Review Article

RESORPTION OF THE BUCCAL BONE PLATE AFTER IMMEDIATE IMPLANTATION: A SYSTEMATIC REVIEW

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ABSTRACT

Anatomy of the buccal bone plate in the esthetic zone of the maxilla indicates its susceptibility to significant resorption after the extraction of a tooth. Immediate dental implant placement helps to maintain the stability of the surrounding tissues but is incapable of stopping the resorption entirely. This systematic review aims to compare two major surgical protocol factors that could impact the amount of bone remodulation after immediate dental implant placement - full-thickness flap elevation and bone grafting. A systematic review was carried out according to the PRISMA guidelines. Only prospective clinical trials which evaluated buccal bone plate of maxilla volumetric changes using CBCT scans pre-operatively and 6-12 months post-operatively were included. A total of 358 publications were identified after the initial search. 8 studies with a total of 272 surgery sites met our inclusion criteria and were included. Results were divided into four categories according to the surgical procedures performed. However, subgroup data heterogeneity was identified, thus no trustworthy intergroup comparison could be performed. However, this study confirms that the buccal bone plate of maxilla resorption after immediate implantation is yet inevitable. Only a tendency could be noted that the flapless procedure and graft placement results in better buccal bone plate stability.

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

Introduction

After the extraction of a tooth remodeling of the soft and hard tissues occurs. Bone fills the defect in the alveoli and resorption occurs on the outer surface of the alveolar bone. Change in bone contour occurs both vertically and horizontally [1]. It is reported that around 87 percent of patients present with a buccal bone plate equal to or thinner than 1 millimeter [2]. Additionally, after the extraction majority of bone resorption takes place buccally from the extraction site [3, 4]. In part, this can be explained by the fact that the buccal bone plate contains bundle bone and blood flow is dependent on the periodontal ligament. Thus, the anatomy of the maxillary buccal bone plate in the esthetic zone indicates its susceptibility to significant resorption after the extraction of a tooth. Immediate dental implant placement is proven to be an effective method for maintaining the surrounding tissue stability, however incapable of stopping bone resorption entirely yet [5, 6]. This means that management of the surgical site requires that all factors must minimize the loss of hard tissues for a pleasing esthetic result and a successful dental implant retained restoration. This study aims to evaluate early bone volumetric changes of the buccal bone plate vertically and horizontally after the immediate dental implant placement. Two major surgical protocol factors that could impact the amount of bone remodulation are compared - full-thickness flap elevation and bone grafting.

Materials and Methods

This systematic review was carried out using the Preferred Reporting Item for Systematic Reviews and Meta-Analyses (PRISMA) statement. Before the beginning of the systematic review, the protocol was written and registered at PROSPERO (the University of York, Centre for Reviews and Dissemination). The unique ID of this publication is CRD42021291731.

Clinical question

The clinical question was prepared by following the Participant, Intervention, Comparison, Outcome (PICO) principle [5]. How does the grafting and flap elevation during the immediate implantation in the aesthetic zone of the maxilla influence early buccal bone plate resorption?

Inclusion and exclusion criteria

Inclusion criteria

- Prospective clinical trials.
- Human clinical studies in which immediate titanium dental implant placement was carried out.
- Participants must be healthy adults without any systemic diseases.
- Immediate implantation (dental implant placement in the fresh alveolar socket after the extraction of a tooth) must be performed in the aesthetic zone of the maxilla (second premolar to the second premolar).
- Implant should be placed subcrestally (1 – 4 millimeters below the surface of the adjacent alveolar bone).

- Jumping space (space between the implant and the buccal wall)
- No buccal bone defects (dehiscence or fenestration) must be present after the extraction of the tooth.
- Buccal bone alterations must be measured using CBCT (cone beam computed tomography) before the intervention and at the follow-up.
- Follow-up period is between 6 to 12 months after the initial surgery.

Exclusion criteria

- Animal studies.
- Retrospective studies.
- Results from dental implantation performed in mandible.
- Buccal wall defects present or not evaluated after the extraction of a tooth.
- No information about the jumping space.

