Received: 24 January 2022 | Revised: 22 March 2022 | Accepted: 10 April 2022

DOI: 10.1111/cid.13095

ORIGINAL ARTICLE

WILEY

Effect of the buccal gap width following immediate implant placement on the buccal bone wall: A retrospective cone-beam computed tomography analysis

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Abstract

Background: The effect of the buccal gap width on the clinical outcome of socket graft and immediate implant placement (IIP) at maxillary central incisor sites has not been investigated. Thus, the aim of the present study was to evaluate the effect of the width of the buccal gap on the thickness of the newly formed buccal wall.

Methods: Forty-two patients and 51 maxillary central incisor sites treated with IIP and ridge preservation by means of graft of the buccal gap at the maxillary central incisor region were included in the study. The width of the buccal gap was measured and filled with deproteinized bovine bone mineral. Implant sites were divided into two groups: wide gap (WG, >2 mm; $n = 34$) and narrow gap (NG, ≤2 mm; $n = 17$). After at least 1 year in function (5 ± 4), CBCT scans were obtained and assessed by a calibrated examiner. The thickness of the buccal and palatal bone walls, the percentage of the implant height covered by bone in the buccal and palatal aspects and the position of the buccal and palatal crests were compared between the two groups. A linear regression model was performed to assess predictors of the thickness of the buccal bone.

Results: The buccal bone was significantly thicker in the WG group than the NG group at all levels observed (overall 1.9 ± 0.9 mm and 0.5 ± 0.6 mm, respectively). The thickness of the palatal bone was similar between both groups (>2 mm). The percentage of the implant height covered by bone at the buccal aspect was significantly higher in the WG group (95 ± 16.6%) than in the NG group (59.4 ± 42.3%). The position of the buccal crest in relation to the implant shoulder was significantly more coronal (0.3 ± 2.2 mm) in the WG group than in the NG group (−4.7 ± 5.6 mm). The regression analysis model indicated that the width of the buccal gap was the only predictor of the thickness of the newly formed buccal bone wall ($p < 0.001$).

Conclusion: Grafting of >2 mm-wide buccal gaps following IIP promoted a thicker buccal bone wall.

KEYWORDS
esthetics, immediate implant placement, maxillary central incisor

SUMMARY BOX

What is known

- Grafting of the buccal gap between the inner aspect of the buccal bone and the implant reduces the bone dimensional changes that occurs following immediate implant placement.

What this study adds

- This study indicates the best gap width for grafting during immediate implant placement to promote a successful buccal bone stability at maxillary central incisor sites.
- A wide gap (>2 mm) increased the chances of presenting a thicker newly formed buccal bone wall.

1 | INTRODUCTION

Following tooth extraction, immediate implant placement (IIP) is an attractive treatment modality because of its reduced number of surgeries and overall treatment time.[1,2] In addition, this treatment approach demonstrates implant survival and success rates similar to other implant placement protocols (early or late).[3,4] IIP is, however, frequently associated with (i) a more difficult surgical procedure, (ii) implants positioned too much in a buccal direction,[5] and (iii) occurrence of marginal mucosal recession.[6,7] In addition, clinical and pre-clinical studies have shown that placing an implant in a fresh extraction socket *per se* does not prevent alveolar ridge reduction.[8,9] Thus, successful IIP is highly depended on proper surgical procedures, including correct 3-dimensional implant positioning and successful ridge preservation procedure to counteract the ridge alterations.

Various factors may compensate for the bone modeling when placing immediate implants, such as thicker alveolar buccal bone wall,[10,11] larger alveolar process,[11] proper 3-dimensional implant positioning,[7,12,13] use of bone grafts,[14–16] and use of connective tissue grafts.[1,17,18] The distance from the implant shoulder to the bone crest (gap) at the buccal aspect is also a factor that is reported to be important to reduce bone alterations. Araujo and colleagues[11] evaluated in a pre-clinical study the healing of wide and narrow buccal gaps following IIP without any bone graft. The authors observed that after 3 months, the amount of bone covering the buccal implant surface was significantly larger at the wide gap (WG) than narrow gap (NG) sites.

Grafting of the gap using deproteinized bovine bone mineral (DBBM) significantly reduces the bone dimensional changes that occurs following IIP.[12,14,16,19] The dimension of the buccal gap has been evaluated in previous studies.[9,10,16,20,21] These studies were, however, performed mostly, if not, only in premolar sites. There is a significant anatomical difference between premolar and anterior sites, especially regarding the thickness of the buccal bone wall.[22–24] A recent systematic review reported that, in premolar sites, the thickness of the buccal wall is greater than 1 mm (1.09–1.96) while at central incisor sites the corresponding value is markedly reduced, about 0.8 mm.[24] Thus, it is plausible to suggest that the healing of a grafted gap would be better protected by the thicker buccal wall at the premolar sites than by the thin buccal wall at the central incisor sites, which would have promoted superior bone formation.

To the best of our knowledge, there is no study in the literature that addressed the role of the dimension of the grafted gap at sites with a thin buccal bone wall. Thus, the aim of the present study was to evaluate at exclusively maxillary central incisor sites the effect of the thickness of the buccal gap, that was grafted following IIP, on the thickness of the newly formed buccal wall. The secondary objectives were to assess the thickness of the palatal bone, the percentage of the buccal and palatal aspects of the implant covered by bone, the position of the buccal and palatal crests in relation to the implant shoulder and to evaluate which implant factors might influence on the buccal bone thickness.

