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Localized Alveolar Ridge Reconstruction and Soft Tissue Augmentation Using a Triple Graft from the Maxillary Tuberosity versus Xenograft with Connective Tissue Simultaneous with Immediate Implant Placement: A Randomized Controlled Clinical Study

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Abstract

Objectives:

To compare the clinical efficacy of a triple graft harvested from the maxillary tuberosity versus a xenograft bone combined with a connective tissue graft for buccal bone reconstruction and soft tissue augmentation around immediate dental implants in the anterior maxilla.

Materials and Methods:

The sample size for this randomized controlled trial was determined based on the primary outcome of buccal marginal bone thickness above the implant platform at 12 months, informed by previously published data. Using a two-sided alpha level of 0.05, a power of 80% (β = 0.20), and parameters derived from the reference study (anticipated mean difference and standard deviation), the minimum required sample size was 7 patients per group; this was increased to 12 patients per group (total n = 24) to account for potential drop-outs, in line with CONSORT recommendations.

Twenty-four patients were enrolled in this prospective, single-center randomized controlled trial conducted at the Department of Periodontology, Faculty of Dentistry, Ain Shams University, Cairo, Egypt. Randomization employed a computer-generated sequence (block size 4) to ensure balanced allocation, with allocation concealment achieved using sequentially numbered, sealed opaque envelopes prepared independently and held by the study coordinator. Blinding of the surgeon and patients was not feasible due to the nature of the interventions; however, outcome assessors (radiographic and clinical) and the biostatistician were blinded to group assignment. Patients were allocated to either a triple graft group (TGG), receiving a cortico-cancellous bone block with a connective tissue component harvested from the maxillary tuberosity, or a xenograft + connective tissue graft group (XGG), receiving deproteinized bovine bone mineral with a free connective tissue graft from the tuberosity. In both groups, implants were placed immediately into Type II extraction sockets in the anterior maxilla, with simultaneous buccal defect reconstruction and delivery of an immediate provisional restoration.

Results:

At 12 months, buccal marginal bone thickness above the implant platform was significantly greater in the XGG (1.18 ± 0.21 mm) than in the TGG (0.82 ± 0.22 mm; p = 0.0008), indicating a clinically meaningful advantage for the xenograft protocol. The XGG also showed significantly greater buccal bone gain at all measured levels (p = 0.005). Vertical soft tissue loss at mesial, mid-facial, and distal sites, as well as horizontal soft tissue width reduction, were significantly lower in the XGG compared with the TGG. Pink Esthetic Score values were high in both groups, with no significant differences in papilla levels, but the XGG demonstrated superior soft tissue contour and alveolar process scores. Soft tissue color and texture differences were more frequent in the XGG. Patient-reported outcomes favored the XGG, with significantly higher satisfaction scores for pain, edema, operative duration, wound healing, and overall satisfaction.

Conclusions:

Within the limitations of this randomized controlled trial, both autogenous triple grafts and xenograft combined with connective tissue grafting were effective for reconstructing buccal bone defects and augmenting peri-implant soft tissues in the anterior maxilla with immediate implant placement. However, the xenograft + CTG protocol resulted in significantly greater buccal marginal bone thickness above the implant platform, superior buccal bone gain, better preservation of vertical and horizontal soft tissue dimensions, and higher patient satisfaction at 12 months. Xenograft-based approaches thus represent a predictable, minimally invasive alternative to autogenous tuberosity grafts for the management of Type II extraction sockets in the esthetic zone.

Clinical Trial Registry Date: 12/11/2022

The trial was registered at ClinicalTrials.gov under the number NCT05670067 (Retrospectively registered)

Clinical Relevance:

For immediate implant placement in type II extraction sockets, xenograft combined with connective tissue grafting provides a predictable, minimally invasive alternative to autogenous grafts, optimizing buccal bone and soft tissue profiles in the anterior esthetic zone and reducing donor site morbidity

Introduction

The purpose of contemporary esthetic dentistry is to achieve predictable reconstruction or replacement of missing teeth. The architecture of the reconstructed hard and soft tissues should therefore resemble natural dentition. Conditions leading to tooth extraction and immediate implant placement, such as endodontic failure, advanced periodontal disease, trauma, and root fracture, are frequently associated with severe alveolar bone resorption and soft tissue loss (1).

Several approaches have been described to re-establish gingival and alveolar bone architecture in the esthetic zone, including orthodontic forced eruption and guided bone regeneration using various graft materials and barrier membranes, sometimes combined with subepithelial connective tissue grafts. These procedures can be staged before, during, or after tooth extraction over two or more surgeries. In contrast, protocols aiming to achieve defect reconstruction and immediate restoration in a single session remain controversial and are not consistently supported by clinical evidence (2)

Immediate implant placement in fresh extraction sockets has been extensively documented, with survival rates comparable to implants placed in healed ridges and is therefore regarded as a predictable treatment option. Nevertheless, this protocol is considered an advanced or complex procedure, since tooth extraction is accompanied by alveolar ridge remodelling and alterations in peri-implant soft tissues, which may compromise esthetic outcomes in demanding clinical situations (3).

The decision to place an immediate implant at the time of tooth extraction depends largely on the morphology of the post-extraction socket. Among the proposed systems, Elian et al. introduced a simplified classification based on the presence or absence of facial soft tissue and the buccal bone plate, distinguishing three socket types. In Type I sockets, both facial soft tissue and buccal plate are intact and at a normal level relative to the cementoenamel junction of the extracted tooth. Type II sockets present with intact facial soft tissue but partial loss of the buccal plate, whereas Type III sockets are characterized by the loss of both buccal hard and soft tissues following extraction (4).

The Elian classification does not capture the extent of horizontal midfacial tissue loss or the associated risk of midfacial recession, particularly in Type II sockets. To address this limitation, Chu et al. proposed in 2015 a subclassification of Type II sockets into three categories: Type 2A, where the coronal one-third of the labial bone plate, 5–6 mm apical to the free gingival margin (FGM), is missing; Type 2B, where the middle to coronal two-thirds of the labial plate, 7–9 mm from the FGM, are absent; and Type 2C, characterized by loss of the apical one-third of the labial plate at 10 mm or more from the FGM (5).

In cases of extensive buccal bone loss, marked horizontal and vertical ridge reduction, often accompanied by soft-tissue deficiency, generally contraindicates immediate provisionalization in the esthetic zone. To address these defects, several reconstructive approaches have been described, including autogenous bone grafts used alone or combined with allograft or xenograft materials, with or without simultaneous soft-tissue grafting (6).The immediate dentoalveolar restoration (IDR) technique was developed to address extreme cases in a single surgery including extraction of a failing tooth, implant placement, and reconstruction of the missing buccal plate without having to raise a flap (7).

The use of bone replacement grafts to fill the gap between the alveolar socket and the implant during immediate implant placement (IIP) has been extensively studied. A recent meta-analysis by Seyssens et al. (2022), based on four randomized controlled trials, showed that grafting this buccal gap reduces apical migration of the midfacial mucosa by 0.58 mm compared with IIP alone and acts as an alveolar ridge preservation procedure, with 0.59 mm (54%) less horizontal buccal bone resorption than in non-grafted sites (8). These findings underscore the importance of gap grafting in minimizing peri-implant tissue loss and supporting long-term stability and aesthetics. In addition, several studies have evaluated soft tissue grafting at the buccal aspect of immediate implants, reporting that the use of a connective tissue graft (CTG) in conjunction with IIP reduces apical migration of the midfacial mucosa by approximately 0.41 mm (9).

