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HUMAN RANDOMIZED CONTROLLED TRIAL

Volumetric facial contour changes of immediately placed implants with and without immediate provisionalization

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[Correction added on 15 July 2020 after first online publication: Figure 1 on p 908 was missing a panel, and Figure 2 on p 909 had an extra panel. Both figures have been replaced with updated versions.]

Abstract

Background: Whether immediate provisionalization can preserve facial tissue contour remains undetermined. The goal of this 12-month randomized controlled clinical trial was to compare three-dimensional (3D) ridge changes after immediate implant placement with and without immediate provisionalization.

Methods: Forty participants with an unrestorable maxillary anterior or premolar tooth were randomized to receive either a provisional crown (test) or standard healing abutment (control) after immediate implant placement. In each participant, three digital models taken before implant surgery, final crown delivery (4 months), and final follow-up (12 months) were registered to analyze linear deviation in 3D and volume changes of ridge contour at the implant site.

Results: The mean value of mid-facial linear 3D spatial resorption ranged from 0.1 to 0.7 mm. Significant difference of linear changes of facial contour was noted over time and not between the groups. Facial volume changes at 12 months remained significantly higher in the control group than in the test group (17.4% versus 11.9%, $P = 0.04$).

Conclusions: Linear changes of facial soft-tissue resorption at immediately placed implants were independent of immediate provisionalization. However, immediate provisionalization showed better volume preservation at the esthetic concern area (mid-facial margin and 2 to 6 mm above) at the final 12-month follow-up.

KEYWORDS

cone-beam computed tomography; dental implant; esthetic, dental; immediate dental implant loading

1 | INTRODUCTION

In the era of unprecedented prevalence of dental implant therapy, post-extraction immediate implant remained an alluring choice to the clinician and patients on the strength of instant esthetics and reduced total treatment time. Following the quest for long-term survival outcome,[1,2] the focus of implant therapy has now transformed into the pursuing of implant success in esthetics. The esthetic outcome of implant therapy was not just examined the harmony of soft tissue architecture,[3,4] but also the stability of facial tissue topography following post-extraction bone remodeling.[5,6]

The dimensional changes following immediately placed implants into freshly extraction socket proved to be inevitable.[7,8] The most common concern of immediately placed implant is the mid-facial mucosal recession following the tissue remodeling after extraction.[2,4,9] To date, several techniques have been developed in an attempt to overcome this challenge, these include but are not limited to: immediate provisionalization,[10,11] flapless surgical

approach,[1,12] CT graft,[13,14] and lingualized or cingulum implant placement.[15,16]

Thick buccal plate (≥1 mm), thick mucosal phenotype (>1 mm), and ideal three-dimensional (3D) position have been advocated for optimizing the esthetic outcome and for minimizing the concerns of immediate implant placement.[6,17,18] Moreover, immediate provisionalization was endorsed as one possible way to support the surrounding soft and hard tissues.[19,20] Yet, the contribution of simultaneously immediate provisionalization to the esthetic outcome of immediate implants remains controversial.[21–24] Thus, the purpose of this study was to assess the 3D volumetric hard and soft tissue changes following immediate implant with or without immediate provisionalization.

2 | MATERIALS AND METHODS

This randomized controlled study randomly assigned 40 participants with an unrestorable maxillary anterior or premolar tooth into either the test (fabricated to support the peri-implant soft tissues following tooth extraction) or the control (healing abutment occupying the most of socket size) group. This study was approved by the human subject review committee of the University of Michigan (protocol # HUM00070747) and was conducted in accordance with the Helsinki Declaration of 1975, as revised in 2013. The study was registered at ClinicalTrial.gov under NCT01925339. Study participants gave informed consent in both oral and written format. All participants signed informed consent before proceeding with the study. Study group randomization, allocation, and participant flow was reported in Figure S1 (see in online *Journal of Periodontology*). This study was focused only on the volumetric changes after immediate implant with or without immediate provisionalization. Briefly, all implants were placed at the cingulum position, aiming for 3 mm below the mid-facial mucosal margin, and achieved primary stability ≥30 N-cm. The gap between the implant and socket wall was filled with particulate allografts.* Clinical procedures of intervention and corresponding radiographs in both groups were illustrated in Figure S2 (see in online *Journal of Periodontology*). Baseline buccal bone thickness (measured 1 mm apical of the crest) >1.0 mm was regarded as thick buccal bone, and thickness ≤1.0 mm was deemed as thin bone wall phenotype.[5] Similarly, baseline mucosal thickness >1.0 mm was categorized as thick mucosal phenotype, and mucosal thickness ≤1.0 mm was considered as thin mucosal phenotype.[25] CBCT scans† at baseline and 4 months postoperative were superimposed using 3D imaging software‡ to linearly measure the crestal bone changes and bone thickness changes at early healing stage (see Figure S3 in online *Journal of Periodontology*). In the current study, additional stratified analysis based on bone morphotype, gingival biotype, and tooth location (anterior versus posterior) were performed to detect the differences of tissue alteration represented on the digital model.

2.1 | Three-dimensional spatial deviation analysis

Three digital models were obtained by scanning the stone models obtained at baseline (T0), 4-month postoperative visit (T1), and the final visit (T2) using a laboratory optical scanner.§ The average resolution of 3D sensor without thinning was 30 μm with 20 μm standard deviation. STL files of digitalized models were introduced into 3D digital inspection software.¶ Each comparison was performed using T0 model as the baseline. In attempt to achieve the best 3D registration, X, Y, and Z coordinates were aligned first using unchanged reference point-based approximation (all tooth surfaces) and then the "global registration" using automated algorithm of point clouds. The "3D compare" built-in function allowed the 3D spatial deviation value to be generated as spatial discrepancy between two digitalized models. The average distance between two surfaces was depicted in 3D color map, and the global deviations at various points were measured at 2 mm intervals (from the mucosal margin to 10 mm above; 2-mm-radius point data) in three cross-sectional planes (mid-facial, mesial, and distal papilla) (Fig. 1). Furthermore, standardized and repeatable measurements on the cross-sectional planes were accomplished by the reference of 1 × 1 × 1 mm grid lines, which were in accordance with the 3D coordinate system of individual model. The final measurements were narrowed down to 0.2-mm-radius point data to eliminate any potential inaccurate points caused by defective model or unwanted areas.

