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Influence of buccal emergence profile designs on peri-implant tissues: A randomized controlled trial

Juan Wang DDS | Yiman Tang DDS | Lixin Qiu DDS | Huajie Yu DDS

4th Division, Peking University Hospital of Stomatology, Beijing, China

Correspondence
Huajie Yu, 4th Division, Peking University Hospital of Stomatology, Beijing, China.
Email: yuhuajie666@163.com

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Abstract

Background: The prosthetic emergence profile design might be an important factor in postsurgical mucosal recession etiology. Therefore, a restorative buccal emergence profile designed correctly might reduce gingival margin recession.

Purpose: To compare the marginal gingival level and the width/height (W/H) ratio between two profile configurations of single implant-supported restorations at molar sites.

Materials and Methods: Twenty-one patients requiring a single mandibular molar tooth replacement with supracrestal mucosal thickness ≥2 mm were recruited and randomly assigned to a prosthesis buccal emergence profile design based on the buccal mucosal W/H ratio (Test Group) or maintained the original emergence profile of the healing abutment (Control Group). Assessments were made before delivery of the definitive restoration (T0), at prosthesis placement (T1), one (T2), and 12 (T3) months after loading. The gingival margin level change (△GM), initial emergence angle, buccal mucosal W/H ratio, marginal bone loss (MBL), implant failure, and complications were assessed.

Results: The gingival recession in the test group (0.13 ± 0.32 mm) was significantly lower than in the control group (0.63 ± 0.38 mm) at T3 ($p = 0.006$). The initial emergence angle in the test group (31.4 ± 7.22 degrees) was significantly lower than the control group (40.0 ± 7.60 degrees) ($p = 0.025$). The W/H ratio in the test group at T2 was significantly higher than at T0 but remained stable thereafter. The W/H ratio presented a continued rising trend in the control group.

Conclusions: When the initial supracrestal soft tissue thickness was ≥2 mm, a restorative emergence profile based on the W/H ratio significantly reduced gingival margin recession. An emergence angle of 32.4 degrees showed better behavior in maintaining the gingival margin than 40 degrees.

Clinical Trial Registration Number: ChiCTR190002210.

Summary Box

What is known:

A recent systematic review suggested that the thickness of soft tissue ≤2 mm was related to diminished vertical bone resorption.

The "biologic height-to-width (W/H) ratio" hypothesis proposed by Wennström states that if an appropriate emergence profile cannot be achieved in the initial period, mucosal recession and subsequent bone resorption might occur.

What this study adds:

This randomized controlled trial showed that a restorative emergence profile design based on the buccal mucosa width/height of 1.3 could maintain the gingival margin level effectively when a thick mucosa (>2 mm) is found around the implant, compared with standard healing abutment emergence profile.

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KEYWORDS
emergence profile, marginal bone loss, mucosa, prosthodontics

1 | INTRODUCTION

Although long-term osseointegration has been confirmed in many studies, maintenance of the soft tissue level and shape around implants is an important issue, which has received much less attention. Postsurgical mucosal recession always occurs within 6–12 months after restoration placement and remains relatively stable after that.[1–3] The mucosal level change could be attributed to the surgical procedure,[4] prosthesis transmucosal design,[5] the soft tissue quantity and quality, supporting bone, and the soft tissue configuration over time.[6,7] Among these, the prosthesis contour design appears to significantly affect the shape of peri-implant soft tissue.[8,9]

In the ninth edition of the Glossary of Prosthodontic Terms, the emergence profile was defined as "the contour of a tooth or restoration, such as the crown on a natural tooth, dental implant, or dental implant abutment, as it relates to the emergence from circumscribed soft tissues".[10] In the esthetic zone, it has been confirmed that proper emergence profile design might affect the esthetic outcome and long-term stability of soft and hard tissue.[8,11] Although the issue of esthetic is not critical for the posterior region, emergence profile might also influence the health of periodontal tissue and hard tissue resorption following soft tissue alteration. A previous retrospective study has confirmed that proper emergence profile design may reduce peri-implant biological complications.[12] Because peri-implant soft tissue could adapt to adjacent structure conditions, an adequate prosthetic emergence profile design is essential for soft tissue maintenance around implants. Studies by Spinato et al. and Borges et al. showed that bone level was better maintained when appropriate abutments and emergence profiles were used to restore the prostheses.[3,13]

The appropriate supracreatal soft tissue height is not a fixed value. The dimensions of peri-implant soft tissue in the thick biotype are greater than in the thin biotype.[14] Wennström developed the hypothesis of "biologic height-to-width (W/H) ratio" and reported that the W/H ratio of the free gingiva around natural teeth was 1.5:1.[15] According to this hypothesis, Bengazi et al. suggested that the height of peri-implants mucosa might also be related to the buccal mucosal width.[16] Nozawa T et al. reported a similar biologic W/H ratio around implants of 1.58:1.[17] Farronato et al. reported the ratio around platform switching implants was 1.19:1.[18] The mucosal W/H ratio can be adjusted by the emergence profile when designing prosthesis.[19]The "biologic height-to-width (W/H) ratio" hypothesis may states that if an appropriate emergence profile cannot be achieved in the initial period, mucosal recession and subsequent bone resorption might take place in association with the biologic ratio.