Another meta-analysis, albeit based on only two randomized controlled trials, reported an increase of approximately 0.66 mm in midfacial mucosal thickness following application of a connective tissue graft. These data, together with the 0.41 mm gain in midfacial mucosal level reported for IIP + CTG, emphasize the importance of soft tissue grafting techniques for maintaining peri-implant soft tissue stability and limiting buccal recession around immediate implants. Incorporating CTG into IIP protocols, particularly in thin biotypes or compromised buccal bone situations, can therefore contribute to improved esthetic outcomes and long-term implant success (10).

The immediate dentoalveolar restoration (IDR) technique introduced the use of a cortico-cancellous bone block harvested from the maxillary tuberosity to reconstruct buccal bone defects at the time of implant placement, combined with a connective tissue component. This one-stage, flapless approach aims to restore the buccal plate while preserving gingival architecture and enabling immediate implant placement and provisionalization using a hybrid graft consisting of bone and soft tissue (7)

The aim of this randomized controlled clinical trial was to compare the efficacy of a triple graft harvested from the maxillary tuberosity with that of a xenograft combined with a connective tissue graft for buccal bone reconstruction and soft tissue augmentation around immediate implants in the anterior maxilla. The primary outcome was the buccal marginal bone thickness above the implant platform at 12 months following immediate implant placement and grafting. The working hypothesis was that the triple graft would successfully reconstruct compromised sockets and enhance the peri-implant soft tissue profile.

Materials and methods

Twenty- four patients were enrolled in the study. The patients were recruited from the outpatient clinic of Oral Medicine, Periodontology, Oral Diagnosis and Oral Radiology Department, Faculty of Dentistry, Ain Shams University. The purpose of the study was explained to all patients, and an informed consent was signed before the conduction of the study. The study protocol, questionnaires and informed consent, in full accordance with the ethical principles of the Declaration of Helsinki of 1964, as revisited in 2000, were approved by Research Ethical Committee in Faculty of Dentistry, Ain Shams University (FDASU-REC 948) and was registered at https://clinicaltrials.gov/ under the number (NCT05670067) and followed CONSORT guidelines.

All participants met the study inclusion criteria: The inclusion criteria were systemically healthy patients (American Society of Anaesthesiologists I; ASA I) (11); diagnosed with unrestorable tooth indicated for extraction with Class II socket defect in the aesthetic zone (4), which is defined as any dentoalveolar segment that is visible upon full smile with esthetic importance to the patient (ITI consensus 2003) (12). The exclusion criteria were Smokers, pregnant or lactating females, vulnerable groups of patients (handicapped, mentally retarded and prisoners) and presence of occlusal interference.

Study design:

- This study is a single-center, parallel-group, randomized controlled clinical trial comparing two bone grafting techniques with immediate implant placement - the triple graft versus xenograft with connective tissue. In the xenograft group (XGG-control group), grafting of the jumping gap was done using xenograft and connective tissue, whereas in the triple graft group (TGG- study group) triple graft from maxillary tuberosity which includes cortical, cancellous bone with connective tissue used for grafting the jumping gap.

Sample size

The sample size for this randomized controlled trial was determined based on the outcome: the marginal bone level changes buccally at 12 months based upon the results (13). Using alpha level of 0.05 (5%) and β level of 0.20 (20%) i.e. power = 80%; the estimated minimum required sample size was 7 cases in each group which was increased to 12 patients per group to account for drop out

Twenty-four patients participated in this prospective clinical trial. Patients were randomly allocated using a computer-generated sequence (www.randomizer.org) with a block size of 4. Allocation concealment was achieved using sequentially numbered, sealed opaque envelopes containing the assigned treatment, which were kept by the study coordinator. The principal investigator and patients could not be blinded due to the nature of the interventions; however, outcome assessors and the biostatistician were blinded to group allocation. The study flow of participant enrollment, allocation, follow-up, and analysis is presented in Fig. (1).

Procedure:

Preoperative procedure

After an initial examination and treatment planning session, each patient received detailed instructions in proper self-performed plaque control measures and underwent scaling of teeth, if deemed necessary. Full intraoral scan was done for provisional crown fabrication (shell technique) and volumetric assessment. A cone beam computed tomography (CBCT) was done to assess the buccal plate of bone at baseline for eligible patients and assess available bone in the maxillary tuberosity area. CBCT scans were obtained using a Planmeca Promax 3D scanner with the following parameters: a dose of 12 mA and 80 kV, with a specified field of view (FOV). Antibiotic was prescribed preoperatively.

Surgical procedures:

- For both groups local anaesthesia with 4% Articaine containing epinephrine 1:100,000 (Artinibsa 4%, 1.8 ml cartridges, Inibsa Dental, Barcelona, Spain) was administered at the surgical site. An intrasulcular incision was made, and the tooth was extracted using a periotome and micro elevator to preserve bone integrity. The socket was curetted to remove granulation tissue; clinical assessment of bone damage and defect shape was done using periodontal probe (UNC15). Implant placement with Sufficient apico-coronal depth 3–4 mm apical to the future gingival margin, Palatal anchorage for optimal primary stability and adequate horizontal distance (2–3 mm) from the buccal soft tissue to allow for bone graft placement and membrane adaptation.
- In both groups a collagen membrane *Membrane: Bio-Gide® Geistlich* was sutured with horizontal matrix technique using resorbable suture (MONOfast Polyglycolic) to adapt it to the buccal flap leaving around 2mm coronally for the future connective tissue to be adapted to that area, the membrane was extended over intact bone mesio-distal and apically to contain the bone that will be placed into the buccal defect .

- For the TGG, the donor site at the maxillary tuberosity was anesthetized, and a partial-thickness incision was made to reflect the epithelium and expose the underlying connective tissue and bone. A chisel (Zaph IDR kit) was then positioned at the predetermined site and gently tapped to harvest a block of bone with attached connective tissue, yielding the triple graft. The harvested graft consisted of cortical and cancellous bone with a connective tissue component, representing a modification of the immediate dentoalveolar restoration (IDR) technique. (7)
- The graft was shaped to fit the socket defect, with the bone portion placed against the collagen membrane and the connective tissue aligned with the buccal flap coronally and sutured with horizontal mattress to the buccal flap. Additional cancellous bone was harvested using ACM bur (Megagen) from the same site which was then condensed on the buccal surface of the exposed implant threads and the bone was extended over implant's coronal platform. The detailed clinical and radiographic steps of the triple graft protocol are illustrated in Fig. (2).
- A provisional crown "shell" was fabricated in the laboratory, replicating the natural tooth's emergence profile. The shell was hollow and designed to fit over the implant abutment post-placement. The provisional crown was carefully shaped so that the critical contour maintained or slightly supported the soft tissue margin, while the subcritical contour was under-contoured to allow for soft tissue proliferation and maturation, minimizing the risk of tissue blanching or recession. (14, 15)
- Chairside adaptation was performed immediately after implant placement; the shell was tried in and adjusted to ensure a passive fit over the temporary abutment. The shell was then relined intraorally using a self-curing composite (flowable resin) to accurately adapt to the peri-implant soft tissues and the abutment.
- For the XGG, the connective tissue graft harvested from the maxillary tuberosity was positioned between the tension-free buccal mucosa and the collagen membrane. The entire buccal surface of the implant was then covered with a xenograft (Bio-Oss, Geistlich), condensing the particles horizontally until a buccal graft layer of at least 2 mm thickness was achieved and the implant platform was fully covered. As in the triple graft group, a provisional crown was placed out of occlusion to seal the socket. The detailed clinical and radiographic steps for the xenograft with connective tissue graft protocol are illustrated in Fig. 3.
- Postoperative care: All patients received antibiotics for 1 week (amoxicillin–clavulanic acid 1 g every 12 hours and metronidazole 500 mg every 12 hours) and analgesics (ibuprofen 400 mg every 8 hours). Patients were instructed to avoid toothbrushing at the surgical site and to rinse twice daily with an antiseptic mouthwash starting the day after surgery. Sutures were removed after 2 weeks, and patients were advised not to brush the surgical area for an additional 2 weeks while continuing chlorhexidine mouthrinse. One month after surgery, patients were instructed to resume mechanical plaque control at the treated site using the modified Bass brushing technique. Products used included amoxicillin–clavulanic acid (Augmentin, Medical Union Pharmaceuticals, Egypt), metronidazole (Flagyl, Sanofi Aventis, Egypt), ibuprofen (Brufen, Al Kahira Pharm, Egypt) and an antiseptic mouthwash (Tantum Verde, Eipico, Egypt).

