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Original Article

Buccal Bone Plate Resorption Following Immediate Implant Placement: A Systematic Review

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ABSTRACT

This study focuses on the anatomical vulnerability of the buccal bone plate in the aesthetic part of the maxilla, which is prone to significant resorption following tooth extraction. While immediate dental implant placement can help preserve the surrounding tissues, it does not completely prevent bone resorption. This systematic review aims to assess how two key surgical protocols—full-thickness flap elevation and bone grafting—affect bone remodeling after the immediate placement of dental implants. The review followed the PRISMA guidelines and included only prospective clinical trials that assessed changes in the buccal bone plate of the maxilla using CBCT scans, comparing pre-operative and 6-12 month post-operative data. A total of 358 publications were initially identified, of which 8 studies with 272 surgical sites met the inclusion criteria. The results were categorized based on the surgical methods used, but due to significant heterogeneity among the subgroups, no reliable intergroup comparisons could be made. Nevertheless, the study shows that buccal bone plate resorption in the maxilla is inevitable after immediate implantation, with a trend suggesting that flapless procedures combined with bone grafting may help maintain better buccal bone plate stability.

Keywords: Maxilla, Dental implantation, Alveolar bone loss, Bone remodeling, Surgical flaps, Alveolar bone grafting.

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Introduction

After a tooth extraction, changes in both soft and hard tissues occur. The bone fills the space in the alveolus, and resorption happens on the outer surface of the surrounding alveolar bone. This results in both vertical and horizontal changes to the bone structure. Research indicates that approximately 87% of patients have a buccal bone plate that measures 1 millimeter or less in thickness [1-3]. Additionally, after tooth removal, the majority of the resorption takes place on the buccal side of the extraction site. This phenomenon can be attributed to the fact that the buccal bone plate contains bundle bone, with its blood supply reliant on the periodontal ligament. Therefore, the maxillary buccal bone plate in the aesthetic zone is especially prone to resorption post-extraction. While immediate dental implant placement has been shown to help stabilize surrounding tissues, it does not completely halt bone resorption. As such, it is essential to manage the surgical site in a way that minimizes hard tissue loss to achieve both functional and aesthetic outcomes for dental implant restoration [2-5]. This study seeks to assess early volumetric changes—both vertically and horizontally—of the buccal bone plate following immediate dental implant placement, with a focus on comparing two surgical protocols: full-thickness flap elevation and bone grafting.

Materials and Methods

This review was conducted following the guidelines outlined in the Preferred Reporting Items for Systematic Reviews and Meta-Analyses statement. Before the commencement of the review, the protocol was developed and registered with PROSPERO at Dissemination, the University of York, and the Centre for Reviews, under the ID number CRD42021291731. The clinical question was framed following the participant, intervention, comparison, and outcome (PICO) framework. Specifically, the question addressed how grafting and flap elevation during immediate implantation in the aesthetic zone of the maxilla affect early buccal bone plate resorption.

The inclusion criteria for this review were as follows: the study must be a prospective clinical trial, and the participants should be healthy adults without systemic conditions. The study must involve immediate titanium dental implant placement in the aesthetic zone of the maxilla (from the second premolar to the second premolar). Additionally, the dental implants must be placed subcrestally, at a depth of 1 to 4 mm below the adjacent alveolar bone surface. There should be a measurable gap, or "jumping space," between the implant and the buccal wall. Furthermore, the study should involve cases where no buccal bone defects, such as dehiscence or fenestration, are present after tooth extraction. The changes in the buccal bone should be measured using cone beam computed tomography (CBCT) both before the procedure and during the follow-up period. The follow-up period must be between six to twelve months post-surgery.

Studies were excluded if they were animal-based, retrospective, or involved dental implant placement in the mandible. Studies where buccal wall defects were present or not assessed following tooth extraction, as well as those without data on the jumping space, were also excluded.

An electronic systematic search was conducted by 2 researchers (D.L. and R.P.) following the PRISMA guidelines [6], using Science Direct, PubMed, and the Cochrane Library from September to November 2021. The search employed the following keywords: "graft," "CBCT," "immediate implantation," "radiograph," "bone," "loss," and "resorption." The search process was carried out in two stages. In the first stage, the titles and abstracts of the identified studies were reviewed to determine eligibility based on the inclusion criteria. Studies that met these criteria were carried forward to the second stage, while duplicates and those failing to meet the inclusion criteria were excluded. In the 2nd stage, full-text publications were thoroughly analyzed, and those that adhered to the inclusion criteria were included in the review. The researchers compared their findings and resolved any discrepancies through discussion. If they could not reach an agreement, the matter was referred to experienced researchers (G.J. and D.R.) for assistance in reaching a consensus.

