10.5005/jp-journals-10015-1493

REVIEW ARTICLE

Effect of Coated Surfaces influencing Screw Loosening in Implants: A Systematic Review and Meta-analysis

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ABSTRACT

Introduction: The abutment screw loosening has been a common clinical mishap affecting the success of the implant in the long run. With repeated insertion and removal of the implant abutment screw during fabrication of the restoration, frictional wear at the microscopic level in the screw threads had been reported.

Aim: To assess the effectiveness of screw coating in minimizing abutment screw loosening in dental implants in literature.

Results: A database search yielded a total of 14 articles out of which 8 were excluded based on the title and abstracts not relevant to the topic of our interest and 6 were included based on the core data. The six articles were reviewed, and four articles were consolidated to perform the meta-analysis. All the four studies showed a similar expression of outcome measure; the detorque values were expressed in Ncm.

The $\chi^2 = 144.71$, df = 3, $p < 0.00001$, and $I^2 = 98\%$. Hence, a Random Effect model with 95% confidence interval was chosen for meta-analysis. The overall effect observed in the meta-analysis was $Z = 0.36$, $p = 0.72$, and no statistically significant differences were observed between the coated and noncoated screws with respect to detorque values.

Conclusion: This meta-analysis inferred that there is no difference between the coated and noncoated screws with respect to screw loosening.

Clinical significance: Noncoated screws are equally effective as coated screws with respect to abutment loosening in endosseous implants. Hence, the additional cost and technique sensitivity incurred with powdered screws may not drastically improve the rate of failure due to screw loosening.

Keywords: Abutment screw, Coated abutment screws, Screw loosening, Surface modification.

How to cite this article: Kannan A, Venugopalan S, Ganapathy DM. Effect of Coated Surfaces influencing Screw Loosening in Implants: A Systematic Review and Meta-analysis. World J Dent 2017;8(6):496-502.

Source of support: Nil

Conflict of interest: None

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INTRODUCTION

Implant, as a treatment modality, has been widely accepted for replacing single or multiple missing teeth. For successful implant therapy and its clinical longevity, the condition of the periodontium and systemic conditions are not the only determining factors. Material aspects and mechanical features of the implant and its abutment screw also play a vital role in it.

Prosthetic screw loosening has been one of the most common clinically encountered problems in implant cases in the long run and has been known to greatly affect its longevity and success.[1-5] Various factors are attributed to its loosening such as screw design, elasticity of the bone, elasticity of the screw joint, initial preload, friction coefficient, applied torque, and rate of tightening.[4-11]

The implant–abutment joint is a dynamic system that exhibits changes continuously. The internal surface of the implant undergoes a series of changes with fabrication of restoration. With insertion of the healing abutment, impression components, and definitive abutments, the surface morphology of the internal portion of the implant starts showing deterioration even before the definitive restoration is even placed. With clinical procedures that mandate the insertion and removal of abutment screw, a microstructural deterioration of the abutment screw surface morphology may be observed.

As deterioration progresses, the detorque values were found to decrease when compared with the torque values and once it reaches its threshold, the threads of the abutment screw disengage from the grooves of the internal surface of the implant and the abutment starts revolving around its own axis posing a clinical problem.

It is, therefore, necessary to address this issue to ensure long-term success of dental implants. Studies show that with surface modification of abutment screws, there was a significant difference in the tightening and reverse torque values and surface morphology of the abutment screws under scanning electron microscopy (SEM).

AIM

The aim of the systematic review was to analyze scientific evidence in the past and present comparing the rate of wear of coated abutment screw surfaces that have been subjected to loading with that of noncoated abutment screw surfaces through torque–detorque values and SEM

study and support the concept that with surface modification, abutment screw elicits resistance to screw loosening.

Structured Question

Is there a difference in screw loosening between coated and noncoated abutment screws?

Null Hypothesis

There is no difference in resistance to screw loosening between coated and noncoated abutment screws in literature.

Alternate Hypothesis

There is a difference in resistance to screw loosening between coated and noncoated abutment screws in literature.

PICO Analysis

- *Population*: Implants and their structural components,
- *Intervention*: Coating/surface modification of abutment screws,
- *Comparison*: Noncoated/nonsurface modified abutment screws,
- *Outcome*: Torque values, reverse torque values, friction coefficient measures, and surface characteristic changes under SEM.

