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Radiographic evaluation of the alveolar bone level change before and after crown-lengthening procedures in a dental school setting

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Purpose: The purpose of the present study was to conduct a radiographic evaluation of the magnitude of alveolar bone height change following crown-lengthening surgery performed in a dental school setting, and to monitor the effects of the level of experience of the operators.

Study design: A total of 158 previously crown-lengthened patients were randomly selected from the patient pool. Clinicians included faculty members (general dentists and periodontists), pre-doctoral students, post-doctoral periodontal residents and general practice residents.

Results: A total of 245 teeth underwent crown-lengthening procedures (several of the patients had multiple crown-lengthened teeth), and both pre- and post-periapical radiographs were collected, along with demographic, tooth-related and operative predictor variables. Of the 245 crown-lengthening procedures performed during the study interval, complete data were available for 57 procedures (23.3%). No single predictor variable was uniformly associated with a change in alveolar bone heights on both the mesial and distal aspects. In addition, no statistically significant results were obtained between level of operator expertise and magnitude of bone reduction. The mean change in mesial alveolar bone height was 9.5%, and the mean change for the distal height was 6.3%. These changes were statistically significant ($P<0.001$).

Conclusions: The results of the present clinical investigation demonstrated that over a period of 2 to 12 months, surgical crown-lengthening procedures resulted in statistically significant changes in alveolar bone heights.

■ Introduction

According to the 2003 American Academy of Periodontology Practice Profile Survey, one of the most common periodontal procedures performed by periodontists is crown lengthening[1]. Crown-lengthening surgery provides adequate supragingival tooth dimensions for proper restoration, and enhances aesthetics when there are discrepant gingival lines or passive eruption deficiencies[2]. Thus, indications for crown-lengthening surgery may include the presence of subgingival caries, subgingival fracture, endodontic perforation or pre-existing faulty subgingival margins that would require an increase in the length of the tooth in order to place restoration.

Crown-lengthening surgery can involve the removal of both hard and soft tissues. After surgery, the biological width re-establishes itself. The bio-

logical width is the dimension of the soft tissue that is attached to the portion of the tooth coronal to the crest of the alveolar bone[3]. Gargiulo et al[4] described this dimension and relationship of the dentogingival junctions in humans. They reported the following mean dimensions: a suclus depth of 0.69 mm, an epithelial attachment of 0.97 mm and a connective tissue attachment of 1.07 mm[4]. Based on this work, the biological width was commonly stated to be 2.04 mm, which represents the sum of the epithelial and connective tissue measurements. However, significant variations in dimensions have been observed, and setting fixed measurements on the biological width discounts the variability between teeth and between surfaces surrounding the same tooth[3,5-8].

Numerous studies have reported that placing restorative margins within the biological width may lead to gingival inflammation, clinical attachment loss and bone loss[3,9-11]. Clinically, these changes manifest as deepened periodontal pockets or gingival inflammation. To respect and preserve the biological width, several authors have suggested leaving a distance of 3 to 5 mm from the level of the planned restorative margin to the level of the newly recontoured osseous crest when performing a crown-lengthening procedure[12-15]. Thus, it is generally recommended that clinicians establish a minimum of 3 mm of distance between restorative margin and alveolar bone[3].

The purpose of the present study was to conduct a radiographic evaluation of the magnitude of alveolar bone height change following crown-lengthening surgery performed in a dental school setting (the Harvard School of Dental Medicine, HSDM). The hypothesis was that over a period of 2 to 12 months, surgical crown-lengthening procedures performed in this setting would demonstrate statistically significant alveolar bone height changes, and that there would be identifiable risk factors (such as level of experience of operators) for failure to achieve changes in alveolar bone heights.

■ Study design

Institutional Review Board (IRB) approval was granted by the university committee governing the use of human subjects in clinical studies. A total of 158 previously crown-lengthened patients were randomly selected from the HSDM patient pool. All patients underwent crown-lengthening surgeries consisting of an apically repositioned flap with osseous resection and recontouring. The surgeries were performed at the discretion of each clinical practitioner, with no knowledge of the present study. The inclusion criteria included adults over the age of 21 years, non-pregnant females, and crown-lengthening procedures that had post-operative radiographs taken within 2 to 12 months. Clinicians included faculty members (general dentists and periodontists), pre-doctoral students, post-doctoral periodontal residents and general practice residents. Other demographic variables that were collected in the study included surgery, smoking and history of metabolic disease. A total of 245 teeth underwent crown-lengthening procedures (several of the patients had multiple crown-lengthened teeth), and both pre- and post-periapical radiographs were collected, along with demographic, tooth-related and operative predictor variables.