2 | MATERIAL AND METHODS

2.1 | Study design and sample population

This study retrospectively assessed 42 patients treated with 51 implants in a private dental office between 2003 and 2018. All patients were treated with an IIP and ridge preservation at maxillary central incisor sites. Ethics approval was obtained by the Institutional Review Board for Research Conducted with Human Beings at the State University of Maringá, Brazil (protocol 27928919.9.0000.0104). The study was conducted in accordance with the Helsinki Declaration and the manuscript preparation followed the STROBE guidelines.[25]

Dental records of patients rehabilitated with implant-supported prosthesis were selected according to the following eligible criteria:

2.1.1 | Inclusion criteria

- Healthy adults (≥21 years-old) exhibiting good oral hygiene
- Failing maxillary central incisor sites with an intact buccal socket wall that after tooth extraction were treated with IIP and ridge preservation by means of grafting the buccal gap
- Record in the clinical chart of the buccal gap width (distance from the implant shoulder to the inner aspect of the intact buccal wall) immediately after implant placement

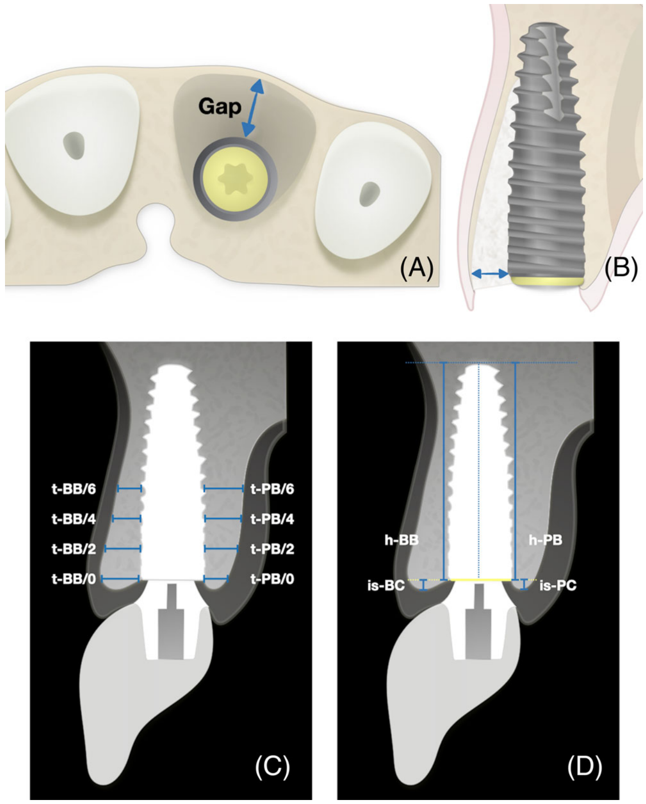

FIGURE 1 Gap illustration, that is, distance between the inner aspect of the buccal wall and the implant, in the occlusal (A) and cross-sectional view (B). CBCT analysis, including the thickness of the buccal (t-BB) and palatal bone walls (t-PB) (C), percentage of the implant covered by bone in the buccal (h-BB) and palatal aspects (h-PB) and distance from the implant shoulder to the buccal (is-BC) and palatal crests (is-PC) (D)

- Complete photographic documentation
- Presence of a cone-beam computed tomography (CBCT) acquired after at least 1 year in function

2.1.2 | Exclusion criteria

- Presence of periimplantitis during the follow-up period
- Presence of soft and/or hard tissues pathosis that required any surgical procedure (eg, cyst and granuloma)
- Crowding and improper tooth alignment in the upper jaw
- Partial loss of the buccal bone wall after tooth extraction
- Presence of any systemic condition or use of drugs that affected bone metabolism
- Tobacco abuse (>10 cigarettes/day)

2.2 | Intervention procedures

A minimally invasive tooth extraction was performed. Any granulation tissue in the socket was removed. The implant bed was prepared using a surgical guide to achieve the proper 3-dimensional position, and implant placement followed the manufacturer's instructions (Straumann AG, Basel, Switzerland or Nobel Biocare AG, Gothenburg, Sweden). The implant was placed 1 mm below the intact buccal crest. Subsequently, at the implant shoulder, the distance between the inner aspect of the buccal wall and the implant (gap) was measured with a periodontal probe (Figure 1A, B). A conical healing cap was adapted to the implant and DBBM particles (Geistlich Bio-Oss®, Geistlich Pharma AG, Wolhusen, Switzerland) soaked in saline were packed firmly into the buccal gap until resistance was achieved.

In a group of patients presenting a gingival thickness of <1 mm, a connective tissue graft (CTG) was harvested from the palate at the premolar region and placed between the outer surface of the socket and the buccal soft tissue, as a full-thickness envelope to the level of the muco-gingival junction and interproximal line angles. Mattress sutures were used to stabilize the CTG at the buccal soft tissues while cross sutures were placed to stabilize the gingival margin.