MATERIALS AND METHODS

A review of literature of studies on resistance to screw loosening in coated *vs* noncoated abutment screws that have been published was carried out without a filter on publication dates and all articles of the past were retrieved (Fig. 1).

Sources used

For identification of studies included or considered for this review, detailed search strategies were developed for the database searched. Search was initiated with the combination of controlled vocabulary-free text terms. The keywords employed in this search were broadly classified into five categories describing population, intervention, comparison, outcome, and the type of study. Keywords within each group were combined using operator (odds ratio) OR and the searches of individual groups were combined using operator AND, to retrieve articles electronically.

Searched Databases

- PubMed
- Medline

Inclusion Criteria

Types of Studies

In vitro study, *in vivo* study, clinical trial, randomized controlled trial, lab study, dental material study, or SEM study dealing with abutment screw loosening.

Exclusion Criteria

- Studies dealing with ceramic and other polymer screw loosening
- Studies dealing with screw loosening due to screw fracture

RESULTS

Out of the 14 articles obtained from electronic search, 8 were excluded based on the title and abstract compared with the topic of our interest and 6 were included based on the core data. The six articles were reviewed, and four articles were consolidated to perform meta-analysis as depicted in Flow Chart 1.

Four studies were consolidated for meta-analysis. All the studies showed a similar expression of outcome measure; the detorque values were expressed in Ncm. The mean detorque values for coated and noncoated screws, respectively, were 20.89 ± 8 and 19.96 ± 7.1 Ncm. The treatment effect measured in this analysis was the difference between the means of coated and noncoated abutment screws, respectively. Random effect model with 95% confidence interval was chosen for meta-analysis. The $\chi^2 = 144.71$, df = 3, $p < 0.00001$, and $I^2 = 98\%$ and the overall effect size observed in the meta-analysis was $Z = 0.36$, $p = 0.72$. Hence, it could be inferred that there is no statistically significant difference between the coated and noncoated screws with respect to screw loosening based on detorque values (Table 1).

DISCUSSION

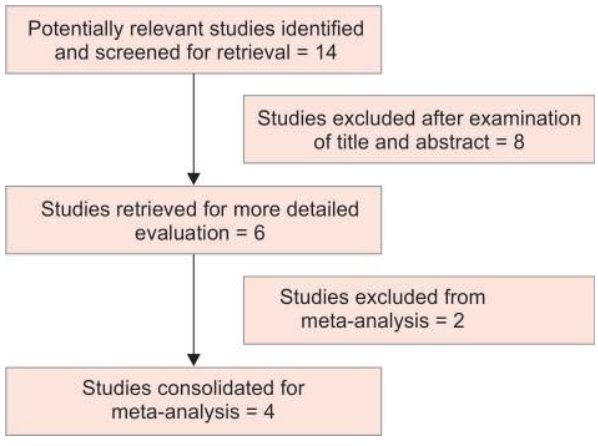
With increasing dental awareness, the scope of implant therapy has increased manifold. This most advocated therapy for replacement of teeth, however, holds many prosthetic complications such as crown loosening because of short abutments, esthetic failures, ceramic fracture, and inappropriate proximal contacts leading to food accumulation, and associated peri-implant diseases. The prosthetic component failures of the dental implant have also been frequently associated with screw loosening or fracture.[1-3]

Nigro et al[4] had mentioned in their article on screw loosening that among the types of mechanical failures, abutment screw loosening is still the most frequently reported in literature. Kano et al[5] stated that factors related to screw loosening are various, including inadequate

