nature of dentin is really challenging in bonding but interesting in attempts for preservation of durability. Achieving a hermetic seal between the interface of bonding surfaces is considered critical. Usually, a minute gap is present between these surfaces. This permits the ingress of bacteria and oral fluids, leading to caries recurrence and restoration failure and, hence, emphasizing the importance of hybrid layer and its quality.¹ Hybrid layer is formed by the interaction of dentin substrate and adhesive system. These elements are the determining factors for quality and durability of this bond.²

Matrix metalloproteinases (MMPs) and cysteine cathepsins are the criminals in the destruction of the collagenous part of dentin involved in the hybrid layer. These enzymes are activated naturally during caries process and artificially during restorative procedures by the acidic monomer in adhesive systems. The prohibition of these active enzymes may help in the creation of a durable bond.^{3,4}

Several materials are classified as inhibitors for collagenolytic enzymes in addition to their antibacterial effect. Chlorhexidine is considered the gold standard in this category. This is due to its ability to target not only MMPs but also cysteine cathepsins in addition to its antibacterial properties. Despite all of these advantages, its effect

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on the previous enzymes is a short-term one.⁵ Hence, new materials are needed to cover the shortage of the older one.

Nowadays metallic nanoparticles like nanosilver (AgNPs) and nanogold (AuNPs) are gaining popularity in medical and dental fields.⁶ NanoCare Gold, a cavity disinfectant containing

nanoparticles of Ag-Au suspended in isopropyl alcohol has been introduced into the market. The manufacturer claims that this disinfectant enhances the adhesion of resin composite to tooth structure and empowers the physical properties of the polymer in addition to the proven antibacterial properties.⁷

Considering conservatism principles, retention of posterior composite restorations depends mainly on the quality of adhesion and cavity configuration. Sometimes, restorations in class I or II cavities would not fall off their restored surfaces even in compromised adhesion. Because of that, the quality of adhesion in such cases is indirectly evaluated by parameters like marginal adaptation and marginal discoloration using FDI criteria.^{8–10}

Reviewing the literature, NanoCare Gold has no negative effect on bond strength of resin composite to dentin but there are no published clinical trials confirming these results yet.⁴ Therefore, this study was performed to investigate its effect clinically on the marginal adaptation, marginal staining, and postoperative sensitivity of resin composite restorations in class II cavities. Restorations were evaluated immediately, after 6 months, 1, and 2 years using FDI criteria for assessment of dental restorations. The null hypothesis tested is that there is no difference among the NanoCare Gold, chlorhexidine, and the standard of care, regarding marginal adaptation, marginal staining, and postoperative sensitivity.

MATERIALS AND METHODS

Sample Size Calculation

This power analysis used marginal adaptation score as the primary outcome. The effect sizes were $w_1 = 0.8885$ and $w_2 = 0.8498$.¹¹ Using alpha (α) level of 5% and beta (β) level of 20% i.e., power = 80%, the minimum estimated sample size was 15 subjects per group for a total of 45 subjects. The sample size was increased to 19 subjects per group (a total of 57 teeth) to compensate for a dropout rate of 25%. Sample size calculation was performed using G*Power version 3.1.9.2.

Protocol Registration

The protocol of the current study was registered in www.clinicaltrials.gov, with unique identification number NCT03669224. All procedures performed involving human participants were in accordance with the ethical standards of Research Ethics Committee of Faculty of Dentistry, Cairo University (CREC) # 42-9-18.

Study Design

The study design included three parallel groups with 1:1 allocation ratio. The groups were divided according to the application of a cavity disinfectant or not. The first group was for NanoCare Gold, the second for chlorhexidine, and the third for the standard of care, which receives no surface pretreatment. Nineteen teeth were used in each group and the total number for all groups was 57 teeth. The restorations were evaluated regarding marginal adaptation, marginal staining, and postoperative sensitivity at different intervals, immediate evaluation, after 6 months, 1, and 2 years.

Eligibility Criteria for Patients

Inclusion Criteria

Participants eligible for the trial should have at least two class II cavities, good oral hygiene, and good general health. Cooperative participants of both genders were included as long as they accepted to sign the informed consent. Age frame lies between 17 and 50 years old.

Exclusion Criteria

Participants younger than 17 or older than 50 years old were excluded. Pregnant females, heavy smokers, participants with disabilities, or severe medical complications were also excluded.

