

Review Article

Evaluation of the effect of antimicrobial nanoparticles on bond strength of orthodontic adhesives: A review article

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ABSTRACT

Background: Antimicrobial nanoparticles (NPs) have various applications in different fields of dentistry. The purpose of incorporating NPs into orthodontic adhesives is to inhibit the cariogenic bacteria and reduce decalcifications around bonded orthodontic brackets. However, they may affect the physical and mechanical properties of adhesive such as shear bond strength (SBS). This review was done to answer the question whether the incorporation of antimicrobial NPs into orthodontic adhesives changes the SBS.

Materials and Methods: An electronic search was performed with keywords such as adhesives AND nanoparticles AND orthodontics AND shear strength. After screening and applying eligibility criteria, 18 relevant studies were included.

Results: The pooled data suggest that except for 10 wt% of various NPs incorporation, there is no significant difference in SBS between control conventional adhesives and experimental modified ones with tested concentrations.

Conclusion: The SBS of orthodontic adhesives containing up to 5% NPs is in clinical acceptable range. However, generalizing the results to *in vivo* situation may be problematic and further studies are required.

Key Words: Adhesives, nanoparticles, orthodontics, shear strength

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INTRODUCTION

Nanotechnology has been used for different medical purposes such as drug delivery and antimicrobial properties.^[1-3] Nanomaterials are usually solid particles with a diameter of 1–100 nm, which are useful in antibacterial field because of their characteristics such as small sizes, large surface-to-volume ratio, and high chemical reactivity.^[4] The high charge density of nanoparticles (NPs) causes interaction with the negatively charged surface of bacterial cells, which results in antimicrobial activity.^[5] Application of

nanomaterials in devices also causes improving the mechanical strength and efficiency of the systems.^[6,7]

Organic and inorganic (metal) NPs such as gold (Au) and silver (Ag) and oxide particles such as zinc oxide (ZnO) and titanium dioxide (TiO₂)^[8,9] have wide usage in various fields of dentistry such as endodontics, restorative dentistry, and orthodontics.^[10,11] Bonding brackets with composite as an adhesive has been widely used in orthodontics. Unfortunately, despite many advantages,

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there are some problems with bonding technique such as debonding and demineralization around the brackets as a result of plaque formation.^[12-14] An ideal bond strength prevents brackets from debonding during treatment, and it is not that high to cause tooth cracks during debonding.^[15] Some factors including enamel conditioning techniques, adhesive systems, and design of the bracket base have been discussed to have effects on the bond strength.^[16,17] Studies have reported that decalcification of dental surfaces occurs in about 50% to 75% of patients during fixed orthodontic treatment.^[18,19] Maintenance of appropriate oral hygiene is problematic with fixed orthodontic appliances. They increase plaque formation and consequently white spot lesions around brackets, which increases the risk of caries.^[20-22] In the oral cavity, combination of dental materials with NPs or coating surfaces with NPs are two mechanisms to reduce microbial adhesion.^[23] Incorporating NPs to composite resins is found not only to have specific chemical and biological properties, such as the antibacterial effects, but also may affect their physical and mechanical features.^[24] It is important not to change the shear bond strength (SBS) adversely, which will affect the clinical performance. Thus, this study aimed to review the published articles on the effects of adding antimicrobial NPs on bond strength of orthodontic adhesives.

MATERIALS AND METHODS

First, we defined a specific research question considering PICO format as shown in Table 1. To collect data, the following electronic databases were searched: EMBASE, SCOPUS, and MEDLINE from 2005 to March 2021. The keywords used in the search process were “orthodontics,” “nanoparticles,” “adhesives,” and “shear strength.” The collected articles were screened, assessed for eligibility, and included in the review process as shown in Figure 1. In details, the following inclusion criteria were applied for selection: (1) articles written

Table 1: Population, intervention, control, and outcomes format

PICO items	Description
Population	Orthodontic adhesives
Intervention	Incorporation of antimicrobial nanoparticles
Comparison	Shear bond strength
Outcome	Affects the SBS beyond the acceptable range or not

SBS: Shear bond strength

in English, (2) *in vitro* studies, and (3) articles indicating SBS of orthodontic adhesives modified with antimicrobial NPs. The exclusion criteria were (1) articles discussing the primer or bonding agent of orthodontic adhesives, orthodontic cements, or other composite resins; (2) articles evaluating orthodontic adhesives containing other antimicrobial agents; and (3) studies experimenting nanofilled orthodontic adhesives. The duplicate records and review articles were also excluded. The authors reviewed the titles and abstracts. Then, the full texts of the selected ones were screened. The information of accepted ones was summarized and classified based on data collection forms with titles: first author, publication year, type of incorporated NPs, sample volume, tested concentrations of NPs, and clinical acceptable SBS.