Search	Add to builder	Query	Items found	Time
#98	Add	Search ((((((((((((((((((((((implant) OR Implants) OR Abutment screw) OR Abutment screws) OR Abutment thread) OR Abutment threads) OR Screw abutment) OR Screw abutments) OR Screw joint) OR Screw thread) OR Screw threads) OR Prosthetic screw) OR Prosthetic screws) OR Implant supported prosthesis) OR Implant supported prostheses) OR Implant supported restoration) OR Implant supported restorations) OR Abutment screw groups) OR Zirconia abutment screws)) AND ((((((((((((((((((((((((((((((Lubricated screw) OR Lubricated screws) OR Coated screw) OR Coated screws) OR Surface modified screw) OR Modified screws) OR Surface modified screws) OR TiN coated screw) OR TiN coated screws) OR Diamond like carbon coated screw) OR Diamond like carbon coated screws) OR Tungsten carbide coated screw) OR Tungsten carbide coated screws) OR Screw surface treatment) OR Cyclic loading of dental implants) OR Coated abutment screw) OR Coated abutment screws) OR Lubricated abutment screw) OR Lubricated abutment screws) OR Coated abutment screw thread) OR Coated abutment screw threads) OR Surface modified abutment screw) OR Surface modified abutment screws) OR TiN coated abutment screw) OR TiN coated abutment screws) OR Carbon coated prosthetic screw) OR Carbon coated prosthetic screws) OR Abutment screw coated with Ti) OR Abutment screws coated with Ti) OR Diamond like carbon coated implant screw) OR Diamond like carbon coated implant screws) OR Abutment screw under wet condition) OR Abutment screws under wet conditions)) AND (((((((((Non lubricated abutment screw) OR Non lubricated abutment screws) OR Non coated abutment screw) OR Non coated abutment screws) OR Non surface modified abutment screw) OR Non surface modified abutment screws) OR Abutment screw under dry condition) OR Abutment screws under dry conditions)) AND ((((((((((((((Torque) OR Detorque) OR Friction co efficient) OR SEM) OR Weight analysis) OR Scratch testing) OR Tightening torque) OR Reverse torque) OR Wear resistance) OR Wear) OR Friction) OR Adhesion) OR Fatigue failure) OR HAGB) OR Preload)) AND ((((((((((((((((In vitro study) OR Invitro study) OR In - vitro study) OR In-vitro study) OR Lab study) OR Laboratory study) OR Material study) OR Dental material study) OR Fractography) OR SEM study) OR Microscopic study) OR Electron microscopic study) OR Scanning electron microscopic study) OR In vivo study) OR Animal study) OR Clinical trial) OR Randomized control trial)	14	00:56:16
#97	Add	Search ((((((((((((((((In vitro study) OR Invitro study) OR In - vitro study) OR In-vitro study) OR Lab study) OR Laboratory study) OR Material study) OR Dental material study) OR Fractography) OR SEM study) OR Microscopic study) OR Electron microscopic study) OR Scanning electron microscopic study) OR In vivo study) OR Animal study) OR Clinical trial) OR Randomized control trial	4003380	00:55:51
#96	Add	Search **Randomized control trial**	208979	00:54:41
#95	Add	Search **Clinical trial**	1013175	00:54:31
#94	Add	Search **Animal study**	1800094	00:54:22
#93	Add	Search **In vivo study**	289602	00:54:14
#92	Add	Search **Scanning electron microscopic study**	131968	00:53:56
#91	Add	Search **Electron microscopic study**	451633	00:53:43
#90	Add	Search **Microscopic study**	62566	00:53:30
#89	Add	Search **SEM study**	40091	00:53:20
#88	Add	Search **Fractography**	184	00:53:08
#87	Add	Search **Dental material study**	76274	00:52:59
#86	Add	Search **Material study**	194785	00:52:50
#85	Add	Search **Laboratory study**	617489	00:52:39
#84	Add	Search **Lab study**	135227	00:52:29
#83	Add	Search **In-vitro study**	514604	00:52:20
#82	Add	Search **In - vitro study**	514604	00:52:07
#81	Add	Search **Invitro study**	275	00:51:53
#80	Add	Search **In vitro study**	514604	00:51:35
#79	Add	Search ((((((((((((((Torque) OR Detorque) OR Friction co efficient) OR SEM) OR Weight analysis) OR Scratch testing) OR Tightening torque) OR Reverse torque) OR Wear resistance) OR Wear) OR Friction) OR Adhesion) OR Fatigue failure) OR HAGB) OR Preload	960465	00:51:23
#78	Add	Search **Preload**	7035	00:50:28
#77	Add	Search **HAGB**	37	00:50:17
#76	Add	Search **Fatigue failure**	7225	00:50:08
#75	Add	Search **Adhesion**	225326	00:49:56

Fig. 1: Search methodology

Flow Chart 1: Search flowchart



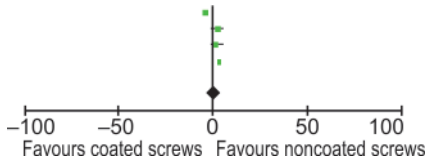
preload torquing, inaccurate fit of framework, poor component fit, flexure of framework, settling, debris trapped in screw receptor, screw design, and bone elasticity.

Jemt et al[2] in their study found abutment screw loosening to be as high as 45% with implant single crowns. Jung et al[6] calculated the cumulative incidence of connection-related complications (screw loosening, 12.7%; screw fracture, 0.35%) during 5 years of clinical service.

