Gingival Recession Treatment With Connective Tissue Grafts in Smokers and Non-Smokers

Kenneth J. Erley,* Gary D. Swiec,* Robert Herold,* Frederick C. Bisch,* and Mark E. Peacock†

Background: Cigarette smoking can adversely affect the results of many periodontal procedures. The purpose of this study was to determine whether cigarette smoking affects wound healing of subepithelial connective tissue grafts.

Methods: Seventeen systemically healthy patients with 22 Miller Class I or II mucogingival defects were divided into a non-smoker group or smoker group. Patients were regarded as smokers if they reported smoking 10 to 20 cigarettes per day. The following parameters were documented at the surgery date and 3 and 6 months postoperatively: recession depth (RD), recession width (RW), keratinized gingiva height measured apico-coronally (KG), relative attachment level (RAL), probing depths (PD), bleeding on probing (BOP), and the full-mouth plaque score (FMP). Salivary cotinine samples were taken at the surgery to confirm the smoking history and to quantify cigarette use.

Results: Non-smokers (0- to 10-ng/ml cotinine level) healed with statistically more recession coverage than the smokers (>10-ng/ml cotinine level) (98.3% versus 82.3%, respectively; \( P = 0.001 \)). Six months postoperatively, the non-smokers healed with a 0.2-mm mean recession depth compared to a 1.0-mm mean recession depth for the smokers. This difference in recession depth was statistically significant \( (P = 0.014) \).

Conclusions: Root coverage with connective tissue grafts appears to be negatively associated with cigarette smoking. Smokers should consider smoking cessation or reducing the use of cigarettes for optimal results with connective tissue grafts. J Periodontol 2006;77:1148-1155.

KEY WORDS
Connective tissue; cotinine; gingival recession; plastic surgery; smoking.

Periodontal plastic procedures to augment attached gingiva and provide root coverage have become more popular with the increase of esthetic awareness. The incidence of gingival recession for adults over the age of 30 years is 58%.1 Some indications for root coverage procedures include esthetics, root sensitivity, and root caries.2 The subepithelial connective tissue graft (CTG) is the most predictable surgical technique to obtain root coverage.2

Approximately 23% of adults in the United States smoke cigarettes.3 Smoking has a wide range of detrimental systemic effects, including lung cancer, cardiovascular disease, and chronic obstructive pulmonary disease.4 Smoking also has a wide range of detrimental effects in the oral cavity. Smokers have a five times greater risk for oral squamous cell carcinoma than non-smokers.5 Smoking increases the risk of periodontal diseases6 and reduces the benefits of non-surgical and surgical treatment of periodontal diseases.7 The effects of smoking on wound healing following many periodontal procedures have been evaluated. Cigarette smoking can compromise the healing of flap debridement surgery,8 impair regeneration in intrabony defects,9,10 and increase implant failure rates.11 The compromised wound healing in smokers is well documented in the medical literature following plastic surgery.12,13
In a retrospective study by Harris,14 smoking did not appear to be a factor in obtaining root coverage when a connective tissue graft with a partial thickness double pedicle flap was used. A study by Tolmie et al.15 reported no adverse effects with free gingival grafts in cigarette smokers, and complete root coverage was obtained in 11 of 12 sites in smokers. A study by Pini Prato et al.16 reported that smoking did not adversely affect root coverage using coronally positioned flaps. In the study, 11 of the 60 patients smoked, and they healed with similar results to the non-smokers (close to 90.52% root coverage). However, Miller17 reported a negative impact on root coverage in heavy smokers (≥10 cigarettes per day) when using the free gingival graft. Smoking may increase complications and reduce root coverage when guided tissue regeneration is used to treat recession defects.18 Currently, there is only one prospective study19 comparing smokers and non-smokers following connective tissue grafts. This study reported that smokers healed with 58.84% root coverage compared to 74.73% root coverage in non-smokers. All of the previous studies used a smoking history reported by the patient to quantify smoking. Self-reported cigarette consumption may be an inaccurate measurement of how much an individual smokes.20 Also, to further understand the biologic effects of nicotine, an objective quantitative expression of nicotine exposure may be necessary. Exposure to tobacco smoke can be monitored by measuring cotinine, a metabolite of nicotine, in a variety of biologic sources including blood, urine, and saliva.21 Salivary cotinine samples can accurately detect exposure to cigarette smoke and are easy to obtain.22

