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Effect of surface modification of orthodontic appliances on biofilm adhesion – A systematic review

Running title: Surface modified archwires effect on biofilm adhesion - SR

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Abstract

Aim: *To evaluate the effect of various coatings and its effect on the microbial adhesion on the orthodontic appliance*

Materials and methods: *A systematic review is being conducted using the available electronic data bases which were analysing the microbial adhesion after coating of appliances against uncoated appliances. Due to the paucity of in vivo studies, invitro studies also were considered. Data extraction was performed from each study and the results were tabulated.*

Results: *8 studies which fulfilled the inclusion criteria were selected. Risk of bias assessment showed a medium to high risk of bias for most of the studies. The effect of various coatings on the appliance was analysed.*

Conclusion: *Roughness is an important but not the only factor for microbial adhesion. The property of the coatings also plays an important role. More high evidence studies are required to obtain more reliable results.*

Key words: *Archwire, Bracket, Coating, Microbial adhesion, Biofilm adhesion, Orthodontics*

1 Introduction

There is an abundance of microorganisms in the oral cavity. The orthodontic appliances act as a nidus for food entrapment and also harbours microorganisms. The microorganisms along with the food particles form tenacious biofilms which can cause white spot lesions and gingival problems.

In a study done by Tufekci et al [1], they concluded that in patients undergoing orthodontic treatment had a time dependent increase in prevalence of white spot lesions.

A study by Liu et al [2] states orthodontic appliances form a conducive environment for factors causing gingival diseases and there is a significant increase in the amount of Porphyromonas gingivalis bacteria during orthodontic treatment which reduced after removal of the appliance.

The number of microorganisms that is harboured by these orthodontic appliances may be determined by its surface roughness. The rougher the surface, the more the biofilm it harbours. This was concluded by Marwa Tawfik et al [3]. Yet some studies are in disagreement and state surface roughness and microbial adhesion are not related [7].

Recently with the development of surface modification of archwire and brackets, a possibility of increasing or decreasing the surface roughness of the appliance is possible. But this also affects the biofilm adhesion of the orthodontic appliance. With the prevalence of these white spot lesions and gingivitis as a concern, appliances with coating of antimicrobials and or impregnated with an antimicrobial agent are also being studied by different authors.

Various surface modification of the archwire have been carried out like epoxy coating, Teflon coating, Rhodium coating, Nitrogen ion implantation and Titanium oxide impregnation.

The aim of this systematic review was to summarise the microbial adhesion or biofilm adhesion on these surface modified archwires and brackets.

2 Research question

In orthodontic appliances, does surface modification of its components reduce the biofilm adhesion or microbial count when compared to conventional orthodontic appliance?

3 Materials and methods

This systematic review is structured in accordance to the PRISMA guidelines [4] (preferred reporting items for systematic reviews and meta-analyses).

3.1 Eligibility criteria

Population: Studies involving the use of an orthodontic appliance including orthodontic wire or bracket which is being studied for the surface adhesion of biofilm and microbial count after surface modification.

Intervention: Articles involving surface modification of the appliance which includes coating, ion implantation and impregnation with antimicrobials.

Comparator: Articles comparing uncoated archwires or brackets with coated or partially coated brackets or archwires are only included in the study. Articles comparing two coated archwires are not included in the study.

Outcome: Studies with the primary outcome of determining the amount biofilm adhesion to the appliance or the number of microbes which are adhered to the appliance in the study period

Studies with the secondary outcome of determining the surface roughness of the appliance which is being surface modified. Studies not involving the above-mentioned outcomes are not included.

Study: Randomised control trials,Prospective controlled clinical trials and invitro studies focussing on biofilm adhesion and surface modification of coated archwire were included. Case reports, case series and descriptive studies, review articles, opinion articles were excluded.

Articles in English were only included

The PICO protocol of the studies included is presented in table 1

3.2 Search strategy

A comprehensive search was done in the electronic search engine using PubMed, Scopus, Google scholar, Cochrane clinical trials, Embase and Medline databases without limitations to identify eligible articles. The initial search was carried out on June 2020 and was repeated on July 2020 to finalise before writeup. The MeSH terms used were Orthodontics AND (archwire OR wires OR Brackets) AND (microbial count OR bacterial adhesion OR Biofilm).

