Delayed versus simultaneous implant placement with ramus block grafts: A retrospective cohort study

Ramus blok grefti ile geç ve eş zamanlı implant yerleştirme prosedürlerinin karşılaştırılması: Retrospektif kohort çalışması

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Abstract

Aim: This study compared the graft stability and implant success of delayed implantation versus simultaneous implantation with autogenous grafts.

Methods: The study sample comprised a population of patients who underwent autogenous block bone grafting using the ramus of the mandible. Patients with data from 1 year of follow-up were divided into two groups according to implantation approach: delayed implantation and simultaneous implantation. Outcome variables were 3D volume changes (the bone graft volumes at post-implantation and 1-year follow-up, resorption volume, and resorption rate of the bone graft), 2D linear changes (the bone graft width at post-implantation and 1-year follow-up, 2D resorption amount, and resorption rate of the bone graft), marginal bone loss, and implant success.

Results: The final sample comprised 21 subjects, and 33 implants were investigated. In total, 51.5% (n=17) were placed with a simultaneous approach and 48.5% (n=16) with a delayed approach. The simultaneous approach resulted in a higher rate of graft resorption in both the 3D and 2D measurements compared to the delayed implantation (p=0.001 and p=0.014, respectively). There was no difference between the two groups in terms of graft volume, graft width, marginal bone loss, or implant success at the 1-year follow-up (p=0.958, p=0.039, p=0.168, and p=1.000, respectively).

Conclusion: Although simultaneous implantation resulted in a higher resorption rate than delayed implantation, the graft volume and width, marginal bone loss, and implant success were similar at the 1-year follow-up.

Keywords: Alveolar bone grafting; alveolar ridge augmentation; dental implantation; three-dimensional image

Öz

Amaç: Bu çalışmada, otojen greftlerle eş zamanlı ve geç yerleştirilen implantlarda greft stabilitesi ve implant başarısı karşılaştırılmıştır.

Yöntemler: Çalışma örneklemi, mandibula ramusu kullanılarak otojen blok kemik grefti uygulanan hasta popülasyonundan oluşmuştur. Bir yıllık takip verilerine sahip hastalar implantasyon yaklaşımına göre iki gruba ayrılmıştır: geç implantasyon ve eş zamanlı implantasyon. Sonuç değişkenleri 3B hacim değişiklikleri (implantasyon sonrası ve 1 yıllık takipteki kemik grefti hacimleri, rezorpsiyon hacmi ve kemik greftinin rezorpsiyon oranı), 2B lineer değişiklikler (implantasyon sonrası ve 1 yıllık takipteki kemik grefti genişliği, 2B rezorpsiyon miktarı ve kemik greftinin rezorpsiyon oranı), marjinal kemik kaybı ve implant başarısı idi.

Bulgular: Nihai örneklem 21 denekten oluşmuş ve 33 implant incelenmiştir. Toplamda, %51,5'i (n=17) eşzamanlı ve %48,5'i (n=16) geç implantasyon yaklaşımla yerleştirilmiştir. Eş zamanlı yaklaşım, geç implantasyona kıyasla hem 3B hem de 2B ölçümlerde daha yüksek greft rezorpsiyonu oranıyla sonuçlanmıştır (sırasıyla p=0,001 ve p=0,014). İki grup arasında 1 yıllık takipte greft hacmi, greft genişliği, marjinal kemik kaybı veya implant başarısı açısından fark yoktu (sırasıyla p=0.958, p=0.039, p=0.168 ve p=1.000).

Sonuç: Eş zamanlı implantasyon, geç implantasyona göre daha yüksek rezorpsiyon oranıyla sonuçlansa da, 1 yıllık takipte greft hacmi ve genişliği, marjinal kemik kaybı ve implant başarısı benzerdi.

Anahtar Sözcükler: Alveolar kemik grefti; alveoler bombe ögmentasyonu; diş implantasyonu; üç boyutlu görüntü

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INTRODUCTION

In augmented alveolar bone, the timing of implantation affects the total treatment time, mechanical loading time of the bone graft, morbidity, and treatment costs (1,2,3). A delayed implantation approach is often preferred (4). If the type of defect allows implant placement with sufficient primary stability in the ideal prosthetic position, a simultaneous implantation approach may be preferred (2). The timing of implantation in augmented alveolar bone remains a controversial issue of debate in the literature. When augmentation is performed with autogenous block grafts, some researchers support the preference for simultaneous implantation because the resorption of bone grafts is not a linear process, and this process is predictable (5). However, researchers advocating delayed implantation have argued that osseointegration and implant success could be compromised when an augmentation-related complication occurs with simultaneous implantation (6,7). In addition, some researchers have suggested that the delayed implantation approach allows higher bone-implant contact and greater implant stability compared to the simultaneous implantation approach (8).

