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ORIGINAL ARTICLE

Effects of *Zingiber Officinale* on shear bond strength of orthodontic bracket adhered into re-bonded tooth surface

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Background

One of the most practical, basic and commonly used tests for evaluating the adhesion resistance of bonded orthodontic brackets is shear bond strength. The ideal shear bond strength of the bracket to enamel is anticipated to resist bracket failure during the orthodontic treatment, while not causing enamel damage during de-bonding and maintaining the enamel integrity after finishing treatment. The aim of this study was to evaluate the shear bond strength of the brackets adhered into bonded and re-bonded teeth surfaces of fluorescent orthodontic adhesive modified by incorporation of *Zingiber officinale* essential oil.

Materials and Methods

Sixty recently extracted human lower first premolars caries-free teeth were used in this study. The teeth were randomly divided into 6 groups. The bonding control, bonding with a fluorescent orthodontic adhesive modified with 1%, 2% *Zingiber officinale* essential oil, control after re-bonding, and re-bonding with a fluorescent orthodontic adhesive modified with 1%, 2% *Zingiber officinale* essential oil. In the re-bonding three groups, they were de-bonded by the bracket removing plier (base method) and the remaining adhesive was removed. Then anew bracket was re-bonded in the same protocol. The shear bond strength was measured in Mega Pascal at cross head speed 1 mm/min. Then, adhesive remnant index was evaluated by a stereomicroscope 10X. Statistical analysis was with p value at $p<0.05$.

Results

The shear bond strength of the control bonding group was significantly higher than the modified bonding groups with 2% *Zingiber officinale* essential oil. Whereas, the control after re-bonding group was higher than the modified re-bonding groups with no statistical significant difference. The distribution of the adhesive remnants index scores was significantly different among the study groups.

Conclusion

Generally, *Zingiber officinale* essential oil addition into fluorescent orthodontic adhesive reduced the shear bond strength in the bonded and re-bonded groups, particularly in the bonding modified with 2% concentration.

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Although orthodontic therapy has various advantages, the appliance's retaining surfaces make cleaning challenging and contribute necessarily to food accumulation and dental plaque formation[1] Orthodontic patients had a higher rate of enamel demineralization than people who were not receiving orthodontic treatment.[2] Cariogenic streptococci adhesion was found to be higher for the orthodontic types of cement and adhesives than for the bracket itself.[3] Since the invention of bonding brackets, researchers and clinicians have attempted to enhance the characteristics of bonding agents.[4] Essential oils may be encouraging ingredients for contributing to the antimicrobial property of composite resin materials.[5,6] Zingiber officinale (ZO) has been regarded as a safe herbal medicine because there have been no observed medication or herb interactions but only minor negative impacts associated with its use.[7] Carvacrol and thymol both showed antibacterial activity against cariogenic bacteria, periodontitis-causing bacteria and antifungal action.[8,9]

Bracket failure from the teeth is still a major concern during orthodontic therapy, which can impact tooth enamel, lengthen overall treatment time, due to re-bonding procedures, and increase the overall cost of the orthodontic procedure.[10] The insufficient dryness of the teeth post-etching and saliva contamination are two common reasons for bond detachment.[11] The bond detachment was more frequent on posterior teeth than anterior teeth, and it was more frequent on the lower arch than the upper arch.[10] By utilizing a blue light emitting illumination source, the Fluorescence-assisted recognition protocol distinguishes between resin composites and tooth structures[12], resulting in a more precise, efficient, safe, and time-savable protocol for correct adhesive removal.[13,14]

MATERIALS AND METHODS

Sample Collection and Inclusion Criteria

The Dentistry Faculty at the University of Mosul provided ethical approval (UoM.Dent/H.DM. 51/22). The teeth were sorted into six groups at random sampling, with every group involving ten teeth. The requirements for tooth collection included teeth free of hypo-plastic zones, caries, cracks, gross anomalies, restorations, not exposed to any sort of orthodontic or endodontic treatment, and no history of prior treatment with various chemical agents including alcohol, and hydrogen peroxide.[15] To ensure that the chosen teeth were sound, a magnifier (X5) was used to examine the labial surface of the teeth. Any soft tissue residues were washed and eliminated. Sixty lower premolars were preserved in distilled water after extraction and at room temperature around (22 C°±3) for a peak period of one month[16] To prevent the growth of microorganisms, the water was changed weekly for the remainder of the research experiments.[16]