The collection of studies was further expanded to major orthodontic journals across the globe like American Journal of orthodontics and dentofacial orthopaedics, Angle Orthodontist, Journal of clinical orthodontics, European journal of orthodontics and Journal of Indian orthodontic society. References and related articles were hand checked using electronic search engines in case they got missed out during the above procedures.

Two reviewers independently scanned the titles of the articles which were identified by electronic as well as manual search and decided whether it was relevant to the study. The abstract of the articles was carefully as well as critically appraised to identify studies that met our inclusion criteria. If a consensus about inclusion of a study was not obtained between the two authors, a third reviewer was consulted with.

PRIMA flow chart for the systematic review is presented in figure 1.

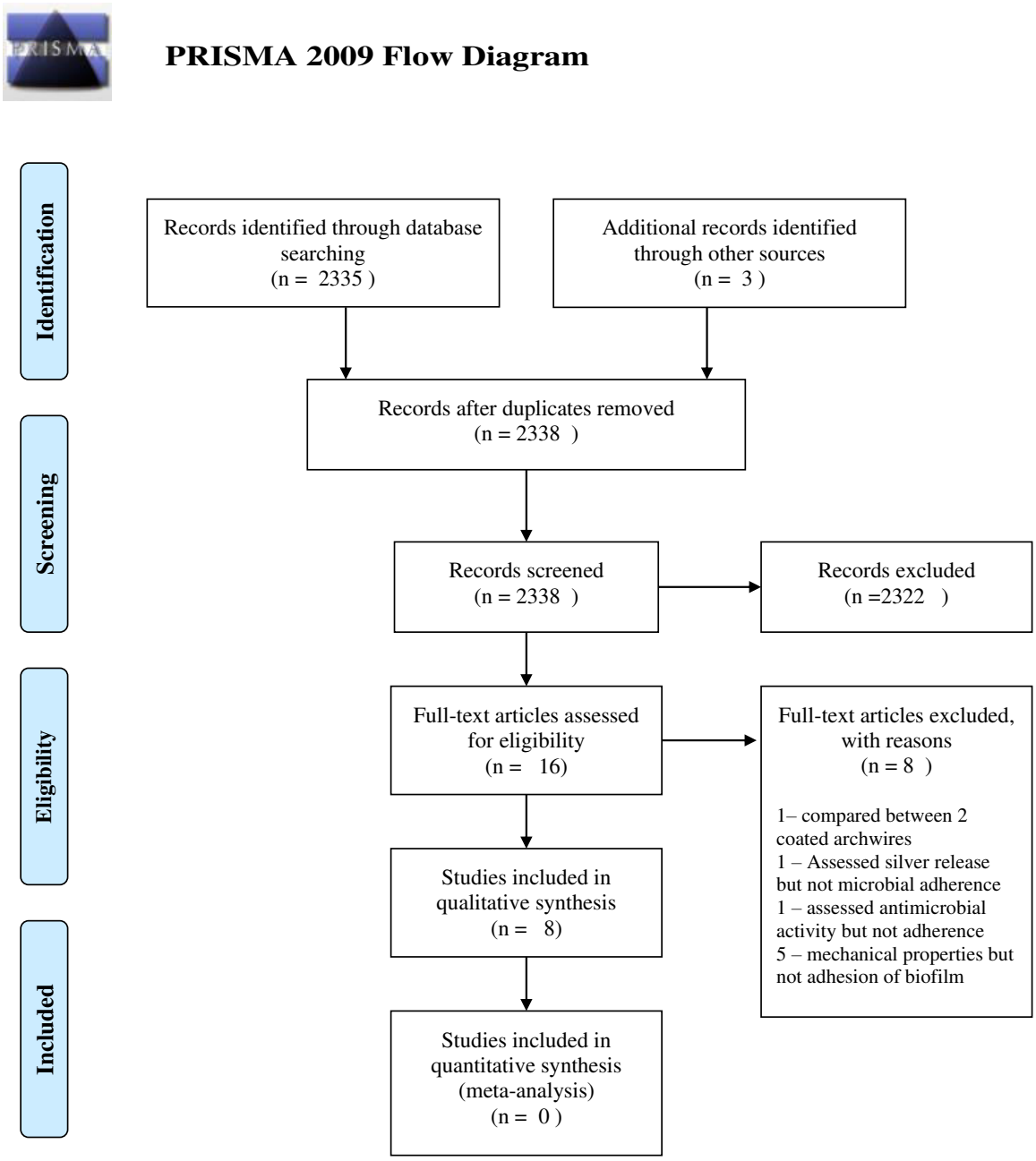
Table 1: PICO table for the studies included