Eligibility Criteria for Teeth

Inclusion Criteria

Any vital posterior tooth with no signs or symptoms of irreversible pulpitis or periapical pathosis was included. Functioning class II carious lesions with healthy periodontium was a must.

Exclusion Criteria of Teeth

Teeth with signs of pulpal, periapical pathosis, or endodontically treated were excluded. Nonfunctioning carious lesions other than class II, in heavy occlusion patients, and severe periodontal affection were also excluded.

Recruitment

Eligible participants were recruited from outpatient clinic of conservative dentistry department in Faculty of Dentistry, Cairo University. Signing the informed consent was mandatory.

At the same day of recruitment, radiographs, cavity preparation, cavity disinfection, restoration's insertion, immediate evaluation of marginal adaptation, marginal staining, and postoperative sensitivity were performed. Then each patient was recalled after 6, 12, and 24 months to evaluate the same aspects that were evaluated immediately.

Radiography

Teeth were radiographed digitally using Digora imaging software (100–240 VAC, 50/60 Hz operating voltage, 17 lp/mm resolution, 5–10 seconds readout time). Bitewing, parallel technique was followed using DIGORA intraoral imaging plate size 2 (SOREDEX, Finland) for the sake of standardization. Each tooth has preoperative (Fig. 1), immediate postoperative, and follow-up radiographs (6, 12, and 24 months).

Randomization

Simple randomization was performed for the prepared cavities to determine which tooth receives which intervention. Two different

Fig. 1: Bitewing radiograph showing carious teeth (tooth of interest: tooth no 5, 6, upper right side)

groups of colored papers were used. The first group contains the prepared tooth identification (e.g., lower right 6). The second group contained the applied materials (e.g., NanoCare Gold). One paper was selected haphazardly from the first group followed by another selection from the second one. This was performed by a blinded person not involved in the trial. The patients and assessors were blinded to the material assignment while the operator was not due to the difference in materials' presentation.¹²

Cavity Preparation

All cavities and restorations were performed by the same operator. Assessment of centric and eccentric occlusal stops was performed with double-sided articulating paper prior to class II cavity preparation.

Cavities were of varying depth (3 mm, 4, >4).^{13,14} An extension for prevention was disregarded for maximum preservation of tooth structure; margins were not beveled.¹ The cavities were prepared by 245 and 330 high speed burs under copious air and water coolant. Cavities walls were finished by yellow coded stones (ISO 198/018, TR-13EF). Any soft caries excavation in dentin was performed by sharp excavator (Maillefer, size 50/52, Dentsply) and the hard spots by a low speed round carbide bur of suitable size, compatible to the size of the carious spot (size 4, 5, or 6). Gingival marginal trimmer (GMT, Zefiro) was also used for any needed adjustments at the gingival seat. After completion of cavity preparation, quadrant rubber dam isolation was done (Fig. 2). All steps were documented by photographs (Nikon D5300, Nikon Macro-Lens 105).

Materials' Application

Scotchbond Universal Etchant (3M ESPE, USA) was applied to the enamel surface only for 15 seconds then rinsed with water for 15 seconds. Excess water was dried leaving the enamel surface chalky white. A small piece of wet cotton was applied over dentin to protect it from the etchant.

Five coats of NanoCare Gold (Dental Nanotechnology, Poland) were applied to dentin surface using micro brush directly after enamel etching. The bottle was shaken every time before use. The coats were left for 3 minutes for the natural evaporation of the solvent (Fig. 3).¹⁵

Consepsis (CHX, Ultradent, USA) was applied immediately after enamel etching for 1 minute then the excess was removed with cotton pellet (no rinsing) (Fig. 4).

Single Bond Universal Adhesive (3M ESPE, USA) was applied for 20 seconds with vigorous agitation followed by gentle air thinning for 5 seconds then light cured with LED light curing unit (CO2-C, Premium Plus International, Hong Kong) of intensity 1200 mW/cm² at zero distance for 10 seconds. The light intensity was regularly checked using a radiometer.

Filtek™ Z350 XT packable resin composite (body shade A2, 3M ESPE, USA) was applied after matricing and wedging (Garrison, Composi-Tight 3D Fusion, USA) using centripetal technique. The rest of the cavity was filled by incremental oblique layers using plastic instrument (Elephant, Germany).

