Alveolar ridge changes 1-year after early implant placement, with or without alveolar ridge preservation at single-implant sites in the aesthetic region

Published in:
Clinical Implant Dentistry and Related Research

Publication status and date:
Published: 01/04/2024

DOI (link to publisher):
10.1111/cid.13297

Document Version
Publisher's PDF, also known as Version of record

Citation for the published version (APA):
Strauss, F. J., Fukuba, S., Naenni, N., Jung, R., Jonker, B., Wolvius, E., & Pijpe, J. (2024). Alveolar ridge changes 1-year after early implant placement, with or without alveolar ridge preservation at single-implant sites in the aesthetic region: A secondary analysis of radiographic and profilometric outcomes from a randomized controlled trial. *Clinical Implant Dentistry and Related Research*, *26*(2), 356-368. https://doi.org/10.1111/cid.13297

Received: 6 July 2023 | Revised: 8 November 2023 | Accepted: 28 November 2023

DOI: 10.1111/cid.13297

ORIGINAL ARTICLE

WILEY

Alveolar ridge changes 1-year after early implant placement, with or without alveolar ridge preservation at single-implant sites in the aesthetic region: A secondary analysis of radiographic and profilometric outcomes from a randomized controlled trial

Franz Josef Strauss[1,2,3] | Shunsuke Fukuba[1,4] | Nadja Naenni[1] | Ronald Jung[1] | Brend Jonker[5] | Eppo Wolvius[5] | Justin Pijpe[5,6]

[1]Clinic of Reconstructive Dentistry, Center of Dental Medicine, University of Zurich, Zurich, Switzerland

[2]Department of Conservative Dentistry, Faculty of Dentistry, University of Chile, Santiago, Chile

[3]Faculty of Dentistry, Universidad Finis Terrae, Santiago, Chile

[4]Department of Periodontology, Graduate School of Medical and Dental Science, Tokyo Medical and Dental University, Tokyo, Japan

[5]Department of Oral and Maxillofacial Surgery, Special Dental Care and Orthodontics, Erasmus University Medical Center, Rotterdam, The Netherlands

[6]Department of Oral and Maxillofacial Surgery, Catharina Hospital Eindhoven, Eindhoven, The Netherlands

Correspondence

Franz Josef Strauss, Clinic of Reconstructive Dentistry, Center of Dental Medicine, University of Zurich, Plattenstrasse 11, CH-8032 Zurich, Switzerland.
Email: franz.strauss@zzm.uzh.ch

Justin Pijpe, Department of Oral and Maxillofacial Surgery, Special Dental Care and Orthodontics, Erasmus University Medical Center, Rotterdam, The Netherlands.
Email: j.pijpe@gmail.com

[Correction added on 9 January 2024 after online publication: The affiliation of author Ronald Jung was updated to Affiliation 1 in this version.]

Abstract

Objectives: To assess both the radiographic and profilometric outcomes of early implant placement with or without alveolar ridge preservation (ARP) (using two different ARP techniques) after 1 year of loading.

Materials and Methods: Seventy-five patients with a failing single tooth in the anterior maxilla were randomly allocated to three groups (1:1:1): (a) ARP using demineralized bovine bone mineral containing 10% collagen (DBBM-C) covered by a collagen matrix (CM), (b) ARP using DBBM-C covered with a palatal graft (PG), and (c) unassisted socket healing (control). Eight weeks after tooth extraction, early implant placement was performed in all patients. Cone-beam computed tomography (CBCT) and impressions were taken 8 weeks after tooth extraction (ARP/unassisted healing) prior to implant placement and 1-year post-loading. Radiographic and profilometric outcomes were evaluated.

Results: Out of the 70 patients available for re-examination at 1-year post-loading, 55 datasets could be assessed (ARP-CM 19; ARP-PG 17; Control 19). The need for additional guided bone regeneration (GBR) at implant placement amounted to 31.6% (ARP-CM), 29.4% (ARP-PG), and 68.4% (unassisted healing). Adjusted models revealed that residual buccal bone height and additional GBR at implant placement significantly influenced the magnitude of the alveolar changes at 1 year ($p < 0.05$). In patients with ARP (group ARP-CM or ARP-PG) without additional GBR, the presence

Franz Josef Strauss and Shunsuke Fukuba contributed equally to this study and should be considered as joint first authors.
Franz J. Strauss and Justin Pijpe contributed equally as senior authors and should be considered as joint corresponding authors.

of bone convexity amounted to 36.0% (9/25) at 1-year post-loading. For patients that received ARP and additional GBR at implant placement, the frequency of bone convexity increased to 72.7% (8/11) ($p = 0.042$). Regarding profilometric measurements, a tendency toward agreement with radiographic outcomes was observed.

Conclusions: Early implant placement with ARP can attenuate alveolar ridge changes at 1-year post loading by minimizing both radiographic and profilometric alterations. However, early implant placement with simultaneous GBR consistently yields superior radiographic and profilometric outcomes, regardless of whether ARP is performed.

KEYWORDS

alveolar ridge, alveolar ridge preservation, ARP, dental implants, early implant placement, GBR, guided bone regeneration

Summary Box

What is known

- Most studies on alveolar ridge preservation (ARP) have primarily focused on changes in alveolar ridge dimensions up to implant placement, neglecting the changes that take place afterward.

What this study adds

- Early implant placement with ARP can attenuate alveolar ridge changes at 1-year post-loading. However, early implant placement with simultaneous guided bone regeneration (GBR) yields superior radiographic and profilometric outcomes compared to early implant placement with ARP and no GBR.
- These findings provide additional radiographic and profilometric evidence that if a single failing tooth can be replaced with an implant within 8 weeks after tooth extraction (e.g., early implant placement), the benefits of ARP might be weakened.

1 | INTRODUCTION

It is well known that alveolar bone resorption occurs after tooth extraction and that resorption is more pronounced buccally than palatally/lingually.[1,2] This is clinically relevant as it may increase the need for guided bone regeneration (GBR) at or prior to implant placement.[3,4] To minimize the catabolic events that lead to alveolar ridge reduction, the concept of alveolar ridge preservation (ARP) was introduced. This concept consists of filling the extraction socket with a bone substitute material with or without applying a sealing material (e.g., membrane, matrix, autogenous graft). Recent clinical studies and systematic reviews have revealed that ARP is an effective therapeutic maneuver to attenuate dimensional changes after tooth extraction regardless of the technique.[5,6] ARP cannot completely prevent bone resorption, but it does limit its extent likely leading to a simplified and less invasive surgery.

The benefits of ARP, nonetheless, seem to depend on the timing of implant placement. In fact, a recent randomized controlled trial (RCT) tested whether ARP combined with early implant placement was able to enhance the clinical, aesthetic, and patient-reported outcomes compared to early implant placement without ARP.[3] The study found that the added value of ARP when combined with early implant placement up to 1-year post-loading is limited. For the decision-making, those findings imply that when a failing tooth could be replaced with an implant within 2 months after tooth extraction, the additional value of ARP might be clinically negligible. These conclusions are in line with the clinical recommendations of the XV European Workshop in Periodontology on the management of the extraction socket and timing of implant placement, which indicated that ARP should be considered in scenarios when "implant placement is significantly delayed after tooth extraction."[7]

One of the most frequently reported benefits of ARP is its ability to reduce the need for additional bone grafting during implant placement.[4,8–10] This may suggest that ARP can achieve comparable ridge dimensions to GBR and simultaneous implant placement while also preventing the common buccal concavity that often occurs after tooth extraction. Interestingly, the evidence to support these assumptions is sparse. The re-establishment of bone convexity has been a field of scientific interest, as buccal concavity may adversely affect aesthetic outcomes, especially in the aesthetic region (e.g., the flattening of the buccal convexity may cause a shadow at the cervical region of the implant). Solid research has demonstrated that the buccal convexity can be restored using GBR or autogenous soft tissue grafts.[11–13] However, whether the buccal convexity can be maintained solely with ARP after implant placement remains unclear. This is rather surprising considering the widespread use of ARP in clinical practice.

