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The Effect of Hydrogen Peroxide and Povidone-Iodine on the Shear Bond Strength of Orthodontic Brackets: An *In Vitro* Study

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Abstract

BACKGROUND: Chlorhexidine, which is the gold-standard antimicrobial mouthwash, cannot effectively decrease the count of severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), which is the causative agent for coronavirus disease-2019 (COVID-19). Since SARS-CoV-2 is susceptible to oxidation, mouthwashes containing oxidizing agents such as hydrogen peroxide (H_2O_2) or Povidone-iodine (PVP-I) are recommended to decrease the viral count.

AIM: This study aimed to assess the effects of H_2O_2 and PVP-I mouthwashes on the shear bond strength (SBS) of metal orthodontic brackets to the enamel.

MATERIALS AND METHODS: This *in vitro* experimental study evaluated 45 freshly extracted maxillary premolars. The teeth were cleaned and randomized into three groups (n = 15) for rinsing with distilled water (control group), 1% PVP-I (betadine), and 1.5% H_2O_2 for 60 s. All teeth were etched with 37% phosphoric acid gel, and metal orthodontic brackets were bonded to the teeth using the Transbond XT bonding system. The teeth were mounted in auto-polymerized acrylic resin and incubated in water at 37°C for 72 h. The teeth were then thermocycled for 48 h, and their SBS was measured in a universal testing machine. The adhesive remnant index (ARI) score was also calculated. The groups were compared by ANOVA and Chi-square Monte Carlo test.

RESULTS: No significant difference was noted among the three groups in SBS ($p = 0.938$) or the ARI score ($p = 0.780$).

CONCLUSION: Use of H_2O_2 and PVP-I mouthwashes has no adverse effect on SBS or mode of failure of metal orthodontic brackets bonded to enamel.

Introduction

In December 2019, a new variant of coronavirus known as the severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) was identified in Wuhan, China, which led to the coronavirus disease-2019 (COVID-19) pandemic that affected over 224 countries worldwide and caused over 5,531,118 deaths [1]. The pandemic is still ongoing and has not yet been completely controlled. COVID-19 is easily transmitted through respiratory droplets and aerosols [2], [3], [4]. A person infected with SARS-CoV-2 can transmit the disease to approximately 406 individuals within 30 days through infected respiratory droplets and aerosols. According to recent estimates, the delta variant is over 2 times more contagious than the initial SARS-CoV-2 variant [5]. Dental clinicians are at high risk of COVID-19 infection because most dental procedures generate aerosols [6]. Thus, dental clinicians, dental staff, and dental patients are all at high risk of COVID-19, which is concerning and calls for specific attention [7], [8], [9]. Due to the ongoing COVID-19 pandemic, there is an excessive demand for infection control products worldwide. A number of mouthwashes have been evaluated for preprocedural use in dental offices to decrease the viral count in the oral cavity and minimize the risk of infection transmission through aerosols [10], [11], [12], [13].

The emergency guidelines of the American Dental Association for dental procedures during the COVID-19 pandemic have recommended the use of preprocedural mouthwashes containing oxidizing agents such as 1% hydrogen peroxide (H_2O_2) and 0.2% Povidone-iodine (PVP-I) to minimize the risk of COVID-19 transmission [14]. Some recently published papers also emphasized on preprocedural use of such mouthwashes to minimize the risk of COVID-19 transmission and cross-contamination through dental procedures [15], [16], [17]. PVP-I is a broad-spectrum antimicrobial agent which can deactivate fungi, bacteria, and several enveloped and non-enveloped viruses [18], [19]. PVP-I has the highest virucidal activity among different antimicrobial mouthwashes, including chlorhexidine and benzalkonium chloride [19]. Furthermore, 1.5% H_2O_2 can be used as an oral disinfectant. H_2O_2 is a strong oxidizing agent that eliminates the majority of bacteria and is also effective against different viruses [20]. These mouthwashes are believed to be suitable for use with COVID-19 since the SARS-CoV-2 is susceptible to oxidation.

Most studies showed that chlorhexidine has a positive virucidal efficacy against HSV-1 and Influenza A strains, but for SARS-CoV-2 strains, *in vitro* studies have shown a lower to none virulence effect [21]. Since COVID-19 infected patients may be healthy carriers, all dental patients should be considered potentially infectious. Since transmission through respiratory droplets has been considered as the main route of COVID-19 transmission, such mouthwashes should be included in the routine clinical treatment protocol for patients, given that their efficacy is confirmed [22].