All surgical procedures were performed by the same experienced periodontist (Robert A. Levine). Patients were asked to rinse with chlorhexidine (0.12%) twice daily for 14 days. Antibiotics and analgesics were prescribed. The sutures were removed after 2–3 weeks.

After 3 months, soft tissue conditioning was started with a screw-retained fixed provisional and the final ceramic crown was commenced 2–3 months later. The patients were enrolled in an individualized periodontal maintenance program that included oral hygiene instructions, prophylaxis with a rubber cup and scaling at bleeding sites. At the final examination (5 ± 4 years later), patients underwent a CBCT scan.

Patients were divided into the following two groups according to the width of the gap between the implant surface and the inner aspect of the buccal bone wall, assessed during implant surgery:

- Wide gap group (WG), sites that presented a >2 mm gap; and
- Narrow gap group (NG), sites that presented a ≤2 mm gap.

2.3 | CBCT reconstruction measurements

Posttreatment CBCT reconstructions were obtained using the CS 9300 scan (Carestream Dental, Trophy, Marne La Vallee, France) with a field of view (FOV) of 5 × 5 cm and a 0.09 voxel size. Image reconstruction for visual analysis was performed using an imaging software (CS 3D Dental Imaging software®, Carestream Health, Atlanta, USA). A single blinded and calibrated examiner performed all the measurements. Cross-sectional reconstructions were obtained from the central portion of the implant and the following landmarks identified: (i) the implant shoulder; (ii) the implant apex; (iii) the first bone to implant contact in the buccal aspect; (iv) the first bone to implant contact in the palatal aspect; (v) the crest of the buccal bone wall; (vi) the crest of the palatal bone wall. A 3-dimensional implant template provided by the software with the same dimension and design of the installed implant was inserted and aligned with the implant reconstruction to perform the following measurements (Figure 1C,D):

TABLE 1 Patient and implant characteristics

Variable	Wide gap	Narrow gap
Patients	***n* = 26**	***n* = 16**
Age, years; mean ± SD	61.5 ± 16.2	52.2 ± 12.3
Gender, *n* (%)		
Male	10 (38.5)	4 (25)
Female	16 (61.5)	12 (75)
Implants	***n* = 34**	***n* = 17**
Implant brand, *n* (%)		
Straumann	26 (76.5)	17 (100)
Nobel active	8 (23.5)	0
Implant design, *n* (%)		
Tapered	19 (55.9)	5 (29.4)
Parallel-walled	15 (44.1)	12 (70.6)
Implant diameter, *n* (%)		
Narrow (3.3–3.5)	7 (20.6)	0
Regular (4.1–4.3)	23 (67.6)	15 (88.2)
Wide (4.8)	4 (11.8)	2 (11.8)
Implant length, *n* (%)		
10 mm	6 (17.6)	3 (17.6)
11–12 mm	15 (44.1)	11 (64.8)
13–14 mm	13 (38.3)	3 (17.6)
Implant-crown connection, *n* (%)		
Screw-retained	29 (85.3)	11 (64.7)
Cemented	5 (14.7)	6 (35.3)
CTG, *n* (%)	24 (70.6)	10 (58.8)
Time in function, years; mean ± SD	4.8 ± 3.4 (1–13)	5.8 ± 3.9 (1–15)

Abbreviation: CTG, connective tissue graft.

- Thickness of the buccal bone (t-BB): The linear distance in millimeters between the outer surface of the buccal bone and implant surface measured at the implant shoulder and 2, 4, and 6 mm below. The measurements were carried out perpendicular to the long axis of the implant.
- Thickness of the palatal bone (t-PB): The linear distance in millimeters between the palatal bone and implant surface measured at the implant shoulder and 2, 4, and 6 mm below. The measurements were carried out perpendicular to the long axis of the implant.
- Height of the buccal bone (h-BB): The vertical distance between the first bone to implant contact and implant apex. Expressed in the percentage of the buccal aspect of the implant covered by bone. The measurements were carried out parallel to the long axis of the implant.
- Height of the palatal bone (h-PB): The vertical distance between the first bone to implant contact and implant apex at the palatal aspect. Expressed in the percentage of the palatal aspect of the implant covered by bone. The measurements were carried out parallel to the long axis of the implant.
- Position of the buccal crest (is-BC): The vertical distance between the buccal crest and the implant shoulder. Expressed in millimeters. The measurements were carried out parallel to the long axis of the implant.
- Position of the palatal crest (is-PC): The vertical distance between the palatal crest and the implant shoulder. Expressed in millimeters. The measurements were carried out parallel to the long axis of the implant.

To calibrate the examiner, the thickness of the buccal bone at 2 mm from the implant shoulder from all CBCT reconstructions were assessed twice in a 48-h interval. The intraclass correlation coefficient (ICC) obtained was 0.955.