Autogenous block grafts show 0–25% resorption in the early period (9). This resorption rate may affect treatment results, especially following simultaneous implantation. Many studies have shown the effects of the timing of implantation on implant success and marginal bone loss as measured by 2D radiography (6,10,11). Although 2D radiographs are useful for planning and implant follow-up in implantology, they cannot provide sufficient information about volumetric changes in the bone graft in horizontally augmented alveolar bone. Thus, 3D radiographic examinations are needed. However, a limited number of studies have evaluated the effects of the timing of implantation on the dimensional changes in augmented bone in 3D radiographs (7). Selecting the region of interest (ROI) is a critical aspect of volumetric analysis. In many studies examining volumetric changes in autogenous grafts, ROIs include all or part of the jaws, including implants placed, and their borders are determined manually (12,13,14,15). Manual determination of the borders of ROIs is not reliable enough for reproducible measurement areas in cone-beam computed tomography (CBCT) images scanned at different time points. Furthermore, because ROIs can contain multiple objects and layers of anatomical structures, acquiring graft volume measurements is challenging (16).

The present study hypothesized that the timing of implantation may affect the dimensional changes in the bone graft and that these changes may affect the success of the implant, which is estimated according to the Implant Quality of Health Scale. (17). Thus, this study aimed to address the following question: Does the simultaneous implantation technique, compared to the delayed implantation approach, influence implant success and the stability of bone grafts in alveolar crests that have undergone lateral augmentation using autogenous grafts? To answer this question, we compared simultaneous and delayed implants after 1 year of prosthetic loading in patients who underwent horizontal reconstruction of the mandible posterior with mandibular ramus grafts. In addition to measuring implant success, marginal bone loss, and bone graft width, we also evaluated 3D bone stability using a measurement method that allowed only the volume of augmented bone to be evaluated.

MATERIAL AND METHODS

Study design

The investigators designed and implemented a retrospective cohort study to compare the graft stability and implant success of delayed implantation versus simultaneous implantation with autogenous grafts. The present study was performed according to the guidelines of the 2013 revision of the Helsinki Declaration and complied with the STROBE guidelines (18). Ethical approval was obtained from the Marmara University Institute of Health Sciences Ethics Committee (date: 15.11.2021, decision no: 127). Every patient signed a written informed consent form.

Study sample

The study sample was derived from the population of patients who underwent autogenous block bone grafting using the ramus of the mandible at the Department of Oral and Maxillofacial Surgery, Marmara University between May 2018 and April 2021. All patients who

met the inclusion criteria were included in the study. The patients' augmentation operations and implant-related data were obtained from the patients' electronic health records. The inclusion criteria were as follows: (1) >18 years of age (2) not smoking; (3) severe horizontal atrophy of the alveolar ridge in the mandibula posterior (Class IV, i.e., knife-edge ridge with adequate height but inadequate width of 4 mm or less) (19); (4) reconstruction with autogenous block bone graft using the ramus of the mandible; (5) simultaneous implantation with autogenous grafts or delayed implantation after augmentation operation; (6) single tooth or partial tooth deficiency (4 teeth) restored with screw-retained fixed implant-supported prosthesis; (7) presence of keratinized gingiva at least 2 mm around the implant; and (8) follow-up for at least 1 year after prosthetic loading. The exclusion criteria were as follows: (1) systemic or local contraindications to implant surgery; (2) vertical alveolar ridge augmentation; (3) poor oral hygiene; (4) implants narrower than 3.5 mm in diameter and shorter than 8 mm in length; and (5) refusal to participate in the study.

Treatment procedures

The performed approach (simultaneous or delayed implantation) was chosen based on the intraoperative CBCT evaluation of each case. The width and shape of the bone ridge were assessed. Simultaneous implantation was preferred if the implants could be expected to achieve primary implant stability of at least 20 Ncm in the appropriate prosthetic position (Figure 1). All surgical procedures were performed by two surgeons (GG and SAE) under local anesthesia.

