



## Literature Review

# The Potential Effect of Silver Nanoparticles to Inhibit Microbial Activity in Orthodontic Adhesive Appliances: A Literature Review

Nur Masita Silviana<sup>1\*</sup>, Safira Fariha<sup>2</sup>, Shevya Nanda Indika Permata<sup>2</sup>, Tasya Safina Utomoputri<sup>2</sup>,  
Thessalonica Pramadita<sup>2</sup>, Zefanya Nicko Sukadi<sup>2</sup>, Lulu Hasnadianti Putri<sup>2</sup>

<sup>1</sup>Department of Orthodontics, Faculty of Dentistry, Universitas Brawijaya, Malang, Indonesia

<sup>2</sup>Faculty of Dentistry, Universitas Brawijaya, Malang, Indonesia

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## Abstract

Silver nanoparticles have been the focus of research in various areas of dentistry, including orthodontics. Orthodontic treatment requires a long period of time, so the brackets are in the oral cavity for a long time. This can potentially trigger the formation of white spot lesions because plaque sticks more easily to the surrounding enamel. Using silver nanoparticles mixed with orthodontic adhesives has been reported to increase antibacterial and antimicrobial characteristics. This literature review aims to investigate the effect of adding silver nanoparticles to orthodontic adhesive devices in inhibiting antimicrobial activity. This study method was carried out by searching the online electronic databases PubMed, Science Direct, and Google Scholar with the keywords "silver nanoparticles AND antimicrobial", "silver nanoparticles AND orthodontic adhesive", "silver nanoparticles AND composite resin", which is an original article published the year 2019- 2023. The results of research from 10 articles that met the inclusion criteria showed that orthodontic adhesives with silver nanoparticles effectively inhibited microbial activity, such as *Streptococcus mutans* (*S.mutans*), *Lactobacillus acidophilus* (*L.acidophilus*), *Streptococcus sanguinis* (*S.sanguinis*) and *Candida albicans* through increased release of Ag<sup>+</sup> ions. Silver has been known to have effects, including producing minimal bacterial resistance compared to antibiotics. Even though it results in a decrease in the shear bond strength (SBS), the decrease level is still within clinically tolerable limits. It can be concluded that research needs to continue to be developed to obtain the right concentration and composition of the addition of silver nanoparticles so that an orthodontic adhesive material is obtained that is not only superior in its antibacterial properties but also in its mechanical properties.

**Keywords:** antimicrobial; orthodontic adhesive; silver nanoparticle; resin composite

## INTRODUCTION

In recent years, orthodontic treatment has become increasingly popular because it can improve dental function and facial appearance. Using orthodontic brackets requires a strong attachment to tooth enamel to achieve the therapeutic goals of orthodontic treatment. The attached bracket can become an area that increases plaque buildup and makes it difficult to clean the bond area, causing enamel demineralization.<sup>1</sup> Demineralization that occurs on the tooth

surface causes the formation of white spot lesions (WSLs), which can result in caries.<sup>2</sup> Prevalence of patients undergoing orthodontic treatment The incidence of WSLs can reach more than 60%.<sup>3,4</sup> Several strategies have been tested to minimize the occurrence of WSLs, including improved oral hygiene, dietary modification, and topical fluoride application. However, this is promising because it cannot rely only on patient compliance.<sup>5</sup>

The increasing popularity of nanotechnology in clinical dentistry today,

\* Corresponding author, e-mail: [nurmasita.fk@ub.ac.id](mailto:nurmasita.fk@ub.ac.id)

combined with its particular antibacterial properties is fueling its application in orthodontic materials. Contemporary approaches primarily investigate the impact of antibacterial carriers incorporated into orthodontic adhesives or cements or used to coat orthodontic appliances to suppress bacterial accumulation, thereby anticipating the formation of WSLs.<sup>5</sup> If a material for attaching brackets with nanotechnology could be found that could prevent bacterial growth, then the patient cooperation required for oral hygiene may be reduced.