Patients who lacked a post-operative radiograph were contacted via telephone for a recall visit within 2 to 12 months of initial crown lengthening. These patients were read an approved script, received a written and pictorial description of the study, and provided written informed consent. The patients that were recalled for the radiographs received complementary intra-oral examination and adult prophylaxis. At the recall visit, the surgical site was examined for healing, and one periapical radiograph of the area was taken as a follow-up procedure if there no periapical post-operative radiograph was available.

Two hundred and forty-five crown-lengthening procedures were analysed for demographic and surgical data (reasons for surgical crown lengthening). Fifty-seven (23.3%) procedures met the criteria for entry into the study. Each periapical radiograph was digitised. Measurements were computed using a validated method for analysing alveolar bone heights digitally (Implant Analysis Toolkit; Harvard School of Dental Medicine, MA, USA)[16]. This program was used to calculate the bone heights on the mesial and distal aspects of pre- and post-operative sites. Comparison of the pre- and post-operative radiographs consisted of a fixed reference point

(apex of the tooth to the cementoenamel junction [CEJ] or furcation) and the level of alveolar bone height. A constant reference point was used within subjects. However, reference points were not uniform between subjects. These are 'relative' measures and were expressed as a percentage. An example might be: CEJ to apex = 1 (fixed reference point) before and after surgery. Bone height (variable pre-surgery = X, post-surgery = Y) to apex. The percentage would be X/1 x 100 for the pre-surgical value and Y/1 x 100 for the post-surgical value. The standard deviation (SD) is given for each measure in brackets.

All measurements were made by one examiner (JC) who had been trained and calibrated prior to the study. The examiner was calibrated by working on a standardised template at three different times to measure for consistency and reproducibility (results not shown).

Additional information collected from the patients consisted of demographic variables, surgical expertise and the indication for crown lengthening (Table 1). Surgical expertise was classified into five categories:

- periodontal-faculty
- non-periodontal faculty
- post-doctoral periodontal residents
- general practice residents
- pre-doctoral students.

Indications for crown lengthening were based on both clinical findings and radiographic examination, and documented notes in each patient's chart. Three categories of indications for crown-lengthening surgery were included:

- subgingival decay
- short clinical crown/inadequate retention
- subgingival restoration.

Finally, the pre- and post-operative status of each tooth was reviewed.

Statistical analysis

Data were entered into a statistical database (SPSS v.11.0, SPSS, Chicago, IL, USA) over the course of the study. Descriptive statistics were computed to compare the subjects included in the study with those excluded, to identify sources of selection bias. Bivariate analyses were computed to identify demographic, tooth-related or operative predictors associated with change in alveolar bone heights. Paired-sample *t*-tests were used to compare pre-operative bone heights with post-operative bone heights. For all analyses, a *P* value of <0.05 was considered statistically significant.

Results

The mean age of the 158 patients was 47 years and approximately 59% were female and 41% male. Of the 245 crown-lengthening procedures performed during the study interval, complete data were available for 57 procedures (23.3%). Most patients were excluded because of inadequate radiographs (either missing preoperative radiographs or poor quality radiographs) or loss of follow-up. In the sampled predictor variables for age, gender, smoking and history of metabolic disease, there were no statistically significant differences between procedures that were included in the study and those that were excluded (Table 1). There were statistically significant differences between the study and excluded group for the indications for surgery (decay, short clinical crown and subgingival restoration); those included in the study were more likely to have decay or a short clinical crown. Crown-lengthening procedures in the study group were less likely to be in patients who smoked ($P<0.01$). There were no incisors that needed crown-lengthening procedures in the study group. The majority of the surgeries (67%) involved molars.

Analysis of levels of surgical expertise included five categories, as outlined above. Of the 57 crown-lengthening procedures in the present study group, the majority of surgeries were performed by pre-doctoral students (21 teeth or 36.8%) and members of the periodontal faculty (17 teeth or 29.8%) (Table 1).

Evaluation of the pre- and post-operative alveolar bone levels is presented in Table 2. Mesial pre-operative alveolar bone level was 106.7% (±29.8), and the mesial post-operative level was 96.7% (±27.3) ($P<0.001$). Distal pre- and post-operative values were 96.7% (±23.0) and 90.0% (±23.3) respectively ($P<0.001$). The mean change in mesial alveolar bone height was 9.5%, and the mean change for the distal height was 6.3%. These changes were statistically significant ($P<0.001$).

Table 1 Descriptive statistics of the study population.