The purpose of this prospective study was to evaluate the healing of connective tissue grafts in smokers and non-smokers as measured by clinical parameters. In addition, the salivary cotinine samples were used to confirm smoking history and quantitatively assess cigarette consumption.

**MATERIALS AND METHODS**

**Patient Selection**

Seventeen patients (16 males and one female) aged 27 to 45 years with a total of 22 recession defects were selected for the study. Patients requested root coverage treatment for esthetic concerns or root hypersensitivity. Criteria for selection included facial gingival recession >2 mm on non-molar teeth. Only defects with no interdental bone or soft tissue loss (Miller Class I or II defects) were included in the study. All patients were in good general health with no medical conditions which could compromise periodontal surgery. All patients were members of the U.S. Army, and all clinical procedures were performed at Tingay Dental Clinic, Fort Gordon, from 2002 to 2004. Patients were informed of the study by means of an oral interview, and a written consent form was completed. The study was approved by the Eisenhower Army Medical Center Institutional Review Board for human research. Patients were classified as non-smokers if they reported a negative smoking history that was later verified with a salivary cotinine sample. Patients in the study were classified as smokers if they reported the use of ≥10 cigarettes per day, which was later verified by a salivary cotinine sample. For ethical reasons, patients were encouraged to stop smoking for the known health benefits, and tobacco cessation information was provided upon request.

**Clinical Parameters**

Prior to surgery, the patients received oral hygiene instruction. The surgery was not performed until patients presented with greater than 80% plaque-free surfaces. All data were collected presurgically and post-surgically by a periodontist unaware of the smoking history and not involved with the surgery. The following parameters were documented at baseline and 3 and 6 months: recession depth (RD), recession width (BW), keratinized gingiva (K), and salivary cotinine (CO) were taken.
Table 1.

Cotinine Samples and Reported Smoking History

<table>
<thead>
<tr>
<th>Cotinine value</th>
<th>Patient report</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 to 10 ng/ml</td>
<td>Denies smoking</td>
</tr>
<tr>
<td>10 to 20 ng/ml</td>
<td>None in study</td>
</tr>
<tr>
<td>20 to 40 ng/ml</td>
<td>One-half pack per day</td>
</tr>
<tr>
<td>&gt;40 ng/ml</td>
<td>One-half to one pack per day</td>
</tr>
</tbody>
</table>

A patient who reported one-half to one pack per day had a high value from the laboratory.

(RW), keratinized gingiva height measured apicocoronally (KG), relative attachment level (RAL), probing depth (PD), the presence of bleeding on probing (BOP), and full-mouth plaque score (FMP). All measurements were performed with a manual probe‡ and rounded to the nearest millimeter (Fig. 1). The RD was measured from the cemento-enamel junction (CEJ) to the free gingival margin at its most apical portion. The RW was measured at the greatest width of the defect. The KG was measured from the free gingival margin to the mucogingival junction. The mucogingival junction was located using the following technique: 1) a periodontal probe was placed against the alveolar mucosa apical to the recession and moved gently in a coronal direction; 2) the alveolar mucosa formed in folds against the attached gingiva; and 3) the intersection of the two tissue types was determined to be the mucogingival junction. The RAL was measured from a mark on a stent to the tip of the probe (base of the pocket) at the mesial, facial, and distal surfaces. The stent used for consistency was described by Isidor et al.23 The PD was recorded from the free gingival margin to the base of the pocket at the mesial, facial, and distal surfaces. BOP was also documented at the three surfaces. If any bleeding occurred within 10 seconds after probing, the area was considered positive for bleeding. The FMP was recorded using the plaque assessment scoring system.24 The percentage of recession coverage (% RC) was calculated by measuring the area of recession (RW × RD/100). No intraexaminer calibration was performed. A saliva sample was taken with a kit designed for cotinine assays.§ The saliva sample was sent to the laboratory for the patient’s cotinine level. The cotinine level returned from the laboratory was reported as either negative, low, medium, or high. These cotinine levels were used to confirm the patient’s self-reported smoking history and help quantify cigarette consumption by the patient (Table 1).

