

Three-Dimensional Quantitative Measurement of Buccal Augmented Tissue After MCAT Technique With SCTG: Preliminary Results of a Prospective Case Series

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Abstract

Background: The aim of this study to investigate three-dimensional quantitative analysis buccal augmented tissue alterations after modified coronally advanced tunnel (MCAT) technique combined with subepithelial connective tissue graft (SCTG) within 1-year based on intraoral scanning.

Methods: 25 Cairo class I gingival recession defects were treated by MCAT technique with SCTG. Two examiners performed digital three-dimensional measurements, including the preoperative gingival recession height (GH), width (GW) and root exposed area (REA), postoperative gingival height gain (HG), area gain (AG), volume gain (VG) and mean thickness gain (MTG) of region of interest (ROI). Then, dynamic alterations of ROI and buccal tissue at 2 weeks, 6 weeks, 3 months and 1-year post-op were analysis.

Results: Intra-class correlation coefficients (ICC) showed almost perfect inter-examiner reliability for digital measurement (ICC > 0.89). Postoperative HG, AG, VG and MTG were encountered distinct at 2 weeks post-op, then gradually decreased. At 1-year, AG, VG and MTG were $7.614 \pm 2.511\text{mm}^2$, $7.690 \pm 4.335\text{mm}^3$ and $0.965 \pm 0.372\text{mm}$, respectively. Significant decreases were recorded between 6 weeks and 1-year in terms of HG, AG and VG. The MTG was sustained after 6 weeks with an increase of nearly 1mm at 1-year.

Conclusions: Digital measurement by intraoral scanning offered an advantage of clinically feasible, non-invasive and reliable evaluation method for achieving volumetric outcomes after periodontal plastic surgery. Augmented tissue acquired by MCAT with SCTG tends to be stable after 3 months post-op.

Trial registration This study was retrospectively registered in Chinese Clinical Trial Registry: ChiCTR1900026768. Date of registration: 21/10/2019.

Background

Gingival recession is defined as the displacement of the gingival margin apical to the cemento-enamel junction (CEJ)[1] resulting in partial exposure of the root surface. It is a frequent clinical feature in both population of high and poor oral hygiene[2, 3]. Several predisposing factors, such as thin gingival phenotype, traumatic toothbrushing habit, cervical restorations, orthodontic treatment, have been suggested contribution to the development of gingival recession[4]. Among multiple surgical procedures[5], the modified coronally advanced tunnel (MCAT) technique in combination with subepithelial connective tissue graft (SCTG) have been introduced to increase gingival dimensions and to cover the exposed root surface effectively with a long-term stability[6, 7, 8].

Objective measurement parameters such as the gain in the height, width and thickness of the gingiva, mean root coverage (MRC), complete root coverage (CRC)[9, 10], as well as subjective assessments such as the root coverage esthetic score (RES)[11] and the smile esthetic index (SEI), are commonly used to evaluate the outcome of periodontal plastic surgery. In terms of linear measurements, the most common

instrument used is a periodontal probe in millimeter scale. However, it is limited by the errors associated with rounded reading and interpretation angles. Other common methods involving plaster model also have a tendency to be inaccuracy for potential deformation in manufacturing and long-term storage. As for the assessment of gingival thickness, the transgingival probing, ultrasound or radiographic methods were used frequently[12, 13]. Either way, there were unavoidable shortcomings such as invasiveness, tissue vary by local anesthesia or compression, radiation and poor site repeatability. Heterogeneity of measurement methods making it difficult to compare among the literature. Therefore, in order to determine the efficacy of different techniques and grafts utilized in periodontal plastic surgery, it is necessary to explore a more convenient quantitative method to evaluate the minor changes of soft tissue morphology precisely after periodontal plastic surgery.

In recent years, the digital measurement method with intraoral scanning instruments has provided clinicians with a new choice[14]. By using analysis software, the measurement parameters can be obtained repeatedly under multiple angles. Even volumetric alteration can be obtained quantitatively. In addition, the digital data can be stored for a long time, making it possible for future secondary research or long-term follow-up[15]. Therefore, the aim of this preliminary study was three-dimensional quantitative analysis buccal augmented tissue after periodontal plastic surgery within 1-year based on intraoral scanning.

