JOURNAL OF COMPLEMENTARY MEDICINE RESEARCH
Journal of Complementary Medicine Research, ISSN: 2146-8397 Vol. 13, No. 5, 2022 (pp. 105-114)
RESEARCH ARTICLE WWW.JOCMR.COM

An In Vitro Evaluation of The Effect of Titanium Dioxide Nanoparticle on The Shear Bond Strength and Antimicrobial Property of Orthodontic Adhesive: A Systematic Review and Meta-Analysis

L Harsha[1], Aravind Kumar Subramanian[2]*

[1]*Resident, Department of Orthodontics, Saveetha Dental College and Hospitals, SIMATS, Chennai.*

[2]*Professor and Head of the Department, Department of Orthodontics, Saveetha Dental College and Hospitals, SIMATS, Chennai.*

ABSTRACT

Objective: The objective of this review was to systematically analyse available literature on the effects of titanium dioxide nanoparticles (TiO_2 NPs) in improving the antimicrobial activity and shear bond strength when incorporated in orthodontic adhesives.
Methods: All invitro studies that have evaluated the shear bond strength and the antimicrobial activity of TiO2 NPs infiltrated orthodontic adhesive were included in this review. A comprehensive search in 5 electronic databases namely, Google scholar, PUBMED, EMBASE, Cochrane and Web of science were done up to January 2023. Using the reference method for invitro studies, the Risk of bias ROB was evaluated. Meta-analysis using Random Effects Model was performed for assessing the antimicrobial activity against S. mutans, C. albicans and L. Acidophilus.
Results: All the included studies had a moderate risk of bias. On qualitative analysis, a significant antimicrobial effect against Streptococcus mutans and Lactobacillus acidophilus and a non-significant shear bond strength of TiO2 infiltrated orthodontic adhesive was reported. The meta-analysis revealed a significant overall antimicrobial effect and non-significant shear bond strength values with a high heterogeneity.
Conclusion: An overall significant antimicrobial effect of TiO_2 infiltrated orthodontic adhesive against S. mutans and L. Acidophilus was noted but with a high heterogeneity and a moderate risk of bias. An overall non-significant shear bond strength of TiO_2 infiltrated orthodontic adhesive was noted but with a high heterogeneity and a moderate risk of bias.

Corresponding Author e-mail: aravindkumar@saveetha.com

How to cite this article: **:** Harsha L, Subramanian K A, An In vitro evaluation of the effect of Titanium dioxide nanoparticle on the shear bond strength and antimicrobial property of orthodontic adhesive: A Systematic review and meta-analysis. Journal of Complementary Medicine Research, Vol. 13, No. 5, 2022 (pp. 105-114)

KEYWORDS:
Bacterial growth,
smokers, non-smokers

ARTICLE HISTORY:
Received June 18, 2022
Accepted Oct 17, 2022
Published Dec 15, 2022

DOI:
10.5455/jcmr.2022.13.05.20

INTRODUCTION

It is known in orthodontic literature that enamel demineralisation, white spot lesions and incipient dental caries around the bonded brackets are the potential adverse effects of fixed orthodontic therapy (1). White spot lesions develop rapidly around the brackets with the 1st month of treatment with a frequency of 2-96% (2,3). This could be associated with compromised oral hygiene due to bonded brackets, leading to biofilm and plaque formation consisting of multispecies cariogenic bacteria (4,5). The primary preventive measures as enumerated over the years include good oral hygiene maintenance and sugar-controlled diet. While the secondary preventive measure includes fluoridation by means of toothpastes, mouthwashes etc. But these methods are not reliable as they are subjective in nature

This void has led to the development of materials that incorporate antimicrobial agents like chlorhexidine into orthodontic adhesives (6,7). However, it provided short term antimicrobial effects and also altered the mechanical properties invariably, questioning its further use in orthodontics (8).

With the development of nanobiotechnology and nanomedicine, a number of novel antimicrobial nanomaterials have been formulated for effective use in dentistry. Studies conducted previously have also evaluated the antimicrobial and mechanical properties of these nano infiltrated orthodontic adhesives (9,10). Titanium dioxide is one such nanoparticle that has proven to be an effective antimicrobial agent that does not affect the mechanical property of the adhesive.

To substantiate the same, a high-quality meta-analysis and pooled data from a systematic review with statistical significance would provide scientific evidence. To the best of our knowledge a previous systematic review was conducted evaluating the effect of antimicrobial agent infiltrated orthodontic adhesives on its mechanical properties (11,12). But there is lack of evidence on the antimicrobial effect of brad spectrum nanoparticles that have been incorporated into orthodontic adhesives to improve its efficiency in preventing enamel demineralisation and White spot lesions. Hence, the present systematic review and meta-analysis aimed to evaluate systematically all available published literature qualitatively and quantitatively on the shear bond strength and antimicrobial effect of titanium dioxide (TiO2) nanoparticle infiltrated orthodontic adhesive.

MATERIALS AND METHODS

Focused Question

With reference to the preferred reporting items for systematic review and meta-analysis the following 2 questions were constructed, A) Does Tio2 NP s incorporation in orthodontic adhesive influence the shear bond strength? B) Does the TiO2 NPs infiltrated orthodontic adhesive have good antimicrobial activity against oral microbes?

