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Short Review Article

Effectiveness of Coatings in Reducing biofilm Adhesion on Arch Wires

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Effectiveness of coatings in reducing biofilm adhesion on archwire was evaluated. Literature search was conducted on PubMed, Medline, Google Scholar, and Science Direct which analysed the anti-adherent property after nano-coating of archwires against uncoated group. Two risk of bias assessment tools were used and the data extracted from each study was then tabulated. Eight studies fulfilled the inclusion criteria. Risk of bias assessment showed a low - moderate risk for most of included studies. Various nanoparticle coatings were analysed for their antimicrobial property. Adequate implementation of each type of coated arch-wire can aid in reducing the bacterial aggregation around the orthodontic attachments and keeping the white spot lesions at bay irrespective of patient compliance. Most of the studies included in this systematic review were assessed fair in risk of bias assessment. Due to presence of heterogenicity in terms of varied coating methods employed to check the antimicrobial property, a meta-analysis was not possible.

Introduction

Well aligned teeth might have a major impact on dental and oral health as well as appearance of an individual in terms of attractive smile which has indirect effects on one's psychological self-esteem and self-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 and 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 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].

As stated by Fejerskov and Kidd "White spot lesion is the first sign of a caries lesion on the enamel that can be detected by a naked eye;" thereby making it crucial to address it early in the treatment to prevent any long-lasting effect on dental aesthetics [3]. High prevalence of WSLs at 6 months into active orthodontic treatment is suggestive of rapid demineralizing process in the presence of fixed appliances owing to poor oral hygiene. According to Øgaard et al., these lesions may become noticeable around the brackets within 1 month of bonding; thereby, making it crucial for the clinician to recognize inadequate oral hygiene early, so that preventive measures could be implemented before the

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development of WSLs occurs.

Several antibacterial strategies have been implemented clinically for prevention of enamel demineralization, including the use of antibacterial mouthwashes and toothpastes. However, these conventional interventions demand high patient compliance, which is lacking for most of the time. To outlook these problems, researches have been constructed to add antibacterial property to orthodontic appliances and bonding systems [4].

During recent years, considerate attention has been paid to surface modification of orthodontic brackets, arch wires, and aligners. 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]. Nanomaterials are materials that have at least one dimension (1–100 nm) in the nanometre scale range or whose basic unit in the three-dimensional space is in this range. NPs have demonstrated broad-spectrum antibacterial properties 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.

A novel idea of surface modification of orthodontic arch wires by utilizing the anti-microbial property of nanoparticles as a coating material has potential to downturn the bacterial colonization thereby decreasing the incidence of WSLs and the associated periodontal problems in patients seeking orthodontic treatment. This systematic review thus aims to compile and summarise antimicrobial effect of orthodontic arch wires coated with nanoparticles. This systematic review has been structed in accordance to the PRISMA.

Eligibility Criteria

The eligibility criteria selected are 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, and 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.

Study design

In vivo, In vitro studies of coatings on arch wire, clinical trials and randomized clinical trials were included. Articles published in English language were included. A panoramic search was carried out in the electronic search engines using PubMed, Ebsco host & Google scholar for articles published from 2015-2021. The terms were combined using suitable Boolean operators (AND, OR, NOT). Individual article, references & related article search was conducted using search engines in case they got bypassed during the previous search procedures. 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).

Discussion

A total of 3122 results were obtained which were then screened by applying mesh terms and inclusion criteria giving a total of 36 articles. These articles were then screened based on abstract of which 12 studies were excluded as they did not meet the study requirement. Thus, we ended up with 24 articles were which were further screened thoroughly; leaving 8 studies which fulfilled the eligibility criteria. Risk of bias was done for all eight studies to be included in the systematic review. To assess the methodological quality and applicability of the included studies, the quality assessment tool for diagnostic accuracy studies-2 (QUADAS-2) was applied (figure 1).

Recent progress in the area of orthodontic coatings enabled the development of a wide range of coatings, which possess an incredible spectrum of properties. Nanocoating is an innovative and a novel method of decreasing the microbial load on a substrate by coating. By nano coating arch wires, the reduction in the microbial

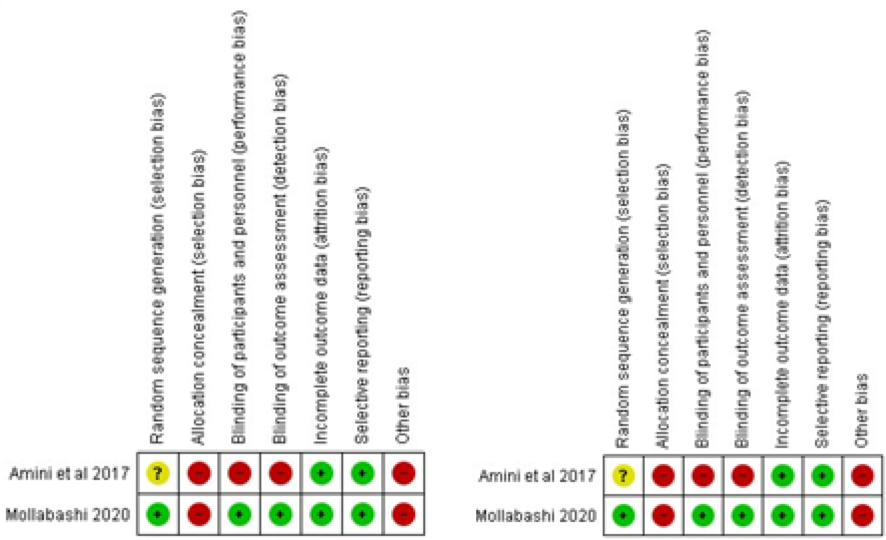

Figure 1: the quality assessment tool for diagnostic accuracy studies-2

Study ID	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 interventions	No	No
Bias due to missing data	No	No
Bias in measurement of outcome	No	No
Bias in selection of the reported result	No	No
Risk of bias	Low	Moderate

