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REVIEW ARTICLE

Critical review on bone grafting during immediate implant placement

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1 | INTRODUCTION

In the last decades, dental implants have been the treatment of choice to replace missing teeth with good long-term prognosis.[1,2] Advances in implant surface have shortened the period required for osseointegration, which suggests early bone healing at implant sites with adequate bone volume.[3,4] This also favors spontaneous bone regeneration of peri-implant defects.[5,6] Consequently, the loading protocol has changed from the initial period of 3–6 months to 6–8 weeks.[7] However, placing dental implants immediately after failing teeth removal is a different scenario.

Historically, conventional protocols of implant placement recommended a healing time of 12 months or longer following tooth extraction for implant installation.[8] Further studies on alveolar socket healing demonstrated that the alveolus is filled with newly formed bone after 3–4 months, and a dental implant can be placed with primary stability in this condition.[9,10] In addition, there is a preference from patients for immediate or early treatment protocols than delayed approach.[11] Thus, in patients with esthetic demands, such as anterior teeth, reduced treatment time with implants placed into fresh extraction sockets is a valid treatment alternative.

A classification for the timing of implant placement after tooth extraction was proposed at the Third ITI Consensus Conference.[12] This classification system is based on the desired clinical outcome of the wound healing process, rather than on descriptive terms or strict time frames following extraction:

1. Type 1 refers to implant placement on the day and within the same surgical procedure of tooth extraction.
2. Type 2 refers to implant placement after soft tissue healing, but before a clinically significant bone formation in the socket.
3. Type 3 describes an implant placement following significant clinical and/or radiographic bone formation in the socket.
4. Type 4 refers to implant placement in a fully healed site.

Since the first publication on implant placement into fresh extraction sockets,[13] the interest for this technique has increased. Some advantages are evident, such as the decrease in the number of surgeries and overall treatment time.[14] Other advantages have been proposed but are heavily debated, such as the implant insertion oriented by the alveolar socket,[15] the possible bone preservation in the extraction area,[16] and more favorable esthetic outcomes due to soft tissue contour preservation.[17] Systematic reviews have shown that the survival rate of type 1 implant placement is similar to those of delayed approach.[11,18–20] However, preclinical and clinical studies revealed that immediate implant placement per se does not preserve the anatomy of the alveolus, leading to bony dehiscence and subsequent soft tissue recession, with great impact on esthetic outcomes.[21–24] Some factors may prevent bone resorption after immediate implant placement, such as alveolar socket size,[22] thickness of the buccal bone plate,[25] buccal gap dimension,[26] flapless procedures,[27] implant diameter,[28] implant positioning,[29] use of bone grafts,[30] and use of connective tissue grafts.[31]

2 | ALVEOLUS AND BUCCAL BONE PLATE

2.1 | Dimensional changes after tooth extraction

The healing events following tooth extraction (remodeling) lead to dimensional changes in the alveolar ridge (modeling). Schropp et al.[32] observed in premolars and molars that approximately 50%

of alveolar ridge width reduction can be expected after extraction, mostly in the first 6 months. Moreover, after 12 months of healing, the most coronal point of the ridge in the buccal side was located 1.2 mm apical to the lingual side. Araujo and Lindhe[33] found in animal models that bundle bone is resorbed and disappears during initial healing following tooth extraction. A systematic review showed that dimensional changes in hard tissues of nonmolar region are more pronounced horizontally (2.73 mm) than vertically (1.71 mm) at mid-buccal sites,[34] corroborating with the findings of previous systematic reviews.[35,36] Local factors, such as the presence of inflammation, multiple versus single tooth extraction, preexisting bone defects, and extraction technique, or systemic factors, such as smoking, can increase the extent of bone resorption.[27,37–40] Implant placement does not change the remodeling process and, therefore, buccal bone loss is not reduced despite type 1 implant placement.[21,22] Hence, bone remodeling after tooth extraction inevitably leads to alveolar ridge defect formation. These defects can pose technical difficulties during implant placement, and may have detrimental esthetic implications in the implant-supported rehabilitation.

2.2 | Factors that may affect post-extraction dimensional changes

Several factors may potentially influence the healing process of the post-extraction alveolar socket. Some of these factors may influence only unassisted socket healing, and some may influence both unassisted socket healing and immediate implant placement. These factors can be local, surgical, or systemic.

In unassisted socket healing, there is strong evidence to support that molar sites exhibit more reduction of alveolar ridge in all dimensions compared to nonmolar sites, except for midfacial vertical changes, and also that facial bone thickness is strongly associated with the extent and magnitude of alveolar bone resorption (the thicker the facial bone, the less ridge resorption). However, nonmolar sites are associated with an increased need of bone grafting procedures. This could be explained by the wider horizontal dimension of molar sites which, despite of undergoing more bone loss after tooth extraction, allow for implant placement without additional bone grafting procedures in a higher proportion of cases compared to nonmolar sites, where the impact of physiologic bone resorption is proportionally larger.[34]

Also, there is evidence to support that socket anatomy and integrity, soft tissue thickness, keratinized mucosa width, supracrestal tissue height, diabetes, smoking status, history of periodontitis and surgical variables such as flap elevation or primary closure may also have an impact on alveolar ridge dimensional changes after tooth extraction.[41]

The existing evidence regarding the influence on some of the clinically more relevant factors on alveolar ridge dimensional changes in immediate implant placement will be discussed below.

2.2.1 | Buccal wall thickness

The influence of the buccal wall thickness was investigated at the time of immediate implant placement and after 3–6 months of healing.[42] Greater vertical buccal bone loss was detected in thinner buccal bone plate, confirmed histologically in an animal study.[43] A buccal wall thickness of at least 2 mm in type 1 implant placement is recommended to achieve optimal results and has been accepted as a threshold below which augmentation procedures are required.[44] The results from a recent systematic review indicate that this ideal clinical condition is rare. Their findings confirmed that the buccal bone wall in the maxillary anterior region is predominantly thin, being most measurements in incisor and canine sites <1 mm.[45] This confirmed the findings of individual clinical studies which reported that anterior teeth had a buccal wall thickness ≤1 mm in approximately 85% of the sites and <5% of incisors and canines had at least 2 mm thickness in the buccal bone wall. In premolar sites, the buccal wall thickness was ≤1 mm in approximately 60% of cases and ≥2 mm in approximately 10% of cases.[46,47] If the 2 mm criterion is applied, bone augmentation would be required in most type 1 implant placement cases, particularly in the anterior maxilla.

2.2.2 | Anterior/posterior location

Despite greater dimensional changes after tooth extraction in molar sites compared to nonmolar sites,[34] it has been documented that nonmolar sites are associated with an increased need for bone grafting procedures prior or at the time of implant placement compared to molar sites (69.7% vs. 45.9%, respectively). This may be partly due to the greater alveolar ridge width in molar sites compared to nonmolar sites that, after resorptive changes may still be sufficient to allow adequate housing of the implant in the bony envelope and tissue height/thickness despite buccal volume loss, and partly due to the fact that esthetic outcomes related to tissue volume preservation are less critical in posterior sites.

2.2.3 | Gap size

After tooth removal, the alveolar socket often presents dimensions that are greater than the diameter of the implant, generating a gap between the implant surface and the alveolar bone walls in the recipient site. This space has been defined as jumping distance.[48] The influence of the gap size between the inner wall of the socket and the implant was investigated in a histological study with human biopsies, in which gaps not exceeding 1.5 mm showed complete defect fill without the use of membranes.[49] The same study suggested that gaps with ≥4 mm may not have a complete bone fill even with the use of a membrane. Also, results from a dog experiment reported that when implants occupied most of the hard tissue wound and gaps <1 mm were present, more resorption would be expected.[22,50] Despite these

histological findings, other authors observed that gaps >3 mm may present complete fill on immediate implants with submerged healing in humans.[51,52] Nevertheless, sites presenting incomplete fill after bone healing had in all cases gaps ≥3 mm. Therefore, although complete histologic bone fill may not be essential for clinical success, it is a desired outcome for long-term results of implant therapy.