In previous studies, the emergence profile was usually subjectively described as concave or convex.[11,12] In order to research it quantificationally, the concept of emergence angle was raised and defined as "the angle between the average tangent of the transitional contour relative to the long axis of a tooth".[10] Although the effect of emergence angle on the peri-implant condition has been verified, measurement of emergence angle of implant-supported restoration was mainly performed on the radiographs, without involving soft tissue. Katafuchi et al. and Yi et al.[12,20] measured the emergence angle by tangent line at the point of the implant shoulder and the implant long axis. Hentenaar et al.[21] calculated the emergence angle at 1, 2, and 3 mm above the implant shoulder. In these studies, however, the relationship between emergence profile and soft tissue was not considered.

To date, no study has considered the influence of the emergence profile and emergence angle, dictated by mucosal width and height, on peri-implant marginal bone resorption and mucosal recession. Furthermore, there is no prospective study on the ratio of thickness to the height of buccal soft tissue around implants.

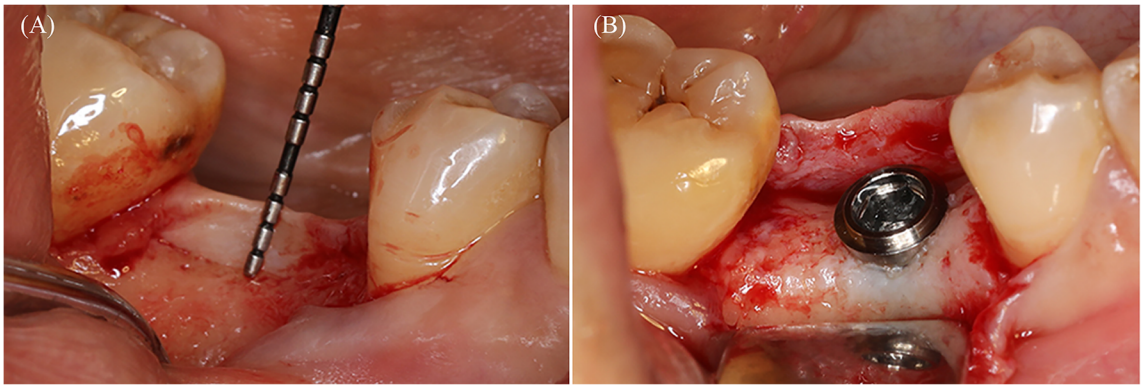

FIGURE 1 Measurement of the supracrestal soft tissue thickness and implant insertion. (A) Patients with supracrestal soft tissue thickness ≥2 mm were included in the research. (B) The implants were placed with 0.5 mm of the machined neck below the alveolar crest level

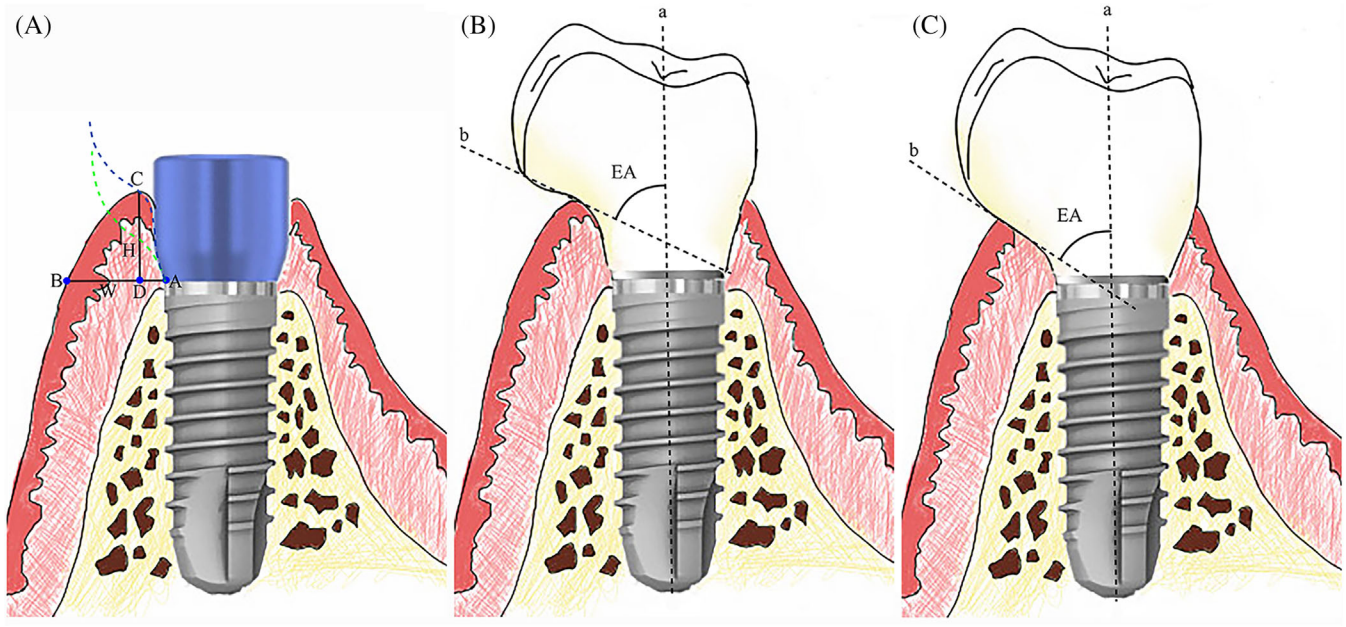

FIGURE 2 Schematic diagram of the emergence profile design. (A) Initial condition of the implant with healing abutment. Point A: the point at the buccal aspect of the implant shoulder. Point B: the most buccal point of the gingival at the implant shoulder level. Point C: the most coronal point of the buccal mucosa. Point D: the meet point of the vertical line drawn from point C to line AB. W: the buccal mucosa width. H: the buccal mucosa height. The blue dotted line showed the emergence profile design in the control group. The green dotted line showed the emergence profile design in the test group. (B) Maintaining the original emergence profile of the healing abutment in the control group. Line a: the implant long axis. Line b: the tangent line of the restoration at the most coronal point of the buccal mucosa. EA: the emergence angle. (C) The emergence profile design based on W/H ratio in Test Group. Line a: the implant long axis. Line b: the tangent line of the restoration at the most coronal point of the buccal mucosa. EA: the emergence angle