To assess the risk of bias, 2 researchers (D.L. and R.P.) independently used Cochrane's risk of bias 2 (RoB 2) tool [7]. Any differences in the results were addressed through discussion to achieve consensus. If the researchers were unable to agree, a third-party consultation (G.J. and D.R.) was sought. The assessment focused on the following areas: the randomization process, deviations from the intended interventions, missing outcome data, outcome measurement, and selection of the reported results.

Results and Discussion

Study Selection

The process of selecting studies is illustrated through a PRISMA flow diagram (**Figure 1**). Initially, 358 publications were identified in the search. After removing duplicates and excluding articles based on their titles and abstracts, 74 studies were considered for inclusion. 1 study was inaccessible for full-text screening. Upon reviewing the full-text articles, 65 studies were excluded because they couldn't be included. The primary reason for exclusion was that the data on buccal bone plate resorption were combined from surgeries conducted in both the maxilla and mandible. Ultimately, 8 studies were deemed eligible and included in this systematic review.

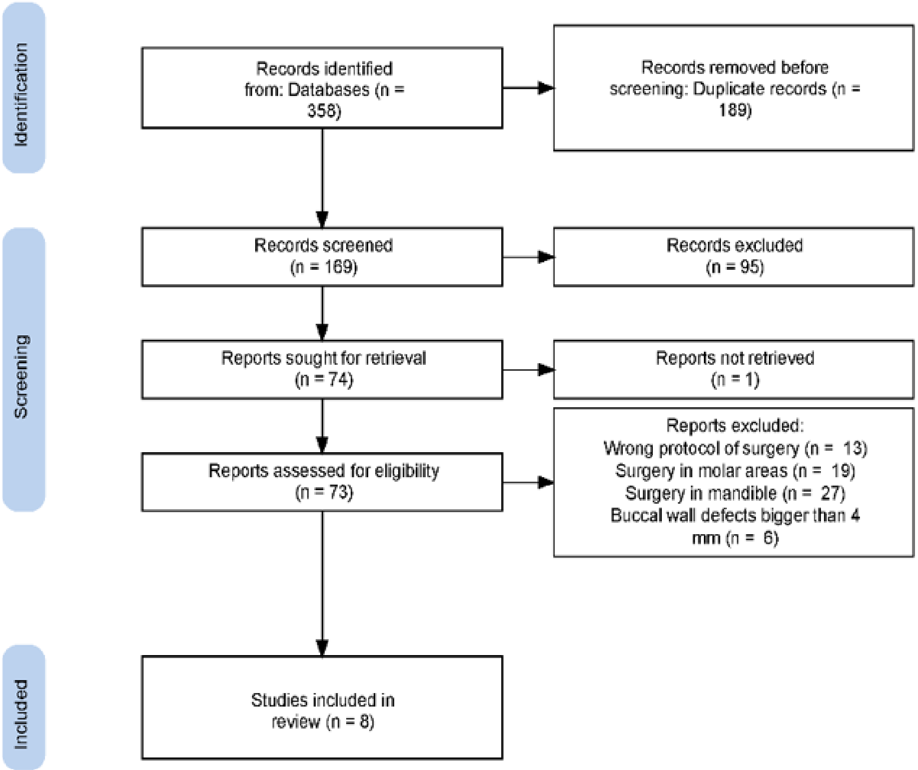

Figure 1. Prisma flowchart

Characteristics of the Studies Included

The studies included in the review were all prospective clinical trials published between 2016 and 2021 (**Table 1**). The clinical trials were conducted in Europe, Africa, Asia, and North America. A total of 272 dental implants were assessed across the studies. The follow-up period varied from 6 to 12 months. Seven studies focused on measuring horizontal changes in the buccal bone plate, while three studies evaluated vertical bone resorption.