Hence, it is reasonable to further explore the potential additional effects of ARP on the alveolar ridge dimensions after implant placement including the maintenance of the buccal bone convexity. A recent commissioned systematic review[14] found a scarcity of studies assessing alveolar ridge changes after implant placement regardless of whether ARP was used or not. Consequently, studies investigating ARP and focusing on the buccal convexity after implant placement are also lacking. This clearly indicates a knowledge gap that has not been filled. The aim of the present study was, therefore, to assess both the radiographic and profilometric outcomes of early implant placement with or without ARP (using two different ARP techniques) after 1 year of loading.

2 | MATERIALS AND METHODS

2.1 | Study design

The study protocol of the present RCT was approved both by the Dutch Medical Ethical Committee and the Central Committee on Human Subjects (MEC-2015-016; NL49965.078.14) and registered in the Dutch trial register (NL6497). The project was conducted according to the principles of the Declaration of Helsinki. The Consolidated Standards of Reporting Trials (CONSORT) statements were used for reporting.[15] The detailed study design can be found elsewhere.[3,16] In brief, 75 patients with a failing tooth in the anterior region planned for extraction were randomly assigned (1:1:1) to the following groups:

1. **ARP-CM**: Alveolar ridge preservation using demineralized bovine bone mineral with 10% collagen (DBBM-C, Geistlich Bio-Oss® Collagen, Geistlich Pharma) and covered with a collagen matrix (CM, Geistlich Mucograft® Seal, Geistlich Pharma)
2. **ARP-PG**: ARP using DBBM-C covered with an autogenous soft tissue "punch" graft (PG) harvested from the palate.
3. **Control**: Unassisted socket healing.

2.2 | Surgical procedure and Implant placement

Early implant placement was performed in all groups 8 weeks after tooth extraction. In case of a thin remaining peri-implant buccal bone thickness (<2 mm)[17] or dehiscence at the buccal aspect, GBR was performed. This implied the coverage of the buccal aspect with locally harvested autogenous bone chips which were combined with DBBM granules (Bio-Oss®, Geistlich Pharma) and covered with a resorbable membrane (Bio-Gide®, Geistlich Pharma). Tension-free flap closure was secured with single interrupted sutures.

2.3 | Follow-up

All implants were restored with single crowns (SC) according to the preference of the referring dentist. All patients were examined 1–4 weeks after crown delivery, at 6 months, and at 1-year post-loading. Cone-beam computed tomography (CBCT) scans were taken 8 weeks after tooth extraction and 1-year post-loading (e.g., 1 year after the insertion of the final restoration).

2.4 | Radiographic analysis

The obtained DICOM files from CBCTs were imported into an image analysis software (Smop, Swissmeda-Software). To ensure consistent measurements for the CBCT analyses at the different time points, anatomic landmarks on the neighboring teeth were used. The reference points for standardization of the two-dimensional sections were established using the adjacent teeth. The sagittal section was determined by dividing the roots of adjacent teeth into two equal parts, whereas the coronal section was selected parallel to the long axis of adjacent teeth. The apico-coronal level of the section was determined by connecting a line between the residual interproximal bone of the adjacent teeth (Figure 1A). The alveolar ridge width was calculated at 3 and 5 mm below that line along with the corresponding changes over time (Figure 1B): from baseline (8 weeks after tooth extraction) to 1-year post-loading. All the measurements were performed twice by the same blinded evaluator (S.F.) with 1 week apart between the measurements. For the second occasion, 10 random patients were selected, and the intra-examiner reliability was calculated. The calibration process continued until an intra-class correlation coefficient >0.7 was achieved. Low-quality CBCT images with numerous artifacts were excluded from the final analysis because they made an accurate analysis impossible.

2.4.1 | Presence of peri-implant buccal bone

The presence of buccal bone was determined based on CBCT and dichotomized (yes/no) when 50% of the buccal bone was present in relation to the palatal/lingual bone wall.

2.4.2 | Horizontal buccal bone convexity

The buccal bone convexity at 1-year follow-up was assessed as previously described, with slight modifications.[13] The horizontal buccal bone convexity at implant sites was evaluated qualitatively (yes/no). The presence of buccal bone convexity was confirmed when the buccal bone contour at the implant exceeded a cross-sectional axial line connecting the buccal bone of the neighboring teeth (Figure 2). The presence of the convexity was measured on axial slides 3 mm apical to the alveolar crest.

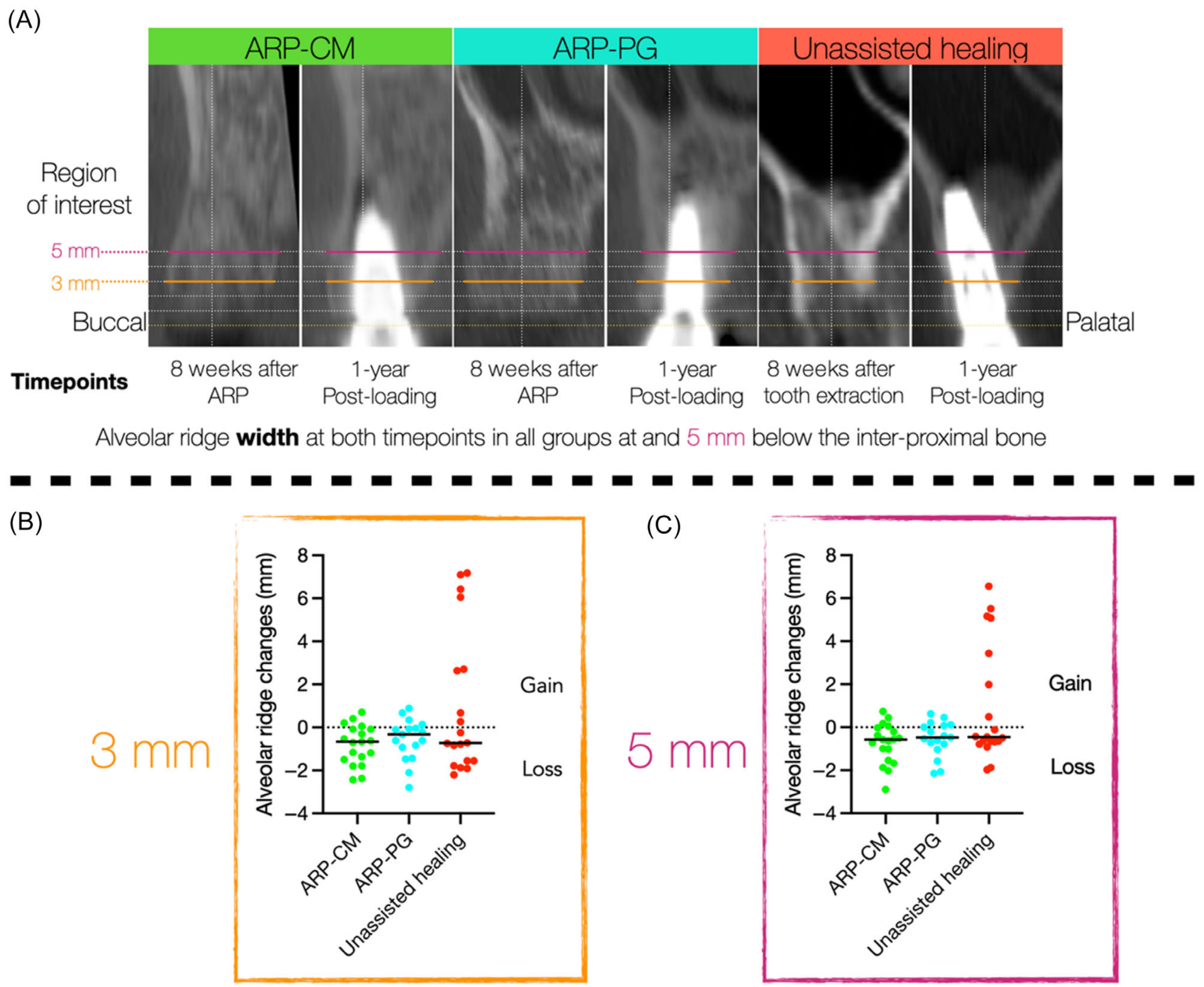

FIGURE 1 Representative cone-beam computed tomography (CBCT) of each treatment group displaying the region of interest (ROIs) at the different timepoints and the corresponding changes over time. (A) Alveolar ridge width at the ROI at both timepoints. (B) Scatterplot illustrating the changes over time at ROI 3 mm in all treatment groups. (C) Scatterplot illustrating the changes over time at ROI 5 mm in all treatment groups.