The primary aim of this study was to compare the changes in the soft tissue between two implant prosthesis emergence profiles in the molar zone. The secondary aim was to evaluate the W/H ratios, peri-implant bone resorption, and survival rates associated with the two emergence profile designs. The null hypothesis was that there is no difference in biological complications or clinical functions during follow-up of 1 year between the two prosthodontic strategies.

2 | MATERIALS AND METHODS

2.1 | Explication of clinical parameters

The following clinical parameters were explicated in order to reach a consensus on the study design and implementation.

Supracrestal soft tissue thickness: The thickness of the soft tissue was measured in the center of the lingual side at the planned implant placement using a periodontal probe (Hu-Friedy, Chicago, IL, USA) after a full-thickness flap was raised on the buccal side (Figure 1A).

Buccal mucosa width (W): The point at the buccal aspect of the implant shoulder was designated point A. A horizontal line was drawn from point A toward the buccal mucosa. The point at which the line crossed the buccal most aspect of the mucosa was designated point B. The distance between point A and point B was recorded as the width of buccal soft tissue (Figure 2A).

Buccal mucosa height (H): The most coronal point of the buccal mucosa was designated point C. The vertical line was drawn from point C to line AB and the meet point was recorded as point D. The distance between point C and point D was recorded as the height of buccal mucosa (Figure 2A).

Buccal mucosa W/H ratio: Quantitative value calculated from buccal mucosa width(W) and height(H).

Emergence angle: The angle between the tangent line of the restoration at the most coronal point of the buccal mucosa and the implant long axis (Figure 2B and C).

Buccal emergence profile: The buccal profile of prosthesis extending from the implant shoulder to the free gingival margin (Figure 2A).

2.2 | Patients inclusion protocol

This is a prospective randomized clinical trial. The sample size was calculated based on the previous study,[7] aiming at detecting the effect of initial soft tissue thickness on peri-implant bone resorption. When the size of each group is 10, a one-group chi-squared test with bilateral significance levels of 0.05 and 80% power would detect a difference between a null hypothesis proportion of 0.5 and an alternative proportion of 0.9. The institutional ethics committee of Peking University School of Stomatology evaluated and approved the study protocol (PKUSSIRB-201840189) prior to

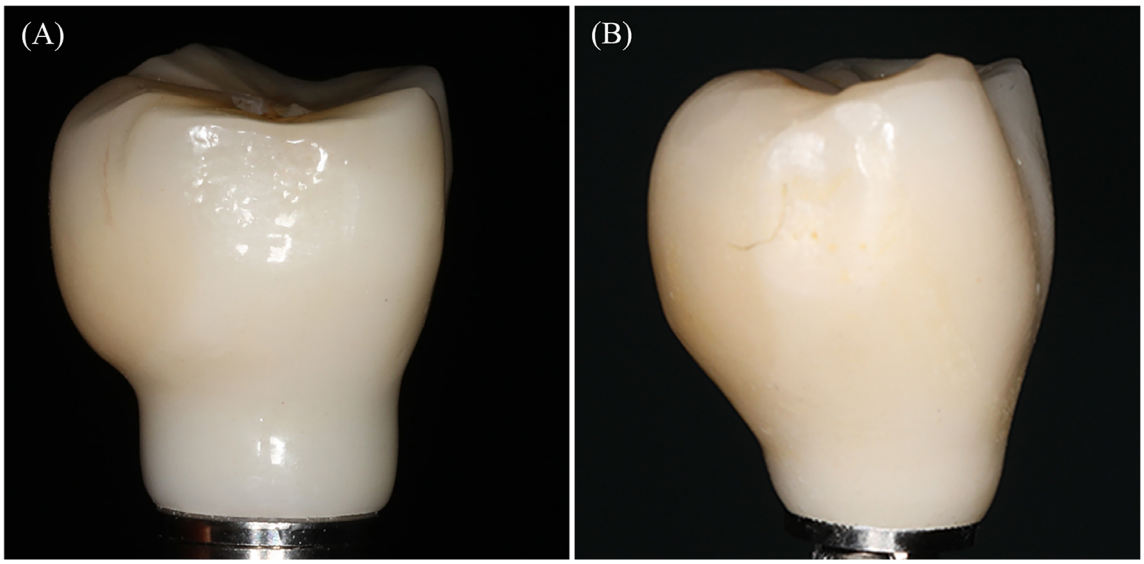

FIGURE 3 Prostheses with different emergence profile designs. (A) Prosthesis with the original emergence profile of the healing abutment in the control group. (B) Prosthesis with a modified buccal emergence profile based on W/H ratio in test group

patient selection. The clinical trial registration number is ChiCTR190002210.

