The effect of incorporation Nano Cinnamon powder on the shear bond of the orthodontic composite (an in vitro study)

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ARTICLE INFO

Keywords:

Nano Cinnamon powder
Shear bond
Orthodontic composite
Streptococcus mutans

ABSTRACT

Objectives: One of the causes of dental caries that occurs due to orthodontic treatment is the lack of antibacterial properties in orthodontic adhesive. This study was designated to investigate the effect of orthodontic resin modified by incorporating Nano Cinnamon powder on the shear bond strength of orthodontic brackets.

Materials and methods: Heliosit Orthodontic Resin, a photo-activated light cure resin was modified by the addition of Cinnamon in the form of Nano particle powder. Twenty uniform disks were made, 5 as a control and 5 for each concentration of the 1%, 3% and 5% wt/wt Cinnamon modified resin. Their antimicrobial activity against *Streptococcus Mutans* was tested using the disk diffusion method. Then, the most effective concentration of the modified resin was used to bond metal orthodontic brackets to human extracted premolars. The universal testing machine was used to record the shear bond strength of the control and the modified resin. Also, the adhesive remnant index was measured.

Results: Disc diffusion method showed that the 3% wt/wt Cinnamon powder modified resin was more effective than 1% with a larger bacterial inhibition zone. Shear bond strengths of the control were 8.50 MPa and 7.20 MPa for the 3% Cinnamon modified resin with no significant difference between them. Also, no significant difference was recorded in the adhesive remnant index scores between the control and the modified resin groups.

Conclusion: Findings of this study revealed that the incorporation of 3% Cinnamon Nano particles in orthodontic resin produced an antibacterial effect against *Streptococcus mutans* without compromising the shear bond strength.

Clinical relevance: Incorporation of Cinnamon Nano particles in orthodontic resin may reduce caries formation around brackets during treatment course.

1. Introduction

One of the problems that faced orthodontists is the white spot lesions which was found in more than 50% of patients undergoing orthodontic therapy.^{1–3} This may be related to several factors such as the duration of treatment and complexity of the appliances which facilitated plaque accumulation on the tooth surface.^{4,5} It was established that oral bacterial count is increased in orthodontic patients and has been proven that *Streptococcus mutans* (*S. mutans*) is the major corresponding bacteria associated with the development of the carious lesion.^{4–6}

Many strategies such as tooth brushing, mouth rinses, and fluoride regimens have been incorporated to prevent or minimize dental caries around the orthodontic appliances.⁷ However, methods that are non-dependent on patient cooperation may be more effective in caries

control.⁸ Therefore, many attempts have been made to add antimicrobial agents to the orthodontic adhesive as a preventive strategy against dental caries.⁹ Among these agents were methacryloyloxylododecyl pyridinium bromide,¹⁰ fluoride,^{11,12} chlorhexidine¹³ and benzalkonium chloride.¹⁴

In recent years, there is an increasing interest in using of different plants and natural products such as spices and herbal extracts against *S. mutans*.^{15,16} Among these products, Cinnamon extract has shown a positive effect against cariogenic bacteria.¹⁷ Cinnamon is one of the plant products that used daily by many people worldwide. It primarily contains vital oils and derivatives, such as cinnamaldehyde, cinnamic acid, and cinnamate. It has been utilized as traditional medicine and its effect as an antibacterial was documented. This activity is due to the presence of products such as phytochemicals and cinnamaldehyde that represent its main components.¹⁸

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<https://doi.org/10.1016/j.jobcr.2020.03.008>

Received 24 October 2019; Received in revised form 11 February 2020; Accepted 17 March 2020

Available online 05 April 2020

2212-4268/ © 2020 Published by Elsevier B.V. on behalf of Craniofacial Research Foundation.