Delayed implantation approach

The recipient and donor sites were exposed through midcrestal and vertical incisions. Crestal, lateral, and apical osteotomies to harvest the bone block graft were performed using piezoelectric surgical instruments (Piezosurgery White, Mectron S.P.A., Italy). Surgical chisels were used to mobilize the graft. The graft was recontoured to the recipient site using a diamond burr. Using screws, the block graft was fixed to the residual crest so that there was no movement of the block graft seen following fixation. (Ramed Medikal, Turkey). Particulate autogenous grafts were collected from the external oblique ridge using a bone scraper (Safe Scraper Twist, Osteogenics Biomedical, Canada). The spaces between the recipient site and the block graft are filled with particulate autogenous bone grafts. A periosteal-releasing incision was made to allow passive primary closure of the flap. The flap was sutured using simple and mattress-absorbable sutures (Dogsan Medical Supplies Industry, Turkey). Four months later, the implantation operation was performed. The recipient site was exposed to a midcrestal incision. Fixation screws were removed. Implant osteotomies were performed, and implants were placed at the bone level The cover screws for the implants were placed, and the flap was closed primarily (Figure 2).

Simultaneous implantation approach

Autogenous block and particulate graft harvesting were performed in a manner similar to the delayed implantation approach. Before the block grafts were fixed to the recipient site, osteotomies of the implants were performed, and the implants were placed at the level of the lingual bone. Block grafts were fixed to the recipient site using 1.6 mm fixation screws. The spaces between the implants and the block graft are filled with particulate autogenous bone grafts. The flap was closed primarily using resorbable sutures without tension (Figure 3).

Except for autogenous graft material, no graft material, membrane, or platelet-rich concentrates were used in either group. The implant stability quotient (ISQ) values during the implantation were measured using an Osstell device (Osstell ISQ, Integration Diagnostics Ltd., Sweden). After surgeries, antibiotics (amoxicillin + clavulanic acid 1 g, two times a day for 7 days), pain medication (naproxen sodium 550 mg + codeine phosphate 30 mg, every 8 hours as needed), and rinsing irrigation (0.12% chlorhexidine gluconate + 0.15% benzydamine hydrochloride, three times daily for 7 days) were administered. The sutures were removed 14 days after the operation. No patients used fixed or removable temporary prostheses during the recovery period. After a healing time of 4 months (simultaneous implantation) or 2 months (delayed implantation), the healing abutments were inserted. Approximately 3 weeks after the placement of the healing abutment, prosthetic procedures were started when soft tissue

Table 1. Health scale for dental implants (17)

Implant Quality Scale Group	Clinical Conditions
I. Success (optimum health)	a) No pain or tenderness upon function b) 0 mobility c) 2 mm radiographic bone loss from initial surgery d) No exudates history
II. Satisfactory survival	a) No pain on function b) 0 mobility c) 2–4 mm radiographic bone loss d) No exudates history
III. Compromised survival	a) May have sensitivity on function b) No mobility c) Radiographic bone loss 4 mm (less than 1/2 of implant body) d) Probing depth 7 mm e) May have exudates history
IV. Failure (clinical or absolute failure)	Any of following: a) Pain on function b) Mobility c) Radiographic bone loss 1/2 length of implant d) Uncontrolled exudate e) No longer in mouth

>18 years of age

Table 2. Demographic data of patients

		Patient (n:21)
Age (years)		42.84±12.04
Gender	Female	18 (85.7)
	Male	3 (14.3)
Systemic disease	None	18 (85.7)
	Allergic asthma	1 (4.76)
	Gastritis	1 (4.76)
	Hypertension	1 (4.76)

n: Number, %: Percentage, SD: Standard deviation

Table 3. Description of implant-related variables between simultaneous and delayed implantation groups.

		Simultaneous implantation	Delayed implantation	p
Sample size		17(51.5)	16(48.5)	
Implant manufacturer	Straumann Bone Level	3 (17.6)	4 (25.0)	
	Megagen ST	9 (52.9)	6 (37.5)	[a]0.730
	Megagen Anyone	5 (29.4)	6 (37.5)	
Follow-up after prosthetic loading (months)		14.12±1.17	15.63±2.45	[b]0.157
Implant diameter (mm)		4.22±0.30	3.90±0.42	[b]0.058

* a : Fisher Freeman Halton Test, b. : Mann Whitney U Test; n (%), Mean±SD, mm: millimeter, n: Number, %: Percentage, SD: Standard deviation

Table 4. The descriptive statistics of outcome variables between simultaneous and delayed implantation groups.

