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Review Article

Effectiveness of coatings in reducing biofilm adhesion on arch wires: A systematic review

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ABSTRACT

Objective: To evaluate the Effectiveness of coatings in reducing biofilm adhesion on arch wire.
Materials and Methods: A literature search was performed on PubMed, Medline, Google Scholar, and Science Direct to examine studies that compared the uncoated group of arch wires to those with nano coatings and assessed the anti-adherent property. After extracting the data from each study, two risk of bias assessment tools were employed and tabulated data was obtained.
Results: 8 Studies met the requirements for inclusion. For majority of the included articles, the risk of bias assessment indicated a low to moderate risk. The antibacterial properties of various nanoparticle coatings were examined and evaluated.
Conclusion: Regardless of patient compliance, a proper application of each type of coated arch-wire can help prevent white spot lesions and reduce bacterial aggregation around orthodontic attachments. Majority of the studies that made up this systematic review have a risk of bias grade of "fair." A meta-analysis was not feasible because of heterogeneity in the different coating techniques used to test the antibacterial property.

1. Introduction

Perfectly aligned teeth may substantially enhance oral and dental health in addition to attractiveness of an individual which indirectly impacts a person's psychological sense of self-worth and confidence.[1] Orthodontic treatment being one of the most efficient paths in governing the position of teeth has led to increasing demands in various age groups worldwide. This goal of enhancing facial aesthetics, along with functional efficiency & structural harmony between the tissue system demands application of complex appliances for a longer time interval in patient's mouth & specific force to displace the teeth within its physiologic limits. However, these complex designs demand perfect patient co-operation; any negligence or incognizance leads to formation of undisturbed plaque retentive areas around these appliances.[2]

Oral environmental factors like pH, salivary flow, salivary immunoglobulins, presence of fluoride, patients' dietary habits further govern this process. It's a well addressed fact that orthodontic attachments as well as bonding materials are known to retain plaque. Presence of arch wires further impedes the cleaning process making the plaque retentive areas difficult to access. Owing to unfaltered retention of plaque which is known to contain higher levels of acidogenic bacteria notably streptococcus mutans & Lactobacilli, which are potent in reducing the pH around the appliances, an acidic shift of pH is observed, ensuing acid diffusion in the enamel substrate thus initiating the process of demineralization in the intact enamel which

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further enhances porosity and has a deleterious effect on the microhardness of enamel presenting itself as opaque, white chalky spots around the appliance which is now referred to as "White Spot Lesions."[3]

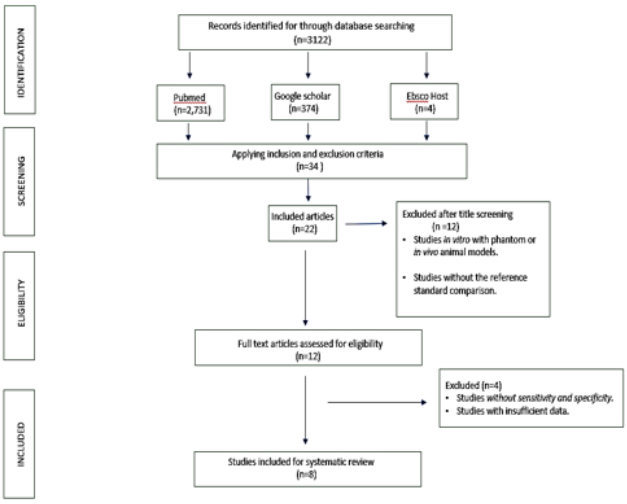
"White spot lesion is the first sign of a caries lesion on the enamel that can be spotted by the naked eye," per Fejerskov and Kidd; thereby making it crucial to address it early in the treatment to prevent any long-lasting effect on dental aesthetics.[3] Due to inadequate dental hygiene, a high frequency of WSLs at six months into active orthodontic treatment suggests a fast demineralizing process in the midst of fixed appliances. As per the research findings of Øgaard et al., these lesions can be detected in the bracket area within a month of bonding. Therefore, it is imperative for the clinician to identify poor oral hygiene as soon as possible to take preventive action before WSLs form.

The use of antibacterial toothpastes and mouthwashes is one of several antibacterial tactics that have been used therapeutically to prevent enamel demineralization. However, nearly all of the time, patients do not comply with these conventional procedures, which call for high levels of compliance. Research has been conducted to address these issues by adding antibacterial properties to bonding methods and orthodontic appliances.[4]

Orthodontic brackets, arch wires, and aligners have had their surfaces modified with consideration in recent years. Metal oxides, organic compounds, metal elements have been used for this purpose which aim at reducing the surface roughness thereby lowering the bacterial adhesion and improving the oral hygiene maintenance. Surface modification with nanoparticle coating is one of the advances which has been gaining popularity in recent times.[5] Materials categorized as nanomaterials have at least one dimension (1–100 nm) in the range of the nano meter scale, or their fundamental unit in three dimensions falls within this range. Broad-spectrum antibacterial activities of NPs have been demonstrated against both Gram-positive and Gram-negative bacteria.[5] Owing to this property they have been used in the medical industry as coating material for dental implants or heart valves.