Methods

Study subjects

Patients were recruited from June 2019 to December 2020 in the Department of Periodontology, the First Clinical Division, Peking University Hospital and School of Stomatology. All procedures performed in present study involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the declaration of Helsinki 1975, which was revised in 2000. The Ethics Committee of Peking University Stomatology Hospital approved the study protocol (PKUSSIRB-201947089). Written informed consent for participation was obtained from each subject recruited in this study. This study has been registered in Chinese Clinical Trial Registry (ChiCTR.1900026768).

Inclusion criteria were as follows: (1) 18–65 years old; (2) Presented at least 2 mm Cairo class I gingival recession[16] at incisors, canines and premolars; (3) Detectable CEJ with no cervical caries or restorations; (4) Bleeding index ≤ 1 , Probing depth ≤ 3 mm; (5) Full-mouth plaque score and full-mouth bleeding on probing $\leq 15\%$. Patients are being affected by systemic diseases, pregnant or breastfeeding women and smokers are excluded from the study.

Surgical procedures

All subjects were treated with MCAT[8] technique in combination with SCTG by the same surgeon (X.F.). The surgical procedure was as follows (Fig. 1): the recipient site was prepared as a split thickness flap

until above muco-gingival junction. Subsequently, a de-epithelialized SCTG, which was about 1 mm in thickness, was harvested from the palate on the same side of the surgical tooth. The graft was guided into the tunnel. Sling sutures were used to coronally reposition the tissue. Patients were instructed to rinse the mouth twice a day using 0.2% chlorhexidine solution for 2 weeks. Fenbid 0.25 g per time were prescribed as painkiller to patients' needs. The sutures were removed at 2 weeks post-op. Re-examinations were conducted 1, 2, 6 weeks and then 3, 6 and 12 months after the surgery. The supragingival plaque was removed when necessary.

Study process

Intraoral scanner (3shape Trios 2 pod color, 3shape, Denmark) was used to obtain digital models at baseline (BL), 2 weeks (2w), 6 weeks (6w), 3 months (3 m) and 1-year (1y) after the surgery. The scanning range includes not only the surgical tooth but also at least two adjacent teeth on each side. Output the file in "*.stl" format and import it into Geomagic Studio 2013 (Geomagic, Morrisville, USA) for measurement. Irrelevant areas were deleted to trim the borders. The surfaces of the teeth excluding the contact area were invoked as the matching area and superimposed by utilization of the "Best Fit Alignment". Re-determine the mesial-distal direction as the X-axis, the buccal-lingual direction as the Y-axis, and the tooth's longitudinal axis as the Z-axis. Two examiners with digital training conducted measurement between BL and 2w post-op respectively to evaluate the reliability of this digital method in particular.

Digital measurement parameters in the Region of Interest (ROI) and buccal soft tissue

Take left upper lateral incisor in an example (Fig. 2). On the preoperative model, the distance between the lowest point of the gingival margin and the CEJ were taken as gingival recession height (RH) while the horizontal width of gingival recession at the middle point of CEJ were measured as recession width (RW), respectively. Then, the marginal gingival and CEJ were used as the boundaries to calculate the root exposure area (REA).

Figure 2. Three-dimensional digital measurement of the left upper lateral incisor between BL and 2w post-op. Measure the RH, RW and REA on the BL model (a); Similar surfaces (red part) of the teeth on the BL (b) and 2w (c) models were selected as the registration area; The two digital models overlapped for superimposition (d); Manually trace the postoperative gingival area gain in the "Select Through" mode (e); Measure the gingival HG and AG on the BL model (f); Use the "Fill Single Hole" function to close the edges of the two digitized surfaces (g, h); Reconstructed gingival VG (i).