Research	Population	Intervention	Comparator	Outcome	Study design
The effect of the titanium nitride coating on bacterial adhesion on orthodontic stainless-steel wires: in vivo study - Amini et al 2017 [6]	Archwire	Coating of SS with TiN	Uncoated SS	Biofilm adhesion	Prospective CCT
Comparative analysis of microorganism adhesion on coated, partially coated, and uncoated orthodontic archwires: A prospective clinical study -Costa Lima et al 2019 [7]	Archwire	Coated NiTi Partially coated NiTi	Uncoated SS Uncoated NiTi	Biofilm adhesion	Prospective CCT
Reduction of biofilm on orthodontic brackets with the use of a polytetrafluoroethylene coating - Demling et al 2010[8]	Brackets	PTFE coated brackets	Uncoated brackets	Biofilm adhesion	Prospective CCT

Long-term antimicrobial assessment of orthodontic brackets coated with nitrogen-doped titanium dioxide against Streptococcus mutans - Salehi et al 2018 [9]	Brackets	TiO2 Coating of brackets	Uncoated brackets	Biofilm adhesion	Invitro
Influence of Epoxy, Polytetrafluoroethylene (PTFE) and Rhodium surface coatings on surface roughness, nano-mechanical properties and biofilm adhesion of Nickel Titanium (Ni-Ti) archwires - Asiri et al 2010 [10]	Archwire	Epoxy coated NiTi PTFE coated NiTi Rhodium coated NiTi	Uncoated NiTi	Biofilm adhesion	Invitro
Bacterial adhesion on conventional and self-ligating metallic brackets after surface treatment with plasma-polymerized hexamethyldisiloxane - Tupinambá et al 2017 [11]	Brackets	Polymer coating of conventional and SL bracket	Conventional and SL brackets	Biofilm adhesion	Invitro
In vitro assessment of stainless-steel orthodontic brackets coated with titanium oxide mixed Ag for anti-adherent and antibacterial properties against Streptococcus mutans and Porphyromonas gingivalis - Fatani et al 2017 [12]	Brackets	Ag + TiO2 coated brackets	SS brackets	Biofilm adhesion	invitro
Quantitative assessment of Mutans Streptococci adhesion to coated and uncoated orthodontic archwires (In vitro study) - Al-Lami et al 2014 [13]	Archwire	Aesthetic Coated SS Aesthetic Coated NiTi	Uncoated SS wire Uncoated NiTi wire	Biofilm adhesion	Invitro

SS – Stainless steel, NiTi – Nickel titanium, TiN – Titanium Nitride, PTFE – Polytetrafluorethylene (Teflon), TiO_2 – Titanium Oxide, SL – Self ligating, CCT – Controlledclinical trial

Figure 1: PRISMA flow chart



3.3 Risk of Bias assessment

Risk of bias was done for all the eight studies which were included in the systematic review. Bias assessment was done using Cochrane Risk of Bias in Non-randomized Studies - of Interventions (ROBINS 1 tool) for in vivo studies and Downs and Black check list for in-vitro studies that were included in the study.

The risk assessment was done independently by two authors. In case of any disagreement between the authors, a third author was consulted with. For invitro studies, scores regarding attrition and sample randomising were excluded as they were not applicable for them.

Due to the high heterogenicity in the type of surface modification used and the methods used to assess the biofilm adhesion in the studies included systematic review, a meta-analysis was not possible.