Figure 2: Risk of Bias summary for Non RCTs

load can be equated to the decrease in the incidence of white spot lesions and the incidence of periodontal problems. Widely popular nanocoating for orthodontic archwires are silver, titanium oxide and zinc oxide nano coatings. The technology of applying layers on the orthodontics wires, such as sol-gel method or radiofrequency magnetron sputtering are widely used in covering surfaces of various shapes with thin layers. By using the appropriate compositions, the coatings can be modified to give them the appropriate porosity or hardness or to adjust their mechanical, physical, or chemical properties or antibacterial protective.

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[9], 2020 conducted a study wherein PVD was used coating method for TiO2 onto stainless steel wires. Bacterial colony counting was done over 4 weeks. It was observed that decreased adhesion of S. mutans on TiO2-coated orthodontic wires resulted from bacterial surface organic molecule degradation. Maximum antibacterial effect of TiO2-coated wire is seen when wire insertion is done and is beneficial for patients who have recently have started orthodontic treatment and not yet acquired sufficient oral health skills recommending use of coated arch wires if a time-dependent effect is desired.

Keerthi Venkatesan et al[10], 2020 determined the antibacterial effect of TiO2 NPs using RT-PCR test by measuring the cycle threshold (Ct). The Ct value is inversely proportional to the amount of bacterial genome present, meaning, the higher the Ct value, lesser is the bacterial load and hence more the antibacterial effect. The nanocoated archwires have greater Ct value than that of uncoated archwires indicating antimicrobial action of TiO2 nanoparticles. They also found a moderate positive correlation between Ct value and Ra of 0.016-in NiTi wires and a moderate negative correlation between 0.016-in TiO2 nanoparticle coated Niti wires and Ct value indicating smoother surface of the wire has some anti-adherence property also.

Silver nanoparticles (AgNPs)

The edge of silver nano particle is that, it possesses high antibacterial activity against a broad range of microbes even in minimal concentrations. The mechanism of action of AgNPs can be attributed to its ability to accumulate at bacterial membrane and form aggregates, as silver ions, thus causing disruption of cell membrane integrity by formation of pores leading to cell death. AgNPs can also cause DNA damage through interaction with the exocyclic nitrogen present in the adenine, guanine, and cytosine bases hence causing cell death. The study by Mhaske et al [6], 2015 states there is both an antibacterial activity and an anti-adhesion activity due to silver nano coating. The uncoated stainless-steel wires showed 35.4% increase in weight and silver nanocoated stainless steel wires showed only 4.08 % increase in weight. Uncoated NiTi wires showed 20.5 % increase in weight whereas silver nanocoated NiTi wires showed 4.4 % increase in weight. But the reason for the anti-adherence property of silver nanocoating was not specified in the study.

A study by Shah et al [7], 2018 states there is a reduction in the friction of silver nanocoated stainless steel archwires which may be attributed to the reduction in the adherence of the microbes.

F. Gil et al [8], 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.

Titanium nitride

Titanium nitride (TiN) or nitrogen ion implanted coated dental materials have been investigated since the mid-1980s (Al Jabbari et al. 2012) and considered in various applications in dentistry such as implants, abutments, orthodontic wires, endodontic files, periodontal/oral hygiene instruments, and casting alloys for fixed restorations, but few studies exist on orthodontic wires are modified with TiN and tested for its antimicrobial properties. 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.

Zinc oxide

Zinc oxide nanoparticles, as an antimicrobial agent, inhibits the growth of microorganisms by permeating into the cell membrane hence the antibacterial activity. The oxidative stress damages lipids, carbohydrates, proteins, and DNA thereby leading to alteration in the cell membrane which eventually disrupts vital cellular functions and eventually all these results into cell death.

M. Gholami et al [11], 2020 conducted a study wherein the wire was surface modified using different methods of surface modification such as CVD, chemical precipitation, electrospinning, polymer composite coating & sol-gel technique and comparisons were made. The highest antibacterial effect with 98%, 96%, and 93% microbial cell reduction accounted for CVD, precipitation method, and sol-gel synthesis, respectively, and the lowest cell reduction was seen in the electrospinning method (72%); suggesting antibacterial activity of smaller NPs with larger surface area helps in reducing the rate of WSLs during the orthodontic treatment.

Conclusion

Orthodontic surface treatment of archwires is an important area of active research. A myriad of materials and techniques have been implemented to modify the surfaces of dental attachments. However, today only a few are being used in clinical orthodontics, especially in areas of reduction of bacterial adhesion and friction control. This systematic review suggests that adequate implementation of each type of coated arch-wire can aid in reducing the bacterial aggregation around the orthodontic attachments & keeping the white spot lesions at bay irrespective of patient compliance. The personal orthodontist should have adequate understanding of the needs and opportunities during each stage of treatment and needs to use the desired features if a specific coated arch wire type based on the requirements of current clinical situation. Surface modifying the orthodontic arch wires using the discussed methods can minimize bacterial adhesion on the surface and improve mechanical properties. Appropriate coating techniques enable the reduction in corrosivity, wear and tear, as well as its delamination. Most of the studies included in this systematic review were assessed fair in risk of bias assessment. Due to presence of heterogenicity in terms of varied coating methods employed to check the antimicrobial property, a meta- analysis was not possible. Consequently, more newer products have been introduced which may have favourable impact in terms of reduction in biological and financial costs and in treatment time which require further investigations.

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