Once superimposed BL and translucent postoperative models, the range of ROI can be obviously distinguished. The vertical distance between the BL and postoperative margins was measured as gingival height gain (HG). Then, the boundaries of these margins were traced in the "Select Through" mode and calculate as gingival area gain (AG). Perform "Flip Normals" on the ROI of the BL model and close the gap between them. The volume of the reconstructed "Crescent-shaped" ROI was taken as gingival volume gain (VG). Divide the VG by the AG to calculate the mean thickness gain (MTG) in this ROI.

Digital measurements of dynamic thickness alteration for buccal soft tissue were shown in Fig. 3. The BL, 2w, 6w, 3 m and 1y digital models were superimposed together. The perpendicular plane Sv was determined by the midpoint of the crown (P-mid) and the midpoint of the buccal (P-b) and lingual CEJ (P-l) as the tooth's longitudinal axis. The line L1 was perpendicular to the plane Sv and 1 mm below the line L, which connect the midpoint of CEJ (P-b and P-l). The points T1-2w, T1-6w, T1-3m, T1-1y and T1-pre were obtained by intersecting line L1 and corresponding digital models. The distance between the point T1-2w and T1-pre was recognized as the increase thickness of buccal tissue at 1 mm below the CEJ 2 weeks post-op. The remaining measurements are achieved in the same way.

Statistical analysis

The variables analyzed were expressed as mean \pm standard deviation (SD). MedCalc Statistical software version is 18.2.1 (Medcalc Software, Ostend, Belgium) was used for statistical analysis. Intra-class correlation coefficients (ICC) were used to measure the reliability between the two examiners[17]. Normality was checked using the Shapiro-Wilk test. Friedman's test with Dunn's multiple comparison correction was used to evaluate the difference of three-dimensional morphology changes in ROI and buccal soft tissue over time. $p < 0.05$ was considered to indicate statistically significant.

Results

A total of 25 teeth (13 in maxillary, 12 in mandibular) were included from 10 patients (5 males, 5 females) aged 26–53 years (average 36.13 ± 8.71 years). All patients were completed surgery and follow-up, and no patients were dropped to follow-up. 22 of 25 teeth achieved complete root coverage at 1-year after MCAT with SCTG surgery.

Table 1 show excellent intra-examiner reliabilities of digital volumetric measurements from BL and 2 weeks post-op digital models acquired by intraoral scanning. The values of ICC for all parameters were perfect over 0.89.

Table 1. Digital measurements of ROI volumetric alteration by 2 examiners

(Mean \pm SD)

	Examiner 1	Examiner 2	ICC
Recession Height (RH)(mm)	2.187 ± 0.521	2.253 ± 0.507	0.914
Recession Width (RW)(mm)	2.907 ± 0.582	2.968 ± 0.670	0.939
Height Gain (HG)(mm)	2.643 ± 0.809	2.601 ± 0.734	0.939
Root Exposure Area (REA)(mm ²)	6.367 ± 1.634	6.187 ± 1.957	0.913
Area Gain (AG)(mm ²)	8.662 ± 2.800	9.336 ± 3.422	0.892
Volume Gain (VG)(mm ³)	10.315 ± 6.344	9.385 ± 4.930	0.968
Mean Thickness Gain (MTG)(mm)	1.052 ± 0.333	1.047 ± 0.391	0.890

The volumetric dynamic alteration of ROI within 1-year after the MCAT with SCTG surgery are presented in Fig. 4 (and Supplementary Table 1). Postoperative HG, AG, VG and MTG were encountered distinct at 2w post-op, then gradually decreased. Statistically significant differences were recorded from 2w-3m, 2w-1y and 6w-1y in terms of HG, AG and VG. At 1-year, AG, VG and MTG were $7.614 \pm 2.511\text{mm}^2$, $7.690 \pm 4.335\text{mm}^3$ and $0.965 \pm 0.372\text{mm}$, respectively. The improvement in MTG after 6w was maintained with an increase of nearly 1 mm.

The thickness dynamic alteration of buccal soft tissue within 1-year is shown in Fig. 5. Similarly, the thickness of buccal soft tissue had the highest increase at 2w post-op, followed a slightly reduced trend afterwards. The thickness change of buccal soft tissue 1 mm and 2 mm below the CEJ yielded higher results than those of 3 mm.