2.2 | Volumetric analysis

For the purpose of detecting volume changes, the region of interest (ROI) at each of the three digital models was chosen with the lower and upper boundaries at 2 and 6 mm above the mid-facial margin, respectively, and enclosed by two bucco-lingual cross-sectional planes crossing the mesial and distal papilla. To standardize the measurement, the coordinate x-z axes of each model were aligned to the reference model with the x-axis antero-posteriorly perpendicular to the tangent line connecting the most buccal surfaces of the adjacent teeth at the mid-facial point. The coronal, apical, mesial, and distal boundaries of the ROI were flattened

* Puros, Zimmer Biomat Dental, Carlsbad, CA.

† Accuitomo 170 unit, JMorita, Japan.

‡ Invivo Dental 5, Anatomage, San Jose, CA.

§ Activity 101 Dental 3D Scanner, Smart Optics, Germany.

¶ Geomagic Control, 3D systems, Rock Hill, SC.

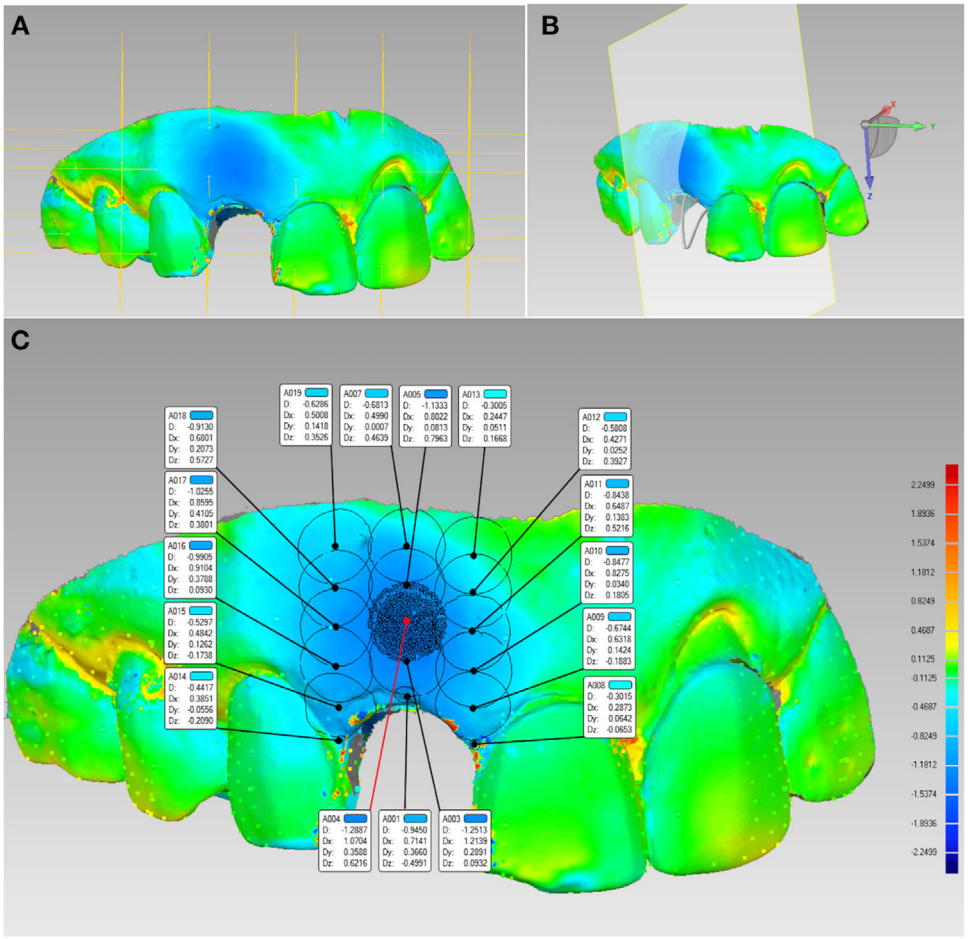

FIGURE 1 Three-dimensional (3D) spatial deviation analysis. **A**) In the process of standardized 1-mm grid formation. **B**) Cross-sectional plane across the mid-facial gingival margin along the standardized z-axis (also applied to mesial and distal papilla). **C**) Three dimenstional deviation at different points of 0, 2, 4, 6, 8, and 10 mm above mid-facial margin, mesial, and distal papilla were obtained based on the preset 2 mm-wide-radius; final measurement was acquired by average of the deviations in a 0.2-mm radius of point data

surfaces automatically selected by the software with the tangent "filling" technique. Finally, the polygon object was generated by closing the boundaries, and the volume (mm^3) was calculated and compared the volumetric changes over time and between groups in percentage (Fig. 2).

One independent masked examiner (IW) performed the repeated measurements three times every other week on five randomly chosen participants. Only when the intra-examiner Cohen kappa values were >0.8 were the remaining measurements started.

2.3 | Statistical analysis

All data were first analyzed descriptively and expressed as mean values (±SD). The normal distribution of observing data in the present study was determined by the Shapiro-Wilk test (P >0.05). Accordingly, independent t tests were performed to analyze the difference of volumetric measurements between two groups. Repeated measures two-way analysis of variance (ANOVA) tests were conducted to compare the differences of 3D deviation analysis within group and between three time points. The interactions of categorical variates (tissue phenotype) on the main outcomes were compared using three-way ANOVA, and the effects of continuous covariate such as bone/ soft tissue thickness (in mm) was analyzed by general linear model (ANCOVA with Bonferroni adjustment). Pearson correlation coefficient (r) was calculated to evaluate the relationship between the dimension changes and tissue phenotype. All statistical tests were performed by a software package* and the level of significance was set at $\alpha = 0.05$.

3 | RESULTS

In total, 38 participants (test: 18 and control: 20) completed the study at 12 months and were included in the study analysis. Among them, the test group comprised 10 anterior teeth

* IBM SPSS Statistics for Macintosh, Version 25.0.