In addition to that, nanotechnology produced an important revolution in the field of dental material. Incorporating different materials in their Nano form to composite resin such as titanium oxide (TiO₂),¹⁹ zinc oxide²⁰ and glutaraldehyde silver Nano particles^{21–23} was recorded. This technology can create materials with enhanced chemical, mechanical, optical, and electrical properties.^{24,25} According to Kasraei et al.²⁰ any antimicrobial material converted into Nano particles, increases its surface-volume ratio and leads to improve its antimicrobial activity.

Several studies have been conducted to test the antimicrobial and mechanical properties of various materials incorporated in orthodontic composite.^{19,20,26,27} These studies revealed a possible reduction in the bond strength that may compromise the orthodontic treatment. For example, Jatania and Shivalinga²⁸ showed that the shear bond strength of the composite decreased as the concentration of ZnO increased despite increasing the antimicrobial activity.

Attempts have been made to find adjunctive natural materials that have an antimicrobial effect and not compromise mechanical bonding capacity.²⁹ According to our best knowledge, there is no available data about the effects of incorporating Cinnamon in the orthodontic adhesive. Thus, the aim of this study was to investigate the effect of Cinnamon Nano particle agent incorporated in the orthodontic adhesive on the shear bond strength of orthodontic brackets.

2. Materials and methods

2.1. Cinnamon Nano particles preparation

The ethical approval was released by the academic authorities of the College of Dentistry, University of Mosul in 2018. The antimicrobial agent used in this study was Cinnamon that collected from the local market (Sri Lankan origin). Nano particles were prepared by mechanical attrition method.³⁰ Preparation of natural product sample was conducted by taking 100 g of Cinnamon crust. It was cleaned, washed well with water, then dried in the shade with the presence of air. The crust was broken into small pieces then was ground. The size of the Nano particle was 5–20 nm. The Nano particles Cinnamon was measured using SEM machine in University of Al-Nahrain laboratory by Philips machine (Model CM10, Holland) as shown in Fig. 1.

2.2. Antimicrobial assessment

2.2.1. Experimental disks preparation

Heliosit orthodontic resin (Ivoclar vivadent, Liechtenstein, Germany) was used in this study. It was modified by the incorporation of Cinnamon in a powder Nano particle form. The resin was formed into 20 uniform disks for the testing procedure. They were divided into two groups:

Fig. 2. Experimental disks preparation. (A) The control disk, (B) Cinnamon powder disk.

- Unmodified resin (5 disks) as a control group in which Heliosit orthodontic composite was used without any modification.
- Cinnamon powder modified resin in which the Nano particles Cinnamon was mixed with Heliosit orthodontic composite in three concentrations: 1%, 3% and 5% wt/wt, with 5 disks for each concentration.

Manual mixing of the Cinnamon with the Heliosit composite resin was done using a plastic spatula continuously for 1 min on a sterilized slap in a dark room with spread of the material on the slap to minimize porosity. The resin was placed in increments inside readymade rubber molds of uniform size with 1 mm thick and 5 mm diameter (Fig. 2). The work is done under the sterilized condition and two glass slabs were placed below and above the mold to create uniform disks. The resin was cured by light exposure for 20 s from up and down by light cure unite³¹ (Coxo Medical Instrument Co. China). Resin that modified by the addition of 5% wt/wt of Cinnamon Nano particle powder was excluded because it performed a partial setting of the modified resin after light exposure. The total number of composite groups was three; one with 0% Cinnamon as a control, one of 1% and the other of 3% Cinnamon powder resin.

In order to produce the desired concentrations of the modified resin, the required amount of Cinnamon was weighed for every 0.5 g of resin according to the following equation: $\text{Cinnamon wt.} / 0.5 \text{ gm. resin} \times 100 = \text{the required percentage \%}$

The disks were removed from the mold and sterilized for 5 min using low intensity (100 W) microwave³² (Panasonic, China).