Search strategy and study selection

An electronic systematic literature search according to PRISMA guidelines [6] was conducted by two researchers (D.L and R.P.) individually in PubMed, Science Direct, and Cochrane library from September to November of 2021. The keywords used in the search were: (Immediate implantation), (Graft), (CBCT), (Radiograph), (Bone), (Loss), (Resorption). The publication search was conducted in two stages. The first stage consisted of screening the publications headlines and abstracts. Studies eligible for our inclusion criteria were included in the second stage of screening. Duplicate studies and studies that were not compliant with our inclusion criteria were excluded. The second stage consisted of analyzing the full-text publications. If they were compliant with the inclusion criteria, they were included in this systematic review. Researchers compared search results and resolved dissimilarities through discussion. When an agreement in a such way could not be achieved the consulting experienced researchers (G.J. and D.R.) were asked to help reach a consensus.

Risk of bias assessment

Two researchers (D.L. and R.P.) independently assessed the risk of bias using Cochrane's Risk of Bias 2 (RoB 2) tool [7]. If there were dissimilarities between the results – researchers discussed them to achieve a consensus. If an agreement could not be reached in such a manner, third consulting party (G.J. and D.R.) helped to resolve issues. The following domains were assessed: randomization process, deviations from the intended interventions, missing outcome data, measurement of the outcome, and selection of the reported result.

Results and Discussion

Study selection

A review of articles, abstracts, and full-text publications is depicted utilizing a PRISMA flow diagram **(Figure 1)**. A total of 358 publications were identified in the initial search. After eliminating duplicates and articles with titles or abstracts that did not meet the inclusion criteria, 74 studies were included. Only one study was unavailable for full-text screening. After reading the available full-text articles 65 publications were excluded because they were not eligible for our inclusion criteria. The most common reason for article exlusion was that the results of buccal bone plate resorption were combined from surgeries performed in the aesthetic zone in both maxilla and mandible. 8 studies met the inclusion criteria and were included in this systematic review.

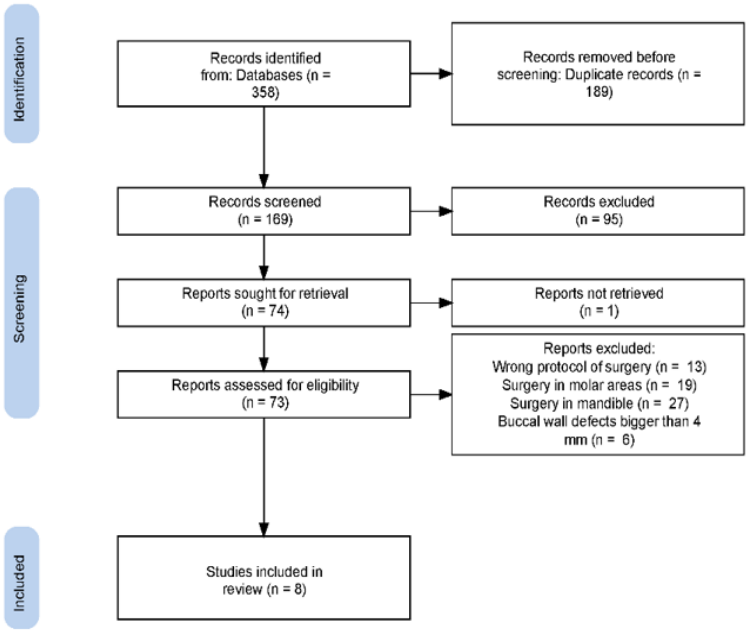

Figure 1. Prisma flowchart

Characteristics of the included studies

The included articles were all prospective clinical trials published from 2016 to 2021 **(Table 1)**.

Table 1. Characteristics of the included studies. Location of clinical trials took place in Europe, Asia, North America and Africa. Total number of evaluated dental implants was 272, follow-up period ranged between 6 and 12 months, 7 studies measured buccal bone plate change horizontally and 3 studies calculated the vertical bone resorption.