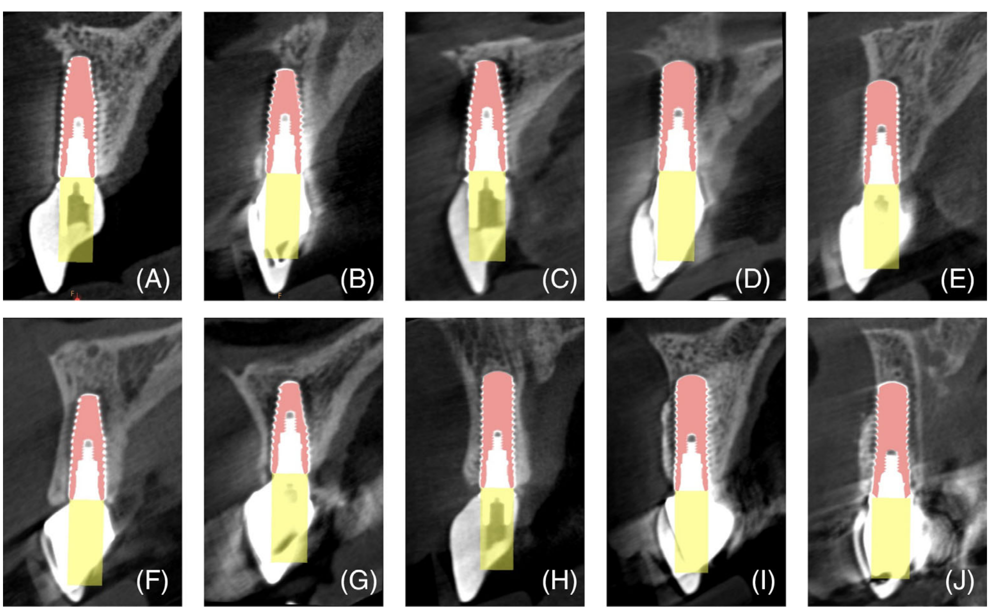

FIGURE 2 CBCT reconstructions for the narrow gap group (A–E) and wide gap group (F–J). Observe the differences in the buccal bone dimension between the two groups. The implant template was inserted and aligned to correct for metallic artifacts

TABLE 2 Thickness of the buccal and palatal bone walls at four different levels from the implant shoulder

	Buccal bone				Palatal bone			
	Implant shoulder	2 mm	4 mm	6 mm	Implant shoulder	2 mm	4 mm	6 mm
GAP >2 *n* = 34	1.7 ± 1 1.8 [1.3; 2.4]	2.1 ± 0.8 2.2 [1.7; 2.4]	1.9 ± 0.9 2 [1.4; 2.4]	1.7 ± 1 1.8 [1; 2.5]	1.1 ± 1.3 0.7 [0; 1.9]	1.9 ± 0.9 2 [1.1; 2.6]	2.4 ± 0.9 2.3 [1.8; 3.2]	2.8 ± 1.2 2.5 [2; 3.7]
GAP ≤2 *n* = 17	0.5 ± 0.8 0 [0; 1.1]	0.8 ± 0.7 0.9 [0; 1.3]	0.6 ± 0.6 0.6 [0; 1]	0.3 ± 0.5 0 [0; 0.6]	1.1 ± 1.2 1 [0; 1.5]	2.2 ± 1.3 1.8 [1.5; 2.7]	3 ± 1.4 2.8 [2.1; 4]	3.7 ± 1.6 3.2 [3; 4.5]
p-value[a]	<0.001	<0.001	<0.001	<0.001	0.812	0.645	0.109	0.046

Note: Mean (SD). Median [IQ range].
[a]Comparison using the Mann–Whitney *U* test.

TABLE 3 Vertical measurements: Percentage of the buccal and palatal aspect of the implants covered by bone and position of the buccal and palatal bone crests in relation to the implant shoulder in each group

	Height of the implant covered by bone		Position of the crest in relation to the implant shoulder	
	Buccal aspect (%)	Palatal aspect (%)	Buccal crest (mm)	Palatal crest (mm)
GAP >2 *n* = 34	95 ± 16.6 100 [100; 100]	96.2 ± 10.4 100 [97.2; 100]	0.3 ± 2.2 0.8 [0.3; 1.5]	0 ± 1.6 0.05 [−0.3; 0.8]
GAP ≤2 *n* = 17	59.4 ± 42.3 90.9 [15.4; 100]	96.2 ± 7.9 100 [97.6; 100]	−4.7 ± 5.6 −1.3 [−10.4; 0]	0.2 ± 1.5 0.4 [−0.3; 1.2]
p-value[a]	<0.001	1.0	<0.001	0.7

Note: Mean (SD). Median [IQ range].
[a]Comparison using the Mann–Whitney *U* test.

2.4 | Outcomes

The primary outcome of the present study was the thickness of the buccal bone measured at 2 mm from the implant shoulder. Secondary variables included the thickness of the buccal bone at the implant shoulder, 4 and 6 mm below, the thickness of the palatal bone at the implant shoulder, 2, 4, and 6 mm below, the height of the buccal and palatal bone walls and the position of the buccal and palatal crests in relation to the implant shoulder.

2.5 | Statistical analysis

The sample size was calculated using data from a previous study[10] based on the assumption that a 0.5 mm difference in thickness would be observed between the WG and the NG group. Assuming an alpha risk of 5% and a beta risk of 20% in a one-sided test, a total of 46 sites (23 sites in each group) were necessary.

Descriptive statistics included mean, SD, median, and inter-quartile (IQ) range for continuous variables and frequency distributions for categorical variables. A Shapiro–Wilk normality test was performed. The differences between the groups were analyzed using a nonparametric test (Mann–Whitney *U* test).