2.2.2. Disc diffusion method (Kirby-Bauer method)

It is the procedure that conducted to test antibiotics activity against the microorganisms. The agar plate was inoculated with the culture media and a filter disk was applied to the surface of the agar by using sterile forceps. The plate incubated at 37 °C for 24 h, after that, the plates were examined to assess the bacterial inhibition zone (clear ring) around the antimicrobial disk. The diameter of zones can be measured in mm, then the activity of microorganisms was detected by this zone.³³

In this study, the following steps were conducted to assess the antibacterial activity of the Cinnamon:

1. Gram positive bacteria (*S. mutans*) was taken from a swab of oral cavity of single donor, isolated at Department of Dental Basic Science, College of Dentistry, University of Mosul.
2. Nutrient agar was used as a culture media for this method.
3. A loop full of the cultures were taken and inoculated in 4 ml of brain heat infusion broth in two vials, mixed well then swabs from the broth were placed on the surface of the culture and were left for 5–10 min to dry on the agar surface.
4. Sterilized forceps was used to put the control (0% of Cinnamon) and experimental disks (1%, 3% of Cinnamon) on the surface of agar

Fig. 1. (A) Philips Nano particles testing machine. (B) SEM picture shows Nano particles size of the Cinnamon.

plate.

5. The plate was inverted and incubated at 37 °C for 24 h.
6. The diameters of inhibition zone was measured in mm.³⁴

2.3. Fourier transformed infrared spectroscopy (FTIR)

Fourier transformed infrared spectroscopy was conducted to functional groups identification. The infrared spectra bands for Cinnamon Nano particles alone, orthodontic resin alone and for modified orthodontic adhesive after mixing and curing were assigned at the range of 400–4000 cm^{-1} . The measurements were done using FTIR spectrophotometer using Alfa Bruker Machine (Bruker, Germany) in the College of Dentistry, University of Mosul.

2.4. Shear bond strength measurement

Twenty human extracted upper premolars were used in this study. The teeth were sound, unrestored, without any carious, cracks or defects on the enamel surfaces. They were cleaned and stored in distilled water at room temperature.³⁵

The teeth were mounted in a cold cure acrylic resin using plastic cylindrical mold of uniform dimensions (Fig. 3). The crowns should be exposed for bonding.³⁴ Dental surveyor (Gerdent, Syria) was used for aligning the buccal surface of the teeth to be parallel to the force applied by shear testing machine. The samples were kept in distilled water at room temperature for 24 h.³⁵

Before bonding procedures, the buccal surface of each tooth was cleaned and polished by pumice and rubber prophylactic cups for 10 s.³⁵ Phosphoric acid gel (37%) was used for etching of the buccal surface of the premolar for 30 s, washed for 20 s, then air dried.³⁴ The brackets used were 0.022 stainless steel Mini Roth brackets of mesh (MSH ORTHO, China). The average surface area of the bracket was 14 mm^2 . These samples were divided into two equal groups:

- Unmodified resin as a control group in which the brackets were bonded with Heliosit Orthodontic composites without any modification.
- Cinnamon powder modified resin in a concentration of 3% wt/wt.

The required concentration of the Cinnamon modified resin was prepared at the time of bonding. Light cure for 20 s from the cervical and incisal surfaces of each bracket according to manufacture instruction. After bonding, the sample was kept in distilled water at room temperature for 24 h before shear bond testing.^{35,36}

All the samples were attached to the lower part of the universal testing machine (Sans, China) having a capacity of 1000 kN. The shear stress were tested by using a crosshead speed of 0.3 mm/min. The force of the machine was delivered perpendicularly to the bracket base by

Fig. 3. Tooth preparation and measurement of shear bond strength. (A) Tooth mounted in a cold cure acrylic resin using plastic cylindrical mold, (B) perpendicular force application to the bracket-tooth interface.

knife-edge rode producing a shear force at the bracket-tooth interface (Fig. 3). Electronic recording of the results of each test were done.^{35,36} The applied force at fracture time was recorded in Newton then it was converted into megapascals (MPa) by dividing the debonding force by the surface area of the bracket.^{37,38}

The amount of the residual adhesive remained on the enamel surface was quantified by the adhesive remnant index (ARI).³⁹

After debonding, the teeth were examined under 10 × magnifications microscope. The ARI scores ranged from 0 to 3 as follows:

- 1 No adhesive remained on the enamel surface.
- 2 Less than half of the adhesive remained on the enamel surface.
- 3 More than half of the adhesive remained on the enamel surface.
- 4 All the adhesive remained on the enamel with a bracket base impression.