2.2.4 | Implant positioning

Implant position in the alveolar socket is very important as when the immediate implant is not in the correct three-dimensional position, buccal bone resorption might be significant.[53] It has been reported that implants placed in a more buccal position have higher risk of buccal recession and, therefore, are associated with bone dehiscence defects.[54] A histomorphometric study in dogs demonstrated that implants lingually placed showed less vertical bone loss as compared to those placed in the center of the alveolus.[29] In a human clinical study, anterior implants placed in a palatal position had less mid-buccal gingival recession in comparison with implants placed toward buccal.[23]

The greater amount of resorption reported in cases where implants were placed in a buccal position within the extraction socket, as discussed in the previous section, could be related to the greater amount of resorption where narrow gaps <1 mm between the inner wall of the socket and the implant are present.

2.2.5 | Dehiscence defects

Another critical factor is the presence of preexisting dehiscence defects. In post-extraction sites, the loss of socket walls is a common finding. A significant variation in terms of horizontal bone loss was found in a clinical study, in which different techniques were compared, namely no augmentation, resorbable membrane with bone autograft, autograft alone, or nonresorbable membrane.[55] Horizontal bone loss was 58% greater in the presence of a dehiscence defect at the time of implant placement in comparison with an intact buccal bone wall. Hence, dehiscence defects are of paramount importance for implants placed in the esthetic zone. Deficient buccal walls are associated with a higher risk of gingival recession, despite the use of flapless techniques, presence of a thick phenotype, or use of connective tissue grafts.[56]

2.2.6 | Periodontal phenotype

Although it may not compromise implant survival, buccal gingival recession after implant placement has a dramatic impact on esthetic outcomes.[57] A thin periodontal phenotype is often associated with a thin buccal bone plate, mostly formed by bundle bone, which is expected to resorb after tooth extraction regardless of immediate implant placement.[21] When a thin periodontal phenotype is present, gingival recession after implant placement is a common finding.[58–60] A systematic review revealed that 21.4% of immediate implants presented buccal gingival recession >1 mm, and sites with a thin periodontal phenotype had a higher risk of gingival recession.[61] An RCT comparing submerged versus non-submerged immediate implants showed that buccal gingival recession was more frequent in thin periodontal phenotype than in thick periodontal phenotype, 85% and 38%, respectively.[62] Approximately, threefold buccal gingival recession is present in thin phenotype cases compared with thick phenotype, 1.50 mm and 0.56 mm, respectively.[20] As bone dehiscences are frequently associated with a thin periodontal phenotype, and a dehiscent buccal bone impact the risk for gingival recession,[56] augmentation procedures of soft tissues may be required in thin periodontal phenotype at the time of immediate implant placement to prevent esthetic complications.[63,64]

3 | POST-EXTRACTION SOCKET CLASSIFICATIONS

Different post-extraction socket classifications have been proposed.[65–70] Assessment of buccal soft and hard tissues may be considered one of the most clinically relevant aspects for immediate implant placement. Elian et al.[68] classified the sockets into three types according to the presence or absence of soft and hard tissues:

- Type I: Buccal soft tissue and buccal bone plate at normal levels in relation to the cementoenamel junction of the extracted tooth and remain intact post-extraction (Figure 1A).
- Type II: Facial soft tissue at normal level, but reduced buccal bone plate following tooth extraction (Figure 1B).
- Type III: Buccal gingival recession and buccal bone plate at a reduced level (Figure 1C).

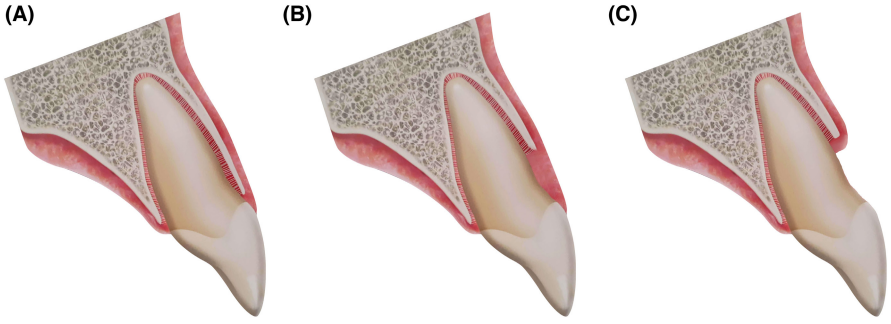

FIGURE 1 Elian et al.[68] classification of alveolar sockets according to the presence or absence of buccal soft and hard tissues. (A) Type I socket. (B) Type II socket. (C) Type III socket.

A subclassification for type II sockets was further proposed as, according to some authors, the Elian et al. classification did not describe type II sockets in sufficient detail to encompass some clinical situations. Chu et al.[71] included the following:

- Type 2A: Intact soft tissues and dehiscence of buccal bone plate up to the coronal third (≤6 mm from the free gingival margin; Figure 2A).
- Type 2B: intact soft tissues and up to two thirds of buccal bone plate dehiscence (7–9 mm from the free gingival margin; Figure 2B).
- Type 2C: intact soft tissues and only the apical third of the buccal bone plate is present (≥10 mm from the free gingival margin; Figure 2C).

4 | BONE REGENERATIVE PROCEDURES IN TYPE I IMPLANT PLACEMENT

Based on the current knowledge, the post-extraction remodeling is a physiological process that cannot be prevented.[72] A realistic goal for mitigating volumetric changes in the alveolar ridge is to compensate the remodeling/modeling processes, aiming to reduce the need for augmentation, the number and complexity of treatment-related procedures, and/or improve aesthetic outcomes.

Current knowledge of the different treatment options after tooth extraction has been assessed in the XV European Workshop in Periodontology on bone regeneration. After tooth extraction, three different approaches can be followed: Alveolar ridge preservation, immediate implant placement and unassisted socket healing with type 2, 3, or 4 implant placement.[73]

The different approaches that have been proposed to be used together with immediate implant in type 1 sockets will be described below, with evidence-based answers on clinical decision making questions such as:

- Do we need to graft the gap between the implant and the socket walls and when? What is the graft of choice?
- Do we need a barrier membrane and when?
- Is it better to follow a flapless approach over flap and when?
- Use of partial tooth extraction/socket shield?
- What about molar sites?

Some relevant studies on this puzzling topic are described in Tables 1 and 2.

4.1 | Do we need to graft the gap between the implant and the socket walls and when? What is the graft of choice?

4.1.1 | Bone grafting in type I sockets

Clinicians frequently use graft materials to fill the buccal gap after immediate implant placement. Different preclinical and clinical studies have been conducted assessing the need for grafting the buccal void between the implant and the buccal bone plate, addressing the influence of different factors such as flap versus flapless approach, socket anatomy, buccal bone thickness, gingival phenotype, gap size, and implant material.