In addition, a multiple linear regression model was built with the thickness of the buccal bone measured at 2 mm from the implant shoulder as the dependent variable. The use of a CTG, presence of an adjacent implant, implant diameter, tapered or parallel-walled implants, width of the gap and time in function were included as covariates. A residual analysis was performed to evaluate the model fit.

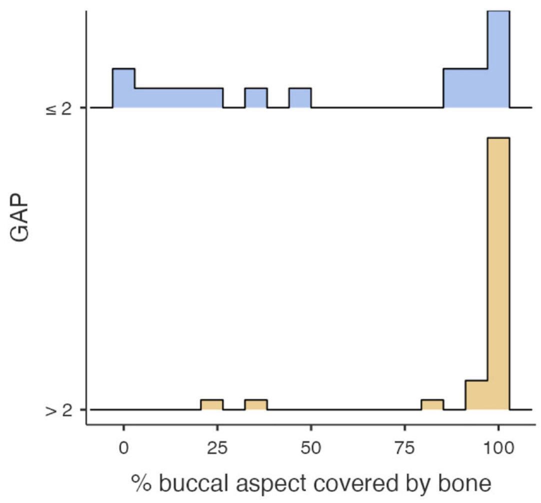

FIGURE 3 Frequency distribution of the percentage of the buccal aspect of the implant covered by bone for WG and NG groups

All statistical analyses were computed with an open-source software (*The jamovi project (2021). jamovi (Version 1.6) [Computer Software]*). The level of significance adopted in the tests was set at 5%.

3 | RESULTS

Patient and implant characteristics of the sample population are shown in Table 1. Most of the individuals were women (61.5% wide group, 75% narrow group) with on average 59 years of age (SD 16). Thirty-four implant sites (66.7%) presented a WG (>2 mm) following implant placement while the remaining 17 sites (33.3%) exhibited a corresponding NG (≤2 mm). Twenty-four sites (47%) received tapered implants, while 27 (53%) were rehabilitated with parallel-wall implants. Seven sites (14%) were treated with narrow diameter implants, while 38 (74%) and 6 (12%) were, respectively, treated with regular and wide diameter implants. Forty sites (78%) were rehabilitated with a screw-retained final prosthesis. In addition, 70.6% of the sites in the wide group and 58.8% in the narrow group received a CTG following IIP. The overall mean time in function of the implants was 5 ± 4 years. Figure 2 illustrates the CBCT reconstructions from the two treatment groups.

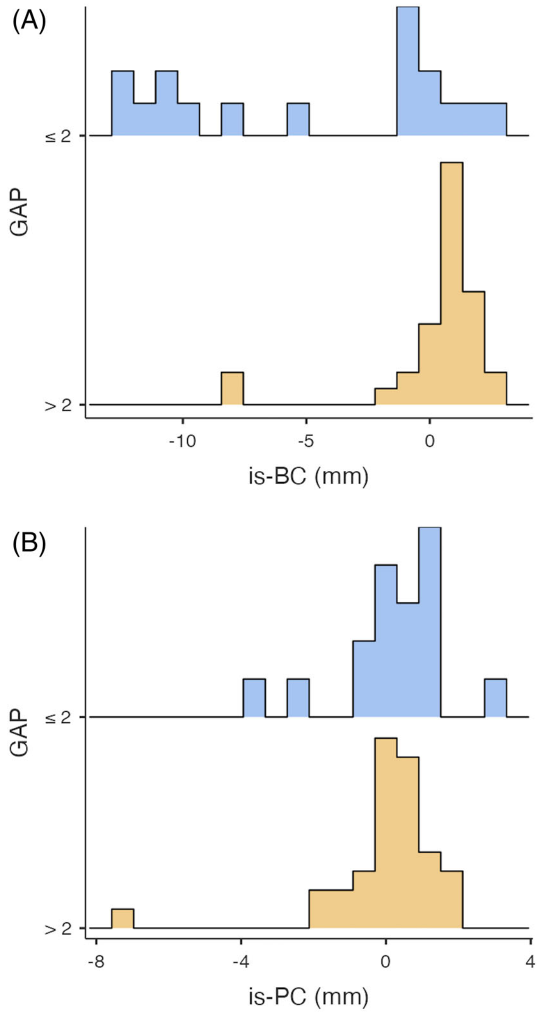

FIGURE 4 Frequency distribution of the distance between the implant shoulder and the buccal (is-BC) (A) or palatal (is-PC) (B) crest for both groups

The mean and median thickness of the buccal and palatal bone walls at four different levels from the implant shoulder are shown in Table 2. In the WG group, the mean (±SD) buccal bone thickness was 1.7 ± 1, 2.1 ± 0.8, 1.9 ± 0.9, and 1.7 ± 1 mm, respectively, 0, 2, 4, and 6 mm below the implant shoulder. While in the NG group, the corresponding mean values were 0.5 ± 0.7, 0.8 ± 0.7, 0.6 ± 0.6, and 0.3 ± 0.5 mm. The buccal bone was significantly thicker in the WG group than in the NG group at all levels observed ($p < 0.001$). The palatal bone thickness in the WG and NG groups was, however, similar and increased from the implant shoulder level to 6 mm below, from 1 to 3.7 mm.