RESULTS

According to the flow diagram in Figure 1, a total of 97 articles were identified through electronic database searching. Following duplicate removal, screening the title/abstracts, and applying eligibility criteria, 18 studies were included [Table 2]. 12 studies used human premolars, 5 used bovine incisors, and 1 study chose human molars to test the SBS of orthodontic adhesives.

For the evaluation of the effects of TiO₂ incorporation, four articles were collected. They reported that except for 10%, the other tested concentrations had no adverse effects on SBS. Four researches evaluated the effect of silver (Ag) NPs and reported that addition of small concentrations of Ag NPs (up to 1%) does not affect the SBS negatively. To evaluate each of copper (Cu),

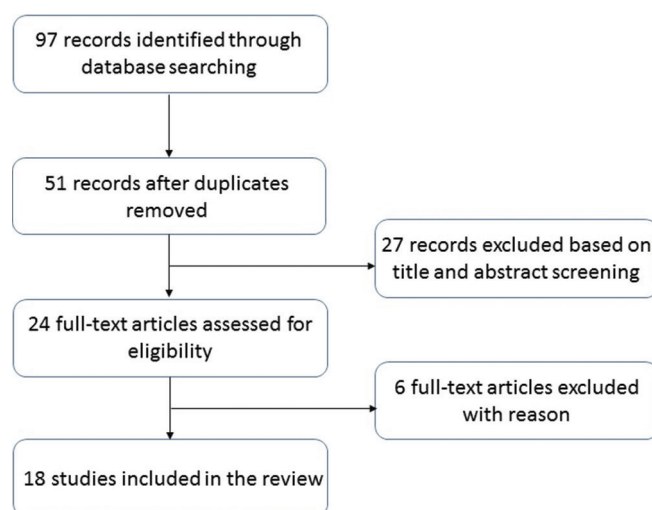


Figure 1: Flow diagram.

Table 2: Studies evaluating antimicrobial nanoparticles on shear bond strength of orthodontic adhesives

Author	Year	Type of Np*	Sample volume	Weight% of Np	Clinical acceptable SBS?
Ahmadi <i>et al.</i> ^[25]	2020	Cur-PLGA	50 human premolars in 5 groups of 10	0	Yes
				3	Yes
				5	Yes
				7	Yes
				10	No
Yaseen <i>et al.</i> ^[26]	2020	Cinnamon	20 human premolars in 2 groups of 10	0	Yes
				3	Yes
Eslamian <i>et al.</i> ^[27]	2020	Ag	34 human premolars in 2 groups of 17	0	Yes
				0.3	Yes
Assery <i>et al.</i> ^[28]	2019	TiO ₂	90 human premolars in 3 groups of 30	0	Yes
				1	Yes
				3	Yes
				5	Yes
Sodagar <i>et al.</i> ^[29]	2019	Propolis	60 bovine incisors in 5 groups of 12	0	Yes
				1	Yes
				2	Yes
				5	Yes
				10	No
Pourhajibagher <i>et al.</i> ^[30]	2019	Cur-ZnO	60 human premolars in 6 groups of 10	0	Yes
				1.2	Yes
				2.5	Yes
				5	Yes
				7.5	Yes
Behnaz <i>et al.</i> ^[31]	2018	TiO ₂	120 human premolars in 4 groups of 30 (with 2 composite brands)	0	Yes
				0.1	Yes
Toodehzaeim <i>et al.</i> ^[32]	2018	CuO	40 human premolars in 4 groups of 10	0	Yes
				0.01	Yes
				0.5	Yes
Sodagar <i>et al.</i> ^[33]	2017	TiO ₂	48 bovine incisors in 4 groups of 12	1	Yes
				0	Yes
				1	Yes
				5	Yes
Felemban and Ebrahim ^[34]	2017	ZrO ₂ -TiO ₂	30 human premolars in 3 groups of 10	10	No
				0	Yes
Zaltsman and Kesler Shvero ^[35]	2017	QPEI	21 human molars in 3 groups of 7	0.5	Yes
				1	Yes
				0	Yes
Degrazia <i>et al.</i> ^[36]	2016	Ag	48 bovine incisors in 4 groups of 12	1	Yes
				0	Yes
				0.11	Yes
				0.18	Yes
Sodagar <i>et al.</i> ^[37]	2016	Cur	48 bovine incisors in 4 groups of 12	0	Yes
				1	Yes
				5	Yes
				10	No
Argueta Figueroa <i>et al.</i> ^[38]	2015	Cu	60 human premolars in 2 groups of 30	0	Yes
				0.01	Yes
Blöcher <i>et al.</i> ^[39]	2015	Ag	Bovine incisors in groups of 16	0	Yes
				0.11	Yes
				0.18	Yes
				0.33	Yes

Contd...