Discussion

Accuracy of the intraoral scanning system has gradually improved in recent years. Not only can it replicate hard tissues such as teeth and restorations precisely, but also digitally reconstruct the surrounding soft tissues[18]. Recent surveys revealed that the accuracy of intraoral scanning of soft tissue in the aesthetic area has reached or exceeded the plaster model[19, 20]. In addition, digital models obtained by intraoral scanning promise convenient and efficient operation, high patient comfort, and convenient data recording and storage. Combined with reverse engineering software, accurate, repeatable and multi-dimensional measurement data can be obtained.

Clinical researches have indicated that intraoral scanning method was superior to periodontal probe, plaster model or scanning plaster model method when measuring the gingival recession and papillary height[21, 22]. The digital measurement which is based on intraoral scanning proved higher repeatability and reproducibility. In spite of some studies had proposed that photogrammetry could be used to evaluate gingival recession and root coverage area. However, it does not take into account the convexity of the root and easily affected by the angle of the photo, the authenticity of the value was lower than the

digital impression. In this study, preoperative REA, postoperative AG and VG were measured with a digital method, which was impossible in traditional methods in the past.

Previous studies have showed the soft tissue volume alterations qualitatively in chromatograms[16, 23]. However, the region defined by this method is too large and susceptible to the size of grafts. Instead, the ROI in the present study may be more instructive for evaluation of the outcome of gingival augmentation and the relapse risk of gingival recession. The MTG of this study was lower than Rebele et al. using the plaster models scanning[24]. It is probably because the ROI they selected was 1 mm smaller than this study, discarding the surrounding thinner edges. However, it is generally stated that the thin gingival phenotypes are at greater risk for developing gingival recessions than thick ones[25, 26], which also verified in the studies of implants[27]. Therefore, the ROI depicted in this study may facilitate higher repeatability and play a more prominent role for maintenance of gingival health.

The modified coronally advanced tunnel in combination with subepithelial connective tissue graft used in this study showed successful root coverage at 1-year post-op. This is consistent with other publications[7, 28], showing a high degree of root coverage of Miller I and II gingival recession. With the help of three-dimensional measurement, the present study found that the gingival HG, AG, VG and MTG were significantly higher at 2 weeks after surgery than baseline. Then, all the parameters decreased gradually which is likely because of graft shrinkage and edema recede. At 1-year after surgery, HG, AG and VG of ROI showed a significant reduction compared to 2 and 6 weeks. In terms of MTG, significant decrease was only observed when compared to 2 weeks. However, no statistically difference was detected in any of the investigated parameters between 3 months and 1-year, suggesting a limited clinical impact that the thickness of augmented tissue of ROI remained stable after 6 weeks post-op while the volume of which maintained stability after 3 months post-op.

Since all the treated sites achieved at least 3 mm keratinized tissue post operation, the present study compared the thickness alteration of buccal soft tissue. It was noted that the thickness gain of buccal soft tissue was about 1 mm, which is comparable to previous studies[29, 30]. In addition, our study showed that the thickness gain from 3 mm below the CEJ yield inferior results than that closer to the gingival margin.

However, the present study had a number of limitations. First of all, the sample size was relatively limited and lack of a control group. In addition, whether the width of keratinized gingiva can be distinguished by color intraoral scan remained to be further studied. Because of the greater mobility of the alveolar mucosa and ligaments, the morphological changes of soft tissue in this area cannot be accurately evaluated by this method. Nevertheless, the results of this study are valuable since we applied a reliable, highly repeatable and three-dimensional measurement protocol to detect volumetric alteration after periodontal plastic surgery within 1-year. Parameters, which difficult to measure accurately in traditional methods and attributed to gingival stability in long-term, were able to be obtained in this digital method. Furthermore, the present study was undertaken based on intraoral scanning, which superior to plaster model scan by overcoming the shortage of deformation.