Table 3 shows the percentage of the implant height covered by bone at the buccal and palatal aspects and the distances between the implant shoulder and the buccal/palatal crests. In the buccal aspect, implants in the WG group (mean 95 ± 16.6%; median 100 [100; 100]) presented a significantly higher percentage of the height of the implant covered by bone than in the NG group (mean 59.4 ± 42.3%; median 90.9 [15.4; 100]). Two sites in the NG group presented no detectable bone wall. A frequency distribution of the percentage of the buccal aspect of the implant covered by bone for both groups is shown in Figure 3. At the palatal aspect, about 100% of the implant aspect was covered by bone in both groups. The buccal crest in relation to the implant shoulder of implants in the WG group was in a significantly coronal position (mean 0.3 ± 2.2 mm; median 0.8 [0.3; 1.5]) than the buccal crest in the NG group (mean −4.7 ± 5.6 mm; median

TABLE 4 Linear regression model with the thickness of the buccal bone wall (mm) at 2 mm from the implant shoulder as the dependent variable

Predictor	Estimate	SE	95% CI	*p*-Value
Intercept	0.3617	0.4121	−0.4694; 1.927	0.385
CTG	0.2725	0.2705	−0.2730; 0.8180	0.319
Adjacent implant	−0.4381	0.2447	−0.9316; 0.0554	0.080
Implant diameter				
“3.3”—“4.1”	−0.0564	0.3217	−0.7052; 0.5924	0.862
“4.8”—“4.1”	−0.4007	0.5211	−1.4516; 0.6502	0.446
Tapered vs parallel-walled implants	0.3684	0.2742	−0.1845; 0.9214	0.186
Gap >2 mm	1.4162	0.2561	0.8997; 1.9328	<0.001
Time in function (years)	0.0386	0.0532	−0.0687; 0.1460	0.472

Abbreviations: CI, confidence interval; SE, standardized estimate.

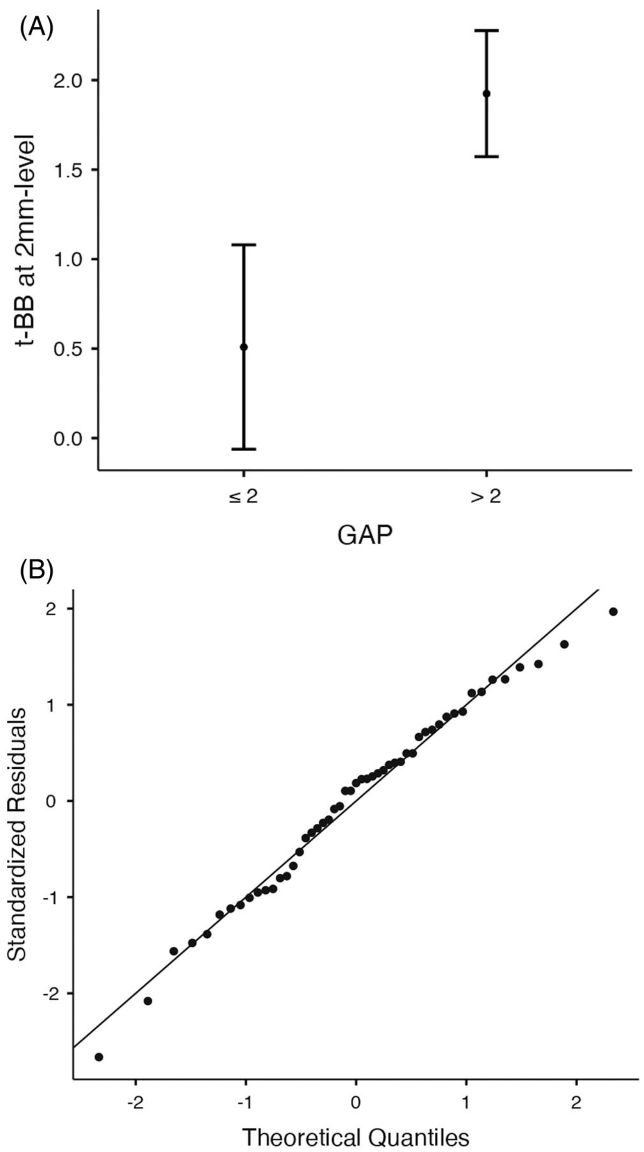

FIGURE 5 Multiple linear regression model with the thickness of the buccal bone measured at 2 mm from the implant shoulder as the dependent variable. (A) Predicted values of the thickness of the buccal bone at 2 mm from the implant shoulder along the GAP effect. (B) Q-Q plot of residuals

−1.3 [−10.4; 0]). The palatal crest was in a similar position in both groups. A frequency distribution of the position of the buccal and palatal crests in relation to the implant shoulder for both groups is shown in Figure 4A,B.

The regression analysis model (Table 4) indicated that the width of the buccal gap was a predictor of the thickness of the newly formed buccal bone wall at the 2 mm-implant level ($p < 0.001$; Figure 5A). The use of a CTG, presence of adjacent implants, implant diameter, use of tapered implants, and time in function failed, however, to predict the thickness of the buccal bone. The model quality was found to be satisfying given the linear relationship of the residuals (Figure 5B).