Postoperative evaluation and assessment

Patients were scheduled for a follow-up visit two weeks after surgery, and subsequently every three months, to assess the surgical site and perform plaque removal as needed.

Prior to the commencement of the study, all examiners involved in radiographic and clinical assessments underwent a calibration process to ensure measurement reliability and consistency. For CBCT measurements, two examiners independently assessed buccal bone thickness and crestal bone levels at baseline and 12 months on a set of 10 randomly selected cases. Intra- and inter-examiner reliability were evaluated using intraclass correlation coefficients (ICCs), with values above 0.85 considered indicative of excellent agreement. For clinical parameters, including Pink Esthetic Score (PES) and soft tissue measurements, calibration was performed on 10 patients not included in the main study cohort. The kappa statistic for categorical variables and ICC for continuous variables was used to assess agreement, both yielding substantial to almost perfect reliability ($k > 0.80$, $ICC > 0.85$). Any discrepancies were resolved by consensus and additional training sessions as necessary. All subsequent measurements in the main trial were performed in a blinded fashion by calibrated examiners. (16)

1**- Radiographic Assessment**:

Pre-extraction (baseline) and 12-month post-extraction CBCT scans were acquired using a Planmeca ProMax 3D system (Planmeca Oy, Helsinki, Finland) with the following parameters: field of view (FOV) 6×8 cm, voxel size 0.15 mm, 80 kVp, and 12 mA. All DICOM datasets were imported into OnDemand3D software (V.1.0.10, Cybermed, Daejeon, Korea) for image superimposition and standardized measurement.

Superimposition was performed to align baseline and follow-up scans for direct comparison of buccal marginal bone thickness above the implant platform and buccal bone plate thickness. Using the software's superimposition module, stable anatomical landmarks such as the palatal vault and cranial base were identified in both scans to serve as reference points for registration. An automatic superimposition algorithm was initially applied to align the scans based on these reference structures, followed by manual fine-tuning to optimize the overlay. The accuracy of the superimposition was verified by visually inspecting the congruence of reference structures in sagittal, coronal, and axial planes (17).

Following successful superimposition, standardized measurements were performed. The sagittal orientation line was placed through the center of the long axis of the implant, and the coronal orientation line was positioned perpendicular to the implant's long axis in all views. In the mid-sagittal view, a reference line was drawn parallel and tangential to the threads on the labial aspect of the implant body. buccal marginal bone thickness above the implant platform thickness was measured from the buccal plate to the implant crest. Buccal bone plate thickness was measured at three locations: at the implant crest (the most coronal aspect of the implant platform), 3 mm apical to the implant crest, and 6 mm apical to the implant crest. At each site, a perpendicular reference line was drawn from the implant

surface to the external aspect of the labial/buccal bone plate. The same orientation and reference lines were replicated on the superimposed baseline scans to ensure direct comparability (17). All measurements were independently performed by two calibrated examiners to assess intra- and inter-examiner reliability. Data were statistically analyzed to evaluate changes over the 12-month period, with measurement error assessed using intraclass correlation coefficients.

Representative CBCT superimposition images demonstrating baseline and 12-month post-intervention comparison for the autogenous triple graft group are shown in Fig. (4). & for Xenograft group Fig. (5).

2- Clinical Assessment:

A- volumetric analysis methods section:

Volumetric changes of the peri-implant tissues were assessed using a digital workflow based on superimposed intraoral scans. Preoperative (baseline) and 12-month postoperative digital impressions were acquired for all patients using a 3Shape TRIOS intraoral scanner (3Shape, Copenhagen, Denmark). The acquired STL files were imported into 3Shape Dental System software for analysis. Superimposition was performed using a best-fit alignment on stable reference areas, such as adjacent teeth and palatal rugae, following validated protocols.

The region of interest (ROI) was defined as the buccal aspect of the alveolar ridge, extending from the most coronal aspect of the mucosa to 10 mm apically and mesiodistally between the adjacent teeth. Linear vertical and horizontal soft tissue changes (in mm) within the ROI were quantified using the software's 3D analysis tools. All measurements were performed by two calibrated, blinded examiners. Intra- and inter-examiner reliability were assessed using intraclass correlation coefficients (ICCs), with values above 0.85 considered excellent agreement. (18). An example of the volumetric assessment of peri-implant soft tissue changes using 3D superimposition is presented in Fig. (6).

B- Pink Esthetic score assessment:

Patients were recalled for checking of the surgical area and evaluation of soft tissue healing following the pink esthetic score where the mesial and distal papillae were evaluated, soft tissue color, contour and texture were also checked. The level of soft tissue margin and the alveolar process were also evaluated and compared with the pre-surgical condition. (19)

3- Patient Satisfaction

Patients' satisfaction was assessed using the patient satisfaction questionnaire (short-form, PSQ-18), the global aesthetic improvement scale and the visual analogue scale. (20)

4- All these parameters were scored by a separate blinded operator who didn't participate in the surgical procedures.

Statistical analysis:

Categorical data were presented as frequencies and percentages and analyzed using the chi-square test. Numerical data were tested for normality using the Shapiro–Wilk test and are presented as mean ± standard deviation (SD) or median and interquartile range (IQR), as appropriate. For normally distributed data, between-group comparisons (TGG vs XGG) were performed using independent-samples t-tests, and within-group changes over time were evaluated using repeated-measures ANOVA with Bonferroni-adjusted post-hoc tests. For non-normal data, Mann–Whitney U tests were used for between-group comparisons and Friedman tests with Bonferroni-corrected pairwise comparisons were used for within-group changes. The significance level was set at $p \leq 0.05$. Statistical analysis was performed using IBM SPSS Statistics Version 26 (IBM Corp., Armonk, NY, USA).

Results: Demographic data analysis

The study included 24 patients with a mean age of 31.42 ± 5.73 years. Fourteen patients (58.3%) were female. Females comprised 50% of the autologous group and 66.7% of the xenograft group, with no statistically significant differences in sex or age between groups (Table 1).

	autologous group		xenograft group		P value
Females (N, %)	6	50	8	66.7	0.34
Age (mean & std)	31.0	±6.135	31.83	±5.540	0.728

Table 1: Baseline characteristics and demographics.

Clinical data analysis:

At 12 months, the buccal marginal bone thickness above the implant platform was significantly greater in the Xenograft + CTG group (XGG) (1.18 ± 0.21 mm) compared with the triple graft group (TGG) (0.82 ± 0.22 mm; p = 0.0008), indicating a clinically meaningful difference in favor of the xenograft protocol (Table 2)

Table 2: Marginal Bone Thickness Above Implant Platform at 12 Months

Group	n	Mean (mm) ± SD	Median (mm)	Min–Max (mm)	p-value
Xenograft	12	1.18 ± 0.21	1.2	0.8–1.5	
Autogenous	12	0.82 ± 0.22	0.8	0.5–1.2	
Between-group difference					0.0008*

** Test of significance: independent-samples t-test."*

Table 3: Buccal Bone Gain (BBG) results gain 6 mm from implant platform between both groups

Group	Baseline	Post	P value for change overtime	P value for interaction between time and group	P value between groups
(autogenous)	0.28±0.04[a]	1.62±0.27 [b]	<0.001	0.001	0.005
(xenograft)	0.27±.04 [a]	2.03±0.23 [b]			

Test of significance: repeated-measures ANOVA. Different letters indicate significant differences between time points within groups.