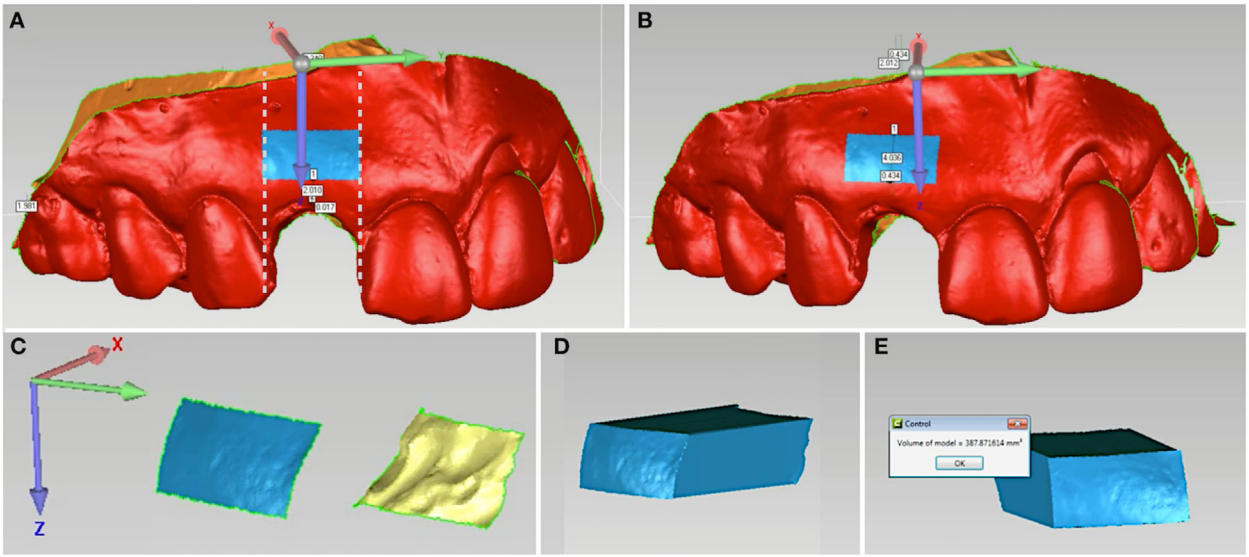

FIGURE 2 Volumetric analysis. Region of interest (ROI) was chosen as a rectangle area with a lower and upper limit at 2 mm (**A**) and 6 mm (**B**) above mid-facial margin. The mesial and distal limit of ROI was dictated by the parallel cross-sectional planes through adjacent papillae. **C**) After trimming away, the unwanted areas of mesh (**D**) edges of four mesh surfaces were "bridged" with flat surfaces by built-in function of Geomagic software. **E**) Finally, the volume (mm^3) was calculated automatically and compared the volumetric changes in unit of percentage

TABLE 1 Baseline clinical characteristics between groups and tooth positions (anterior and posterior teeth)

Mean ± SD	Mid-facial mucosa thickness	Mucosal phenotype (thin/thick)	Buccal bone thickness	Bone phenotype (thin/thick)	Buccal bone dehiscence depth	Implant apico-coronal depth	Buccal gap	Lingual gap
Test (n = 18)	0.6 ± 0.2	15/2	1.1 ± 0.5	8/10	1.0 ± 1.1	2.7 ± 0.7	2.6 ± 0.8	0.3 ± 0.4
Control (n = 20)	0.7 ± 0.4	15/5	1.3 ± 0.8	8/12	0.5 ± 0.7	3.4 ± 0.6	2.7 ± 0.8	0.9 ± 0.9
P value	0.38	0.76	0.33	0.78	0.08	0.004*	0.8	0.009*
Anterior	0.6 ± 0.2	2/17	1.0 ± 0.6	11/9	1.0 ± 1.0	3.1 ± 0.7	2.4 ± 0.8	0.3 ± 0.5
Posterior	0.7 ± 0.4	4/13	1.4 ± 0.7	5/13	0.4 ± 0.9	3.1 ± 0.7	3.0 ± 0.6	1.0 ± 0.2
P value	0.35	0.58	0.05*	0.09	0.10	0.9	0.01*	0.001*

*Statistically significant difference ($p < 0.05$) between groups or between different tooth positions.

and eight premolars; the control group included 10 anterior teeth and 10 premolars. Table 1 illustrates the baseline data between test and control group and between anterior and posterior teeth. All baseline data showed no statistical significant different ($P > 0.05$) except implant apico-coronal position between two groups (test versus control: 2.7 ± 0.7 versus 3.4 ± 0.6 mm, $P < 0.01$) and lingual gap (0.3 ± 0.4 in test and 0.9 ± 0.9 in control group, $P < 0.01$).

3.1 | Dimensional changes of bone crest based on CBCT scan at 4 months

The global changes of bone crest at 4 months post-implant were reported in another part of this clinical trial[26] that 1.6 ± 0.6 and 1.7 ± 0.6 mm were found in test and control group, respectively. This includes 1.5 ± 0.7 versus1.4 ± 0.6 mm horizontal bone resorption and 0.3 ± 0.4 versus 0.7 ± 0.6 mm vertical bone resorption (test versus control, respectively). Only the vertical resorption of the buccal bone crest showed that the test group resorbed significantly less than the control group ($P = 0.02$). On the palatal side, the resorption of bone crest was similar between the two groups (test versus control: horizontally: 0.6 ± 0.6 versus 0.6 ± 0.5 mm; vertically: 1.0 ± 0.5 versus 1.1 ± 0.7 mm; overall: 1.1 ± 0.45 versus 1.3 ± 0.74 mm). The additional three-way ANOVA analysis of current report did not reveal any significant influence from bone phenotype or mucosal phenotype on the difference of crestal changes (buccal or palatal) between the two groups.

Further stratified analysis of tooth location did not show further significant impact on the difference between two groups, except for palatal crest horizontal resorption (mean: 0.4 mm in anterior, 0.8 mm in premolar area, $P = 0.02$). The highest crestal spatial changes on the buccal aspect occurred in the control group with thin mucosal phenotype and thin bone phenotype jointly in the anterior sextant (2.3 ± 1.4 mm); however, there was no significant difference between the two groups nor the influence of tooth location ($P > 0.05$).

3.2 | Dimensional changes of bone thickness based on CBCT scan at 4 months

The horizontal resorption of buccal bone plate at the implant platform added up to 23.9% (test) and 23.3% (control), and of the palatal bone wall was 18.2% (test) and 28.0% (control). All the reduction of bone thickness at different levels (2-mm interval above the implant platform) failed to show significant difference between two groups; furthermore, after adjusting the covariate of implant vertical position, bone phenotype or mucosal thickness fails to show significant difference.

Collectively, the percentage of horizontal resorption in anterior region at 4 mm above the platform was significantly higher (28.2% versus 10.7%, $P = 0.02$) compared with premolar area; although not reaching significant difference, the horizontal resorption at implant platform and 2 mm above platform presented a dramatic difference (28.2% versus 18.9% and 23.2% versus 12.1%, respectively). At the palatal aspect, the horizontal changes of crest bone were significantly lower in the anterior zone (0.4 versus 0.8 mm, $P = 0.02$), and similar result was found in the horizontal reduction of bone thickness at the palatal platform level (14.5% versus 32.4% [0.2 versus 0.5 mm], $P = 0.04$).