Protocol registration

The systematic review was prepared adhering to the reporting guidelines for Systematic reviews and Meta-Analysis in the PRISMA 2020 statement. The Systematic review Is not registered in PROSPERO.

Literature Search Protocol

A comprehensive search in 5 databases namely, Google scholar, PUBMED, EMBASE, Cochrane and Web of science were done up to January 2023. Using, open access sources, open grey and grey net, Grey literature were also searched. The detailed search stratergy on PubMed is mentioned in Table 1. The same search stratergy was applied for all other databases. The article references lists were also screened. The search was restricted to only invitro English literature published before January 2023. Using the Endnote application (version X9; Clavirate Analytics, Philadeplhia, PA, USA) all duplicates were removed.

Table 1: Search Strategies

PUB MED SEARCH	
Search Details	Results
((((((TITANIUM dioxide nanoparticle[Title/Abstract]) OR (TiO2 Nanoparticle[Title/Abstract])) OR (noninfiltrated[Title/Abstract])) OR (Titanium dioxide nanoparticle)) OR (TiO2) AND (fha[Filter])) AND ((((((((Shear bond strength) OR (mechanical property)) OR (bond strength)) OR (debonding strength)) OR (antimicrobial activity)) OR (antibacterial activity)) OR (s. mutans)) OR (oral microbes) AND (fha[Filter]))) AND ((((Orthodontic adhesive)) OR (orthodontic cement)) OR (orthodontic composite) AND (fha[Filter])) AND (fha[Filter])	67
((((((((Shear bond strength) OR (mechanical property)) OR (bond strength)) OR (debonding strength)) OR (antimicrobial activity)) OR (antibacterial activity)) OR (s. mutants)) OR (oral microbes) AND (fha[Filter])) AND (((((TITANIUM dioxide nanoparticle[Title/Abstract]) OR (TiO2 Nanoparticle[Title/Abstract])) OR (noninfiltrated[Title/Abstract])) OR (Titanium dioxide nanoparticle)) OR (TiO2) AND (fha[Filter]))	3.065
((((((TITANIUM dioxide nanoparticle[Title/Abstract]) OR (TiO2 Nanoparticle[Title/Abstract])) OR (noninfiltrated[Title/Abstract])) OR (Titanium dioxide nanoparticle)) OR (TiO2) AND (fha[Filter])) AND ((((((((Shear bond strength) OR (mechanical property)) OR (bond strength)) OR (debonding strength)) OR (antimicrobial activity)) OR (antibacterial activity)) OR (s. mutans)) OR (oral microbes) AND (fha[Filter]))) AND ((((Orthodontic adhesive) OR (bonding)) OR (orthodontic cement)) OR (orthodontic composite)	244
(((Orthodontic adhesive) OR (bonding)) OR (orthodontic cement)) OR (orthodontic composite)	2,90,084

(((((((Shear bond strength) OR (mechanical property)) OR (bond strength)) OR (debonding strength)) OR (antimicrobial activity)) OR (antibacterial activity)) OR (s. mutants)) OR (oral microbes)	8,79,219
(((((((Shear bond strength) OR (mechanical property)) OR (bond strength)) OR (debonding strength)) OR (antimicrobial activity)) OR (antibacterial activity)) OR (s. mutans)) OR (oral microbes)	7,63,692
((((TITANIUM dioxide nanoparticle [Title/Abstract]) OR (TiO2 Nanoparticle[Title/Abstract])) OR (noninfiltrated[Title/Abstract])) OR (Titanium dioxide nanoparticle)) OR (TiO2)	34.575

Eligibility Criteria

The PICO for this systematic review is, Population (P): Orthodontic adhesiveIntervention (I) TiO_2 NPs Comparison (C): Control with no nano infiltrationOutcomes (O): Shear bond strength, antimicrobial activityStudy (S): Invitro studiesThe inclusion and exclusion criteria for including studies in this systematic review are mentioned in Table 2.

Table 2: PICO Analysis and eligibility criteria

PICO	Inclusion criteria	Exclusion criteria
Population (P): Orthodontic adhesive	Only orthodontic adhesive	Restorative composites, glass ionomer cement, varnish
Intervention (I): Titanium dioxide nanoparticle	Only Titanium dioxide nanoparticle	Other nanoparticles like Ag, or silica, etc.
Comparison (C): no nanoparticle	_	_
Outcomes (O): Primary: shear bond strength, antimicrobial activity	Shear bond strength and Anti- microbial activity	Any other properties
Study Design	Only in-vitro studies	Randomized and non-randomized Control trials.

Data Extraction And Assessment

All studies that fit as per the inclusion criteria after full text reading by the three authors (HL, AKS, PA) were included in this review. The selection process is represented in the PRISMA flowchart 2020 Figure 1. The intra-examiner agreement based on kappa statistics was 95%. Any disagreements were resolved by discussion. The data extracted by the 3 authors from the included studies were the name of the author, year of publication, concentration of TiO_2 NPs infiltrated in the orthodontic adhesive, the shear bond strength and the antimicrobial activity specifying the organism against which the sample was tested. Table 3 represents the study characteristics of the review which comprises all of the general information of the included studies. Table 4 represents the data of the outcomes evaluated in this systematic review.