Table 1. Characteristics of the included studies

Reference	Country	Number of Implants	Interventions described (+ yes, - no)				Flow-up period (Months)	Results described (+ yes, - no)	
			No graft	Graft	Flapless	Flap		Buccal bone plate width	Buccal bone plate height
Abd-Elrahman *et al.* [8]	Egypt	20	+	-	+	-	6 m.	+	+
Mazzocco *et al.* [9]	Spain	35	-	+	+	+	6m.	-	+
Grassi *et al.* [10]	Italy	44	+	+	+	+	6m.	+	-
Naji *et al.* [11]	Saudi Arabia	45	+	+	+	+	6m.	+	-
Atef *et al.* [12]	Egypt	21	-	+	+	-	6m.	+	+
Bittner *et al.* [13]	United State of America	32	+	-	+	-	9m.	+	-
Fujita *et al.* [14]	Japan	20	-	+	-	+	12m.	+	-
Zuiderveld *et al.* [15]	Netherlands	55	-	+	+	+	12m.	+	-

A total of 272 dental implants were evaluated in the included studies. Among these, 4 studies [8, 10, 11, 13] did not use any grafting material, while 6 studies [9-12, 14, 15] involved the application of allogenic, autogenic, or xenogenic bone substitutes to fill the space between the implant and the buccal bone. Additionally, 7 studies [8-13, 15] investigated flapless immediate implant placement, and 5 studies [9-11, 14, 15] explored the impact of flap elevation. 7 studies [8, 10-15] focused on changes in buccal bone thickness, whereas only 3 [8, 9, 12] examined vertical resorption. When multiple patient groups were included in a study, only those meeting the inclusion criteria were considered. For example, patients in the Fujita *et al.* [14] study, who underwent soft tissue augmentation, and those in the Abd-Elrahman *et al.* [8] study, who had socket shield procedures, were excluded.

Risk of Bias Assessment

The bias risk for each study is illustrated in **Figure 2**. 2 studies [9, 14] presented a high risk due to possible knowledge of allocation by enrolling investigators. However, no baseline imbalances were found that suggested a problem with randomization. 3 studies [8, 14, 15] raised concerns regarding bias in outcome measurement, as the assessors were aware of the interventions, which might have influenced their evaluations. Moreover, Bittner *et al.*'s study had insufficient information on allocation concealment, raising concerns about randomization. No major risk of bias was identified in terms of intervention deviations, missing data, or outcome reporting. 3 studies [10-12] were deemed to have low risk, 3 [8, 13, 15] showed some concerns, and 2 [9, 14] were classified as high risk.

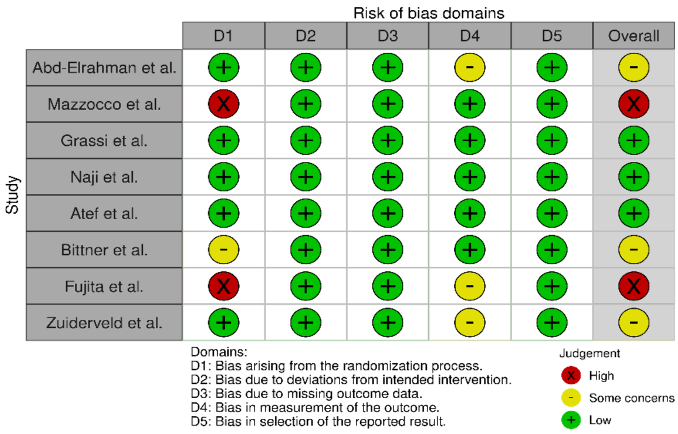

Figure 2. Visual representation of the risk of bias assessment results. Results of individual domains and overall risk of bias are visualized.

The findings from the studies were organized based on the type of surgical intervention applied. Four distinct groups were formed: flapless with no graft, flapless with graft, flap with no graft, and flap with graft. The dimensional changes of the buccal bone plate, both horizontally and vertically, were assessed at the midline of the implant. As previously noted, the follow-up period for all studies ranged from 6 to 12 months. For horizontal resorption, the region of interest was defined as the area extending from the implant neck (0 mm) to 5 millimeters apically. To better assess horizontal resorption, two subgroups were established based on the measurement location: 0-2 mm and 3-5 mm in the bucco-palatal direction. The results are shown in **Table 2**. The dimensional changes in bone are reported as mean values with standard deviations, where negative values indicate resorption and positive values indicate bone growth during the follow-up period.

Table 2. Results of buccal bone plate resorption, both vertically (buccal to the implant) and horizontally; the horizontal resorption group includes results of buccal bone plate resorption at 0-2 mm and 3-5 mm below the shoulder of the implant.