3.4 Data Extraction

After eliminating the duplicates, full texts were obtained for the all the studies which were eligible for the study. Two authors independently extracted the data form the articles. Sample size, Appliance type, surface modification used, bacterial exposure type and duration. Invitro characteristics like storage and sterilization of the appliance before study, number of tests done per sample, how the microbial count was performed and surface roughness determination if any as an outcome.

4 Results

Electronic data search received 2335 results in the online data bases that were available. Manual searching was also done for articles matching the inclusion criteria. The studies were then screened based on the title for relevancy to the inclusion criteria, after which 2322 studies were excluded. In case of uncertainty, the abstract was studied.

Full texts were obtained for the remaining 16 articles and 8 of them was excluded because it did not meet with the eligibility criteria of the present systematic review. [14] compared between two coated archwire, [15] studied the silver release alone but didn't report the microbial count or adhesion, [16] did a research on coating but didn't not quantify the microbial adhesion or the cell count, but gave anti-microbial activity by disc diffusion method, [17], [18], [19], [20] were studies which researched about the surface and mechanical properties but didn't not gave the biofilm adhesion of these coated wires, [21] described the relationship between the aesthetic coating of archwire and roughness but didn't mention about the bacterial adhesion. Finally, eight studies which fulfilled the eligibility criteria were used for the systematic review.

4.1 Risk of bias

The risk of bias assessment that was performed using ROBINS – 1 tool is being recorded in table 2.1 and the ones assessed using downs and black check list is tabulated in table 2.2. Most of the invivo studies had moderate to low risk of bias and the invitro studies had moderate to high risk of bias.

Table 2.1: Risk of Bias assessment for invivo studies

	Bias due to confounding	Bias in selection of participants into the study	Bias in classification of interventions	Bias due to deviations from intended interventions	Bias due to missing data	Bias in measurement of outcomes	Bias in selection of the reported result	Overall

Amini et al 2017 [6]	1.1 PN 1.7 NI Low risk	2.1 N 2.4 NI Moderate risk	3.1 Y 3.2 Y 3.3 PY Low risk	4.1 N 4.3 Y 4.4 Y 4.5 Y Low risk	5.1 N 5.2 PY 5.3 PY 5.4 NA 5.5 NA Serious risk	6.1 PY 6.2 Y 6.3 Y 6.4 N Serious risk	7.1 N 7.2 N 7.3 N Low risk	Serious risk of bias
Costa Lima et al 2019 [7]	1.1 PN 1.7 NI Low risk	2.1 N 2.4 NI Moderate risk	3.1 Y 3.2 Y 3.3 PY Low risk	4.1 N 4.3 Y 4.4 Y 4.5 Y Low risk	5.1 PY 5.2 N 5.3 N Low risk	6.1 PY 6.2 N 6.3 Y 6.4 N Low risk	7.1 N 7.2 N 7.3 N Low risk	Moderate risk of bias
Demling et al 2010 [8]	1.2 PN 1.7 NI Low risk	2.1 N 2.4 NI Moderate risk	3.1 Y 3.2 Y 3.3 PY Low risk	4.1 N 4.3 Y 4.4 Y 4.5 Y Low risk	5.1 PY 5.2 N 5.3 N Low risk	6.1 PY 6.2 N 6.3 Y 6.4 N Low risk	7.1 N 7.2 N 7.3 N Low risk	Moderate risk of bias

4.2 Data extraction

Of the eight studies reviewed, four [8], [9], [11], [12] studies were based on surface modification of the bracket and Four [6], [7], [10], [13] studies were based on the surface modification of the archwire. The results of the data extraction are presented in table 3.

Roughness was estimated as secondary outcome in three studies of which two were done with surface profilometer [7], [10] and one with confocal microscopy [11] which are described in Table 4.

Titanium compounds [6], [9], [12], rhodium coating [7], [10], Teflon coating [7], [8], [10], [13] and Polymer coating [10], [11], [13] were studied in this systematic review.