References	Country	Number of implants	Interventions described (+ yes, - no)				Follow-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	-	+	+	+	6 m.	-	+
Grassi *et al*. [10]	Italy	44	+	+	+	+	6 m.	+	-
Naji *et al*. [11]	Saudi Arabia	45	+	+	+	+	6 m.	+	-
Atef *et al*. [12]	Egypt	21	-	+	+	-	6 m.	+	+
Bittner *et al*. [13]	United States of America	32	+	-	+	-	9 m.	+	-
Fujita *et al*. [14]	Japan	20	-	+	-	+	12 m.	+	-
Zuiderveld *et al*. [15]	Netherlands	55	-	+	+	+	12 m.	+	-

The total number of implants is 272. There were 4 studies [8, 10, 11, 13] in which no graft was used, in 6 [9-12, 14, 15] studies autogenic, allogenic, or xenogenic bone substitute was used to fill the jumping space. In 7 [8-13, 15] trials flapless immediate implantation was evaluated and in 5 [9-11, 14, 15] publications the results of flap elevation were described. 7 papers [8, 10-15] measured early changes in the buccal bone plate thickness and only 3 publications [8, 9, 12] evaluated the vertical resorption of the buccal bone plate. If the article included a group of patients that were eligible for our analysis – we included only that group in our paper. For example, Fujita *et al*. article includes group of patients in which the soft tissue augmentation procedure was performed and Abd-Elrahman *et al*. evaluates effects of socket shield technique. Groups of patients from these interventions groups were excluded from this study.

Risk of bias assessment

The results of the risk of bias assessment for each study is presented visually bellow in **Figure 2**. High risk of bias was arising from the randomization process in two [9, 14] papers that we included in our study. This occurred due to a suspect that enrolling investigators had knowledge of the forthcoming allocations. It is worth noting that none of the trials included had any baseline imbalances that would suggest a problem with the randomization process. Some concerns arose when evaluating the bias in measurement of the outcome in three studies [8, 14, 15]. In these studies, outcome assessors were aware of the intervention received, therefore the assessment could have been influenced. Also, there were some concerns with Bittner *et al*. trial regarding the randomization process due to lack of information on allocation sequence concealment. All studies demonstrated low risk of bias due to deviations from intended intervention, missing outcome data and selection of the reported result domains. Overall, three studies [10-12] were considered as low risk of bias, another three publications demonstrated some concerns [8, 13, 15], and two trials [9, 14] were rated as high risk of bias.

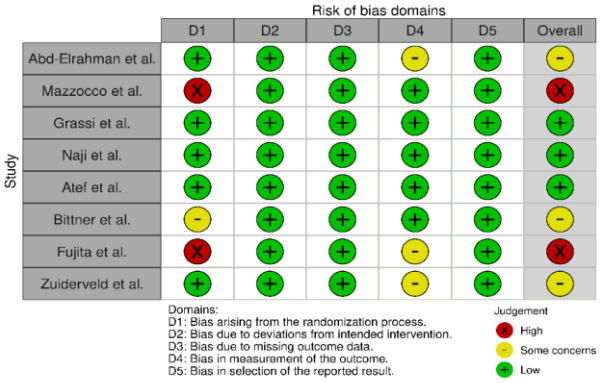

Figure 2. Visual representation of the risk of bias assessment's results. Results of individual domains and overall risk of bias are visualised.

Results of individual studies

The results from individual studies were grouped according to the interventions made during the surgery. Four groups were formed: flapless and no graft, flapless and graft, flap and no graft, and flap and graft. Results of the buccal bone plate horizontal and vertical dimensional change in all studies were measured in the midline of the implant. As mentioned before, the follow-up period was between six and

twelve months. The area of interest for the horizontal resorption was chosen to be the 5 millimeters starting from the neck of the implant (0 mm) advancing apically to the 5th millimeter. Two subgroups were formed for the assessment of the horizontal resorption taking place in the bucco-palatal direction according to the location of measurement (0 – 2 mm. and 3 – 5 mm.). Results are presented in **Table 2**. The amount of dimensional bone change in the table is presented as a mean and a standard deviation. Negative numbers indicate bone resorption, positive numerical results indicate the growth of bone after the follow-up period.