Group	Study	Number of implants	Horizontal resorption (mm)	Vertical resorption (mm)
Flapless and no graft	Abd-Elrahman *et al.* [8]	20	0-2 mm: -0.28 (0.15)	3-5 mm: -0.77 (0.35)
	Grassi *et al.* [10]	15	0-2 mm: -1.0 (1.1)	3-5 mm: -0.8 (0.8)
	Naji *et al.* [11]	15	0-2 mm: -0.24 (0.11)	N/A
	Bittner *et al.* [13]	5	N/A	3-5 mm: -0.14 (0.8)
		Total: 27	Average: -0.26 (0.96)	N/A
Flapless and graft	Mazzocco *et al.* [9]	20	N/A	3-5 mm: -0.07 (1.42)
	Atef *et al.* [12]	21	0-2 mm: -1.45 (0.72)	3-5 mm: -1.71 (1.02)
	Zuiderveld *et al.* [15]	27	0-2 mm: -0.91 (0.77)	3-5 mm: -0.31 (0.63)
			0-2 mm: -0.42 (0.57)	3-5 mm: -0.35 (0.69)
			0-2 mm: -0.37 (0.62)	3-5 mm: -0.37 (0.63)

Flap and no graft	Grassi *et al.* [10]	14	0-2 mm: -1.1 (0.9)	N/A
	Naji *et al.* [11]	16	0-2 mm: -0.91 (0.54)	N/A
Flap and graft	Mazzocco *et al.* [9]	15	N/A	3-5 mm: -1.03 (1.09)
	Grassi *et al.* [10]	15	0-2 mm: -0.4 (0.8)	N/A
	Naji *et al.* [11]	14	0-2 mm: -0.37 (0.09)	N/A
	Fujita *et al.* [14]	10	0-2 mm: -0.47 (0.40)	N/A
			0-2 mm: -0.06 (0.53)	N/A
			0-2 mm: -0.50 (0.57)	N/A
			0-2 mm: -0.1 (0.57)	N/A
	Zuiderveld *et al.* [15]	28	0-2 mm: -1.21 (1.07)	3-5 mm: -0.72 (0.63)
			0-2 mm: -0.80 (0.86)	3-5 mm: -0.69 (0.59)
			0-2 mm: -0.81 (0.77)	3-5 mm: -0.65 (0.63)

N/A: Data not available.

Heterogeneity Assessment

To compare the bone resorption results occurring at various implant height intervals, both horizontally and vertically, it is essential to evaluate the variability between studies. This variability must be because of heterogeneity, rather than being attributed to sampling error. To assess this, Levene's test for equality of variance is applied [16].

The first step in this assessment is calculating the pooled standard deviation (s):

$$s = \sqrt{\frac{(n_1 - 1)s_1^2 + (n_2 - 1)s_2^2}{n_1 + n_2 - 2}} \quad (1)$$

- s1 and s2s_2s2 are the standard deviations of the two samples,
- n1n_1n1 and n2n_2n2 are the sample sizes of the two groups.

$$se(\bar{x}_1 - \bar{x}_2) = s \times \sqrt{\frac{1}{n_1} + \frac{1}{n_2}} \quad (2)$$

Finally, the t-test is used to determine the significance level (or P-value) between the two results [17].

$$t = \frac{\bar{x}_1 - \bar{x}_2}{se(\bar{x}_1 - \bar{x}_2)} \quad (3)$$

The results of all subgroup calculations are displayed in the following tables, categorized based on the location of measurement (**Table 3**). In each table, "Sample size 1" refers to the number of surgery sites from the first result in a given publication. "Mean 1" and "Sd 1" represent the mean bone resorption and standard deviation from the first publication, respectively. "Sample size 2" denotes the number of surgery sites from the 2nd publication, with "Mean 2" and "Sd 2" corresponding to the mean bone resorption and standard deviation from that 2nd publication. If the t-test reveals a p-value less than 0.05 between the two subgroup results, it indicates that the results from the two subgroups are significantly different. All results are analyzed and compared in this way. The final column shows whether there is a significant difference between the two results.

A total of 56 calculations were conducted. Out of these, 19 (34%) of the two-tailed t-tests confirmed the presence of heterogeneity.

Table 3 presents the intergroup results of the heterogeneity assessment. Each result is compared within the same group. If there is a statistically significant difference between results within one group, the symbol "*" is used in the last column.

Table 3. The intergroup results of the heterogeneity assessment.

