Comparison of peri-implant clinical and radiographic status around short (6 mm in length) dental implants placed in cigarette-smokers and never-smokers: Six-year follow-up results

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Funding information
King Saud University, Grant/Award Number: RG-1438-075

Abstract
Background: It is hypothesized that peri-implant clinical and radiographic inflammatory parameters (probing depth [PD], bleeding on probing [BOP] and plaque index [PI]; and radiographic (crestal bone loss [CBL]) are worse among cigarette-smokers (CS) compared with never-smokers (NS) with short implants.

Purpose: The present 6-year follow-up retrospective study compared the peri-implant clinical and radiographic parameters in CS and NS with short dental implants (6 mm in length).

Materials and methods: Fifty-six male individuals were included. These individuals divided into 2 groups as follows: (a) Group-1: 29 self-reported systemically healthy CS with 48 short-implants; and (b) Group-2: 27 self-reported systemically healthy NS with 43 short implants. Peri-implant PD, PI, BOP, and CBL were measured. Group comparisons were done using the Kruskal-Wallis test and sample size was estimated. Level of significance was set at P values <.05.

Results: In groups 1 and 2, the follow-up durations were 6.2 ± 0.1 years and 6.1 ± 0.3 years, respectively. A cigarette smoking history of 8.9 ± 3.6 pack years was reported by individuals in Group-1. At follow-up, scores of peri-implant PD, BOP, PI, and mesial and distal CBL were comparable around short implants in both groups.

Conclusion: Under strict oral hygiene maintenance protocols, short dental implants can remain functionally stable in CS in a manner similar to NS.

KEYWORDS
cigarette smoking, crestal bone loss, peri-implant inflammation, questionnaire, short dental implant

1 | INTRODUCTION

Standard dental implants, that are at least 10 millimeters (mm) in length are commonly used for the treatment of partial and/or complete edentulism; however, dental implant surgery in patients with a compromised crestal bone height may necessitate supplementary surgical procedures (such as distraction osteogenesis, sinus augmentation, and use block grafts) prior to implant placement. Furthermore, patients may deny such additional surgical procedures for reasons including additional costs, donor site morbidity, and increased treatment time. In order to circumvent these invasive surgical procedures, short implants, which are 6 to 8 mm in length were developed. Clinical studies have shown that short implants can exhibit clinical and radiographic stability in a manner similar to standard 10 mm long implants. Moreover, in a 14-year follow-up longitudinal clinical study, the survival rates of standard-length and short dental implants were similar, 97.1% and 97.9%, respectively. These results indicate that variations in implant length does not compromise the effectiveness of implant therapy.
Habitual cigarette smoking is a risk-factor for periodontal and peri-implant soft tissue inflammation\textsuperscript{7,8}; and crestal bone loss (CBL) around natural teeth and dental implants.\textsuperscript{7–9} One explanation in this regard is that habitual smoking increases the production and deposition of advanced glycation endproducts (AGES) in the periodontal tissues.\textsuperscript{10,11} Connection of AGES with their receptors (RAGE), destructive inflammatory cytokines such as interleukin (IL)-6, and matrix metalloproteinase (MMP)-1 are produced by human gingival fibroblasts that promote inflammation.\textsuperscript{12,13} Moreover, cigarette smoking increases collagen degradation by affecting membrane-associated MMPs and tissue inhibitors of metalloproteinases.\textsuperscript{14} Furthermore, metabolites of nicotine, such as nor-nicotine, upregulate the expression of RAGE in the gingival tissues; and stimulates the formation reactive oxygen species, which jeopardize the periodontal tissues.\textsuperscript{11} Besides compromising periodontal wound healing, these factors may also risk the healing of peri-implant tissues. To our knowledge, peri-implant clinical and radiographic inflammatory parameters (probing depth [PD], plaque index [PI], bleeding on probing [BOP], and CBL, respectively) around short implants in cigarette-smokers (CS) and never-smokers (NS) are not yet reported. It is therefore hypothesized that peri-implant clinical and radiographic inflammatory parameters are worse around short implants placed in CS compared with NS.

The present 6 years’ follow-up retrospective clinical case-control study compared the peri-implant clinical and radiographic status around short (6 to 8 mm in length) dental implants placed in CS and NS.

2 | MATERIALS AND METHODS

2.1 | Ethical guidelines

The Research Review Board of the College of Dentistry, King Saud University, Riyadh, Saudi Arabia approved the present study. It was mandatory for all volunteering individuals to read and sign a consent form printed in simple English and Arabic. All participants were informed that they could withdraw their participation at any phase of the study without penalty.