Patients requiring a single mandibular molar tooth replacement were included in this study. A panoramic radiograph and cone-beam computed tomography (CBCT) scans were acquired to evaluate the bone dimensions available for implant placement. Patients were recruited according to the following inclusion criteria: (1) adult patients (20–80 years old); (2) one missing tooth on one side of the mandibular molar zone; (3) supracrestal soft tissue thickness >2 mm; (4) no need of soft or hard tissue augmentation procedure before or during implant placement. The exclusion criteria were: (1) any condition that precluded oral surgery, including uncontrolled diabetes and a history of head and neck radiotherapy; (2) large bone or soft tissue defect in the operative region; (3) poor oral hygiene or smoking more than 10 cigarettes/day.

All patients received periodontal treatment to achieve a good oral environment before operation.

2.3 | Surgical procedures

Implants placement was performed by two experienced surgeons (QLX and YHJ). After administering 4% articaine for local anesthesia, a mid-crestal incision was performed. A full-thickness flap was raised on the buccal side, while the lingual part was not elevated, and the soft tissue thickness was accurately measured. Patients with supracrestal soft tissue thickness ≥2 mm were included in the research. After the measurement, a full-thickness flap was elevated on the lingual side to expose the surgical site. The 4.5 mm-diameter implants (Thommen Medical AG, Grenchen, Switzerland) with a 1.0-mm machined neck were inserted into the prepared sites using a standardized surgical procedure. All implants were placed with 0.5 mm of the machined neck below the alveolar crest level (Figure 1B). Healing abutments were installed on the implants, and the flaps were sutured to accommodate the healing abutments.

Patients were instructed to gargle with 0.2% chlorhexidine for 20 s, three times a day for 1 week. The healing condition was evaluated 2 weeks after the operation.

2.4 | Prosthetic procedures

After 3 months, prosthetic procedures were performed, with zirconia crowns cemented on titanium abutments extraoral and screwed into the implants. The prosthetic procedures were performed by two experienced prosthodontists (WJ and TYM).

Patients were randomized to receive a prosthesis with the emergence profile designed based on a buccal mucosal W/H ratio of 1.3 (Test group; Figure 2C), or maintaining the original emergence profile of the healing abutment (Control group; Figure 2B). Randomization was created by computer-generated permuted blocks of two patients with an allocation ratio of 1:1. If multiple implants were required in the same patient, each implant was grouped and randomized separately. A person not involved in any part of the clinical treatment is assigned treatment allocation using sealed envelopes. The treatment assignment was disclosed to the prosthodontists immediately after taking the impression.

Patients in the test group received prostheses with a modified emergence profile. One experienced technician fabricated all restorations. The buccal transmucosal portion of the definitive cast was modified to achieve an appropriate soft tissue W/H ratio before crown production. The soft tissue height or width was modified to achieve a W/H ratio of 1.3. The prosthesis was then made according to the fixed gingival margin and transmucosal configuration (Figures 2C, 3B).

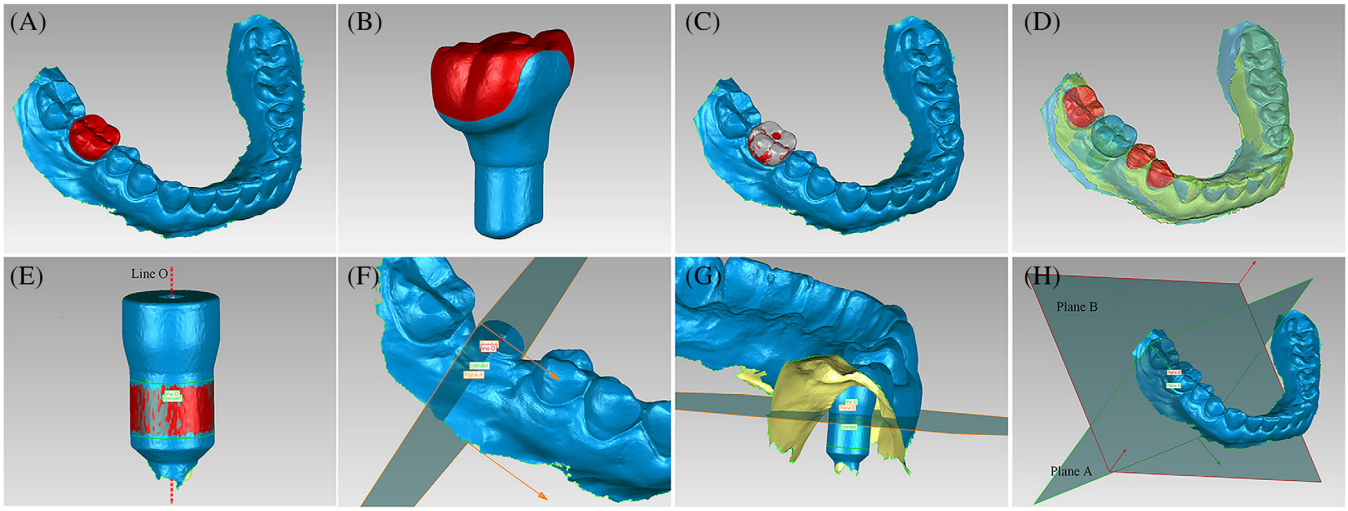

FIGURE 4 Digital model management. (A) Digital model after restoration delivery. (B) Digital model of the restoration with analog. (C) The digital models in illustrations a and b were aligned and merged based on similar areas (red parts) using the "best-fit alignment." (D) The before and after restoration delivery model alignment. (E) The cylinder and the central axis (Line O) were established by the "best-fit alignment" to the implant analog. (F) The measurement plane (plane A) was defined by Line O and the buccal zenith of the implant site (point A). (G) The reference plane (plane B) was defined by any three points on the superior border of the implant analog. (H) Planes A and B were copied into digital models generated when the patients were assessed 1 and 12 months after loading

In the control group, the definitive casts were not modified. The prostheses were designed and fabricated to maintain the original emergence profile of the healing abutment (Figures 2B and 3A).

