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Reconstruction of Defective Alveolar Bone With Non-Resorbable and Titanium Reinforced Membrane Implantation Success

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ABSTRACT

Aim: The aim of this study is to present the clinical success of cases in which implants were placed in defective alveolar bone in a single surgical procedure.
Material and Methods: Thirty-three patients with alveolar bone defects in the maxillary canine and premolar regions were included in the study. Before the procedure, cone-beam computed tomography (CBCT) images were obtained from all patients and the heights of the defective walls were recorded. In the surgical operation, primary stability of the implant was ensured, guided bone regeneration was applied. The prosthetic restoration was completed as cemented or screwed. Six months after this stage, the amount of bone regained was recorded by CBCT imaging. Clinically, peri-implant probing depth and bleeding on probing indexes were examined. The Mann-Whitney U test was applied for comparisons between types of restoration, while bone heights were compared using the Wilcoxon Sign test ($p<0.05$).
Results: The mean total bone height gain was 8.91 ± 1.30 mm. The pocket depth was significantly greater in cemented restorations compared to screwed restorations ($p=0.006$). The mean pink esthetic score score was 12.3 ± 1.8 and the mean white esthetic score score was 8.4 ± 1.5.
Conclusion: In cases where there is a defect of more than half the implant length on one or both sides of the alveolar bone, implants can be placed in a single session with a meticulous surgical approach and appropriate material. The use of screw retainers in prosthetic restorations has been found to be more successful than cemented restorations.

Defektif Alveolar Kemiğin Rezorbe Olmayan ve Titanyumla Güçlendirilmiş Membranla Rekonstrüksiyonu ve İmplantasyon Başarısı

Makale Bilgisi

Makale Geçmişi

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Anahtar Kelimeler:
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Alveolar kemik defekti,
Implant destekli protezler,
Titanyum mesh.

ÖZET

Amaç: Bu çalışmanın amacı, implantların defektif alveoler kemiğe tek bir cerrahi prosedürle yerleştirildiği vakaların klinik başarısını sunmaktır.
Gereç ve Yöntemler: Maksiller kanin ve premolar bölgelerinde alveolar kemik defekti olan 33 hasta çalışmaya dahil edildi. İşlem öncesinde tüm hastalardan konik ışınlı bilgisayarlı tomografi (CBCT) görüntüleri elde edildi ve defektif duvarların yükseklikleri kaydedildi. Cerrahi operasyonda implantın primer stabilitesi sağlandı, yönlendirilmiş kemik rejenerasyonu uygulandı. Protetik restorasyon simante veya vidalı olarak tamamlandı. Bu aşamadan altı ay sonra, kazanılan kemik miktarı CBCT görüntüleme ile kaydedildi. Klinik olarak, peri-implant sondalama derinliği ve sondalamada kanama indeksleri incelendi. Restorasyon tipleri arasındaki karşılaştırmalar için Mann-Whitney U testi uygulanırken, kemik yükseklikleri Wilcoxon İşaret testi kullanılarak karşılaştırıldı ($p<0.05$).
Bulgular: Ortalama toplam kemik yüksekliği kazancı 8.91 ± 1.30 mm idi. Cep derinliği simante restorasyonlarda vidalı restorasyonlara göre anlamlı olarak daha fazlaydı ($p=0.006$). Ortalama pembe estetik skor 12.3 ± 1.8 ve ortalama beyaz estetik skor 8.4 ± 1.5 idi.
Sonuçlar: Alveoler kemiğin bir veya iki tarafında implant uzunluğunun yarısından fazla defekt olduğu durumlarda, titiz bir cerrahi yaklaşım ve uygun materyal ile implantlar tek seansta yerleştirilebilir. Protetik restorasyonlarda vida tutucuların kullanımı simante restorasyonlara göre daha başarılı bulunmuştur.

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INTRODUCTION

Nowadays, dental implant therapy is the first choice of treatment for toothlessness with good functional and esthetical outcomes.[1] However, extensive bone loss can result from a number of procedures such as traumatic tooth extraction, surgical removal of impacted teeth, retrieval of failed implants and cyst enucleation.[2,3] This makes implant placement difficult and prolongs the treatment period. Absence of sufficient alveolar bone may interfere with implant stabilization, osseointegration and long-term prognosis as well as aesthetic considerations.[4]

Classification of alveolar bone defects and determination of appropriate treatment methods are of great importance for clinicians.[5] In a 2022 consensus study, alveolar bone defects were categorized into five types and treatment recommendations were presented for each type. Accordingly, staged treatment is recommended for all defect types except Type I.-0.[6,7] However, this approach prolongs the treatment time and decreases patient comfort.[8] Therefore, faster and more comfortable methods should be investigated.

