

CLINICAL RESEARCH

Dynamic changes of peri-implant soft tissue after interim restoration removal during a digital intraoral scan



Junying Li, DDS, MS,^a Zhaozhao Chen, DDS, MS,^b Meijie Wang, DDS,^c Hom-Lay Wang, DDS, MS, PhD,^d and Haiyang Yu, DDS, PhD^e

Achieving esthetic success remains challenging for dental implant treatment in the maxillary anterior area. Soft tissue molding using implant-supported fixed interim restorations (IRs) has become a routine procedure for achieving a harmonious gingival margin level and papilla height.¹⁻³ The optimal subgingival emergence profile of the IR is key to sculpting, supporting, and stabilizing the optimal soft tissue contour, which influences the long-term health and esthetics of the peri-implant soft tissues.⁴⁻⁷

An accurate replica of soft tissue dimensions derived from the IR is essential to the fabrication of the definitive prosthesis.^{8,9} During the impression procedure, the peri-implant soft tissue collapses rapidly after removal of the IR, making it difficult to transfer the established profile. To overcome this problem, a variety of analog impression

ABSTRACT

Statement of problem. During a digital intraoral scan for an esthetic implant restoration, the peri-implant soft tissue will collapse rapidly after the interim restoration (IR) is removed, making it difficult to replicate the established emergence profile. The rate of this collapse is unclear.

Purpose. The purpose of this clinical study was to determine whether significant dimension differences could be found between peri-implant soft tissue supported by an IR and that immediately after removal of the restoration and to assess the changes over time.

Material and methods. Optical scans were made of 12 single implant sites in the esthetic zone of 10 participants. The scans in the first group replicated the peri-implant soft tissue contour with the support of the IR; in the second group, scans were made at different times from 0 seconds to 20 minutes after removal of the restoration. The changes in the soft tissue contour, including the height of the mesial papilla, distal papilla, and gingival margin, the facial and palatal soft tissue thickness, and emergence profile discrepancies (EPDs), were assessed. A linear mixed model was built to estimate the EPD.

Results. After the removal of IR, the palatal soft tissue thickness increased over time, and only minimal changes were found in the height of the mesial papilla, distal papilla, and gingival margin (up to -0.27 mm at 20 minutes). A significant EPD was immediately present at all the measurement sites after the removal of the IR. The linear mixed model showed a significant positive correlation between the natural logarithm of time and EPD. Significant positive correlations between gingiva thickness/implant depth and EPD were only seen at some of the sites.

Conclusions. A small reduction in the papilla level occurred, but no clinical influence on the proximal contact design of the restoration was detected. For the emergence profile, a significant but small discrepancy occurred immediately and continued to increase over time. (J Prosthet Dent 2019;122:288-94)

techniques have been proposed. These include the use of a custom impression coping that has the same emergence contour as the IR,^{10,11} the use of the IR as an impression

Funding: This project was financially supported by the Foundation of State Key Laboratory of Oral Diseases, National Clinical Research Center for Oral Disease, West China Hospital of Stomatology, Sichuan University, (grant number: SKLOD201709).

^aDoctoral candidate, State Key Laboratory of Oral Diseases, National Clinical Research Center for Oral Disease, West China Hospital of Stomatology, Sichuan University, Chengdu, PR China.

^bDoctoral candidate, State Key Laboratory of Oral Diseases, National Clinical Research Center for Oral Disease, West China Hospital of Stomatology, Sichuan University, Chengdu, PR China.

^cDoctoral candidate, State Key Laboratory of Oral Diseases, National Clinical Research Center for Oral Disease, West China Hospital of Stomatology, Sichuan University, Chengdu, PR China.

^dProfessor, Department of Periodontics and Oral Medicine, University of Michigan School of Dentistry, Ann Arbor, Mich.

^eProfessor, State Key Laboratory of Oral Diseases, West China Hospital of Stomatology, Sichuan University, Chengdu, PR China.

Clinical Implications

An intraoral scan of the peri-implant soft tissue captured immediately after removal of the interim restoration has small but significant inaccuracy. Whether this small inaccuracy could impact esthetic outcomes is not clear.

coping,^{8,12} and the injection of impression material around the IR that is seated on a definitive cast.¹³

Recently, intraoral scanners have become popular in implant dentistry. A digital scan is more time-efficient, cost-effective, and easier to adopt than conventional impressions, especially for inexperienced dentists.¹⁴ However, capturing the dimensions of the peri-implant soft tissues after removal of the IR remains a problem with the digital procedure and can lead to misinterpretation of the subgingival configuration. To capture the tissue profile accurately, techniques that include an individualized scan body,¹⁵ a scannable custom coping,¹⁶ and scanning the IR¹⁷ have been advocated. However, these techniques have not been widely adopted because additional steps and chairside time are required.