Oral hygiene instruction and professional periodontal maintenance were performed on all patients.

2.5 | Follow-up and clinical assessments

The patient assessments were made before prosthesis placement (T0), after delivery of the definitive restoration (T1), 1 (T2), and 12 (T3) months after loading. Digital impressions at T0 (with the healing abutment), T2, and T3 (with definitive restoration) were obtained using an intraoral scanner (3Shape Trios, 3Shape, Copenhagen, Denmark) by one experienced operator. The digital healing abutment and definitive restoration models with implant analogs were acquired by the intraoral scanner.

2.5.1 | Digital model alignment and measurement

The Standard Tessellation Language (STL) files were exported to image analysis software (Geomagic Qualify 2014; 3D Systems). The STL data acquired from the patients were superimposed with the corresponding digital model of the healing abutment or definitive restoration, and the two were combined (Figure 4A–C). The T2 and T3 STL data (with definitive restoration) were superimposed with the corresponding digital T0 model data (with the healing abutment). Similar zones of the adjacent teeth were marked manually to superimpose two selected digital models, using the reference surface according to the "best-fit alignment" algorithm (Figure 4D).

After the superimposition of the three digital models, the reference point and reference plane were constructed in the software. A cylinder shape was established in the baseline STL data by "best-fit" to the implant analog. The center axis of the cylinder was defined (line O in Figure 4E). The buccal zenith of the implant site was identified as point A. The measurement plane (plane A) was defined by line O and point A (Figure 4F). Any three points on the superior border of the implant analog were selected, and the reference plane (plane B) was defined based on them (Figure 4G). Planes A and B were copied to the digital models generated for T2 and T3 (Figure 4H).

A transverse section was made along plane A in each digital model. All soft tissue measurements were performed in this section.

2.5.2 | Primary outcome measure

The gingival margin level change (△GM) was the primary outcome measure. Digital models at T2 and T3 were viewed together, and the change in gingival margin was measured on the transverse section (Figure 5A).

2.5.3 | Secondary outcome measures

Initial emergence angle

The emergence angle of the implant restoration was measured on the section of the STL model at T1. The implant long axis was defined as Line a, and the tangent line of the restoration at the most coronal

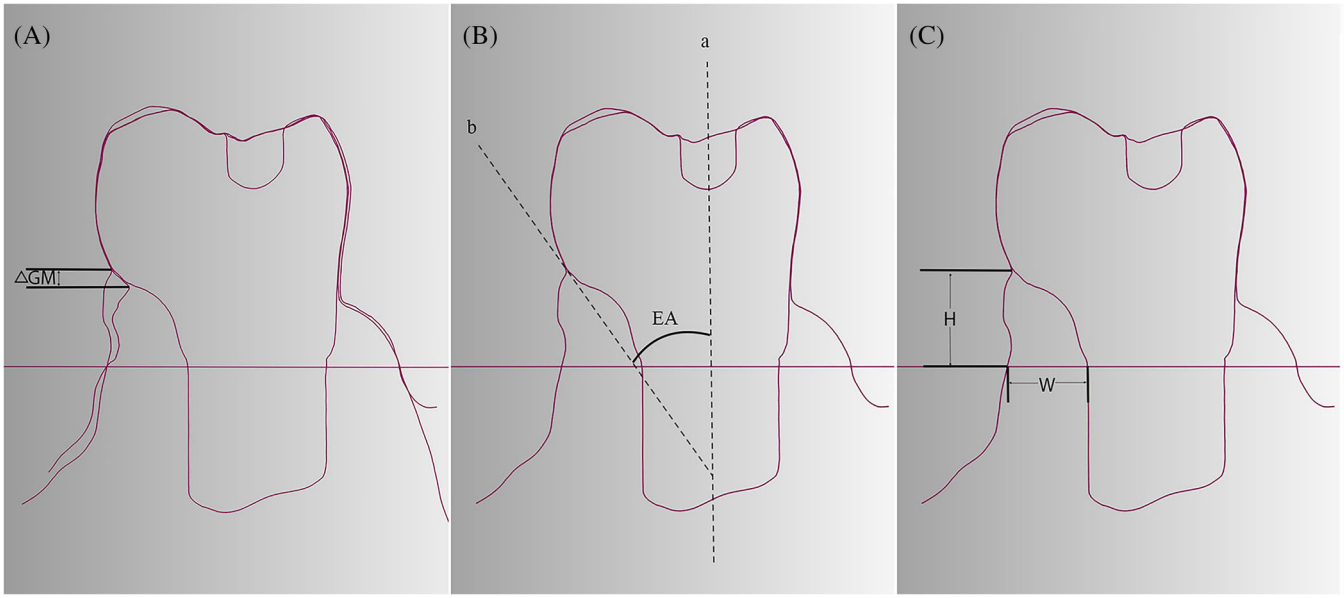

FIGURE 5 Analysis of soft tissue alterations in the transverse section of plane A. (A) Measurement of the change in the gingival margin (△GM). (B) Measurement of the initial emergence angle. Line a: the implant long axis. Line b: the tangent line of the restoration at the most coronal point of the buccal mucosa. EA: the emergence angle. (C) Examination of the buccal soft tissue width (W) and height (H)

point of the buccal mucosa was defined as Line b. The angle between Line a and Line b was measured as EA (Figure 5B).