Each increment was polymerized for 20 seconds. After polymerization of the last layer, rechecking of tooth restoration interface was done by dental explorer and any visible overhang was removed with a scaler before removal of rubber dam.¹ The occlusion was checked after restoration placement with double-

Fig. 3: NanoCare Gold inserted inside the cavity (tooth of interest: tooth no 5, mesial side)

Fig. 2: Isolated prepared cavities with matricing and wedging (tooth of interest: tooth no 5, 6)

Fig. 4: Application of Consepsis inside the cavity (tooth of interest: tooth no 5, distal side)

sided articulating paper. The proximal contact was checked using dental floss. The restorations were finished with white tapered abrasive bur and polished immediately by opti-brush (HiLuster PLUS™, Kerr) after removal of rubber dam.

Restorations' Evaluation

Two experienced and calibrated assessors performed the evaluation. For training purpose, the examiners observed 10 photographs that were representative of each score for each criterion using a web-based training and calibration tool called e-calib.¹⁶ An intra-examiner and inter-examiner agreement of at least 85% was necessary before beginning the evaluation. Both examiners evaluated all the restorations once and independently. When disagreements happened during the evaluations, they had to reach a consensus before the participant was dismissed.^{12,17}

The restorations were evaluated by FDI criteria at baseline (Fig. 5), 6 months, 1, and 2 years (Fig. 6) of clinical service. The primary clinical endpoint was marginal adaptation; the secondary endpoints were marginal staining and postoperative sensitivity.

To classify the marginal gaps, two special probes (Deppeler, Switzerland) were used with tip diameters of 150 and 250 μm . The depth of the gap should be at least the same size (0.25 mm), in addition to usage of digital radiograph to measure the hidden gap.

The status of the restoration fitted in one of the five categories in FDI scoring system for evaluation of marginal adaptation.⁸

Regarding marginal staining, the evaluation method was visual inspection and photographs which is reflected in FDI categorical scoring system that is divided into five categories.

Evaluation of the postoperative sensitivity was performed one week after the restorative procedure by applying a blast of cold air for 10 seconds from a dental triple airway syringe placed 2 cm from the occlusal surface of the tooth, and the patient was asked if there was sensitivity caused by the air jet or postoperative pain at some other time prior to the evaluation.^{12,18} Evaluation was reflected into FDI categorical scoring system.⁸

Statistical Analysis

Statistical analysis was performed using IBM SPSS Statistics Version 26 for Windows. Data were presented as frequencies (n) and percentages (%) for qualitative data; and mean and standard deviation (SD) for quantitative data. Kolmogorov-Smirnov and Shapiro-Wilk tests were used to assess data normality. For demographic data, the Chi-square test was used for intergroup comparisons of qualitative data, and independent Student t -test was used for quantitative data. Kruskal-Wallis was conducted to compare distribution of FDI scores between different surface

Figs 5A and B: (A) Intraoral photograph of (tooth of interest: tooth no 5 mesial and distal side, tooth no 6, mesial side) after insertion of restorations; (B) Bitewing radiograph (tooth of interest: tooth no 5 mesial and distal side, tooth no 6, mesial side) after insertion of restorations

Figs 6A and B: (A): Intraoral photograph of (tooth of interest: tooth no 5 mesial and distal side, tooth no 6, mesial side) on 2 years follow-up; (B) Bitewing radiograph (tooth of interest: tooth no 5 mesial and distal side, tooth no 6, mesial side) on 2 years follow-up

pretreatments at each interval. Friedman test was performed to compare FDI scores among different intervals within each group. Multiple comparisons were performed using Steel-Dwass test. The significance level was set at $p \leq 0.05$.

RESULTS

This clinical trial is formed of three groups. Nineteen teeth were employed for each group. These groups were evaluated using FDI criteria regarding marginal adaptation, marginal staining, and postoperative sensitivity. Evaluation was performed immediately, after 6 months, 1, and 2 years.

Demographic Data

Mean, standard deviation (SD), frequencies (n), percentages (%), and p -value for demographic data were presented in Table 1. The mean age of the 19 participants was 29.9 ± 7.4 years old. Seven were males (36.8%) and 12 were females (63.2%). Twenty-seven maxillary (47.4%) and 30 mandibular (52.6%) teeth were restored. Thirty-one restorations (54.4%) were placed in premolars and 26 (45.6%) were placed in molars. There was no statistically significant difference in age, gender, arch, and tooth type distribution among study groups ($p = 0.896$, $p = 1.000$, $p = 0.399$, and $p = 0.612$, respectively).