Surgical Procedure

All surgical procedures were performed by the same operator not involved with clinical measurements. Following local anesthesia with 2% lidocaine with 1:100,000 of epinephrine and 0.5% marcaine with 1:200,000 of epinephrine, the exposed root surface was instrumented with a cavitron and curets. The exposed root surface was root planed, and any concavities were flattened to allow for a smooth root surface. A flap design similar to the Langer technique was used except a full-thickness flap was reflected. The connective tissue was harvested using a technique described by Bruno except that the epithelium collar was excised before suturing. The connective tissue harvested from the palate was ~1 to 2 mm in thickness. The connective tissue was trimmed to cover the defect, and four 5-0 bioabsorbable sutures¶ were used to stabilize the graft. The papillae mesial and distal to the recession defect were deepithelialized. The flap was coronally positioned with the use of a periosteal releasing incision and sutured with 5-0 bioabsorbable sutures using the technique described by Langer and Langer.25

Postoperative Procedures

Patients were given a palatal stent to protect the wound at the donor site. They were prescribed ibuprofen 800 mg and oxycodone 5 mg/acetaminophen 325 mg for postoperative pain, and were advised to take the pain medication as needed. A chlorhexidine rinse was also prescribed to be used for 2 weeks, twice a day, for 30 seconds. Patients were provided a supragingival prophyl and oral hygiene instructions every 2 weeks for the first month and every 4 weeks until 6 months.

The patients were reevaluated at 3 and 6 months postoperatively to document RD, RW, KG, RAL, PD, FMP, and BOP. At these appointments, smoking habits and smoking history were recorded for any changes.

Statistical Methods

Student t tests, two-way analysis of variance (ANOVA), and three-way ANOVA were calculated for clinical parameters to determine statistically significant differences (P ≤ 0.05) between groups at different time intervals. Chi-square analysis (P ≤ 0.05) was performed for BOP differences between smoking and non-smoking groups at 3 and 6 months. Correlation values were calculated to determine association between cotinine levels and mean % RC. Correlation

‡ Hu-Friedy, Chicago, IL.
§ Heritage Labs, Kansas City, MO.
¶ Vicryl, Ethicon, Somerville, NJ.
values were also calculated for cotinine levels and mean KG.

RESULTS

The mean recession depths presurgically for both groups were similar for smokers and non-smokers (3.33 – 1.39 mm and 3.20 – 0.98 mm, respectively; Fig. 2). The mean RD 6 months postoperatively was larger for smokers than non-smokers (1.0 – 0.85 mm and 0.20 – 0.42 mm, respectively). This was statistically significant at 6 months (Fig. 2) using the Student t test (\(P = 0.014\)). The parameter of % RC at 6 months was 82.33% ± 14.90% for smokers and 98.3% ± 4.42% for non-smokers. This was statistically significant (\(P = 0.001\)) using the two-way ANOVA (Table 2). Only 25% of smokers healed with complete root coverage compared to 80% of non-smokers. Non-smokers healed with a larger increase of keratinized gingiva compared to the smokers (2.8 and 2.06 mm, respectively). This was not statistically significant (\(P = 0.300\)) using the Student t test comparing baseline to 6 months (Fig. 3). A difference in mean RAL was noted between non-smokers and smokers (1.8 and 1.65 mm, respectively) but was not statistically significant (\(P = 0.478\)) using the three-way ANOVA. Mean PD at 6 months was 1.5 mm for non-smokers and 1.7 for smokers, which was not statistically significant (\(P = 0.18\)) using the Student t test.