Preparation of Modified Adhesive

The electrical sensitive balance (Kern, Germany) was used to prepare the ratios of the modified adhesive with ZO essential oil (Sigma-Aldrich, USA). The micropipette (DRAGON lab, China) had been utilized to aspirate ZO essential oil, at 1% and 2% concentrations in the (weight to weight) ratio. The modified adhesive (Maquira, Brazil) had been incorporated by utilizing a plastic spatula and a sterile glass slab.[17] To attain a homogenous consistency, the blend had been manually blended for around one minute in a semi-dull area, the blend was at that point spread out on a surface to diminish porosity.[17-19] The altered adhesive was at that point exchanged to a sterilized expendable syringe, and a bit of tape of a dull colour was utilized to ensure the blend from coordinate light presentation.[17] The concentrations of the ZO oil were chosen as takes after: to begin with group 10 μL of ZO oil in 1gm of the adhesive, and the second group 20 μL of ZO oil, in 1 gm of the adhesive.

Sample Preparation

Plastic rings were utilized, with the measurement of 26 mm stature, 18 mm interior distance across, and 20 mm exterior distance across. The rings were filled to around half their stature by a dental stone. After the stone was set, the teeth were secured within the plastic rings by applying sticky wax to the stone's surface, the teeth positioned opposite to the ring's base and within the centre of the ring.[20]

The ring was installed on the surveyor's platform so that its long axis was essentially parallel to the surveyor's analytical rod, as shown in **Figure 1**, and the cold cure acrylic resin filled the ring until the

Figure 1 *Mounting procedure: surface parallelism after acrylic pouring*

Figure 2 *Bracket under constant pressure*

Figure 3 *De-bonding procedure from occlusal view*

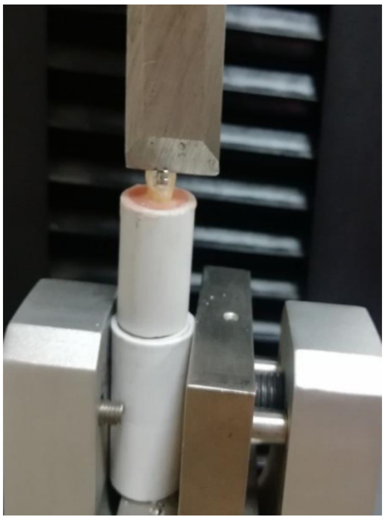

Figure 4 *The SBS testing in a universal testing machine with a knife-edged blade*

cementoenamel junction.[21] After the setting of the cold cure resin, the teeth were polished for about 10 seconds with non-fluoridated pumice by utilizing a polishing cup and a slow-speed handpiece. After thoroughly rinsing the tooth surface with water for ten seconds to remove any pumice or debris, the teeth were ready for use.[21]

Bonding Procedure

The buccal surface of the enamel of each tooth was treated with 37% ortho-phosphoric acid (Gel Acid – Maquira) for about 15 seconds and later washed with water for 10 seconds according to the manufacturer's instructions and subsequently, air dried by the triple syringe and a chalky appearance was observed.[22] The clamping tweezers held the standard Edgewise bracket 0.022-inch slot without a hook (Dentaurum, Germany), then a layer of the orthodontic adhesive was applied at the base of the bracket, and then the researcher transferred the bracket to the centre of the buccal surface of the crown of premolar tooth at a distance of approximately 4.5 mm from the occlusal surface as shown in.[23] A load of200 gm was applied at a right angle to the bracket in keeping with pressure standardizing protocols (**Figure 2**), and then the dental explorer removed the excess of the orthodontic composite before curing.[24]

The Woodpecker light curing device then started the curing procedure with an intensity of (900-950) mW/ cm^2 measured with a light-intensity tester (Woodpecker, China). The curing light was applied for 20 seconds on the distal, mesial, gingival and occlusal aspects respectively[20], so the curing was extended for about 80 seconds. Following the completion of the bonding process, all specimens were retained in the distilled water for twenty-four hours, just before de-bonding and re-bonding procedures had been carried out.[25]

De-bonding and Re-bonding Procedures

The bracket was detached with the bracket removing plier using the (base method) for de-bonding in which the plier's beaks were positioned at the point of the interlayer between the bracket and the tooth (**Figure 3**).[26] The instrument squeezed the bracket until the separation from the enamel.[27,28] The tungsten carbide burs eliminated the remaining adhesive from the buccal surface by utilizing a slow-speed handpiece until no visible residue was noticed, polishing was done using a rubber cup with pumice at 5000 rpm for 30 seconds.[29] Then, the new bracket was re-bonded in the same previous protocol that was previously mentioned.