Conclusions

Based on intraoral scanning and analysis software, digital three-dimensional quantitative analysis was recommended to monitor the dynamic alteration of buccal soft tissue after periodontal plastic surgery. Within the limitations of the study, outcomes indicate that augmented tissue was stable after 3 months post-op and only has slightly volumetric decrease in a follow-up of 1-year. Further clinical research is needed to deliberate what makes periodontal plastic surgery outcomes more predictable.

Abbreviations

CEJ: cemento-enamel junction; MCAT: modified coronally advanced tunnel; SCTG: subepithelial connective tissue graft; MRC: mean root coverage; CRC: complete root coverage; RES: root coverage esthetic score; SEI: smile esthetic index; BL: baseline; 2w: 2 weeks; 6w: 6 weeks; 3m: 3 months; 1y: 1-year; ROI: region of interest; RH: gingival recession height; GW: gingival recession width; REA: root exposure area; HG: gingival height gain; AG: gingival area gain; VG: gingival volume gain; MTG: mean thickness gain; SD: standard deviation; ICC: intra-class correlation coefficients; ANOVA: analysis of variance.

Declarations

Ethics approval and consent to participate

All procedures performed in present study involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the declaration of Helsinki 1975, which was revised in 2000. The Ethics Committee of Peking University Stomatology Hospital approved the study protocol (PKUSSIRB-201947089). Written informed consent for participation was obtained from each subject recruited in this study.

Consent for publication

Not applicable.

Availability of data and materials

The complete documentation of all patients enrolled in this study belongs to the authors and is available only upon reasonable request.

Competing interests

The authors declare that they have no competing interests.

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Author's contributions

XF has made a substantial contribution to the conceptualization and execution of this study. ZY, CY and KN have contributed to the acquisition of clinical and digital data. The statistical analysis and interpretation of the data were performed by ZR. XF was a major contributor in writing the manuscript and CY and LQX revised and edited the manuscript. All authors read and approved the final manuscript.

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Figures

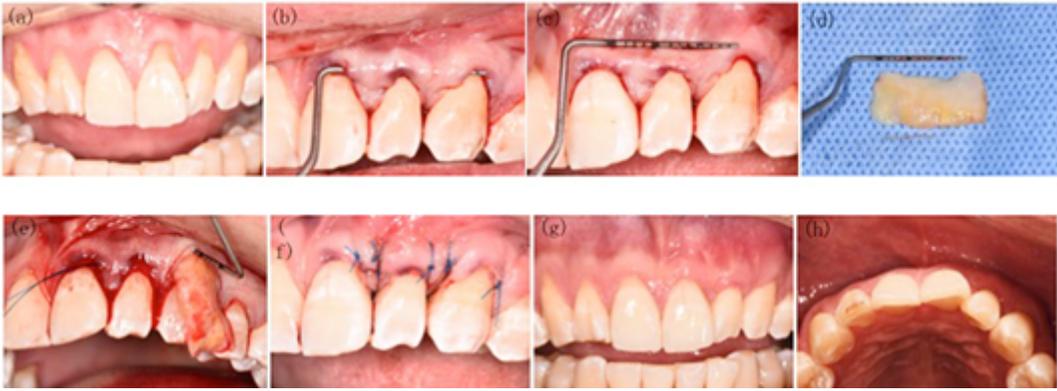


Figure 1

Surgical protocol of gingival recession defects treated with MCAT with SCTG. Baseline (a); Prepared tunnel (b, c); De-epithelialized SCTG harvested from palate (d); SCTG was induced into the tunnel (e); The tunneled flap was sling sutured coronally (f); Facial and occlusive view at 6 weeks postoperative (g, h).