By applying nanoparticles' anti-microbial properties as a coating material to orthodontic arch wires, a novel idea has the potential to reduce bacterial colonization and consequent incidence of WSLs and associated periodontal problems in patients undergoing orthodontic treatment. Thus, the intent of this systematic review is to integrate and summarize the antibacterial impact of nanoparticle-coated orthodontic arch wires.

2. Materials and Methods



The PRISMA guidelines have been employed in the construction of this systematic review.

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2.1. Eligibility criteria

1. **Population:** Studies involving comparison of nanoparticle coated & uncoated orthodontic arch wires for antimicrobial property.
2. **Intervention:** Studies involving coating of the wires with nanoparticles
3. **Comparator:** Studies comparing nano-coated arch wires with uncoated orthodontic arch wires
4. **Outcome:** Studies assessing the anti-adherent or microbial colony counts as the preliminary outcome & surface properties such as roughness/ friction as secondary outcomes were included

2.2. Study design

In-vivo, In-vitro studies of coatings on arch wire, Clinical trials, randomized clinical trials were included. Articles published in English language were included.

2.3. Search strategy

A comprehensive search for publications published between 2015 and 2021 was conducted using PubMed, Ebsco Host, and Google Scholar in the electronic search engines. We employed the suitable Boolean operators (AND, OR, NOT) for combining the phrases. Search engines were employed to seek for specific articles, references, and related articles in case the prior search methods had missed them.

2.4. Data extraction

Post duplicate elimination, full texts were obtained for all the studies to be included. The data was extracted by two independent reviewing authors in the form of: (Study, Material/substrate, coating composition, method of coating, microbial strains, results). The data was then tabulated (Table 1)

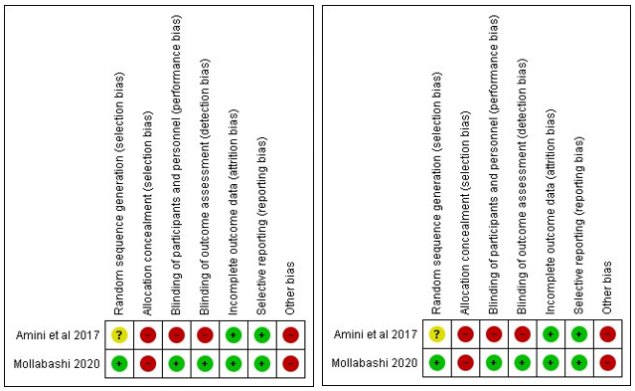
3. Results

A total of 3122 results were obtained which were then screened by applying mesh terms & inclusion criteria giving a total of 36 articles. Once the abstracts of these papers were evaluated, 12 studies were disqualified for failing to satisfy the study criterion.

Thus, we ended up with 24 articles were which were further screened thoroughly; leaving 8 studies which fulfilled the eligibility criteria.

3.1. Risk of bias

All eight papers were assessed for bias before being included in the systematic review. The quality assessment instrument for diagnostic accuracy studies-2 (QUADAS-2) was utilized in order to evaluate the methodological quality and applicability of the included research.



Risk of Bias summary for Non RCTs

4. Discussion

Modern advances in the realm of orthodontic coatings have rendered it possible to create a vast array of coatings with a remarkable range of characteristics. One creative and original way to reduce the microbial burden on a substrate by coating is nanocoating. The incidence of periodontal issues and white spot lesions can be anticipated to decrease in tandem with the reduction in the microbial load with the application of nano coating on arch wires. For orthodontic arch wires, silver, titanium oxide, and zinc oxide nano coatings are quite popular. Orthodontic wire coating technologies, such as radiofrequency magnetron sputtering and the sol-gel technique, are frequently employed to cover an array of surfaces with thin layers. The coatings can be produced to have the right amount of hardness or porosity, or to alter their mechanical, chemical, or physical characteristics, such as their antibacterial safeguarding, by utilizing the right compositions.

4.1. Titanium oxide

TiO_2 is a thermally stable and biocompatible chemical compound with high photocatalytic activity that has good antimicrobial action. Titanium dioxide NPs are of particular interest due to its abilities, such as bactericidal photocatalytic activity. A study conducted by M. Chun et al (2007) concluded that TiO_2 coated orthodontic wires reported effective anti- adherent properties when tested against S. mutans with illumination UV-A light.