4.1.2 | Preclinical studies

Araújo et al.[30] published a study in Beagle dogs in which bone modeling after tooth extraction and immediate implant placement, with or without grafting the buccal gap, was analyzed. After extraction, a 3.3 diameter implant was placed avoiding contact with the buccal bone plate, leaving a buccal gap. In the control group, no gap filling was performed and, in the test group, the buccal gap was filled with deproteinized bovine bone mineral with 10% porcine collagen (DBBM-C). After 6 months, the control group showed a vertical buccal bone loss of 1.3 mm while the test group showed a buccal bone crest at a similar level as from the time of implant installation. According to this study, grafting the buccal gap prevents vertical buccal bone loss. Conversely, a study in Labrador dogs did not find differences between grafted and nongrafted groups.[74] In the test group, deproteinized bovine bone mineral (DBBM) particles were placed in the defect followed by a collagen membrane. In the control group, no graft material was used. Implants were left to heal in a nonsubmerged approach. After 3 months, the buccal bone crest was located at the same level from baseline in both groups. Different aspects can be discussed between these studies. First, socket

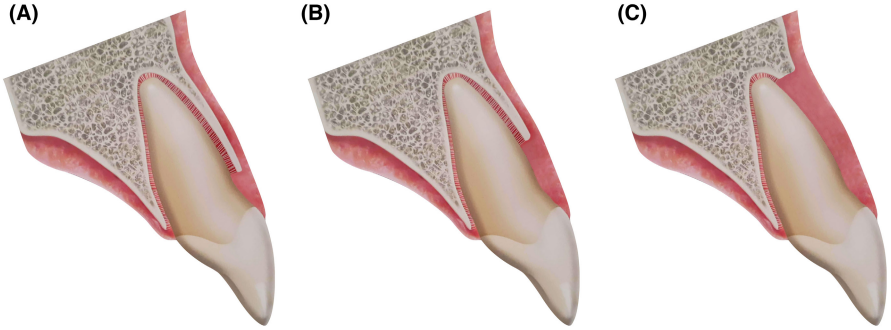

FIGURE 2 Chu et al.[71] subclassification of Type II sockets according to the distance from the dehiscence of buccal bone plate up to soft tissue margin. (A) Type 2A socket (≤6 mm from the free gingival margin). (B) Type 2B socket (7–9 mm from the free gingival margin). (C) Type 2C socket (≥10 mm from the free gingival margin).

TABLE 1 Clinical studies on immediate implants with versus without gap filling.

Study	Patients/implants groups	Follow-up (reference)	Area	Implant type	Implant neck position	Flap/ flapless	Gap size	Buccal wall situation
Bittner et al.[78]	32/32 Test ($n=16$) Control ($n=16$)	3, 6, and 12 months (surgery)	Maxillary and mandibular incisors (7 test/10 control), canines (one control), and premolars (9 test/5 control)	Certain, Zimmer Biomet	At the level of the buccal plate or 1 mm below, and 3–4 mm from cemento-enamel junction of adjacent teeth	32 flapless	Test: 2.9 ± 1.3 mm Control: 3.1 ± 0.9 mm	Intact buccal bone plate Thickness at 4 mm from the crest (mm): • Test: 0.8 ± 0.6 • Control: 0.8 ± 0.6
Naji et al.[79]	45/45 G1: Flap with graft ($n=14$) G2: Flap, no graft ($n=16$) G3: Flapless, no graft ($n=15$)	6 months (surgery)	Maxillary premolars	Neo Biotech, Seoul, Korea	1 mm subcrestal to the buccal bone	30 flap/15 flapless	Horizontal gap size >2 mm	Intact socket walls Buccal bone plate thickness >1 mm
Sanz et al.[80]	86/86 Test ($n=43$) Control ($n=43$)	4 months (surgery)	Maxillary incisors, canines, and premolars	Fixture micro- thread Osseo- Speed; Dentsply, Molndal, and Sweden (3.5 or 4.0 diameter)	Not mentioned	86 flap	Not mentioned	Accepted facial bone fenestration <3 mm Buccal bone thickness (mm): • Test: 0.94 ± 0.67 • Control: 0.87 ± 0.9
Chen et al.[55]	62/62 G1: e-PTFE membrane ($n=12$) G2: absorbable membrane ($n=11$) G3: absorbable membrane + autogenous bone graft ($n=13$) G4: no membrane, autogenous bone graft ($n=14$) G5: control ($n=12$)	6 months (surgery) + 12 and 24 months (loading)	Maxillary incisors, canines and premolars (31 central incisors, 17 lateral incisors, 11 canines, and 3 premolars)	Titanium implants with a turned surface (Brane-mark System, Nobel Biocare, Gothenburg, Sweden)	At the level of the bone crest on the labial aspect	62 flap	Not mentioned	Dehiscence or absence of the labial plate was accepted
Chen et al.[54]	30/30 G1: bone graft ($n=10$) G2: bone graft + resorbable membrane ($n=10$) G3: Control ($n=10$)	6 and 8 months (surgery) + 1, 2, and 3 years (loading)	Maxillary incisors, canines, and premolars (18 central incisors, 2 lateral incisors, 3 canines, and 4 premolars)	Sand-blasted and acid-etched surface (ITI Implant System; Straumann AG, Walden-berg, Switzer-land)	At the level of the buccal crestal bone	30 flap	1.8 ± 0.7 mm	Dehiscence of the buccal bone plate was accepted

(Continues)

TABLE 1 (Continued)

Study	Patients/implants groups	Follow-up (reference)	Area	Implant type	Implant neck position	Flap/ flapless	Gap size	Buccal wall situation
Gher et al. 1994[110]	36/43 G1: TPS implants, GTR alone ($n=11$) G2: TPS implants, GTR + DFDBA ($n=12$) G3: HA implants, GTR alone ($n=10$) G4: HA implants, GTR + DFDBA ($n=10$)	6 months (surgery)	Maxillary and mandibular teeth (incisors, canines, premolars, and molars)	Titanium plasma sprayed (TPS), Straumann Hydroxy-apatite (HA) coated, Calcitek	At the level of the crestal bone (mesial and distal)	43 flap	Not mentioned	Bone defects accepted
Girlanda et al.[83]	22/22 Test ($n=11$) Control ($n=11$)	3 and 6 months (surgery)	Maxillary incisors	Internal hexagon connection (Biomet 3i Full Osseotite Tapered Certain—Palm Beach Gardens, FL) with 4.1 mm diameter	A 3 mm apical to the bucco-gingival margin of the adjacent teeth	22 flapless	Test: 2.55 ± 0.52 mm Control: 2.45 ± 0.52 mm	Presence of the buccal wall (no information about the status)
Grassi et al.[95]	45/45 G1: Flap + graft G2: Flap + no graft G3: No flap + no graft	3 and 6 months (surgery)	Maxillary premolars	Titanium cylindrical-shaped implants (Bone System "2P" Implant, Italy), diameter of 4.1 mm and length from 10 mm–13.5 mm	A 1 mm apically to the marginal level of the palatal bone	30 flap/15 flapless	Not mentioned	No more than a 3 mm loss in the buccal bone plate (determined by clinical sounding)
Jacobs et al.[85]	33/33 Test ($n=19$) Control ($n=14$)	3, 4.5, 7 and 9 months (surgery)	Maxillary incisors ($n=24$), canines ($n=6$), and first premolars ($n=3$)	A 4.5 mm diameter sloped-platform implants of 11, 13, or 15 mm in length (Osseo-Speed TX Profile, Dentsply Sirona)	A 2 mm palatal from the mucosal zenith (horizontally)	33 flapless	Not mentioned	Excluded sites with facial bone wall defect >4 mm from the soft tissue margin Buccal bone thickness <1 mm
Paknejad et al.[86]	15/27 Test ($n=14$) Control ($n=13$)	4 months (surgery)	Maxillary incisors ($n=7$), canines ($n=5$), and premolars ($n=15$)	Dentium Implants, Implantium, Seoul, Korea (12–14 mm in length and 3.5–4.3 mm in diameter)	1–2 mm below the buccal bone crest	27 flapless	Not mentioned	Intact buccal bone plate

TABLE 1 (Continued)