Marginal Adaptation Using FDI Scoring System

All restorations in all groups scored 1 till the first year as presented in Table 2. There was no statistically significant difference in distribution of FDI scores among different groups ($p = 1.000$ for immediately, 6 months and 12 months, and $p = 0.188$). On the contrary, there was a statistically significant difference in distribution of FDI scores among different intervals within each group ($p < 0.001$ within control group, $p = 0.007$ within NanoCare Gold group, and $p < 0.001$ within chlorhexidine group). After 24 months, all groups showed higher score of 2%.

Marginal Staining Using FDI Scoring System

There was no statistically significant difference among the different groups and within each group till 1 year as presented in Table 3. After 2 years, there was a statistically significant difference among the different groups. The NanoCare group showed no marginal stains after 2 years. The other groups showed a statistically significant difference with their own previous scores and with NanoCare Gold group.

Postoperative Hypersensitivity Using FDI Scoring System

There was no statistically significant difference among the different groups and within the same group at different intervals as presented in Table 4.

DISCUSSION

Although adhesive restorations show acceptable survival rates, huge amount of time and money are wasted on replacement of failed restorations. The failure rate ranges from 15 to 50%. The most common reasons for failure are fracture, secondary caries, marginal deficiencies, wear, and postoperative sensitivity, while fracture is assumed to occur early, secondary caries occurs later within the function period of the restoration.¹⁹

It has been reported that bonding strength to dentin decreases 30–40% after 6 months and 60–70% after 1 year.²⁰ Degradation of the hybrid layer could be broadly divided into two major categories: hydrolytic degradation of the collagen matrix and hydrolytic degradation of the adhesive within the hybrid layer (the resinous part in the form of plasticization).^{21,22}

In this study, the used universal adhesive represents a type of self-etching (SE) adhesives. The durability and stability of bonded interfaces created by this adhesive continue to be questionable. One of the advantages of using the universal adhesive in the clinical routine would be allowing the clinician to choose the type of application protocol according to the clinical situation, optimizing the final result of the procedure.¹⁸

Using multimode adhesive in self-etch mode, in both noncarious and carious lesions, led to marginal discoloration or degradation of marginal adaptation in 18–24-month clinical follow-up.²³ Selective enamel etch followed by the application of a mild universal adhesive appears to be the best choice to effectively achieve a durable bond to tooth tissues in the form of better esthetic, functional sealing and reduced marginal discoloration and improved adaptation. The problem that we may face with this technique is that the clinician may unintentionally etch the dentin. In this condition, bond strength may decrease when self-etch adhesives are applied on acid-etched dentin when compared with the same adhesive applied in the self-etch mode.^{17,18,24}

The remaining bacteria are one of the contributing factors in caries recurrence that's why the prohibition of these bacteria is mandatory. It has been proven that the remaining bacteria may survive and multiply up to 139 days after insertion of restoration

Table 1: Mean $\pm$ SD, frequencies (n), percentages (%), and p -value for demographic data

Demographic data	Total (N = 57)	Control (N = 19)	NanoCare Gold (N = 19)	Chlorhexidine (N = 19)	p value
Age (years)	29.9 ± 7.4	29.9 ± 7.4	29.9 ± 7.4	29.9 ± 7.4	1.000 NS
Gender					
Male	21 (36.8%)	7 (36.8%)	7 (36.8%)	7 (36.8%)	1.000 NS
Female	36 (63.2%)	12 (63.2%)	12 (63.2%)	12 (63.2%)	
Arch					
Maxilla	27 (47.4%)	10 (52.6%)	9 (47.4%)	8 (42.1%)	0.399 NS
Mandible	30 (52.6%)	9 (47.4%)	10 (52.6%)	11 (57.9%)	
Tooth type					
Premolar	31 (54.4%)	11 (57.9%)	12 (63.2%)	8 (42.1%)	0.612 NS
Molar	26 (45.6%)	8 (42.1%)	7 (36.8%)	11 (57.9%)	