The abutment screw loosening or fracture is also associated with frequent insertion and removal of the abutment screws during the various clinical and laboratory procedures; the abutment screw undergoes wear at

Table 1: Meta-analysis—detorque values

Study or subgroup	*Coated screws*			*Noncoated screws*				*Mean difference IV, random, 95% CI*
	Mean	*SD*	*Total*	*Mean*	*SD*	*Total*	*Weight*	
Bacchi A 2015	22.4	1.14	20	26.4	1.16	20	25.9%	–4.00 (–4.71, –3.29)
Juliana 2012	13.62	1.68	9	11.25	4.71	9	23.2%	2.37 (–0.90, 5.64)
Kim HJ 2007	16.05	1.23	7	14.69	2.03	7	25.2%	1.36 (–0.40, 3.12)
Nigro F 2010	31.5	1.2	10	27.5	1.5	10	25.7%	4.00 (2.81, 5.19)
Total (95% CI)			46			46	100.0%	



Heterogeneity: Tau^2 = 22.50; χ^2 = 144.71, df = 3 (p < 0.00001); I^2 = 98%; Test for overall effect Z = 0.36 (p = 72)

microscopic level with each episode. With an increase in this wear, there is a subsequent decrease in the detorque values, and during further prosthetic loading, the screw loses its threshold limit to engage into the grooves, and it either starts revolving around its own axis or tends to fracture.[7-9]

Factors related to screw loosening are various, including poor tightening (inadequate preload), inaccurate fit of framework, poor component fit, flexure of framework, settling, debris trapped in screw receptor, screw design, and bone elasticity.[4,10,11,13-41]

Various methods to combat this potential problem of screw loosening would include ensuring an adequate preload which supersedes the masticatory force, proper fit of the component, a considerably rigid framework, care taken to prevent entrapment of debris at the screw receptor site, choosing an appropriate screw design based on the nature of the bone, and coating of abutment screws.

Coating of abutment screws has been done in many ways including radiofrequency sputtering, physical vapor deposition, radiofrequency plasma-assisted chemical vapor deposition, plasma-enhanced chemical vapor deposition, hot filament chemical vapor deposition, filling the inner threads of the implants with artificial saliva, cathodic arc deposition, and microwave plasma-enhanced chemical vapor deposition.[6,12-16,42-45]

Abutment screws are available in various materials such as titanium, zirconium, and gold.[4,10,11] However, titanium is the most preferred owing to its compatibility and success rate. To bring about an increase in the detorque values and prevent screw loosening, various surface modifications had been done on the abutment screws using carbon, diamond-like carbon, titanium nitride, and gold.[6,16-18] The outcomes had been measured through detorque values, weight analysis, preload assessment, and SEM study (Table 2).[4,6,16,19]

While the study by Kim et al[12] shows a mean value of 1.36 lying close to the weighted mean difference (WMD), studies by Nigro et al[4] and Bacchi et al[17] had their mean values showing further deviation from WMD with values of 4.0 and –4.0 respectively.

Table 2: Types of outcome measures

Types of outcome measures
Torque—detorque values
Friction coefficient values
Measures of weight
Surface characteristics and associated changes under SEM

Although Bacchi et al's[17] study is contradictory and favors noncoated screws, its significant effect on the outcome of the meta-analysis may be attributed to its higher sample size (Table 3).

Under SEM study performed on coated and noncoated screws, the surface topography of the coated and noncoated abutment screws subjected to loading cycles was assessed. In all studies, the authors inferred that noncoated abutment screws showed more wear when compared with coated ones.

Jörn et al[19] simulated the friction coefficient of dry and wet conditions in abutment screws, assigned a calculated preload, and evaluated the corresponding stress values accordingly. She suggested higher preload values in friction coefficients corresponding to wet (coated) conditions, thereby vouching coating of abutment screws over conventional ones in resistance to screw loosening. Jung et al[6] compared the weight difference between coated and noncoated abutment screws after multiple insertion cycles, and there was a positive correlation for weight loss and surface abrasion, which could affect the torque values.