When the peri-implant soft tissue is not supported, dimensional changes will occur, increasing over time. The authors are unaware of studies that have evaluated soft tissue collapse as a function of time. Therefore, the purpose of this study was to determine whether dimensional differences could be found between peri-implant soft tissue supported by an IR and that immediately after the removal of the restoration and to assess the dimensional stability of the peri-implant soft tissue with time. The null hypotheses were that no differences would be found between the tissue contour supported by a restoration and immediately after removal of the restoration and that no correlation would be found among change of soft tissue dimension, time, peri-implant soft tissue height, and thickness.

MATERIAL AND METHODS

This study was approved by the Institutional Review Board of the West China Hospital of Stomatology (IRB#: WCHSIRB-D-2015-099). It was conducted from December 2015 to October 2017 in the Department of Prosthodontics, West China Hospital of Stomatology, Sichuan University. The inclusion criteria were systemically healthy patients who had received implant treatment in the esthetic zone (maxillary first premolar to first premolar), the presence of teeth adjacent to the implant, and a minimum 3 months of soft tissue molding using an implant-supported fixed IR. Participants with a history of periodontal disease or gingival recession were excluded. Written informed consent was obtained from all participants.

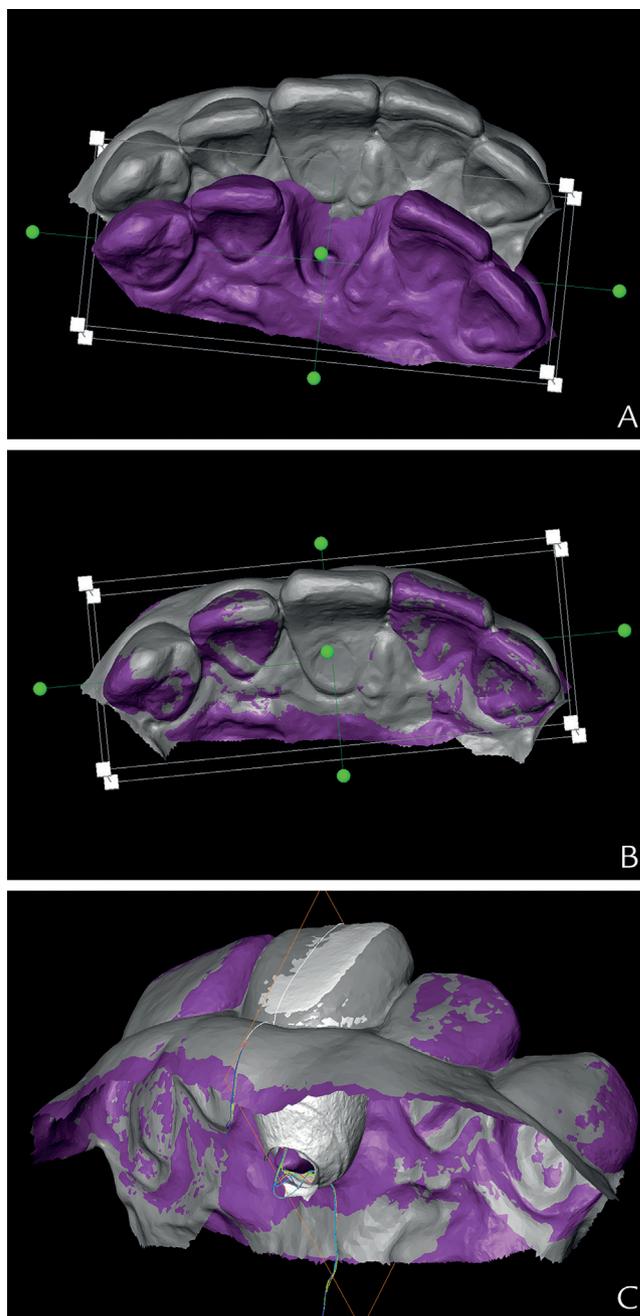


Figure 1. Registration IR (gray) and NoIR₂₀ (violet). A, Before registration. B, After registration. C, Facial-palatal cross section. IR, interim restoration.

An intraoral scanner (TRIOS Color Pod; 3Shape) was used to capture the peri-implant soft tissue and adjacent teeth. For each participant, 2 groups of scans were made. The first group (IR) replicated the peri-implant soft tissue supported by the IR and represented the baseline. The second group (NoIR) recorded the soft tissue profile at different times after restoration removal. All scanned data were saved as standard tessellation language (STL) files.