Heterogeneity identification of the flapless and no graft intervention group results.							
Flapless and no graft (0-2 MM)							Significantly different ($P < 0.05$*)
Sample size 1	Mean 1	Sd 1	Sample size 2	Mean 2	Sd 2	Difference (P)	
20	0.28	0.15	15	1	1.1	0.0065	*
20	0.28	0.15	15	0.24	0.11	0.3902	
15	1	1.1	15	0.24	0.11	0.0127	*
Flapless and no graft (3-5 MM)							
Sample size 1	Mean 1	Sd 1	Sample size 2	Mean 2	Sd 2	Difference (P)	
15	0.8	0.8	5	0.14	0.8	0.1275	
15	0.8	0.8	27	0.26	0.96	0.072	
5	0.14	0.8	27	0.26	0.96	0.795	
Flapless and no graft (Vertical)							
Sample size 1	Mean 1	Sd 1	Sample size 2	Mean 2	Sd 2	Difference (p)	
20	0.77	0.35	N/A	N/A	N/A	N/A	N/A
Heterogeneity identification of the flapless and graft intervention group results.							

Flapless and graft (0-2 MM)							Significantly different (P < 0.05*)
Sample size 1	Mean 1	Sd 1	Sample size 2	Mean 2	Sd 2	Difference (P)	
21	1.45	0.72	27	0.91	0.77	0.0169	*
21	1.45	0.72	27	0.42	0.57	0.0001	*
21	1.45	0.72	27	0.37	0.62	0.0001	*
27	0.91	0.77	27	0.42	0.57	0.0104	*
27	0.91	0.77	27	0.37	0.62	0.0065	*
27	0.42	0.57	27	0.37	0.62	0.7589	
Flapless and graft (3-5 MM)							
Sample size 1	Mean 1	Sd 1	Sample size 2	Mean 2	Sd 2	Difference (P)	
27	0.31	0.63	27	0.35	0.69	0.8248	
27	0.31	0.63	27	0.37	0.63	0.7278	
27	0.35	0.69	27	0.37	0.63	0.9119	
Flapless and graft (Vertical)							
Sample size 1	Mean 1	Sd 1	Sample size 2	Mean 2	Sd 2	Difference (P)	
20	0.07	1.42	21	1.71	1.02	0,0001	*
Heterogeneity identification of the flap and no graft intervention group results.							
Flap and no graft (0-2 MM)							Significantly different (P < 0.05*)
Sample size 1	Mean 1	Sd 1	Sample size 2	Mean 2	Sd 2	Difference (P)	
14	1.1	0.9	16	0.91	0.54	0.4826	
Flap and no graft (3-5 MM)							
Sample size 1	Mean 1	Sd 1	Sample size 2	Mean 2	Sd 2	Difference (P)	
N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Flap and no graft (Vertical)							
Sample size 1	Mean 1	Sd 1	Sample size 2	Mean 2	Sd 2	Difference (P)	
N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Heterogeneity identification of the flap and graft intervention group results.							
Flap and graft (0-2 MM)							Significantly different (P < 0.05*)
Sample size 1	Mean 1	Sd 1	Sample size 2	Mean 2	Sd 2	Difference (P)	
15	0.4	0.8	14	0.37	0.09	0.8902	
15	0.4	0.8	10	0.47	0.40	0.801	
15	0.4	0.8	10	0.06	0.53	0.2507	
15	0.4	0.8	10	0.50	0.57	0.7364	
15	0.4	0.8	10	0.1	0.57	0.3173	
15	0.4	0.8	28	1.21	1.07	0.014	*
15	0.4	0.8	28	0.80	0.86	0.1443	
15	0.4	0.8	28	0.81	0.77	0.1082	
14	0.37	0.09	10	0.47	0.40	0.372	
14	0.37	0.09	10	0.06	0.53	0.0416	*
14	0.37	0.09	10	0.50	0.57	0.4066	
14	0.37	0.09	10	0.1	0.57	0.0928	
14	0.37	0.09	28	1.21	1.07	0.0058	*
14	0.37	0.09	28	0.80	0.86	0.0711	
14	0.37	0.09	28	0.81	0.77	0.0404	*
10	0.47	0.40	10	0.06	0.53	0.0666	
10	0.47	0.40	10	0.50	0.57	0.8931	
10	0.47	0.40	10	0.1	0.57	0.1102	
10	0.47	0.40	28	1.21	1.07	0.0411	*
10	0.47	0.40	28	0.80	0.86	0.253	
10	0.47	0.40	28	0.81	0.77	0.1933	
10	0.06	0.53	10	0.50	0.57	0.0907	
10	0.06	0.53	10	0.1	0.57	0.8727	