Study	Patients/implants groups	Follow-up (reference)	Area	Implant type	Implant neck position	Flap/flapless	Gap size	Buccal wall situation
Spinato et al.[82]	41/45 Test ($n=23$) Control ($n=22$)	Mean follow-up 32 months, ranged from 12 to 58 months (loading)	Maxillary incisors, canines, and premolars	Screw-vent tapered, Zimmer Dental, Carlsbad, CA (11.5–16 mm in length and 3.7–4.7 mm in diameter)	A 3 mm below the line drawn between adjacent teeth cemento-enamel junction	45 flapless	2.14 ± 0.64 mm (range from 1.0 to 3.5 mm)	Intact alveolar bone walls
Mastrangelo et al.[96]	102/115 Test ($n=51$ patients) Control ($n=51$ patients)	4 months (surgery) + 3, 12, and 36 months (loading)	Maxillary premolars	tioLogic implant system, Dentaurum, Germany (diameter 4.2 and 3.7 mm/length 11 and 13 mm)	A 1–2 mm below the bone peak and slightly palatal	115 flap	Not mentioned	Not mentioned

Abbreviations: CM, collagen membrane; CTG, connective tissue graft; DBBM, demineralized bovine bone mineral; DBBM-C, demineralized bovine bone mineral with 10% collagen (Bio-Oss Collagen, Geistlich Pharma AG, Wolhusen, Switzerland); DFDBA, demineralized freeze-dried bone allograft; IIP, immediate implant placement; IP, immediate provisionalization; PES, Pink Esthetic Score; PIS, Papilla Index Score; PLGA, poly-lactic-co-glycolic acid.

dimension is wider in the premolar region of Labrador dog than in Beagle dog (5 mm vs. 3.5–3.9 mm). Another point was the thickness of the buccal bone plate, which is thinner in Beagle dogs at the premolar mandibular area than in Labradors. Finally, the time points for evaluation, 6 months versus 3 months, respectively. Another study in Labrador dogs compared extraction sockets treated with immediately placed implants and buccal gap (1.0–1.4 mm) grafting with a biphasic synthetic biomaterial, 60% hydroxyapatite (HA) and 40% beta-tricalcium phosphate (TCP), or with blood clot alone.[75] After 4 months of healing, the top of the bone crest and the first bone-to-implant contact were located apically to the implant shoulder, respectively, at 0.1 and 1.5 mm in the test group, and at 0.6 and 1.2 mm in the control group. No statistically significant difference was detected between groups. Limited vertical buccal bone loss was found in this model, which may be related to the socket size, thickness of buccal bone plate, or lingual position of the implant.

A mongrel dog study analyzed the effect of placing DBBM-C into the buccal gap in one piece zirconia implants.[76] A total of 36 implants were immediately placed with flapless approach at a lingual position of mandibular premolars. A buccal void <2 mm or ≥2 mm in width, and ≥3 mm in depth, similar to a three-wall bone defect was created between the implant and the inner socket walls. The marginal level of the zirconia surface was located even or slightly apical (<1 mm) to the buccal bone crest. In the test group, the buccal void was filled with DBBM-C and, in the control, no grafting was performed. After 6 months, bone modeling was more evident in the control group. In the test group, the first bone-to-implant contact was almost at the level of the rough–smooth border. However, in the control group, the first bone-to-implant contact was located 1.43 mm apical to that landmark. The buccal bone crest in the control group was 1 mm apically positioned in comparison with the test group, indicating a more pronounced vertical bone loss, also verified when the buccal void was <2 mm.

It seems that the smaller the jumping distance, the more vertical bone loss can be expected. Grafting outside the buccal bone plate does not seem to be a suitable technique to compensate the alterations after tooth extraction.[77] On the other hand, a positive impact on bone volume preservation occurs when grafting is performed into this void. In addition, the thickness of the buccal bone plate may play an important role in bone preservation. Grafting the buccal gap not only prevents the vertical bone loss but also results in a thicker bone plate after 6 months of healing, which may be important for hard and soft tissues stability in the long term.

4.1.3 | Clinical studies

Different human studies have evaluated the impact of grafting the buccal void upon marginal bone level and esthetics after immediate implant placement.

Bittner et al.[78] compared the dimensional changes in soft and hard tissues, with or without grafting the buccal gap with DBBM-C, after immediate implant placement and temporization.

TABLE 2 Esthetic outcomes and dimensional changes in hard and/or soft tissues ($n = 12$).

Study	Implant survival	Intervention	Comparison	Esthetic outcomes	Mucosa recession	Mean horizontal dimensional changes (mm)	Mean vertical dimensional changes (mm)
Bittner et al.[78]	All implants survived	Test: IIP + gap filling (DBBM-C) + IP	Control: IIP + no gap filling + IP	Not evaluated	Not evaluated	3 mm below the bone crest: • Test: −0.84 ± 0.64 • Control: −1.01 ± 0.45	From a tooth-supported stent to gingival margin: • Test: −0.9 ± 1.2 • Control: −1.3 ± 1.5
Naji et al.[79]	All implants survived	G1: IIP + gap filling (calcium sulphate) + CM + primary wound closure G3: IIP + no gap filling + open healing	G2: IIP + no gap filling + primary wound closure	Not evaluated	Not evaluated	1.5 mm below the bone crest G1: −0.37 ± 0.09 G2: −0.91 ± 0.54 G3: −0.24 ± 0.11	Not evaluated
Sanz et al.[80]	One implant lost (test)	Test: IIP + gap filling (DBBM-C) + healing abutment + flap repositioning	Control: IIP + no gap filling + healing abutment + flap repositioning	Not evaluated	Not evaluated	1 mm below the crest: • Test: −1.07 ± 1.10 • Control: −1.59 ± 1.0	From implant rim to bone crest buccal: • Test: −0.26 ± 1.21 • Control: −0.26 ± 1.36
Chen et al.[55]	Two implants lost (G4) One postsurgical implant loss after implant surgery (cause: infection) One implant loss after surgical reentry (cause: peri-implant infection)	G3: IIP + gap filling (autogenous bone) + absorbable membrane (PLGA) + CTG + flap repositioning G4: IIP + gap filling (autogenous bone) + CTG + flap repositioning	G1: IIP + no gap filling + e-PTFE membrane + CTG + flap repositioning G2: IIP + No gap filling + absorbable membrane (PLGA) + CTG + flap repositioning G5: IIP + No gap filling + CTG + flap repositioning	Not evaluated	Not evaluated	From the most buccal extent of the implant collar to the buccal bone crest G1: −2.6 ± 0.2 G2: −2.5 ± 0.3 G3: −2.1 ± 0.2 G4: −2.2 ± 0.2 G5: −2.0 ± 0.3	Not evaluated
Chen et al.[54]	All implants survived	G1: IIP + gap filling (DBBM) + flap repositioning G2: IIP + gap filling (DBBM) + CM + flap repositioning	G3: IIP + no gap + filling + flap repositioning	Final esthetic outcome (operator reported): Satisfactory: 22 Unsatisfactory: 8 (implant buccally positioned: 6/correct implant position: 2)	At reentry, 10 out of 30 (33.3%) sites exhibited recession of the marginal mucosa of 1–3 mm: G1 = 3 G2 = 4 G3 = 3	From implant shoulder to the external border of the socket at the midpoint of the implant at reentry surgery (6 months after IIP) G1: −0.4 ± 0.5 G2: −0.6 ± 0.7 G3: −1.1 ± 0.3	From implant shoulder to bone crest at reentry surgery (6 months after IIP) G1: −0.1 ± 3.4 G2: +0.5 ± 3.7 G3: −1.3 ± 0.9
Gher et al. 1994[110]	All implants survived	G2 and G4: IIP + gap filling (DFDBA) + healing abutment (not always) + barrier membrane (W.L. Gore, Flagstaff, AZ) + flap repositioning	G1 and G3: IIP + no gap filling + healing abutment (not always) + barrier membrane (W.L. Gore, Flagstaff, AZ) + flap repositioning	Not evaluated	Not evaluated	Not evaluated	From the most coronal socket crest to the implant at reentry surgery (6 months after IIP) Grafted sites (G2 and G4): −1.53 ± 1.38 Nongrafted sites (G1 and G3): −1.59 ± 1.66

