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Assessment of alveolar bone changes in response to minimally invasive periodontal surgery: A cone-beam computed tomographic evaluation

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ABSTRACT

Purpose: The aim of this study was to evaluate 3-dimensional cone-beam computed tomography (CBCT) images of alveolar bone changes in patients who underwent minimally invasive periodontal surgery–namely, the pinhole surgical technique (PST).

Materials and Methods: Alveolar bone height was measured and compared on CBCT images of 254 teeth from 23 consecutive patients with Miller class I, II, or III recession who had undergone PST. No patient with active periodontal disease was selected for surgery. Two different methods were used to assess the alveolar bone changes postoperatively. In both methods, the distance between the apex of the tooth and the mid-buccal alveolar crestal bone on pre- and post-surgical CBCT studies was measured.

Results: An average alveolar bone gain >0.5 mm following PST was identified using CBCT ($P=0.05$). None of the demographic variables, including sex, age, and time since surgery, had any significant effect on bone gain during follow-up, which ranged from 8 months to 3 years.

Conclusion: PST appears to be a promising treatment modality for recession that results in stable clinical outcomes and may lead to some level of resolution on the bone level. More long-term studies must be done to evaluate the impact of this novel technique on bone remodeling and to assess sustained bone levels within a larger study population. ***(Imaging Sci Dent 2023; 53: 1-9)***

KEY WORDS: Alveolar Bone Loss; Cone-Beam Computed Tomography; Gingival Recession; Minimally Invasive Surgery Procedures

Introduction

Gingival recession (GR) refers to the apical migration of the free gingival margin. In a healthy individual, the free gingival margin is approximately 1-2 mm coronal to the cementoenamel junction (CEJ) and the alveolar crest is 1-2 mm apical to the CEJ. In GR, the gingival margin is displaced beyond the CEJ, subsequently exposing the root surface to the oral cavity.[1] Treatment is imperative to protect the exposed surface from potential challenges in the oral environment, such as tooth decay and hypersensitivity. In addition, recession on anterior teeth compromises facial esthetics. Empirical evidence suggests that exposure of the

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root surfaces is caused by a lack of bone support accompanied by apical migration of the soft tissue margin.

The primary objective of treating GR is to restore root coverage. Several periodontal surgical procedures for root coverage have been reported in the literature. Among those, periodontal plastic surgery techniques applying grafts beneath a coronally advanced flap (CAF) have been reported to improve patient esthetics through root coverage.[2] In addition, the combination of CAF with a connective tissue graft attained successful clinical results in patients with GR.[3] A free connective tissue graft (FCTG) has been reported as a technique with predictable clinical outcomes and sustainable results for complete root coverage.[4] Even though connective tissue grafts have been widely employed, considering postoperative complications and donor site morbidity, the focus has been on developing minimally invasive surgical approaches.[5] One such technique is the pinhole surgical technique (PST) introduced by Chao.[6]

PST requires a small horizontal incision of 2-3 mm placed in the alveolar mucosa[6] and uses specially designed elevators designated as trans-mucosal papilla elevators inserted into pinhole incisions to elevate and guide the full-thickness flap coronally and horizontally beyond the CEJ into a healthy position and to place the graft material.[6] A salient feature of this technique is that the graft strips are held in place by tissue tension with no additional need for sutures or tissue adhesives.[6] PST can treat several GR defects at one time, whereas autogenous grafting is limited in treating GR defects because it depends on the ability to harvest an adequate amount of tissue to cover the desired area.[7] PST has been reported to be successful in treating Miller class I and II GR involving multiple teeth in a single session.[6,8]

PST results in esthetically favorable outcomes, with a significant time advantage, no scar formation, less discomfort for the patient after surgery, faster recovery than with traditional grafting, and the lack of necessity of invasive surgical tools or donor tissue from the patient's palate.[6] PST also has an additional benefit of not interfering with the regional vascularity.[9]

Postoperative pain following root coverage procedures has consistently been reported to be lower than after grafting procedures, with no noticeable difference after 3 weeks.[8] Reddy reported that the patients were on analgesics for 4 days, and the only complication noted after PST was postoperative, edema which was severe on day 2 and reduced thereafter in 3 out of five patients.[8]