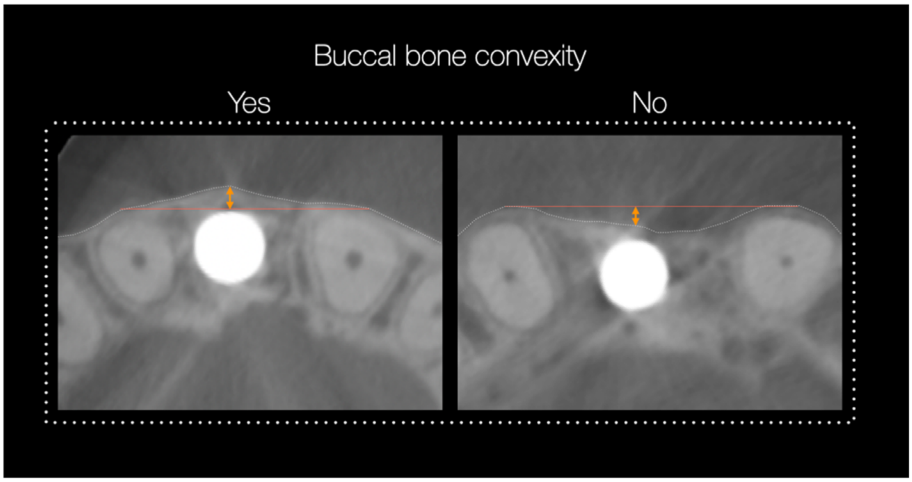

FIGURE 2 Cone beam computed tomography (CBCT) images showing two representative cases with (left) and without (right) peri-implant buccal bone convexity at 1-year follow-up.

2.5 | Profilometric analysis

2.5.1 | Contour changes

Alginate impressions were taken at baseline and 1-year post-loading, and dental casts were fabricated. Cast models were then scanned with a three-dimensional scanner (Prime scan, Dentsply Sirona). The obtained Standard Tessellation Language (STL) files were imported into an image analysis software (Smop, SWISSMEDA Software; Swissmeda AG). The surfaces of the neighboring teeth were used as reference points for the superimposition of STL data between both time points. Subsequently, a region of interest (ROI) at each implant site was defined and the contour changes between both time points were calculated.[18] The ROI was defined as a rectangular area measuring 4 mm in width and 2 mm in height, positioned ≈1 mm apical to the mid-facial mucosal margin as previously described.[3,16] The software calculated the profilometric changes and reported them in mm as the mean distance within the ROI between the two time points. The profilometric analysis was performed by a blinded examiner (S.F.), who was not involved in the surgical or prosthetic treatment.

All the measurements were performed twice by the same blinded evaluator with 1 week apart between the measurements. For the second occasion, 10 random patients were selected, and the intra-examiner reliability was calculated. The calibration process continued until an intra-class correlation coefficient >0.7 was achieved. The size of the measured area varied between sites due to individual anatomical differences but remained constant at each site over time.

2.6 | Statistical analysis

The metric variables were described as means, standard deviations, median, and quartiles. Categorical variables were described in proportions. A nonparametric Brunner–Langer model for longitudinal data was used to compare alveolar ridge changes over time between the groups. The Brunner–Langer model analysis of variance (ANOVA)-type test statistic was used to estimate the main effects involving group, time, and their interaction (group × time). The model was extended and adjusted for the presence of at least 50% of the buccal bone height (yes/no) and additional GBR during implant placement (yes/no). To compare proportions, chi-square test and Fisher's test were used. The profilometric buccal changes were compared using Kruskal–Wallis test. For the presence of bone convexity at implant sites after 1-year loading, the ARP groups (ARP-CM and ARP-PG) were merged into one group (ARP = yes/no). No corrections for multiple testing were applied. All the analyses were performed with two statistical software (SPSS version 27.0 and R Studio version 4.1.3). A p value <0.05 was considered statistically significant.

3 | RESULTS

3.1 | Study sample

Out of the 70 patients that were available for re-examination at 1-year post-loading, 55 datasets could be assessed (ARP-CM 19; ARP-PG 17; Control 19). The remainder had to be excluded due to pronounced artifacts, which did not allow accurate measurements.

3.2 | Bucco-palatal width of the alveolar ridge

The radiographic alveolar ridge dimensions at baseline and 1-year post-loading in the different groups and the changes over time are shown in Supplement Table 1. From baseline to 1-year follow-up, the median alveolar ridge width changed −0.67 mm (ARP-CM), −0.33 mm (ARP-PG), and −0.74 mm (unassisted socket healing) at 3 mm below the imaginary line that connected the interproximal bone of the neighboring teeth (Figure 1B). At 5 mm below that line, the median alveolar ridge width changed (=loss) −0.58 mm (ARP-CM), −0.48 mm (ARP-PG), and −0.46 mm (unassisted healing) (Figure 1C).

Based on Brunner–Langer modeling, all these changes (at 3 and 5 mm) were significant over time ($p < 0.05$) (Supplement Tables 2 and 3). At 3 mm, the model indicated a trend toward interaction (group × time, $p = 0.06$) (Supplement Table 2), suggesting differences in both the magnitude and pattern of changes among the groups. Specifically, the unassisted healing group tended to behave differently from the ARP groups. At 5 mm, the model showed a similar trend toward interaction (group × time, $p = 0.081$) (Supplement Table 3), suggesting a different behavior of the unassisted healing group compared to ARP groups. To investigate this distinct behavior/pattern and exclude possible confounder factors such as additional GBR and the residual buccal bone height at implant placement, both confounders were considered in remaining analyses.

3.3 | Radiographic changes of alveolar ridge width based upon additional GBR

Twenty-four (43.3%) out of the 55 patients analyzed received additional GBR at implant placement; 6 (31.6%) out of 19 individuals in the ARP-CM group, 5 (29.4%) out of 17 individuals in the ARP-PG group, and 13 (68.4%) out of 19 individuals in the unassisted healing group. The alveolar ridge changes between baseline and 1-year post-loading, stratified by additional GBR, are shown in Table 1.

After adjusting for additional GBR, the results revealed that GBR tended to influence the changes over time ($p = 0.07$) (Supplement Table 4). In addition, the same model revealed two-way interactions (treatment × GBR, $p < 0.001$ and GBR × time, $p = 0.00$) (Supplement Table 4). These interactions suggest that the magnitude of changes in the alveolar ridge depended on whether GBR was performed; when

TABLE 1 ARW at the different regions of interest (−3 and −5 mm) at 8 weeks after tooth extraction (*T*1) and 1-year post-loading (*T*2) and the corresponding changes over time (Δ*T*2 − *T*1) stratified by the performance of GBR.