TABLE 2 (Continued)

Study	Implant survival	Intervention	Comparison	Esthetic outcomes	Mucosa recession	Mean horizontal dimensional changes (mm)	Mean vertical dimensional changes (mm)
Girlanda et al.[83]	From the initial 30 implants, four implants were excluded (low insertion torque) and four implants were lost	Test: IIP + gap filling (DBBM-C) + IP (for 3 months)	Control: IIP + no gap filling + IP (for 3 months)	Not evaluated	Not evaluated	Buccolingual measurement (not the change) apical to the bone crest At 1 mm: • Test: 7.04 ± 0.49 (baseline)/6.57 ± 0.45 (6 months) • Control: 6.75 ± 0.27 (baseline)/6.07 ± 0.24 (6 months) At 3 mm: • Test: 7.12 ± 0.49 (baseline)/6.65 ± 0.45 (6 months) • Control: 6.83 ± 0.28 (baseline)/6.15 ± 0.24 (6 months) At 5 mm: • Test: 7.15 ± 0.49 (baseline)/6.69 ± 0.45 (6 months) • Control: 6.86 ± 0.27 (baseline)/6.18 ± 0.24 (6 months)	Not evaluated
Grassi et al.[95]	All implants survived	G1: IIP + gap filling (cortical equine bone, Bio-Gen, Bioteck) + flap repositioning (primary closure)	G2: IIP + no gap filling + flap repositioning (primary closure) G3: IIP + no gap filling + open healing	Not evaluated	Not evaluated	From the marginal cervical implant spire to the external buccal bone landmark G1: −0.4 ± 0.8 G2: −1.1 ± 0.9 G3: −1.0 ± 1.1	From the top of the crest to the implant bevel plane G1: −0.3 ± 0.7 G2: −0.2 ± 0.6 G3: −0.1 ± 0.6
Jacobs et al.[85]	One implant lost (32 out of 33 implants survived) but was replaced and included in the study	Test: IIP + gap filling (DBBM) + absorbable collagen dressing (stabilization with sutures)	Control: IIP + no gap filling + absorbable collagen dressing (stabilization with sutures)	PES 9 months after surgery: • Test: 8.2 ± 2.5 • Control: 8.2 ± 1.8	9 months after surgery: • Test: −0.94 ± 1.13 mm • Control: −0.92 ± 0.67 mm	Buccal bone measurement (not the change) at 1 mm subcrestal: • Test: 1.63 ± 0.71 • Control: 1.47 ± 0.85	Not evaluated
Paknejad et al.[86]	All implants survived	Test: IIP + gap filling (Compact-Bone, Dentegris, Duisburg, Germany) + healing abutment	Control: IIP + no gap filling + healing abutment	Not evaluated	Not evaluated	Not evaluated	From the top of the buccal bone crest to the implant platform • Test: −1.30 ± 2.38 • Control: −1.66 ± 2.67
Spinato et al.[82]	All implants survived	Test: IIP + gap filling (autogenous bone, DBBM, DFDBA, or a combination) + IP	Control: IIP + no gap filling + IP	PIS (test/control): • papilla fills the entire proximal space (18/20) • at least half of the papilla is present (24/24) • less than half of the papilla is present (2/2)	Not evaluated	Not evaluated	Not evaluated

(Continues)

TABLE 2 (Continued)

Study	Implant survival	Intervention	Comparison	Esthetic outcomes	Mucosa recession	Mean horizontal dimensional changes (mm)	Mean vertical dimensional changes (mm)
Mastrangelo et al.[96]	Two implants lost (one in the test group and one in the control group)	Test: IIP + gap filling (DBBM) + CM + flap repositioning (primary closure)	Control: IIP + no gap filling + flap repositioning (primary closure)	PES at 36 months • Test: 8.14 ± 1.89 • Control: 9.70 ± 2.02	Not evaluated	Not evaluated	Not evaluated

Abbreviations: CM, collagen membrane; CTG, connective tissue graft; DBBM, demineralized bovine bone mineral; DBBM-C, demineralized bovine bone mineral with 10% collagen (Bio-Oss Collagen, Geistlich Pharma AG, Wolhusen, Switzerland); DFDBA, demineralized freeze-dried bone allograft; IIP, immediate implant placement; IP, immediate provisionalization; PES, Pink Esthetic Score; PIS, Papilla Index Score; PLGA, poly-lactic-co-glycolic acid.

Thirty-two patients with an anterior maxillary hopeless tooth and intact socket walls received an immediate implant and a provisional custom healing abutment after flapless extraction. In 16 patients (test), the buccal gap was filled with DBBM-C and, in the other 16 patients (control), no grafting was performed. The thickness of the cortical bone plate at baseline was approximately 0.8 mm. Horizontal and vertical soft tissue changes were analyzed at 3, 6, and 12 months. Test group showed less horizontal dimensional change than control group, although no statistically significant difference was detected. Mid-buccal recession was 0.9 mm in test group and 1.3 in control group, again, with no differences between groups. The distal papilla shrinkage was more evident in the control group when compared to patients of the test group. Despite the minor differences, the authors stated that grafting the gap with DBBM-C reduced the changes in soft tissues 12 months after IIP.

Naji et al.[79] assessed the horizontal changes in alveolar bone immediately after dental implant placement in the maxillary premolar area with horizontal gaps >2 mm. Forty-eight patients were enrolled in this randomized clinical trial, and were randomly assigned to one of the three groups: Group I (flap with graft, $n = 16$), in which patients received IIP with alloplastic bone substitute (calcium sulphate), collagen membrane, and primary flap closure; Group II (flap without graft, $n = 16$), in which patients received IIP with primary flap closure only; and Group III (flapless without graft, $n = 16$), in which patients received IIP without graft, membrane, or primary closure. Cone beam computed tomography (CBCT) scans were obtained preoperatively, immediately after implant placement, and 6 months postoperative to evaluate horizontal dimensional change in the buccal bone. Horizontal dimensional change was 0.37 for group I, 0.91 for group II, and 0.24 mm for group III. The 0.5 mm difference for group II could be related to flap elevation without placing the graft as in group I. Short-term results suggested that the "flapless without graft" technique have similar results as the "flap with graft" technique for IIP in the maxillary premolar extraction site with a horizontal gap >2 mm and intact bone. However, most of sockets showed a buccal bone plate >1 mm. Pain intensity was assessed, and flapless approach showed a significant reduction in postoperative pain as compared with other groups. Thus, grafting may counteract the impact of elevating a flap upon horizontal bone loss without grafting material.

Sanz et al.[80] evaluated the use of a bone graft combined with immediate implants to compensate the dimensional changes on the alveolar ridge. Eighty-six implants were immediately placed following tooth extraction with flap elevation in the anterior maxilla. In 43 implants (test), a DBBM-C was placed in the gap between the implant and the bone wall, and in 43 implants (control), no grafting was performed. The thickness of the buccal bone wall was >1 mm for both groups (test = 0.94 mm, control = 0.87 mm). Four months after implant placement, the horizontal crest dimension showed significant changes during healing mainly in the buccal aspect of the alveolar crest where this reduction was 1.1 mm (29%) in the test group and 1.6 mm (38%) in the control group, being more pronounced at sites in the anterior maxilla with thinner buccal bone wall. This study

demonstrated that placing a DBBM-C graft significantly reduced the horizontal bone changes of the buccal bone after immediate implantation in fresh extraction sockets, particularly when the buccal bone plate is thin, which corroborates with previous publications.[25,81]

Chen et al.[54] evaluated the healing of marginal defects in alveolar sockets treated with immediate implants grafted with DBBM, assessing clinical and radiographic outcomes 3–4 years following restoration. After elevating a buccal flap, 30 immediate implants in maxillary anterior extraction sites randomly received DBBM ($n=10$, BG), DBBM + collagen membrane ($n=10$, BG-M), or no graft ($n=10$, control) in a semi-submerged approach. A reentry procedure was performed after 6 months and hard tissue changes were analyzed. The vertical defect height reduced 81% in BG, 70% in BG-M, and 68% in control, while the horizontal defect depth reduced 72% in BG, 82% in BG-M, and 55% in control. Horizontal resorption was significantly greater in control group (48%) when compared with BG (16%) and BG-M (20%) groups. Ten sites (33.3%) exhibited recession of the mucosa after 6 months, and eight (26.7%) had an unsatisfactory esthetic result due to recession. Mucosal recession was associated with buccally positioned implants. Nineteen patients had a mean follow-up of 4 years showing stable marginal mucosal and bone levels after restoration. This study is in agreement with other clinical studies.