Silver nanoparticles (AgNPs) have been introduced as antimicrobial agents. Microbial cell death occurs due to the formation of reactive oxygen on the surface of AgNPs or through the release of free silver ions (Ag<sup>+</sup>). AgNPs have attractive properties such as chemical stability, catalytic activity, and high conductivity. The surface of AgNPs has reactive oxygen or the release of free silver ions can cause microbial cell death through cell membrane disruption and DNA modification; thus, imparting antibacterial and antifungal properties to silver nanoparticles. Silver nanoparticle material became a discovery when used in orthodontic adhesives by adding silver nanoparticles with unique antibacterial characteristics.<sup>5</sup> AgNPs have antibacterial capabilities against gram-negative and positive bacteria, including strains resistant to several drugs.<sup>6</sup> This literature review study aims to determine how adding silver nanoparticles to orthodontic adhesive devices inhibits

microbial activity, especially in the oral cavity.

## **MATERIALS AND METHODS**

Literature search to obtain information on several online electronic databases PubMed, Science Direct, and Google Scholar with the keywords "silver nanoparticles AND antimicrobial", "silver nanoparticles AND orthodontic adhesive", "silver nanoparticles AND composite resin". The inclusion criteria in the literature search were original articles in English, the publication year 2019-2023, full access, full text, international scale scientific articles, and results related to the application of silver nanoparticles to orthodontic adhesives as an antimicrobial agent. Meanwhile, the exclusion criteria are scientific articles, literature reviews, and systematic reviews, which have unrelated variables and explanations. Several articles were excluded with certain considerations, namely articles not included in the inclusion criteria and did not specifically discuss the application of adding silver nanoparticles to orthodontic adhesives as an antimicrobial agent. After review, 10 articles met the criteria.

## **RESULT**

After a literature search was carried out and then linked to the inclusion/exclusion criteria, 10 articles were taken that met the criteria. Table 1 highlights the main findings of the included studies.