Outcome Variables		Simultaneous implantation (n=17)	Delayed implantation (n=16)	*p*
3D Volume Changes	3D resorption rate (%)	57.18±22.75	31.98±17.55	[a]***0.001***
	Volume1(mm^3)	209.54±94.83	122.02±32.46	[a]***0.003***
	Volume2(mm^3)	80.22±42.29	85.18±38.77	[a]0.958
	3Dresorp (mm^3)	128.26±78.75	35.88±17.91	[a]***0.001***
2D Linear Changes	2D resorption rate (%)	54.81±30.88	38.44±18.86	[a]***0.014***
	Width1(mm)	3.13±1.08	2.28±0.87	[a]***0.014***
	Width2(mm)	1.55±1.47	1.60±0.87	[a]0.309
	2Dresorp (mm)	1.64±1.08	0.75±0.52	[a]***0.017***
Marginal Bone Loss (mm)		1.15±0.47	0.88±0.60	[a]0.168
Implant success	Success (optimum health)	16 (94.1)	15 (93.7)	[b]1.000
	Satisfactory survival	1 (5.9)	1 (6.3)	

* a:Mann Whitney U Test, b:Fisher's Exact Test; Mean±SD, mm3: Cubic millimeter, n: Number, %: Percentage, SD: Standard deviation

healing was complete. Single or 2-tooth deficiencies were restored with implant-supported, screw-retained single crowns. 3-tooth deficiencies were restored with two implant-supported, 3-unit screw-retained dental prostheses. The cantilever design was not used in any patients. At the control appointments 1 year after prosthetic loading, the implants were evaluated clinically and radiologically. CBCT scans were carried out preoperatively (T0), post-implantation (T1), and a year following prosthetic loading (T2). Intraoral radiographs were taken post-implantation (T1) and a year following prosthetic loading (T2).

Study variables

The predictor variable was the timing of implantation (simultaneous or delayed approaches). The primary outcome variable was the 3D resorption rate of the bone graft after 1 year of prosthetic loading. Secondary outcome variables were 3D volume changes, 2D linear changes, marginal bone loss, and the success of the implant. The 3D volume changes were volume1 (the bone graft volume at post-implantation), volume2 (the bone graft volume at 1-year follow-up), and 3Dresorp (resorption volume of the bone graft). The 2D linear changes were width1 (the bone graft width at post-implantation), width2 (the bone graft width at 1-year follow-up), 2Dresorp (2D resorption amount of the bone graft), and 2D resorption rate. The variables were assessed separately for each implant if a patient had more than one implant.

Outcome measures

All data were collected by a single investigator (SAE). Intraexaminer calibration was determined by reassessing 3D measurements, 2D measurements, and marginal bone loss for 10 randomly selected implants, including duplicate measurements performed on different days, before evaluating the entire implant sample. The intraclass correlation coefficients for intraexaminer reliability were 0.947, 0.864, and 0.912 for the 3D measurements, 2D measurements, and marginal bone loss, respectively.

3D CBCT measurements

The same machine (Planmeca Promax 3D Mid, Helsinki, Finland) and the same protocol (90 kVp, 10 mA, 10.08 s, 0.20 mm voxel, 160x160 mm field of view [FOV]) were used for all CBCT scans. Images were exported with the Planmeca Romexis Viewer 4.6.2.R software (Planmeca, Helsinki, Finland). The procedures recommended in previous studies were followed when determining both 2D and 3D measurement protocols (16).