In the context of tooth extraction and flapless immediate implant placement with immediate nonfunctional loading, a retrospective study conducted by Spinato et al.[82] assessed implant success, as well as peri-implant hard and soft tissues, comparing five different treatments for the buccal gap: autogenous bone (A), DBBM (H), demineralized freeze-dried bone allograft (DFDBA; D), a mixture of A + H, and a mixture of treatments A + D. Forty-one patients received 45 implants in this study, from which 22 implant sites received a graft material and 23 were not grafted. Patients were followed for a mean time of 32 months with a 100% implant survival rate. No significant difference was found between graft and no graft groups regarding marginal bone levels, papilla index, or mucosal recession, which means that buccal gap grafting had no benefit on clinical outcomes. However, all cases were considered with thick phenotype, what could explain those results.

Girlanda et al.[83] analyzed soft and hard tissue dimensions after flapless immediate implant placement and immediate temporization with or without bone graft in maxillary anterior sites. In the test group, 11 sites received DBBM-C in the buccal gap. In the control group, 11 sites were treated the same way as in test group but without bone grafting. Soft tissue measurements were evaluated at baseline, 3 months, and 6 months after implant therapy. CBCT scans were performed at baseline and at 6 months after implant placement to evaluate hard tissue dimensions. After 6 months, the grafted group showed more soft tissue height at mesial and distal sites in comparison with the control (1 mm difference). The buccal marginal mucosa remained stable during follow-up in the test group; however, in the control group, a 1 mm buccal mucosa recession was observed after 3 months, which remained stable at 6 months. The grafted group had a larger buccolingual ridge dimension at 6 months as compared to the control group.

Assaf et al.[84] evaluated buccolingual alterations of the alveolar ridge after immediate implant placement with a synthetic biphasic calcium phosphate (BCP) consisting of a mixture of 60% hydroxyapatite and 40% tricalcium phosphate in the buccal gap. Buccolingual width of the alveolar ridge was assessed in 20 sites using CBCT, before and after 6 months from flapless tooth extraction and immediate implant placement. Test group (11 patients) received BCP to fill the buccal gap between the alveolar walls and the implant and control group (nine patients) did not receive BCP. Buccal bone plate at surgery had at least 1 mm thickness, and the buccal gap was approximately 2 mm. Six months after treatment, in the test group, there was no significant reduction of buccolingual dimensions. In the control group, there was a reduction of approximately 1 mm. Therefore, filling the buccal gap with BCP graft can preserve buccolingual dimensions of the alveolar ridge in immediate implant procedures.

Jacobs et al.[85] evaluated the facial alveolar bone dimension in maxillary anterior teeth after flapless immediate implant placement with or without DBBM in the buccal gap. Nineteen implants received DBBM and collagen dressing plug in the buccal gap and 14 implants had no gap filling and no collagen dressing. Tomographic exams were performed before tooth extraction and 10 months following immediate implant placement. Ten months after treatment, crestal alveolar bone thickness showed no difference between groups (graft: 1.63 mm; no graft: 1.47 mm). Pink Esthetic Score (PES) was similar for both groups (mean = 8.2), as well as midfacial recession (mean = 0.9 mm). This study could not demonstrate differences between grafted or no grafted buccal gaps. However, no information regarding the preoperative dimension of the buccal gap was provided.

Paknejad et al.[86] evaluated the effect of gap filling on buccal alveolar crestal bone level after flapless immediate implant placement with or without grafting the buccal gap in a 4–6 months observation period. The study was conducted in 20 patients requiring tooth extraction in 27 sites of the anterior maxilla. After flapless tooth extraction and immediate implant placement, in the test group, a xenograft was applied in the buccal gap (14 implants), while no graft material was used in the control group (13 implants). Implant shoulder was placed 1–2 mm below the buccal bone crest. Clinical and CBCT examinations were performed to assess the buccal plate height (BH) and implant complications. After 4–6 months of healing, differences in bone height were not significant between test and control groups, approximately 1.3 and 1.66 mm, respectively. However, the buccal bone was coronal to the implant shoulder in the test group and apical in the control group, which could be clinically relevant.

A recent systematic review[19] performed meta-analysis to assess the impact of grafting the gap between the implant surface and socket wall on implant survival rates. A survival range of 97%–98% was noted in the grafted group with follow-up periods ranging 2–5 years and a range of 94%–100% in the nongrafted group with follow-up ranging 2–10 years. Meta-regression analysis was performed, and nonstatistical significance was found for implant survival of implants between the grafted and nongrafted groups.

Thus, according to preclinical and clinical studies, it seems that placing a bone graft into the buccal gap during immediate implant

placement may play an important role in preventing vertical bone loss, if the thickness of the buccal bone plate is ≤1 mm. Moreover, this might improve esthetic outcomes. The most common studied material was DBBM with or without 10% collagen. Also, a synthetic material (BCP) has shown good results. Nevertheless, the current evidence failed to find significant differences on implant survival with or without the use of grafts between the implant surface and the inner socket wall.

4.2 | Do we need a barrier membrane and when?

A recent systematic review analyzed the effect of guided bone regeneration (GBR) at the time of immediate implant placement (IIP) on crestal bone level changes after at least 12 months of functional loading.[87] This review conducted three meta-analyses comparing crestal bone level changes: (1) IIP + GBR versus IIP without GBR; (2) IIP + bone graft alone versus IIP + bone graft with membrane; and (3) IIP + GBR versus conventional implant placement. The results revealed a mean difference in crestal bone level changes of 0.18 mm in favor of IIP without GBR when compared with implant with GBR. However, IIP with bone graft and membrane showed better results when compared with IIP with bone graft alone (crestal bone level changes = 0.53 mm). Bone level preservation was observed in IIP with GBR as compared to conventional implant placement (crestal bone level changes = −0.001 mm). Meta-analyses showed minimal differences in crestal bone level around IIP with bone graft compared with no bone graft or IIP with GBR compared with conventional implant placement, which may indicate that GBR is not always needed during IIP.

Cornelini et al.[88] showed that the soft tissue margin in proximal sites was located 2.6 mm coronally to the implant shoulder with the use of DBBM and a collagen membrane following immediate implant placement.

De Angelis et al.[89] revealed that GBR with bone substitutes around implants had more peri-implant marginal bone than implants with membrane alone. Taken together, esthetic outcomes seem to be significantly better for implants placed with bone grafts and collagen membrane.

Thus, according to little evidence, the use of a membrane in type 1 sockets might not be necessary in immediate implant placement. Moreover, the placement of a membrane implies raising a flap, which may lead detrimental effect on esthetic results. This will be discussed in the next section.

4.3 | Is it better to follow a flapless approach over flap and when?