The success of fixed orthodontic treatment highly depends on the adequate bond strength of orthodontic brackets to enamel [23]. The prevalence of bracket bond failure ranges from 0.5% to 16% [24], [25]. At present, mouthwashes are commonly prescribed as an oral hygiene aid for orthodontic patients, and the number of commercial mouthwashes available in the market is on the rise [26], [27].

According to recent studies, bleaching with hydrogen peroxide decreases the SBS of brackets in patients undergoing orthodontic treatment, especially if the time interval between bleaching and bonding procedures is short and a high concentration of hydrogen peroxide is used [28]. As far as the authors know, the effect of PVP-I mouthwash on SBS of orthodontic brackets has not yet been studied, but the application of chlorhexidine solution and gel significantly decreased SBS [29].

Therefore, the null hypothesis that hydrogen peroxide and Povidone-iodine mouthwashes would not affect the shear bond strength of orthodontic brackets to enamel was studied. Hence, if we use them as oral antiseptic mouthwashes, they can be used safely without weakening the shear bond strength (SBS) of metal orthodontic brackets to the enamel.

Materials and Methods

Preparation of specimens

This *in vitro* experimental study was conducted on 45 maxillary premolars freshly extracted as part of orthodontic purposes. The patients were informed of the research, and required consent forms were obtained. The teeth were stored in saline until the experiment. The saline was refreshed every 24 h. The inclusion criteria were teeth with sound enamel on the buccal surface, no history of use of chemical agents such as H_2O_2, absence of hypoplastic enamel lesions or enamel surface defects, and absence of caries or cracks caused by extraction with forceps. The tissue residues, debris, dental plaque, and calculus were removed, and the buccal surface of each test tooth was cleaned by fluoride-free pumice and a rubber cup for 10 s, and the teeth were randomized into three groups (n = 15) as follows:

Group 1 (control group): The teeth were rinsed with distilled water for 60 s.

Group 2: The teeth were rinsed with 1% PI (betadine; Kaveh, Tehran, Iran) for 60 s. The main 10% solution was diluted down to 1%.

Group 3: The teeth were rinsed with 1.5% H_2O_2 (Payadental, Isfahan, Iran) for 60 s.

Enamel etchant

The teeth were then rinsed with air/water spray for 15 s and dried with compressed air. The buccal surface of each tooth was then etched with 37% phosphoric acid gel (Morvabon, Tehran, Iran) for 20 s. The teeth were rinsed with water spray for 15 s and dried with oil-free compressed air for 10 s.

Bracket bonding

Stainless-steel metal bicuspid brackets(Super MBT brackets, Zhejiang Protect Medical Equipment Co., Ltd, Hangzhou, China) with a base surface area of 12.68 mm^2 measured with a digital caliper (Mitutoyo, Japan) were bonded to 4 mm from the incisal edge of the clinical crown buccal surface of each tooth with Transbond XT light-curing composite (3M Unitek Orthodontic Products, Ontario, Canada) following the application of bonding agent was applied to the prepared surface for 20 s, and then medium air pressure was applied to the surface for 5 s by the same person. Before curing, the excess composite resin was removed by the sharp tip of a scaler, then the resin was cured for 20 s (5 s for each mesial, distal, occlusal and gingival part of the bracket) using a light-cured with a LED curing unit (Wood Pecker, Muenster, Germany) with a light intensity of 150 mW/cm^2. All samples were prepared and bonded by one operator, and a 300 g force was applied during bracket bonding using a force gauge (ZUG-UND 28, 450 g; Dentaurum, Ispringen, Germany).

Bracket debonding and measurement of SBS

The teeth were mounted in auto-polymerizing acrylic resin (Acropars, Tehran, Iran) to the level of their cementoenamel junction. A mounting jig was used for perpendicular mounting of the teeth relative to the bottom of the acrylic mold. They were then stored in deionized water and incubated at 37°C for 72 h (Kavoosh mega, Tehran, Iran). To simulate the intraoral environment, the teeth were subjected to thermocycling (TC-300; Vafaei Industrial, Tehran, Iran) for 3000 cycles between 5 and 55°C for 48 h with a dwell time of 20 s and a transfer time of 10 s. The buccal surface of each tooth was positioned such that the applied load was parallel to the tooth surface.