The IR file was obtained according to the method of Monaco et al.¹⁷ The first scan captured the IR and

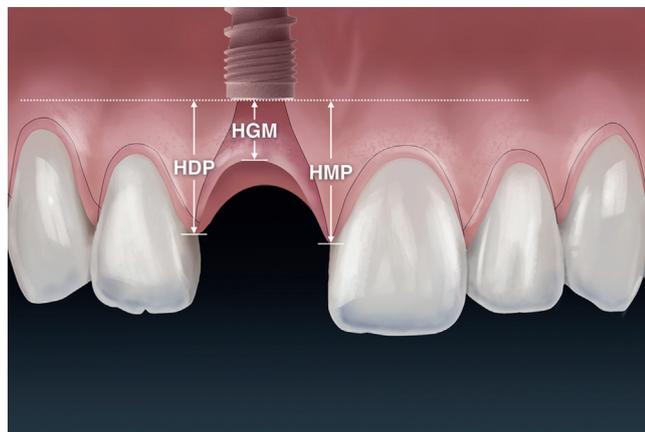


Figure 2. Measurement of height of gingival margin (HGM), height of mesial papilla (HMP), and height of distal papilla (HDP).

adjacent teeth. The restoration was then removed and scanned. These two 3D images were superimposed using a software program (Amira; Mercury Computer Systems) by recognizing the crown part of the restoration to achieve a new merged file with the implant position, peri-implant soft tissue outline, and emergence profile. After removal of the IR, 10 scans of the peri-implant soft tissue were made. The first scan (NoIR_{0.2}) was performed immediately after restoration removal. The time points of the remaining scans were at 30 seconds (NoIR_{0.5}) and at 1 (NoIR₁), 2 (NoIR₂), 3 (NoIR₃), 4 (NoIR₄), 6 (NoIR₆), 8 (NoIR₈), 10 (NoIR₁₀), and 20 minutes (NoIR₂₀).

STL files (IR and NoIR) of the same site were imported into the Amira 3D software and superimposed on a single 3D project by matching the adjacent teeth (Fig. 1). The heights of the gingival margin (HGMs), mesial papilla (HMPs), and distal papilla (HDPs) were measured from the level of the implant-abutment junction in a facial view (Fig. 2). Using IR as the baseline, changes in HGM, HMP, and HDP at each time point in NoIR were calculated.

From the gingival margin to the implant platform, the peri-implant soft tissue was divided into 3 zones. At the middle of each zone, soft tissue thickness (STT) was measured in a facial-palatal section view (Fig. 3A). In addition, another 6 points were set at the mesial and distal walls of the emergence profile. The contour distance between IR and each time point of NoIR was measured as the emergence profile discrepancy (EPD) at these 12 sites (Fig. 3B).

A statistical software package (IBM SPSS Statistics, v23.0; IBM Corp) was used to analyze the data. The 1-sample *t* test with a test value of 0.00 mm was performed to address the significant discrepancy of HMP, HDP, and HGM at 0.2 and 20 minutes and EPD at 0.2 minutes. The paired sample *t* test was used to detect the difference of STT between IR and NoIR_{0.2}. To investigate the