NS, nonsignificant at $p > 0.05$

Table 2: Frequency (n/%) of FDI scores for marginal adaptation

	Control		Nano		ChX		
Adaptation	n	%	n	%	n	%	p value
Imm (n = 19)							
Score 1	19	100.0%	19	100.0%	19	100.0%	1.00 NS
Score 2	0	0.0%	0	0.0%	0	0.0%	
Score 3	0	0.0%	0	0.0%	0	0.0%	
Score 4	0	0.0%	0	0.0%	0	0.0%	
Score 5	0	0.0%	0	0.0%	0	0.0%	
Rank	aA		aA		aA		
6M (n = 17)							
Score 1	17	100.0%	17	100.0%	17	100.0%	1.00 NS
Score 2	0	0.0%	0	0.0%	0	0.0%	
Score 3	0	0.0%	0	0.0%	0	0.0%	
Score 4	0	0.0%	0	0.0%	0	0.0%	
Score 5	0	0.0%	0	0.0%	0	0.0%	
Rank	aA		aA		aA		
12M (n = 15)							
Score 1	15	100.0%	15	100.0%	15	100.0%	1.00 NS
Score 2	0	0.0%	0	0.0%	0	0.0%	
Score 3	0	0.0%	0	0.0%	0	0.0%	
Score 4	0	0.0%	0	0.0%	0	0.0%	
Score 5	0	0.0%	0	0.0%	0	0.0%	
Rank	aA		aA		aA		
24M (n = 15)							
Score 1	8	53.3%	11	73.3%	6	40.0%	0.188 NS
Score 2	7	46.7%	4	26.7%	9	60.0%	
Score 3	0	0.0%	0	0.0%	0	0.0%	
Score 4	0	0.0%	0	0.0%	0	0.0%	
Score 5	0	0.0%	0	0.0%	0	0.0%	
Rank	bA		bA		bA		
p value	<0.001*		0.007*		<0.001*		

*Significant; NS, nonsignificant. Different uppercase letters within each row indicate significant difference. While different lowercase letters indicate significant difference within each column

Table 3: Frequency (n/%) of FDI scores for marginal staining

	Control		Nano		ChX		
Staining	n	%	n	%	n	%	p value
Imm (n = 19)							
Score 1	19	100.0%	19	100.0%	19	100.0%	1.00 NS
Score 2	0	0.0%	0	0.0%	0	0.0%	
Score 3	0	0.0%	0	0.0%	0	0.0%	
Score 4	0	0.0%	0	0.0%	0	0.0%	
Score 5	0	0.0%	0	0.0%	0	0.0%	
Rank	aA		aA		aA		
6M (n = 17)							
Score 1	15	88.2%	13	76.5%	13	76.5%	0.614 NS
Score 2	2	11.8%	4	23.5%	4	23.5%	
Score 3	0	0.0%	0	0.0%	0	0.0%	
Score 4	0	0.0%	0	0.0%	0	0.0%	
Score 5	0	0.0%	0	0.0%	0	0.0%	
Rank	aA		aA		aA		

12M (<i>n</i> = 15)							
Score 1	11	73.3%	12	80.0%	11	73.3%	0.889 NS
Score 2	4	26.7%	3	20.0%	4	26.7%	
Score 3	0	0.0%	0	0.0%	0	0.0%	
Score 4	0	0.0%	0	0.0%	0	0.0%	
Score 5	0	0.0%	0	0.0%	0	0.0%	
Rank	aA		aA		aA		
24M (<i>n</i> = 15)							
Score 1	9	60.0%	15	100.0%	9	60.0%	0.018*
Score 2	6	40.0%	0	0.0%	6	40.0%	
Score 3	0	0.0%	0	0.0%	0	0.0%	
Score 4	0	0.0%	0	0.0%	0	0.0%	
Score 5	0	0.0%	0	0.0%	0	0.0%	
Rank	aB		aA		aB		
<i>p</i> value	0.058 NS		0.063 NS		0.112 NS		

*Significant; NS, nonsignificant. Different uppercase letters within each row indicate significant difference. While different lowercase letters indicate significant difference within each column ($p > 0.05$)