			ARP-CM		ARP-PG		Control (Unassisted socket healing)	
			Mean (SD) (mm)	Median (Q1, Q3) (mm)	Mean (SD) (mm)	Median (Q1, Q3) (mm)	Mean (SD) (mm)	Median (Q1, Q3) (mm)
GBR		Time point						
Yes	ARW − 3 mm	*N*	6		5		13	
		*T*1	8.99 (1.09)	8.66 (8.31, 9.46)	8.14 (2.08)	8.49 (6.35, 9.77)	5.07 (3.13)	5.96 (1.77, 8.05)
		*T*2	8.32 (1.08)	8.72 (7.28, 9.13)	8.16 (1.81)	8.38 (6.49, 9.72)	7.27 (1.28)	7.50 (6.36, 7.96)
		Δ*T*2 − *T*1	−0.67 (1.20)	−0.38 (−1.98, 0.33)	0.01 (0.56)	−0.11 (−0.43, 0.51)	2.20 (3.37)	0.68 (−.76, 6.24)
No	ARW − 3 mm	*N*	13		12		6	
		*T*1	8.52 (1.82)	8.96 (7.14, 9.46)	8.47 (1.39)	8.66 (7.69, 9.52)	10.74 (1.21)	10.73 (9.67, 12.00)
		*T*2	7.65 (1.63)	7.50 (6.51, 8.36)	7.67 (1.22)	7.88 (6.44, 8.49)	9.10 (1.33)	9.28 (8.16, 10.13)
		Δ*T*2 − *T*1	−0.87 (0.80)	−0.71 (−1.43, −0.20)	−0.81 (1.02)	−0.73 (−1.47, −0.06)	−1.64 (0.50)	−1.72 (−1.98, −1.36)
Yes	ARW − 5 mm	*N*	6		5		13	
		*T*1	9.67 (1.10)	9.56 (8.62, 10.49)	9.61 (1.26)	9.67 (8.57, 10.61)	6.25 (2.79)	6.74 (3.33, 9.01)
		*T*2	9.12 (0.91)	9.49 (8.29, 9.75)	9.57 (1.14)	9.61 (8.55, 10.56)	8.09 (1.38)	7.85 (6.88, 8.99)
		Δ*T*2 − *T*1	−0.55 (1.17)	−0.27 (−1.92, 0.51)	−0.04 (0.40)	0.07 (−0.42, 0.28)	1.84 (2.93)	0.48 (−0.55; 5.11)
No	ARW − 5 mm	*N*	13		12		5	
		*T*1	9.30 (1.97)	9.24 (8.27, 10.29)	9.20 (1.15)	9.06 (8.54, 10.21)	10.77 (1.04)	11.00 (9.78, 11.66)
		*T*2	8.46 (1.92)	7.89 (7.55, 9.26)	8.46 (1.13)	8.58 (7.90, 9.08)	9.87 (1.44)	10.26 (8.82, 10.87)
		Δ*T*2 − *T*1	−0.85 (0.82)	−0.64 (−1.29, −0.30)	−0.74 (0.86)	−0.63 (−1.45, −0.10)	−0.90 (0.49)	−0.73 (−1.16, −0.62)

Abbreviations: ARP, alveolar ridge preservation; ARW, alveolar ridge width; CM, collagen matrix; GBR, guided bone regeneration; PG, palatal graft; SD, standard deviation.

GBR was performed the changes were attenuated, as indicated by differences in the slopes difference of the lines (nonparallel slopes) (Figure 3A). This influence was particularly pronounced in the unassisted healing group: additional GBR (light blue lines) led to bone increase, whereas no GBR caused bone decrease (Figure 3A).

At the second ROI (5 mm below the imaginary line that connected the interproximal bone of the neighboring teeth), a similar picture emerged. The adjusted model failed to reveal a significant influence of additional GBR on the overall changes ($p = 0.39$) (Supplement Table 5). Nevertheless, the model exhibited two-way interactions (treatment × GBR, $p < 0.00$ and GBR × time, $p = 0.00$) (Supplement Table 5). These interactions indicate that the changes of the alveolar ridge were influenced by GBR, as indicated by the slope difference of the lines (nonparallel slopes) (Figure 3B). This influence was stronger in the unassisted healing group; additional GBR (light blue lines) increased bone, whereas no GBR (light red lines) decreased bone (Figure 3B).

3.4 | Radiographic changes in the bucco-palatal width of the alveolar ridge based upon the residual buccal bone wall height at baseline

The residual buccal bone height was dichotomized into <50% and ≥50% of the original height. Out of the total sample, 15 out of 19 individuals in the ARP-CM group, 14 out of 17 individuals in the ARP-PG group, and 11 out of 19 individuals in the Control unassisted healing group had a residual buccal bone wall height that exceeded 50% of the original height. The alveolar ridge changes between baseline and 1-year post-loading, stratified by the residual buccal bone wall height, are shown in Table 2. After adjusting for the residual buccal bone height, the results revealed a significant impact of the residual buccal bone height on the changes over time ($p = 0.02$) (Supplement Table 6). In addition, the same model revealed a three-way interaction (treatment × residual-wall × time; $p = 0.04$) (Supplement Table 6). This indicates that the magnitude of changes in the alveolar ridge varied between the groups over time in relation to the heights of available residual buccal bone. This influence was stronger in the unassisted healing group, as demonstrated by the opposite direction of the slope in the line plots (nonparallel slopes): patients with minimal buccal bone experienced bone gain over time, whereas patients with higher residual buccal bone height exhibited bone loss over time (Figure 4A).

At the second ROI (5 mm below the imaginary line that connected the interproximal bone of the neighboring teeth), a similar pattern emerged, although less robust. The results failed to reveal a significant influence of the residual buccal wall height on the overall changes ($p = 0.13$) (Supplement Table 7). Nonetheless, a significant three-way interaction (treatment × buccal_wall × time; $p = 0.04$) (Supplement Table 7) was still observed. This means that the magnitude of changes in the alveolar ridge varied between the groups over time, relative to the amount of residual buccal bone height available:

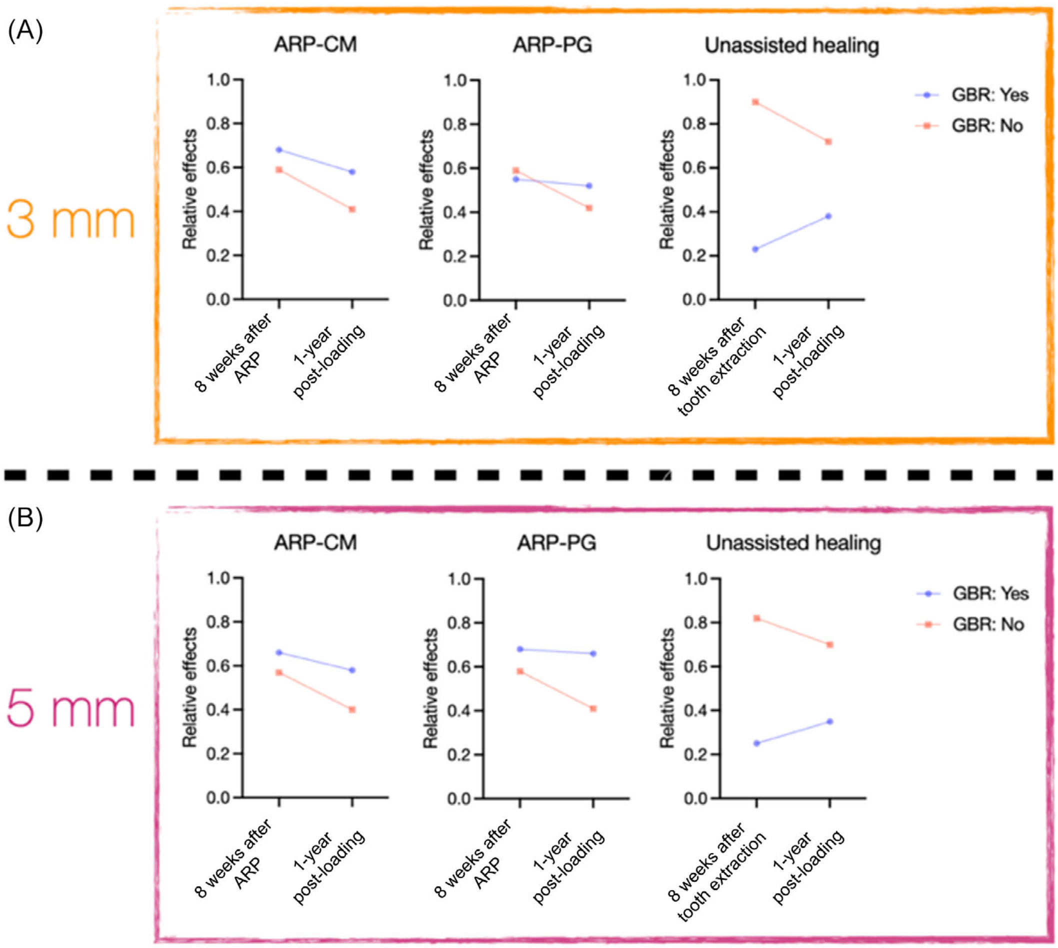

FIGURE 3 Line plots derived from the from the Brunner–Langer model indicating the relative effect of guided bone regeneration (GBR) on the residual buccal bone height over time on alveolar ridge width in all treatment groups at 3 mm (A) and 5 mm (B). Light blue lines indicate patients that underwent GBR, whereas light red lines indicate patients with no GBR. Differences were calculated using analysis of variance (ANOVA)-type statistics (Brunner–Langer). A relative effect is the probability that the value of the score of a patient from a certain group at a certain time is greater than that of a patient randomly selected from the global sample.

an increase in bone in patients with a residual buccal bone <50% (light red lines) and a decrease in those with ≥50% (light blue lines) (Figure 4B).

3.5 | Horizontal buccal bone convexity at implant sites after 1-year loading

In patients with ARP (group ARP-CM or ARP-PG) without additional GBR, the presence of bone convexity amounted to 36.0% (9/25) at 1-year post-loading. For patients that received ARP and additional GBR at implant placement the frequency of bone convexity increased to 72.7% (8 of 11) (intergroup $p = 0.042$).

In patients with unassisted healing and without GBR, the presence of the bone convexity amounted to 66.7% (4/6) at 1-year follow-up. In patients with unassisted healing receiving GBR at implant placement, the frequency of bone convexity amounted to 61.5% (8/13) at 1-year follow-up (intergroup $p = 0.829$).

3.6 | Profilometric analysis: Buccal contour changes

The median changes in buccal ridge contour between baseline and 1-year post-loading amounted to 0.14 mm (*Q*1: −0.12, *Q*3: 0.53) in ARP-CM, to 0.15 mm (*Q*1: −0.15, *Q*3: 0.63) in ARP-PG and to 0.26 mm (*Q*1: 0.03, *Q*3: 1.04) in the unassisted healing group (inter-group comparison: $p = 0.295$) (Figure 5). The buccal changes stratified according to GBR residual buccal bone height and additional GBR are presented in Tables 3 and 4, respectively.

4 | DISCUSSION

The present clinical study assessing the radiographic and profilometric outcomes of early implant placement with or without ARP (using two different sealing techniques) after 1 year of loading predominantly revealed:

TABLE 2 ARW at the different regions of interest (−3 and −5 mm) at 8 weeks after tooth extraction ($T1$) and 1-year post-loading ($T2$) and the corresponding changes over time ($\Delta T2 - T1$) stratified by the residual buccal bone.

			ARP-CM		ARP-PG		Unassisted socket healing	
			Mean (SD) (mm)	Median (Q1, Q3) (mm)	Mean (SD) (mm)	Median (Q1,Q3) (mm)	Mean (SD) (mm)	Median (Q1, Q3) (mm)
Residual buccal bone		Time point						
≥50%	ARW −3 mm	N	15		14		11	
		$T1$	8.79 (1.77)	8.89 (7.81, 9.57)	8.51 (1.35)	8.66 (7.78, 9.26)	9.34 (1.87)	8.99 (7.87, 11.0)
		$T2$	8.03 (1.50)	8.05 (7.09, 8.76)	7.92 (1.40)	8.10 (6.62, 8.95)	8.17 (1.47)	7.63 (6.79, 9.41)
		$\Delta T2 - T1$	−0.76 (0.83)	−0.63 (−1.36; −0.09)	−0.59 (0.89)	−0.48 (−1.06; −0.01)	−1.16 (0.87)	−1.56 (−1.87; −0.73)
<50%	ARW −3 mm	N	4		3		8	
		$T1$	8.21 (0.85)	8.28 (7.38, 8.97)	7.74 (2.61)	8.49 (4.83, NA)	3.45 (2.96)	2.33 (1.41, 5.78)
		$T2$	7.23 (1.45)	7.14 (5.89, 8.67)	7.29 (1.40)	7.78 (5.72, NA)	7.39 (1.59)	7.64 (6.28, 8.56)
		$\Delta T2 - T1$	−0.97 (1.33)	−1.08 (−2.20, 0.36)	−0.44 (1.53)	−0.11 (−2.11, NA)	3.94 (3.16)	4.38 (0.86, 6.92)
≥50%	ARW −5 mm	N	15		14		11	
		$T1$	9.45 (1.84)	9.33 (8.59, 9.79)	9.30 (1.12)	9.30 (8.63, 9.93)	9.76 (1.48)	9.44 (8.73, 11.39)
		$T2$	8.82 (1.74)	9.01 (7.57, 9.67)	8.78 (1.28)	8.80 (7.90, 9.60)	8.92 (1.60)	8.79 (7.32, 10.68)
		$\Delta T2 - T1$	−0.62 (0.81)	−0.58 (−1.02, 0.06)	−0.52 (0.73)	−0.51 (−0.85; 0.08)	−0.84 (0.57)	−0.66 (−0.92, −0.50)
<50%	ARW −5 mm	N	4		3		8	
		$T1$	9.32 (1.38)	9.35 (7.99, 10.62)	9.41 (1.57)	10.21 (7.60, NA)	4.81 (2.60)	4.28 (2.39, 6.64)
		$T2$	8.07 (1.41)	8.21 (6.65, 9.35)	8.80 (1.05)	8.36 (8.05, NA)	8.27 (1.63)	8.29 (7.02, 9.25)
		$\Delta T2 - T1$	−1.25 (1.27)	−1.03 (−2.56, −0.15)	−0.61 (1.31)	−0.21 (−2.07, NA)	3.47 (2.55)	4.25 (0.86, 5.42)

Abbreviations: ARP, alveolar ridge preservation; ARW, alveolar ridge width; CM, collagen matrix; PG, palatal graft; SD, standard deviation.