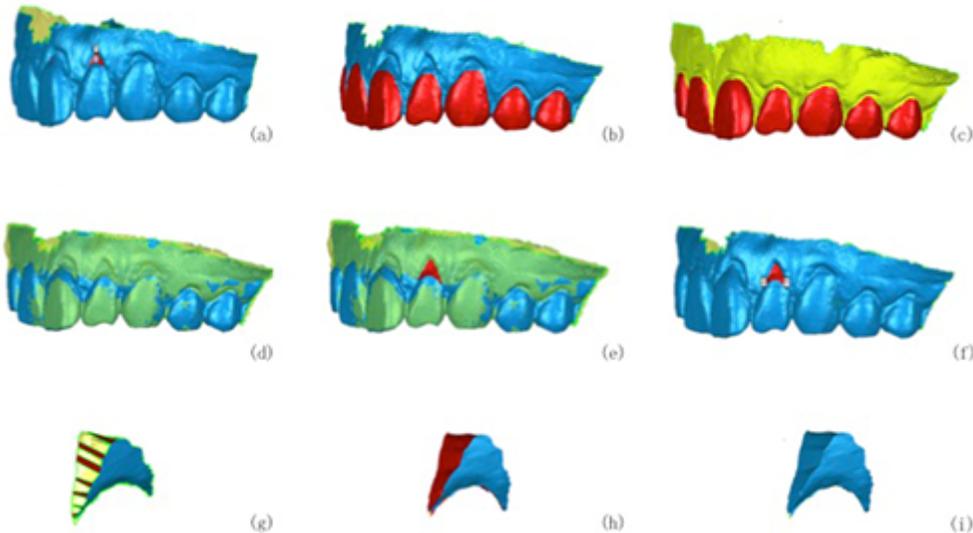


Figure 2

Three-dimensional digital measurement of the left upper lateral incisor between BL and 2w post-op. Measure the RH, RW and REA on the BL model (a); Similar surfaces (red part) of the teeth on the BL (b) and 2w (c) models were selected as the registration area; The two digital models overlapped for superimposition (d); Manually trace the postoperative gingival area gain in the "Select Through" mode (e); Measure the gingival HG and AG on the BL model (f); Use the "Fill Single Hole" function to close the edges of the two digitized surfaces (g, h); Reconstructed gingival VG (i).

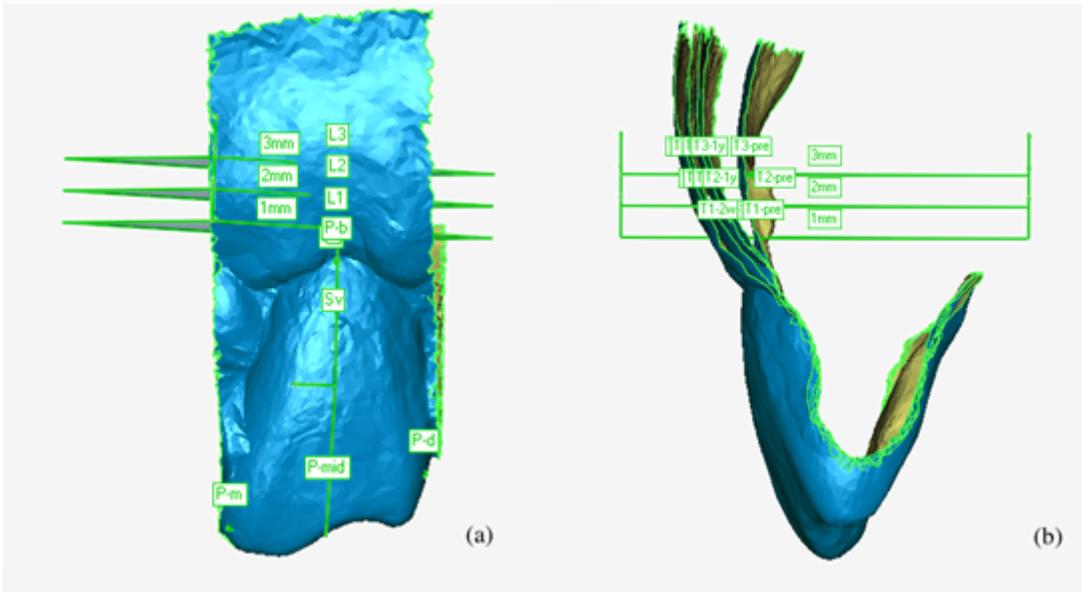


Figure 3

Frontal (a) and lateral (b) view of digital measurements of thickness alteration in buccal soft tissue.