Variable**	Study group (n = 57)	Excluded (n = 188)	*P* value
Demographic variables			
Age (years)	47.5 (14.3)	47.3 (16.6)	0.94
Gender (female)	35 (61.4)	109 (58.0)	0.68
Indication for surgery			<0.01
Decay	28 (49.1)	45 (23.9)	
Short clinical crown	21 (36.8)	21 (11.2)	
Subgingival restoration	1 (1.8)	14 (7.4)	
Inadequate retention	2 (3.5)	107 (56.9)	
Not recorded	5 (8.8)		
Smokers	3 (5.3)	22 (11.7)	0.03
Evidence of metabolic disease	12 (21.1)	42 (22.3)	0.84
Tooth-related variables			
Tooth type			<0.01
Incisor	0 (0.0)	36 (19.1)	
Canine	2 (3.5)	23 (12.2)	
Premolar	17 (29.8)	58 (30.9)	
Molar	38 (66.7)	66 (35.1)	
Not recorded	0 (0.0)	5 (2.7)	
Previous root canal treatment	38 (66.7)	58 (30.9)	0.29
Extractions	2 (3.5)	7 (3.7)	0.42
Operative variables			
Operator experience			0.21
Pre-doctoral student	21 (36.8)	43 (22.9)	
General practice resident	1 (1.8)	3 (1.6)	
Periodontal resident	14 (24.6)	51 (27.1)	
Faculty, non-periodontal	4 (7.0)	9 (4.8)	
Faculty, periodontal	17 (29.8)	82 (43.6)	
Time between preoperative radiograph and surgery (days)	301.9 (471.9)	309.1 (470.1)	0.94
Outcome variables			
Time between surgery and post-operative radiograph (days)	103.6 (83.3)	200.3 (240.6)	0.12
Preoperative bone height, mesial*	106.7 (29.8)	NA	NA
Post-operative bone height, mesial*	96.5 (27.3)	NA	NA
Preoperative bone height, distal*	96.7 (23.0)	NA	NA
Post-operative bone height, distal*	90.0 (23.3)	NA	NA

* Bone heights were measured from the apex of the tooth to a pre-identified reference point (either CEJ or furcal level). A constant reference point was used within subjects. However, reference points were not uniform between subjects.

** Continuous measures are listed as mean (SD); categorical measures are listed as numbers (per cent).

Bivariate associations between the predictor variables and change in alveolar bone height are summarised in Table 3. No single predictor was uniformly associated with a change in alveolar bone height on both the mesial and distal aspects. Increasing age was associated with increased change in alveolar bone height on the mesial aspect ($P=0.01$). Increasing time between surgery and the post-operative radiographic evaluation was associated with an increased magnitude of change on the distal alveolar crest ($P=0.01$). Of note, teeth without root canal treatment (RCT) had a trend towards larger changes in alveolar bone height on the mesial and distal aspects ($P=0.06$ and 0.07, respectively), compared with teeth with RCT. Interestingly, no statistically significant results were obtained between level of operator expertise and magnitude of bone reduction (Table 3).

■ Discussion

The results of the present study show that the greatest mean change in bone reduction occurred in the mesial alveolar bone height, with a reduction of 10.2% (Table 2). This change was 3.5% greater than in the distal area (6.7%). The present study is consistent with Herrero et al[17], who concluded that the greatest bone reduction occurred on the facial and mesiofacial sites. The discrepancy between the mesial and distal sites may be attributable to the ease of accessibility of the mesial aspects compared with the distal aspects of the crown. Another factor may be that no incisors were included in the study. The majority of the surgeries involved molars, 38 in total (66.7%).

The greatest reduction in alveolar bone was reported by Lanning et al[8], who applied a method of measuring the biological width by presurgical bone sounding. Osseous resection in their study was reported to be ≥3 mm at 90% of treated sites. In addition, the biological width was re-established to its original vertical dimension by 6 months, and a consistent 3 mm gain of coronal tooth structure was observed at the 3- and 6-month examinations[8]. The authors concluded that the amount of bone removal in their study could have been a significant factor contributing to the stability of the gingival margin over time[8]. Nevertheless, other studies reported that the desired amount of crown lengthening was either not predictably attained or was subject to change over time[17,18]. For example, Bragger et al[18] examined changes in marginal soft tissue levels after 6 weeks and 6 months of healing. Looking at 43 teeth in 25 patients, they found that 96% of sites had ≤2 mm of bone removed whereas only 7% of sites had the desired bone removal of ≥3 mm[18]. A follow-up study by Deas et al[19] reported similar results with ≤2 mm of bone reduction (93% of sites) and ≥3 mm of bone reduction (7% of sites). They also reported a significant tissue rebound following crown-lengthening surgery, which had not fully stabilised by 6 months[19]. Furthermore, Pontoriero and Carnevale[20] reported mean bone removal of 0.9 mm (interproximal) and 1.0 mm (buccal/lingual), and bone removal of ≥2 mm in only 8% of sites. In addition, there was a coronal rebound of supragingival tissue of 3.2 mm (interproximal) and 2.9 mm (buccal/lingual) 1 year after crown-lengthening surgery (~85% occurring in 6 months)[20]. Interestingly, the degree of soft tissue rebound seemed to be related to the position of the flap relative to the alveolar crest at suturing[20]. The studies all indicate that proper surgical alveolar bone reduction is necessary to accommodate the re-establishment of the biological width, and greater bone removal during crown-lengthening proce-