Table 2.2: Risk of Bias assessment of invitro studies

Assessment	**Salehi et al 2018 [9]**	**Asiri et al 2010 [10]**	**Tupinambá et al 2017 [11]**	**Fatani et al 2017 [12]**	**Al-Lami et al 2014 [13]**
Aim	1	1	1	1	1
Outcomes	0	0	0	1	1
Inclusion criteria	1	0	1	0	1
Interventions	1	1	1	0	1
Confounders	0	0	0	0	0

Main outcomes described?	1	1	1	1	1
Estimates of random variability	1	0	1	0	1
ADR reporting	0	0	0	0	0
Attrition reported?	0	0	0	0	0
Actual p value reported?	1	0	1	0	1
Samples asked to participate represent population	1	1	1	1	1
Samples prepared represent population	1	1	1	1	1
Samples from facility used?	0	1	0	1	1
Blind samples?	0	0	0	0	0
Researcher blinding?	0	0	0	0	0
Data dredging?	1	1	1	1	1
Length of follow up same?	1	1	1	1	1
Statistical tests used appropriate?	1	1	1	1	1
Compliance reliable?	1	1	1	1	1
Outcomes accurately measures?	1	1	1	1	1
Samples from same population?	1	1	1	1	1
Samples recruited at same time?	1	1	1	1	1
Randomisation?	NA	NA	NA	NA	NA
Concealment of allocation	0	0	0	0	0
Adjustment of confounding factors?	0	0	0	0	0
Attrition taken into account	NA	NA	NA	NA	NA
Power	1	1	1	1	1
Total	16/28 fair	14/28 poor	16/28 fair	14/28 poor	18/28 fair

NA – Not applicable,Excellent (25-28) Good (20-24) Fair (15-19) Poor (≤14)

Study	Sample size	Bracket and wire	Control	Coating	Medium	Time of exposure
Amini et al 2017 [6]	20	-	10 - 19 x 25 SS/ 20 mm	10 - 19 x 25 SS with TiN coating /	Patient saliva invivo	4 weeks

				20 mm		
Costa Lima et al 2019 [7]	48	0.022 slot MBT with 0.019x0.025" SS	12 – Uncoated SS / 7 mm 12 – Uncoated NiTi / 7 mm	12- NiTi coated with Rhodium / 7mm 12- NiTi partly coated with Teflon / 7 mm	Patient saliva invivo	4 weeks
Demling et al 2010[8]	26	SL bracket 3M with 0.016x0.022" SS	13 – uncoated SS bracket	13 – PTFE coated SS bracket	Patient saliva invivo	8 weeks
Salehi et al 2018 [9]	40	SS premolar brackets	20 – uncoated SS brackets	20 – TiO2 coated SS brackets	Bacterial suspension of S. mutans (1.5 x 10^6)	1(T0), 30, (T1)60(T2) and 90(T3)-days
Asiri et al 2010 [10]	-	NiTi archwires	2cm uncoated NiTi	2cm PTFE coated NiTi (group 1) 2cm Epoxy coated NiTI (group 2) 2cm Rhodium coated NiTi (group 3)	BHI broth	24h
Tupinambá et al 2017 [11]	68	Conventional and SL brackets	34 SS Uncoated conventional and SL brackets	34 -polymer coated conventional and SL brackets	BHI broth	72h
Fatani et al 2017 [12]	140	0.022 MBT	25 – SS brackets	25 – SS + Ag 25 – SS + TiO2 25 – SS + Ag – TiO2	Blood agar	24h
Al-Lami et al 2014 [13]	72	0.018 "archwires	12 – NiTi archwires 12 – SS archwires	12 – Tooth coloured SS – group 1 12 – tooth coloured NiTi – group 2 12 – Teflon SS coated – group 3	Pure isolate of S. mutans from stimulated saliva with and without vortex mixer	5, 90, 180min

				12 – NiTi Teflon coated – group 4	+ serial dilution	

Table 3: Biofilm Data extraction

SS – Stainless steel, NiTi – Nickel titanium, TiN – Titanium NitridePTFE – Polytetrafluorethylene (Teflon), TiO_2 – Titanium Oxide, SL – Self ligating