**Table 1.** Antimicrobial Effect of Silver Nanoparticles in Orthodontics Adhesive

Author (year)	Title	Study Design	Name of Bacteria	Result
Tristan-Lopez J et al. (2023). <sup>7</sup>	“Application of Silver Nanoparticles to Improve the Antibacterial Activity of Orthodontic Adhesives: An In Vitro Study”	The study used 180 human premolars and metal brackets. Divided into groups: commercial adhesives and adhesives with AgNPs with a diameter of 11 nm and dispersed in water at 535 µg/mL.	Streptococcus mutans, Lactobacillus acidophilus	Test results using the standard microdilution method of AgNPs added to orthodontic adhesives, both hydrophilic and non-hydrophilic, maintain the quality of their mechanical properties while increasing their antibacterial effectiveness against strains relevant to the formation of WSL.
Bahador A et al. (2020). <sup>8</sup>	“Antimicrobial Efficacy of Silver Nanoparticles Incorporated in an Orthodontic Adhesive: An Animal Study”	The study was conducted using twenty-eight male Wistar rats. Transbond XT orthodontic adhesive was used in four groups (n=7), containing 0%, 1%, 5% and 10% AgNPs produced experimentally.	Streptococcus sanguinis, Streptococcus mutans, Lactobacillus acidophilus	Adding 5% and 10% AgNPs significantly reduced the number of S. sanguinis and L. acidophilus compared to the control and 1% AgNP groups. The antimicrobial effect of added silver nanoparticles is dose-dependent. The effective concentration is 5%. The 10% concentration significantly reduced the number of S. mutans colonies compared to the control group, 1% and 5% AgNPs.
Soans C et al. (2019). <sup>9</sup>	“Evaluation of Antimicrobial Properties of Orthodontic Adhesive Mixed with Silver Nanoparticles: An In Vitro Study”	They were mixing the synthesized SNP with TransbondTM XT orthodontic adhesive in 1%, 5%, and 10% w/w concentrations. The specimens were shaped into discs, and incubated with Streptococcus mutans MTCC 497 and Lactobacillus acidophilus MTCC10307. Disc Diffusion Test assessed the growth inhibition zone.	Streptococcus mutans, Lactobacillus acidophilus	This research shows extraordinary antibacterial activity in orthodontic bonding adhesives containing silver nanoparticles against Streptococcus mutans and Lactobacillus acidophilus at low doses 1%. The zone of inhibition for Streptococcus mutans was higher than for Lactobacillus acidophilus in adhesives mixed with SNP in various concentrations.
Eslamian L et al. (2020). <sup>10</sup>	“Evaluation of the Shear Bond Strength and Antibacterial Activity of Orthodontic Adhesive Containing Silver Nanoparticle, An In-Vitro Study”	The study used 34 extracted premolars and then randomly divided into two groups (n = 17). Using conventional orthodontic adhesive Transbond XT, 3M Unitek, and nano adhesive by mixing AgNPs (50 nm, 0.3% w/w)	Streptococcus mutans	At 24 h and 30 days, the nano adhesive containing AgNPs showed strong antibacterial effects and did not change much. Incorporating AgNPs [0.3% (w/w)] reduced the shear bond strength, although it was still within the recommended limit of 5.9–7.8 MPa.
Mirhashemi et al. (2021). <sup>11</sup>	“Evaluation of Antimicrobial Properties of nano-silver Particles Used in Orthodontics Fixed Retainer Composites: An Experimental In-Vitro Study”	Testing with disk diffusion agar on nanocomposite resin samples with NAg concentrations of 1%, 2%, and 5%	Lactobacillus acidophilus, Streptococcus mutans, Streptococcus sanguinis	The antibacterial effect was demonstrated by a composite containing silver nanoparticles at a concentration of 5% with a visible growth inhibition zone, diameter of 9.5 ± 0.71 mm for S. mutans, 8.5 ± 0.71 mm for S. sanguis, and 8 ± 1.41 for L. acidophilus. The composite resin disk diffusion agar test results containing Nag concentrations of 1% and 2% showed no growth inhibition zone. The antibacterial effect is demonstrated by composites containing silver nanoparticles that at possibly prevent dental caries around fixed orthodontic retainers.
Jenabi N et al. (2023). <sup>12</sup>	“Antibacterial Activity and Shear Bond Strength of fiber-reinforced Composites and Bonding Agents Containing 0.5%, 1%, 2.5%, and 5% Silver	Adding nanosilver 0% (control), 0.5%, 1%, 2.5%, and 5% into the flowable composite and bonding agent, fiber-reinforced composite (FRC)	Streptococcus mutans	Bacterial growth could be reduced significantly by adding nanosilver at all concentrations of 0.5%, 1% or 2.5% and stopped in samples containing 2.5% and 5% nanosilver on the composite disc. The shear bond strength of FRC decreased only significantly for 5% nanosilver.