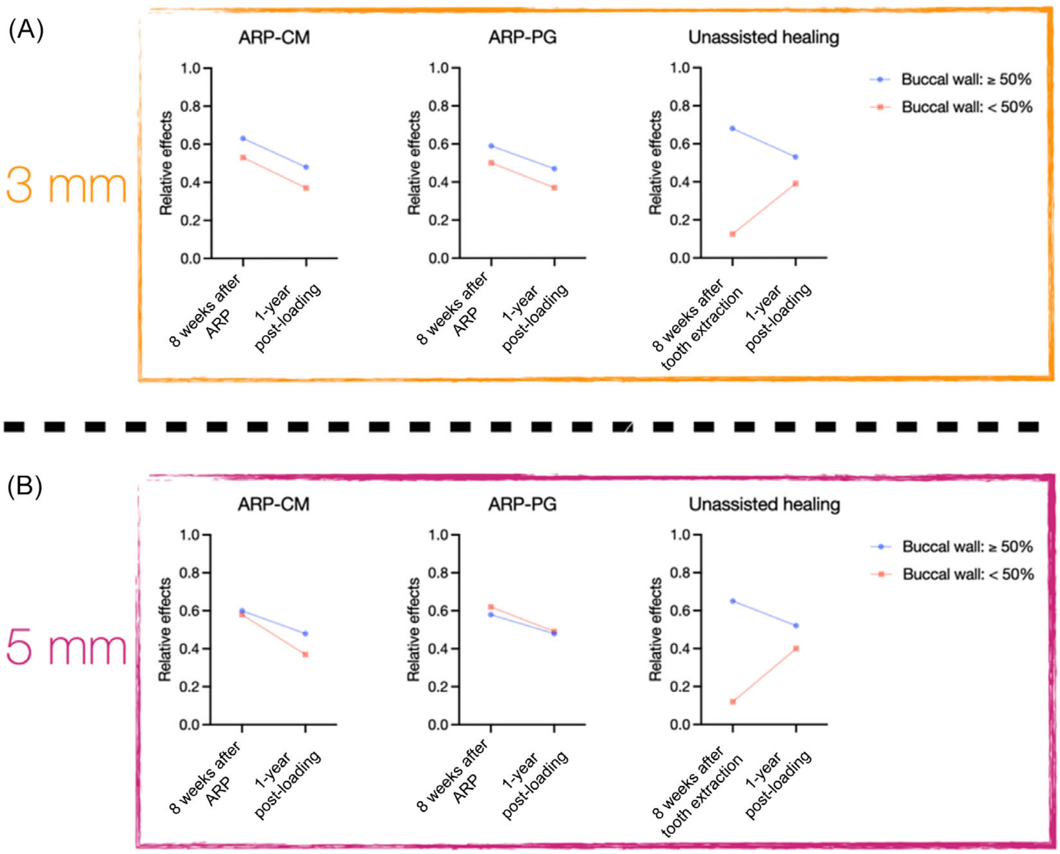

FIGURE 4 Line plots derived from the from the Brunner–Langer model indicating the relative effect of the residual buccal bone height over time on alveolar ridge width in all treatment groups at 3 mm (A) and 5 mm (B). Light blue lines indicate patients with a residual buccal bone height <50%, whereas light red line indicate patients with a residual buccal bone height ≥50%. Differences were calculated using analysis of variance (ANOVA)-type test (Brunner–Langer). A relative effect is the probability that the value of the score of a patient from a certain group at a certain time is greater than that of a patient randomly selected from the global sample.

FIGURE 5 Scatterplot illustrating the profilometric changes at the region of interest in all treatment groups between 8 weeks after tooth extraction and 1-year post-loading. Differences were tested using Kruskal–Wallis test.

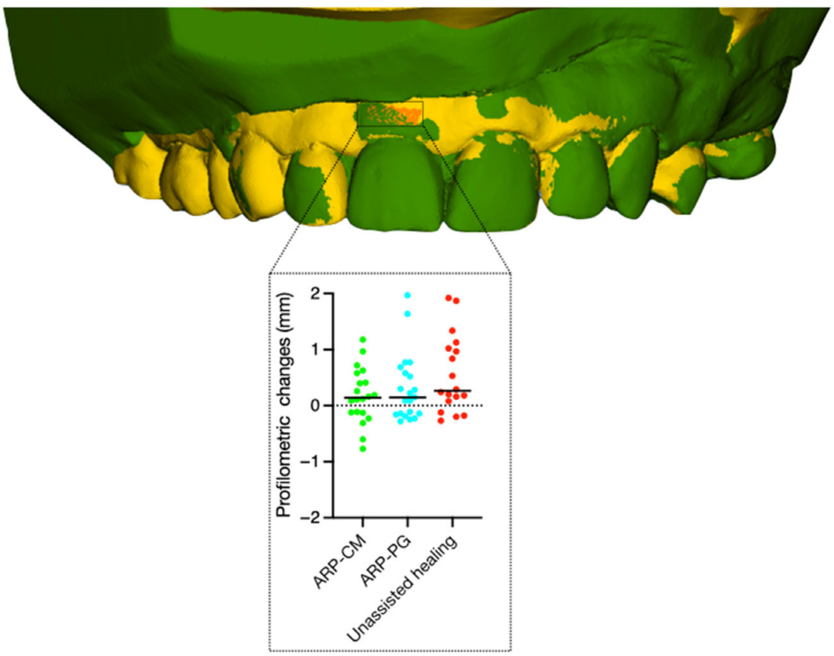

TABLE 3 Profilometric buccal changes (Δ$T2 - T1$) between 8 weeks after tooth extraction and 1-year post-loading stratified by the performance of GBR.

GBR		ARP-CM		ARP-PG		Unassisted socket healing	
		Mean (SD) (mm)	Median (Q1, Q3) (mm)	Mean (SD) (mm)	Median (Q1, Q3) (mm)	Mean (SD) (mm)	Median (Q1, Q3) (mm)
	Time point						
Yes	*N*	6		5		12	
	Δ$T2 - T1$	0.44 (0.46)	0.41 (0.14; 0.77)	0.45 (0.87)	0.22 (−0.13; 1.14)	0.81 (0.71)	0.91 (0.17; 1.29)
No	*N*	12		10		5	
	Δ$T2 - T1$	0.05 (0.51)	−0.01 (−0.27; 0.48)	0.44 (0.70)	0.30 (−0.21, 0.93)	0.03 (0.25)	0.08 (−0.24; 0.27)

Abbreviations: ARP, alveolar ridge preservation; CM, collagen matrix; GBR, guided bone regeneration; PG, palatal graft; SD, standard deviation.

TABLE 4 Profilometric buccal changes (Δ$T2 - T1$) between 8 weeks after tooth extraction and 1-year post-loading stratified by the residual buccal bone.

Residual buccal bone		ARP-CM		ARP-PG		Unassisted socket healing	
		Mean (SD) (mm)	Median (Q1, Q3) (mm)	Mean (SD) (mm)	Median (Q1, Q3) (mm)	Mean (SD) (mm)	Median (Q1, Q3) (mm)
	Time point						
≥50%	*N*	14		12		10	
	Δ$T2 - T1$	0.11 (0.44)	0.10 (−0.16, 0.40)	0.07 (0.32)	−0.01 (−0.16; 0.20)	0.48 (0.81)	0.20 (−0.14, 1.10)
<50%	*N*	4		3		7	
	Δ$T2 - T1$	0.45 (0.75)	0.61 (−0.31, 1.04)	1.01 (0.86)	0.77 (0.30, NA)	0.71 (0.55)	0.97 (0.18, 1.13)

Abbreviations: ARP, alveolar ridge preservation; CM, collagen matrix; PG, palatal graft; SD, standard deviation.

1. Attenuation of the alveolar ridge changes by ARP.
2. Greater gains in the alveolar ridge width by GBR compared to ARP.
3. A significant influence of the residual buccal bone height on the subsequent alveolar ridge changes.
4. The limited capacity of ARP compared to GBR to maintain the buccal bone convexity.
5. A tendency toward agreement between profilometric and radiographic outcomes.