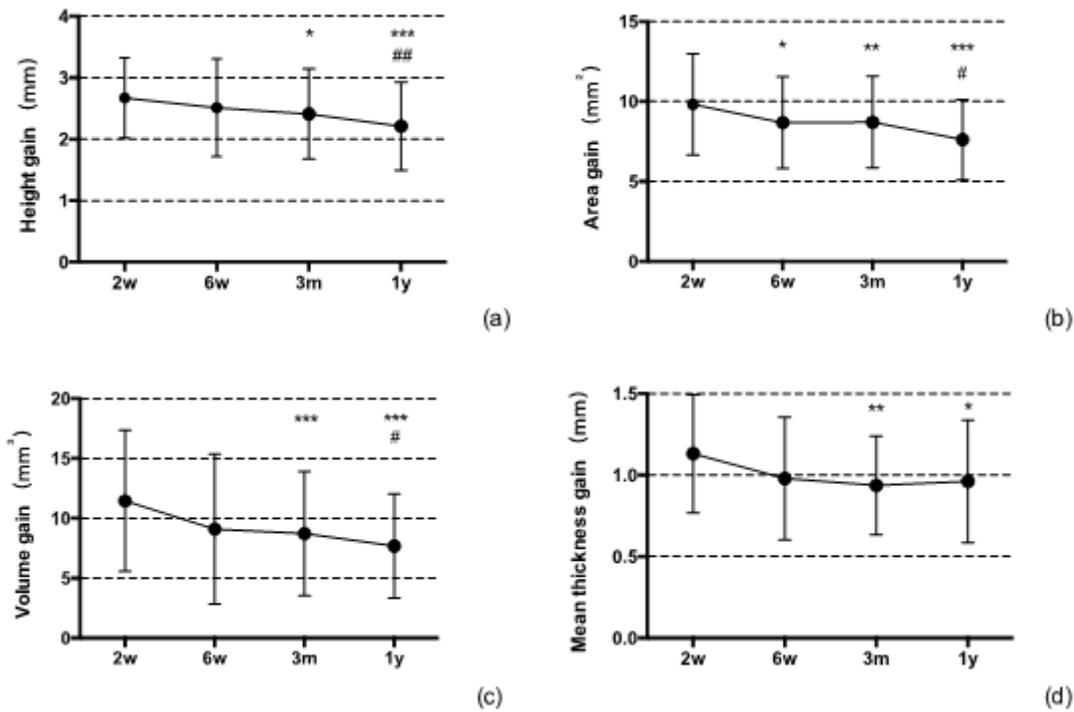


Figure 4

ROI volumetric dynamic alteration within 1-year after the MCAT with SCTG surgery. *p < 0.05, ** p < 0.01, *** p < 0.001 indicate statistically significant compared to 2w. # p < 0.05, ##p < 0.01 indicate statistically significant compared to 6w.

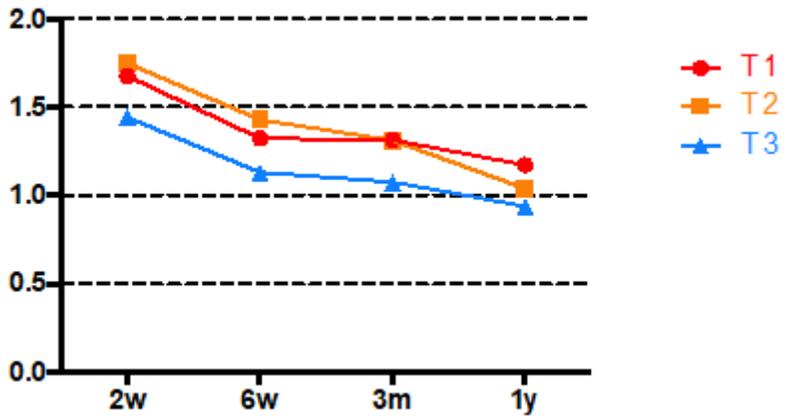


Figure 5

The thickness dynamic alteration of buccal soft tissue within 1-year after the MCAT with SCTG surgery.

Supplementary Files

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