Quality assessment

The risk of bias assessment tool was adapted from previously published systematic reviews (22,23). (Table 5) Studies with one to three “Yes” responses were deemed to have a low risk of bias. Studies scoring four to six “Yes” were considered to have a medium risk of bias, while those scoring seven to nine “Yes” were considered to have a high risk of bias.

Quantitative Assessment of the included studies

Meta-analysis of the primary outcomes was performed using Cochrane review manager software (Revman version 5.4). The overall effects were calculated using a random effects model (DerSimonian-Laird random effects pooling method). The antimicrobial effect was expressed in the form of mean CFU/ml.

RESULTS

Study Selection

The electronic search identified a total of 584 articles. After removing the duplicates, 553 studies were further screened. After screening of the titles and abstracts, only 14 studies were selected. On further screening of the studies for eligibility criteria 5 studies were excluded. Finally, 9 studies were relevant and were included for qualitative analysis. 3 studies were selected for quantitative analysis of the outcome shear bond strength, 2 studies each were included for quantitative analysis of antimicrobial activity against S. mutans and L. Acidophilus (Figure 1).

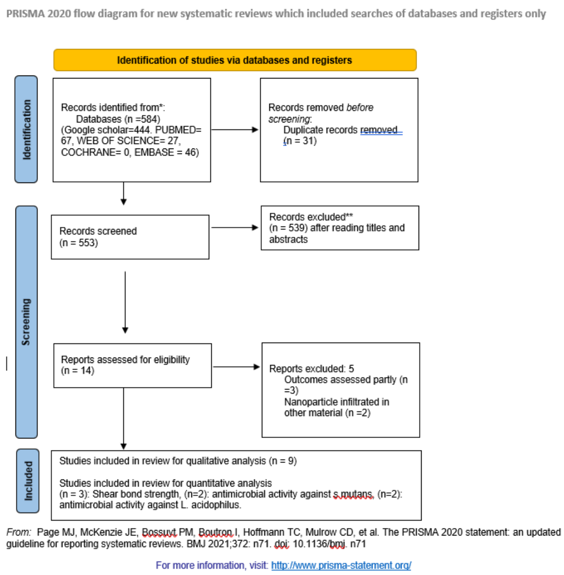

Figure 1: PRISMA Flowchart for study selection.

Study characteristics

Table 3 provides a summary of the characteristics of the eleven studies that were included. Shear bond strength and antimicrobial activity was the primary outcome evaluated by all of the included studies (Table 4). The antimicrobial effect of the coated brackets against Streptococcus mutans; Lactobacillus Acidophilus; and S. sanguinis was assessed as the number of Colony Forming Units (CFU/ ml $\times 10^5$).

Table 3: Characteristics table

AUTHOR	YEAR	GROUPS	N	NP %	PARAMETERS EVALUATED	METHODS	REF
PUTRI et al	2021	G1 – Teeth bonded with TiO2 infiltrated orthodontic adhesive. G2 - Teeth bonded with chitosin infiltrated adhesive G3 - teeth bonded using orthodontic adhesive resin only	G1 – 10 G2 – 10 G3 - 10	Not mentioned	AMA	s. mutans colony count after incubation at 37 deg C for 24 hrs.	13
Assery et al	2019	G1 - 1% TiO2 infiltrated adhesive G2 - 3% TiO2 infiltrated adhesive G3- control	G1- 30 G2 -30 G3- 30	1% and 3%	SBS, AMA	SBS - UTM AMA - S. mutans CFU in BHI agar.	14
Poosti et al	2013	G1 - 1% TiO2 infiltrated adhesive G2 - Control	G1 – 15 G2 - 15	1%	SBS, AMA	SBS - UTM AMA – CFU in blood agar	15
Yassaei et al	2020	10 groups	66 samples totally.	1%	AMA	AMA - CFU & Zone of inhibition	16

		One among them is 1% TiO2 infiltrated composite	6 per group				
Behnaz et al	2018	G1 – Control G2 - TiO2 infiltrated composite		0.1%	SBS	SBS – UTM	17
Sodagar et al	2017	G1 - 1% TiO2 infiltrated adhesive G2- 5% TiO2 infiltrated adhesive G3- 10% TiO2 infiltrated adhesive G4 – control	G1 – 12 G2 – 12 G3 – 12 G4 – 12	1%, 5%, 10%	SBS, AMA	SBS – UTM AMA – Disc diffusion assay	18
Mahendra et al	2020	G1 - 1% TiO2 infiltrated adhesive G2 – Control	G1 – 20 G2 – 20	1%	SBS, AMA	SBS – UTM AMA – disc diffusion assay	19
Reddy et al	2016	G1 - 1% TiO2 infiltrated adhesive G2 – control	G1 - 30 G2 – 30	1%	AMA	SBS – UTM	20
Felemban et al	2017	G1 - 1% TiO2 infiltrated adhesive G2 – 0.5% TiO2 infiltrated adhesive G3 – control	G1 – 20 G2 – 20 G3 - 20	0.5%, 1%	SBS	SBS – UTM	21

