

Shear Bond Strength of Orthodontic Primer and Adhesive Composite Containing Silver Nanoparticles

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Abstract

Objective: The objective of this study is to evaluate the shear bond strength (SBS) of orthodontic primer and composite containing various concentrations of silver nanoparticles (Ag NPs).

Materials and Methods: Sixty newly extracted premolars were divided into three groups of two different concentrations (1% w/w and 5% w/w). The nanoparticles were incorporated into orthodontic primer and composite known as nano primer group, nanocomposite group, and nano combination group, where both nano primer and nanocomposite used for bonding the 0.022 SS brackets. An Instron - universal testing machine was used to measure shear bond strength (SBS). The data were analyzed by SPSS software, and then, the normal distribution of the data was confirmed by one way ANOVA test and Tukey’s post hoc procedures were used to compare between groups.

Results: 1% w/w and 5% w/w nanocomposite group ($19.11 \pm 2.816, 13.91 \pm 2.21$) had higher shear bond strength values than the nano primer group ($11.52 \pm 1.862, 8.44 \pm 1.98$) and nano combination group ($8.26 \pm 1.257, 6.86 \pm 1.50$). There is a statistically significant difference found between the groups.

Conclusion: Incorporation of various concentrations of silver nanoparticles (Ag NPs) into adhesive materials that the concentration of Ag NPs is inversely related to the mechanical properties of the adhesive system, i.e., as the concentration of Ag NPs increases there is a decrease in SBS.

Keywords: Adhesive, primer, nanoparticles, shear bond strength

Introduction

Enamel demineralization is a commonly recognized complication of orthodontic treatment with fixed appliances that reduce the self-cleaning capacity of the tooth surface.^{1,2} Fixed orthodontic attachments act as a

retentive area for plaque accumulation, causing a rapid shift in the bacterial microflora of plaque resulting in elevated levels of acidogenic bacteria, most notably *Streptococcus mutans* and *Lactobacillus*.³ Decalcification occurs when specific bacteria are retained on the enamel surface for an extended period and produce organic acids;

These lesions are prevented by educating and motivating the patient to perceive good oral hygiene. Also, oral prophylaxis should be carried out with topical fluoride. Other materials and methods, including CPP-ACP, antiseptics, probiotics, polyols, sealants, etc.⁴ The use of specific nanoparticles (NPs) as antimicrobial agents has attracted much attention in the field of dentistry. They are the new strategy for treating and preventing dental infections. The physicochemical nature of NP's enables them to interact with the negatively charged surface of bacterial cells to a greater extent resulting in enhanced antibacterial activity.⁵ *Streptococcus mutans* are sensitive to nanoparticles of silver, zinc oxide, and gold, titanium, which allows achieving critical clinical effects.⁶

Silver nanoparticles (NPs) have distinctive characteristics, I.e., high chemical stability, and photostability makes them easy to be synthesized and manipulated. Biocompatibility makes them nontoxic for the organism that make them a possible choice to be used as fillers for dental nanocomposite.⁷

Akhavan et al.⁸ in stated that the addition of 1% nano-silver into the primer leads to an increase in bond strength, and increasing the concentration of NPs showed a decrease in the bond strength. However, the results were antagonist to the results obtained by G Salem et al.[1] so in the present study 1% (w/w) and 5%(w/w) concentration of silver nanoparticles were

added to the orthodontic primer and adhesive to investigate their influence on shear bond strength(SBS). Accordingly, the development of clinically acceptable orthodontic adhesives with additional antimicrobial features could be undertaken if their mechanical properties have also been considered. It is essential to obtain a reliable adhesive bond between an orthodontic attachment and the tooth enamel. so it may seem valuable to assess adding nanoparticles to the adhesive system and evaluate their effect on the shear bond strength of orthodontic brackets to the enamel.⁹

Therefore the goal of this in vitro study was to evaluate the shear bond strength(SBS) after incorporation of different concentrations of silver nanoparticles in either orthodontic primer, adhesive, or combination of both used for bonding the brackets.

Materials and Methods

Sixty newly extracted premolars were collected and stored in distilled water until the start of the study. The criteria for tooth selection were anatomically and morphologically well-defined premolars with an intact buccal surface, and the teeth with enamel cracks, caries, restorations, and fluorosis teeth were excluded from the study.

The materials and equipment used in the study are listed in Table 1.

Table 1: Materials and equipment used in the study are

Materials	Manufacturer
Conventional composite	Enlight,Ormco Crop, CA
Stainless steel premolar orthodontic brackets - MBT 0.022 slot	Ortho Organizers, Di-MiM, Mini -Twin
Etachent (37% phosphoric acid)	Eazetech, Anabond

Orthodontic Primer	Orthosolo, Ormco, CA
Titanium oxide nanoparticles (Anatase, Dry Powder form, Average particle size: 20-30nm Purity: 99.9%)	Nano Research Lab, Jamshedpur, Jharkhand-832102, India.
Silver nanoparticles (Dry Powder form, Average particle size: 30-50nm Purity: 99.9%)	Nano Research Lab, Jamshedpur, Jharkhand-832102, India.
Extracted premolar teeth	
Equipment	Manufacturer
Composite mixer	High energy ball mill (RETSCH-EMAX).
Scanning Electron Microscope	JEOL JSM-881 OSV.
Universal testing machine	INSTRON model-8801
Calibrated pipette	
Centrifuge machine	
Stereomicroscope	

Silver nanoparticles were incorporated into either the adhesive or primer, and the newly prepared bonding system is known as experimental composite.