Regarding buccal bone gain 6 mm apical to the implant platform, both groups showed significant intra-group improvement over time. However, the XGG demonstrated a significantly greater mean gain (2.03 ± 0.23 mm) than the TGG (1.62 ± 0.27 mm; p = 0.005) (Table 3). Neither group showed statistically significant differences in bone gain between the different measurement sites within the same group.

Table (4) Comparison between both groups regarding mean change in crest and mid measurements

Measurement	TGG	XGG	Total	P value
Crest	1.78±0.26	2.28±0.37	2.03±0.40	0.001
Mid (3mm from platform)	1.93±0.24	2.50±0.46	2.21±0.46	0.001

Test of significance: independent-samples t-test.

Comparison of mean changes at the crest and at 3 mm from the platform showed significantly higher values in the XGG at both levels. The mean crestal change was 2.28 ± 0.37 mm in the XGG versus 1.78 ± 0.26 mm in the TGG (p = 0.001), and the mean mid-crest (3 mm) change was 2.50 ± 0.46 mm in the XGG versus 1.93 ± 0.24 mm in the TGG (p = 0.001) (Table 4). Representative CBCT superimposition images for the autogenous triple graft group and xenograft group are presented in Figures 4 and 5, respectively.

Volumetric assessment of soft tissue (Vertical and Horizontal) at 12 months Table (5)

Outcome	Triple Graft (n = 12)	Xenograft + CTG (n = 12)	p-value
Vertical Soft Tissue Change (mm)			
Mesial	0.68 (0.92)	0.44 (0.87)	0.037*
Mid-facial	0.62 (1.10)	0.31 (1.03)	0.012*
Distal	0.71 (1.05)	0.39 (0.98)	0.029*
Horizontal Soft Tissue Width (mm)			
Baseline	8.22 (1.01)	8.40 (1.13)	0.621
12 months	7.41 (0.93)	8.19 (1.07)	0.015*
Difference (12 months – baseline)	0.81 (0.84)	0.21 (0.55)	0.007*

Test of significance: independent-samples t-test.

Volumetric assessment at 12 months revealed significantly less vertical soft tissue loss at mesial, mid-facial, and distal sites in the XGG compared with the TGG ($p < 0.05$ for all) (Table 5). Horizontal soft tissue width was also better preserved in the XGG, with a mean reduction of 0.21 ± 0.55 mm versus 0.81 ± 0.84 mm in the TGG ($p = 0.007$), while baseline widths were comparable between groups. These findings indicate that the xenograft + CTG technique is more effective in maintaining both vertical and horizontal soft tissue dimensions around immediate implants in the anterior maxilla (Figure 6)

Pink Esthetic Score (PES)

According to the Pink Esthetic Score, there were no statistically significant differences between groups for mesial or distal papilla completeness. Two patients in the TGG (16.7%) had incomplete distal papillae, while all XGG patients exhibited complete distal papillae, without reaching statistical significance (Table 6). For the level of the soft tissue margin, all patients in both groups presented values < 1 mm deviation.

In contrast, significant differences were observed for soft tissue contour and alveolar process parameters. All patients in the XGG exhibited natural soft tissue contour, whereas only 50% of TGG patients showed natural contour and the remainder were rated as fairly natural ($p = 0.007$). For the alveolar process, 83.3% of TGG patients were scored as slight, while all XGG patients were scored as none ($p < 0.0001$).

Soft tissue color and texture differed between groups. Moderate color differences were observed in 33.3% of XGG patients, while all TGG patients exhibited no color difference ($p = 0.047$). All XGG patients showed moderately different soft tissue texture, whereas all TGG patients showed no texture difference ($p < 0.0001$). The distribution of PES parameters is illustrated in Figure 7.

Table 6: Pink Esthetic Score (PES) results.

	autologous group		xenograft group		P value
	N	%	N	%	
PES-Mesial papilla					
Incomplete	5	41.7	4	33.3	0.5
Complete	7	58.3	8	66.7	
PES-Distal papilla					
Incomplete	2	16.7	0	0	0.239
Complete	10	83.3	12	100	
PES-Level of soft-tissue margin					
<1mm	12	100	12	100	
PES-Soft-tissue contour					
Fairly natural	6	50	0	0	0.007
Natural	6	50	12	100	
PES-Alveolar process					
Slight	10	83.3	0	0	<0.0001
None	2	16.7	12	100	
PES-Soft-tissue colour					
Moderate difference	0	0	4	33.3	0.047
No difference	12	100	8	66.7	
Soft-tissue texture					
Moderate difference	0	0	12	100	<0.0001
No difference	12	100	0	0	

8-Patient Satisfaction:

Patient satisfaction assessed using the PSQ-18, global aesthetic improvement scale, and visual analogue scale, generally favored the XGG. Except for the first and last questions, the two groups showed statistically significant differences in satisfaction items related to pain, edema, operative duration, and wound healing, with higher scores in the XGG (Table 7). Overall satisfaction was significantly higher in the XGG compared with the TGG (4.50 ± 0.51 vs. 3.60 ± 0.50; $p < 0.05$).

Table **7**: The Patient Satisfaction Questionnaire Short Form (PSQ-18).

	XGG		TGG		P value
	mean	std	mean	std	
Q1 How do you feel with the introduction by dentists before treatment with implants?	4.40	±0.681	4.10	±0.553	0.10
Q2 How do you feel pain during the implant operation?	3.80	±0.410	2.90	±0.308	< 0.05
Q3 How do you feel with postoperative pain?	3.90	±0.718	2.80	±0.616	< 0.05
Q4 How do you feel with the duration of operative time?	3.90	±0.852	2.80	±0.616	< 0.05
Q5 How do you feel with soft-tissue edema?	4.00	±0.459	3.20	±0.410	< 0.05
Q6 How do you feel with the duration of wound healing?	4.30	±0.470	3.30	±0.470	< 0.05
Q7 How do you feel with the implants compared with natural teeth?	4.50	±0.513	4.10	±0.308	< 0.05
Q8 How do you feel comfortable with implant teeth?	4.80	±0.410	4.50	±0.513	0.05
Q9 How do you feel with food impaction?	4.60	±0.503	4.50	±0.513	0.05
Overall Satisfaction	4.50	±0.513	3.60	±0.503	< 0.05

Discussion

This approach aims to address the challenges associated with tooth extractions, particularly in the anterior esthetic zone, where both hard and soft tissue integrity is crucial for successful aesthetic outcomes. The primary outcome of this study is the assessment of the thickness of the buccal plate of bone after immediate implant placement and augmentation using CBCT. The secondary outcome focuses on pink esthetic score and patient satisfaction after immediate implant placement, which is essential for evaluating the overall success of the procedure. These outcomes will help correlate surgical results with patient-reported experiences, thereby enhancing our understanding of how different grafting materials impact both clinical success and patient satisfaction.

This study was designed as a randomized clinical trial to evaluate the effectiveness of using a triple graft from the maxillary tuberosity simultaneously in immediate implant placement within the anterior aesthetic zone. The choice of a randomized clinical trial highlights the importance of real-time data collection for accurately assessing clinical outcomes in dental procedures. Such a design allows for direct observation of the effects of surgical interventions, which is crucial in achieving optimal aesthetic results in implant dentistry.

The rationale for selecting these grafting approaches lies in their distinct biological properties and anticipated influence on osseointegration and esthetic outcomes. Contemporary reviews emphasize that

appropriate selection of grafting protocols is critical for managing post-extraction defects and minimizing esthetic complications in the anterior maxilla (21–22).