In the test group, eight participants had thin bone phenotype, and 10 had thick bone phenotype. In the control group, thin versus thick was eight versus 12 participants, respectively. In thin bone phenotype, the percentage of horizontal bone resorption at 2 mm above platform was significantly higher than thick bone phenotype (25.5% versus 12.7%, $P = 0.05$), and similar pattern was found in 4 mm (28.3% versus 14.5%) and 6 mm (15.9% versus 28.8%) above the platform. In terms of palatal side, no significant differences were found, but thick phenotype exhibited much higher horizontal resorption at the palatal platform (29.2% versus 13.3%, $P = 0.07$).

For the mid-facial mucosal thickness, in test group, 15 had thin tissue phenotype and two possessed thick tissue phenotype, while in the control group, 15 had thin phenotype and four had thick tissue phenotype. Overall, there was a moderately positive correlation between mid-facial mucosal thickness and buccal bone thickness at platform ($r = 0.36$, $P = 0.03$), 2 mm ($r = 0.44$, $P = 0.01$), 4 mm ($r = 0.46$, $P = 0.01$), 6 mm ($r = 0.43$, $P = 0.02$), and 8 mm above the platform ($r = 0.48$, $P = 0.05$). The reduction of bone thickness at 2 mm ($r = -0.46$, $P = 0.01$) and 4 mm (-0.45, $P < 0.01$) above platform significantly negatively correlates to the mid-facial mucosal thickness and this significant difference lies in the anterior sextant ($r = -0.59$, $P < 0.01$ and -0.58, $P = 0.01$, respectively).

The distance between the implant and the outer surface of buccal bone plate was negatively associated with the horizontal reduction percentage at the platform and 2 mm above platform ($r = -0.4$, $P = 0.02$).

3.3 | Three dimensional spatial deviations

The majority of the mean 3D spatial deviation from baseline model in linear measurements were significantly higher at T2 than at T1 in both groups, suggesting that there was a continuous change between 4 and 12 months after implant placement (Table 2). Negative value of 3D spatial deviation indicates the resorption of ridge contour compared with the baseline digital model. General trends of the mean deviation in the control group was higher than that in the test group but without statistical significance in all measured sites on the facial side at both time points (Fig. 3).

After adjusting for mid-facial mucosal thickness, the 3D deviation after 1 year (T2) demonstrated a significant difference between the two groups at 4 mm level, especially in the premolar area (test versus control: -0.34 ± 0.12 mm versus -0.84 ± 0.13 mm [mean $\pm$ SE], $P = 0.02$).

3.4 | Volumetric reduction

At T1 (postoperative 4 months), volume reduced to 94.2% (test) and 92.2% (control) with a P value of 0.08. The test group with immediate provisionalization preserved significantly higher percentage of tissue volume at T2 (1-year) compared with the control group at esthetic-concerned area ROI (remaining volume 88.1% versus 82.6%, $P = 0.04$) (Fig. 4). In other words, loss of volume in test group (11.9%) was significantly lower than the control group (17.4%). Difference between two groups in the anterior sextant and the premolar area was not significant ($P > 0.05$). Although two-way ANOVA did not find significant interaction effect between mucosa phenotype and bone phenotype on volume reduction at T2 ($P > 0.05$), but they both showed a tendency that higher reduction occurred in the thin mucosal phenotype and bone phenotype.

4 | DISCUSSION

In the present study, early contour changes of buccal bone plate were analyzed at separate level. Foremost, for the horizontal dimension of bone crest, the remodeling on the buccal aspect was similar between two groups; on the contrary, the vertical dimension demonstrated significantly less resorption in test group. Secondly, the bone plate thickness at the implant platform reduced ≈24% (buccally), which was in agreement with the previous animal reports with similar diminution amount of grafted (25%),[27] and non-grafted sockets (30%).[28]

Botticelli et al. had observed the spontaneous healing at 4-month re-entry following immediate implant installation with flap elevation, they reported a buccal crestal resorption of 1.9 $\pm$ 0.9 mm horizontally and 0.3 $\pm$ 0.6 mm vertically; moreover, the buccal bone plate underwent horizontal resorption

TABLE 2 Three-dimensional deviation at different levels above mid-facial gingival margin, mesial papilla, distal papilla, and mid-palatal gingival margin