As with any surgical procedure, known limitations include the application of this technique in medically compromised patients, heavy smokers, and patients taking any medication that alters the normal healing process or immune response. Furthermore, the presence of occlusal discrepancies, parafunctional habits, bone defects, the amount of keratinized gingiva available, and the gingival phenotype are also risk factors.[10] Another limitation of PST is the need for specialized instruments and operator expertise, since success is heavily technique-dependent, especially as it relates to the handling of soft tissues.[11] PST is performed only along the facial/buccal surface of teeth with clinical GR.[7]

After facial root coverage of a maxillary premolar with a subepithelial connective tissue graft, a histologic evaluation indicated periodontal regeneration along the facial recession defect.[12] Histologic findings suggested there was new attachment and new bone gain on the facial aspect of a mandibular first premolar with a thick free autogenous epithelium and a connective tissue graft in an area of deep recession.[13] Grafting procedures have been shown to induce periodontal regeneration in some studies that conducted histological evaluations.[12,13] Imaging is also essential for following up the outcomes of surgery to monitor ongoing bone changes. In recent years, cone-beam computed tomography (CBCT) has been shown to be an accurate and easily accessible imaging modality that could be used to detect morphological changes in alveolar bone, including osteolysis.[14,15] To the authors' knowledge, there are no studies in the extant literature reporting the impact of PST on alveolar bone.

This study attempted to evaluate 3-dimensional CBCT images of alveolar bone changes in patients who had undergone pinhole surgery for GR. The results of this study may further highlight the effect of PST on periodontal regeneration and aid clinicians in the decision-making process.

Materials and Methods

The study received an exemption from the Institutional Review Board of the University of Texas Health Science Center at San Antonio, Texas, USA (protocol number: HSC20190199E exempt on 04/09/2019).

Case selection

Patients who had undergone PST for GR and had available CBCT scans from before and after surgery were selected for this retrospective study. A single periodontist in private practice performed all surgical procedures for consistency. The exclusion criteria were: 1) postopera-