Width-to-height ratio

The buccal mucosa width and height were measured in each digital model. The distance between the implant platform and gingival margin was measured as mucosa height (H). the mucosa width (W) was measured as the horizontal distance between the most buccal points of the implant shoulder and the buccal mucosa (Figure 5C). The W/H ratio was then calculated.

Peri-implant marginal bone loss (MBL)

Digital radiographs of the implants were made at the time of T1 and T3, using an X-ray device (Minray INTR, Soredex). Film holders were used to ensure paralleling technique and diminish distortion of the image. All digital radiographs were taken by one technician.

The peri-implant marginal bone level was determined by measuring the distance between the implant shoulder and the most apical contact point of the bone on the mesial and distal sides. Measurements were made on each image using the ImageJ 1.52a software (National Institutes of Health) by an external clinical examiner who was blind to the treatment protocol. The image scales were calibrated according to a known 1-mm distance between the implant screw threads.

Probing depth (PD)

PD was assessed using a Williams probe (Hu-Friedy) at three buccal sites per implant—mesiobuccal, midbuccal, and distobuccal, and recorded to the nearest 0.5 mm. The average buccal PD was calculated for each implant.

Implant failure

Implant survival was concluded when the following criteria were absent: clinically implant mobility, recurrent peri-implant infection, undue subjective sensation, peri-implant continuous radiolucency, and progressive marginal bone resorption.

Complications

Biological and technical complications were recorded at every visit of the patients.

All the radiographic assessments, clinical evaluations, and digital measurements were each performed by one operator not involved in the study.

The measurements of △GM, EA, W/H ratio, MBL, and PD were measured by one examiner who was not involved in the therapy. All measurements were repeated three times with a time interval of 1 week. The average values of these measurements were used for the statistical analysis. Intra-observer reliability was calculated by means of an intra-class correlation coefficient. All intra-class correlation coefficients for the repeated objective measurements were greater than 0.85.

2.6 | Statistical analysis

All statistical analyses were performed using SPSS Statistics for Windows, Version 16.0 (SPSS Inc.). The data were analyzed using a pre-established analysis plan. Descriptive statistics were computed and are presented as means and standard deviations (SDs). The independent samples *t*-test compared the buccal GM, MBL, PD between groups. The W/H ratio was analyzed using paired *t*-test. A *p*-value <0.05 was considered statistically significant.

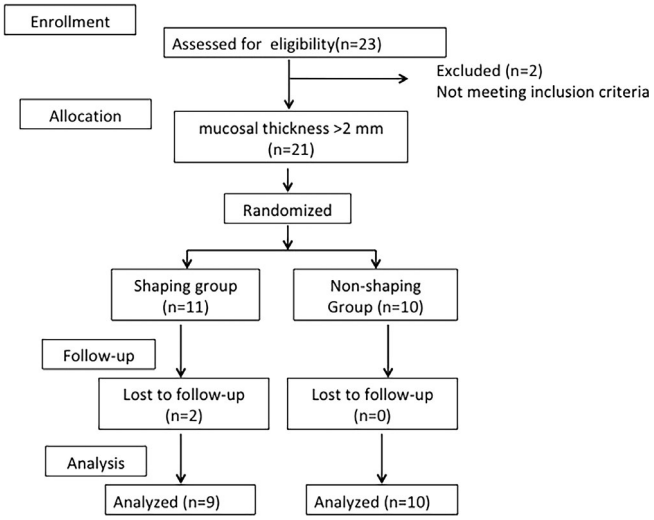

FIGURE 6 Study flowchart

TABLE 1 Patient and intervention characteristics

	Test group	Control group
Number of patients	9	10
Mean age (y)	37.7	40.8
Number of inserted implants	10	10

Test Group: prostheses with a modified buccal emergence profile.
Control Group: prostheses with the original emergence profile of the healing abutment.

The contents of this report followed the CONSORT checklist.

3 | RESULTS

Twenty-one patients (10 males, 11 females) with a mean age of 38.9 years (range, 20–63 years) were consecutively recruited from those seeking implant rehabilitation of a single missing molar tooth on one side between January 12 and May 10, 2019, at the Forth Division of Peking University School and Hospital of Stomatology.

Two recruited patients dropped out before T3. Eventually, 19 patients with 20 implants completed all the study phases and were included in the final analysis (Figure 6). Among them, one patient received two implants on two sides each. The diameter of all placed implants was 4.5 mm. The baseline patient characteristics are presented in Table 1.

3.1 | Primary outcome measure—gingival margin level change

Patients in the control group (0.13 ± 0.32 mm) showed a significantly greater decrease in the gingival margin at T3 than those in the test group (0.63 ± 0.38 mm) ($p = 0.006$). (Table 2).