Table 3 continued: Biofilm data extraction

Study	Roughness	Counting	Control count	Experiment count	Bacteria
Amini et al 2017 [6]	-	Serial dilution + blood agar	8 ± 7.4	4± 3.4	Mixed
Costa Lima et al 2019 [7]	Profilometer	Serial dilution + Blood agar	SS – 8.15 ± 1.37 NiTi – 9.28 ± 2.13	NiTi with Rhodium coating – 11.80 ± 0.82 NiTi with partial Teflon – 7.01 ± 0.79	Mixed
Demling et al 2010[8]	-	SEM	0.9±0.8 mm^2	4.8±1.2 mm2	Mixed
Salehi et al 2018 [9]	-	Serial dilution + TPY agar	T0 - 37.71 ± 5.21 T1 - 37.81 ± 5.03 T2 - 37.98 ± 5.37 T3 - 37.74 ± 5.21	T0 - 400.91 ± 14.67 T2 - 401.58 ± 14.01 T3 - 400.31 ± 14.68 T4 - 402.04 ± 13.98	S. mutans (ATCC 25175)
Asiri et al 2010 [10]	Profilometer	Serial dilution + BHI medium	3.40 ± 0.39 2.49 ± 0.12	Group 1 4.76 ± 0.27, 3.73 ± 0.12 Group 2 5.55 ± 0.26), 4.64 ± 0.21 Group 3 3.85 ± 0.20, 2.79 ± 0.14	Streptococcus mutans Streptococcus sobrinus
Tupinambá et al 2017 [11]	Confocal inferometry	BHI agar	SL - 9.13 ± 0.63 C - 7.99 ± 1.82	SL -9.00 ± 0.31 C - 5.79 ± 2.78	Streptococcus mutans, ATCC #35688
Fatani et al 2017 [12]	-	Lysoge-ny broth + serial dilution	S. mutans 0.36 ± 0.036 P.gingivalis 0.21 ± 0.02	**S. mutans** 0.27 ± 0.043 0.29 ± 0.050 0.25 ± 0.058 **P.gingivalis**0.17 ± 0.022 0.15 ± 0.024	S. mutans P.gingivalis

				0.13 ± 0.027	
Al-Lami et al 2014 [13]	-	CFU strips	95 ± 93.67 148±148	Group 1 - 120 ± 120 Group 2 - 109 ± 109.33 Group 3 - 89 ± 90 Group 4 - 74 ± 75.33	S. mutans

BHI – Brain heart infusion, PBS – Phosphate buffered saline, EDTA - Ethylenediaminetetraacetic acid, CFU – Colony forming units, SEM – Scanning electron microscopy

Table 4: Roughness data extraction

Study	Method	Control group roughness	Experimental group roughness
Costa Lima et al 2019 [7]	Profilometer	Uncoated SS – 0.59 ± 0.39 μm Uncoated NiTi – 0.57 ± 0.36 μm	Partially coated teflon NiTi archwire – 1.79 ± 0.41 μm Rhodium coated NiTi archwires – 0.90 ± 0.37 μm
Asiri et al 2010 [10]	Profilometer	Uncoated NiTi archwire – 0.29 ± 0.16	PTFE coated NiTi – 0.74 ± 0.49 Epoxy coated NiTi – 1.29 ± 0.49 Rhodium coated NiTi – 0.34 ± 0.31
Tupinambá et al 2017 [11]	Confocal inferometry (median values)	Uncoated conventional bracket – 3.760 Uncoated self-ligating bracket – 1.749	Coated conventional bracket – 1.749 Coated self-ligating bracket – 1.649

SS – Stainless steel, NiTi – Nickel titanium, TiN – Titanium Nitride, PTFE – Polytetrafluorethylene (Teflon)

4.2 Data extraction

Of the eight studies reviewed, four [8], [9], [11], [12] studies were based on surface modification of the bracket and Four [6], [7], [10], [13] studies were based on the surface modification of the archwire. The results of the data extraction are presented in table 3.

Roughness was estimated as secondary outcome in three studies of which two were done with surface profilometer [7], [10] and one with confocal microscopy [11] which are described in Table 4.

Titanium compounds [6], [9], [12], rhodium coating [7], [10], Teflon coating [7], [8], [10], [13] and Polymer coating [10], [11], [13] were studied in this systematic review.