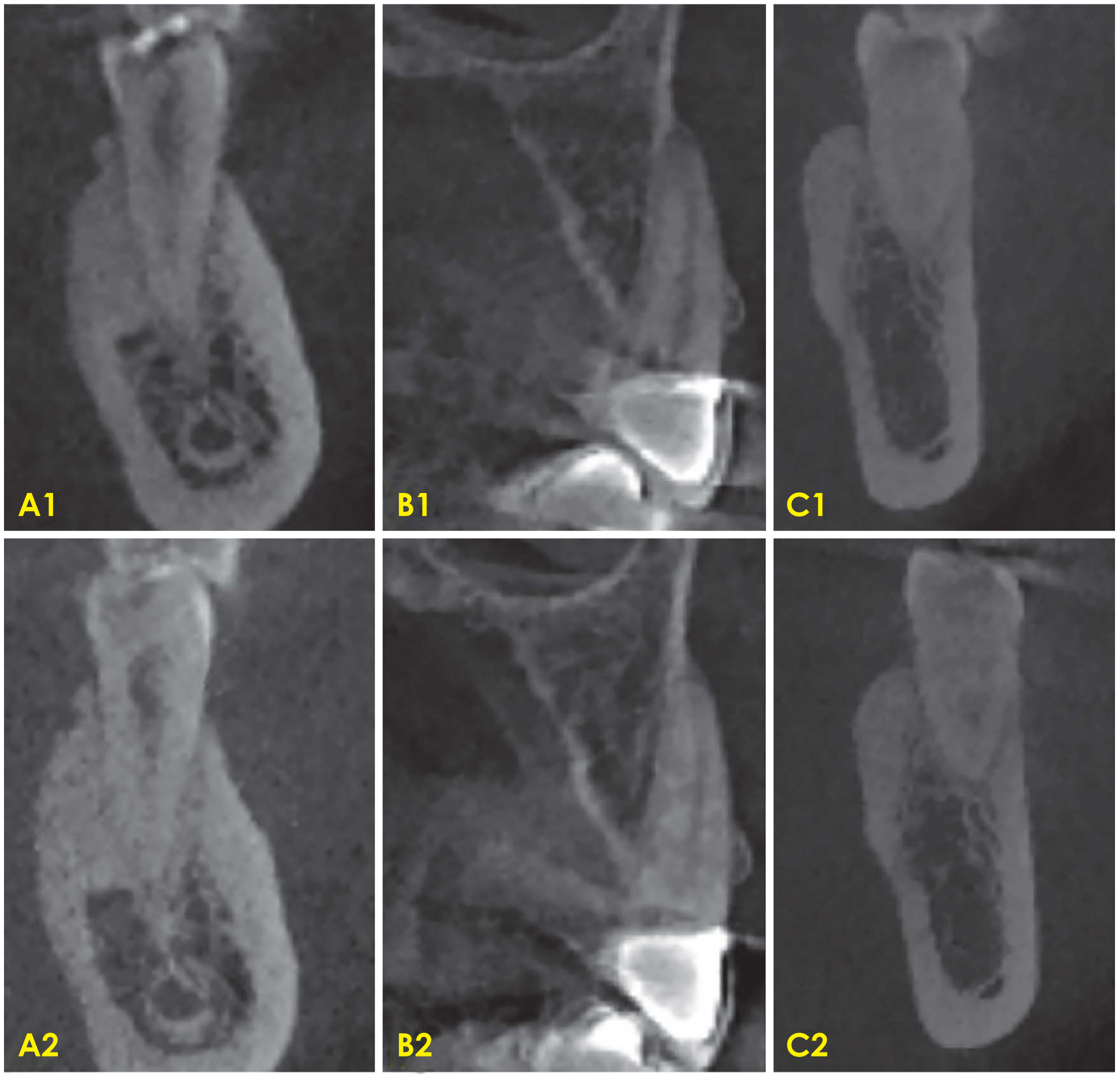

Fig. 1. Cross-sectional cone-beam computed tomographic images show the similarities in image features, such as the teeth and surrounding structures used to generate similar slices for comparison of before and after surgery bone levels. A1 (pre-treatment) and A2 (post-treatment): similarities in the features of mental foramen and surrounding trabeculation bone pattern. B1 (pre-treatment) and B2 (post-treatment): similarities in features of the floor of maxillary sinus and restorations. C1 (pre-treatment) and C2 (post-treatment): similarities in the features of the trabeculation bone pattern and buccal/lingual cortices.

tive CBCT acquired prior to 8 months and after 3 years following surgery; 2) unacceptable CBCT image quality in the relevant area due to operator errors, patient movement, artifacts, or other problems, as determined by a board-certified radiologist with 12 years of experience; and 3) a remarkable medical, dental, or drug history with a potential impact on the periodontium. A total of 254 teeth from CBCT studies of 23 patients (7 men and 16 women) were included. Each subject had between 1 and 28 surgery sites. All subjects had stable periodontal status with no signs of disease progression, such as bone loss, as measured over time. They belonged to various races, and ranged in age from 30 to 83 years. All demographic and procedure-related information, such as age, sex, number of teeth involved, and the length of follow-up, was collected retrospectively from patient records.

CBCT imaging

Two CBCT studies at least 8 months apart were acquired for each patient's pre- and post-surgical evaluation using a Galileos Comfort device (Sirona Dental Systems, Bensheim, Germany) with the following exposure parameters: 7 mA, 85 kVp, 5 s exposure time, and a field-of-view (FOV) of 15 cm × 15 cm × 15 cm. Reconstructed slices (300 μm thick) were evaluated with a slice interval of 0.0 mm. CBCT images (as DICOM) were analyzed simultaneously using a Carestream viewer (CS 3D Imaging v3.8.6, Rochester, NY, USA) to evaluate bone changes for each site. Images were evaluated on 2 Dell monitors (Dell U2312HM, with 1920 × 1080 resolution, Round Rock, TX, USA) in a semi-dark environment. For an optimum visualization of images, focusing on anatomic entities such as the periodontal ligament space and root canal morphology, the window and level were preset by the investigators using the software tools. The CBCT images were acquired between 8 to 36 months after surgery.