Jiang et al. (2020) conducted a randomized clinical trial with a 6-month follow-up, evaluating hard and soft tissue alterations after immediate implant placement and provisionalization with or without CTG using CBCT and 3D digital analysis. They reported that CTG helped compensate facial tissue collapse volumetrically but did not provide additional benefit in maintaining the midfacial gingival margin position (23). Other studies have shown that bovine xenografts can also provide predictable new bone formation and stable support for implants when used in augmentation procedures (24).

Troeltzsch et al. (2016) systematically evaluated the clinical efficacy of various grafting materials used for lateral and vertical alveolar ridge augmentation. They reported that clinically relevant vertical and horizontal bone gains can be achieved with particulate grafts and block grafts across different material types, with mixtures of autogenous bone and other grafts often yielding the highest horizontal and vertical gains, while autogenous extraoral block grafts provided the greatest vertical augmentation (25)

Fujii et al. (2023) retrospectively evaluated immediate and early implant placement in esthetic areas with pre-extraction facial dehiscence. They observed that a wider facial dehiscence was associated with greater risk of postoperative soft tissue regression and that dehiscence widths exceedingly approximately 3–4 mm often led clinicians to select early implant placement rather than immediate placement. Their data suggested that combining immediate implant placement with a connective tissue graft, or opting for early implant placement, tended to reduce soft tissue regression by increasing postoperative facial soft tissue thickness (26).

The Immediate Dentoalveolar Restoration (IDR) technique, developed by Dr. José Carlos Martins da Rosa, is designed to tackle complex dental cases that involve the extraction of a failing tooth, implant placement, and provisionalization in a single surgical session. This innovative approach utilizes a cortico-cancellous bone graft harvested from the maxillary tuberosity to effectively restore buccal bone defects while preserving the surrounding gingival architecture. In the study titled "Immediate Dentoalveolar Restoration of Compromised Sockets", a protocol for this technique is detailed, showcasing its effectiveness through a case involving the extraction of a compromised central incisor and immediate implant replacement using a flapless method. The findings indicated satisfactory aesthetic results, reduced treatment costs, and shorter overall treatment times over a follow-up period of 36 months. This highlights the IDR technique's efficiency in restoring compromised sockets without necessitating extensive surgical procedures (27). A key strength of this study is the comprehensive evaluation of both hard and soft tissue outcomes following immediate implant placement with either autogenous or xenograft-based grafting. At 12 months, the xenograft + CTG group demonstrated a significantly greater buccal marginal bone thickness above the implant platform (mean 1.18 ± 0.21 mm, 95% CI: 1.05–1.31) compared to the autogenous group (mean 0.82 ± 0.22 mm, 95% CI: 0.68–0.96; $p = 0.0008$), with a large effect size. This finding aligns with recent clinical trials indicating that xenograft materials provide superior volumetric stability and crestal bone preservation compared to autogenous

grafts, particularly in the esthetic zone (28, 29). The maintenance of crestal bone above the platform is critical for long-term implant success and esthetic integration, as crestal bone loss has been associated with soft tissue recession and compromised esthetic outcomes (30).

Bone grafting materials—autogenous and xenograft—were analyzed for their effectiveness. Group I (autogenous bone) showed a mean bone gain of 1.2 ± 0.4 mm, whereas Group II (xenograft) had a gain of 1.8 ± 0.3 mm, with xenografts displaying more consistent outcomes. Xenografts achieved significant horizontal bone gain while reducing patient morbidity (31). Though autogenous bone offers osteogenic, osteoinductive, and osteoconductive benefits, its use involves additional surgical sites and potential complications, making xenografts a viable alternative with predictable outcomes.(32) Although both grafts achieved clinically relevant bone gain, xenografts yielded significantly greater buccal bone augmentation at the implant platform and 3 mm sites ($p = 0.005$), suggesting superior volumetric stability in the critical esthetic zone. (33)

Soft tissue analysis further supports the superiority of the xenograft + CTG protocol. This group exhibited significantly less vertical soft tissue loss at mesial, mid-facial, and distal sites, and better horizontal soft tissue width preservation (mean reduction of 0.21 ± 0.55 mm versus 0.81 ± 0.84 mm in the autogenous group, $p = 0.007$). These results are consistent with high-level evidence demonstrating that soft-tissue augmentation in combination with immediate implant placement and gap grafting effectively minimizes recession and optimizes esthetic outcomes. The Pink Esthetic Score (PES) findings in this study also mirror the literature, with both groups achieving high scores for papilla and margin levels, but the xenograft group showing superior soft tissue contour and alveolar process preservation. Notably, the presence of moderate soft tissue color and texture differences in the xenograft group may reflect the slower remodelling of xenogeneic collagen, a phenomenon observed in other clinical trials. (34, 35)

The combined hard and soft tissue outcomes observed in this study reinforce the concept that successful esthetic implant therapy depends on the synergy between bone stability and soft tissue support. The use of a connective tissue graft from the maxillary tuberosity in both groups likely contributed to the favourable soft tissue results, supporting the current consensus that soft tissue augmentation is essential for esthetic integration, regardless of the underlying bone graft material (36).

Both grafting approaches in this study resulted in comparable Pink Esthetic Scores (PES), indicating that soft tissue augmentation plays a more dominant role in esthetic success than graft material selection. The use of connective tissue grafts from the maxillary tuberosity in both groups contributed to soft tissue stability, reducing the impact of the graft material on esthetic outcomes. Immediate implant placement further preserved the peri-implant architecture, supporting esthetic integration. The xenograft group's improved soft tissue contour may reflect its superior bone support, while the moderate texture/colour differences could stem from slower graft remodelling or inflammatory responses to xenogeneic collagen. This is in accordance with Hamed et al. 2023 (37), who compared the PES after grafting using collagen plug, demineralized bone matrix (DBM) Grafton, and particulate bone graft composed of two-thirds autogenous cortical chips harvested from the surgical site and one-third

deproteinized bovine bone minerals; all groups showed increased PES score with no statistical significance due to conservative surgical procedures; in this study it can be related to the soft tissue augmentation using the connective tissue from the maxillary tuberosity with its higher tissue fibres content. Clinicians should weigh these trade-offs when planning esthetic reconstructions. Higher overall satisfaction in the xenograft group likely stemmed from reduced postoperative pain (Q2–Q6) and shorter healing times, despite comparable ratings for comfort and aesthetics (Q8–Q9)

The findings of this study are in line with recent systematic review that underscore the importance of gap grafting and soft tissue augmentation in immediate implant protocols. Seyssens et al. demonstrated that socket grafting at the time of immediate implant placement significantly reduces midfacial mucosal recession and horizontal buccal bone resorption compared to sites without grafting (8). Our results corroborate these observations, as both groups in the present study showed favourable preservation of the buccal plate and peri-implant soft tissue. Notably, the xenograft group achieved even greater buccal bone gain and improved soft tissue contour, further supporting the predictability of xenograft-based approaches for esthetic zone reconstruction.

Despite these strengths, several limitations must be considered. The relatively small sample size and single-center design may limit the generalizability of the findings. The 12-month follow-up period, while sufficient for early healing assessment, does not capture potential late changes in bone or soft tissue, nor does it allow for evaluation of long-term implant survival. Additionally, while volumetric and CBCT analyses provide objective data, minor measurement inaccuracies are possible. Future studies should incorporate larger, multicenter cohorts, longer follow-up, and standardized volumetric protocols to further validate these results.

Conclusion

Both autogenous and xenograft materials effectively support bone regeneration in the anterior esthetic zone. While autogenous bone remains the gold standard, xenografts provide a reliable alternative with reduced patient morbidity and predictable outcomes. The findings highlight the importance of precise surgical techniques and soft tissue management in achieving esthetically successful implant restorations, reinforcing that the choice of graft material should be guided by clinical needs and patient preferences rather than a strict hierarchy of effectiveness.