The SBS of the bracket to enamel was measured by a universal testing machine (Zwick Roell, Ulm, Germany). The vertical load was applied by a flat-end stainless steel rod to the bracket-enamel interface (Figure 1). The brackets were debonded by application of shear-peel load at a crosshead speed of 1 mm/min. The debonding force was recorded. The SBS was measured in megapascals (MPa) by dividing the load that caused debonding in Newtons (N) by the bracket base surface area in square millimeters (mm^2).

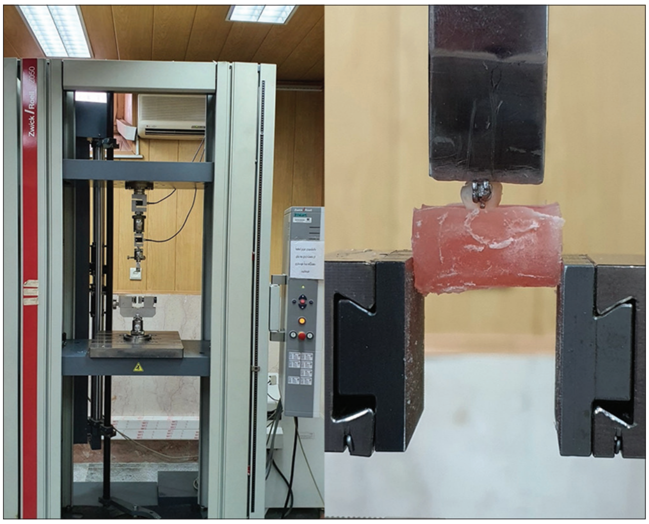
Figure 1: The sample was placed in the universal testing machine

Calculation of adhesive remnant index (ARI) score

The surfaces were inspected Under Stereomicroscopes (Optika, Ponteranica, Italy) at ×20 magnification after debonding, and the amount of residual adhesive on the enamel surface was quantified using a 5-point scoring system as follows [30]:

- Score 1: The entire composite remained on the enamel surface
- Score 2: Over 90% of the composite remained on the enamel surface
- Score 3: Over 10% but <90% of the composite remained on the enamel surface
- Score 4: <10% of the composite remained on the enamel surface
- Score 5: No composite remained on the enamel surface.

Statistical analysis

The Kolmogorov–Smirnov test was used to assess the normality of data distribution. Since the data were found to be normally distributed, ANOVA was applied to compare the groups regarding the SBS, and the Chi-square Monte-Carlo test was applied to compare the groups regarding the ARI scores. All statistical analyses were performed using SPSS version 18 (SPSS Inc., IL, USA) at 0.05 level of significance.

Results

Shear bond strengths in MPa (mean standard deviation [SD]) for all groups are shown in Table 1. The mean shear bond strength for the control group was 57.53 ± 21.77 MPa. Means for the hydrogen peroxide group were 54.91 ± 20.95 MPa and 55.95 ± 17.96 MPa, for the Povidone-Iodine group. ANOVA showed no significant difference in SBS among the three groups (p = 0.938). Tukey test showed that there was no statistically significant difference in the SBS variable in pairwise comparisons between study groups (Tukey HSD, p > 0.05) (Table 2).

Table 1: Descriptive analysis shear bond strength of the study groups (n = 15)

Group	SBS (MPa)				p†
	Count	Mean ± SD	Minimum	Maximum	
Control	15	57.53 ± 21.77	23.93	97.14	0.938
Povidone iodine	15	55.95 ± 17.96	23.11	82.99	
Hydrogen peroxide	15	54.91 ± 20.95	24.98	94.33	

†ANOVA. SD: Standard deviation, SBS: Shear bond strength.

Data on residual adhesive on the enamel surfaces as evaluated by ARI scores and the frequency distribution of different ARI scores in the study groups are presented in Table 3. The Chi-square Monte-Carlo test revealed no significant difference in the frequency distribution of different ARI scores among the three groups (p = 0.780). A pair-wise comparison of the groups is shown in Tables 4-6.