Table 1 *The descriptive statistics for the SBS after mixing with ZO*

Variable	Mean	SD±	Minimum	Maximum
Control	18.31	6.95	9.20	31.70
Modified with 1% ZO	12.58	6.25	6.60	24.60
Modified with 2% ZO	6.51	3.03	3.50	14.30

SBS measurement unit is megapascal.

Table 2 *The descriptive statistics for the SBS re-bonded adhesive*

Variable	Mean	SD±	Minimum	Maximum
Control	7.01	3.18	4.10	14.30
Modified with 1% ZO	6.72	3.64	2.30	14.20
Modified with 2% ZO	8.92	2.01	6.20	12.50

SBS measurement unit is megapascal.

Shear Bond Strengths Measurement

So after the bonding and re-bonding procedures, all specimens were left in distilled water for twenty-four hours at room temperature before the monitoring by the universal testing machine (GESTER, China).[30] At a crosshead velocity of 1 millimeter/minute, the stress necessary for the detachment of the brackets was calculated in Newtons (N).[30] The specimens were then secured in the device's bottom jaw such that the bracket base paralleled the shear force orientation, as can be seen in Figure 4.[31] The test's findings were electronically documented.[16] The applied load at the fracture point was captured in Newton and then changed to (MPa) by dividing the de-bonding force by the surface area of the bracket, which is a round (9 millimetres) based on the manufacturer's catalogue (MPa = N/mm^2).[21]

Adhesive Remnant Index (ARI)

ARI quantified the amount of residual adhesive residue on the enamel surface.[32,33] The ARI scores were utilized to identify the locations of bond failure among the enamel, resin, and bracket base. After de-bonding, the teeth were inspected with a stereomicroscope at 10X magnification. The following are the scores, which range from 0 to 3:

0. No adhesive left on the enamel surface.
1. Only about half of the adhesive is on the surface of the enamel.
2. More than half of the adhesive on the surface of the enamel.
3. With a bracket base impression, all of the adhesive on the enamel.

Table 3 *One-way analysis of variance for shear bond strength among the bonded and re-bonded groups*

	Sum of Squares	DF	Mean Square	F	P-value
Between Groups	1087.22	5	217.44	10.50	*0.001*
Within Groups	1117.99	54	20.70		
Total	2205.21	59			

RESULTS

Descriptive Analysis of SBS (Bonded Groups)

Table 1 depicts the descriptive data (mean and standard deviation) for SBS. This information included the standard deviation, minimum, maximum and mean. SBS values for every bonded research group. Based on the description of the original bonded groups, the control revealed a higher SBS mean value, followed by the modified adhesive with 1% ZO essential oil, and the 2% group had the lowest mean value.

Descriptive Analysis of SBS of the Re-bonded Groups

The descriptive of the re-bonded groups (mean and standard deviation) revealed that orthodontic adhesive modified with 2% ZO essential oil group had the highest SBS mean value followed by the control after re-bonding group, while the 1% group showed the lowest mean value as depicted in the Table 2.

Analysis of Variance of SBS among the Bonded and Re-bonded Groups

Table 3 shows the outcomes of the (ANOVA) test statistic, which demonstrated a significant difference in the mean values of the SBS for the various bonded and re-bonded groups in this research at $p < 0.05$.

As depicted in Table 4, a more specific multiple comparison (Scheffe's) test, was administered among all the research groups, discovering a significant difference between the control group and the control after re-bonding. Furthermore, except for the 1% modified bonding group, there was a significant difference between the control bonding group and all of the modified groups in this study. Finally, there was no significant difference between the control after re-bonding and all of the study's modified groups at $p < 0.05$.

Adhesive Remnant Index

The chi-squared test showed that there was a statistically significant difference in ARI score among

Table 4 *The multiple comparisons among the bonded and re-bonded groups*

	Mean Difference	Std Error	*p* value
	Control		
Bonded after modifying with 1% ZO	5.73	2.03	0.180
Bonded after modifying with 2% ZO	11.79	2.03	*0.001*
Control after re-bonding	11.30	2.03	*0.001*
Re-bonded after modifying with 1% ZO	11.59	2.03	*0.001*
Re-bonded after modifying with 2% ZO	9.39	2.03	*0.002*
	Bonded after modifying with 1% ZO		
Bonded after modifying with 2% ZO	6.06	2.03	0.133
Control after re-bonding	5.57	2.03	0.206
Re-bonded after modifying with 1% ZO	5.86	2.03	0.160
Re-bonded after modifying with 2% ZO	3.66	2.03	0.665
	Bonded after modifying with 2% ZO		
Control after re-bonding	.049	2.03	1.000
Re-bonded after modifying with 1% ZO	0.20	2.03	1.000
Re-bonded after modifying with 2% ZO	2.40	2.03	0.922
	Control after re-bonding		
Re-bonded after modifying with 1% ZO	0.29	2.03	1.000
Re-bonded after modifying with 2% ZO	1.91	2.03	0.970
	Re-bonded after modifying with 1% ZO		
Re-bonded after modifying with 2% ZO	2.20	2.03	0.946

the different study groups, x2 (5)= 24.187, p = 0.001, with a mean rank ARI of 21.15 for control group,23.70 for re-bonded control, 21.15 for 1% bonded group, 50.55 for 2% bonded group,29.40 for 1% rebounded and 37.05 for the 2% re-bonded group.