5 Discussion

In this systematic review, the adhesion of various microorganisms especially *S. mutans* was studied. Although only mixed microbial flora can be studies in the oral cavity, invitro studies offer us the method to assess the selective adhesion of certain microbes like *S. mutans* and *P.gingivalis*which have been attributed to causing dental caries and periodontal problems respectively. In the various methods of surface modification of the orthodontic appliance some are aimed for aesthetic enhancement which includes Rhodium, Teflon and polymer coating while some titanium compounds and silver compounds are used as antimicrobial coating aimed for reducing the bacterial load adhering on the orthodontic appliance.

5.1 Titanium compounds

Titanium is a silvery white metal with high strength and low-density possessing corrosion resistant properties. Oxide of titanium mainly TiO_2 is used as a pigment in food and cosmetics due to its white coloured appearance. It also possesses antimicrobial activity due to hydroxyl ion formation

The study by Fariborz et al [6] state there is a statistical significance in reduction of the microbial count and a 49.65% reduction in the cell count of the microbes which was present on the archwire. Although the article taken into the study did not measure the roughness of the wire after coating, a study by Scarano et al [22] state that the reduction in micro-organism count is not a function of the surface roughness of the coating but because of the antimicrobial effect of the titanium nitride coating as the roughness slightly increased in titanium – nitride coated implants. Another study [23] also states there is a slight increase in the roughness due to the coating, from 19.2 nm for the untreated nickel titanium wire and 21.9 nm for the Titanium – nitrogen coated wire. Hence there is a reduced microbial count due to the antimicrobial activity of the titanium nitrogen coating and improved oral hygiene at the cost of a mild increase in surface roughness of the material.

The study [9] by Parisa et al comprising of nitrogen doped titanium oxide coating of brackets state there is a significant reduction in the microbial count mainly due to the antimicrobial action of the titanium oxide coating which can be attributed towards formation of superoxide ions and hydroxyl radicals after exposure to UV light, which causes oxidative damage to the bacterial cell membrane ultimately leading to cell death [24]. Nitrogen doping is shown to alter the photocatalytic activity of titanium oxide making it active to visible light along with UV light [24]. Titanium oxide coated brackets showed a highly significant reduction in the microbial count when compared to regular brackets, from a mean 400 colonies in control to just 38 colonies in the study group indicating a 9.5-fold reduction in the colony count. A study by [26] state there is a significant reduction in the surface roughness of the brackets after titanium oxide coating.

The study by Fatani et al [12] also conclude that there is a significant reduction in the biofilm adhesion to the wire following the coating with titanium oxide. It also compared silver coating and silver with titanium oxide coating. The reduction in microbe count in by silver coating maybe caused due to the antimicrobial activity of silver [27] as it causes damage of bacterial cell wall and suppresses bacterial proliferation, reducing the bacterial counts. Naturally with the use of titanium oxide and silver coating, there is an additive effect on the antimicrobial activity significantly

reducing the adhesion of bacteria and biofilm formation although a small increase in surface roughness is inevitable with silver coating [28].

5.2 Teflon

Teflon is polytetrafluorethylene. It is a hydrophobic substance. It is used in coating of catheters in the medical field so that it won't harbour microorganisms preventing the development of nosocomial infections.

In the study by Costa Lima et al [7], he states that when compared to complete coating by rhodium, and uncoated nickel titanium archwires, teflon coating has much lesser biofilm adhesion. However, the article also states there is correlation between the surface roughness and biofilm adhesion and that roughness of an archwire increases progressively in intra oral conditions due to abrasions caused by brushing and eating. The increase in roughness of teflon is more compared to the increase in roughness of uncoated nickel titanium archwires. Hence, according to the study, partial coating of organisms causes lesser biofilm adhesion than complete coating.

In the study by Aliaa Abdul Rhman Al-Lami et al [13], they state there is a reduction in the number of microorganisms adhering to teflon coated archwires.

In a study by Demling et al [8], they studied about the effect of coating teflon on brackets and found that there was a 5-fold reduction in the number of microbes adhering to the teflon coated brackets than uncoated brackets, may be due to the anti-adhesive effect of teflon. The teflon coated brackets did get abraded over the course of time especially where sheer forces acted on the bracket.

Although the decrease in roughness of teflon coating is may be the cause for the decrease in the number of microbes adhering to the archwire, other possibilities include the fluoride side chain which may increase the hydrophobicity of the material hence reducing the wettability and contact angle on the coating [29].