Guided bone regeneration (GBR) is a widely used technique for the treatment of bone defects.[9,10] The success of GBR depends on the properties of the membrane and graft materials used.[11] In recent years, titanium reinforced PTFE membranes have come to the forefront due to their high stability and biocompatibility.[3,12] However, the efficacy of these materials in different defect types is still not fully investigated.[13]

The primary hypothesis of this study is that the GBR technique using a titanium reinforced polytetrafluoroethylene (PTFE) membrane will be effective in Type I.-I and Type II-0 alveolar bone defects when combined with one-stage implant placement. Supporting hypotheses are that this technique will provide acceptable marginal bone loss and high aesthetic scores, and that screw-retained restorations will offer better peri-implant health than cemented ones.[14]

No research has been done in the literature on implant placement with GBR simultaneously in Type I.-I and Type II-0 alveolar bone defects. This gap is a deterrent to doctors who may want to provide single-stage treatment for these patients.[15] Consequently, this study seeks to generate new information that can be used by doctors for implementing single-stage treatments.

The purpose of this study was to determine the effectiveness of using GBR technique plus titanium reinforced PTFE membrane in treating Type II-0 and Type I.-I alveolar clefts alongside one-stage dental implant placements. Further, the research will seek to investigate how well this method increases bone mass, controls marginal ridge resorption, maintains a stable functional position for implants, and preserves peri-implant tissues including aesthetics. This will not only give more options that promise a shorter therapy period but also enhance patient satisfaction since they are painless alternatives during the healing process as it shortens the therapy phase besides increasing their comfort.

MATERIAL AND METHODS

Ethical Approval

This study has been approved by Nigde Ömer Halisdemir University Non-Interventional Clinical Research Ethics Committee on 25/01/2024 with protocol number 2024/14. It was carried out in compliance with guidelines stated in the Declaration of Helsinki (1964). All subjects gave informed consent prior to their inclusion in the experiment.

Study Design /Sample

Oral, Maxillofacial and Maxillofacial Surgery Clinic hosted this clinical study

between October 2022 to January 2023. It involved 33 patients (15 males, 18 females) aged between 40.0 ± 14.0 years who had single missing teeth in the maxillary canine or premolar areas together with damaged alveolar bones. The inclusion criteria included (1) being above 18 years old; (2) having only one tooth missing in the upper jaw canines or premolars area; (3) a defect on one side (>5 mm) or two sides (<5 mm) of the alveolar bone for a standard implant size of 10 mm (Type I.-I and Type II-0). Malignancy within the defect region, unoperated cysts or active infections, smoking, and uncontrolled diabetes were among the exclusion criteria used. Impacted tooth extraction, traumatic tooth extraction, and failed implant extraction were identified as causes of defects.

Predictor / exposure / independent variable

The absence of canines or premolars in the maxilla was the independent variable.

Main outcome variable(s)

The main outcome variables were the difference in T0 and T1 bone heights, aesthetic scores, and BOP and PPD indexes related to the type of prosthetic restoration.

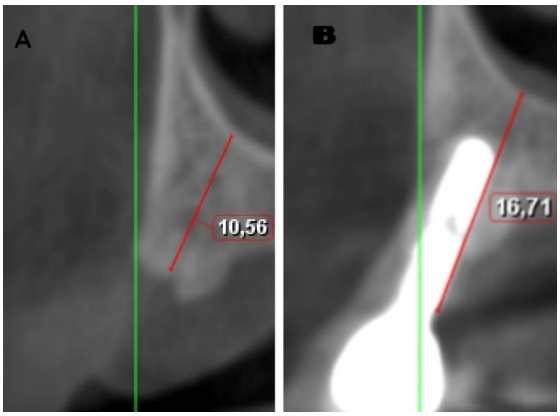
Covariates

The covariates were patient age, gender, and measured bone volumes.

Radiographic Evaluation

Radiographic evaluations were performed before implant placement (T0) and six months after final restoration (T1) using a Planmeca ProMax® 3D Mid CBCT device. Patients were positioned in a sitting position with a grid support. Bone height measurements were taken from the sinus floor in the premolar region and from the base of the nose to the end of the alveolar wall in the canine region. Buccal and palatal defects were analyzed on the sagittal axis, while mesial and distal defects were analyzed on the frontal axis (Figure 1).

Figure 1. a) For tooth 25, the measurement of the defective wall from the sinus floor b) The new bone height 6 months after the prosthetic restoration is shown



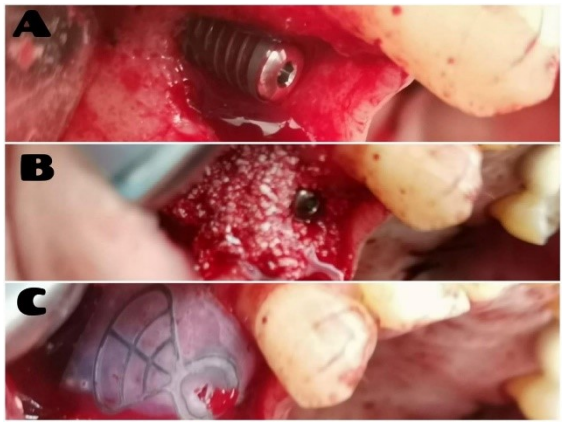
To minimize measurement errors, consistency of measurements by the same researcher was ensured and the calibration of the instrument was checked regularly. Calibration was performed in accordance with the manufacturer's instructions and periodic tests were performed using a standard phantom to improve measurement accuracy. In addition, intra-observer and inter-observer reliability analyses were performed to assess measurement errors and the results were statistically analyzed.