Methodology

Bone gain (defined as the difference in bone height prior to and after surgery) was measured only on the buccal surfaces of teeth that underwent surgery. In addition to bone gain, the sex and age of the patient and time since surgery were recorded.

For data assessment, coronal reconstructions were used for posterior teeth and sagittal reconstruction for anterior teeth. A specified coronal or sagittal slice was then chosen as the representative slice of interest to measure the height of mid-buccal alveolar bone for each tooth. In order to ensure that contiguous slices were at the same location for each tooth in both imaging studies, the similarities of anatomic features, such as the mental foramen, sinus borders, morphology of teeth, and even bone architecture, were considered (Fig. 1). The mid-buccal crestal bone and apex of the operated teeth were used as reference points to measure bone height for each tooth. To assess the height of buccal bone surrounding posterior teeth with multiple roots, the apex and alveolar crest at the mid-buccal aspect of the mesiobuccal root of maxillary and the mesial root of mandibular molars were used (Figs. 2A and B). In each slice, the long axis of the tooth was viewed parallel to the y-axis (Fig. 2C).

Measurements were performed using 2 different strategies. In method 1, the alveolar bone height was measured as the distance between the most apical point of the root and the most coronal point of the mid-buccal alveolar crestal bone on each tooth (Fig. 3A). In method 2, 2 parallel horizontal lines were drawn: one line at the level of the mid-buccal alveolar crestal bone, and the other line parallel to the first line at the level of the root apex. The distance between the 2 lines was measured (Fig. 3B). Three measurements were made, and the mean value was used. All measurements were carried out independently by 2 different radiologists, following a calibration session. The observers then compared their results; in case of differences, a consensus approach was used.[16] The postoperative mean value was subtracted from the preoperative mean value to calculate the interval change.

Statistical analysis

The statistical analysis involved the 1-sided binomial test of proportions for the results across patients, and a hierarchical model of the mean bone gain of teeth nested within patients, adjusted for the possible effects of sex, age, and time since surgery. The statistical analysis was conducted using the R statistical software version 3.5.0 (R Core Team, R Foundation for Statistical Computing, 2018, Vienna, Austria) and Microsoft Excel 2010 (Microsoft, Redmond, WA, USA). The measure of interest was whether bone gain occurred after PST, with the hypotheses that the mean value of bone gain would be greater than 0.0 mm, and that more than half the teeth would have positive bone gain.

Results

Analysis using method 1

Figure 4A demonstrates the average bone gain per patient, and Figure 4B shows the percentage of teeth within each patient that demonstrated positive bone gain. In Figure 4B, 2 patients with only 1 tooth that received surgery were excluded because the values could have only been 0% or 100% (both of them were 100%). Using the criterion of average bone gain, as seen in Figure 4A, 22 of 23 patients (96%) had a mean value of bone gain greater than 0 mm. This was significantly greater than the 50% that would be expected if PST surgery had no effect ($P < 0.05$, using the binomial test of proportions). Using the criterion of the percentage of teeth with positive bone gain, as seen in Figure 4B, and setting a standard that at least 67% of the teeth within a patient must show positive bone gain, 19 of 21 patients (90%) met this standard. This was likewise significantly greater than the 50% expectation ($P < 0.05$, using the binomial test of proportions).

A hierarchical model of bone gain using teeth nested within patients was also conducted, with adjustments for age, sex, and time since surgery. Based on the distribution of ages, patients were grouped into age groups of 30-44, 45-59, 60-69, and 70-85 years, with each group having at least 5 patients. There were 16 female and 7 male patients in the study. The time since surgery was categorized into 8-12 months, 17-26 months, and 29-36 months, again based on the distribution of values and with at least 5 patients in each category. The patient was treated as a random-effects variable, and the 3 demographic variables