After testing of data distribution, the independent t-test was used to assess the difference in shear strength between groups.

3. Results

3.1. Antimicrobial assessment

The results of the antimicrobial test showed that the experimental disks of both concentrations 1% and 3% Cinnamon powder modified resin had an effect against *S. mutans* by the presence of clear ring around the antimicrobial disks in the agar plate as shown in Table 1 and Fig. 4.

Control group had no antimicrobial effect, with no clear zone around the disk. The antimicrobial effect was increased with increase the zone of inhibition by increasing the concentration of the cinnamon from 1% to 3% for the Cinnamon powder modified resin.

3.2. Fourier transformed infrared spectroscopy

Fourier transformed infrared spectroscopy functional groups for Cinnamon Nano particles and orthodontic resin before mixing were measured (Figs. 5 and 6). By comparing the vibration frequencies before and after mixing and curing of FTIR spectrum of Cinnamon Nano particles, assigned bands from 3300 to 3200 cm^{-1} regions, The FTIR diagram also showed the presence of O-H stretch, H-bonded for alcohol and phenol at 2920–2850 cm^{-1} medium intensity(m) indicate C-H stretch for alkane. The absorbance band at 1667 cm^{-1} (m) indicated the presence of C=O bond for aldehyde. Due to the influence of conjugation and aromatic ring, the peak is wide than the normal cases of aldehyde compound. A strong absorption band at 1027 cm^{-1} confirmed the presence of aromatic C=C. A medium-weak band between 1680 and 1600 cm^{-1} showed the presence of alkenes C=C stretch. The FTIR spectra after mixing the Cinnamon Nano particles give similar and identical bands (Fig. 7).

3.3. Shear bond and adhesive remnant index

After establishing the antibacterial effects of the modified resin, we investigated the effect of the addition of cinnamon powder to orthodontic resin in the larger concentration (3% wt/wt) Cinnamon powder

Table 1

Bacterial inhibition zone of the control and Cinnamon powder modified resin groups.

Group	Bacteria inhibition zone
Control	0 mm
1% Cinnamon powder modified resin	2 mm
3% Cinnamon powder modified resin	25 mm

Fig. 4. Bacterial inhibition zone for 1% and 3% Cinnamon powder modified resin groups.

Table 2

Comparison of shear bond strength between the control and Cinnamon powder modified resin.

Study group	Mean	SD	T value	P value
Control	8.50	1.66	1.22	0.256
Experimental	7.20	1.68		

Measurement in MPa, *Significant, $p < 0.05$.

resin on shear bond strength of metal orthodontic brackets.

Although the mean of control group (8.50 MPa) was higher than that of the experimental group (7.20 MPa), no significant difference was recorded in shear bond strength as shown in Table 2. Moreover, no significant difference was recorded in ARI between the study groups as p value was 0.242.

4. Discussion

Enamel demineralization around the orthodontic brackets still represents one of the problems associated with orthodontic treatment.⁴⁰ Among several causative bacteria, *S. mutans* has been proven to be one of the corresponding species of carious lesion.⁴¹ In this study, the researchers tried to combine the benefits of the antimicrobial activity of Cinnamon and the nanotechnology to work as a preventive measure in carious control.