Of the several factors influencing abutment screw loosening, coating the screws with various methods was assumed as a potential remedial measure to combat screw loosening. The difficulties with screw loosening include utilization of advanced technology to coat the screws, which will reflect in additional time consumption and escalated costs. However, this present meta-analysis has observed a similar behavior between coated and noncoated abutment screws with respect to screw loosening. Nevertheless, additional methods of powder coating and different choice of materials for abutment screws, which might influence screw loosening, need to be explored by further research. Outcome variables and CEBM level of evidence of various studies are mentioned in Tables 4 and 5 respectively..

Table 3: General information of studies included in the review

Study	Intervention	Design	Sample size	Name of implant system	Outcome assessment			Statistical tests	Inference
					Rt values	SEM	Wt. analysis		
Bacchi et al[17]	Coating of titanium screws with diamond-like carbon	*In vitro*	n = 40	Titamax ti cortical, he, neodent	Detorque calculation with digital torque meter	–	–	Two-way ANOVA–Tukey's test	Conventional titanium screws promoted significantly higher loosening torque values than diamond like carbon (DLC) for universal abutment fixation
Nigro et al[4]	Coating of Zr screws with saliva	*In vitro*	n = 20	Nobel Biocare	Detorque values measured using torque precision device from torque controller	–	–	Student's t-test	No statistical difference was observed between dry and wet groups
Jung et al[6]	Titanium nitride coating of titanium screws	*In vitro*	n = 28	Osstem, 3i	–	SEM study under ×10,000 magnification	Precision electronic balance (sartorius la 220s) for weight measurement	Mann–Whitney test	A statistical significance was shown in comparison of mean weight loss. Tin-coated abutment showed the least weight loss
Kim et al[13]	DLC-coated Ti screws	*In vitro*	n = 20	Astm	Number of cycles until screw loosening is observed was recorded with cyclic loading machine	Specimens were examined with SEM (s-4700), Hitachi, Hitachinaka, Japan	–	t-test—Mann–Whitney test	At statistically significant levels, the implants of DLC coating group were more resistant to screw loosening at the force tested here to surface is more rough and less resistant than DLC before and after cyclic loading
Diez et al[36]	DLC-coated titanium screws	*In vitro*	n = 36	Neodent	Torque and reverse torque values using analogue torque meter	Interfaces were analyzed using a stereoscope (aus Jena, Carl Zeiss) with ×100 magnification	–	–Two way ANOVA–t-test–Pearson correlation	–DLC-coated screws show an increase in vertical gap after mechanical cycling –Statistically significant differences were observed between all groups except internal hex without dlc coating –No correlations were seen for any comparison (difference in mean of implant–abutment interface area and difference between torque and reverse torque)
Kim et al[12]	Tin-coated titanium screws (control: gold screws)	*In vitro*	n = 14	3i	Detorque values using hand torque controller and digital torque gauge	SEM study at ×10,000 magnification	–	–Repeated measures ANOVA–Student's t-test –Hierarchical cluster analysis	There was no statistically significant difference between coated and noncoated screws

ANOVA: Analysis of variance

Table 4: Outcome variables of various studies

Study	*Intervention*	*Outcome of SEM*	*Detorque values (Ncm)*
Bacchi et al[17]	Coating of Ti screws with DLC	–	Noncoated—26.4 ± 1.16 Coated—22.4 ± 1.14
Nigro et al[4]	Coating of Zr screws with saliva	–	Noncoated (dry)—27.5 ± 1.5 Coated (wet)—31.5 ± 1.2
Jung et al[6]	Coating of Ti screws with TiN	Noncoated—rough Coated—smooth	–
Kim et al[13]	Coating of Ti screws with DLC	Noncoated—porous Coated—homogeneous	–
Diez et al[36]	Coating of Ti screws with DLC	–	Noncoated—11.25 ± 4.71 Coated—13.62 ± 1.68
Kim et al[12]	Coating of Ti screws with TiN	Noncoated—rough Coated—smooth	Noncoated—14.69 ± 2.03 Coated—16.05 ± 1.23

Table 5: CEBM level of evidence of included studies

Study	*Study design*	*CEBM level of evidence*
Bacchi et al[17]	*In vitro* study	Level 5
Nigro et al[4]	*In vitro* study	Level 5
Jung et al[6]	*In vitro* study	Level 5
Kim et al[13]	*In vitro* study	Level 5
Diez et al[36]	*In vitro* study	Level 5
Kim et al[12]	*In vitro* study	Level 5

CONCLUSION

This meta-analysis inferred that there is no statistical difference between the coated and noncoated screws with respect to dental abutment screw loosening. Hence, both can be used in suitable clinical situations.

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