V. Mollabashi et al[6] 2020 conducted a study wherein PVD was used coating method for TiO2 onto stainless steel wires. A total of four weeks were devoted to counting bacterial colonies. It was discovered that the disintegration of organic molecules on the bacterial surface led to a reduction in S. mutans' adherence on TiO2-coated orthodontic wires. TiO2-coated wire delivers its maximum antibacterial effect during wire insertion, which is advantageous for patients who have just begun orthodontic treatment and do not yet possess the oral health knowledge necessary to advocate the use of coated arch wires if a time-dependent effect is desired.

Keerthi Venkatesan et al[7], 2020 assessed the cycle threshold (Ct) of the RT-PCR test to ascertain the antibacterial impact of TiO2 NPs. Considering the Ct value and the amount of bacterial genome present are inversely correlated, a higher Ct value suggests a reduced bacterial load and, thus, a greater antibacterial impact. The TiO2 nanoparticles' antibacterial activity is indicated by the nanocoated arch wires' higher Ct value than that of the uncoated archwires. Additionally, they discovered a somewhat negative correlation between the Ct value and 0.016-in NiTi wires coated with TiO2 nanoparticles and a moderately positive correlation between the Ct value and Ra of the wires, suggesting that the wires with a smoother surface also have some anti-adherence properties.

4.2. Silver nanoparticles (AgNPs)

The key benefit of silver nanoparticles is their remarkable antibacterial action, even at minimal levels, against a variety of microorganisms. The potential of AgNPs to stack up at bacterial membranes and form aggregates, or silver ions, is thought to be the mechanism of action. This breach of cell membrane integrity conduces to the creation of holes, that eventually cause cell death. AgNPs have the capability to bind with the exocyclic nitrogen found in

StudyID	Venkatesan et al 2020	Fatene et al 2021
Bias due to confounding	No	No
Bias in selection of participants into the study	No	Moderate
Bias in classification of interventions	No	No
Bias due to deviations from intended intervention	No	No
Bias in measurement of outcome	No	No
Bias in selection of the reported results	No	No
Risk of bias	Low	Moderate

	Doamain : References Standard						
Author	**Random sequence generation (selection bias)**	**Allocation concealment (election bias)**	**Blinding of Participants and personnel (performance bias)**	**Blinding of outcome data (detection bias)**	**Incomplete data (attrition bias)**	**Selective reporting (reporting bias)**	**Other bias**
Amini etal(2017)	Unclear	High risk	High risk	High risk	Low risk	Low risk	High risk
Mollabashi(2020)	Low risk	High Risk	Low risk	Low risk	Low risk	Low risk	High risk

adenine, guanine, and cytosine bases to damage DNA and eventually destroy cells., According to a study by Mhaske et al.[8] 2015, silver nanocoating exhibits antibacterial and anti-adhesion qualities. The weight of the uncoated stainless steel wires increased by 35.4%, while the weight of the silver nanocoated stainless steel wires increased by just 4.08%. The weight of uncoated NiTi wires increased by 20.5%, whereas the weight of silver nanocoated NiTi wires increased by 4.4%. Nevertheless, the study was unable to clarify why silver nanocoating has this anti-adherence property.

According to a study by Shah et al.[9] (2018), there is a decline in friction on stainless steel archwires coated with silver nanoparticles, which might have been related to a drop in microbial adherence.

F. Gil et al[10] 2020 determined bactericidal treatment for NiTi wires by electrodeposition of AgNPs on its surface. A reduction in bacterial cultures was observed due to presence of silver NPs suggesting AgNPs as a good candidate for bactericidal orthodontic archwires. The risk of bias assessment was low for the study thereby suggesting high accuracy for the outcomes concluded by the study.

4.3. Titanium nitride

Since the mid-1980s, dental materials coated with nitrogen ion implants, also referred to as titanium nitride (TiN) or nitrogen ion implanted coated dental materials, have been looked at and considered for implementation in a variety of dental applications, involving implants, abutments, endodontic files, orthodontic wires, periodontal/oral hygiene instruments, and casting alloys for fixed restorations. Nonetheless, there aren't numerous research investigations that examine the antimicrobial properties of TiN-modified orthodontic wires. A study by Fariborz Amini, Abbas Bahador et al, 2017 reported a significant difference in colony count on TiN coated stainless steel wires when compared to its control (uncoated) group. This suggested that coated wires lead to decline in bacterial adhesion and enhanced oral hygiene.

4.4. Zinc oxide

Given that zinc oxide nanoparticles penetrate through cell membranes and act as an antimicrobial agent, they impede the growth of pathogens. Oxidative stress causes breakdown of proteins, lipids, carbohydrates, and DNA. This contributes to alterations in the cell membrane, which eventually disrupt with crucial cellular functions and inevitably result in cell death.