Table 4: Results of primary outcome

Author	Shear bond strength	Antimicrobial activity: (Cfu/ml) $\times 10^5$	P value	Conclusion
PUTRI et al, 2021. Incubation period: 24 h	-	*S. Mutans* Groups G 1: 2.36 +/- 1.94 G 2: 2.09 +/- 1.92 G 3: 1.5 +/- 1.24	($p > 0.05$)	No significant difference in the number of Streptococcus mutans colonies around the bracket which was bonded using orthodontic adhesive resin incorporated with titanium dioxide nanoparticles
Assery et al, 2019 Incubation period: 48 h	G1 – 13.2 +/- 1.8 G2 – 12.9 +/- 2.7 G3 – 12.3 +/- 0.9	*S. mutans* *G1 - 5.2* *G2 - 5.8* *G3 - 44.2*	SBS: ($p > 0.05$) AMA: ($p > 0.05$)	1% TiO_2 infiltrated orthodontic adhesive had bactericidal effect against S. mutans. No statistically significant difference between SBS between the 3 groups.

Poosti et al, 2013 Incubation period: 24 h	G1 – 14.3 +/- 1.26 G2 – 14.4 +/- 1.2	*S. Mutans* G1 – 8.2 +/- 3.9 G2 – 69.1 +/-14.59			SBS: (p>0.05) AMA: (p<0.05)	Adding TiO2 nanoparticle to orthodontic composite enhances its antibacterial effect without compromising the shear bond strength.
Yassaei et al, 2020 Incubation period: 24 h	-	*S. mutans* 1% TiO2 orthodontic composite: 241.67 +/- 66.45 Control: 300 +/- 0			(p>0.05)	1% titanium oxide reduced the number of colonies but presented no significant difference with control group,
Behnaz et al, 2018	G1 – 145 +/- 3.87 G2 – 123.92 +/- 3.17	-			(p < 0.05)	The addition of TiO2 nanoparticles might reduce SBS, but the adhesion might still be at an acceptable level.
Sodagar et al, 2017	*G1 – 18.1 +/- 4.6* *G2 – 13.9 +/- 6.00* *G3 – 3.5 +/- 3.28* *G4 – 34.47 +/- 6.7*	*S. Mutans* *G1 – 435.33 +/- 41.04* *G2 – 133 +/- 23.25* *G3 – 14 +/- 3.606* *G4 – 889.6 +/- 115.1*	*S. sanguinis* *G1 – 181.6 +/- 17.2* *G2 – 47 +/- 5.5* *G3 – 173 +/- 4.5* *G4 – 630.6 +/- 94.69*	*L. acidophilus* *G1 – 54+/- 13.74* *G2 – 28 +/- 1* *G3 – 7 +/- 2* *G4 – 89 +/- 19.31*	SBS: (p < 0.05)	Incorporating TiO2 nanoparticles into composite resins confer antibacterial properties to adhesives, while the mean shear bond of composite containing 1% and 5% nanoparticles still in an acceptable range.
Mahendra et al, 2020	G1 – 17.17 +/- 8.3 G2 – 24.67 +/- 6.4	*S. Mutans* G1 – 1.908 +/- 0.202 G2 – 2.405 +/- 0.102		*L. acidophilus* G1 – 1.611 +/- 0.22 G2 – 2.20 +/- 0.13	SBS: (p < 0.05) AMA: (P<0.05)	there is a significant difference in the antibacterial activity and shear bond strength of nanocomposites.
Reddy et al, 2016	G1 – 6.33 +/- 1.51 G2 – 9.43 +/- 3.03	-			(p < 0.05)	A significant difference was observed between the 2 groups.
Felemban et al , 2017	G1 – 25.05 +/- 0.2 G2 – 20.32 +/- 0.47 G3 – 14.75 +/- 0.25	-			(p < 0.001)	The addition of ZrO2–TiO2 nanoparticles on resin-based adhesives increase the shear bond strengths of the adhesive in vitro.

Risk of bias within included studies

Out of the included studies, all studies had moderate risk of bias. The overall risk of bias of the review was reported as moderate risk of bias (Table 5). In all of the included studies, sample randomization and blinding were not reported. In studies showing moderate risk of bias, in addition to the above parameters sample size calculation was not done.

Table 5: Assessment of the risk of bias in the included studies.