Measuring position	Time points	Differences between groups			Between time points
		Test	Control	*P* value	*P* value
Mid-facial margin (MF)	T1	−0.5 ± 0.5	−0.7 ± 0.5	0.18	<0.01*
	T2	−0.5 ± 0.5	−0.7 ± 0.5	0.19	
2 mm above MF	T1	−0.3 ± 0.4	−0.4 ± 0.4	0.75	<0.01*
	T2	−0.5 ± 0.5	−0.5 ± 0.4	0.67	
4 mm above MF	T1	−0.2 ± 0.4	−0.3 ± 0.6	0.26	<0.01*
	T2	−0.5 ± 0.4	−0.7 ± 0.5	0.32	
6 mm above MF	T1	−0.3 ± 0.3	0.1 ± 0.4	0.45	<0.01*
	T2	−0.4 ± 0.4	−0.5 ± 0.5	0.74	
8 mm above MF	T1	−0.2 ± 0.2	0.1 ± 0.3	0.2	<0.01*
	T2	−0.5 ± 0.5	−0.9 ± 0.6	0.63	
Facial mesial papilla (FMP)	T1	−0.3 ± 0.4	−0.5 ± 0.6	0.23	<0.01*
	T2	−0.2 ± 0.4	−0.4 ± 0.6	0.19	
2 mm above FMP	T1	−0.2 ± 0.3	−0.3 ± 0.4	0.11	<0.01*
	T2	−0.2 ± 0.3	−0.3 ± 0.3	0.14	
4 mm above FMP	T1	−0.1 ± 0.3	−0.1 ± 0.3	0.99	<0.01*
	T2	−0.1 ± 0.3	−0.3 ± 0.3	0.23	
6 mm above FMP	T1	−0.03 ± 0.4	0.01 ± 0.3	0.9	0.02*
	T2	−0.1 ± 0.4	−0.2 ± 0.2	0.65	
8 mm above FMP	T1	−0.02 ± 0.2	0.1 ± 0.1	0.19	0.048*
	T2	−0.2 ± 0.4	−0.2 ± 0.1	0.83	
Facial distal papilla (FDP)	T1	−0.3 ± 0.4	−0.5 ± 0.6	0.17	<0.01*
	T2	−0.2 ± 0.4	−0.6 ± 0.7	0.07	
2 mm above FDP	T1	−0.2 ± 0.3	−0.3 ± 0.3	0.4	<0.01*
	T2	−0.2 ± 0.3	−0.4 ± 0.5	0.14	
4 mm above FDP	T1	−0.1 ± 0.3	−0.04 ± 0.3	0.34	<0.01*
	T2	−0.2 ± 0.3	−0.3 ± 0.6	0.3	
6 mm above FDP	T1	−0.1 ± 0.3	0.1 ± 0.3	0.07	<0.01*
	T2	−0.2 ± 0.4	−0.4 ± 0.5	0.44	
8 mm above FDP	T1	0.05 ± 0.3	0.03 ± 0.3	0.9	0.03*
	T2	−0.3 ± 0.6	−0.5 ± 0.7	0.25	
Mid-palatal margin (MP)	T1	−0.03 ± 0.3	−0.5 ± 0.5	<0.01*	<0.01*
	T2	−0.2 ± 0.4	−0.4 ± 0.5	0.07	
2 mm above MP	T1	−0.1 ± 0.4	−0.5 ± 0.4	0.01*	<0.01*
	T2	−0.2 ± 0.3	−0.3 ± 0.4	0.27	
4 mm above MP	T1	0.01 ± 0.4	−0.4 ± 0.4	<0.01*	0.01*
	T2	−0.04 ± 0.3	−0.2 ± 0.4	0.22	
6 mm above MP	T1	−0.1 ± 0.3	−0.4 ± 0.4	0.05	0.04*
	T2	−0.1 ± 0.2	−0.2 ± 0.4	0.75	
8 mm above MP	T1	−0.4 ± 0.4	−0.4 ± 0.4	0.38	0.02*
	T2	−0.2 ± 0.3	−0.1 ± 0.3	0.2	
Palatal mesial papilla (PMP)	T1	0.04 ± 0.3	−0.3 ± 0.3	<0.01*	0.17†
	T2	−0.1 ± 0.5	−0.1 ± 0.5	0.58	
2 mm above PMP	T1	−0.05 ± 0.3	−0.2 ± 0.4	0.02*	0.65†

(Continues)

TABLE 2 (Continued)

Measuring position	Time points	Differences between groups			Between time points
		Test	Control	*P* value	*P* value
	T2	−0.03 ± 0.4	−0.02 ± 0.3	0.95	
4 mm above PMP	T1	0.06 ± 0.3	−0.3 ± 0.4	<0.01*	0.19†
	T2	−0.07 ± 0.3	−0.05 ± 0.3	0.69	
6 mm above PMP	T1	0.07 ± 0.4	−0.2 ± 0.3	0.01*	0.69†
	T2	−0.04 ± 0.3	−0.01 ± 0.3	0.67	
8 mm above PMP	T1	0.01 ± 0.2	−0.1 ± 0.3	0.24	0.41
	T2	−0.1 ± 0.5	−0.1 ± 0.3	0.86	
Palatal distal papilla (PDP)	T1	−0.03 ± 0.4	−0.3 ± 0.5	0.07	0.02*
	T2	−0.1 ± 0.3	−0.2 ± 0.4	0.07	
2 mm above PDP	T1	0.02 ± 0.2	−0.2 ± 0.3	0.07	0.03*
	T2	−0.1 ± 0.3	−0.1 ± 0.3	0.27	
4 mm above PDP	T1	0.08 ± 0.3	−0.2 ± 0.3	0.02*	0.048*
	T2	−0.1 ± 0.3	−0.1 ± 0.3	0.81	
6 mm above PDP	T1	0.04 ± 0.4	−0.1 ± 0.3	0.26	0.46
	T2	−0.03 ± 0.3	−0.1 ± 0.3	0.76	
8 mm above PDP	T1	−0.04 ± 0.3	−0.1 ± 0.4	0.6	0.14
	T2	−0.2 ± 0.3	−0.2 ± 0.3	0.76	

*Represented significant difference of 3D deviation values (P <0.05) between groups or between time points.

†Indicated that significant difference between different time points within control group, but not significant in the test group.

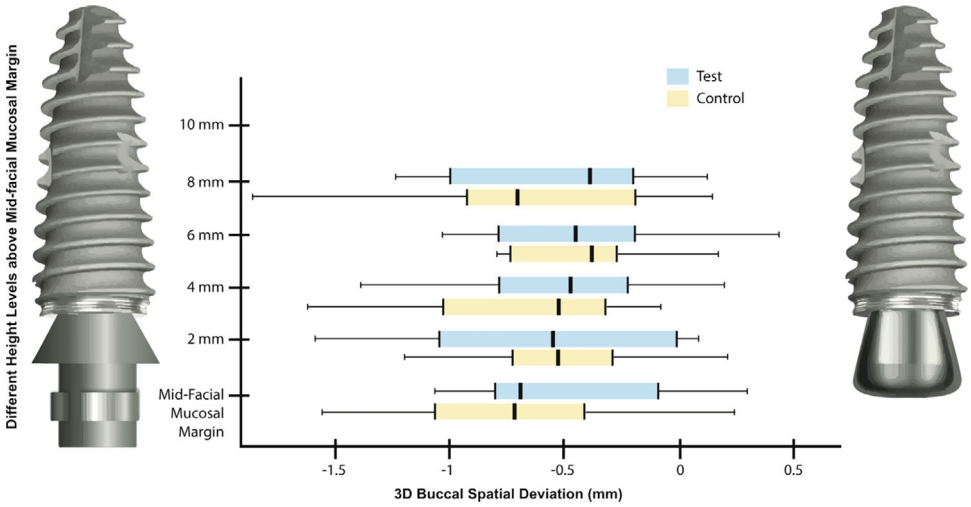

FIGURE 3 Box plots of 3D spatial deviation (only presented with buccal surface) at 2-mm intervals. Median and interquartile range were displayed at different height levels above mid-facial mucosal margin. Left implant with temporary abutment exhibits more divergent profile compared with the right implant with healing abutment; and the implant platform was at 3 mm above the mid-facial mucosal margin

of 56%.[7] In another clinical study at 4-month re-entry following immediate implants with natural healing, a 36% horizontal resorption of buccal crest (1.1 mm) and vertical reduction of 1.0 mm was denoted.[29] Recently, the same group published the results of dimensional variations when grafted the gaps with deproteinized bovine bone minerals with 10% collagen (DBBM-C) which stated a significantly difference of buccal crest reduction horizontally between grafted and non-grafted sites (1.1 mm [29%] versus 1.6 mm [38%]) with similar 0.3 mm vertical crest reduction.[30] In current investigation, the horizontal resorption of buccal bone wall was comparatively less which could be attributed to the grafting with allograft bone particles,[31] flapless surgical protocol,[12,32,33] and lingualized (cingulum) implant position.[34,35]