Nanoparticles.”				
Wang J et al. (2022). <sup>13</sup>	“Influence of Silver Nanoparticles on the Resin-Dentin Bond Strength and Antibacterial Activity of a self-etch Adhesive System”	The control study used Universal Single Bond Adhesive (3M ESPE) and added silver nanoparticles to the orthodontic adhesive at 0.05% and 0.1%.	Streptococcus mutans	Damage to the quality of the dentin bond caused by Streptococcus mutans can be prevented by modifying the adhesive material with silver nanoparticles. Exposure to S.mutans significantly reduced bond strength in the control group. Antibacterial activity showed significant results after less than 6 months of treatment.
Aguiar R et al. (2021). <sup>14</sup>	“Experimental Composite Containing Silicon dioxide-coated Silver Nanoparticles for Orthodontic Bonding: Antimicrobial Activity and Shear Bond Strength”	Using fifty bovine incisors divided by composite. Transbond XT resin as control group (G1), Experimental composite without Ag@SiO <sub>2</sub> NPs (G2); Experimental composite with 0.5% Ag@SiO <sub>2</sub> NPs (G3); Experimental composite with 1% Ag@SiO <sub>2</sub> NPs (G4); Experimental composite with 3% Ag@SiO <sub>2</sub> NPs (G5).	Streptococcus mutans	Incorporating silicon dioxide-coated silver nanoparticles at a concentration of 3 wt% into dental adhesives reduced the population of Streptococcus mutans around orthodontic brackets. The SBS value also decreased compared to the 1% group. However, the difference was not significant with the control group
Yassaei S et al. (2021). <sup>15</sup>	“Comparison of Antibacterial Effects of Orthodontic Composites Containing Different Nanoparticles on <i>Streptococcus mutans</i> at Different Times”	Nanoparticle concentrations were made with a weight of 0.5% and 1%: hydroxyapatite, zinc oxide, titanium oxide, copper oxide, and silver oxide. Streptococcus mutans colonies were counted on Streptococcus mutans strain cultures. Place the composite in the culture medium, and measure the growth inhibition diameter after incubation. Colony counts were carried out on days 3, 15, and 30 to investigate the long-term effects of the nanoparticles.	Streptococcus mutans	The number of bacteria significantly decreased at 1% copper oxide and 1% silver oxide, whereas there was no significant difference between the other and the control groups. On day 30, the colonies had grown in all groups but did not show significant differences from the control group.
Kachoei et al. (2021). <sup>16</sup>	“A Novel Developed Bioactive Composite Resin Containing Silver/ Zinc Oxide (Ag/ZnO) Nanoparticles as an Antimicrobial Material against <i>Streptococcus mutans</i> , <i>Lactobacillus</i> , and <i>Candida albicans</i> ”	Study of bracket bonding through disc-shaped specimens made from composites without nanoparticles (O), composites containing ZnO(Z) nanoparticles, composites containing ZnO nanoparticles and silver ions (A&Z), and composites containing Ag/ZnO (AZ) nanoparticles containing Streptococcus mutans, Lactobacillus, and Candida albicans.	Streptococcus mutans, Lactobacillus, Candida albicans	Composite resins with the addition of nanoparticles (ZnO, ZnO with silver particles, and synthesized Ag/ZnO) can increase antibacterial characteristics against oral pathogens. A significant decrease occurred in the shear bond strength of A&Z composite resin compared to conventional composite resin. The highest shear bond strength occurred in the AZ group.

The materials used in the study on the antimicrobial effect of silver nanoparticles in orthodontics adhesive included extracted human premolars.<sup>7,10</sup> Another study used bovine incisors, and one study was conducted in vivo using an animal study, male Wistar rats.<sup>8,14</sup> The rest were experimental studies using composite resin disks.<sup>9,11-13,15,16</sup>

All studies evaluated the antimicrobial effectiveness of silver

nanoparticles against bacteria that contribute to tooth demineralization, Streptococcus mutans. The use of one type of bacteria was analyzed by making different AgNPs mixture concentrations. Almost all use a concentration of 1% apart from other higher or lower concentrations.<sup>7-16</sup> Research on more than one type of bacteria, most of which use Lactobacillus acidophilus as a comparison.<sup>7-9,11-16</sup> Apart from these two

bacteria, there are also compared with other bacteria, *Streptococcus sanguinis* or *Candida albicans*.<sup>8,9,11-16</sup>

Almost all studies focus on the addition of silver nanoparticles to orthodontic adhesives. One study compared the effectiveness of adding silver nanoparticles with materials other than silver, namely hydroxyapatite, zinc oxide, titanium oxide, and copper oxide.<sup>15</sup> Five other studies discussed changes in the mechanical properties of composites if silver nanoparticles were added.<sup>7,10,12,14-16</sup> Four of them investigated the shear bond strength properties, where one study measured the shear strength of Silicon Dioxide Composite coated silver nanoparticles and produced the same shear strength properties as the control group.<sup>16</sup>

## DISCUSSION

Although the field of orthodontics has made progress, the use of dental brackets still carries the risk of causing WLS, which often cannot be cured. Therefore, antimicrobial properties become another desirable property of orthodontic adhesives as the dental brackets adhere to the enamel and remain in the oral cavity for at least two years.