Author		PUTRI et al, 2021.	Assery et al, 2019	Poosti et al, 2013	Yassaei et al, 2020	Behnaz et al, 2018	Sodagar et al, 2017	Mahendra et al, 2020	Reddy et al, 2016	Felemban et al , 2017
Reporting Bias	Quantitative analysis	+	+	+	+	+	+	+	+	+
	Definitive values	+	+	+	+	+	+	+	+	+
Assessment Bias	Presence of control group	+	+	+	+	+	+	+	+	+
	Blinding	-	-	-	-	-	-	-	-	-
	Assessment methods	+	+	+	+	+	+	+	+	+
Sampling Bias	Sample randomization	-	-	-	-	-	-	-	-	-
	Sample preparation	+	+	+	+	+	+	+	+	+
	Sample size calculation	-	-	-	-	-	-	-	+	-
Method of Preparation of composite		+	+	+	+	+	+	+	+	+
Risk of bias		M	M	M	M	M	M	M	M	M

2/ less: Low (L), 3-6: Moderate (M), > 6: High (H)

Summary of findings

Table 4 gives the results of the primary outcomes. 6 studies evaluated the antimicrobial effect of titanium dioxide nanoparticle infiltrated orthodontic adhesive against S. mutans, 2 studies reported the activity against l. Acidophilus and 1 study evaluated the activity against s. sanguinis all reported lesser CFUs /ml of S. mutans when compared to conventional orthodontic adhesive indicating a good antimicrobial effect (13-16, 18,19.

7 studies (14,15, 17-21) summarized the outcome, shear bond strength of the TiO_2 infiltrated orthodontic adhesive. 1% TiO_2 when infiltrated into orthodontic adhesive showed no significant difference in the SBS when compared to conventional orthodontic adhesive.

Results of quantitative analysis

The meta-analysis of the 3 included studies (15,18,19) reported the shear bond strength of 1%TiO_2 infiltrated orthodontic adhesive. The overall heterogeneity across the studies was found to be high (I^2= 86%). Thus, a random effects model was used to quantitatively assess the shear bond strength. Figure 2 shows no significant pooled mean difference between 1% TiO_2 infiltrated orthodontic adhesive and conventional orthodontic adhesive (SMD = -1.19; p value = 0.07; 95 % CI = -2.47 to 0.09.

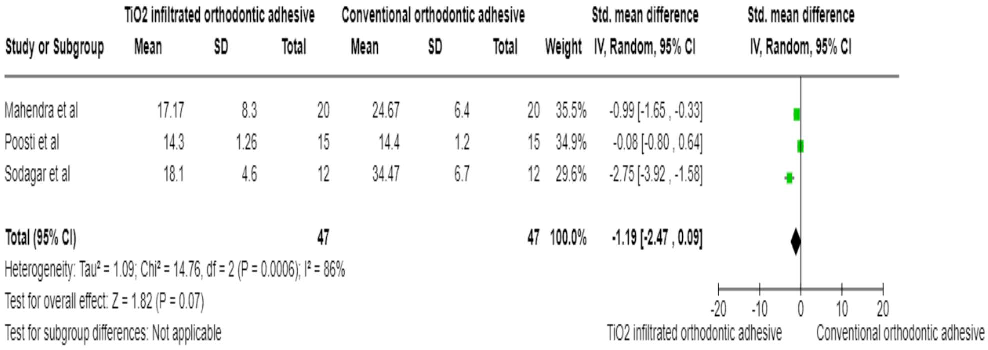

Figure 2: Metanalysis for the outcome shear bond strength of 1% TiO2 infiltrated orthodontic adhesive when compared to conventional orthodontic adhesive.

The meta-analysis of the 2 included studies reported the antimicrobial effect of 1%TiO2 infiltrated orthodontic adhesive against S. mutans. The overall heterogeneity across the studies was found to be low (I2= 0%). Thus, a random effects model was used to quantitatively assess the antimicrobial effect. Figure 3 shows significant pooled mean difference between 1% TiO2 infiltrated orthodontic adhesive and conventional orthodontic adhesive (SMD = -5.33; p value = 0.00001; 95 % CI = -6.54 to -4.11) for number of CFUs against S. mutans.

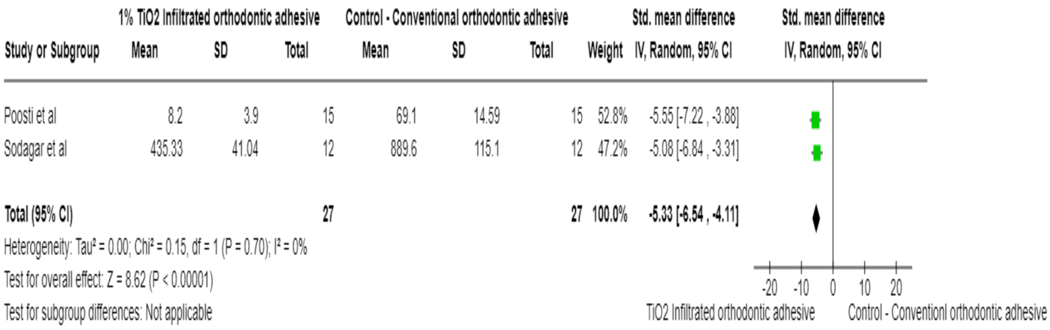

Figure 3: Metanalysis for the outcome antimicrobial activity against S. mutans of 1% TiO2 infiltrated orthodontic adhesive when compared to conventional orthodontic adhesive.