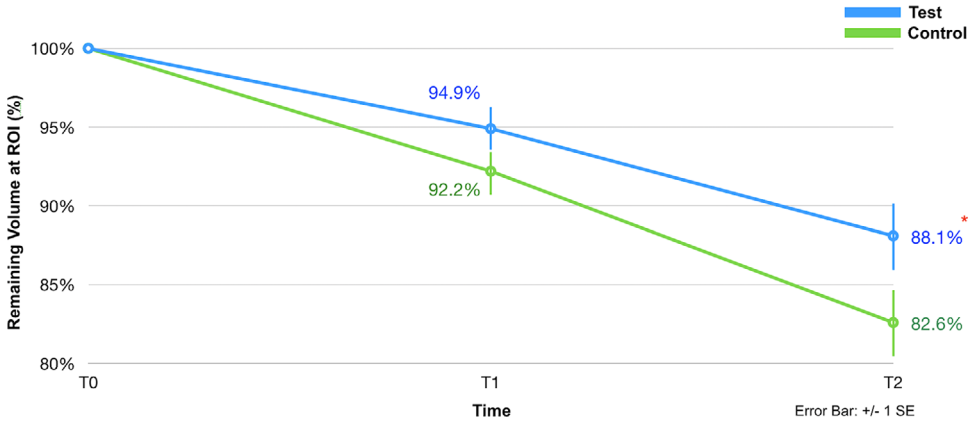

FIGURE 4 Changes of remaining volume at ROI region at different time points. The difference between test and control group reached significance at T2 (postoperative 1 year) (88.1% versus 82.6%, test versus control, $^{*}P = 0.04$)

On the other hand, the vertical buccal crest resorption in current investigation (pooled mean: 0.5 ± 0.6 mm, 0.2 mm [test] versus 0.7 mm [control]) was comparable to the results of 0.3 mm revealed by Botticelli et al. with semi-submerged natural healing[7] or 0.1[34] to 0.3 mm[30] in sites grafted with bovine bone; yet, much less than other studies with flap elevation protocol after natural healing, such as 1.0 mm by Sanz et al.[29] or 1.3 mm by Chen et al.[34] Vertical component of crestal bone changes mainly are under the influences of surgical trauma,[36] the vertical position of rough-to-smooth surface junction of the implant,[37] post-extraction physiological bone modeling/remodeling related to different periodontal phenotype,[5,35,38] and "critical gap size" with or without grating to sustain the new bone formation and compensate for the crestal resorption.[39,40] It has been shown in an animal study that lingualized and deeper implant position had less vertical resorption of buccal bone crest compared with centered position in extraction sockets.[41] In the present study, the implant platform was flush with the buccal bone crest indicating 0.5 mm subcrestally placement and in combination with lingualized (cingulum) position, may compensate for the bone remodeling as well as for the reformation of biologic width vertically. This was in line with previous observations reported by Chen et al.[34]

Another attempt in the current experiment was to analyze the influence of different periodontal phenotype among individuals and the different tissue response between incisors and premolar area. It has been shown that there is significant difference of the mean thickness of buccal bone between anterior and premolar sites (0.8 versus 1.1 mm), and majority (87.2%) of buccal walls in the anterior sites had a width ≤1 mm, and the corresponding percentage in posterior area was 59.3%.[42] Similar results were also revealed by a CBCT investigation, and significant difference between anterior and premolar sites was also found (0.8 versus 1.1 mm, median).[43] However, the observation in the current study was more profoundly different (1.0 versus 1.6 mm, $P = 0.02$); 55% (anterior) and 22% (posterior) were presented with thin phenotype. In a report by Chappuis et al., the fate of facial bone wall after extraction at 8 weeks can mount to a median vertical loss of 7.5 mm (62%) in thin bone phenotype, and 1.1 mm (9%) in the thick bone phenotype in the esthetic zone.[5] For immediate implant in spontaneous socket healing, Ferrus et al. found that the vertical bone loss of buccal crest after 4-month can be twice at the anteriors as the premolar area.[35] It was concluded that the bone phenotype significantly affects the crest bone change that thick bony wall or larger gap exhibits smaller reduction of the height and width of the crest, which was in concordance with the findings in the current study that the wider the distance between outer bone surface to the implant surface which included the bone thickness and buccal gap, the less the horizontal reduction in percentage ($r = -0.4$).

The benefits of immediate provisionalization are postulated to preserve the osseous and soft tissue architecture.[19,20,44,45] A recent study with 4-year follow-up showed significantly better tissue volume maintenance without any grafting for immediate implant provisionalization in the intact socket.[46] Results from this study showed the volume of ROI (2 to 6 mm above the mid-facial margin) significantly demonstrated less resorption in test group after 1 year, and the significant difference of linear changes in three-dimension lies in the 4 mm coronal to mid-facial mucosa after adjusting for mid-facial gingiva thickness. In the present study, although bone modeling at 4 months did not show significant difference between two groups; the buccal 3D deviation at the esthetic concern area (mid-facial margin and 2 to 6 mm above) after 1 year demonstrated that the test group rendered less resorption than the control group. It may be hypothesized that the more divergent sublingual contour (30 degree) found on the temporary abutment of current implant system compared with healing abutment (15 degree) preserve more soft tissue volume by mimicking the shape of anatomic root. It has been suggested

that modifications in the facial "subcritical contour" elicit different modeling responses from peri-implant soft tissue.[47] This is in agreement with the dual-zone concept proposed by Chu et al., which showed placing bone graft with an anatomic provisional crown reduces facial-lingual ridge collapse to <0.2 mm and increased peri-implant soft tissue dimension by 0.5 to 1 mm.[48,49] Linkevicius et al. showed vertical thickness of soft tissue strongly associated with crestal bone loss in healed ridge,[50] whether the soft tissue volume preservation at crestal level can lessen the vertical bone loss in immediate implant placement requires future studies to clarify. A limitation in the current study would be that the 3D analysis was attained from the stone cast at different time points, which could express a certain degree of deviation of accuracy.