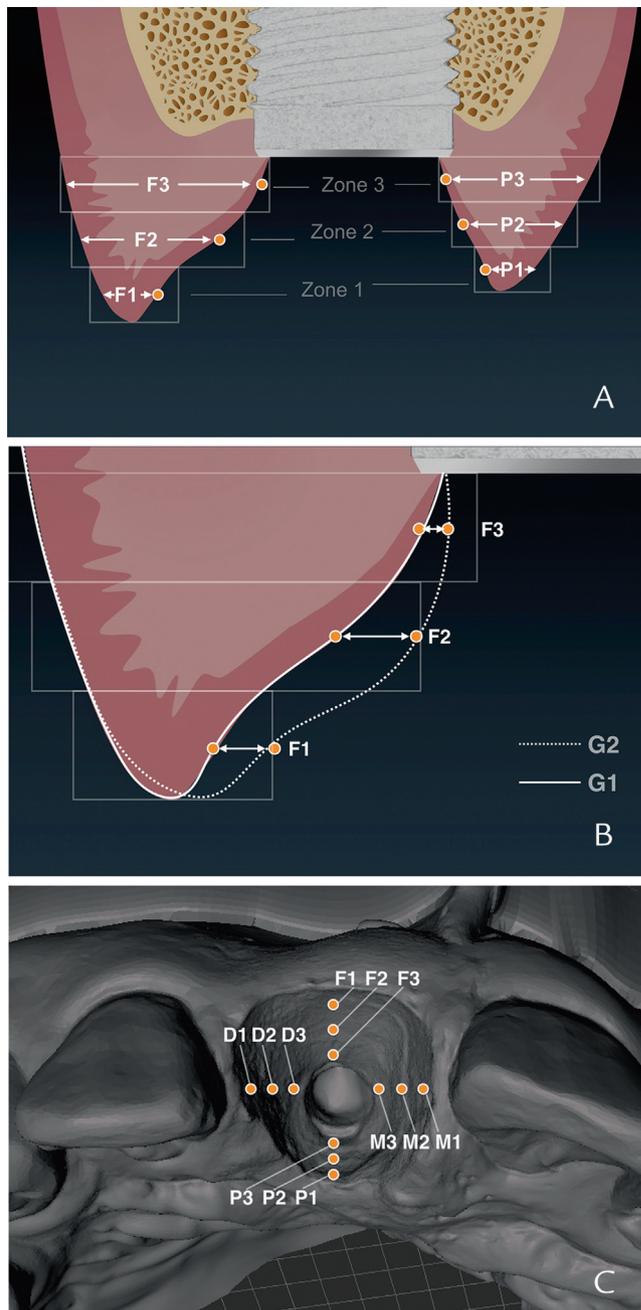


Figure 3. Measurements of soft tissue thickness (STT) and emergence profile discrepancy (EPD). A, Six sites for assessment of STT. B, Assessment of EPD. C, 12 sites for measurement of EPD.

relationship among EPD, time, peri-implant soft tissue height (HGM), and thickness (STT at facial zone 2), a linear mixed model with fixed effects was performed ($\alpha=.05$ for all tests).

RESULTS

Ten participants with a total of 12 maxillary implants (5 central and 7 lateral incisors) were included. Two of

Table 1. Changes of HMP, HGM, and HDP at 0.2 minutes and 20 minutes after removal of restoration

Time (min)	Site	Changes (mm)	SD	95% CI for Changes		P ^a
				Lower Bound	Upper Bound	
0.2	HMP	0.01	0.09	-0.05	0.07	.697
	HGM	-0.07	0.06	-0.11	-0.04	.001 ^b
	HDP	-0.01	0.05	-0.03	0.03	.761
20	HMP	-0.27	0.07	-0.31	-0.23	<.001 ^b
	HGM	-0.15	0.08	-0.2	-0.1	<.001 ^b
	HDP	-0.2	0.05	-0.24	-0.17	<.001 ^b

SD, standard deviation; CI, confidence interval; HDP, height of distal papilla; HGM, height of gingival margin; HMP, height of mesial papilla. ^aOne-sample *t* test of mean difference with test value of 0.00 mm. ^b*P*<.05.

them had implants for both the right and left lateral incisors.

The changes of HGM, HMP, and HDP are shown in Table 1. Immediately after restoration removal, a significant reduction of HGM was present (-0.07 ± 0.06 mm, *P*<.01), whereas there were no significant changes in HMP or HDP. HGM, HMP, and HDP decreased over time. Up to 20 minutes, the change of HMP was -0.27 ± 0.07 mm (*P*<.01); the change of HGM was 0.15 ± 0.08 mm (*P*<.01); and that of HDP was -0.20 ± 0.05 mm (*P*<.01).

The peri-implant STTs at different times are presented in Table 2. Compared with IR, NoIR_{0.2} showed significantly increased STT at points of B1 (+0.04 mm), B2 (+0.10 mm), P2 (+0.06 mm), and P3 (+0.15 mm). The STT increased over time after removal of the IR (Fig. 4). At 20 minutes, the mean STT was 1.99 mm at B1 (+0.55 mm), 3.02 mm at B2 (+0.63 mm), 3.93 mm at B3 (+0.80 mm), 1.46 mm at P1 (+0.21 mm), 2.67 mm at P2 (+0.48 mm), and 3.48 mm at P3 (+0.63 mm).

Regarding the EPD, significant changes were found at all 12 times in NoIR_{0.2}. Figure 5 shows that EPD increased over time at each site. A logarithmic relationship was suggested between EPD and time (Fig. 6). As seen in Table 3, two models were built for EPD estimation. Generally, model 1, which only took the logarithm of time (ln [time]) as a covariate, showed a better fit than model 2, which took ln (time), gingiva thickness, and implant depth as covariates. Significant positive correlations were found between EPD and ln (time) for all sites. A significantly positive relationship for thickness was found at P3, M1, and M3, whereas a significant correlation for height was found at P3, M1, and D1.