Table 2. Results of the buccal bone plate resorption occurring vertically (buccally from the implant) and horizontally. Horizontal resorption group contains results of horizontal buccal bone plate resorption at 0-2 mm. bellow the shoulder of the implant and 3-5 mm. bellow the shoulder of the implant.

FLAPLESS AND NO GRAFT				
Study	**Number of implants**	**Horizontal dimensional change (mm.)**		**Vertical dimensional change (mm.)**
		0 – 2 mm.	**3 – 5 mm.**	
Abd-Elrahman *et al*. [8]	20	-0.28 (0.15)	N/A	-0.77 (0.35)
Grassi *et al*. [10]	15	-1.0 (1.1)	-0.8 (0.8)	N/A
Naji *et al*. [11]	15	-0.24 (0.11)	N/A	N/A
Bittner *et al*. [13]	5	N/A	-0.14 (0.8)	N/A
	27	N/A	-0.26 (0.96)	N/A
FLAPLESS AND GRAFT				
Study	**Number of implants**	**Horizontal dimensional change (mm.)**		**Vertical dimensional change (mm.)**
		0 – 2 mm.	**3 – 5 mm.**	
Mazzocco *et al*. [9]	20	N/A	N/A	-0.07 (1.42)
Atef *et al*. [12]	21	-1.45 (0.72)	N/A	-1.71 (1.02)
Zuiderveld *et al*. [15]	27	-0.91 (0.77)	-0.31 (0.63)	N/A
		-0.42 (0.57)	-0.35 (0.69)	
		-0.37 (0.62)	-0.37 (0.63)	
FLAP AND NO GRAFT				
Study	**Number of implants**	**Horizontal dimensional change (mm.)**		**Vertical dimensional change (mm.)**
		0 – 2 mm.	**3 – 5 mm.**	
Grassi *et al*. [10]	14	-1.1 (0.9)	N/A	N/A
Naji *et al*. [11]	16	-0.91 (0.54)	N/A	N/A
FLAP AND GRAFT				
Study	**Number of implants**	**Horizontal dimensional change (mm.)**		**Vertical dimensional change (mm.)**
		0 – 2 mm.	**3 – 5 mm.**	
Mazzocco *et al*. [9]	15	N/A	N/A	-1.03 (1.09)
Grassi *et al*. [10]	15	-0.4 (0.8)	N/A	N/A
Naji *et al*. [11]	14	-0.37 (0.09)	N/A	N/A
Fujita *et al*. [14]	10	-0.47 (0.40)	N/A	N/A
		-0.06 (0.53)	N/A	
	10	-0.50 (0.57)	N/A	
		-0.1 (0.57)	N/A	
Zuiderveld *et al*. [15]	28	-1.21 (1.07)	-0.72 (0.63)	N/A
		-0.80 (0.86)	-0.69 (0.59)	
		-0.81 (0.77)	-0.65 (0.63)	

N/A – no available data.

Heterogeneity assessment

In order to compare the results of bone resorption occurring at different intervals of implant height both horizontally and vertically throughout the examination of significant variability among studies must be assessed. In order to evaluate variability in effect estimates which is due to heterogeneity rather than sampling error Levene's Test for Equality of Variance is applied [16].

Firstly, the pooled standard deviation *s* is calculated:

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

s_1 and s_2 are the standard deviations of the two samples with sample sizes n_1 and n_2. the standard error *se* of the difference between the two means is calculated as:

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

Lastly, the significance level (also known as the P-value) between the two results is calculated using the *t*-test [17]:

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

All of the subgroup calculation results are presented in the following tables and divided according to the measurement location **(Table 3)**. In each table "Sample size 1" represents the number of surgery sites from the first result of a particular publication. "Mean 1" and "Sd 1" represents the result of bone resorption mean with standard deviation from the same first publication. "Sample size 2" refers to the number of surgery sites from the second publication. "Mean 2" and "Sd 2" represents the result of bone resorption mean with standard deviation from the second publication. If the t-test indicates that the p-value between the first and second subgroup results is less than 0,05 – two different subgroup results are statistically different. All of the results are compared in such a manner. The last column of the table indicates whether the two results are significantly different or not.