Most of the experimental studies on immediate implant placement were performed raising a flap.[21,22,50,90] However, the surgical trauma of periosteum detachment can cause vascular damage and inflammatory response, triggering bone resorption,[91,92] which could partially explain some dimensional alterations occurred in the alveolar socket after extraction when an immediate implant is placed.[22]

4.3.1 | Preclinical studies

In a preclinical study, buccal bone resorption after immediate implant placement was reduced when performed flapless.[27] Buccal bone loss at 3 months was 1.33 mm for the flap group and 0.82 for the flapless group.

Suaid et al.[93] assessed the buccal bone plate remodeling and the impact of vertical implant positioning, equicrestal versus 2 mm subcrestal, after immediate implant placement in a flapless approach with or without synthetic bone graft (60% HA/40% TCP) into the buccal gap. After 3 months of healing, the equicrestal placed implants presented minimal buccal bone wall resorption in both groups. Subcrestal implants showed buccal bone loss, regardless the bone graft applied. Nevertheless, the buccal bone was coronal to the implant shoulder since buccal bone loss was inferior to 2 mm and implants were placed 2 mm subcrestal.

Maia et al.[94] evaluated the influence of the gingival thickness and bone grafting on buccal bone plate remodeling after immediate implant placement using flapless approach in sites with thin phenotype. The buccal gingival tissue of eight dogs was thinned in one side of the mandible. Mandibular premolars were extracted bilaterally without flap elevation, and implants were placed immediately leaving a 1.5 mm buccal gap. Four experimental groups were analyzed: thin gingiva (mean: 0.8 mm); thin gingiva + graft material; normal gingiva (mean: 1.2 mm); and normal gingiva + graft material. The buccal bone plate thickness was 0.66–0.8 mm. After 12 weeks of healing, the animals were killed. Histological analysis revealed that the buccal gap was filled with newly formed bone in all groups. Buccal bone height was slightly apical to the implant shoulder, with vertical buccal bone loss of 0.7–1.39 mm. There was no statistically significant difference between groups for histomorphometric parameters, but a trend for higher vertical bone loss in thinner buccal bone plates was observed. Taken together, these results have shown that the buccal bone thickness is a key factor for buccal bone resorption, even in flapless approach. Gingival thickness or gap filling with biomaterials did not influence buccal bone remodeling.

4.3.2 | Clinical studies

Grassi et al.[95] analyzed the buccal bone alterations after immediate implant placement in maxillary premolar area using three techniques: open flap and grafting (flap-graft), open flap and no grafting (flap-no graft), and flapless and no graft (no flap-no graft). CBCT scans were performed immediately after the intervention and 6 months later. In flap-graft and flap-no graft groups, the surgical procedure aimed a submerged healing approach. The graft material was a particulate cortical bone of equine origin. Forty-five patients were recruited and randomly allocated to the treatment groups. One patient was lost during follow-up. The three techniques demonstrated almost

complete fill of marginal gap, with a mean residual vertical gap of 0.27 mm and horizontal gap of 0.5 mm. The distance from the implant shoulder to the external buccal bone plates was reduced in all groups. However, less reduction occurred in flap-graft group, approximately 0.4 mm, than in flap-no graft and no flap-no graft groups, approximately 1 mm. Regression models indicated a positive effect of thick phenotype on gap filling and dimensional bone reduction. The no flap-no graft approach resulted in less pain according to a visual analog scale (VAS) score. However, flap design included vertical and horizontal releasing incisions which may increase the pain experienced by patients when compared with flapless approach. In summary, filling the buccal gap with a bone graft might compensate the buccolingual dimensional reduction by 0.6 mm in a 6-month period after immediate implant placement.

Mastrangelo et al.[96] analyzed single immediate implant placement with and without bone graft in the maxillary premolar area with a 3-year follow-up. After tooth extraction, 102 patients received 115 immediate dental implants. Patients were randomly allocated to immediate implant placement with (group A, $n=51$) or without (group B; $n=51$) DBBM + CM. A small full-thickness flap was raised to completely cover the implant with interrupted sutures. Second-stage surgery was performed 4 months after implant placement. Patients were recalled for radiographic and clinical follow-up examination after 3 months, 1 year, and 3 years following implant loading. In the 3-year period, one implant failed in each group. No statistically significant differences were found between the two groups regarding marginal bone levels or pocket depths. The PES and patient satisfaction were higher in group B (PES = 9.7) than A (PES = 8.1). Grafting the buccal gap with DBBM + CM in immediate implants seems to improve the esthetic outcomes after a 3-year follow-up period.

A randomized controlled clinical trial compared esthetic, clinical, and patient-reported outcomes of immediate dental implants placed in fresh alveolar sockets using a flap or a minimal split-thickness envelope flap (MSTEF).[97] Implants following random assignment into a flap or MSTEF group were placed immediately in anterior and premolar areas. Guided bone regeneration (collagen membrane plus bone allograft) and autogenous connective tissue graft were used in all cases. A temporary prosthesis was provided followed by the final prosthesis at 16–18 weeks. Success and survival rates together with radiographic buccal bone thickness and patient satisfaction were evaluated at 12-month post-loading. The esthetic outcome was evaluated through the Pink (PES) and White (WES) Esthetic Score by eight blind clinicians of different training background and incorporated in modified success criteria. No statistically significant differences were noted in PES (10.54 control vs. 10.80 test), WES scores (6.97 control vs. 6.95 test), or success criteria including esthetic parameters (modified success criteria) for the different specialty groups (range: 69%–92%). In addition, no statistically significant differences were noted in survival (100%), success (100%), buccal wall thickness between control (0.72 ± 0.22) and test group (0.92 ± 0.31) and patients'-reported outcomes. Thus, the authors did not report differences between groups. However, esthetic failures were common in both.

A recently published systematic review[98] assessed the impact of mucoperiosteal flap elevation for single immediate implant placement (IIP) on buccal hard and soft tissue changes, and on clinical, esthetic, and patient-reported outcomes. Only RCTs studies were included. Five RCTs were selected reporting on 140 patients who received 140 single immediate implants (flapless: 68; flap: 72). Four RCTs reported on type 1 sockets. Meta-analysis demonstrated a mean difference of 0.48 mm (95% confidence interval [CI] [0.13, 0.84], $p=0.007$) in horizontal buccal bone change between surgical approaches, favoring flapless surgery. Meta-analysis failed to demonstrate a significant difference in implant survival between the groups (RR 1.00, 95% CI [0.93, 1.07], $p=0.920$). The authors reported that current studies were consistent in the direction of the effect favoring flapless surgery for vertical buccal bone change as well as for pain. Clinical and esthetic parameters were underreported.

Thus, preclinical and clinical studies show improved results in terms of buccal bone loss and esthetic outcomes with a flapless approach than elevating a flap. Thus, in type 1 sockets, flapless procedures are recommended in immediate implant placement.

4.4 | Use of partial tooth extraction/socket shield?

In the recent years, the interest on the socket shield technique for immediate implant placement has increased. In this technique, part of the tooth is maintained in the socket to prevent or minimize undesired hard tissue changes following complete tooth extraction.[99] A randomized controlled clinical trial compared the dimensional changes of peri-implant soft and hard tissues around single immediate implants in the esthetic zone with socket shield technique versus filling the buccal gap with a xenograft.[100] Forty-two single nonrestorable teeth were replaced by immediate implants, randomly assigned either to socket shield technique (test) or to buccal gap filling with a xenograft (control). Implants were placed 1–2 mm apical to the buccal alveolar crest. Regarding the buccolingual position, implants were placed slightly palatal to have at least a 2 mm buccal gap between the implant and the inner surface of the buccal bone plate. Following implant placement, the buccal gap in the control sites was filled with DBBM while, in the test sites, the gap between implant and retained root was not grafted. Vertical and horizontal buccal bone resorption were measured 6 months after implant placement. Esthetic outcomes were evaluated by PES, as well as midfacial mucosal alteration and patient satisfaction, assessed through a VAS-based questionnaire 1 year following implant restoration. Socket shield group yielded significantly less vertical and horizontal buccal bone resorption, 0.35 mm and 0.29 mm, respectively, as compared to the xenograft group, which showed a vertical and horizontal buccal bone resorption of 1.71 mm and 1.45 mm, respectively. Moreover, there was a midfacial mucosal recession in the xenograft group, −0.46 mm, compared to a midfacial mucosal coronal migration in the socket shield group of 0.45 mm. There was no significant difference between groups regarding PES or patient satisfaction despite the fact that the socket shield group showed an improved preservation for soft and hard tissues.