Discussion

According to a recently published article, dental clinicians are at higher risk of COVID-19 infection, compared with nurses and physicians, due to the close contact between patients and dental clinicians [31]. COVID-19 is transmitted by inhalation, deglutition, or direct contact of the mucosa with salivary and respiratory droplets, which are spread during speaking, coughing, and sneezing [32], [33]. Moreover, evidence shows that salivary gland epithelial cells that are widely present in the oral cavity have high expression of the ACE receptor for COVID-19, and their number in the oral cavity is even higher than their number in the lungs [34].

This study assessed the effects of 1.5% H_2O_2 and 1% PVP-I antimicrobial mouthwashes on SBS of metal orthodontic brackets to the enamel.

Table 2: Multiple comparisons of mean shear bond strength between the study groups

Tukey HSD						
Group (I)	Group (J)	Mean difference (I−J)	SE	Significant	95% CI	
					Lower bound	Upper bound
Control	Povidone iodine	1.585	7.409	0.975	−16.415	19.585
	Hydrogen peroxide	2.627	7.409	0.933	−15.374	20.627
Povidone-iodine	Control	−1.585	7.409	0.975	−19.585	16.415
	Hydrogen peroxide	1.042	7.409	0.989	−16.959	19.042
Hydrogen peroxide	Control	−2.627	7.409	0.933	−20.627	15.374
	Povidone iodine	−1.042	7.409	0.989	−19.042	16.959

CI: Confidence interval, SE: Standard error

Vergara-Buenaventura and Castro-Ruiz [15] suggested the preprocedural use of mouthwashes for reduction of SARS-CoV-2 viral load and minimizing the risk of cross-contamination in dental offices during the COVID-19 pandemic. They recommended gargling H_2O_2 and PVP-I at different concentrations for 30 s.

Table 3: Frequency distribution of different adhesive remnant index scores in the study groups

ARI	Group						p†
	Control		Povidone-iodine		Hydrogen peroxide		
	Count	Column N %	Count	Column N %	Count	Column N %	
I	1	6.7	0	0.0	1	6.7	0.780
II	7	46.7	5	33.3	6	40.0	
III	7	46.7	10	66.7	7	46.7	
IV	0	0.0	0	0.0	1	6.7	
V	0	0.0	0	0.0	0	0.0	

†Chi-square Monte Carlo test. ARI: Adhesive remnant index.

According to the COVID-19 diagnosis and treatment guideline (5th version) published by the National Health Commission of the Republic of China, chlorhexidine, which is the gold-standard antimicrobial mouthwash, is not effective for the reduction of viral count in COVID-19. Instead, oxidizing mouthwashes such as those containing 1% H_2O_2 or 0.2% PVP-I are recommended for the reduction of viral load in saliva and possible transmission of COVID-19 [35]. This statement was confirmed by the results of a systematic review [34] that pointed to a significant reduction in salivary viral load following the use of mouthwashes containing 1% PVP-I. Moreover, an *in vivo* study indicated that long-term gargling of 1%–1.25% PVP-I did not irritate the mucosa and had no adverse effect during the 28-month study period. Gargling of PVP-I does not cause tooth staining and does not alter the sense of taste either [36], [37], [38].

Table 4: Frequency distribution of different adhesive remnant index scores control and povidone iodine groups (*P* = 0.458, Chi-square Monte Carlo)

ARI	Group				P†
	Control		Povidone iodine		
	Count	Column N %	Count	Column N %	
I	1	6.7	0	0.0	0.458
II	7	46.7	5	33.3	
III	7	46.7	10	66.7	
IV	0	0.0	0	0.0	
V	0	0.0	0	0.0	

†Chi-square Monte Carlo. ARI: Adhesive remnant index.

An in vitro study evaluated the Median Tissue Culture Infectious Dose and showed that PVP-I had virucidal effects against SARS-CoV-2. Gargling and rinsing the mouth with solutions containing 1% PVP-I resulted in over 99.99% virucidal activity [39], which corresponds to over 4 log10 reductions in viral load after 30 s of contact [18]. This result was in agreement with the findings of Hassandarvish *et al*. who concluded that 1% PVP-I decreased the viral titer by over 5 log10 after 15, 30, and 60 s of treatment [40].