A total of 56 calculations were performed. 19 (34 %) of all two-tailed *t*-tests confirmed that heterogeneity is indeed present.

Table 3. Intergroup results of heterogeneity assessment. All of the individual results are compared between the same group results. If the difference between the results inside of one group are statistically significant – " *" symbol is written in the last column.

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

N/A – no available data.

Statistical data analysis

The results of the horizontal bone change in the 0-2 mm. group are heterogenic. Further statistical analysis is possible, yet worthless. Any conclusions would be potentially misleading. Results in both the vertical bone resorption group and horizontal bone change at 3-5 mm groups contain too little data. Further statistical data analysis is not possible.

It is known that after the immediate dental implant placement the loss of fragile buccal bone results in the collapse of soft tissues. In turn, recession buccally from implant develops. This leads not only to the compromised esthetic result of restoration but to the serious risk of peri-implantitis development and to the total loss of implant if not treated. To avoid such complications proper immediate implant placement protocol should be established.

The present study aimed to assess flap elevation and bone substitute use influence on buccal bone plate resorption after immediate dental implant placement in the esthetic zone of maxilla.

In order to achieve trustworthy results in our review only high-quality clinical trials were included. Surgical procedures were similar in order to exclude bias arising due to the surgery protocol inconsistencies. The gathered data contains information about the loss of bone both horizontally and vertically. Groups of results from four different surgery protocols were formed. Even though intergroup bone remodulation outcomes are different, no statistical data comparison could be performed due to the presence of heterogeneity in subgroup data. This was evaluated utilizing Levene's Test for Equality of Variance. It means that our paper fails to present a trustworthy comparison of flap elevation and bone grafting influence on buccal bone plate resorption in the maxilla. However, we can certainly state that to this day buccal bone plate resorption occurs regardless of the flap elevation and bone graft use. This information for a clinician presents the fact that both the use of grafting material and a flapless procedure can not stop the process of buccal bone plate resorption after the immediate dental implant placement. Only a tendency could be noted – flap and no graft protocol results in the greatest reduction of bone volume near the implant neck. This indicates that bone augmentation procedures and preservation of intact soft tissues help to maintain buccal bone stability.

The fact that to this day buccal bone plate resorption after the immediate dental implant placement is inevitable is in accordance with previous systematic reviews [18, 19].

On the other hand, it means that our strict inclusion criteria aspects were not able to exclude all factors that could influence different bone alterations. Our recommendations for factors which should be taken into account by future researchers include: implant surface morphology and properties [20-23], implant type of connection, length and diameter [24, 25], implant insertion torque [26, 27], patient's bone quality and quantity [28-30], jumping space grafting material [31-34], use and type of healing abutment [35], timing and type of provisionalisation [36, 37], soft tissue phenotype [38] and type of final restoration [39-44]. All of these factors should be considered because their impact on early bone remodulation is still debatable. We believe that the lack of standardization of before mentioned factors and a lack of high-quality clinical trials resulted in a heterogeneity of the included studies.

Conclusion

All in all, regardless of flap elevation or jumping gap grafting, immediate dental implant placement in the esthetic zone of the maxilla results in buccal bone plate resorption. Only a tendency could be noted that the flapless procedure and graft placement results in better buccal bone plate stability post-surgery. Due to the lack of data and present heterogeneity between studies no reliable comparisons between flap elevation and grafting groups could be performed. Further high quality, well documented, homogenous clinical trials are necessary in order to evaluate flap elevation and grafting impact on buccal bone plate remodelling.

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Ethics statement: None

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