The major obstacles of immediate implant therapy are the surgical skill for precise implant placement in the socket and the ability to predict the amount of tissue remodeling after implant placement. These two challenges impede the wide application of this technique into daily practice.[2,51] Nonetheless, tissue remodeling after immediate implant is a dynamic process under multifactorial influence. It was generally acknowledged that thick tissue phenotype and bone thickness in addition to intact socket wall are the prerequisites for success of immediate implant;[6,20] with that in mind, on the basis of ideal 3D implant position, immediate provisionalization might further contribute to peri-implant tissue preservation.

5 | CONCLUSIONS

Linear changes in three-dimension of facial soft-tissue resorption at immediately placed implants were independent of immediate provisionalization. However, immediate provisionalization showed higher volume preservation at the esthetic concern area (mid-facial margin and 2 to 6 mm above) at the final 12-month follow-up.

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AUTHOR CONTRIBUTIONS

I-Ching Wang contributed to conception, design, data acquisition, and interpretation, statistical analyses, and draft of manuscript. Hsun-Liang Chan contributed to the data analysis and critical review of manuscript. Janet Kinney acted as the study coordinator. Hom-Lay Wang contributed to conception, design, surgery, data interpretation, and critically revised the manuscript.

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REFERENCES

1. Cooper LF, Reside G, Raes F, et al. Immediate provisionalization of dental implants in grafted alveolar ridges in the esthetic zone: a 5-year evaluation. *Int J Periodontics Restorative Dent*. 2014;34:477-486.
2. Cosyn J, Eghbali A, Hermans A, Vervaeke S, De Bruyn H, Cleymaet R. A 5-year prospective study on single immediate implants in the aesthetic zone. *J Clin Periodontol*. 2016;43:702-709.
3. Cooper LF. Objective criteria: guiding and evaluating dental implant esthetics. *J Esthet Restor Dent*. 2008;20:195-205.
4. Chen ST, Buser D. Esthetic outcomes following immediate and early implant placement in the anterior maxilla–a systematic review. *Int J Oral Maxillofac Implants*. 2014;29(Suppl):186-215.
5. Chappuis V, Engel O, Reyes M, Shahim K, Nolte LP, Buser D. Ridge alterations post-extraction in the esthetic zone: a 3D analysis with CBCT. *J Dent Res*. 2013;92:195S-201S.
6. Chappuis V, Araujo MG, Buser D. Clinical relevance of dimensional bone and soft tissue alterations post-extraction in esthetic sites. *Periodontol 2000*. 2017;73:73-83.
7. Botticelli D, Berglundh T, Lindhe J. Hard-tissue alterations following immediate implant placement in extraction sites. *J Clin Periodontol*. 2004;31:820-828.
8. Araujo MG, Sukekava F, Wennstrom JL, Lindhe J. Ridge alterations following implant placement in fresh extraction sockets: an experimental study in the dog. *J Clin Periodontol*. 2005;32:645-652.
9. Cosyn J, Hooghe N, De Bruyn H. A systematic review on the frequency of advanced recession following single immediate implant treatment. *J Clin Periodontol*. 2012;39:582-589.
10. Block MS, Mercante DE, Lirette D, Mohamed W, Ryser M, Castellon P. Prospective evaluation of immediate and delayed provisional single tooth restorations. *J Oral Maxillofac Surg*. 2009;67:89-107.
11. De Rouck T, Collys K, Wyn I, Cosyn J. Instant provisionalization of immediate single-tooth implants is essential to optimize esthetic treatment outcome. *Clin Oral Implants Res*. 2009;20:566-570.
12. Raes F, Cosyn J, Crommelinck E, Coessens P, De Bruyn H. Immediate and conventional single implant treatment in the anterior maxilla: 1-year results of a case series on hard and soft tissue response and aesthetics. *J Clin Periodontol*. 2011;38:385-394.
13. Bianchi AE, Sanfilippo F. Single-tooth replacement by immediate implant and connective tissue graft: a 1-9-year clinical evaluation. *Clin Oral Implants Res*. 2004;15:269-277.