The meta-analysis of the 2 included studies reported the antimicrobial effect of 1%TiO2 infiltrated orthodontic adhesive against L. Acidophilus. The overall heterogeneity across the studies was found to be moderate (I2= 63%). Thus, a random effects model was used to quantitatively assess the antimicrobial effect. Figure 4 shows significant pooled mean difference between 1% TiO2 infiltrated orthodontic adhesive and conventional orthodontic adhesive (SMD = -2.62; p value = 0.00001; 95 % CI = -3.78 to -1.46) for number of CFUs against L. acidophilus. There is a substantial unexplained heterogeneity between the included studies within each of the subgroups. Therefore, the validity of the total effect estimate for each subgroup is uncertain.

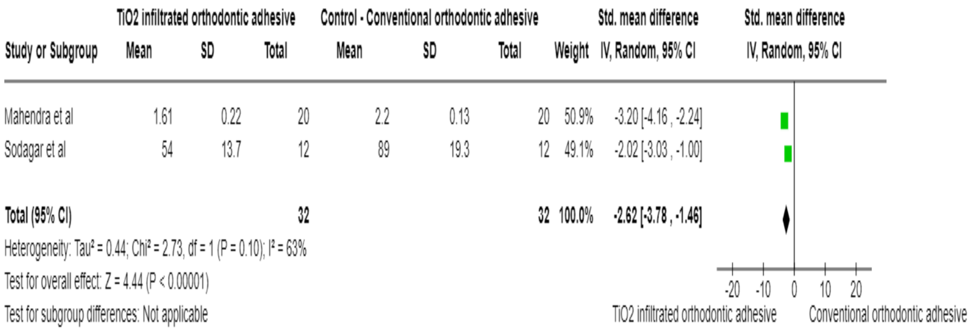

Figure 3: Metanalysis for the outcome antimicrobial activity against L. acidophilus of 1% TiO2 infiltrated orthodontic adhesive when compared to conventional orthodontic adhesive

DISCUSSION

Previously, many attempts were made to develop orthodontic adhesives with good antimicrobial properties in order to prevent enamel demineralisation around bonded orthodontic brackets, but how successful the same would be was not evaluated (24-27). Studies do agree that orthodontic adhesives infiltrated with TiO2 nanoparticles have improved antimicrobial activity when tested in vitro. But in vivo evaluation of the antimicrobial activity and its effect on the shear bond strength needs to be evaluated.

The present systematic review and meta-analysis confirmed the collected effect of the data from in vitro experimental studies that revealed associated between antimicrobial activity and shear bond strength of TiO2 infiltrated orthodontic adhesive. According to the results of the meta-analysis, no significant difference in the shear bond strength was observed between 1%TiO2 infiltrated orthodontic adhesive and conventional orthodontic adhesive. This indicates that incorporating TiO2 nanoparticle does not influence the sg=hear bond strength which is similar to a recent meta-analysis (12).

In addition to evaluation of shear bod strength, the antimicrobial activity of the Tio2 infiltrated orthodontic adhesive against S. mutans and L. acidophilus was evaluated. Since white spot lesions are usually detected around orthodontic brackets, it is critical that the adhesive possess antimicrobial properties. In the present study, quantitative analysis showed that there was a significant improvement in the antimicrobial activity of TiO2 infiltrated orthodontic adhesive against S. mutans and L. acidophilus.

The antimicrobial effect of TiO_2 coatings was due to release of hydroxyl ions. TiO_2 exhibited this property either by UV light illumination or by N-doping in visible light spectrum (28-33). Therefore, visible regions have more clinical acceptability. Most studies claim the annealing temperature of 450 degrees at 2 h results in the formation of anatase phase of TiO_2 which has better antimicrobial activity than the other phases. F. Özyildilz et al (30) and S. Cao et al. (34) showed strong antimicrobial potential at 500 degrees Celsius and 700 degrees Celsius respectively.

The role of adding 1%TiO2 nanoparticles to orthodontic adhesives in controlling WSLs and tooth decay around bonded orthodontic brackets is still poorly explained; the data available are sparse and, to the best of our knowledge, there is no systematic review and meta-analysis relating the characteristics of such modification and outcome. This highlights the necessity of programs to produce orthodontic adhesives containing antimicrobial nano- particles in standardized commercial-scale due to the WSLs, particularly in cases with poor oral hygiene, to reduce the caries rate and maintain oral health and the low potential for post- treatment complications.

LIMITATIONS

Different concentrations of TiO2 used in 3 studies.

The diameter and thickness of the test discs were not clearly mentioned in all included studies.

In vivo studies to correlate the obtained outcomes is essential.

CONCLUSIONS

The results were well described in all included studies and none of them had a high risk of bias due to missing data.

1%TiO2 nanoparticle infiltrated orthodontic adhesive had significant improvement in antimicrobial activity against S. mutans and L. Acidophilus.

1%TiO2 nanoparticle infiltrated orthodontic adhesive had no significant difference in the shear bond strength when compared with conventional orthodontic adhesive.