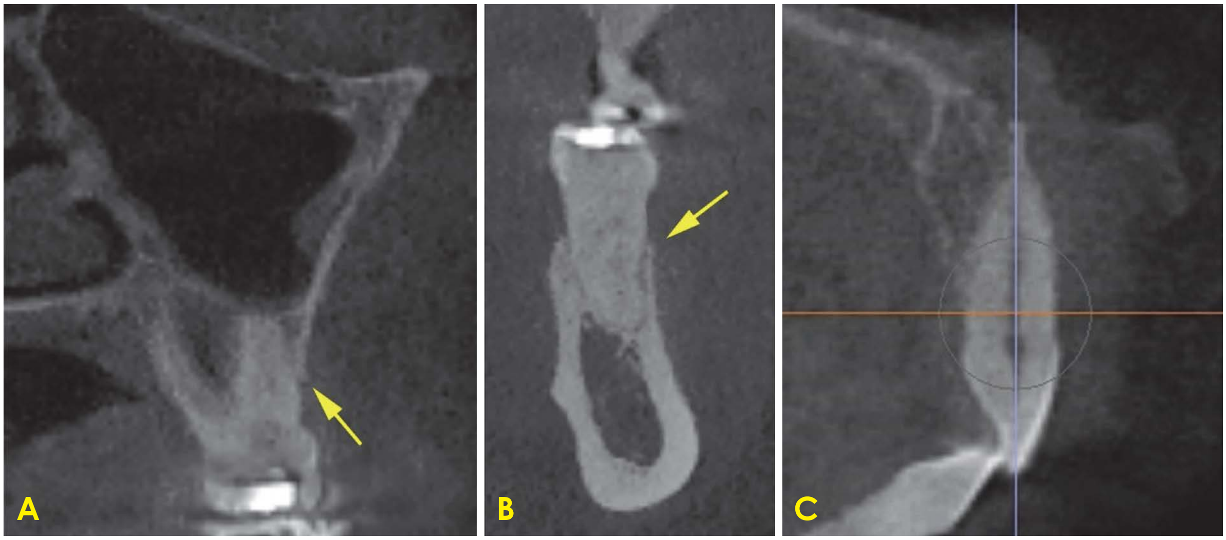

Fig. 2. Measurements of the height of buccal bone surrounding teeth with multiple roots: (A) between the apex and the alveolar crest at the mid-buccal aspect of the mesiobuccal root of maxillary molars; (B) between the apex and the alveolar crest at the mid-buccal aspect of the mesial root of mandible molars. (C) The vertical orientation line is adjusted to be parallel with the long axis of the tooth; therefore, the horizontal orientation line lies perpendicular to the tooth's long axis.