The % RC at 6 months with varying cotinine levels is displayed in Figure 4. Non-smokers (0- to 10-ng/ml cotinine level) healed with 98.3% RC and showed a 2.8-mm KG increase. Smokers (10- to 40-ng/ml cotinine level) healed with 84.2% RC and a 2.11-mm KG increase. Heavy smokers (>40-ng/ml cotinine levels) healed with 76.6% RC and a 2.0-mm KG increase. Calculating a correlation value with cotinine levels and mean percent root coverage resulted in a high correlation (\(r = 0.97\)). Calculating a correlation with cotinine levels and mean KG increase also resulted in a high correlation (\(r = 0.85\)).

Two of the patients tried to quit smoking following the surgery but were unable to sustain it for more than a week. Following their unsuccessful attempts, both patients reported that they resumed their normal smoking habits. Representative examples of recession treatment in a non-smoker and a smoker with a high cotinine level are shown in Figures 5 and 6, respectively.

Table 2.

Mean Clinical Parameters (± SD) of Non-Smokers (NS) and Smokers (S)

<table>
<thead>
<tr>
<th></th>
<th>Baseline NS</th>
<th>Baseline S</th>
<th>3 Months NS</th>
<th>3 Months S</th>
<th>6 Months NS</th>
<th>6 Months S</th>
</tr>
</thead>
<tbody>
<tr>
<td>RD (mm)</td>
<td>3.20 ± 0.42</td>
<td>3.33 ± 0.98</td>
<td>0.20 ± 0.42</td>
<td>0.67 ± 0.78</td>
<td>0.20 ± 0.42</td>
<td>1.00 ± 0.85*</td>
</tr>
<tr>
<td>RW (mm)</td>
<td>4.00 ± 1.15</td>
<td>3.50 ± 0.67</td>
<td>0.30 ± 0.67</td>
<td>1.33 ± 1.61</td>
<td>0.30 ± 0.67</td>
<td>1.75 ± 1.36*</td>
</tr>
<tr>
<td>% RC</td>
<td>NA†</td>
<td>NA†</td>
<td>96.9%</td>
<td>86.3%</td>
<td>98.3%</td>
<td>82.3%*</td>
</tr>
<tr>
<td>KG (mm)</td>
<td>1.70 ± 0.95</td>
<td>2.42 ± 1.44</td>
<td>4.20 ± 1.47</td>
<td>4.25 ± 1.60</td>
<td>4.50 ± 1.71</td>
<td>4.50 ± 1.44</td>
</tr>
<tr>
<td>RAL (mm)</td>
<td>NA†</td>
<td>NA†</td>
<td>1.93 ± 1.36</td>
<td>1.57 ± 1.06</td>
<td>1.86 ± 1.42</td>
<td>1.60 ± 0.69</td>
</tr>
<tr>
<td>PD (mm)</td>
<td>1.96 ± 0.67</td>
<td>2.08 ± 0.81</td>
<td>1.67 ± 0.50</td>
<td>1.75 ± 0.69</td>
<td>1.53 ± 0.51</td>
<td>1.72 ± 0.61</td>
</tr>
</tbody>
</table>

* Statistically significant difference (\(P \leq 0.05\)) between smoking and non-smoking groups using two-way ANOVA.
† Mean increase from baseline was not applicable (NA).

Figure 2.