Most studies on ARP have primarily focused on changes in alveolar ridge dimensions up to implant placement, neglecting the changes that take place afterwards. The present study revealed that ARP without additional GBR was able to attenuate the changes in alveolar ridge dimensions at 1-year post-loading compared to unassisted healing sites (ARP-CM −0.8 mm; ARP-PG −0.8 mm; and unassisted socket healing −1.6 mm). It is important to note that the comparison with other datasets is limited due to the lack of studies examining alveolar ridge changes after implant placement.[14] In addition, ARP has traditionally been combined with delayed loading, not with early implant placement. Nevertheless, in relative terms, the present study showed that ARP was able to attenuate alveolar ridge changes by ≈50% at 1-year post-loading. This finding aligns with the current evidence supporting ARP as an effective therapy for mitigating alveolar ridge changes following tooth extraction.[5,19]

Interestingly, when comparing only the groups that received GBR at implant placement, the unassisted socket healing with GBR was the only one that exhibited gains in the alveolar ridge. One possible explanation for this finding is that the unassisted healing group had a higher proportion of cases where GBR was performed at implant placement compared to the ARP group. Specifically, in both ARP groups, about 30% of cases required additional GBR, whereas approximately 70% of cases in the unassisted healing group did not. Clinically, there is a tendency to over-augment during GBR procedures to offset for potential bone graft resorption during the healing period.[20] Conversely, the goal of ARP is to preserve the alveolar ridge rather than to augment it. More recently, it has also been hypothesized that there is an individual phenotypic dimension.[21] This individual phenotype may limit bone augmentation and might potentially explain variations among different group of individuals, as presently observed. In theory, any augmentation beyond this individual phenotypic boundary will inevitably resorb, causing the alveolar ridge to return to its original or phenotypic dimension.[21]

The superior gains with GBR compared to ARP can further be explained by anatomical factors, such as the height of residual buccal bone. In fact, when patients were stratified based on the height of the residual buccal bone, those in the unassisted group who lacked intact buccal bone demonstrated the greatest gains in the alveolar ridge. Once again, this is likely due to the tendency to extend the augmentation beyond the boundaries of the extraction socket during GBR procedures.[20] This commonly occurs in cases where peri-implant dehiscences are present. In such cases, clinicians often augment beyond the bony envelope, whereas when the buccal bone is intact, bone grafting is primarily performed within the bony envelope. Previous clinical studies including in damaged sockets, have highlighted the significance of residual buccal bone height and the amount of newly formed bone.[22–24]

The re-establishment of bone convexity has been a field of scientific interest, as an alveolar process deficiency may adversely affect aesthetic outcomes, especially in the aesthetic region. At 1-year post loading, the presence of buccal bone convexity amounted to approximately 36% in patients that only received ARP (and no additional GBR). Notably, by performing additional GBR the presence of bone convexity increased up to 70%. Although recent RCTs have demonstrated that GBR can effectively restore the buccal convexity,[11–13] this is the first RCT that has examined whether ARP can maintain buccal convexity over time (1-year post loading) after implant placement. Clinicians should be aware that although ARP can reduce the need for additional bone grafting at implant placement, it might be insufficient to restore the buccal bone convexity.

Profilometric outcomes presented a similar trend to radiographic results but were less robust. This is not unexpected as soft tissue may account for only 40% of the final volume[25] and thus may have compensated for the pronounced differences found in the underlying bone.[26,27] A recent RCT examined whether the healing time (3, 6, or 9 months) influenced the profilometric and radiographic outcomes after alveolar ridge preservation. The authors detected differences in radiographic outcomes, but these differences were not significant in the profilometric assessments. This further underscores the notion that profilometric changes may be less robust compared to radiographic changes, in accordance with the current findings.[28] Moreover, a recent case series evaluated periodontal phenotype characteristics on post-extraction dimensional changes of the alveolar ridge.[29] The authors found significant associations between baseline bone characteristics and subsequent bone changes, but they did not find such significant associations with profilometric outcomes, consistent with the present observations. Nevertheless, the unassisted healing group clearly showed a higher tendency to exhibit the greater gains than the ARP groups. As previously mentioned, this might be explained by the higher frequency of GBR in this particular group (unassisted healing), which led to a more frequent over augmentation (due to GBR) and therefore greater gains.

When considering early implant placement, the question arises: is ARP a suitable recommendation? On one hand, ARP reduces the need for additional GBR, thereby simplifying the surgical procedure. GBR, in general, is a more demanding and invasive technique (e.g., flap elevation, releasing incision). In addition, ARP has shown the ability to mitigate longer-term alveolar ridge changes. On the other hand, ARP may not fully restore the buccal convexity, and its capacity for bone augmentation is rather limited. Furthermore, there is a considerable variability and uncertainty in the reduction of additional GBR at early implant placement and the need for additional GBR is inherently associated with an increased cost burden for the patient. A very recent systematic review on complications and cost-efficacy in ARP suggested that the need for additional GBR following ARP indicates that the desired outcomes of ARP were not achieved.[8] This raises concerns about justifying a "nothing-to-lose" approach (e.g., perform ARP in every case). Indeed, it has recently been suggested that in specific scenarios such as type 2 implant placement (e.g., 6–8 weeks after tooth extraction) ARP might be considered overtreatment[30] with limited additional clinical value.[3] Nevertheless, the ultimate decision depends on the practitioner's preference and clinical judgment.

Some limitations should be acknowledged when interpreting the present findings: (i) not all 75 patients could be included in the analyses. (ii) The present findings are secondary outcomes thus remaining as exploratory. (iii) lack of clinician's reported outcomes: many clinicians may select their treatment protocol based on their own experience and preference, but this was not evaluated in the present study and has been somewhat overlooked in clinical research. (iv) Inherent variability of the sites. (v) Different concepts: Although GBR and ARP share a similar therapeutic goal (e.g., adequate ridge dimensions) they are distinct concepts and not entirely comparable. GBR can be performed at various stages (primary augmentation or simultaneously) and its principles are well established. In contrast, ARP is carried out immediately after tooth extraction, but the underlying physiological are yet to be fully understood.

5 | CONCLUSIONS

Early implant placement with ARP can attenuate alveolar changes at 1-year post loading by minimizing both radiographic and profilometric alterations. However, early implant placement with simultaneous GBR consistently yields superior radiographic and profilometric outcomes, regardless of whether ARP is performed.

AUTHOR CONTRIBUTIONS

All authors made substantial contributions to conception and design of the study. Franz Josef Strauss, Brend Jonker, Eppo Wolvius, Justin Pijpe, Nadja Naenni, and Ronald Jung were involved in data collection and data analysis. Franz Josef Strauss, Shunsuke Fukuba, and Nadja Naenni interpreted the data and drafted the manuscript. All authors critically revised the draft and approved the final version.

ACKNOWLEDGMENT

Implants were provided by Straumann AG and biomaterials by Geistlich Pharma AG.

CONFLICT OF INTEREST STATEMENT

The authors declare no conflicts of interest.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request.

ORCID

Franz Josef Strauss https://orcid.org/0000-0002-5832-7327
Shunsuke Fukuba https://orcid.org/0000-0002-1066-7541
Nadja Naenni https://orcid.org/0000-0002-6689-2684
Brend Jonker https://orcid.org/0000-0003-0100-3871