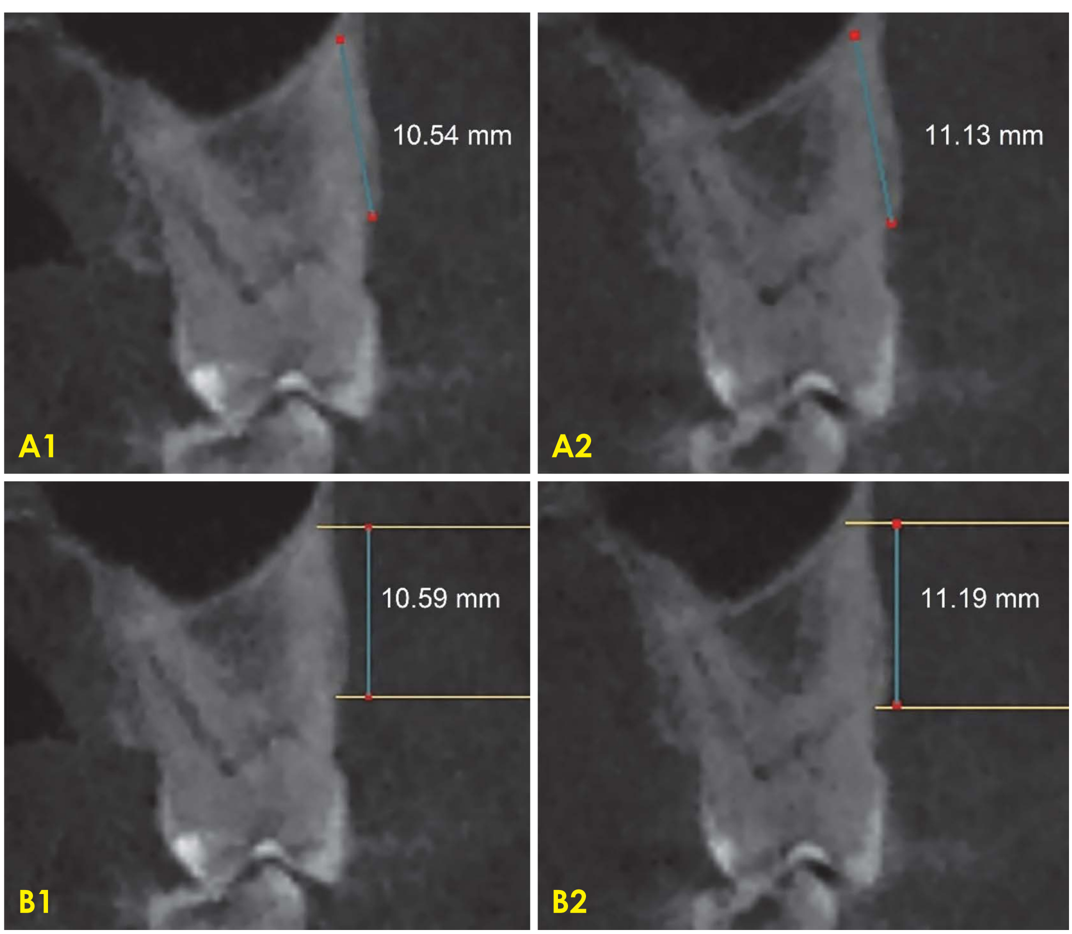

Fig. 3. Measurements of mid-buccal alveolar bone height using 2 different methods. Images A1 and B1 are pre-treatment and A2 and B2 are post-treatment. (A1 and A2) Method 1 measures the distance between the apex and the mid-buccal alveolar crestal bone. (B1 and B2) Method 2 measures the distance between 2 parallel lines at the level of the mid-buccal alveolar crestal bone and the apices of teeth.