DISCUSSION

Compared to the demands for composite restorations in the operative dental branch, in which the restorations are aimed to serve a longer period, an orthodontic adhesive must be simple to remove at the end of the orthodontic therapy with no risks to teeth surfaces.[34] The ZO methanolic as well as crude extract have an incredibly ultrahigh cariostatic ability.[35] The reason behind selecting the mandibular first premolar as a sample in the current study is because of the high rate of the bracket, failure occurs on the lower premolars as compared with uppers.[10] Previous research reviewed the adhesive residue's removal, and probable enamel harm, and noticed that the usage of fluorescent adhesives with ultraviolet light, provides fast, convenient, and more efficient removal of the remnants.[12,36] The existing research observed a significant decline in SBS after the re-bonding. However, our results are in contrast to the outcomes of previous reports that the SBS was not different significantly[37,38] or the SBS value elevated after re-bonding of the new brackets[39,40], but in a study by Eslamian et al the SBS was lower after re-bonding.[41] The existing research results are consistent with previous research, which discovered that after immersion in eucalyptus oil, the shear forces of the composite resin were diminished to the lowest value. Peppermint oil, like eucalyptus oil, lessened shear forces.[41,42] Free-radical seekers tend to involve phenolic acids, flavonoids, as well as polyphenols. The chemical nature of polyphenols makes them excellent for free radicals adventuring as well as attracting metal ions[43-45] Free radicals inhibited the polymerization of methyl-methacrylate by phenolic compounds, with eugenol serving as the most potent inhibitor.[46]

Previous literature on Salvadora persica's impact on the health of the oral cavity concluded that the meswak-treated self-etching subgroup had the least bond strength explained due to the presence of certain essential oils in meshwork-extract, which may interfere with the bonding process, while, higher bond strength was noticed in the total-etching subgroup, as the remaining oil gets washed away in the etch-and-rinse process.[47]

A comparison of the present findings and similar research might be complicated. This seems to be due to the numerous bracket loadbearing devices utilized (bovine /human teeth or plastic blocks), the various size of the sample, bracket kinds (different models, recycled or new), bracket base surface area, or shear bonding strength evaluation procedures (shear or tensile) utilized. Furthermore, because of variations in methodological approaches, such as tooth choice, kinds of preventive components, exposure intervals, the concentration of the antimicrobial agent, bonding system, as well as whether or not the thermos-cycling approach is utilized.[48,49] The morphological characteristics of the enamel might be a significant factor that influences multiple styles of adhesive failure during de-bonding.[50] Less adhesive on the tooth after de-bonding in orthodontics means that removing it will take the orthodontist less time and effort, so, a lower ARI score would be preferable.[51] Since the majority of the specimens in each of the four groups fell within the 0–1 range, (control group, re-bonding control, 1% bonding, 1% re-bonding, 2% re-bonding) the bracket and the majority of the adhesive were removed together during the de-bonding process. So that minimal effort is required to remove any remaining adhesive and it can do so without damaging the dental enamel.

Eslamian et al explored the role of numerous de-bonding patterns on the shear strength of stainless steel brackets and concluded that the noticed weakness in the shear strength is most probably due to incomplete disturbance of the etching sequence, and weakening retentive enamel morphological characteristics.[41] The demineralizing dentin as compared to sound dentin, its SBS with resin was much lower.[52] This may be explained by the mineral loss from the dentin peri-tubular and inter-tubular regions, which impairs the ability of the monomers to bond in demineralized dentin. The remaining unsupported collagen system acts as water-filled channel.[52] The composite resin's ability to bond in the enamel surface may be decreased because of the hydrophilic substrate.[52] Although natural products with their various forms have several applications in different medical and dental fields [53,54], further studies are indicated to improve their efficacy in dental practice.

CONCLUSION

From this study, it was concluded that, the incorporation of ZO, an essential oil, to the fluorescent adhesive, reduce the shear bond strength in the bonded and re-bonded brackets particularly with 2% concentration. The ARI revealed an evident difference among the study groups.

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