TABLE 2 Soft and hard tissue variation between 1 month and 12 months after restoration

	Test group	Control group	*p* value
△GM (mm)	0.13 ± 0.32[a]	0.63 ± 0.38[a]	0.006
MBL (mm)	0.00 ± 0.44	0.11 ± 0.36	0.62

[a]Significant difference between the test and control group. △GM, Gingival margin level change; MBL, Peri-implant marginal bone loss.

3.2 | Secondary outcome measures

Initial emergence angle

The initial emergence angle was 31.4 ± 7.22 degree and 40.0 ± 7.60 degree in the test and control group, respectively, with a significant difference ($p = 0.025$).

Width-to-height ratio

The W/H ratio in the test group changed significantly by T2 but remained stable after that. The W/H ratio presented a reversed trend in the control group. It remained stable by T2 but then increased significantly at T3 (Figure 7).

The W/H ratio at T2 in the test group corresponded to the original design of the transmucosal configuration, which demonstrates that the crown was produced according to the predefined W/H (Table 3).

Peri-implant marginal bone loss

MBL in the test group was slightly lower than in the control group, but differences did not reach the statistical significance level (Table 2).

Probing depth

The PD value at T2 was similar in the test (2.06 ± 0.53 mm) and control (2.57 ± 0.63 mm) groups ($p = 0.06$). However, the PD value in the test group at T3 (2.45 ± 0.48 mm) was significantly lower ($p = 0.01$) than in the control group (3.23 ± 0.75 mm).

Implant survival rates and complications

All implants survived, and there were no reports of adverse effects after implant placement.

4 | DISCUSSION

This prospective study investigated the influence of the emergence profile on the soft tissue and bone resorption around the implants in the molar region. The results suggested that the emergence profile design based on the mucosal W/H ratio could effectively maintain the buccal soft tissue level.

Soft and bone tissue remodeling/resorption around implants are affected by comprehensive factors. Initial soft tissue condition and configuration around implants has been considered one of the factors having an impact on hard and soft tissue stability.[11] Numerous studies have suggested that the buccal mucosa shows a 10–60% recession

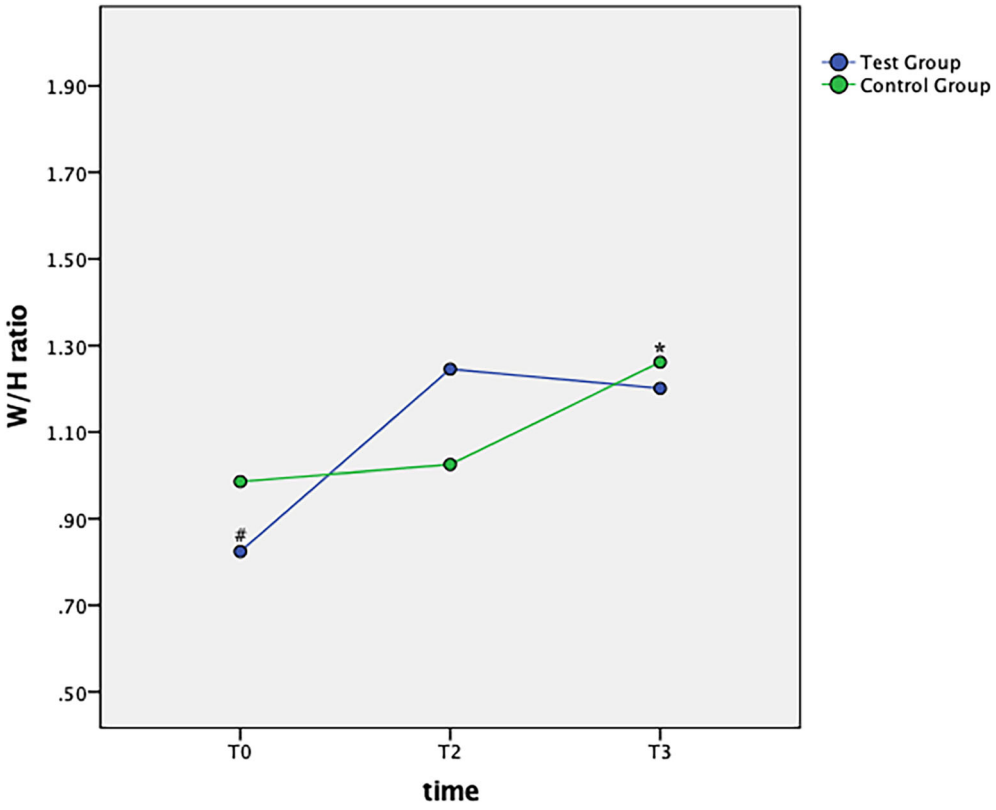

FIGURE 7 Changes in the W/H ratio at various time points. *The W/H ratio at T0 in the test group was significantly different from those at T2 and T3. #The W/H ratio at T3 in the control group was significantly different from those at T0 and T2

TABLE 3 Mucosal height and width measurements and their ratio(W/H)

	T0			T2			T3		
	H (mm)	W(mm)	W/H	H (mm)	W(mm)	W/H	H (mm)	W(mm)	W/H
Test Group	3.35 ± 0.43	2.73 ± 0.47	0.82[a]	2.70 ± 0.46	3.37 ± 0.62	1.25	2.57 ± 0.57	3.08 ± 0.68	1.2
Control Group	3.45 ± 0.39	3.42 ± 1.02	0.99	3.08 ± 0.48	3.15 ± 0.56	1.03	2.55 ± 0.56	3.15 ± 0.74	1.26[#]

T0, before loading; T2, one month after loading; T3, one year after loading.
H, buccal gingival height; W, buccal gingival width;
[a]The W/H ratio at T0 was significantly different from T2 and T3 in the test group. #The W/H ratio at T3 was significantly different from T0 and T2 in the control group.

within 2 years of loading.[22,23] Linkevicius et al. found that a gingival thickness ≤2.0 mm might contribute to crestal bone loss.[4,24] This study set a baseline supracrestal soft tissue thickness minimum of 2 mm in order to exclude the effect of thin gingival on bone resorption. Single crowns supported by 4.5-mm-diameter implants were included in the molar area at the same vertical position, thus reducing the bias as much as possible.