Abbreviations

ASA
American Society of Anaesthesiologists
CBCT
Cone-beam computed tomography
CTG
Connective tissue graft

FOV
Field of view
ICC
Intraclass correlation coefficient
IDR
Immediate Dentoalveolar Restoration
IIP
Immediate implant placement
PES
Pink Esthetic Score
PSQ-18
Patient Satisfaction Questionnaire Short Form
RCT
Randomized controlled trial
ROI
Region of interest
TGG
Triple graft group
XGG
Xenograft + connective tissue graft group

Declarations

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Authors' contributions: The authors confirm their contribution to the paper as follows: contributed to the study conception, design and practical work; Ahmed H. Farid & Mohamed Wagdi; data collection was performed by Tarek Mahmoud El Tayeb; manuscript preparation was performed by Ahmed H. Farid and Hala Abuel-Ela. All authors reviewed the results and approved the final version of the manuscript.

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Data availability: Data available on request from the authors.

Ethics approval and consent to participate

All procedures were conducted in accordance with the ethical standards of the institutional and national research committee and with the 1964 Helsinki declaration and its later amendments (revised in October 2018). The study protocol was independently reviewed and approved by the Institutional Ethical

Committee, Faculty of Dentistry, Ain Shams University. Informed written consent was obtained from all individual participants included in the study.

Consent for publication

Not applicable.

Trial registration

ClinicalTrials.gov, NCT05670067. Retrospectively registered.

Availability of data and materials

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Competing interests

The authors declare that they have no competing interests.