The CBCT data scanned at T0, T1, and T2 were used for 3D measurements. CBCT images were exported in DICOM format and uploaded to Slicer 5.2.2 software (Slicer Community) (20). Regarding the anatomical points, all CBCT scans were superimposed based on the T1 CBCT scans for each patient. The same threshold value was used for mandible segmentation in CBCT scans taken at different times for each patient. After that, background noise or artifacts were

eliminated slice by slice following the cortical border of the mandibular alveolar bone, and segmentation was completed manually in the axial, coronal, and sagittal planes. Implant segmentation was performed at the appropriate threshold value in the T1 CBCT images. To standardize the measurement area, 10 × 10 × 10 mm cubes were segmented. While the cubes were superimposed, the cervical border of the cubes was placed at the most coronal point of the implant and the lingual border at the most lingual point of the implant. The cubes were aligned so that the implants were centered in the axial plane and that their axis was parallel to the implant's long axis. All data were exported in STL format and uploaded to the Meshmixer program (AutoDesk, CA, USA). In this software, the measurement area was constructed by separating the implant segment from the cube segment to examine only the volume change in the bone graft. To identify ROIs, the areas that the mandible segments covered within the measurement area were digitally identi-

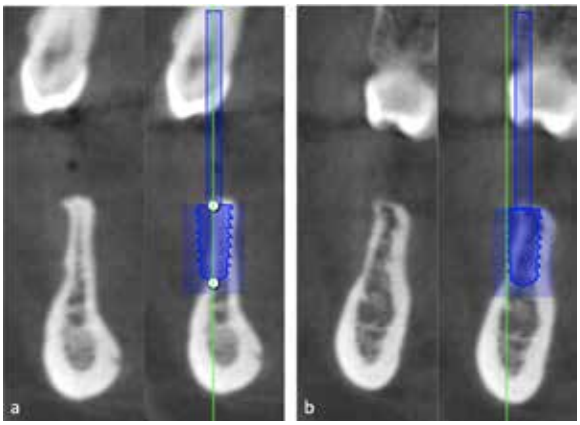

Figure 1. Choosing the implantation approach based on the CBCT examination **a)** Delayed implantation due to inadequate primary stability **b)** Simultaneous implantation due to adequate primary stability

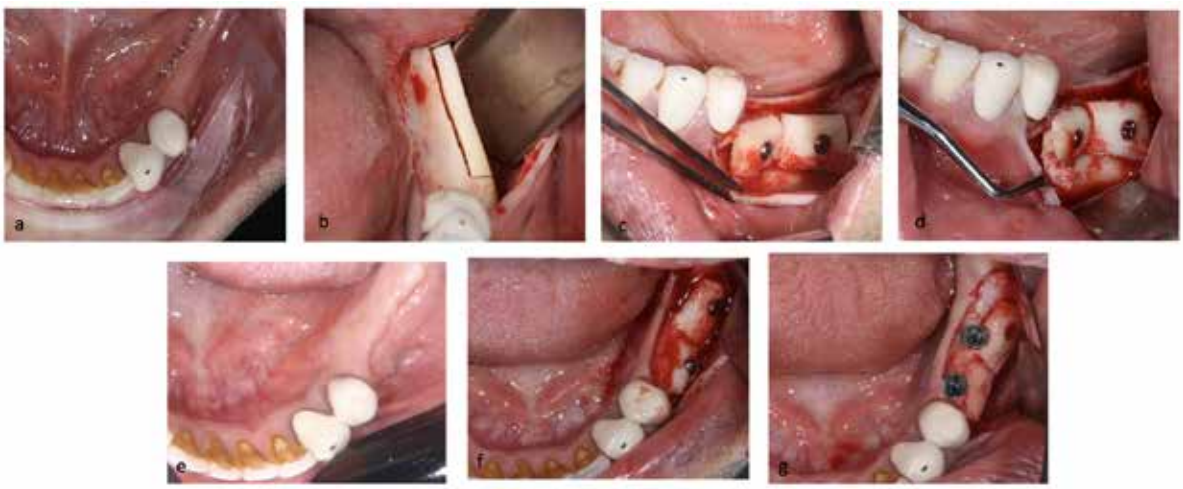

Figure 2. Delayed implantation approach **a-d)** Lateral alveolar ridge augmentation with ramus block graft **e-g)** Delayed implant placement 4 months after the augmentation procedure

Figure 3. Simultaneous implantation approach with augmentation procedure
a) Horizontally inadequate alveolar crest **b)** Implant placement and defect in buccal aspect **c)** Block graft fixation and filling of gaps with particulate grafts