A. Nanocomposite preparation

1% and 5% by weight of silver nanoparticles were used for the study. This was measured by using a digital weighing machine for the fabrication of composite containing different concentrations of nanoparticles.

To achieve 1% (w/w) concentration 20 mg of nanoparticles was added to 2000 mg of orthodontic adhesive (Enlight, Ormco Crop, CA) and blended by

using a composite mixer (HIGH ENERGY BALL MILL) at a speed of 3500 revolutions per minute(RPM) in dark environment for 5min.

To achieve 5% (w/w) concentration 100 mg of nanoparticles was added to 2000 mg of orthodontic adhesive (Enlight, Ormco Crop, CA) and blended by using a composite mixer (HIGH ENERGY BALL MILL) at a speed of 3500 revolutions per minute(RPM) in dark environment for 5min.

B. Nanoprimer preparation

1% and 5% (w/w) concentrations of nanoparticles were added to every 1mm of the primer using a pipette and mixed using centrifuge mixer at a speed of 500 rpm for 2min.

A scanning electron microscope (SEM) examination was performed on the nanocomposite and nano primer to check the uniform distribution of the nanoparticles within the composite paste and primer.

C. Sample preparation

The extracted teeth were mounted in self-polymerizing acrylic resin poured in PVC tubes. The teeth were embedded in the acrylic vertically, with an only crown portion exposed till CEJ. The buccal enamel surfaces of the teeth were cleaned and polished with non-fluoridated pumice, and prophylactic rubber cups washed with water and air-dried. The mounting blocks were divided into nanocomposite group, nano primer group, nano combination group as following

Ag NPs in adhesive system used for bonding	Experimental composite group
Orthodontic composite	Nanocomposite
Orthodontic primer	Nano primer
Both composite and primer	Nano combination

D. Bonding procedure

After cleaning the enamel surface with prophylaxis paste, the labial enamel surface was etched for 30 s with a 37% phosphoric acid gel rinsed with a water syringe for 20 s and dried thoroughly at least for 10s until the chalky white appearance was observed. A thin coat of primer was applied with an applicator brush and light-cured for 15 s then orthodontic adhesive was applied to the bracket base and pressed onto the enamel surface, and excessive adhesive was removed before polymerization, which was conducted for 20 s each from the mesial and distal sides.

Nano primer group: 1% (w/w) silver primer mixture, 5% (w/w) silver primer mixture were used instead of the conventional primer for bonding.

Nanocomposite group: 1% (w/w) silver adhesive mixture, 5% (w/w) silver adhesive mixture, were used instead of the conventional composite for bonding.

Nano combination group: 1% (w/w) silver mixture, 5% (w/w) silver mixture was used instead of the conventional primer and composite for bonding.

E. Shear bond strength test

After the bonding procedure, all the samples from each of the four categories were stored for 72 hours in distilled water before subjected to a shear bond strength test using a Universal Testing Machine (Instron machine, model-8801). An occlusal-gingival load was applied as close to the bracket-tooth interface with the help of a chisel attached to the crosshead of the Universal testing machine. Testing was performed at a crosshead speed of 1mm/minute. The force required to shear the bracket causing bond failure was recorded in Mega Pascals(MPa).

Results

Descriptive statistics including the mean, standard deviation, minimum and maximum values for the

different tested groups are presented in Table 2. From the results of Table 3, it can be seen that a statistically significant differences in bond strength among the various groups ($p < 0.001$). The results demonstrated that in 1% w/w concentration of silver nanoparticles the nanocomposite group had higher shear bond strength values than the nano primer group and nano combination group. There is a statistically significant difference found between the groups.

Table 2: Mean, standard deviation and 95% confidence interval for mean of SBS

1%(w/w) silver nanoparticles

		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean	
						Lower Bound	Upper Bound
1%	Nano composite	20	19.11	2.816	.891	17.09	21.12
1%	Nano primer	20	11.52	1.862	.589	10.18	12.85
1%	Nano combination	20	8.26	1.257	.398	7.36	9.16
Total		60	12.96	5.040	.920	11.08	14.84

Table 3: Comparison of groups with shear bond strength by one-way analysis of variance.(1%w/w Ag NPs)

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	619.882	2	309.941	71.636	.0001*
Within Groups	116.819	27	4.327		
Total	736.701	29			

* $p < 0.001$

In 5% w/w concentration of silver nanoparticles the mean, standard deviation and 95% confidence interval for mean of SBS represented in Table 4. from the

results of Table 5, that a significant difference was observed between the groups. The nanocomposite group had higher shear bond strength values than the nano primer group and nano combination group. No statistically significant differences were found between the nano primer and nano combination groups.