DISCUSSION

The results of the present study led to rejection of the null hypothesis that no significant differences would be found between the tissue contour supported by an IR and immediately after restoration removal. Regarding the hypothesis on the relationship between change in the

Table 2. Facial and palatal soft tissue thickness (STT) in IR and NoIR_{0.2}

Site	STT (mm) in IR	STT (mm) in NoIR _{0.2}	Mean Difference	P ^a
B1	1.44 ± 0.57	1.48 ± 0.58	0.04 ± 0.05	.020 ^b
B2	2.39 ± 0.77	2.49 ± 0.77	0.10 ± 0.06	<.001 ^b
B3	3.13 ± 1.11	3.27 ± 1.05	0.15 ± 0.26	.079
P1	1.25 ± 0.23	1.27 ± 0.27	0.02 ± 0.05	.199
P2	2.19 ± 0.26	2.25 ± 0.25	0.06 ± 0.09	.035 ^b
P3	2.85 ± 0.38	3.00 ± 0.35	0.15 ± 0.14	.003 ^b

IR, group with support of interim restoration; NoIR_{0.2}, group 0.2 minutes after removal of interim restoration. ^aPaired samples *t* test between IR and NoIR_{0.2}. ^b*P*<.05.

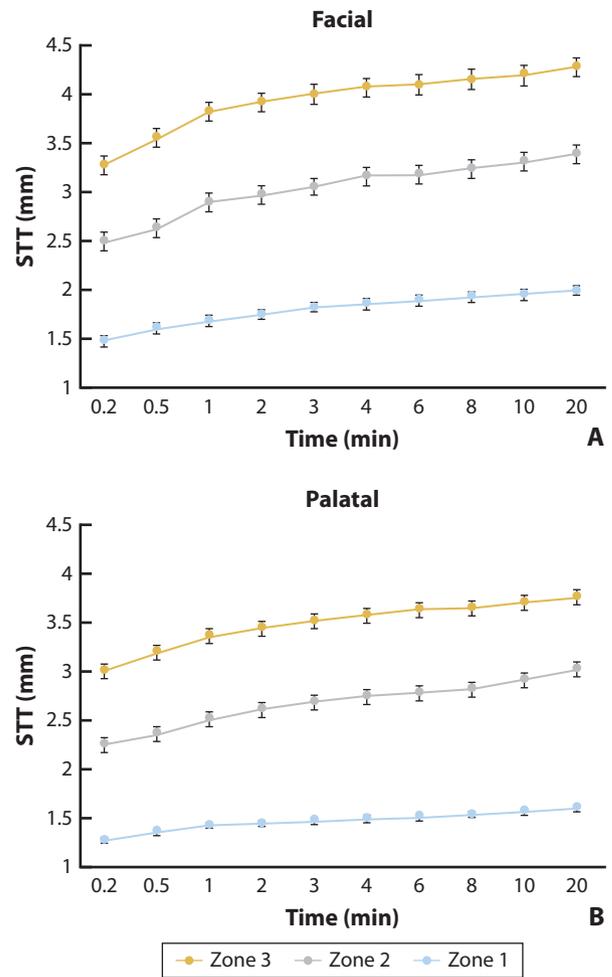


Figure 4. Changes of soft tissue thickness over time in facial (A) and palatal (B) directions. STT, soft tissue thickness.

soft tissue dimension and other parameters, the results supported significant positive correlations between time and tissue dimension change at all sites, whereas significant associations between STT/HGM and emergence profile changes were only detected at some measurement sites.

To register the earliest change in soft tissue, the first scan was performed as soon as the restoration was removed, and the scan took about 10 seconds. The