4 | DISCUSSION

The present cohort study evaluated the effect of the buccal gap width on the newly formed buccal bone following IIP and ridge preservation by means of socket graft. Only sockets with an intact buccal wall after tooth extraction were included. The implant sites were divided into two groups according to the width of the buccal gap measured immediately after implant placement, WG (>2 mm) and NG (≤2 mm) groups. It was observed that implant sites in the WG group exhibited a significantly thicker newly formed buccal bone wall and, a higher percentage of its buccal aspect covered by bone than sites in the NG group. In addition, the regression analysis model demonstrated that a wide buccal gap was a predictor of a thicker newly formed buccal bone.

Only maxillary central incisor sites were included in the present study. The width and height of the alveolar process and basal bone at the upper central incisors differ anatomically from the corresponding structures at upper lateral incisors and canines.[24,26,27] Botelho and colleagues[26] described the anatomical features of 174 healthy maxillary central and lateral incisors, and canines. The authors observed that the alveolar process at the central incisor region was significantly wider and longer than at lateral incisors but narrower and shorter than at the canine region. Few studies evaluated, however, the effect of IIP exclusively at one single tooth region, such as the maxillary central incisors.[18,28] Most of the clinical studies considered a mixture of different anterior tooth regions[21] or combined with first and second premolar regions.[29–34] Thus, as a different anatomy of alveolar process exhibit resultant different alveolar alterations,[10] it is suggested that the effect of reconstructive procedures is better evaluated when performed at sites with similar anatomy.

In the present investigation, the healed buccal bone was significantly thicker in the WG group than the NG group at all levels evaluated (overall 1.9 and 0.5 mm). The results of the current study are in agreement with Groenendijk and colleagues,[21] who retrospectively studied 16 patients treated with IIP at maxillary central and lateral incisors presenting a gap of at least 2 mm filled with DBBM. After about 2 years, the mean buccal bone thickness was similar to the present study, 1.8 mm. Comparable results were also reported by Zuiderveld and colleagues[32] in a RCT evaluating the effect of CTG on the buccal bone wall. Fifty-five sites were included, of which 49% were central incisors. Following IIP, the authors grafted the gap with DBBM and autologous bone, obtaining a >2 mm-thick buccal wall consisting of the pristine buccal wall and the grafted gap. The mean thickness of the buccal bone at the 1-year follow-up was 1.7 mm. On the contrary, Benic and colleagues[31] evaluated the dimension of the buccal bone wall at immediately placed implants after 7 years of follow-up. The study included 14 sites from second premolar to second premolar of maxilla or mandible, being 11 premolar sites. Gaps of at least 0.5 mm were grafted with DBBM and covered by a collagen membrane. The mean gap width at baseline was 1.5 mm but the resulting mean buccal bone thickness was 0.4 mm. Thus, it can be suggested that the wider the gap and larger the space for the bone graft, the thicker the newly formed buccal bone wall will be.

In the WG group, the grafting of >2 mm buccal gaps promoted a newly formed buccal wall that varied from 1.7 to 2.2 mm in thickness. This observation indicates that the thin buccal bone of the alveolar process was markedly resorbed during the socket healing process. Several histological studies support such findings.[8,11,14,35,36] Araujo and colleagues[14] evaluated in a preclinical study the healing of buccal bone gaps following bone graft and IIP. The authors observed that the original buccal wall was severely resorbed, and the newly formed buccal wall corresponded to the bone formed in the gap previously grafted. It may be suggested that the thin buccal bone wall, which is mainly made of bundle bone, acts as a reinforced resorbable barrier that not only protects the wound but also helps to keep the shape of the ridge.

The thickness of newly formed buccal bone observed in of the WG group was also in agreement with findings from other surgical approaches, such as early implant placement (EIP) associated to guided bone regeneration (GBR). Buser and colleagues[37] installed 41 tissue-level implants following EIP and GBR, including 25 central incisors, 11 lateral incisors, 1 canine, and 4 first premolars. They reported, after 5 to 9 years of follow-up, a mean thickness of 1.6 mm at 2 mm, 2.2 mm at 4 mm, and 2.3 mm at 6 mm apical to the implant shoulder. In the present study, the corresponding values in the WG group were 2.1, 1.9, and 1.7 mm. Chappuis and colleagues[38] in a 10-year follow-up study using bone-level implants following EIP, including 14 central incisors, 3 lateral incisors, 1 canine, and 2 first premolars reported a mean buccal bone thickness of 1.7 mm (from 1 to 2.5 mm). These findings demonstrate that both IIP associated with ridge preservation or early implant placement associated with ridge augmentation may result in predictable outcomes regarding the buccal bone dimension.

In the present study, the thickness of the palatal bone was, on average, 2 mm (±1.3) in the wide group and 2.5 mm (±1.7) in the narrow group, with a slight significant difference between them only at the 6 mm level. Thus, the implants in both groups were placed in similar positions in relation the palatal bone wall. Based on these findings, it is suggested that the reason why a NG was obtained after implant placement was the limited width of the alveolar process in the NG group.