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Figures

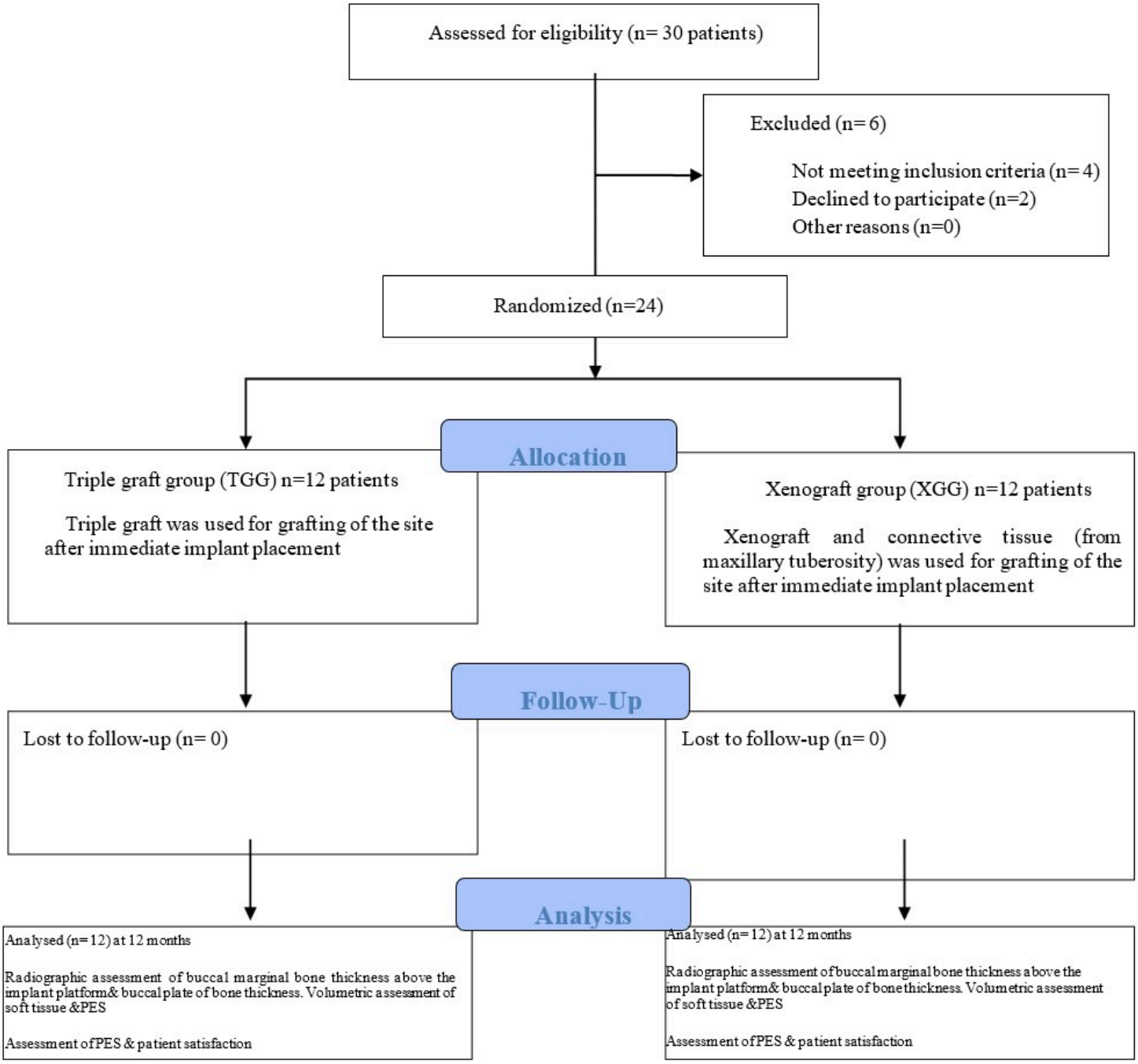


Figure 1

Consort Flowchart

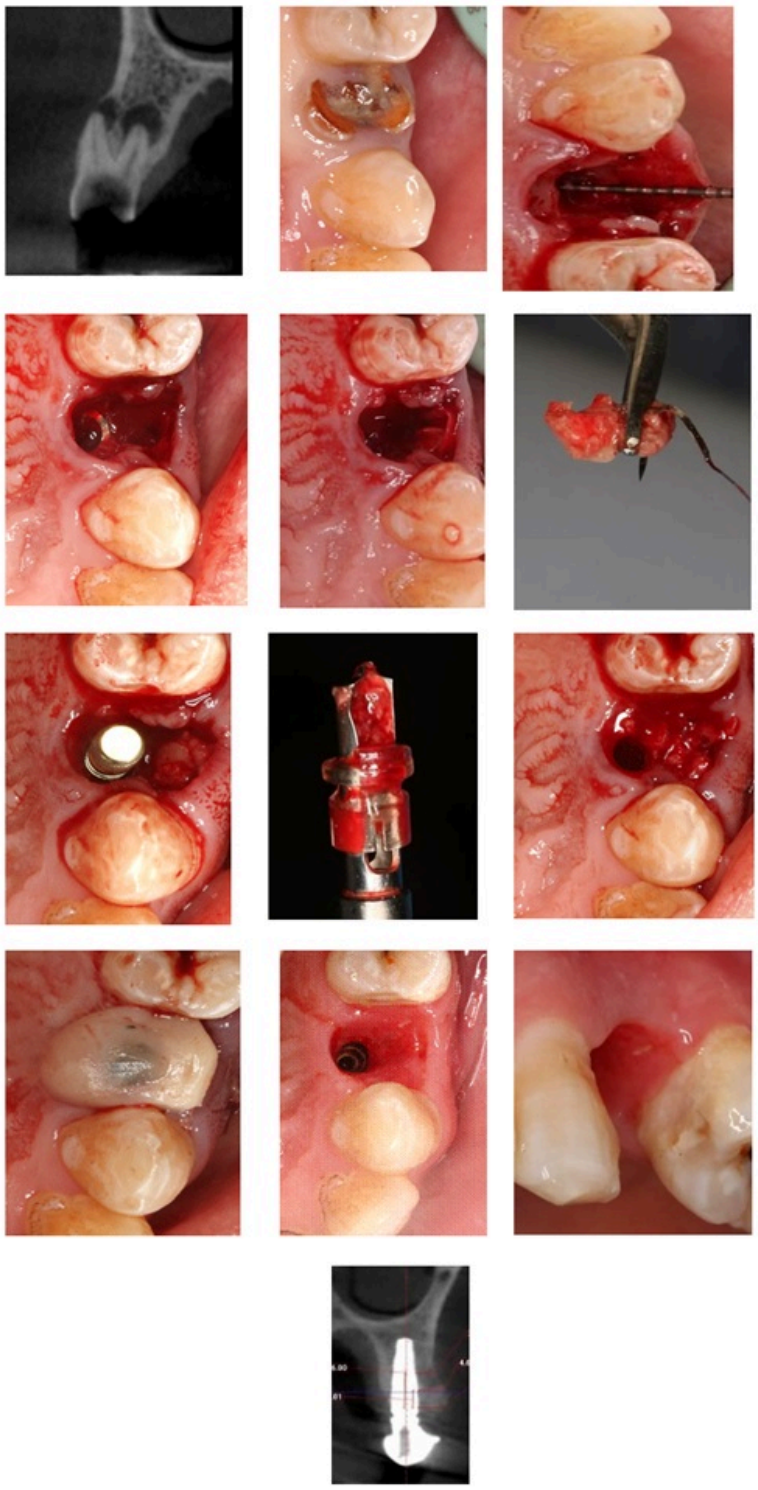


Figure 2

Surgical steps for Triple graft group (A)Preoperative Cone beam CT showing buccal bone defect (B)Preoperative picture of the site (C) Atraumatic extraction showing buccal bone defect (D) Implant placement maintaining buccal gap space (E) Collagen membrane adaptation and stabilization(f) Harvested triple graft (G) Adaptation of the triple graft buccally (H) Harvesting autogenous bone chips by ACM (I) Adaptation of the autogenous bone chips buccally between implant threads and triple graft (J)

Temporization (K) Emergence profile occlusal view 12 month (L) Emergence profile side view showing papillary height (M) 12 month follow up CBCT.

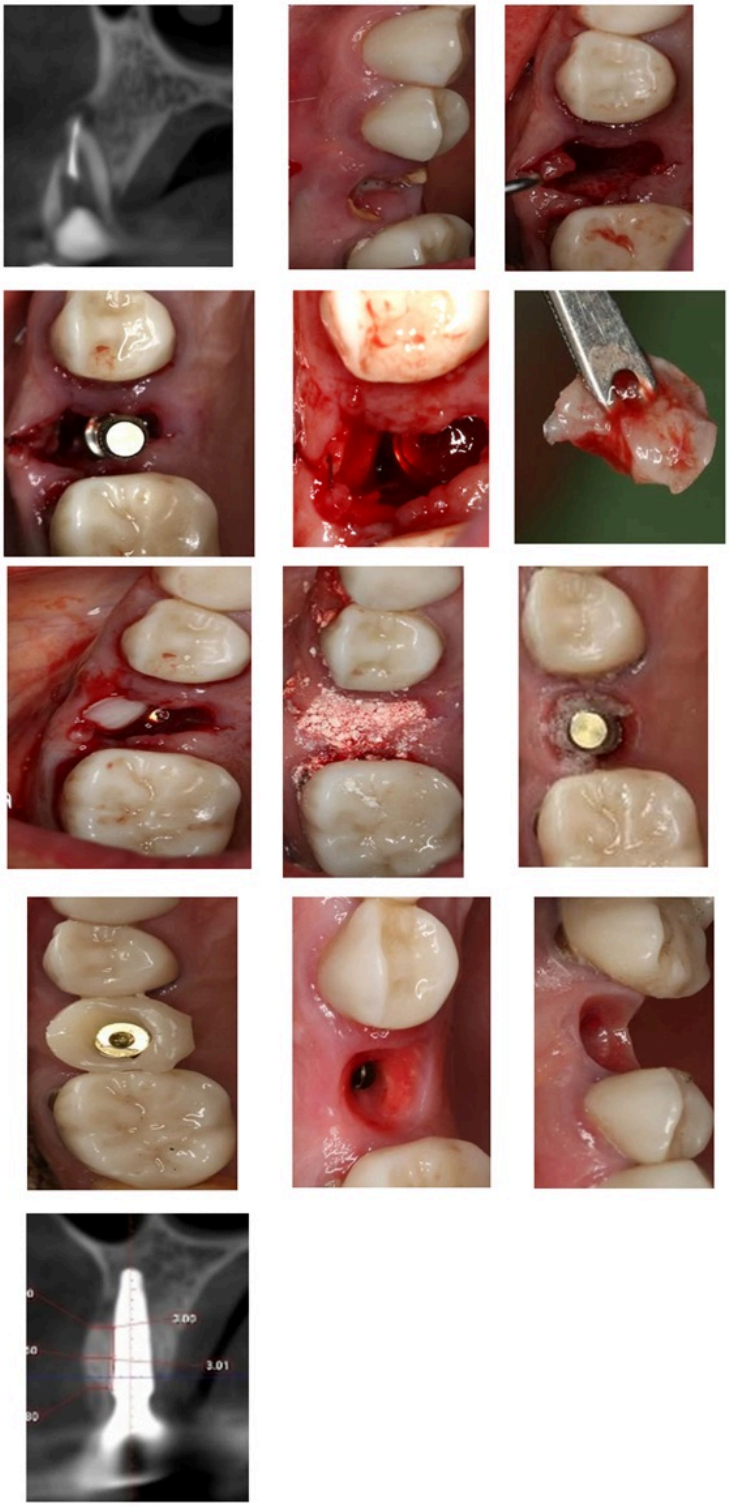


Figure 3

Surgical steps For Xenograft group A-J for the Xenograft group (A)Preoperative Cone beam CT showing buccal bone defect (B)Preoperative picture of the site (C) Atraumatic extraction showing buccal bone

defect (D) Implant placement maintaining buccal gap space (E) Collagen membrane adaptation buccally and stabilization (F) Harvested connective tissue graft from maxillary tuberosity (G)Adaptation of connective tissue graft (H) xenograft bone particulates placement buccally covering implant crest (I) Temporization (J) Emergence profile occlusal view 12 month (K) Emergence profile side view showing papillary height (L) 12 month follow up CBCT