REFERENCES

1. Araujo MG, Lindhe J. Dimensional ridge alterations following tooth extraction. An experimental study in the dog. *J Clin Periodontol*. 2005;32(2):212-218. doi:10.1111/j.1600-051X.2005.00642.x
2. Schropp L, Wenzel A, Kostopoulos L, Karring T. Bone healing and soft tissue contour changes following single-tooth extraction: a clinical and radiographic 12-month prospective study. *Int J Periodontics Restorative Dent*. 2003;23(4):313-323.
3. Jonker BP, Strauss FJ, Naenni N, Jung RE, Wolvius EB, Pijpe J. Early implant placement with or without alveolar ridge preservation in single tooth gaps renders similar esthetic, clinical and patient-reported outcome measures: one-year results of a randomized clinical trial. *Clin Oral Implants Res*. 2021;32(9):1041-1051. doi:10.1111/clr.13796
4. Thoma DS, Bienz SP, Lim HC, Lee WZ, Hammerle CHF, Jung RE. Explorative randomized controlled study comparing soft tissue thickness, contour changes, and soft tissue handling of two ridge preservation techniques and spontaneous healing two months after tooth extraction. *Clin Oral Implants Res*. 2020;31(6):565-574. doi:10.1111/clr.13594
5. Avila-Ortiz G, Chambrone L, Vignoletti F. Effect of alveolar ridge preservation interventions following tooth extraction: a systematic review and meta-analysis. *J Clin Periodontol*. 2019;46(suppl 21):195-223. doi:10.1111/jcpe.13057
6. Avila-Ortiz G, Gubler M, Romero-Bustillos M, Nicholas CL, Zimmerman MB, Barwacz CA. Efficacy of alveolar ridge preservation: a randomized controlled trial. *J Dent Res*. 2020;99(4):402-409. doi:10.1177/0022034520905660
7. Tonetti MS, Jung RE, Avila-Ortiz G, et al. Management of the extraction socket and timing of implant placement: consensus report and clinical recommendations of group 3 of the XV European Workshop in Periodontology. *J Clin Periodontol*. 2019;46(suppl 21):183-194. doi:10.1111/jcpe.13131
8. Barootchi S, Tavelli L, Majzoub J, Stefanini M, Wang HL, Avila-Ortiz G. Alveolar ridge preservation: complications and cost-effectiveness. *Periodontol 2000*. 2023;92:235-262. doi:10.1111/prd.12469
9. Couso-Queiruga E, Mansouri CJ, Alade AA, Allareddy TV, Galindo-Moreno P, Avila-Ortiz G. Alveolar ridge preservation reduces the need for ancillary bone augmentation in the context of implant therapy. *J Periodontol*. 2022;93(6):847-856. doi:10.1002/JPER.22-0030
10. Jung RE, Ioannidis A, Hammerle CHF, Thoma DS. Alveolar ridge preservation in the esthetic zone. *Periodontol 2000*. 2018;77(1):165-175. doi:10.1111/prd.12209
11. Bouckaert E, De Bruyckere T, Eghbali A, Younes F, Wessels R, Cosyn J. A randomized controlled trial comparing guided bone regeneration to connective tissue graft to re-establish buccal convexity at dental implant sites: three-year results. *Clin Oral Implants Res*. 2022;33(5):461-471. doi:10.1111/clr.13906
12. De Bruyckere T, Cosyn J, Younes F, et al. A randomized controlled study comparing guided bone regeneration with connective tissue graft to re-establish buccal convexity: one-year aesthetic and patient-reported outcomes. *Clin Oral Implants Res*. 2020;31(6):507-516. doi:10.1111/clr.13587
13. De Bruyckere T, Eeckhout C, Eghbali A, et al. A randomized controlled study comparing guided bone regeneration with connective tissue graft to re-establish convexity at the buccal aspect of single implants: a one-year CBCT analysis. *J Clin Periodontol*. 2018;45(11):1375-1387. doi:10.1111/jcpe.13006
14. Monje A, Roccuzzo A, Buser D, Wang HL. Influence of buccal bone wall thickness on the peri-implant hard and soft tissue dimensional changes: a systematic review. *Clin Oral Implants Res*. 2023;34(3):157-176. doi:10.1111/clr.14029
15. Moher D, Hopewell S, Schulz KF, et al. CONSORT 2010 explanation and elaboration: updated guidelines for reporting parallel group randomised trials. *J Clin Epidemiol*. 2010;63(8):e1-e37. doi:10.1016/j.jclinepi.2010.03.004
16. Jonker BP, Gil A, Naenni N, Jung RE, Wolvius EB, Pijpe J. Soft tissue contour and radiographic evaluation of ridge preservation in early implant placement: a randomized controlled clinical trial. *Clin Oral Implants Res*. 2021;32(1):123-133. doi:10.1111/clr.13686
17. Grunder U, Gracis S, Capelli M. Influence of the 3-D bone-to-implant relationship on esthetics. *Int J Periodontics Restorative Dent*. 2005;25(2):113-119.
18. Sanz Martin I, Benic GI, Hammerle CH, Thoma DS. Prospective randomized controlled clinical study comparing two dental implant types: volumetric soft tissue changes at 1 year of loading. *Clin Oral Implants Res*. 2016;27(4):406-411. doi:10.1111/clr.12579
19. MacBeth N, Trullenque-Eriksson A, Donos N, Mardas N. Hard and soft tissue changes following alveolar ridge preservation: a systematic review. *Clin Oral Implants Res*. 2017;28(8):982-1004. doi:10.1111/clr.12911
20. Naenni N, Lim HC, Papageorgiou SN, Hammerle CHF. Efficacy of lateral bone augmentation prior to implant placement: a systematic review and meta-analysis. *J Clin Periodontol*. 2019;46(suppl 21):287-306. doi:10.1111/jcpe.13052
21. Quirynen M, Lahoud P, Teughels W, et al. Individual "alveolar phenotype" limits dimensions of lateral bone augmentation. *J Clin Periodontol*. 2023;50(4):500-510. doi:10.1111/jcpe.13764
22. Koo TH, Song YW, Cha JK, Jung UW, Kim CS, Lee JS. Histologic analysis following grafting of damaged extraction sockets using deproteinized bovine or porcine bone mineral: a randomized clinical trial. *Clin Oral Implants Res*. 2020;31(1):93-102. doi:10.1111/clr.13557
23. Lee JS, Park JY, Chung HM, Song YW, Strauss FJ. Vertical ridge augmentation feasibility using unfixed collagen membranes and particulate bone substitutes: a 1- to 7-year retrospective single-cohort observational study. *Clin Implant Dent Relat Res*. 2022;24(3):372-381. doi:10.1111/cid.13084
24. Park JY, Chung HM, Strauss FJ, Lee JS. Dimensional changes after horizontal and vertical guided bone regeneration without membrane fixation using the retentive flap technique: a 1-year retrospective study. *Clin Implant Dent Relat Res*. 2023;25:871-880. doi:10.1111/cid.13237
25. Schneider D, Schmidlin PR, Philipp A, et al. Labial soft tissue volume evaluation of different techniques for ridge preservation after tooth extraction: a randomized controlled clinical trial. *J Clin Periodontol*. 2014;41(6):612-617. doi:10.1111/jcpe.12246
26. 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(12 suppl):195S-201S. doi:10.1177/0022034513506713
27. Chappuis V, Engel O, Shahim K, Reyes M, Katsaros C, Buser D. Soft tissue alterations in esthetic postextraction sites: a 3-dimensional analysis. *J Dent Res*. 2015;94(9 suppl):187S-193S. doi:10.1177/0022034515592869
28. Couso-Queiruga E, Weber HA, Garaicoa-Pazmino C, et al. Influence of healing time on the outcomes of alveolar ridge preservation using a collagenated bovine bone xenograft: a randomized clinical trial. *J Clin Periodontol*. 2023;50(2):132-146. doi:10.1111/jcpe.13744
29. Couso-Queiruga E, Graham ZA, Peter T, Gonzalez-Martin O, Galindo-Moreno P, Avila-Ortiz G. Effect of periodontal phenotype

characteristics on post-extraction dimensional changes of the alveolar ridge: a prospective case series. *J Clin Periodontol*. 2023;50(5):694-706. doi:10.1111/jcpe.13781
30. Mardas N, Macbeth N, Donos N, Jung RE, Zuercher AN. Is alveolar ridge preservation an overtreatment? *Periodontol 2000*. 2023. Online ahead of print. doi:10.1111/prd.12508

SUPPORTING INFORMATION

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

How to cite this article: Strauss FJ, Fukuba S, Naenni N, et al. Alveolar ridge changes 1-year after early implant placement, with or without alveolar ridge preservation at single-implant sites in the aesthetic region: A secondary analysis of radiographic and profilometric outcomes from a randomized controlled trial. *Clin Implant Dent Relat Res*. 2024;1-13. doi:10.1111/cid.13297