Table 4: Frequency (*n*/%) of FDI scores for postoperative sensitivity

	Control		Nano		ChX		
Sensitivity	<i>n</i>	%	<i>n</i>	%	<i>n</i>	%	<i>p</i> value
Imm (<i>n</i> = 19)							
Score 1	13	68.4%	13	68.4%	13	68.4%	1.00 NS
Score 2	6	31.6%	6	31.6%	6	31.6%	
Score 3	0	0.0%	0	0.0%	0	0.0%	
Score 4	0	0.0%	0	0.0%	0	0.0%	
Score 5	0	0.0%	0	0.0%	0	0.0%	
Rank	aA		aA		aA		
6M (<i>n</i> = 17)							
Score 1	13	76.5%	13	76.5%	15	88.2%	0.614 NS
Score 2	4	23.5%	4	23.5%	2	11.8%	
Score 3	0	0.0%	0	0.0%	0	0.0%	
Score 4	0	0.0%	0	0.0%	0	0.0%	
Score 5	0	0.0%	0	0.0%	0	0.0%	
Rank	aA		aA		aA		
12M (<i>n</i> = 15)							
Score 1	13	86.7%	12	80.0%	12	80.0%	0.862 NS
Score 2	2	13.3%	3	20.0%	3	20.0%	
Score 3	0	0.0%	0	0.0%	0	0.0%	
Score 4	0	0.0%	0	0.0%	0	0.0%	
Score 5	0	0.0%	0	0.0%	0	0.0%	
Rank	aA		aA		aA		
24M (<i>n</i> = 15)							
Score 1	15	100.0%	15	100.0%	15	100.0%	1.00 NS
Score 2	0	0.0%	0	0.0%	0	0.0%	
Score 3	0	0.0%	0	0.0%	0	0.0%	
Score 4	0	0.0%	0	0.0%	0	0.0%	
Score 5	0	0.0%	0	0.0%	0	0.0%	
Rank	aA		aA		aA		
<i>p</i> value	0.070 NS		0.096 NS		0.078 NS		

NS, nonsignificant at $p > 0.05$

while others reported that bacteria left in the prepared cavities could survive for longer than a year especially in the presence of microleakage.^{25–27} Sadly, not all of the dental materials possess antibacterial properties. Therefore, the concept of toileting of the cavity is gaining wider acceptance with a variety of commercially available dentin disinfectants available in the market.⁷

The two main mechanisms for gaining the benefits of any antibacterial agents in conservative dentistry are either their incorporation in the dental materials or their usage as a separate entity. Their incorporation inside the materials may negatively affect the polymerization process, color, and mechanical properties. Therefore, in this study, the cavity disinfectants (antimicrobial agents) were used as a separate step before the application of the adhesive system.⁵ The use of cavity disinfectants with composite resin restorations appears to be material specific regarding their interactions with various dentin bonding systems.²⁸

Deterioration of the marginal adaptation of the restorations with the use of 10-methacryloyloxydecyl dihydrogen phosphate (MDP) universal adhesive was observed after 6 and 18 months of clinical evaluation, both for the adhesive protocol with etch-and-rinse (ER) and SE application modes.¹⁸ Marginal adaptation failure can lead to the occurrence of secondary caries, so it is an important factor in prediction of restorations' durability.¹⁶

In this study, the results of marginal adaptation in different groups at different evaluation intervals showed no statistically significant difference among all groups. The same results applied to other criteria (marginal staining and postoperative sensitivity). This means that after 1 year of clinical service, usage of the two surface pretreatment (NanoCare Gold and chlorhexidine) did not produce an obvious difference.

Regarding NanoCare Gold and its ingredients, its application is supported for many reasons: the antibacterial properties without any risk of bacterial resistance and^{29,30} absence of any interference with bond strength,^{31–33} improving the wetting of the adhesive system.³⁴ AgNPs enhance the physical properties of some dental materials.^{35,36}

The discoloration produced by AgNPs is minute compared to silver nitrate and silver diamine.³⁷ AuNPs inhibit MMP 1, 2, 8, and 9.^{38–41} AuNPs have a weak or no antimicrobial effect against many species but their mixtures with other antimicrobial agents enhance the bactericidal properties of these agents.²⁹

Borczyk and Pietranek found that the application of NanoCare Gold before placement of resin composite results in the formation of a layer of silver and gold NPs in the interface between the tooth cavity and the restoration.⁴² Their presence in this area resists the development of bacteria in the microgaps and consequently reduces the risk of caries recurrence. They also mentioned that isopropyl alcohol reduces the surface tension to reach the smallest dentinal tubule and dry the cavity in addition to its antiseptic properties.