Table 5: Frequency distribution of different adhesive remnant index scores control and hydrogen peroxide groups (p = 1.000, Chi-square Monte Carlo)

ARI	Group				p†
	Control		Hydrogen peroxide		
	Count	Column N %	Count	Column N %	
I	1	6.7	1	6.7	1.000
II	7	46.7	6	40.0	
III	7	46.7	7	46.7	
IV	0	0.0	1	6.7	
V	0	0.0	0	0.0	

†Chi-square Monte Carlo. ARI: Adhesive remnant index.

The optimal antiviral efficacy of H_2O_2 against SARS-CoV-2 and influenza viruses has been documented [16]. H_2O_2 targets the lipid virus envelope, especially in SARS-CoV-2 [41]. It releases oxygen free radicals and degrades the lipid membrane [35]. A major advantage of H_2O_2 is that it is safe for mucosal membranes. It can be used as an oral rinse or nasal spray even in concentrations as high as 3% for 6 months [42]. A previous study showed that 0.5% H_2O_2 inactivated the coronavirus on the surface within 1 min [20]. An *in vitro* study reported that 3% H_2O_2 was suitable for inactivation of viruses within 1–30 min, and coronavirus and influenza virus were the most susceptible to H_2O_2 [43]. Some other studies reported a safe daily rinse of 1% to 1.5% H_2O_2 with no adverse effects or complications for the soft tissue [44], [45]. Thus, 1.5% H_2O_2 was used in the present study.

Table 6: Frequency distribution of different adhesive remnant index scores hydrogen peroxide and Povidone-iodine groups (p = 0.558, Chi-square Monte Carlo)

ARI	Group				p†
	Povidone iodine		Hydrogen peroxide		
	Count	Column N %	Count	Column N %	
I	0	0.0	1	6.7	0.558
II	5	33.3	6	40.0	
III	10	66.7	7	46.7	
IV	0	0.0	1	6.7	
V	0	0.0	0	0.0	

†Chi-square Monte Carlo. ARI: Adhesive remnant index.

Studies on the effects of H_2O_2 or PVP-I are limited, and the available ones have mainly focused on their tooth discoloration potential, surface properties [45], [46], efficacy for oral hygiene, and antimicrobial activity [47], [48], [49]. Most published articles deal with the effect of hydrogen peroxide with much higher percentages (about 35%) for teeth bleaching and its effect on SBS of brackets [28]. Bleaching with 35% hydrogen peroxide reduces SBS, and its high dosage results in a statistically significant reduction in SBS irrespective of the time interval between the procedures [28]. Moreover, a recently published article by Kutuk *et al*. [22] investigated the effect of PVP-I and hydrogen peroxide mouthwashes on the enamel/dentin shear bond strength (SBS) of a universal adhesive. Therefore, the effect of these mouthwashes with routine concentrations on the relationship between brackets and adhesive was questionable. To the best of the authors' knowledge, this study is the first to address the effects of H_2O_2 and PVP-I mouthwashes with concentrations of 1.5% and 1% (which are the routine concentrations used in their mouthwashes) on SBS of orthodontic brackets with adhesive.

Considering the present results confirming no adverse effects of H_2O_2 and PVP-I mouthwashes on SBS, dental clinicians can prescribe these mouthwashes as an alternative to the commonly used mouthwashes by orthodontic patients to benefit from their anti-COVID-19 effects during this pandemic. The SBS values in the present study were all within the clinically acceptable range [30], and the ARI scores were mainly 2 or 3, indicating that the majority of the composite remained on the enamel surface after debonding. This finding highlights the stronger bond of resin-enamel than resin bracket.

Within the limitations of this *in vitro* experimental study, due to not evaluating the effect of artificial saliva and temperature alterations, the results should be generalized to the clinical setting with caution. Future clinical studies are required to confirm the present findings.

Conclusion

The results of this study showed no significant difference in SBS or ARI scores of the three groups. H_2O_2 and PVP-I mouthwashes have no adverse effect on SBS of metal orthodontic brackets, and they may be considered as an alternative to the currently used mouthwashes by orthodontic patients to benefit from their antiviral properties against COVID-19.

Data Availability

Data used to support the findings of this study are included in the article.

Ethical Approval

The study was approved by the ethics committee of Kermanshah University of Medical Sciences (IR.KUMS.REC.1399.939), and the patients consented to the use of their extracted teeth for research purposes.

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