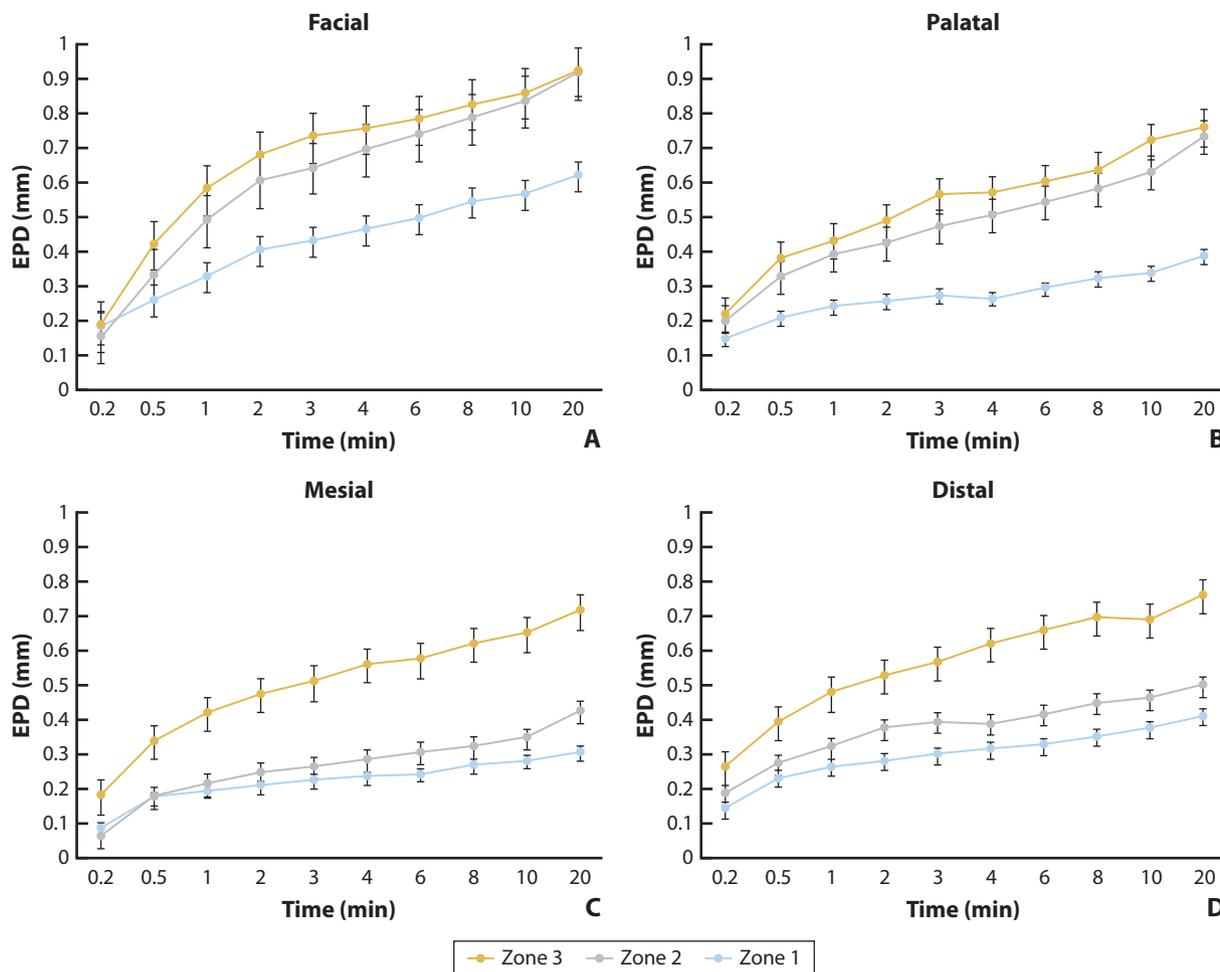


Figure 5. Emergence profile discrepancy (EPD) over time in facial (A), palatal (B), mesial (C), and distal (D) directions.

displacements of the papilla and gingival/mucosal zenith level were minimal (range from 0.01 mm to -0.07 mm immediately, up to -0.27 mm at 20 minutes). Clinically, these limited changes would barely influence the proximal contact and margin position design of the restoration. Regarding the emergence profile, statistically significant discrepancies were shown immediately after removal of the IR, suggesting some inaccuracy in capturing the emergence profile using a digital intraoral scan. However, as this inaccuracy was small (range from 0.08 mm to 0.18 mm in zone 1), whether it has a clinical impact on esthetic outcomes is not clear.

Duran et al¹⁸ focused on dimensional variations of peri-implant soft tissue after removal of implant-supported IRs. The intraorally scanned emergence profile was compared with the cast poured from a customized impression, with dimensional differences of 0.51 mm at the coronal level and 1.35 mm at the middle level reported. In the present study, measurements were made separately at the facial,

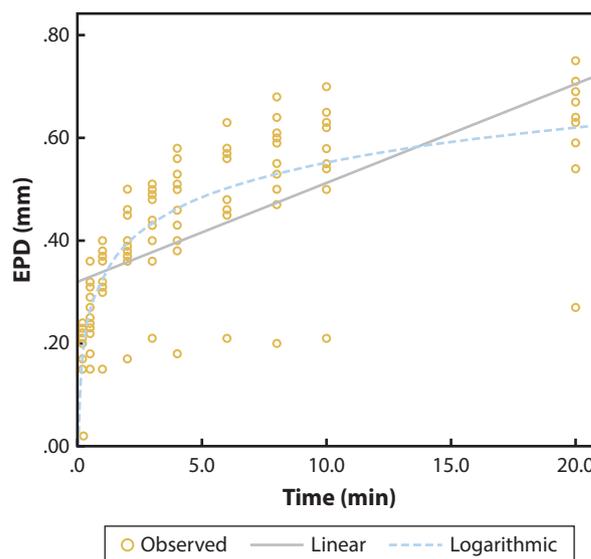


Figure 6. Scatter plot of emergence profile discrepancy (EPD) and time.