Also, teflon being fluoropolymers have high electronegativity which prevents certain dispersive factors like Vander walls force of attraction which is considered as the main mechanism of microbial adhesion [8].

In the study by Asiri et al [10], he states that rhodium coating and uncoated nickel titanium archwires have lesser biofilm adhesion when compared to teflon coated archwires and that there is a positive correlation between surface roughness and biofilm adhesion. This is in direct contradiction to the previous studies [2], [8], [13].

5.3 Rhodium

Rhodium is a silvery white metal which is relatively inert, hence corrosion resistant. Due to its white appearance and chemically inert nature, it is sued for coating orthodontic archwires for aesthetic purposes.

In the study by Costa Lima et al [7], they state the roughness of as received nickel titanium archwires is more compared to the uncoated and teflon coated nickel titanium archwires, but the roughness increase of Rhodium coated archwires is less than those of uncoated and teflon coated archwires. The microbial count adhering on rhodium coated nickel titanium archwires is more compared to the uncoated and teflon coated archwire.

The study by Asiri et al [10] state Rhodium has closer surface roughness to uncoated nickel titanium archwires and lesser roughness than teflon or epoxy coated wires. The biofilm adhesion was also reduced which is in disagreement with the previous study [7].

5.4 Polymer coating

Epoxies are thermosetting polymers which contains one or more epoxide groups. Epoxy resin coating provides excellent adhesion, chemical resistanceand dimensional stability. In orthodontics, it is used in composite resins for bonding and as aligners. It is also used as archwire coatings for aesthetic purposes.

In the study by Aliaa Abdul Rhman Al-Lami et al [13], they state that the roughness of the epoxy coating is slightly higher than that of uncoated archwires and hence there is a slight increase in the number of microbes adhering to the surface of the archwires.

The study by Asiri et al [10] state there is an increase in the surface roughness of the epoxy coated archwires and hence an increase in the number of microbes adhering to the surface of the archwire. The roughness of archwire as highest for epoxy coated archwires followed by teflon coated archwires and lastly rhodium coated archwires.

One study [11] assessed the microbial adhesion of a bracket with an organosilicon compound – hexamethyldisiloxane (HMDSO). Hexamethyldisiloxane is used for its hydrophobic property and anti-adherent nature, hence decreasing microbial adhesion on the bracket. The article concluded that there is a reduction in surface roughness and microbial adhesion in the polymer coated conventional bracket.

Although a number of studies state surface roughness of the coating is a function of microbial adhesion, some studies are in disagreement to it. Surface roughness may be an important but not the only factor in determining the microbial adhesion on the surface of the appliance. The chemical reactivity against the microbes, its antimicrobial nature, the minimum inhibitory concentration of that substance, polar nature of the coating substance, ability to withstand oral functions and abrasiveness of the coating, wettability with oral fluids, feasibility to completely coat the bracket or archwire without disrupting archwire bracket play or bracket adhesion to the tooth, intra oral age changes of the coating whether it undergoes degradation or its dimensional stability in the varying oral conditions like temperature and pH are also to be considered.

6 Conclusion

Within the limitations of this systematic review, we have discussed the various surface modifications of orthodontic appliances that have been studied for their biofilm or microbial adhesion nature.

The surface modification of an orthodontic appliance does bring about changes in the number of microbes it harbours. This systematic review indicates the requirement of many studies with high methodological qualityand randomised control trials for further developments in the field of surface modifications of appliances which are both aesthetic and possessing antimicrobial property low bio film adhesion property.

7.1 Ethics approval and consent to participate

Not applicable

7.2Consent for publication

Not applicable

7.3Availability of data and materials

All data generated or analysed during this study are included in this published article [and its supplementary information files].

7.4 Competing interests

The authors declare that they have no competing interests

7.5 Funding

Not funded

7.6Authors' contributions

NS and DS contributed towards searching the electronic database for suitable studies. NS and DD performed Risk of bias assessment. DS and DD performed data extraction. In case of any disagreement RK was consulted with. All authors read and approved the final manuscript.

7.7Acknowledgements

Not applicable

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