Table 2 Evaluation of pre- and post-operative bone levels.

	Preoperative % (SD)	Post-operative % (SD)	*P* value
Bone height, mesial	106.7 (29.8)	96.5 (27.3)	<0.001
Bone height, distal	96.7 (23.0)	90.0 (23.3)	<0.001

Bone heights were measured from the apex of the tooth to a pre-identified reference point (either CEJ or furcal level). A constant reference point was used within subjects. However, reference points were not uniform between subjects.

dures should be considered to maximise final crown length[19].

The present study has shown that, over 2 to 12 months, a statistically significant amount of alveolar bone reduction has been attained in treated sites. Out of the three indications for surgical crown lengthening (decay, short clinical crown and subgingival restoration), decay or short clinical crowns were more significant than subgingival restorations as indications for surgery. This finding indicates that the majority of crown lengthening performed stems from subgingival decay and inadequate crown length. It is possible that crown lengthening needed for subgingival restorations has been overlooked. Analysis of operator expertise indicated no correlation between level of operator expertise and magnitude in bone reduction (Table 3). The data contradict those of the study by Herrero et al[17], which indicated that the level of surgical expertise positively correlated to the amount of bone reduction, whereby more experienced periodontists removed a greater amount of bone. However, they found no significant correlation between experience level and resultant biological width[17]. The discrepancy between these results may correspond to the variation in data collected. The present investigation used pre- and post-operative radiographs, while the study conducted by Herrero et al[17] elicited the use of stents for clinical measurements. Also, the sample size of Herrero et al[17] was only six patients, whereas the present study included 57 patients. Other related factors may result from differentiation in surgical skill, healing time and patient variation. Furthermore, the constant level of bone reduction among operators at HSDM may result from use of standardised surgical instrumentation (crown-lengthening burs); in addition, pre-doctoral crown-lengthening procedures were supervised by post-doctoral periodontal residents and periodontists.

Limitations of this study stem from the reliance on radiographs for determination of alveolar bone height. Thus, errors due to magnification and discrepancy in angulation between pre- and post-operative radiographs may affect the data. A variation of 2 mm is possible in each radiograph because of divergence of the central beam[21]. Owing to the limitations of periapical radiographs, determination of the magnitude of alveolar bone resection and hence biological width was difficult to achieve millimetre-accuracy. However, a constant reference point was used within subjects, and results were determined using a computer analysis program in a percentage form, thereby reducing variation among measured tooth lengths. Other recognised limitations include possible bias between study patients and the excluded group.

Table 3 Association between predictor variables and percentage change in bone height. There is a statistically significant association between the amount of change in bone level and a history of root canal treatment (RCT) on the tooth undergoing the crown-lengthening procedure. Teeth that did not have RCT had a statistically significantly greater change in bone levels following RCT, compared with those teeth that had undergone RCT prior to crown lengthening. There were no other statistically significant associations between the predictor variables and changes in the alveolar bone levels.

	*P*value	
Variable**	**Mesial bone level**	**Distal bone level**
Demographic variables		
Age (years)	0.44	0.01
Gender (female)	0.85	0.45
Indication for surgery	0.94	0.99
Smokers	0.87	0.69
Evidence of metabolic disease	0.28	0.74
Tooth-related variables		
Tooth type	0.50	0.63
Previous root canal treatment	0.06	0.07
Extractions	0.07	0.26
Operative variables		
Operator experience	0.47	0.42
Time between preoperative radiograph and surgery (days)	0.74	0.90
Outcome variables		
Time between surgery and post-operative radiograph (days)	0.01	0.72

■ Conclusions

The results of the present clinical investigation demonstrated that over a period of 2 to 12 months, surgical crown-lengthening procedures resulted in statistically significant changes in alveolar bone height. Further investigation is required to quantify this change and address whether or not the biological width was achieved.

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