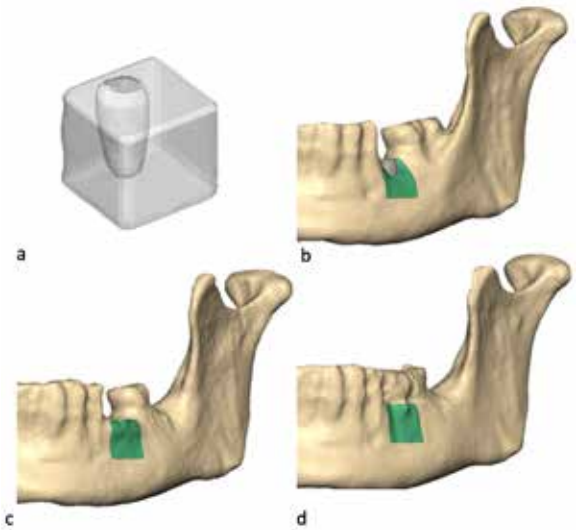

Figure 4. Identification of ROIs **a)** Separation of the implant segment from the cube segment to create a measurement area **b)**The green area represents ROI-0 **c)**The green area represents ROI-1 **d)** The green area represents ROI-2

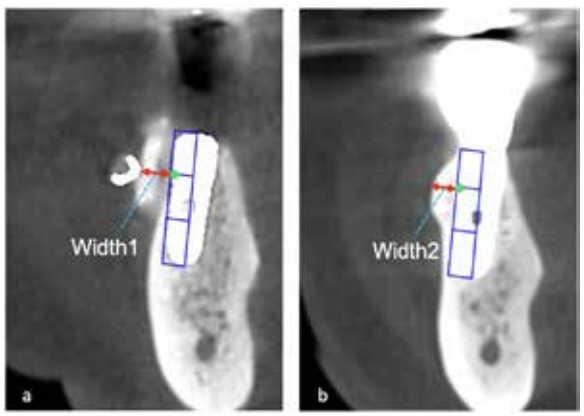

Figure 6. Determination of the 2D linear measuring points **a)** The bone graft width at post-implantation (Width1) **b)** The bone graft width at 1-year follow-up (Width2)

fied. Since the measurement area was superimposed at the same location in all mandible segments, it allowed measurement in a reproducible and standardized area specific to each implant. A total of 3 ROIs were created for each implant: preoperative ROI (ROI-0), post-implantation ROI (ROI-1), and 1-year follow-up ROI (ROI-2) (Figure 4). Volume1 was calculated by subtracting ROI-0 from ROI-1. Volume2 was calculated by subtracting ROI-0 from ROI-2. 3Dresorp was calculated by subtracting ROI-1 from ROI-2 (Figure 5). The 3D resorption rate was calculated using the following formula:

Figure 5. 3D volume measurements **a)** The purple area represents Volume1 **b)** The blue area represents Volume2 **c)** The red area represents 3Dresorp

$$\text{3D resorption rate} = 100 \times \frac{\text{Volume1} - \text{Volume2}}{\text{Volume1}}$$

2D CBCT measurements

The 2D measurements were made in Planmeca Romexis Viewer 4.6.2.R software using CBCT data scanned at T1 and T2. The procedures recommended by previous studies were followed to ensure that each spline on the axial view was the same for each patient through a series of scans taken at each measurement point (21). Measurements were taken on a cross-sectional image passing through the center of each implant. To establish the measurement point, a box parallel to the implant's long axis was made. The box's cervical border was lined up with the implant's most coronal point, the apical border was lined up with its most apical point, the lingual border was lined up with the implant's midline, and the buccal border was lined up with the implant's buccal line. This box was divided vertically into three equal parts. The width of the bone graft was determined by measuring the distance from the most buccal and coronal points of the middle part of the buccal bone in the direction perpendicular to the long axis of the implant (Figure 6).

The difference in the width of the bone graft between the T1 and T2 CBCT images was evaluated as the amount of 2Dresorp. The 2D resorption rate was calculated using the following formula:

$$\text{2D resorption rate} = 100 \times \frac{\text{Width1} - \text{Width2}}{\text{Width1}}$$

Marginal bone loss

Intraoral radiographs were obtained at T1 (baseline) and at T2 using the same device (Belmont Phot-X II

Model 303-CM, New Jersey, USA) with the aid of Kerr Super-Bite (KerrHawe SA, Switzerland) to achieve parallelism. Images were scanned using the VistaScan Mini Plus (DÜRR Dental SE, Almanya) device and exported with DBSWIN software (DÜRR Dental SE, Almanya) before being saved in JPEG format. Measurements were made using Digimizer Image Analysis Software Version 6.0 (MedCalc Software Ltd., Belgium). To minimize the distortion factor, the images were calibrated based on the implant length. The distance between the implant shoulder and the lowest point of the crestal bone in intimate contact with the implant was measured. For each implant, marginal bone loss was a single score recorded as the greatest value from either the mesial or distal measurements.

