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

Abinaya Kannan, Suresh Venugopalan, Dhanraj M Ganapathy

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.


Source of support: Nil

Conflict of interest: None

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. 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.

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 al4 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 al5 stated that factors related to screw loosen-
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
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Table 1: Meta-analysis—detorque values

<table>
<thead>
<tr>
<th>Study or subgroup</th>
<th>Coated screws</th>
<th>Noncoated screws</th>
<th>Mean difference IV, random, 95% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bacchi A 2015</td>
<td>22.4</td>
<td>1.14</td>
<td>26.4</td>
</tr>
<tr>
<td>Juliana 2012</td>
<td>13.62</td>
<td>1.68</td>
<td>11.25</td>
</tr>
<tr>
<td>Kim HJ 2007</td>
<td>16.05</td>
<td>1.23</td>
<td>14.69</td>
</tr>
<tr>
<td>Nigro F 2010</td>
<td>31.5</td>
<td>1.2</td>
<td>27.5</td>
</tr>
<tr>
<td>Total (95% CI)</td>
<td></td>
<td></td>
<td>46</td>
</tr>
</tbody>
</table>

Heterogeneity: Tau² = 22.50; \( \chi^2 = 144.71, df = 3 (p < 0.00001); I^2 = 98\%; Test for overall effect Z = 0.36 (p = 72)

Table 2: Types of outcome measures

<table>
<thead>
<tr>
<th>Types of outcome measures</th>
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<tbody>
<tr>
<td>Torque—detorque values</td>
</tr>
<tr>
<td>Friction coefficient values</td>
</tr>
<tr>
<td>Measures of weight</td>
</tr>
<tr>
<td>Surface characteristics and associated changes under SEM</td>
</tr>
</tbody>
</table>

As 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.

Although Bacchi et al.\(^{17}\) 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

<table>
<thead>
<tr>
<th>Study</th>
<th>Intervention</th>
<th>Design</th>
<th>Sample size</th>
<th>Name of implant system</th>
<th>Outcome assessment</th>
<th>Statistical tests</th>
<th>Inference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bacchi et al²⁻⁷</td>
<td>Coating of titanium screws with diamond-like carbon</td>
<td>In vitro</td>
<td>n = 40</td>
<td>Titamax ticortical, he, neodent</td>
<td>Detorque calculation with digital torque meter</td>
<td>Two-way ANOVA—Tukey's test</td>
<td>Conventional titanium screws promoted significantly higher loosening torque values than diamond like carbon (DLC) for universal abutment fixation</td>
</tr>
<tr>
<td>Nigro et al⁴</td>
<td>Coating of Zr screws with saliva</td>
<td>In vitro</td>
<td>n = 20</td>
<td>Nobel Biocare</td>
<td>Detorque values measured using torque precision device from torque controller</td>
<td>Student’s t-test</td>
<td>No statistical difference was observed between dry and wet groups</td>
</tr>
<tr>
<td>Jung et al⁶</td>
<td>Titanium nitride coating of titanium screws</td>
<td>In vitro</td>
<td>n = 28</td>
<td>Osstem, 3i</td>
<td>SEM study under ×10,000 magnification</td>
<td>Mann–Whitney test</td>
<td>A statistical significance was shown in comparison of mean weight loss. Tin-coated abutment showed the least weight loss</td>
</tr>
<tr>
<td>Kim et al³⁻¹³</td>
<td>DLC-coated Ti screws</td>
<td>In vitro</td>
<td>n = 20</td>
<td>Astra</td>
<td>Number of cycles until screw loosening is observed was recorded with cyclic loading machine</td>
<td>Specimens were examined with SEM (s-4700), Hitachi, Hitachinaka, Japan</td>
<td>t-test—Mann–Whitney test</td>
</tr>
<tr>
<td>Diez et al³⁶</td>
<td>DLC-coated titanium screws</td>
<td>In vitro</td>
<td>n = 36</td>
<td>Neodent</td>
<td>Torque and reverse torque values using analogue torque meter</td>
<td>Interfaces were analyzed using a stereoscope (aus Jena, Carl Zeiss) with ×100 magnification</td>
<td>Two way ANOVA—t-test—Pearson correlation</td>
</tr>
<tr>
<td>Kim et al¹²</td>
<td>Tin-coated titanium screws (control: gold screws)</td>
<td>In vitro</td>
<td>n = 14</td>
<td>3i</td>
<td>Detorque values using hand torque controller and digital torque gauge</td>
<td>Repeated measures ANOVA—Student’s t-test—Hierarchical cluster analysis</td>
<td>There was no statistically significant difference between coated and noncoated screws</td>
</tr>
</tbody>
</table>

ANOVA: Analysis of variance
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.

REFERENCES


42. Available from: https://www.en.wikipedia.org/wiki/Cathodic_arc_deposition#Applications

43. Available from: https://www.en.wikipedia.org/wiki/Physical_vapor_deposition#Application