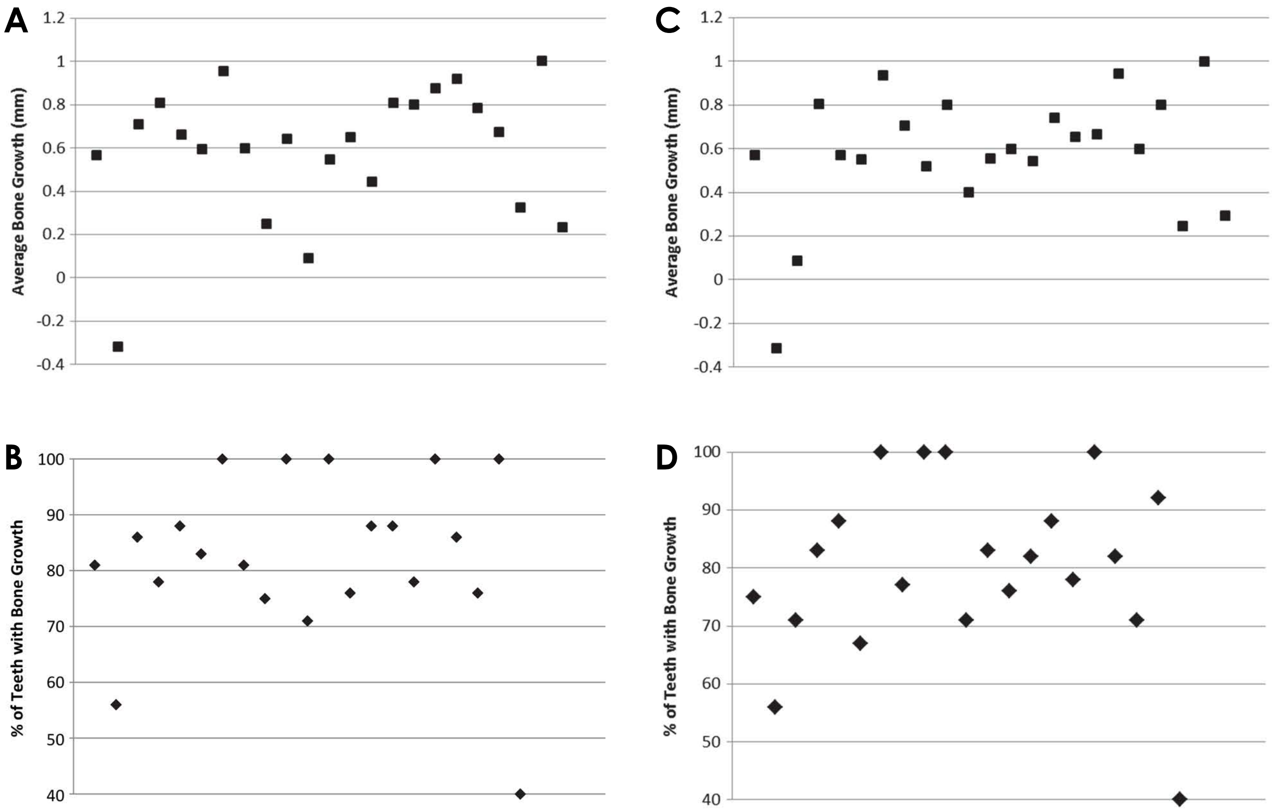

Fig. 4. A and C show the average values of bone gain using 2 different methods of measurement; A is method 1 and C is method 2. B and D show the percentage of teeth with positive bone gain using 2 different methods of measurement; B is method 1, and D is method 2.

were fixed effects at the patient level.

A mixed-effects analysis confirmed that none of the demographic variables had a statistically significant effect on the mean value of bone gain, with *P*-values of 0.76 for age group, 0.35 for sex, and 0.31 for time since surgery. Allowing the model to use these variables for adjustment, the mean bone gain after PST surgery was estimated to be 0.574 mm (95% CI, 0.127-1.021 mm). The *P*-value for the hypothesis that the mean bone gain would be greater than 0 mm was <0.05

Analysis using method 2

Figure 4C shows the average bone gain per patient, and Figure 4D demonstrates the percentage of teeth within each patient that had positive bone gain, again excluding the 2 patients with only 1 tooth that underwent surgery. Figure 4C also shows that 22 of 23 patients (96%) had a mean value of bone gain greater than 0 mm using method 2, with the same statistical result ($P<0.05$). For the criterion of at least 67% of teeth with positive bone gain (Fig. 4D), again 19 of 21 patients (90%) met this standard, with the same statistical result ($P<0.05$).

A mixed-effects analysis of the results using method 2 to measure bone gain resulted in the same statistical conclusions, with *P*-values of 0.83 for age group, 0.79 for sex, and 0.38 for time since surgery. Allowing the model to use these variables for adjustment, the mean bone gain after PST surgery was estimated as 0.811 mm (95% CI, 0.205-1.416). The *P*-value for the hypothesis that the mean bone gain would be greater than 0 was <0.05. Method 2 had slightly more statistical uncertainty than method 1, but the conclusions were the same for each method.

Discussion

A subepithelial connective tissue graft in conjunction with CAF has been considered the gold standard approach for the correction of root coverage.[11] However, this method involves the creation of a second surgical site, which increases morbidity, and includes vertical releasing incisions, which cause scarring and compromise the esthetics.[11,17] Therefore, other methods, such as PST, have been devised to avoid these drawbacks.[11]

Chao reported an increase in keratinized tissue, with a mean of 1.3 mm in the recessed area using the pinhole technique.[6] Additionally, the width of keratinized tissue significantly increased from baseline to 6 months,[11] which aligned with the findings of studies by Reddy[8] and Zucchelli and De Sanctis.[18]

The clinical evaluation records of the cases analyzed herein were in accordance with the studies conducted by Reddy,[8] Chao,[6] and Agarwal et al.[11] where the follow-up clinical examination records indicated that root coverage was achieved after PST surgery.

Mostafa et al.[10] found that the gingival volume and biotype thickness increased in the surgically treated area, which was consistent with Chao's finding[6] that PST could increase tissue volume and produced stable, predictable results with a minimum tissue thickness of 0.8-1 mm. Additionally, they showed an increase in the width of keratinized tissue from baseline to 8 months.

It is crucial to note that PST has limitations. Mostafa et al.[10] reported some limitations, such as technique sensitivity and the need for specialized devices to elevate the flap without exposing the inner tissue, which raises the risk of flap perforation.