2.2 | Inclusion and exclusion criteria

The following inclusion criteria were imposed: (a) CS (Group-1); and (b) NS (Group-2). The exclusion criteria were as follows: (a) dual-smokers (individuals smoking cigarettes in addition to other nicotinic products such as bidi, waterpipe, and electronic cigarettes), (b) individuals using smokeless tobacco products; (c) habitual alcohol consumers; (d) patients with medical conditions including hepatic disorders and renal disease, diabetes mellitus, cardiovascular diseases, and patients with human immunodeficiency virus infection or acquired immunodeficiency syndrome; (e) completely edentulous patients; (f) patients with misaligned dentition.

2.3 | Participants

Between March 2016 and April 2017, a retrospective case-control study was performed at the Department of Prosthetic Dental Sciences, College of Dentistry, King Saud University, Riyadh, Saudi Arabia. Self-reported systemically healthy habitual CS and NS were included. CS were defined as individuals who smoked more than 5 packs of cigarettes (100 cigarettes) in their life and presently smoked more than 1 cigarette daily.\textsuperscript{15} NS were defined as participants that have never used tobacco in any form.\textsuperscript{16,17}

2.4 | Questionnaire

Information about age, highest level of education, duration and daily frequency of cigarette smoking, family history of smoking, and daily tooth brushing and flossing was collected. Individuals with primary level education were defined as those who received elementary education from the age of approximately 5 to 12 years, coming after preschool and before college. Individuals with secondary level education were defined as those having 2 years of college education after primary level education. Individuals with a university level education were defined as those having tertiary level education. The questionnaire was administered by a trained investigator (FV).

2.5 | Implant surgery and prosthetic protocol

A trained and experienced oral surgeon (TA) performed the surgical procedures under local anesthesia. Preoperatively, all patients received 1 g of amoxicillin as prophylactic antibiotic starting the night before the surgery, and then 1500 mg amoxicillin daily for 7 days postoperatively. For patients with Penicillin allergy, clindamycin 2 g daily was used as an alternative preoperative and postoperative antibiotic. In addition, pain medication (ibuprofen, 600 mg as needed every 6 to 8 hours) was also prescribed. Participants were also advised to rinse twice daily with 0.2% chlorhexidine digluconate for 14 days starting the first preoperative day. Using a midline crestal incision, full-thickness mucoperiosteal flaps were reflected. The implant osteotomy sites were prepared according to a standard drilling sequence as described elsewhere.\textsuperscript{18} In summary, to minimize the risk of maxillary sinus or inferior alveolar injury, adjustable rubber stop devices were placed around the drills to place them at least 1 mm shorter than the radiographic working length above the maxillary sinus and mandibular canal, respectively. In each individual up to 2 short implants (length \times diameter: 6 mm \times 4 mm) (OsseoSpeed, DENTSPLY Implants, Mönstad, Sweden) were placed in the areas of missing maxillary/mandibular premolar and/or molar teeth. All implants in both groups were placed at bone level and were left submerged for 3 to 4 months following which, they were loaded. Screw-retained porcelain fused to metal fixed dental prostheses were delivered 8 to 10 weeks after healing abutment connection. All patients were enrolled in a biannual routine maintenance care during which, they underwent full-mouth mechanical plaque and calculus debridement using handheld ultrasonic scalers (ART-M1 Magnetostriuctive Ultrasonic Scaler Unit, Cary, North Carolina). Oral hygiene instructions were reinforced at each recall appointment for individuals in both groups.

2.6 | Assessment of clinical and radiographic peri-implant parameters

One calibrated and trained examiner (N.A.) (kappa 0.86) blinded to the study groups assessed the peri-implant soft tissue inflammatory
parameters. Peri-implant PD, PI, and BOP were measured at 6 sites/implant (mesiobuccal, midbuccal, distobuccal, distopalatal/distolingual, midpalatal/midlingual, and mesiopalatal/mesiolingual). PD was measured using a standard probe (Hu-Friedy Manufacturing, Chicago, Illinois). A trained and calibrated investigator (Z.H.A.) performed all radiographic evaluations. CBL was defined as the linear distance from 2 mm below the implant-abutment interface to the most crestal location of jaw bone. Digital bitewing radiographs (Ektaspeed plus; Kodak, Rochester, New York) were taken; and the mean mesial and distal peri-implant CBL was measured to the nearest millimeter in both groups using a software program (Scion Image, Scion Corp, Fredrick, Maryland).