4.5 | Molar sites

All above-described studies focused on immediate implants in the esthetic zone. However, there are studies that evaluated the impact of placing or not a graft material inside the gap between the implant surface and the inner part of the socket in molar sites. A RCT evaluated the survival rate, the buccolingual bone volume reduction, and the stability of peri-implant hard and soft tissues following immediate implant placement of wide diameter implants in molar extraction sites.[101] Peri-implant defects were grafted with autogenous bone (AB) or biphasic bone substitute material (BBGM) analyzed after 1–3 years of follow-up. Fifty wide diameter implants were placed immediately after molar extractions in a flapless approach. Peri-implant defects were filled with either AB or BBGM. One implant of the BBGM group was lost and one patient withdrew the study. Forty-eight patients were followed for up to 31 months after implant placement. Marginal bone level increased from −7.5 mm to the level of the implant shoulder (AB +0.38 mm, BBGM +0.1 mm) at the last follow-up. These results suggested a high survival rate, a favorable amount of bone, and a low dimensional reduction in the buccolingual aspect of immediate implants in molar sites.

5 | BONE REGENERATIVE PROCEDURES IN TYPE II AND III SOCKETS WITH IMMEDIATE IMPLANT PLACEMENT

Immediate implant placement in type II sockets has not been as extensively studied as in intact sockets. Clinical studies have shown that the healing of type II sockets may result in greater bone loss in comparison with intact buccal bone plate.[55] Although excellent short-term survival rate has been reported for implants placed immediately after tooth extraction in type II sockets, there are some concerns regarding the incomplete regeneration of the buccal bone, which may lead to soft tissue recession and poor esthetics.[56,102] In a case series, incomplete formation of the buccal bone has been reported after the use of autologous bone chips for reconstruction of dehiscence defects.[103] Sarnachiaro et al.[104] found a complete formation of buccal bone with a minimum thickness of 2 mm after flapless placement of implants in fresh alveolar sockets with bone dehiscence defects. The reconstruction of defects was performed with bone allografts and cross-linked collagen membranes. Soft tissue recession >1.5 mm was a common finding (34.7% of cases) after immediate implant placement with bone xenografts and collagen membranes in a flapped approach for the reconstruction of dehiscence defects. The incidence of soft tissue recession was lower in narrow defects (8.3% of cases), meaning that large dehiscences are not predictable for peri-implant regeneration with immediate implant placement.[56]

Liu et al.[102] observed a 0.59 mm mean soft tissue recession after immediate implant placement with flap elevation, use of bone xenografts, and collagen membranes. Compromised esthetic results were reported with a prevalence of unfavorable soft tissue esthetics (PES <8) in 9% of cases and PES ≥12 only in 40%. Nevertheless, another clinical study failed to find differences in esthetic outcomes after immediate placement in dehiscent versus intact sockets when bone grafts and collagen membranes were applied.[105] This may be of paramount relevance when replacing anterior teeth.

5.1 | Immediate dentoalveolar restoration

Type II sockets, especially subclasses B and C, and type III sockets constitute a major clinical challenge for immediate implant placement due to the high risk of soft tissue recession and esthetic compromise. Da Rosa et al.[106] have proposed the immediate dentoalveolar restoration (IDR), a flapless approach for the treatment of type II sockets, regardless of bone defect extension, using a cortico-cancellous bone graft harvested from the maxillary tuberosity to reconstruct the buccal bone simultaneous to tooth extraction and immediate implant placement. According to the IDR protocol, in cases of partial or total loss of the buccal bone wall, a cortico-cancellous bone graft can be harvested from the maxillary tuberosity with chisels, trimmed to fit the defect, and inserted between the buccal soft tissue and the implant, without raising a flap. The gap between the graft and the implant is filled with autologous bone chips harvested from the same donor site, the maxillary tuberosity. A provisional restoration with the desired emergence profile is placed immediately after the surgical procedure. Case series showing promising results have been published.[107,108] Nevertheless, the available evidence to support this approach is limited, and controlled studies are needed to further investigate the outcomes of this technique.

Type III sockets represent an even greater clinical challenge than type II due to the presence of soft tissue dehiscences in partially or totally compromised buccal bone walls. Da Rosa et al.[108] proposed the use of a three-layered autograft harvested from the maxillary tuberosity, which include connective tissue, cortical and cancellous bone. Despite the potential advantages of this technique in terms of reducing the number of surgeries and, therefore, shortening treatment time, the evidence to support this approach is scarce.

6 | SUMMARY AND DECISION-MAKING PROCESS

As in most medical therapies, case selection is crucial for a successful implant treatment. At patient level, primary conditions of soft and hard tissues must be controlled and systemic risk factors like smoking or diabetes should be addressed. The decision of performing an immediate implant must be discussed with the patient, weighting potential benefits and drawbacks. If a decision for immediate implant placement was taken, adequate planning is mandatory. Nowadays, the use of CBCT scans provides information to guide the surgery, revealing the presence of bony dehiscences or fenestrations. Following a minimally traumatic tooth extraction, a thorough cleaning of the socket with curettes and saline or chlorhexidine is

recommended as well as a good inspection of the socket walls to verify the absence of bone defects. Soft tissue characteristics, particularly in the buccal aspect, must be analyzed in order to place the implant with the soft tissue margin as a reference instead of the bone. The implant should be placed toward the palatal wall and subcrestal to the buccal bone plate, considering a prosthetically guided position.

As a general rule, the buccal gap between the socket walls and the implant surface should be filled with a slowly resorbing bone graft. However, in sites with a thick buccal bone (>1.5 mm), thick phenotype, and gap size <1.5 mm, one can decide not to place the graft, as the clinical benefit will probably be minimal.[80] Although is not within the scope of this narrative review, a connective tissue graft (CTG) can be considered below the marginal soft tissue level on the buccal aspect immediately after implant placement, particularly in thin periodontal phenotype and highly esthetic demands,[109] since CTG contributes to midfacial soft tissue stability following IIP. Therefore, CTG should be considered when elevated risk for midfacial recession is expected in the esthetic zone (thin gingival biotype, <0.5 mm buccal bone thickness).[109] Also, if primary stability is achieved, a provisional restoration can be placed, since may lead to midfacial soft tissue stability at immediate implants.[98] Strong occlusal contacts must be avoided, and whenever possible, with no interocclusal contact.

In summary, and considering the studies discussed in this review, it might be concluded that:

1. Bone grafting into the buccal void between socket walls and implant surface preserve, at least in part, the dimensions of alveolar ridge after immediate implant placement;
2. The benefits of grafting the buccal gap are more evident in the anterior maxilla, where the majority of patients have a thin buccal bone plate, with 1 mm thickness or less.
3. Currently, there is little evidence to support the use of a specific bone grafting material over another with immediate implant placement, although the use of a xenogeneic graft from bovine origin (DBBM and DBBM-C) is widespread.
4. The use of a membrane according to the GBR principle does not seem to improve the clinical outcomes of immediate implant placement in intact sockets.
5. Flapless procedures may preserve the buccal contour of the ridge and could positively affect patient satisfaction.
6. Although some promising strategies such as IDR have been discussed in the recent years, immediate implant placement should be avoided in type III sockets.

DATA AVAILABILITY STATEMENT

Data openly available in a public repository that issues datasets with DOIs.

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