Griffin et al.[19] claimed that the length of the procedure—particularly when utilizing an autogenous graft—was the most significant predictor of postoperative pain. However, the investigations found that PST could be completed quickly even when there were numerous recession defects. Furthermore, when analyzing significant improvements in various parameters after PST, recession reduction and the increase in keratinized tissues were found to be similar to the results of previous studies with modified CAF.[19]

The advantages of using PST could be summarized as multiple root coverage and regeneration of the mucogingival apparatus without the use of sutures or a donor site, which reduces the risk of graft exposure and second surgical sites, yields favorable long-term esthetic results, shortens the surgical time, speeds up healing with no scarring, minimizes postoperative complications, and produces immediate results.[8] The limitations of PST involve the requirement for special instruments for flap elevation and the need for particular technical skills to avoid flap perforation.[8] It has also been shown to be risky for the treatment of lingual gingival defects and could not be used to treat palatal recession defects.[8] In this study, PST was performed only on the buccal aspects of the involved teeth. The presence of bone and the height of the interdental papilla between the teeth determined whether GR could be reversed.[20]

The combination of various examination methods such as clinical, radiographic, and histological assessment could accurately evaluate the periodontal status.[21] Radiographic assessment is an essential tool that shows tissue changes to determine the success of periodontal regeneration. Conventional radiography results in distortion, which diminishes the accuracy of the analysis, especially when assessing small osseous changes after regenerative periodontal procedures.[22-25] Bitewing radiographs were exemplarily used to assess bone remodeling following regenerative surgery if the entire perimeter of the bony defect was adequately visualized on the radiographic image.[26] PST is performed on the facial/buccal surface of the alveolar bone of teeth with GR; therefore, none of the conventional radiographic techniques can be used to evaluate the bone changes on the facial/buccal aspect.

Some studies have shown that CBCT provided better outcomes compared with 2-dimensional radiographs regarding the periodontal diagnosis.[14] Van Dessel et al.[15] demonstrated that CBCT was a reliable and accurate approach compared to multislice computed tomography for quantitative assessments of alveolar bone. At the same time, Zhang et al.[27] validated the suitability of CBCT for periodontal evaluations.

Wang et al.[24] found that alveolar bone gain was promoted by applying low-intensity pulsed ultrasound combined with guided tissue regeneration surgery in periodontal disease with class II furcation involvement. They used micro-computed tomography (micro-CT) because of its capability for precise 3-dimensional measurements of alveolar bone and high resolution. However, micro-CT is not a clinical tool.

At the time of this study, there were no published studies reporting the impact of PST on bone. This study evaluated CBCT for assessment of bone changes in patients who had undergone pinhole surgery for GR and established the presence of bone gain of more than 0.5 mm, which was significantly greater than a complete absence of bone gain.

Our study further confirmed that none of the demographic variables including sex, age, and time since surgery had a significant effect on bone gain, in an analysis of records from 8 to 36 months after surgery. As this was a retrospective study, the earliest postoperative CBCT was done at 8 months. Nevertheless, some experts have suggested that old age may be a risk factor for periodontitis due to physiological changes that adversely affect bone healing after periodontal therapy.[28,29]

Since this was a retrospective study, large-volume CBCT scans were utilized, with limited voxel size and, consequently, limited resolution. In future studies, small FOVs and improved resolution may alter the outcomes. This study could not consider the success rate in terms of bone gain in the presence of incipient caries, abfraction, or restorations on the facial aspect of the teeth at the time of the PST procedure. Information on patient compliance was also not available. All of these factors can affect the success of any periodontal procedure, including PST. The results, therefore, should be interpreted with caution. Future studies controlling for these extraneous variables will provide further valuable information on the treatment outcomes of PST.

In conclusion, for patients with GR, PST appears to be a promising treatment modality that results in stable clinical outcomes, as observed in this cohort. To the authors' knowledge, this retrospective study is the first to evaluate periodontal bone gain following PST using preoperative and postoperative CBCT images. Further studies are recommended to evaluate the impact of this technique on bone remodeling with a larger study population, while controlling for other factors as indicated above.

Conflicts of Interest: None

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