Table 3. Linear mixed model for emergence profile discrepancy (mm) estimation

Site	Model 1					Model 2								
	Intercept		Ln (Time)		AIC ^a	Intercept		Ln (Time)		Gingiva Thickness		Implant Depth		AIC ^a
	Estimate	P	Estimate	P		Estimate	P	Estimate	P	Estimate	P	Estimate	P	
B1	0.327	<.001 ^b	0.098	<.001 ^b	-377.525	0.260	.372	0.098	<.001 ^b	-0.002	.970	0.018	.733	-368.806
B2	0.451	<.001 ^b	0.164	<.001 ^b	-142.003	0.968	.127	0.164	<.001 ^b	-0.038	.695	-0.109	.340	-137.183
B3	0.516	<.001 ^b	0.153	<.001 ^b	-124.192	1.389	.045 ^b	0.153	<.001 ^b	-0.069	.496	-0.181	.142	-121.138
P1	0.226	<.001 ^b	0.046	<.001 ^b	-368.604	-0.215	.390	0.046	<.001 ^b	0.049	.236	0.083	.098	-362.717
P2	0.372	<.001 ^b	0.107	<.001 ^b	-163.230	-0.537	.212	0.107	<.001 ^b	0.104	.144	0.169	.051	-160.768
P3	0.422	<.001 ^b	0.113	<.001 ^b	-206.922	-0.323	.131	0.113	<.001 ^b	0.123	.004 ^b	0.115	.012 ^b	-208.270
M1	0.175	.001 ^b	0.043	<.001 ^b	-363.012	-0.798	.016 ^b	0.042	<.001 ^b	0.137	.012 ^b	0.165	.010 ^b	-364.128
M2	0.192	.001 ^b	0.068	<.001 ^b	-321.878	-0.185	.657	0.068	<.001 ^b	0.070	.315	0.053	.496	-315.772
M3	0.389	<.001 ^b	0.110	<.001 ^b	-196.994	-0.114	.811	0.110	<.001 ^b	0.187	.035 ^b	0.015	.871	-196.997
D1	0.243	<.001 ^b	0.053	<.001 ^b	-344.777	-0.597	.045 ^b	0.053	<.001 ^b	0.075	.107	0.170	.007 ^b	-345.084
D2	0.306	<.001 ^b	0.065	<.001 ^b	-354.073	0.494	.223	0.065	<.001 ^b	-0.071	.278	-0.005	.950	-348.265
D3	0.453	<.001 ^b	0.108	<.001 ^b	-326.399	0.414	.049 ^b	0.108	<.001 ^b	0.001	.981	0.010	.787	-315.900

AIC, Akaike information criterion. ^aSmaller AIC value indicates better model fit. ^bP<.05.

palatal, mesial, and distal walls of the emergence profile and tested at different times. Moreover, the current results showed fewer soft tissue outline changes than the earlier study.¹⁸ This variation may arise from the difference of the control group in the 2 studies. Duran et al¹⁸ used the implant-supported IR as an impression coping to pour the cast and scanned the emergence profile of the cast as the control group. During the laboratory procedures, the attrition of the cast may cause a wider emergence profile in the control group and larger discrepancies. The present study directly used the digital scan of IR as the baseline of comparison. This method should be more accurate because fewer steps were used, possibly reducing the accumulative deviation from each procedure.

The collapse of peri-implant soft tissue during the impression procedure has been assumed as a movement of the mucosa after losing physical support.¹⁹ Interestingly, the present study observed that instead of an inward movement of the whole surrounding tissue, it was the thickening of the mucosa that resulted in the deviation of the inner tissue outline (Fig. 7). Based on this observation, the peri-implant soft tissue could be assumed to impart pressure against the transmucosal part of the restoration. Once this pressure disappears with restoration removal, the low osmotic pressure in the mucosa leads to an inflow of interstitial fluid, causing edema and the collapse of the emergence profile.²⁰ This pressure between the restoration and the tissue interface may contribute to the sealing of the gingival sulcus and play a role in the defense mechanism of the supracrestal tissue attachment.

This study has several limitations. Only implants of maxillary central and lateral incisors were included. Other esthetic sites such as canines and first premolars may provide different outcomes. Also, only single implants with adjacent natural teeth were assessed. Multiple

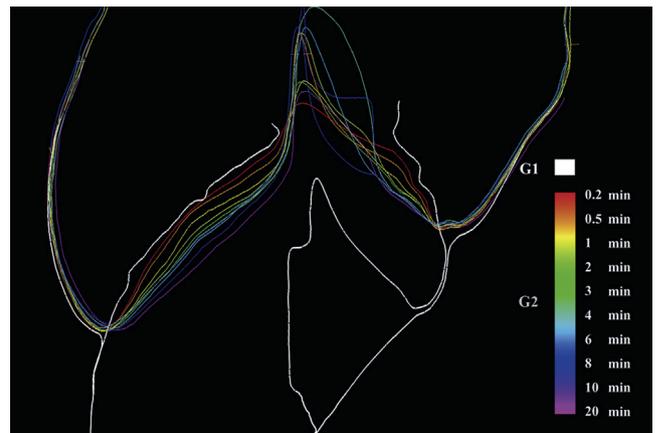


Figure 7. Soft tissue emergence profile changes over time in facial-palatal cross-sectional view.

implants may be associated with different collapse patterns because of the lack of periodontal ligament support from adjacent teeth. Future research should focus on multiple missing sites and the comparison between digital scan techniques and analog impression approaches. Whether digital algorithm based on the present data can be used to compensate for the collapse to generate a more accurate scan from a direct intraoral scan also should be studied.