10	0.06	0.53	28	1.21	1.07	0.0026	*
10	0.06	0.53	28	0.80	0.86	0.0155	*
10	0.06	0.53	28	0.81	0.77	0.0074	*
10	0.50	0.57	10	0.1	0.57	0.134	
10	0.50	0.57	28	1.21	1.07	0.0545	
10	0.50	0.57	28	0.80	0.86	0.314	
10	0.50	0.57	28	0.81	0.77	0.2535	
10	0.1	0.57	28	1.21	1.07	0.0037	*
10	0.1	0.57	28	0.80	0.86	0.0226	*
10	0.1	0.57	28	0.81	0.77	0.0117	*
28	1.21	1.07	28	0.80	0.86	0.1199	
28	1.21	1.07	28	0.81	0.77	0.1142	
28	0.80	0.86	28	0.81	0.77	0.9636	
Flap and graft (3-5 MM)							
Sample size 1	Mean 1	Sd 1	Sample size 2	Mean 2	Sd 2	Difference (P)	
28	0.72	0.63	28	0.69	0.59	0.8548	
28	0.72	0.63	28	0.65	0.63	0.6792	
28	0.69	0.59	28	0.65	0.63	0.8072	
Flap and graft (Vertical)							
Sample size 1	Mean 1	Sd 1	Sample size 2	Mean 2	Sd 2	Difference (P)	
15	1.03	1.09	N/A	N/A	N/A	N/A	N/A

Statistical Data Analysis

The data from the 0-2 mm horizontal bone change group revealed significant variability, preventing further statistical analysis from being meaningful. Additionally, both the vertical bone resorption group and the 3-5 mm horizontal bone change group lacked sufficient data to allow any meaningful statistical analysis.

Following the immediate placement of dental implants, the loss of fragile buccal bone often results in soft tissue collapse, which can cause buccal recession around the implant. This issue not only compromises the esthetic outcome but also heightens the risk of peri-implantitis and implant failure if not addressed. To minimize these complications, it is essential to establish a clear and effective protocol for immediate implant placement.

This investigation was designed to evaluate how flap elevation and the use of bone substitutes influence buccal bone plate resorption following immediate dental implant placement in the aesthetic region of the maxilla. To ensure high-quality evidence, only top-tier clinical trials were included. Standardized surgical procedures were used to reduce bias from varying methods. The data covered both horizontal and vertical bone loss, and the results were grouped according to four different surgical protocols. While bone remodeling varied across these groups, statistical analysis was hindered by heterogeneity in subgroup data, as assessed using Levene's Test for Equality of Variance. Consequently, no definitive comparison of flap elevation and bone grafting effects on buccal bone plate resorption could be made.

Nevertheless, it can be conclusively stated that buccal bone plate resorption persists despite the use of bone grafting or flapless procedures. This indicates that neither approach can prevent resorption after immediate dental implant placement. However, a trend was noted where the flap and no graft protocol resulted in the greatest reduction in bone volume near the implant neck, suggesting that bone augmentation and the preservation of soft tissue might help stabilize buccal bone.

These findings are consistent with past systematic reviews [18, 19], which also concluded that buccal bone plate resorption following immediate implant placement is unavoidable. Additionally, this highlights that our strict inclusion criteria were unable to exclude all potential influencing factors. Future research should account for various factors, such as implant surface characteristics [20-23], implant connection type, dimensions [24, 25], insertion torque [26, 27], bone quality and quantity of the patient [28-30], graft material for the jumping space [31-34], healing abutment type [35], provisional restoration timing and type [36, 37], soft tissue phenotype [38], and final restoration type [39-44]. Given that their impact on early bone remodeling remains debated, we believe that the absence of standardization in these factors and a lack of high-quality trials contributed to the heterogeneity observed in the included studies.

Conclusion

In summary, immediate dental implant placement in the esthetic zone of the maxilla leads to resorption of the buccal bone plate, regardless of whether flap elevation or grafting is used to fill the gap. A potential trend suggests that flapless procedures combined with graft placement may contribute to better stability of the buccal bone plate following surgery. However, due to the insufficient data and heterogeneity observed across studies, reliable comparisons between groups involving flap elevation and grafting could not be made. Therefore, further high-quality, well-documented, and consistent clinical trials are essential to thoroughly assess the effects of flap elevation and grafting on the remodeling of the buccal bone plate.

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Ethics Statement: None

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