2.7 Statistical analysis

The SPSS software (Version 18, Chicago, Illinois) was used for statistical analysis. Peri-implant PD, PI, BOP, and CBL were statistically evaluated among CS and NS using the Kruskal-Wallis test. Means and SDs were calculated. To determine the sample-size in each group, a post hoc power analysis was performed using a software (nQuery Advisor 6.0, Statistical Solutions, Saugas, Massachusetts). It was estimated that inclusion of at least 27 individuals in each group would yield a study power of 88%. Level of significance was set at \( P < .05 \).

3 RESULTS

3.1 General characteristics

In groups 1 \((n = 29)\) and 2 \((n = 27)\), all participants were male with comparable mean ages and education status. In Group-1, the participants had a cigarette smoking history of 8.9 ± 2.6 pack years. In groups 1 and 2, 72.4% and 66.7% individuals reported to brush teeth once a day. In groups 1 and 2, dental flossing was reported by none of the individuals (Table 1). None of the participants had self-reported penicillin allergy.

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Group-1</th>
<th>Group-2</th>
</tr>
</thead>
<tbody>
<tr>
<td>(n)</td>
<td>29</td>
<td>27</td>
</tr>
<tr>
<td>Male</td>
<td>29</td>
<td>27</td>
</tr>
<tr>
<td>Age in years (mean ± SD)</td>
<td>40.3 ± 2.5</td>
<td>42.6 ± 3.1</td>
</tr>
<tr>
<td>Duration of smoking habit (in pack years)</td>
<td>8.9 ± 3.6</td>
<td>0</td>
</tr>
<tr>
<td>Family history of smoking (n)</td>
<td>18</td>
<td>7</td>
</tr>
<tr>
<td>Education status</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Primary level (n)</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Secondary level (n)</td>
<td>21</td>
<td>17</td>
</tr>
<tr>
<td>Tertiary level (n)</td>
<td>8</td>
<td>10</td>
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<tr>
<td>Daily tooth brushing</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Once (n)</td>
<td>21</td>
<td>18</td>
</tr>
<tr>
<td>Twice (n)</td>
<td>8</td>
<td>9</td>
</tr>
<tr>
<td>Daily flossing</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Once (n)</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Twice (n)</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

Abbreviation: SD, standard deviation.

3.2 Clinical and radiographic parameters

In groups 1 and 2, a total of 48 and 43 short implants, respectively were placed. The follow-up durations in groups-1 and -2 was 6.2 ± 0.1 and 6.1 ± 0.3 years, correspondingly. At follow-up, peri-implant PD, PI, BOP, and mesial and distal CBL was comparable in both groups (Table 2).

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Group-1 (mean ± SD)</th>
<th>Group-2 (mean ± SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plaque index (%)</td>
<td>23.5 ± 0.6</td>
<td>20.2 ± 0.3</td>
</tr>
<tr>
<td>Bleeding on probing (%)</td>
<td>10.5 ± 0.4</td>
<td>11.6 ± 0.6</td>
</tr>
<tr>
<td>Probing depth (in millimeters)</td>
<td>2.1 ± 0.3</td>
<td>1.8 ± 0.1</td>
</tr>
<tr>
<td>Crestal bone loss</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mesial</td>
<td>1.4 ± 0.5</td>
<td>1.1 ± 0.2</td>
</tr>
<tr>
<td>Distal</td>
<td>1 ± 0.2</td>
<td>1.2 ± 0.1</td>
</tr>
</tbody>
</table>

Abbreviation: SD, Standard deviation.

3.3 Influence of jaw location on the clinical and radiographic parameters

There was no statistically significant difference in PD, BOP, PI, and mesial and distal CBL around short implants placed in the maxilla and mandible of individuals in groups 1 and 2 (Table 3).

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Jaw location</th>
<th>Group-1 (mean ± SD)</th>
<th>Group-2 (mean ± SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of implants placed</td>
<td></td>
<td>29</td>
<td>19</td>
</tr>
<tr>
<td>Plaque index (%)</td>
<td></td>
<td>24.2 ± 0.5</td>
<td>21.7 ± 0.8</td>
</tr>
<tr>
<td>Bleeding on probing (%)</td>
<td></td>
<td>12.4 ± 0.2</td>
<td>8.2 ± 0.3</td>
</tr>
<tr>
<td>Probing depth (mm)</td>
<td></td>
<td>2.3 ± 0.1</td>
<td>2 ± 0.4</td>
</tr>
<tr>
<td>Crestal bone loss</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mesial</td>
<td></td>
<td>1.7 ± 0.1</td>
<td>1.2 ± 0.2</td>
</tr>
<tr>
<td>Distal</td>
<td></td>
<td>1.5 ± 0.2</td>
<td>0.8 ± 0.1</td>
</tr>
</tbody>
</table>