According to Porenczuk et al. and Ramasetty et al., the application of NanoCare Gold did not affect the bond strength to dentin, but the mode of failure changed after its application. This change varies according to the sequence of application of materials (either before or after cavity priming). When applied after primer, the mode of failure is either mixed or adhesive with the same frequency while when applied before priming step, adhesive failure is reduced by 34%.^{4,15}

NanoCare Gold enlarges the bonding area for the adhesive system; this may be due to the formation of a homogenous layer of NPs on the surface after alcohol evaporation.¹⁵ Alcohols can act

as MMPs inhibitors especially MMP-9 and endogenous proteases of dentin matrix in a dose-dependent manner. High alcohol concentrations may denature enzymes by removing water from the enzyme structure, causing their denaturation.^{19,43}

Durner et al. and Sokołowski et al. are against the AgNPs as it could affect the polymerization process in dental materials and deterioration of resin–filler interactions so the materials are more susceptible to leaching of components and grayish discoloration of the materials.^{29,44}

Chlorohexidine is considered the gold standard in cavity disinfection due to its antimicrobial properties and inhibition of MMPs.^{22,45,46} In an *ex vivo* study by Carrilho et al., after 14 months *in vivo*, cohesive failure within the hybrid layer was more frequently observed in untreated samples compared to that treated with 2% chlorhexidine.⁴⁷ Soares et al., Sartori et al., and Jowkar et al. are supportive to the positive effect of its application and mentioned that its application in deep carious cavities increases the clinical success of direct and indirect pulp capping procedures.^{5,48,49}

In addition to the ability of chlorohexidine to produce partial removal of smear layer (removes the loose smear debris), it provides slight opening of dentinal tubules orifices. This may enhance the penetration of the acidic monomers of the self-etch adhesive. This also converts the smear layer from loosely to firmly bonded layer that minimizes convective and evaporative water fluxes from the underlying dentin, which enhances the bonding capacity of the adhesive.⁵⁰ Its application increases the surface energy of dentin, which increases the dentin-wetting ability of the adhesive and provides better chance for chemical interaction.²⁶

Chlorohexidine can increase the bond durability of mild universal adhesives.³ One of the important points is the effect of chlorohexidine on the degree of conversion of the adhesive systems; it was reported that chlorohexidine at concentrations ranging from 0.5 to 2% did not affect the degree of conversion of resinous monomers in adhesive systems.⁴⁶

Although clinical trials remain the ultimate tool, preclinical evaluation of materials is still important. However, it is not fully understood whether there is a relationship between laboratory data and clinical outcomes but nearly there is a consensus that dentin pretreatment with chlorohexidine showed a higher bond strength values in aged samples compared to untreated dentin.⁵¹ Both self-etch and etch-and-rinse systems showed to be benefited by the chlorohexidine *in vitro*.²² The controversial results among studies may be due to the different dentin adhesive systems used (different types of self-etch and total-etch adhesives) and these adhesives may be acetone-based or ethanol-based.⁵²

Singla et al. are against the disinfection of cavities with chlorohexidine and justify this by the nature of the layer formed on dentin surface after application of cavity disinfectant that was resistant to acidic conditioning and might inhibit the ability of the weak acidic primer to effectively demineralize dentin and hydrophilic resin to impregnate the dentinal surface and decreases dentin wettability.⁵³ Chlorhexidine usage with self-etch adhesive causes a more pronounced nano leakage.⁵⁰

Chlorohexidine is washed away from the hybrid layer during 1–2 years, resulting in collagen degradation. The adverse effect of 2% chlorohexidine on bond strength of self-etch adhesives may be due to the presence of functional monomer (MDP), which is not compatible with chlorohexidine.²⁰

According to Göstemeyer and Schwendicke, the clinical data in usage of chlorohexidine do not convincingly support the idea

of surface pretreatment for the sake of reduction of retention loss or restoration failure. This is due to the effect of attrition in some studies, great uncertainty of their effect (benefits, harm), so far the longest follow-up was 36 months, presence of confounders in the available clinical trials such as type of substrate (caries, noncaries), type of dentition (deciduous, permanent), moisture control tools (rubber dam, cotton roll), type of adhesive system (etch and rinse, self-etch), concentration of chlorhexidine, and cavity size. Another issue is the quality of evidence due to the absence of blindness (operator, patient, and examiner), allocation concealment, limited sample size, short follow-up period, attrition rate, safety aspect (pulpal status), clinical applicability, and cost-effectiveness of the additional treatment step.⁵⁴

Montagner et al. tested chlorhexidine clinically in the adhesive step and did not present any benefit of its use.^{11,22} Favetti et al. tested the effect of chlorhexidine on restoration retention (noncaries cervical lesions, 3 years trial, etch and rinse, 60 seconds, FDI criteria).² They found that chlorhexidine did not promote further retention or any beneficial effect to the clinical performance of restorations in this condition. In another clinical trial, 2% chlorhexidine solution was used before acid etching in the ER and SE and before the application of the adhesive in the SE group.¹⁸ According to Sartori et al., after 3 years of follow-up, chlorhexidine application to acid-etched dentin does not improve the clinical durability of noncaries cervical lesions.⁴⁹ Moraes et al. in a 2 years clinical trial found that the addition of chlorhexidine into adhesive systems or its use as dentin pretreatment did not add clinical advantages and did not improve the clinical durability of adhesive restorations.⁴³