One of the most commonly used nanomaterials as a specialist antimicrobial is nanoparticles (NPs).<sup>7</sup> Nanoparticles are created with special properties that make them highly sought after in materials science and biology. Among various types of nanoparticles, silver nanoparticles have been extensively researched in recent years. These nanoparticles typically contain 20 to 15,000 silver molecules with a spacing of less than 100 nm.<sup>17</sup>

Several methods have been used to assess the potential effect of silver nanoparticles in inhibiting the antimicrobial activity of orthodontic adhesive devices. The use of human premolars and cow teeth gave the same results, showing the effectiveness of adding silver nanoparticles.<sup>7,10,14</sup> In vivo studies carried out by attaching brackets to male Wistar

rats also gave the same results as experimental studies using composite resin disks exposed to oral bacteria.<sup>9,11-13,15,16</sup>

Silver nanoparticles can be added to dental appliance materials. This material can be used directly in restorative treatment, incorporated into orthodontic adhesives, membranes that can be used to regenerate tissue in periodontal treatment, adhesive materials for making prosthetic dentures, and titanium coatings for dental implant treatment.<sup>18</sup> Placement of titanium coatings for implanted teeth are known to activate the immune system causing a reaction between the host and the biomaterial.<sup>19</sup> In the context of orthodontic adhesives, silver nanoparticles may provide several advantages. Research findings showed that incorporating silver nanoparticles into orthodontic adhesives can improve antibacterial and antimicrobial characteristics.<sup>7</sup>

Silver has been known to provide effects including (1) minimal bacterial resistance compared to antibiotics, (2) constant ion release and long-term antibacterial effect; and (3) biocompatibility with human cells.<sup>10</sup> Silver nanoparticles are considered the best choice for antibacterial applications due to their great potency and broad-spectrum activity. The adhesive containing silver nanoparticles has important antibacterial activity against *Streptococcus mutans*, which has been reported in all the results of this study. Silver nanoparticles showed resistance to *Streptococcus mutans*' ability to weaken dentin bond strength. The study found that adhesives modified with silver nanoparticles showed antibacterial activity for less than six months.<sup>10,13,15</sup> Silver nanoparticles have also been shown to have potent antibacterial properties against cariogenic microbes, including *Lactobacillus acidophilus* (*L. acidophilus*) and *Streptococcus sanguinis* (*S. sanguinis*).<sup>7-9,11,16</sup> The antibacterial activity of AgNPs is because bacteria cannot resist them. Silver (Ag) also has antiviral and antifungal properties. Its

effectiveness against *Candida albicans* was reported by Mojgan et al. 1, 2021.<sup>16</sup> This property is characterized by an increase in the release of Ag<sup>+</sup> ions resulting from the use of finer AgNPs with a particle size of less than 10 nm compared to larger AgNPs. Overall, these things can result in DNA damage, ribosome instability, enzyme interactions, cell death, and cell leakage.<sup>10,20</sup>

Increasing the quality of composite resin by incorporating silver nanoparticles into the composite resin does show good antimicrobial properties. However, this addition is contrary to aesthetic purposes because it can cause a dull gray color change in the composite caused by silver nanoparticles.<sup>16</sup> Meanwhile, shear bond strength in orthodontic brackets that were attached using a binder with AgNPs decreased in trials compared to the control group.<sup>13,16</sup> This was because silver nanoparticle composite's shear strength and surface roughness decreased along with increasing concentrations of AgNPs mixed in the orthodontic adhesive. However, all levels of SBS, whether containing nanosilver or not, are above the range of 6–8 MPa so they can still be tolerated clinically (15.3-27.6 MPa).<sup>10,14,20</sup>

## CONCLUSION

The main advantage of using silver nanoparticles in orthodontic cement was its ability to inhibit the growth of bacteria and microorganisms around orthodontic brackets and adhesive-coated tooth surfaces. It could help reduce the risk of infection and improve oral hygiene during orthodontic treatment. The antibacterial properties of silver nanoparticles could also help prevent plaque formation and tooth decay due to food retention around orthodontic brackets. The disadvantage was the reduction in surface roughness, thereby reducing the shear strength, although it was still within tolerable limits. Therefore, research and development on the use of silver nanoparticles in orthodontic

adhesives needs to continue to be carried out to obtain the right composition.

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