REFERNCES

1. Sardana D, Zhang J, Ekambaram M, Yang Y, McGrath CP, Yiu CKY. Effectiveness of profes- sional fluorides against enamel white spot lesions during fixed orthodontic treatment: a systematic review and meta-analysis. J Dent 2019;82:1–10.
2. Biria M, Jafary M. A review on preventive measures and treatment of white spot lesions in patients with fixed orthodontic appliances. J Dent Sch 2015;33:106–17.
3. Huang GJ, Roloff-Chiang B, Mills BE, Shalchi S, Spiekerman C, Korpak AM, et al. Effec- tiveness of MI Paste Plus and PreviDent fluor- ide varnish for treatment of white spot lesions: a randomized controlled trial. Am J Orthod Dentofacial Orthop 2013;143:31–41.
4. de Souza-e-Silva CM, Parisotto TM, Steiner- Oliveira C, Kamiya RU, Rodrigues LK, Nobre- dos-Santos M. Carbon dioxide laser and bond- ing materials reduce enamel demineraliza- tion around orthodontic brackets. Lasers Med Sci 2013;28:111–8.
5. Nascimento PLMM, Meereis CTW, Maske TT, Ogliari FA, Cenci MS, Pfeifer CS, et al. Addi-tion of ammonium-based methacrylates to an experimental dental adhesive for bonding metal brackets: Carious lesion development and bond strength after cariogenic challenge. Am J Orthod Dentofacial Orthop 2017;151:949–56.
6. Sharon E, Sharabi R, Eden A, Zabrovsky A, Ben-Gal G, Sharon E, et al. Antibacterial activity of orthodontic cement containing quaternary ammonium polyethylenimine na-noparticles adjacent to orthodontic brackets. Int J Environ Res Public Health 2018;15:606– 14.
7. Pudyani PS, Safitri F, Alhasyimi AA. Effect of orthodontic sealant containing antimicrobial selenium on the shear bond strength of orthodontic bracket. J Orofac Sci 2018;10:96–100.
8. Sodagar A, Akhavan A, Hashemi E, Arab S, Pourhajibagher M, Sodagar K, et al. Evalua-tion of the antibacterial activity of a conven-tional orthodontic composite containing silver/hydroxyapatite nanoparticles. Prog Orthod 2016;17:40–6.
9. Gutiérrez MF, Malaquias P, Hass V, Matos TP, Lourenço L, Reis A, et al. The role of copper nanoparticles in an etch-and-rinse adhesive on antimicrobial activity, mechanical proper- ties and the durability of resin-dentine inter- faces. J Dent 2017;61:12–20.