CONCLUSIONS

Within the limitations of this clinical study, the following conclusions were drawn:

1. After implant-supported IRs were removed, a small reduction of papilla height occurred but had no clinical influence on the restoration contact-point design.

2. For emergence profile, significant but minimal discrepancies occurred immediately and increased over time.

REFERENCES

1. Touati B. Improving aesthetics of implant-supported restorations. *Pract Periodontics Aesthet Dent* 1995;7:81-92.
2. Potashnick SR. Soft tissue modeling for the esthetic single-tooth implant restoration. *J Esthet Restor Dent* 1998;10:121-31.
3. 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):216-20.
4. 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;20:566-70.
5. 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;30:335-43.
6. Chow YC, Wang H-L. Factors and techniques influencing peri-implant papillae. *Implant Dent* 2010;19:208-19.
7. Tarnow DP, Magner AW, Fletcher P. The effect of the distance from the contact point to the crest of bone on the presence or absence of the interproximal dental papilla. *J Periodontol* 1992;63:995-6.
8. Elian N, Tabourian G, Jalbout ZN, Classi A, CHO S-C, Froum S, et al. Accurate transfer of peri-implant soft tissue emergence profile from the provisional crown to the final prosthesis using an emergence profile cast. *J Esthet Restor Dent* 2007;19:306-14.
9. Tsai B-Y. A method for obtaining peri-implant soft-tissue contours by using screw-retained provisional restorations as impression copings: a clinical report. *J Oral Implantol* 2011;37:605-9.
10. Buskin R, Salinas TJ. Transferring emergence profile created from the provisional to the definitive restoration. *Pract Periodontics Aesthet Dent* 1998;10:1171-9; quiz 1180.
11. Hinds KF. Custom impression coping for an exact registration of the healed tissue in the esthetic implant restoration. *Int J Periodontics Restorative Dent* 1997;17:584-91.
12. Chee WW, Cho GC, Ha S. Replicating soft tissue contours on working casts for implant restorations. *J Prosthodont* 1997;6:218-20.
13. Neale D, Chee WW. Development of implant soft tissue emergence profile: a technique. *J Prosthet Dent* 1994;71:364-8.
14. Lee SJ, Gallucci GO. Digital vs. conventional implant impressions: efficiency outcomes. *Clin Oral Implants Res* 2013;24:111-5.
15. Joda T, Wittneben J-G, Brägger U. Digital implant impressions with the "Individualized Scanbody Technique" for emergence profile support. *Clin Oral Implants Res* 2014;25:395-7.
16. Lin W-S, Harris BT, Morton D. The use of a scannable impression coping and digital impression technique to fabricate a customized anatomic abutment and zirconia restoration in the esthetic zone. *J Prosthet Dent* 2013;109:187-91.
17. Monaco C, Evangelisti E, Scotti R, Mignani G, Zucchelli G. A fully digital approach to replicate peri-implant soft tissue contours and emergence profile in the esthetic zone. *Clin Oral Implants Res* 2016;27:1511-4.
18. Duran JC, Aguirre F, Pino R, Velásquez D. Dimensional variations in the soft tissue profile after removal of implant-supported fixed interim restorations: a pilot clinical study. *Implant Dent* 2018;27:28-32.
19. Jansen CE. Guided soft tissue healing in implant dentistry. *J Calif Dent Assoc* 1995;23:57-8.
20. Scallan J, Huxley VH, Korthuis RJ. Capillary fluid exchange: regulation, functions, and pathology. San Rafael: Morgan & Claypool Life Sciences; 2010. p. 54-7.

Corresponding author:

Dr Haiyang Yu
 State Key Laboratory of Oral Diseases
 West China Hospital of Stomatology
 Sichuan University
 14 Renmin South Road, 3rd section
 Chengdu, Sichuan, 610041
 PR CHINA
 Email: yhyang6812@scu.edu.cn

Copyright © 2019 by the Editorial Council for *The Journal of Prosthetic Dentistry*.
<https://doi.org/10.1016/j.prosdent.2018.07.020>