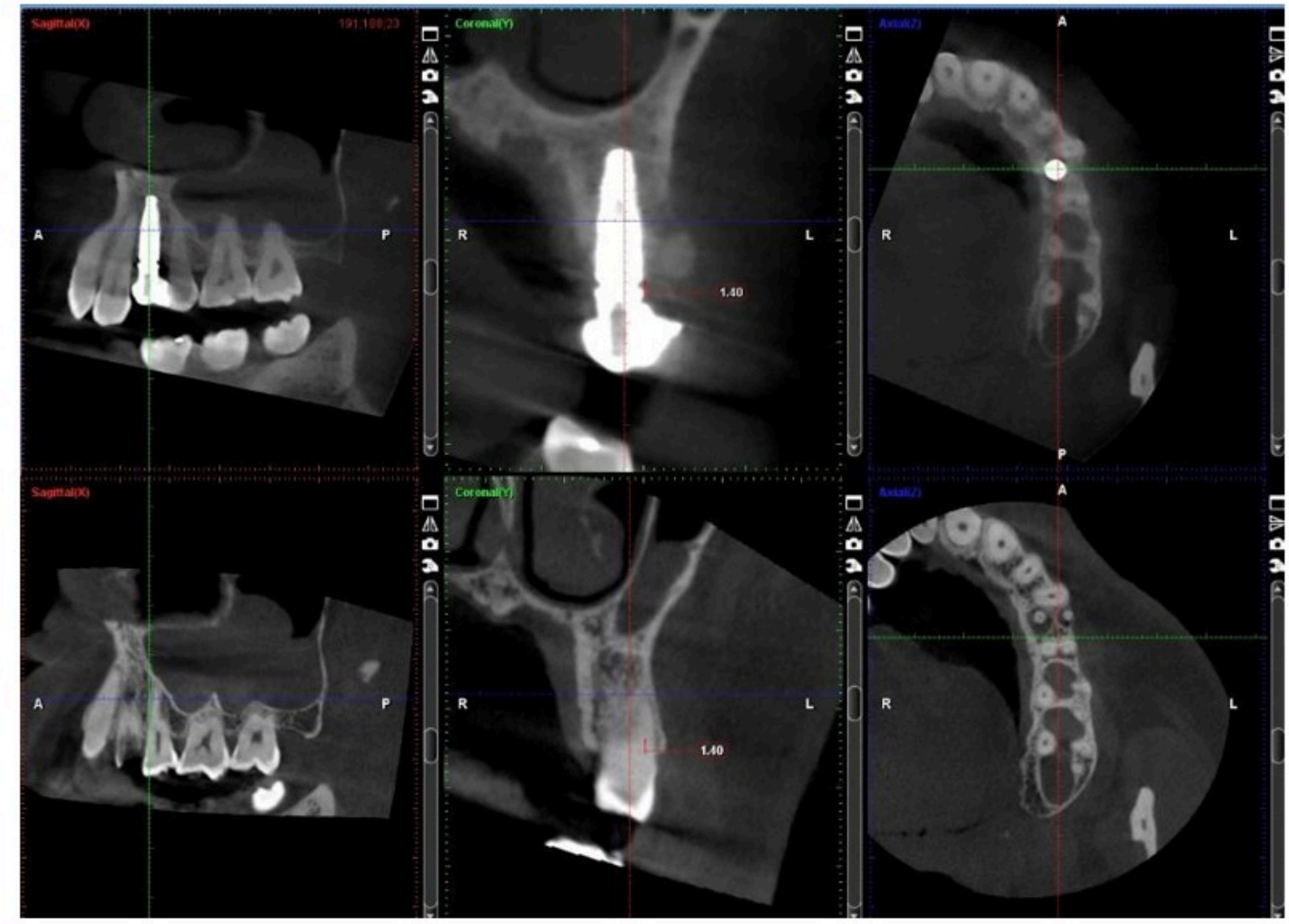


Figure 4

Cone Beam CT superimposition before and after intervention Group 1 the autogenous triple graft (TGG)



Figure 5

Cone Beam CT superimposition before and after intervention Group 2 the Xenograft augmentation group (XGG)

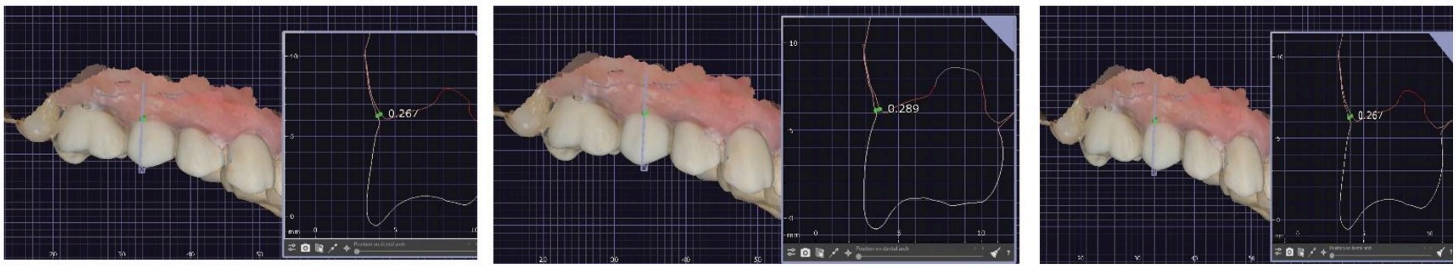


Figure 6

Volumetric assessment of the soft tissue

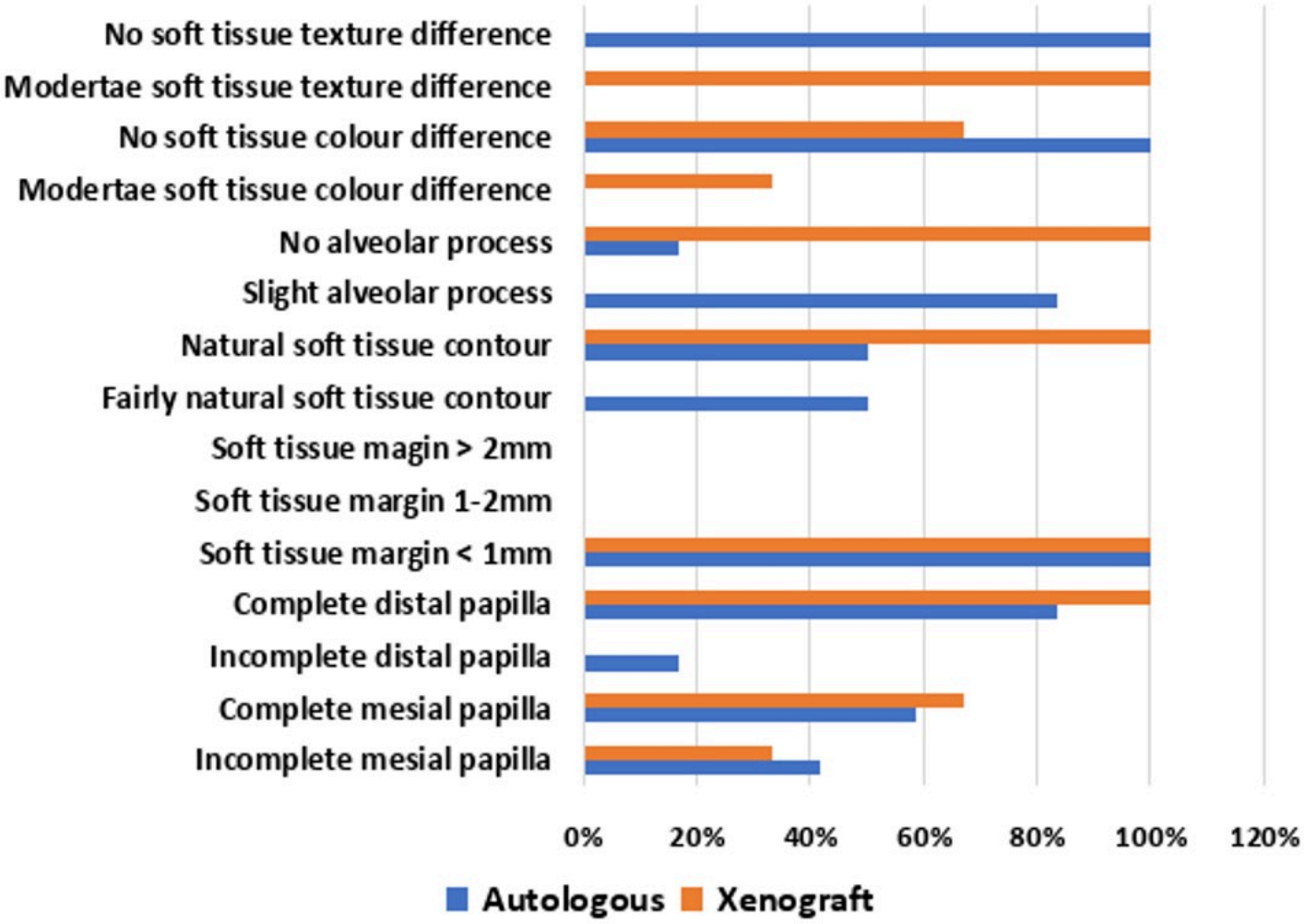


Figure 7

showing the pink esthetic score results.

Supplementary Files

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