Table 2: Contd...

Author	Year	Type of Np*	Sample volume	Weight% of Np	Clinical acceptable SBS?
Akhavan <i>et al.</i> ^[40]	2013	Ag-HA	48 human premolars in 4 groups of 12	0	Yes
				1	Yes
				5	Yes
				10	No
Poosti <i>et al.</i> ^[41]	2012	TiO ₂	30 human premolars in 2 groups of 15	0	Yes
				1	Yes
Ahn <i>et al.</i> ^[42]	2009	Ag	Human premolars in groups of 17	0	Yes
				0.025	Yes
				0.05	Yes

Np: Nanoparticle; Cur: Curcumin; Cur-PLGA: Cur-poly lactic-co-glycolic acid; TiO₂: Titanium dioxide; Cur-ZnO: Cur- zinc oxide; CuO: Copper oxide; ZrO₂: Zirconium oxide; QPEI: Quaternary ammonium polyethyleneimine; Cu: Copper; Ag: Silver; Ag-HA: Silver hydroxyapatite; SBS: Shear bond strength

copper oxide (CuO), curcumin (Cur), cinnamon, quaternary ammonium polyethyleneimine (QPEI), propolis, zirconium oxide-TiO₂ (ZrO₂-TiO₂), curcumin-ZnO, curcumin-poly-lactic-co-glycolic acid, and silver-hydroxyapatite (Ag-HA) NPs, one study was found and their results reported that the SBS of adhesives containing these tested NPs up to 5% was in acceptable clinical range (5.9–7.8 MPa as suggested by Reynolds).^[43]

DISCUSSION

The aim of antimicrobial NP incorporation in orthodontic adhesives is to reduce the microbial load in orthodontic patients, but they should not have adverse effects on adhesive SBS. This review article was performed to answer the question whether the combination of antimicrobial NPs with orthodontic adhesive compromises its SBS.

Based on the pooled data, incorporating up to 1 wt% Ag NPs maintained the SBS of orthodontic adhesives at acceptable level.^[26,35,38,41] Yaseen *et al.*^[25] evaluated addition of 3% nano-cinnamon and reported no adverse effects on SBS. Similarly, both tested concentrations of QPEI (1% and 1.5%)^[34] revealed no significant difference in SBS compared to unmodified orthodontic adhesives as control group.

Addition of different percentages of ZrO₂-TiO₂ (0.5, 1 wt%),^[33] Cu (0.01 wt%),^[37] and CuO (0.01, 0.5, and 1 wt%)^[31] was shown to have not only adverse effects on SBS but also increased it.

The results of the study by Sodagar *et al.*^[29] on propolis NPs in 1%, 2%, 5%, and 10% wt/wt concentrations showed that incorporation of nano-propolis at the first three concentrations maintained the SBS within the acceptable clinical range. However, the 10% propolis NPs group had a significantly lower SBS, which was

not recommended for clinical use. These results were in agreement with the results of the study done by Akhavan *et al.*^[40] They stated that incorporation of 1% and 5% Ag-HA NPs maintained and increased the SBS of orthodontic adhesives, but the concentration of 10% had negative effect on it when compared to control group. Similar results were obtained in the study conducted by Flemban *et al.* on experimenting these three concentrations of ZrO₂-TiO₂.^[34] Similarly, in three other separate studies, Sodagar *et al.* compared the adhesives with 1%, 5%, and 10% Cur^[37] and TiO₂^[32] NPs and showed that mean shear bonds of composite containing 1% and 5% NPs were still in acceptable range. Based on Assery *et al.*'s^[28] study results, adhesive with 1% TiO₂ offered the highest SBS followed by 3% TiO₂ Np and the control group of nonreinforced resin composite had the lowest SBS. However, both groups had acceptable clinical SBS. Behnaz *et al.*^[31] also reported that the addition of TiO₂ NPs might decrease SBS, but the adhesion may still be in an acceptable range. Poosti *et al.*^[41] showed equal SBS in the composite containing 1% TiO₂ NPs and the control group.

In all these studies, the SBS was evaluated in an *in vitro* environment. However, the forces may be different in oral cavity. There are various types of forces and tensions such as microbial plaque, temperature changes, and humidity *in vivo*, which causes the *in vitro* results to be interpreted carefully.^[44] It is also recommended to assess the toxicity and biocompatibility of NPs with different concentrations in future studies.

CONCLUSION

Overall, the review of *in vitro* articles showed no significant difference among SBS of orthodontic adhesives with antimicrobial NPs and unmodified

conventional orthodontic adhesives. To summarize, incorporation of all types of tested NPs up to 5 wt% offered clinically acceptable SBS.

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Conflicts of interest

The authors of this manuscript declare that they have no conflicts of interest, real or perceived, financial or non-financial in this article.

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