Implant success

The success of the implants was evaluated at T2 using the ICOI Implant Health Scale(17) (Table 1). Pain or tenderness during function was questioned on clinical examination. Through visual inspection, probing, and applying pressure, suppuration and implant mobility were evaluated. Probing depth measurements were made at six points of the implants (mesiobuccal, buccal, distobuccal, mesiolingual, lingual, and distolingual), and a probing depth value was obtained for each implant by considering the largest value.

Statistical analysis

The Number Cruncher Statistical System (NCSS) 2007 (Kaysville, Utah, USA) program was used for the statistical analysis. Descriptive statistical methods (mean, standard deviation, median, frequency, percentage, minimum, and maximum) were used to evaluate the study data. The conformity of the quantitative data to the normal distribution was determined using the Shapiro–Wilk test and graphical examinations. The Mann–Whitney U test was used for comparisons between two groups of quantitative variables that did not show a normal distribution. Fisher's exact test and the Fisher–Freeman–Halton test were used to compare the qualitative data. Statistical significance was accepted as $p < 0.05$. Statistical significance was accepted as $p < 0.05$. Post hoc analysis was performed based on the 3D resorption rate, which is the primary outcome, to investigate the power of the study.

RESULTS

During the study period, 56 subjects were screened for eligibility. The final sample comprised 21 subjects with a mean age of 42.8 ± 12 years, and 18 (89.5%) were female. In total, 33 implants were investigated, 51.5% (n = 17) of which were placed using a simultaneous approach and 48.5% (n = 16) using a delayed approach. In the delayed implantation approach group, the interval between augmentation and implantation operations ranged between 4 and 7 months, with a mean of 4.87 ± 0.83 months.

Three implant brands with platform-switching designs were used. (Straumann Bone Level, Institut Straumann AG, Basel, Switzerland; Megagen Anyone, MegaGen, Daegu, Korea; Megagen ST, MegaGen, Daegu, Korea) Demographic data and implant-related variables are compiled in tables (Table 2 and Table 3).

In both groups, the ISQ values of all implants were above 60 at implantation. No postoperative graft infection, graft loss complications, or prosthesis-related complications occurred in any of the patients. The descriptive statistics for 3D volume change, 2D linear change, marginal bone loss, and implant success between the simultaneous and delayed implantation groups are summarized in a table (Table 4).

The 3D volume measurements showed that the 3D resorption rate, volume1, and 3Dresorp values were higher in the simultaneous implantation group than in the delayed group. This difference was statistically significant ($p = 0.001$, $p = 0.003$, and $p = 0.001$, respectively). According to the results of the post hoc analysis based on the 3D resorption rate, the power of the study was 99.4%.

The 2D linear measurements showed that the 2D resorption rate, width1, and 2Dresorp values were higher in the simultaneous implantation group than in the delayed group. This difference was statistically significant ($p = 0.014$, $p = 0.014$, and $p = 0.017$, respectively)

There were no significant differences between the two groups with respect to volume2, width2, marginal bone loss, and implant success at the 1-year follow-up ($p = 0.958$, $p = 0.309$, $p = 0.168$, and $p = 1.000$, respectively).

DISCUSSION and CONCLUSION

This retrospective study aimed to demonstrate the effects of the timing of implantation on the dimensional changes in the bone graft and implant success in ridges augmented with autogenous grafts. The results showed that the simultaneous implantation approach demonstrated a higher rate of graft resorption compared to delayed implantation. This finding supports the hypothesis that the timing of implantation affects the dimensional changes in the bone graft.