Table 4: Mean, standard deviation and 95% confidence interval for mean of SBS

5% silver nanoparticles

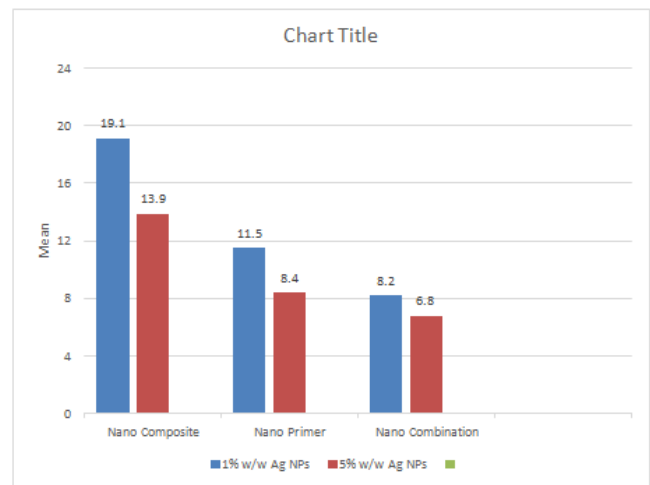
	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean	
					Lower Bound	Upper Bound
5% si comp	20	13.9140	2.21747	.70123	12.3277	15.5003
5% si primer	20	8.4490	1.98583	.31175	7.7438	9.1542
5% si both	20	6.8670	1.50956	.47736	5.7871	7.9469
Total	60	9.7433	3.45883	.63149	8.4518	11.0349

Table 5: Comparison of groups with shear bond strength by one-way analysis of variance.(5% w/w Ag NPs)

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	273.431	2	136.715	50.215	.0001*
Within Groups	73.510	27	2.723		
Total	346.941	29			

*p<0.001

The graph 1 shows the mean SBS of all the groups, 1% w/w concentration of silver nanoparticles is found to be the highest when compared to 5% w/w concentration. It denotes that as the concentration of silver nanoparticles increases, there is a decrease in shear bond strength of the experimental composite.



Graph 1: Comparison between mean shear bond strength of 1% and 5% w/w concentration of Ag NPs.

Discussion

Buonocore introduced the concept of the acid-etch technique, and bonding of the Orthodontic brackets by G.V.Newman has changed the practice of orthodontics.¹⁰ However, it also associates risks and complications of fixed appliance therapy, which leads to plaque accumulation, Orthodontic brackets can also play a crucial role in enamel demineralization because they provide additional adhesion sites for pathogenic bacteria.¹¹

Previous studies^{12, 13} have confirmed that the application of silver nanoparticles is increasingly growing in orthodontic material and has shown significant effects in terms of antibacterial properties. Although the addition of silver nanoparticles to resin composite brings about excellent antibacterial properties, the possible adverse effects on mechanical features should not be overlooked.

Reddy et al.¹⁴ concluded that the incorporation of nanoparticles into adhesive materials, even in minimal amounts, can affect the SBS, which may lead to the failure of bracket or adhesive. On the other hand, studies conducted by Blocher S et al.¹³ and Miresmaeili A et al.¹⁵ found that the addition of a small

concentration of nanosilver particles into the orthodontic primer did not affect the SBS.

In the present study, 1% w/w and 5% w/w concentrations of nanosilver particles were mixed in adhesive and primer to evaluate the effect on SBS of experimental composite used for the bonding, I.e., nanocomposite, nano primer, nano combination. The incorporation of silver nanoparticles reduces the shear bond strength but is within the clinically acceptable figure (6-8 Mpa), according to Reynolds et al.¹⁶

From the results, the nanocomposite group showed the highest SBS than nano primer and nano combination groups. This was in accordance with Salem G et al.¹

In accordance with the results of the previous studies conducted by Akhavan et al.⁸ and Naslapur et al.¹⁷ stated that the increase in the concentration of nanoparticles, there is a decrease in bond strength. There was a significant reduction in the SBS nano primer group due to an agglomeration of particles, creating defect points, and interfering with the curing process. Further investigations are undoubtedly required to investigate the biological effects of adding such amounts and the need for in vivo studies since laboratory conditions do not exactly reproduce oral conditions.

Conclusion

1) The nanocomposite shows the highest SBS than nano primer and nano combination groups but demonstrated SBS, which were within the range of clinically acceptable range.

2) Concentration of Ag NPs is inversely related to the mechanical properties of adhesive system I.e, as the concentration of Ag NPs increases there is a decrease in SBS.

3) There is a statistically significant decrease in bond strength on the Incorporation of Ag NPs in the orthodontic primer.

Abbreviations

SBS-Shear bond strength

NPs- Nanoparticles

Ag NPs- Silver nanoparticles

SS- Stainless Steel

ANOVA- Analysis of variance

SPSS- Statistical Package for the Social Sciences

W/W- Weight concentration

RPM-Revolutions Per Minute

SEM-Scanning Electron Microscope

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