14. Rungcharassaeng K, Kan JY, Yoshino S, Morimoto T, Zimmerman G. Immediate implant placement and provisionalization with and without a connective tissue graft: an analysis of facial gingival tissue thickness. *Int J Periodontics Restorative Dent*. 2012;32:657-663.
15. Evans CD, Chen ST. Esthetic outcomes of immediate implant placements. *Clin Oral Implants Res*. 2008;19:73-80.
16. Cosyn J, Sabzevar MM, De Bruyn H. Predictors of inter-proximal and midfacial recession following single implant treatment in the anterior maxilla: a multivariate analysis. *J Clin Periodontol*. 2012;39:895-903.
17. Morton D, Chen ST, Martin WC, Levine RA, Buser D. Consensus statements and recommended clinical procedures regarding optimizing esthetic outcomes in implant dentistry. *Int J Oral Maxillofac Implants*. 2014;29(Suppl):216-220.
18. Cook DR, Mealey BL, Verrett RG, et al. Relationship between clinical periodontal biotype and labial plate thickness: an in vivo study. *Int J Periodontics Restorative Dent*. 2011;31:345-354.
19. Garber DA, Salama MA, Salama H. Immediate total tooth replacement. *Compend Contin Educ Dent*. 2001;22:218.
20. Kan JYK, Rungcharassaeng K, Deflorian M, Weinstein T, Wang HL, Testori T. Immediate implant placement and provisionalization of maxillary anterior single implants. *Periodontol 2000*. 2018;77:197-212.
21. Hall JA, Payne AG, Purton DG, Torr B, Duncan WJ, De Silva RK. Immediately restored, single-tapered implants in the anterior maxilla: prosthodontic and aesthetic outcomes after 1 year. *Clin Implant Den Relat Res*. 2007;9:34-45.
22. den Hartog L, Raghoebar GM, Stellingsma K, Vissink A, Meijer HJ. Immediate non-occlusal loading of single implants in the aesthetic zone: a randomized clinical trial. *J Clin Periodontol*. 2011;38:186-194.
23. Slagter KW, den Hartog L, Bakker NA, Vissink A, Meijer HJ, Raghoebar GM. Immediate placement of dental implants in the esthetic zone: a systematic review and pooled analysis. *J Periodontol*. 2014;85:e241-e250.
24. Arora H, Ivanovski S. Clinical and aesthetic outcomes of immediately placed single-tooth implants with immediate vs. delayed restoration in the anterior maxilla: a retrospective cohort study. *Clin Oral Implants Res*. 2018;29:346-352.
25. Kan JY, Morimoto T, Rungcharassaeng K, Roe P, Smith DH. Gingival biotype assessment in the esthetic zone: visual versus direct measurement. *Int J Periodontics Restorative Dent*. 2010;30:237-243.
26. Chan HL, George F, Wang IC, Suarez Lopez Del Amo F, Kinney J, Wang HL. A randomized controlled trial to compare aesthetic outcomes of immediately placed implants with and without immediate provisionalization. *J Clin Periodontol*. 2019;46:1061-1069.
27. Araujo MG, Lindhe J. Socket grafting with the use of autologous bone: an experimental study in the dog. *Clin Oral Implants Res*. 2011;22:9-13.
28. Araujo M, Linder E, Wennstrom J, Lindhe J. The influence of Bio-Oss Collagen on healing of an extraction socket: an experimental study in the dog. *Int J Periodontics Restorative Dent*. 2008;28:123-135.
29. Sanz M, Cecchinato D, Ferrus J, Pjetursson EB, Lang NP, Lindhe J. A prospective, randomized-controlled clinical trial to evaluate bone preservation using implants with different geometry placed into extraction sockets in the maxilla. *Clin Oral Implants Res*. 2010;21:13-21.
30. Sanz M, Lindhe J, Alcaraz J, Sanz-Sanchez I, Cecchinato D. The effect of placing a bone replacement graft in the gap at immediately placed implants: a randomized clinical trial. *Clin Oral Implants Res*. 2017;28:902-910.
31. Tarnow DP, Chu SJ, Salama MA, et al. Flapless postextraction socket implant placement in the esthetic zone: part 1. The effect of bone grafting and/or provisional restoration on facial-palatal ridge dimensional change-a retrospective cohort study. *Int J Periodontics Restorative Dent*. 2014;34:323-331.
32. Fickl S, Zuhr O, Wachtel H, Bolz W, Huerzeler M. Tissue alterations after tooth extraction with and without surgical trauma: a volumetric study in the beagle dog. *J Clin Periodontol*. 2008;35:356-363.
33. Blanco J, Nunez V, Aracil L, Munoz F, Ramos I. Ridge alterations following immediate implant placement in the dog: flap versus flapless surgery. *J Clin Periodontol*. 2008;35:640-648.
34. Chen ST, Darby IB, Reynolds EC. A prospective clinical study of non-submerged immediate implants: clinical outcomes and esthetic results. *Clin Oral Implants Res*. 2007;18:552-562.
35. Ferrus J, Cecchinato D, Pjetursson EB, Lang NP, Sanz M, Lindhe J. Factors influencing ridge alterations following immediate implant placement into extraction sockets. *Clin Oral Implants Res*. 2010;21:22-29.
36. Qian J, Wennerberg A, Albrektsson T. Reasons for marginal bone loss around oral implants. *Clin Implant Den Relat Res*. 2012;14:792-807.
37. Hartman GA, Cochran DL. Initial implant position determines the magnitude of crestal bone remodeling. *J Periodontol*. 2004;75:572-577.
38. Tomasi C, Sanz M, Cecchinato D, et al. Bone dimensional variations at implants placed in fresh extraction sockets: a multilevel multivariate analysis. *Clin Oral Implants Res*. 2010;21:30-36.
39. Araujo MG, Wennstrom JL, Lindhe J. Modeling of the buccal and lingual bone walls of fresh extraction sites following implant installation. *Clin Oral Implants Res*. 2006;17:606-614.
40. Araujo MG, Linder E, Lindhe J. Bio-Oss collagen in the buccal gap at immediate implants: a 6-month study in the dog. *Clin Oral Implants Res*. 2011;22:1-8.
41. Caneva M, Salata LA, de Souza SS, Baffone G, Lang NP, Botticelli D. Influence of implant positioning in extraction sockets on osseointegration: histomorphometric analyses in dogs. *Clin Oral Implants Res*. 2010;21:43-49.
42. Huynh-Ba G, Pjetursson BE, Sanz M, et al. Analysis of the socket bone wall dimensions in the upper maxilla in relation to immediate implant placement. *Clin Oral Implants Res*. 2010;21:37-42.
43. Vera C, De Kok IJ, Reinhold D, et al. Evaluation of buccal alveolar bone dimension of maxillary anterior and premolar teeth: a cone beam computed tomography investigation. *Int J Oral Maxillofac Implants*. 2012;27:1514-1519.
44. Wohrle PS. Single-tooth replacement in the aesthetic zone with immediate provisionalization: fourteen consecutive case reports. *Pract Periodontics Aesthet Dent*. 1998;10:1107-1114. quiz 1116.
45. Kan JY, Rungcharassaeng K. Immediate placement and provisionalization of maxillary anterior single implants: a surgical and prosthodontic rationale. *Pract Periodontics Aesthet Dent*. 2000;12:817-824. quiz 826.
46. Crespi R, Cappare P, Crespi G, Gastaldi G, Romanos GE, Gherlone E. Tissue remodeling in immediate versus delayed prosthetic

restoration in fresh socket implants in the esthetic zone: four-year follow-up. *Int J Periodontics Restorative Dent*. 2018;38:s97-s103.
47. Su H, Gonzalez-Martin O, Weisgold A, Lee E. Considerations of implant abutment and crown contour: critical contour and subcritical contour. *Int J Periodontics Restorative Dent*. 2010;30:335-343.
48. Chu SJ, Salama MA, Salama H, et al. The dual-zone therapeutic concept of managing immediate implant placement and provisional restoration in anterior extraction sockets. *Compend Contin Educ Dent*. 2012;33:524-532, 534.
49. Chu SJ, Salama MA, Garber DA, et al. Flapless postextraction socket implant placement, part 2: the effects of bone grafting and provisional restoration on peri-implant soft tissue height and thickness–a retrospective study. *Int J Periodontics Restorative Dent*. 2015;35:803-809.
50. Linkevicius T, Puisys A, Steigmann M, Vindasiute E, Linkeviciene L. Influence of vertical soft tissue thickness on crestal bone changes around implants with platform switching: a comparative clinical study. *Clin Implant Den Relat Res*. 2015;17:1228-1236.
51. Tonetti MS, Cortellini P, Graziani F, et al. Immediate versus delayed implant placement after anterior single tooth extraction: the timing randomized controlled clinical trial. *J Clin Periodontol*. 2017;44:215-224.

SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section at the end of the article.

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