M. Gholami et al[11], 2020 carried out a study wherein the wire was surface modified utilizing an assortment of techniques, comprising chemical precipitation, sol-gel, electrospinning, polymer composite coating, and CVD, and comparisons were made. The electrospinning method displayed the lowest cell reduction (72%) and the precipitation method (96%) the highest antibacterial effect (98%, 96%, and 93% microbial cell reduction accounted for CVD, sol-gel synthesis, and so on). This indicates that antibacterial activity of smaller nanoparticles with larger surface area helps in reducing the rate of WSLs during orthodontic treatment.

5. Conclusion

One significant area of ongoing study is the orthodontic surface treatment of arch wires. The surfaces of dental attachments have been altered via a wide range of materials and techniques. Only a couple of them are now utilized in clinical orthodontics, most notably in the areas of friction

Table 1:

Study	Material/substrate		Coating composition	Method of coating	Microbial strains	Results	
M. Chun et al (2007)	Stainless steel wire		Photocatalytic TiO_2	Sol-gel thin film dip-coating method	S. mutans and P. gingivalis	**Control** 720 CFU	**Experimental** 100 CFU
A Mhaske, P. Shetty, N. Bhar el al (2015)	a) 20 Uncoated NiTi arch wires	20 Silver nano coated NiTi arch wires	Silver Coating	Thermal evaporation method	L. acidophilus	**Control** CFU - 836.60 ± 48.97 Wt diff - 0.085 ± 0.024	**Experimental** CFU - 220.90 ± 30.73Wt diff - 0.010 ± 0.020
	b) 20 Uncoated SS arch wires	20 Silver nano coated SS archwire				CFU - 748.90 ± 35.64Wt diff - 0.045 ± 0.028	CFU - 203.20 ± 41.94Wt diff - 0.010 ± 0.021
Fariborz Amini , Abbas Bahador et al (2017)	0.019 * 0.025 Stainless steel wire		Titanium Nitride	Electrolytic treatment system.	S. mutans, P. gingivalis,	**Control** 8±7.4x104 (P=0.03)	**Experimental** 4 ± 3.4 ×104
F. Gil, Escalona, et al (2020)	25 NiTi wires		Silver Nanoparticles	Electrodeposition	S. sanguinis, A. actinomycete L. salivarius	higher than 90% reduction in bacteria seen due to presence of AgNPs.	
V. Mollabas hi, A. Farmany, M. Alikhani et al (2020)	Stainless steel wire		Titanium dioxide	Physical Vapor Deposition (PVD)	S. mutans mco mitans, S. sanguis,	viability of L929 cells in the coated wire group: 90.3%±9.5% and for the uncoated-wire group 86.6%±8.1%. Early in the wire insertion process, TiO2 effectively reduces bacterial adherence.	
M Gholami et al (2020)	Stainless steel wire		ZnO Nanoparticles	CVD, Chemical Precipitation, Polymer Composite coating, Sol-Gel, Electrospinning process	S. mutans S. pyogenes & S. sanguinis	The vapor deposition approach accounted for 98.6% of the microbial cell reduction, followed by the precipitation method (96.14%), sol gel synthesis (93.5%), and the electrospinning group (72%).	
Keerthi Venkatesan et al, 2020	Control 12 uncoated NiTi archwires	Experimental 12 TiO2 nanocoated NiTi archwires	Titanium dioxide	Radio Frequency magnetron sputtering method	S. mutans	**Control** PCR -Ct - 37.00 ± 6 1.90	**Experimental** PCR -Ct - 30.97 ± 6 2.23
N. Fatene, et al (2021)	0.016*0.022' and 0.017*0.025" Niti wires		50 μL of each conc. of the 2 types of Eugenol was added (biological & chemical)		S. mutans	Biological Eugenol has greater effect than the chemical one.	

management and bacterial adhesion reduction. Pursuant to this comprehensive evaluation, regardless of patient compliance, proper application of each type of coated arch-wire may assist with prevention of white spot lesions while minimizing bacterial aggregation around orthodontic attachments.

The personal orthodontist must utilize the appealing characteristics of a particular coated arch wire type in accordance with the demands of the current clinical condition and possess a sufficient knowledge of the needs and opportunities during each stage of treatment. By implementing the approaches that have been outlined, it is possible to reduce bacterial adherence on the surface of orthodontic arch wires and enhance their mechanical qualities. implementing suitable coating processes, corrosivity, wear and tear, and delamination can all be mitigated. Almost all the studies that made up this systematic review are at a risk of bias grade of "fair." A meta-analysis was not feasible because of heterogenicity in the different coating techniques used to verify the antibacterial property. As consequence, more recent products have been developed that could benefit from a reduction in biological and financial expenses as well as treatment duration, although further investigation is needed to validate this.

6. Source of Funding

None.

7. Conflict of Interest

None.

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