The effect of dentin pretreatment with AgNPs on the bond strength was comparable to that of chlorhexidine for the etch-and-rinse adhesive system and better than that of chlorhexidine for the self-etch adhesive system. This was referred to the hydrophilic nature of AgNPs which increases the surface tension of the dentin surface and improves the inadequate penetration of the adhesive system through dentin, in addition to the capability of silver to form compounds with oxide, phosphate, chloride, and proteins with a relatively low solubility inside dentinal tubules. This may lead to a gradual and long-lasting release of small amounts of silver ions, providing long-term antibacterial efficacy at the adhesive-tooth interface.⁵

Torres et al. reported that postoperative sensitivity may be affected by factors like polymerization shrinkage and failures in the polymerization of the deep portions of the resinous layers. Sensitivity to cold commonly occurs during mastication and the first week after insertion of the restoration.¹⁶

Regarding the results of demographic data in this study, there was no significant difference in age, gender, arch, and tooth type distribution among study groups. These results are in agreement with results of Maurer et al. that there was no difference in occlusion between males and females and consequently a difference in the performance of the restorations⁵⁵ while Koç et al. found that bite force was significantly higher in men than women due mostly to the greater muscular potential of men.⁵⁶

Also, males have type-II fibers in the masseter muscle, which have larger diameter. Tripathi et al. confirmed that dental component of males is also larger than in females which in turn increases the periodontal support further contributing to increased biting force.⁵⁷ These differences among studies may be due to the difference in the number of males and females included in the studies. Krämer

et al. mentioned that location of restorations either in the upper or lower jaw had no effect on clinical outcome after 6 years.¹ In general, deterioration of restorations is more pronounced in molars than premolars, especially the lower molars based on von Spee's curve. This mainly occurs due to enamel cracks and chippings that increase with time.¹³

Clinical research is a faithful and relevant method to evaluate the performance of dental restorations, as it analyses the actual influence of masticatory forces, as well as the salivary enzymes and bacterial action on the evaluated material and technique. With split-mouth design, two or more interventions are tested in the same patient. It is possible to obtain more realistic results since all treatments will receive the same type of load and protocols; thus, the interindividual variability is minimized. According to Carvalho et al., split-mouth study design was performed so that the same participant could receive the three groups to be evaluated.¹⁸ While the disadvantage of split-mouth following Balkaya et al. is that the possible patient loss means loss of more than one restoration.¹³

FDI World Dental Federation criteria were created in 2007 and modified in 2010 and have been widely used in current clinical studies. These criteria are more sensitive to small variations and for short follow-up durations, being able to detect smaller differences between the restorations when compared with the criteria proposed by the United States Public Health Service (USPHS) especially in the marginal adaptation parameter.^{18,24} Therefore, it was selected as the method of choice used in this study to evaluate dental restorations.¹⁶

Short follow-up period is one of the limitations of this study. Although long-term follow-up is important to compare and evaluate the clinical performance of different interventions, short-term clinical data can also give some useful information about the clinical performance of the materials. Although this study is a short-term clinical study, the patients will continue to be followed up for additional longer durations.

The combination of strategies to improve bond durability of adhesive systems with improved oral health care and patient motivation is the key for success of adhesive restorations.⁹

RECOMMENDATIONS

The effect of the two cavity disinfectants may be manifested after a longer follow-up period to determine if it is worthy to add an extra step to the ordinary steps or not. Further studies are needed to detect the impact of NanoCare Gold cavity disinfectant on bacterial count, adjacent mucosa, general oral health, and prevention of new carious lesions.

CONCLUSION

NanoCare Gold could be promising in durability preservation of direct tooth-colored restorations. Marginal staining and postoperative sensitivity are regulated by other factors than surface pretreatment.

Research Ethics Committee Approval

The protocol of the current study was registered in www.clinicaltrials.gov, with unique identification number NCT03669224. All procedures performed in this study, involving human participants, were in accordance with the ethical standards of Research Ethics Committee of Faculty of Dentistry, Cairo University (CREC) # 42-9-18.

Consent Statement

An informed consent with an easy Arabic language was signed by the recruited participants.

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