Abbreviation: SD, Standard deviation.
inflammatory cytokines, such as IL-6 and IL-1β.20,21 Increased levels of these cytokines in the oral fluids have been associated with the etiology of periodontal and peri-implant diseases.22–27 Interestingly, our results showed no statistically significant difference in peri-implant PD, BOP, PI, and mesial and distal CBL around short implants placed in both groups. It is however imperative to interpret these results with caution as a number of factors seem to have influenced the reported results. Firstly, it is noteworthy that individuals in groups 1 and 2 were relatively young (approximately 40 years old). Increasing age is a risk-factor for alveolar bone resorption (ABR) around natural teeth.28 In the study by Javed and colleagues,7 ABR was significantly higher among ≥60 years old compared with younger individuals, ≤45 years old. It is therefore hypothesized that CBL around short dental implants is significantly higher among older individuals (≥60 years old) compared with relatively younger individuals (≤45 years old). Moreover, individuals in Group-1 had a smoking history of approximately 9 pack years. It is likely that individuals with a longer history of smoking (such as ≥15 pack years) exhibit worse peri-implant soft tissue inflammation and increased CBL as compared to individuals with a shorter history of tobacco smoking. Further studies are needed to test these hypotheses.

It is pertinent to note that participants in groups 1 and 2 underwent biannual mechanical plaque and calculus debridement. Nonsurgical periodontal therapy (such as plaque and calculus debridement using ultrasonic hand instruments) contributes toward minimizing oral soft tissue inflammation.24–26 The biannual visits to oral healthcare providers may also have encouraged the participants in both groups to routinely maintain their oral hygiene status. It is therefore likely that regular oral hygiene maintenance contributed toward maintaining a healthy peri-implant soft tissue status and minimizing ABR around short implants in both groups. These results are in accordance with those of a previous study27 which, showed that as long as the oral hygiene status is satisfactory, dental implants can exhibit a 100% survival rate. In the present study, approximately 72% and 67% subjects in groups 1 and 2, correspondingly reported that they brushed teeth once a day. Although twice daily tooth brushing is usually recommended by healthcare providers, it has also been reported that tooth brushing once a day helps preserve oral health and contributes toward reducing the risk of periodontal inflammation.28 This is an additional factor that may have contributed toward maintaining the peri-implant soft tissue status and crestal bone levels in groups 1 and 2. Nevertheless, it is recommended that oral healthcare providers should encourage their patients to brush twice daily.

Bone density and quality varies in the posterior maxilla and mandible majorly due to the presence of maxillary sinuses in the former.29 Six-year follow-up results of a clinical study30 showed CBL to be significantly higher around implants placed in the posterior maxilla compared with the mandible. However, the current results showed no statistically significant difference in terms of clinical peri-implant parameters and CBL in the maxillae and mandibles in both groups. Since all participants in the present study received oral prophylaxis biannually, it is hypothesized that this factor may have contributed in toward the maintenance peri-implant soft and hard tissue status. In our study, family history of smoking was more frequently reported by individuals in Group-1 than Group-2. It is therefore imperative to elucidate to the public (particularly those who have smoking family members) about the detrimental effects of smoking on health (including oral/periodontal health) and to educate the community about the benefits of routine oral hygiene toward an overall improved quality of life.

One limitation of the present investigation is that individuals with systemic disorders were not sought. It is well-known that poorly-controlled diabetes mellitus is a risk-factor for peri-implant diseases (peri-implant mucositis and peri-implantitis).30 Moreover, individuals using other forms of tobacco products (such as smokeless tobacco products) in conjuction with smoking were excluded. It is therefore likely that CBL around short implants is significantly higher among CS with poorly-controlled diabetes and CS chewing ST products than systemically healthy CS and CS not using other forms of tobacco products, respectively. Furthermore, all participants in the present investigation were male. There is a possibility that irrespective to smoking, hormonal changes in females (particularly in the postmenopausal phase) may affect the oral soft and hard tissue status around short implants as compared to males. Furthermore, in the present study short implants placed in CS and NS were loaded 3 to 4 months after placement. Further studies are needed to assess the outcome of immediate and/or early loading of short implants in CS and NS.

5 | CONCLUSION

Under strict oral hygiene maintenance protocols, short dental implants can remain functionally stable in CS in a manner similar to NS.

ACKNOWLEDGMENT

The authors extend their appreciation to the Deanship of Scientific Research at King Saud University, Riyadh, Saudi Arabia for funding this work through Research Group No.: RG-1438-075.

CONFLICT OF INTEREST

The authors declare that they have no conflict of interest related to the present study.

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