The supracrestal gingival thickness (gingival height) and gingival biotype (gingival width) might affect the facial gingival level. Based on reported gingival W/H ratios around implants,[17,18] preliminary experiments, and data on the implant-abutment connection, a ratio of 1.3 was used to produce the transmucosal configuration in the present study. The biological ratio hypothesis was followed to design the emergence profile.

When the supracrestal soft tissue thickness is ≥2 mm, the transmucosal shaping procedure in the test group mostly involves penetrating the height while maintaining the width to achieve the mucosal W/H ratio target. The test group's facial gingival level expressed less recession than the control group, with the difference being statistically significant. While the retrospective study of Koutouzis et al. showed that there was no correlation between facial peri-implant mucosa margins and emergence profile for implants in the posterior region.[19] In that study, the emergence profile was described and measured in the X-ray photograph with soft tissue invisible, which might affect the result of measurement.

The W/H ratio at T2 in the control group was similar to the baseline value (1.03 and 0.99, respectively). The ratio has increased to 1.26 at the expense of gingival recession by T3, keeping the biological ratio consistent. These results were in agreement with the findings of Nozawa et al.[17] When the initial ratio was lower, attempts made to decrease the height did not cause a further mucosal recession and consequent bone resorption. Although mucosal heights in the two

groups were similar at T3, the modified emergence profile could effectively maintain the stability of the soft tissue after implant restoration, that is, the change before and after follow-up is minimal. From a long-term perspective, the method used in the experimental group could better maintain soft tissue stability, while the control group may further develop gingival recession,

The emergence angle in the test group was significantly smaller than in the control group. The modified emergence profile with an emergence angle of 32.4 degree in the test group showed better behavior in maintaining the gingival margin. Previous studies have measured the emergence angle of implant restorations using periapical radiographs and found a greater prevalence of peri-implantitis with restoration emergence angle ≥30 degrees.[12,25] The trend of the influence of emergence angle on gingival is consistent. The deviation of the value might come from the measuring method. The emergence angle in these studies was described as the angle between the line tangential to the restoration and implant axis, without considering the gingival margin and emergence profile of implant restoration. In the present study, the emergence angle was measured using the digital model instead of periapical radiographs. The exact point of emergence through the gingival margin was shown distinctly in the digital model. The angle between the tangent line at the gingival margin of the prothesis and the long axis of the implant was described more clearly and consistently with the definition of emergence angle. To reduce the initial instability of the gingival margin due to emergence profile shaping, digital impressions at T1 (1 month after loading) were obtained to be a baseline for evaluating peri-implant mucosa. To our knowledge, this is the first study to evaluate the emergence angle in the digital model, which is characterized by repeatability and high precision compared to conventional measurement.

This study showed a slightly lower bone loss in the test group than in the control group, although these differences did not reach the statistical significance level. The PD observed in the test group at T3 was significantly lower than in the control group. From a long-term perspective, the too-thick supracrestal soft tissue around the implants appeared to harm peri-implant tissue health, especially in patients with periodontitis.[26] An additional benefit of the emergence profile shaping technique used in this study is its ability to reduce the vertical thickness and establish a shallow pocket (PD), thus minimizing the risk for peri-implant biological complications. This aspect was verified in a retrospective study.[12]

A further finding is the difference in the W/H ratio between the present study and previous investigations.[17,18] This difference could be due to differences in the implant-system connection. Higher stability and better sealing could be associated with lower microbial penetration and W/H ratio.[27,28]

Some limitations of the present study should be considered when interpreting the results. The number of cases was limited, and the follow-up duration was relatively short. Among the included cases, one patient received two implants on two sides each, which may lead to dependency among data. This study collected data only on one missing mandibular molar and bone resorption in its mesial and distal aspects. Therefore, further investigation is necessary to include changes in the buccal bone level and generalize these results to other sites in the mouth.

5 | CONCLUSION

Within the study limitations, it was demonstrated that emergence profile design based on the mucosal W/H ratio of 1.3 could significantly preserve the facial peri-implant mucosa. The present study provides a novel digital way to measure the emergence angle of implant restoration and an emergence angle of 32.4 degree showed better behavior in maintaining the gingival margin than 40 degree.

CONFLICT OF INTEREST

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AUTHOR CONTRIBUTIONS

Juan Wang: Data analysis, Drafting article. Yiman Tang: Data collection and analysis. Lixin Qiu: Concept/Design. Huajie Yu: Approval of article, Critical revision of the article.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

ORCID

Lixin Qiu https://orcid.org/0000-0003-3451-0191
Huajie Yu https://orcid.org/0000-0001-9244-5813

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SUPPORTING INFORMATION

Additional supporting information may be found in the online version of the article at the publisher's website.

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