10. Hosida TY, Delbem ACB, Morais LA, Moraes JCS, Duque C, Souza JAS, et al. Ion release, antimicrobial and physio-mechanical proper- ties of glass ionomer cement containing micro or nanosized hexametaphosphate, and their effect on enamel demineralization. Clin Oral Investig 2019;23(5):2345–54.
11. Paiva L, Fidalgo TKS, da Costa LP, Maia LC, Balan L, Anselme K, et al. Antibacterial properties and compressive strength of new one-step preparation silver nanoparti-cles in glass ionomer cements (NanoAg- GIC). J Dent 2018;69:102–9.
12. Altmann AS, Collares FM, Leitune VC, Samuel SM. The effect of antimicrobial agents on bond strength of orthodontic adhesives: a meta-analysis of in vitro studies. Orthod Cra-niofac Res 2016;19:1–9.
13. Putri WL, Siregar E, Anggani HS. ANTIBACTERIAL EFFECT OF TITANIUM DIOXIDE NANOPARTICLES AND CHITOSAN NANOPARTICLES IN ORTHODONTIC ADHESIVE RESIN ON STREPTOCOCCUS MUTANS COLONY. Dentino: Jurnal Kedokteran Gigi.;6(1):111-6.
14. Assery MK, Ajwa N, Alshamrani A, Alanazi BJ, Durgesh BH, Matinlinna JP. Titanium dioxide nanoparticles reinforced experimental resin composite for orthodontic bonding. Materials Research Express. 2019 Dec 11;6(12):125098.
15. Poosti M, Ramazanzadeh B, Zebarjad M, Javadzadeh P, Naderinasab M, Shakeri MT. Shear bond strength and antibacterial effects of orthodontic composite containing TiO2 nanoparticles. European journal of orthodontics. 2013 Oct 1;35(5):676-9.
16. Yassaei S, Nasr A, Zandi H, Motallaei MN. Comparison of antibacterial effects of orthodontic composites containing different nanoparticles on Streptococcus mutans at different times. Dental Press Journal of Orthodontics. 2020 May 29;25:52-60.
17. Behnaz M, Dalaie K, Mirmohammadsadeghi H, Salehi H, Rakhshan V, Aslani F. Shear bond strength and adhesive remnant index of orthodontic brackets bonded to enamel using adhesive systems mixed with tio 2 nanoparticles. Dental Press Journal of Orthodontics. 2018 Jul;23:43-e1.
18. Sodagar A, Akhoundi MS, Bahador A, Jalali YF, Behzadi Z, Elhaminejad F, Mirhashemi AH. Effect of TiO 2 nanoparticles incorporation on antibacterial properties and shear bond strength of dental composite used in Orthodontics. Dental press journal of orthodontics. 2017 Sep;22:67-74.
19. Mahendra TV, Muddada V, Gorantla S, Karri T, Mulakala V, Prasad R, Chintala SK, Mounica K. Evaluation of antibacterial properties and shear bond strength of orthodontic composites containing silver nanoparticles, titanium dioxide nanoparticles and fluoride: An in vitro study. Dental Press Journal of Orthodontics. 2022 Nov 7;27.
20. Reddy AK, Kambalyal PB, Patil SR, Vankhre M, Khan MY, Kumar TR. Comparative evaluation and influence on shear bond strength of incorporating silver, zinc oxide, and titanium dioxide nanoparticles in orthodontic adhesive. Journal of orthodontic science. 2016 Oct;5(4):127.
21. Felemban NH, Ebrahim MI. The influence of adding modified zirconium oxide-titanium dioxide nano-particles on mechanical properties of orthodontic adhesive: an in vitro study. BMC Oral Health. 2017 Dec;17:1-8.
22. Alamri A, Salloot Z, Alshaia A, Ibrahim MS. The Effect of Bioactive Glass-Enhanced Orthodontic Bonding Resins on Prevention of Demineralization: A Systematic Review [Internet]. Vol. 25, Molecules. 2020. p. 2495. Available from: http://dx.doi.org/10.3390/molecules25112495
23. AlShahrani SS, AlAbbas MS, Garcia IM, AlGhannam MI, AlRuwaili MA, Collares FM, et al. The Antibacterial Effects of Resin-Based Dental Sealants: A Systematic Review of In Vitro Studies [Internet]. Vol. 14, Materials. 2021. p. 413. Available from: http://dx.doi.org/10.3390/ma14020413
24. Asiry MA, Alshahrani I, Alqahtani ND, H. Durgesh B. Efficacy of Yttrium (III) Fluoride nanoparticles in orthodontic bonding. J Nanosci Nanotechnol 2019;19:1105–10.
25. Govindankutty D. Applications of nanotech-nology in orthodontics and its future implica-tions: a review. Int J App Dent Sci 2015;1:166– 71.
26. Song W, Ge S. Application of Antimicrobial Nanoparticles in Dentistry. Molecules 2019;24:1033–48.
27. Varon-Shahar E, Sharon E, Zabrovsky A, Houri-Haddad Y, Beyth N. Antibacterial ortho- dontic cements and adhesives: a possible solution to streptococcus mutans outgrowth adjacent to orthodontic appliances. Oral Health Prev Dent 2019;17:49–56
28. Cao B, Baocheng CAO, Wang Y, Na LI, Bin LIU, Zhang Y. Preparation of an orthodontic bracket coated with an nitrogen-doped TiO2-xNy thin film and examination of its antimicrobial performance [Internet]. Vol. 32, Dental Materials Journal. 2013. p. 311–6. Available from: http://dx.doi.org/10.4012/dmj.2012-155
29. Ghasemi T, Arash V, Rabiee SM, Rajabnia R, Pourzare A, Rakhshan V. Antimicrobial effect, frictional resistance, and surface roughness of stainless steel orthodontic brackets coated with nanofilms of silver and titanium oxide: a preliminary study. Microsc Res Tech. 2017 Jun;80(6):599–607.
30. Özyıldız F, Güden M, Uzel A, Karaboz I, Akil O, Bulut H. Antimicrobial activity of TiO2-coated orthodontic ceramic brackets against Streptococcus mutans and Candida albicans [Internet]. Vol. 15, Biotechnology and Bioprocess Engineering. 2010. p. 680–5. Available from: http://dx.doi.org/10.1007/s12257-009-3005-4
31. Math M, Shah AG, Gangurde P, Karandikar AG, Gheware A, Jadhav BS. In-vitro Comparative Assessment of Antibacterial and Anti-adherent Effect of Two Types of Surface Modificants on Stainless Steel Orthodontic Brackets Against Streptococcus mutans [Internet]. Journal of Indian Orthodontic Society. 2021. p. 030157422110372. Available from: http://dx.doi.org/10.1177/03015742211037298
32. Cao S, Liu B, Fan L, Yue Z, Liu B, Cao B. Highly antibacterial activity of N-doped TiO2 thin films coated on stainless steel brackets under visible light irradiation [Internet]. Vol. 309, Applied Surface Science. 2014. p. 119–27. Available from: http://dx.doi.org/10.1016/j.apsusc.2014.04.198
33. Shah AG, Shetty PC, Ramachandra CS, Sham Bhat N, Laxmikanth SM. In vitro assessment of photocatalytic titanium oxide surface modified stainless steel orthodontic brackets for antiadherent and antibacterial properties against Lactobacillus acidophilus [Internet]. Vol. 81, The Angle Orthodontist. 2011. p. 1028–35. Available from: http://dx.doi.org/10.2319/021111-101.1
34. Cao S, Wang Y, Cao L, Wang Y, Lin B, Lan W, et al. Preparation and antimicrobial assay of ceramic brackets coated with TiO2 thin films. Korean J Orthod. 2016 May;46(3):146–54.