Graft resorption is a natural consequence of graft healing. Studies have shown that 18–60% of the autogenous block graft volume is resorbed (22,23,24,25,26,27). In our study, autogenous graft stability in alveolar crests implanted using simultaneous implantation approaches was evaluated utilizing 3D measurement methods and compared with delayed implantation. In studies examining the volume changes in autogenous grafts in alveolar crests implanted with delayed implantation, both the graft volume gained and the resorbed graft volume values were higher than in the present study (12,13,14,15). The ROIs in these studies included the whole jaw or the whole region where grafting was performed. In patients undergoing augmentation, CBCTs obtained after implantation contain both the bone graft and the implant, which are absent in preoperative CBCT images. In the event of bone graft resorption over time, the implant continues to exist outside the pre-augmentation crest margins. In this case, if the implant is not removed in the measurement area, the implant volume is identified by the software as bone graft volume. In addition, if there is no mechanical stimulation on the bone graft for 6 months after augmentation, the bone graft begins to resorb, and its volume decreases (28,29). In the ROIs including the entire augmented area or the jaw, resorptions observed at unloaded graft sites may be misleading. Given these facts, this study focused on changes in peri-implant bone graft volume, and implant volume was not included in the digitally determined ROI borders. This method of determining ROI borders resulted in lower volume values compared to the literature. However, this allowed measurements to be made in a standardized and reproducible manner at different time points at each implant site.

The results of our study indicated that the width1 and volume1 in both the 2D and 3D CBCT evaluations were significantly higher in the simultaneous implantation group than in the delayed group. This result is consistent with a meta-analysis reporting higher width gains as a result of the simultaneous approach compared to the delayed approach (30). The thickness of the external oblique ridge restricts the graft's size in the ramus block graft procedure (31). In the simultaneous approach, due to the placement of the implant between the residual crest and the graft, the blocks are fixed away from the residual crest, and more bone thickness can be obtained. Additionally, in the present study, post-implantation evaluations were performed immediately with the augmentation in the simultaneous approach and 4 months after the augmentation in the delayed approach. During implantation, autogenous block grafts resorb at a rate ranging from 0% to 25% (9). Performing measurements 4 months after the grafting procedure may have been a factor in the delayed implantation group's lower volume1, width1, 3Dresorp, and 2Dresorp values compared to those of the simultaneous implantation group.

The present study's findings revealed that there was no difference between the two groups in terms of graft volume, graft width, marginal bone loss, and implant success at the 1-year follow-up. This result rejects the hypothesis that the timing of implantation influences implant success and showed that the two groups had similar results, at least at the 1-year follow-up. There is no consensus in the literature on the results of simultaneous and delayed implantation approaches. Tosun et al. evaluated autogenous bone graft resorption using 2D linear measurements in CBCT. The higher graft resorption rate as a result of the simultaneous implantation approach compared to the delayed implantation approach reported in this study is consistent with our study (7). Some researchers who compared simultaneous and delayed implantation approaches in alveolar crests augmented with autogenous grafts observed that marginal bone loss was higher following the simultaneous implantation approach (6,7,11) Aloy-Prósper et al. indicated that marginal bone loss was higher in the simultaneous group, but when bone grafting was successful, marginal bone loss was not significantly different between the groups. (6) In the present study, no

graft-related complications occurred. On the contrary, several researchers have indicated that marginal bone loss was not different between the two groups (10). Similarly, studies have reported that implant success and survival are higher following the delayed implantation approach, while others have reported that they are similar regardless of the approach (6,11,32).

Limitations of the present study include its short follow-up period, retrospective design, and small sample size. Additionally, dividing groups based on preoperative CBCT evaluations may cause bias. However, the present study has the strength is that comparable results are obtained by creating a standardized measurement area for each implant at different times.

The results of the study showed that although the simultaneous implantation approach was associated with a higher rate of graft resorption than the delayed implantation approach in crests augmented with autogenous grafts, the implants in the two groups showed similar results at the 1-year follow-up. The literature indicates that alveolar crests augmented with autogenous grafts acquire a stable bone level around the implant after 3 years, regardless of the timing of implantation (1,3,33) Therefore, the 1-year follow-up may not be the endpoint when it comes to measuring graft volume changes and implant success. Prospective comparative studies with longer follow-ups and larger sample sizes are needed to show the effects of the timing of implantation on implant success and graft stability in crests augmented with autogenous grafts.

Conflict-of-interest and financial disclosure

The authors declare that they have no conflict of interest to disclose. The authors also declare that they did not receive any financial support for the study.

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