Measurements of mean recession depth (mm) at baseline and 3 and 6 months postoperatively (post-op) are displayed. Recession depth between smokers and non-smokers was similar at baseline. At 6 months, the differences were statistically significant (*\(P = 0.014\)). Standard deviations are displayed on the graphs. Standard errors for non-smokers at baseline and 3 and 6 months were 0.442, 0.133, and 0.133, respectively. Standard errors for smokers at baseline and 3 and 6 months were 0.284, 0.225, and 0.246, respectively.
DISCUSSION

The results of this clinical study suggest that root coverage obtained with connective tissue grafts was reduced in smokers. Fewer smokers healed with complete root coverage compared to non-smokers (25% and 80%, respectively). Also, smokers healed with a lower % RC and more recession depth at 3 and 6 months.

The combined percentage of root coverage obtained in this study using a connective tissue graft was 90.3%, which was similar to the average 91% reported from a previous meta-analysis. However, the root coverage obtained in this study was less than the average of 97.1% reported by Harris using the double-pedicle technique. When evaluating root coverage in only smokers, the study by Martins et al. reported a 58.4% root coverage compared to the 82.33% in our study. This difference in root coverage may be due to the patients’ smoking history. The study by Martins et al. evaluated heavy smokers (more than one pack per day for 5 years). In contrast, the smokers in our study smoked fewer cigarettes (one-half to one pack per day on average).

The findings of the % RC and final recession depth between the smokers and non-smokers were statistically significant (Table 2). This is an important clinical finding because root coverage is a primary goal of connective tissue grafts. A statistically significant difference was not found in gains of keratinized gingiva increase or probing depth differences. One possible reason why these parameters were not statistically significant may have been that the sample size was not large enough. A larger sample size would improve consistency in measuring these parameters. In our study, the % RC was calculated in terms of defect coverage. It has been suggested by Greenwell et al. that reporting information as a percentage of defect coverage may be a more accurate assessment of the root coverage outcome. This may be true because it accounts for the severity of the recession defect preoperatively.

An interesting result was observed when comparing the patient cotinine levels with % RC and KG. The correlation between cotinine levels and % RC and KG was strong ($r = 0.97$ and $r = 0.85$, respectively). This dose dependent relationship with cotinine levels and clinical parameters was also reported by Gonzalez et al. This may indicate that reducing cigarette use before and after surgery may benefit final outcomes and improve healing.
Patients were counseled on the effects of cigarette smoking and encouraged to quit for ethical reasons. Both patients reported that they returned to normal smoking habits before 1 week of cessation. The slight reduction in smoking may have benefited the healing in these two smoking patients, but the effect was not seen with measured parameters. When questioned at follow-up visits, other smoking patients stated that they did not modify their smoking habits.

The mechanism in which smoking interferes with wound healing is not well understood. Smoking can cause vasoconstriction and reduced blood flow systemically. An adequate blood supply is critical for revascularization of the connective tissue. There are over 4,000 substances in tobacco smoke including carcinogens. Substances such as cyanide, carbon monoxide, and nitrosamines may contribute to the poor wound healing in cigarette smokers. Smoking interferes with neutrophil function, which is needed to remove bacteria and foreign substances during wound healing. In animal studies, a dose dependent suppression of immunoglobulin M (IgM) and IgG was noted in smoking subjects. The function of immunoglobulins is a critical component of the immune system and wound healing.

Smokers produce less hydroxyproline and collagen than non-smokers. Hydroxyproline and collagen are essential for production and maintenance of connective tissue. The presence of nicotine on root surfaces in smokers has also been documented. This nicotine can be stored in fibroblasts, which can alter fibroblast function and proliferation. When fibroblasts are exposed to nicotine, cellular changes such as transient cell vacuolization, decreased proliferation, and cell death can occur. This altered function of fibroblasts due to nicotine exposure could also be the cause of the poor periodontal wound healing seen in cigarette smokers. These combined effects of cigarette smoking may lead to poor wound healing with connective tissue.
Gingival Recession Treatment With Connective Tissue Grafts in Smokers and Non-Smokers

grants and periodontal surgical procedures. Furthermore, smoking cessation or reducing the number of cigarettes smoked may increase the success and prognosis of root coverage treatment.

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