Zainal-Abidin et al.⁴² recorded that the minimal inhibitory concentration of Cinnamon oil against major oral pathogens responsible about caries and periodontal diseases was 0.21–0.63 mg/mL. Also, the minimum bactericidal concentration of cinnamaldehyde against *S. mutans* was recorded to be 0.2% (v/v).⁴³ So that, the tested Cinnamon concentration in this study was among these ranges (1%, 3% and 5% wt/wt). Cinnamon concentration of 0.5% wt/wt was excluded from this study as it showed partial setting of the orthodontic resin after light curing.

Disc diffusion method was used to assess the antimicrobial effect of the 1% and 3% wt/wt cured modified resin. The results showed that 3% wt/wt was more effective more than 1% with larger zone of inhibition. For that reason, only 3% concentration was tested for the shear bond strength.

The Cinnamon modified resin was dark in color, this property gives the material two advantages: This dark color facilitate the removal of any excess material from the bracket borders during bracket positioning, also, facilitate the removal of any composite from the tooth surface in bracket removal when used in patients in addition to that this material will be behind the bracket which is invisible.

In current study, although the shear bond strength of the modified resin was smaller than control, the difference was not statistically significant. Furthermore, the value of the bond strength was higher than the 6 MPa that recommended for orthodontic purposes.⁴⁴

Our results are in agreement with studies that found that no significant effect for the incorporation of various products such as benzalkonium chloride or monomer 2-methacryloxyethyl hexadecyl methyl ammonium bromide on shear bond strength of orthodontic brackets.^{34,39} Also, our results are in agreement with Sehgal et al.³⁵ who modified the orthodontic composite by the incorporation of

Fig. 5. Cinnamon Nano particles before mixing.

Fig. 6. Orthodontic resin before mixing.

benzalkonium chloride, chlorhexidine, and triclosan.

The antimicrobial activity of Cinnamon is due to the presence of several compounds such as cinnamaldehyde (50.5% of Cinnamon bark), eugenol (4.7%), benzoic acid, benzaldehyde and cinnamic acid as the effect of these compounds is responsible for its antimicrobial property.^{45–48} These compounds are known to be either bactericidal or bacteriostatic agents, depending upon concentration used.⁴⁹

Although the incorporation of Cinnamon Nano particles in orthodontic resin brings active antimicrobial properties against *S. mutans*, we should not overlook the possible adverse effects on the mechanical properties of this modified resin. This study revealed that incorporation of 3% cinnamon Nano particles to orthodontic resin produce an antibacterial effect against cariogenic bacteria without compromising the

shear bond strength. Further studies are indicated to investigate the release ability of this modified resin as the antibacterial materials could be divided into two types: agent-releasing and non-agent-releasing antibacterial materials.³⁹ Also, the clinical application of this modified resin, its effect on the brackets bonding in vivo and the long-term anti-cariogenic effect should be investigated.

5. Conclusions

1. The incorporation of 3% Nano particles Cinnamon powder in the orthodontic composite resin enhanced its antimicrobial properties without compromising the shear bond strength of orthodontic brackets.

Fig. 7. Orthodontic resin with Cinnamon Nano particles.

- The FTIR measurements indicated no any chemical reaction between cinnamon powder and the composite, before and after curing.

Funding

No Funding was received.

Ethical approval

The ethical approval was released by the academic authorities that represented by the College of Dentistry, University of Mosul in 2018. This article does not contain any studies with human participants or animals performed by any of the authors.

Informed consent

For this type of study, formal consent is not required.

Declaration of competing interest

Saba N Yaseen declares that she has no conflict of interest. Amer A. Taka declares that he has no conflict of interest. Ali R. Al-Khatib declares that he has no conflict of interest.

Acknowledgement

The authors wish to express their gratitude to College of Dentistry, University of Mosul for providing all necessary assistance that helped them to conduct this research. Also, our thanks have been send to Mr. Arjuan Mohamad form Department of Dental Basic Science in College of Dentistry, University of Mosul for his help in this study.

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