The buccal aspect of the implant in the WG group was fully covered by bone (mean 95%), while less than 60% of the implant height in the NG group presented detectable bone. Only two sites (4%) presented no detectable bone wall, belonging to the NG group. This observation differed from Seyssens and colleagues[7] who evaluated, after 10 years, IIP combined with grafting of the buccal gap. The authors reported that 17% of the sites (3 out of 18 implants) had no detectable buccal bone wall. No information, however, was provided on the dimension of the grafted gap. Another long-term study[39] also reported a higher frequency of missing buccal bone walls (35.7%) when buccal gaps narrower than 2 mm were found. The buccal crest in the WG group was positioned coronally to the implant shoulder (median 0.8 mm), while in the NG group, in most cases, it was positioned apically to the implant shoulder (median −1.3 mm). Of the 51 implants, 79% in the WG group and 29% in the NG group presented positive values. The results of the WG group were in agreement with Chappuis and colleagues[38] following 10 years of EIP associated with GBR, who reported that 15 out of 19 implants (79%) had a positive value, with the peak of the bone wall being located coronally to the implant shoulder. Thus, it may be suggested that grafting of >2 mm gaps promotes complete coverage of the buccal aspect of the implants by bone.

This study evaluated predictors of the thickness of the newly formed buccal bone at 2 mm from the implant shoulder following IIP. The regression analysis model indicated that the width of the buccal gap was a predictor of the thickness of the newly formed buccal bone wall. It could be hypothesized that the wider the gap, the further the implant is from the buccal wall, promoting more space to place the bone graft and also allowing the granules to reach the most apical portion of the bone defect. This finding is in agreement with a previous study[40] that evaluated factors that could affect bone alterations 4 months following IIP in a multilevel model. The authors observed that the wider the buccal gap, lesser postoperative hard tissue changes took place. On the other hand, the use of tapered implants or parallel-walled implants had no significant impact on the model. This could be explained due to the methodological assessment. At 2 mm from the implant shoulder, tapered or parallel-walled implants probably exhibited a similar diameter. In the middle to apical thirds, the implant design could have an effect as the area to be filled by the biomaterial would be larger. Besides, in the present study, DBBM particles were packed firmly into the buccal gap until resistance was achieved, acting as a stable scaffold in order to avoid any micromovement of the bone graft. This concept is similar to ridge preservation procedures without IIP, considering that the DBBM presents osteoconductive properties and shall be integrated in the newly formed bone tissue.[41]

The use of a CTG that included the necessary flap elevation also failed to predict the buccal bone thickness. This finding is in agreement with previous studies that did not observe a significant effect of the CTG on the buccal bone wall.[18,42] The presence of an adjacent implant failed to influence the thickness of the buccal bone, suggesting that the marginal bone loss that could have occurred between the two platform-switching implants did not affect the buccal aspect.[43] Implant sites with a higher time in function did not present thinner buccal walls, suggesting that most of the bone changes took place before the first year of healing.[35,44,45] Narrow, regular or wide diameter implants did not predict the buccal bone thickness, demonstrating that the distance between the implant surface and the buccal wall is more important than the implant diameter *per se*.[8,46] It may be suggested that the clinician should consider an implant diameter that allows for a >2 mm buccal gap dimension when virtually planning the implant.

Among the 51 implant sites included in the present study, the mean buccal bone thickness at 2 mm from the implant shoulder was 2.1 mm in the WG group and 0.8 mm in the NG group. The original power analysis in the present study was performed anticipating a 0.5 mm difference between the groups; however, the observed difference was considerably more than the postulated

0.5 mm (1.3 mm). Based on this finding, a post hoc power analysis was performed, and a 99% power was observed for the study objectives.

The observations from this retrospective study should be interpreted with caution due to some limitations. All patients were treated by an experienced Periodontist, with extensive training and knowledge of the technique. The individuals were evaluated after a mean period of 6 years but exhibited a range from 1 to 15 years. Besides, throughout the years, new implant designs, as well as improved surgical and prosthodontic procedures emerged and may have changed over time. The analyses of the buccal bone thickness on CBCT reconstructions also have some limitations due to image artifacts produced by the implant.[47] Nevertheless, a plethora of studies using this methodologic assessment are available in the literature.[15,29,30,32–34,37,38,42,48] In the current study, an implant template with the same dimensions of the implant was aligned in the imaging software. Extremely thin buccal walls, however, remain difficult to detect. IIP in the maxillary central incisors area is considered a complex procedure (straightforward advanced complex [SAC] classification[49]), thus, all cases had to be treated by a team approach rigorously following with a 10-key protocol to reduce complications.[50–52]

5 | CONCLUSION

The findings of the present study suggest that grafting of a >2 mm-wide buccal gap following IIP promotes a thicker newly formed buccal bone wall.

ACKNOWLEDGMENTS

Drs. Levine and Araújo give lectures sponsored by Geistlich Pharma. The study was self-funded by the authors and their institutions.

CONFLICT OF INTEREST

Drs. Dias and Wang report no conflicts of interest related to this study.

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.

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How to cite this article: Levine RA, Dias DR, Wang P, Araújo MG. Effect of the buccal gap width following immediate implant placement on the buccal bone wall: A retrospective cone-beam computed tomography analysis. *Clin Implant Dent Relat Res*. 2022;1-11. doi:10.1111/cid.13095