Implant and Graft Materials

For the research, implant materials with a conical shape and hydrophilic surface were used (INNO®, Cowellmedi, Pusan, Korea). The average length of the implants was 10 ± 1.0 mm while the average diameter was 4.0 ± 0.4 mm. All patients undergoing GBR had graft material made of Bio-Oss (Geistlich Pharma AG, Wolhusen, Switzerland) and Wifi-Mesh (COWELL® InnoGenic™, Korea) titanium reinforced PTFE membrane (Figure 2). Their choices were based on clinical success and efficacy as reported in scientific literature. INNO® implants foster osseointegration as well as enhance healing through their hydrophilic nature. Since it is similar to natural bone structure, Bio-Oss has been widely

employed for bone volume reconstruction and aids bone integration through its high biocompatibility. Composed of titanium reinforced PTFE, Wifi-Mesh membranes are stable and can be tolerated by human bodies. These membranes hold grafted bones steady and prevent growth of soft tissues into them considering that titanium reinforced membranes have been established to be effective in bone regeneration.

Figure 2. a) Placing the two walls of the implant in the defective area b) Covering the implant surface with graft material c) Applying titanium supported membrane to protect the surgical field



Surgical Procedure

All surgical procedures were performed by a single oral surgeon with 8 years of experience. Lidocaine 2% (Dentsply Sirona, York, PA) was applied to the mucogingival junction and interdental papilla as a local anesthetic. After anesthesia, alveolar bone incision and vertical incisions were made to the adjacent teeth. The flap was lifted to expose the defective area and all surfaces were curetted. The implant position was planned to be aligned and parallel to the adjacent teeth. A 3 mm length and 3.5 mm diameter drill was made at the apex for apical support. The implant was placed with a torque of 35 N and a cap screw was inserted. The implant periphery was filled with graft material and covered with a barrier membrane. The membrane was fixed with matrix suture and the flap was closed as much as possible with simple suture using Vicryl (Johnson & Johnson, New Brunswick, NJ) after the release incision was made. Four months later, secondary surgery was performed and the membrane skeleton was removed and a healing cap was placed.

A surgeon's experience is vital to the success of a surgical procedure. An eight-year-experienced surgeon in these operations has proven to reduce complications and increase success rates. Success may also be affected by other factors including but not limited to; how well the doctor can use their hands, techniques they employ during an operation, sterilization methods adopted as well as general patient health and oral habits like brushing teeth regularly — among others. Additionally, it is important that surgeons are able to see what they're doing while making incisions or placing implants hence adequate lighting should be provided for them always. In ensuring infection control throughout the process before and after procedures, measures were taken such as closing off areas where surgery was done properly so no germs could enter inside, plus making sure patients follow postoperative instructions carefully. Wound dehiscence and infectious complications were not observed.

Prosthetic Procedure

Since the alveolar bone was defective preoperatively, the restoration was performed after a 4-month healing period. After the second surgery, the impression was taken after waiting for soft tissue healing. A provisional restoration was made, and when no problems were observed, the final restoration was cemented or screwed in place.

Periodontal Evaluation

Peri-implant soft tissue status was assessed by the same clinician using a periodontal probe (15 UNC/CP-11.5B Screening Color-Coded Probe, Hu-Friedy). Peri-implant probing depth (PPD) and bleeding on probing (BOP) were measured at six points around each implant. The mean PPD and percentage of BOP positive sites were calculated (Figure 3).

Figure 3. a) 6 months after the restoration, examination of the restoration perimeter with a periodontal probe starting from the distal papilla b) intraoral view of a sample restoration

Data collection methods

Radiographically, the difference between T1 and T0 bone heights was recorded as bone gain. Clinically, PPD and BOP scores were recorded by periodontal examination, and PES and WES scores were recorded for aesthetic evaluation. STROBE checklist is completed at all stages.

Data Analyses

Continuous variables are mean (standard deviation) and median [minimum-maximum]; categorical variables are expressed as n (%). The Mann-Whitney U test was applied for comparisons between types of restoration, while bone heights were compared before and after the procedure using the Wilcoxon Sign test. The SPSS software (IBM Corp., Released 2017, Version 25.0) was used for statistical analysis; $p < 0.05$ indicated a significant difference. Non-parametric tests like the Mann-Whitney U test and Wilcoxon Sign test are used when the data is not normally distributed or the sample size is small. For comparing the medians of two independent groups, we used the Mann-Whitney U test, and for comparing the medians of two dependent groups, we employed the Wilcoxon Sign test. Since the normal distribution assumption was violated according to Shapiro-Wilk's Test, parametric tests were not considered appropriate for this study.

RESULTS

The study consisted of 33 patients (15 men, 18 women) with a mean age of 40.0 ± 14.0 years. Tooth extraction due to impact was the reason for defective alveolar bone formation in 18 cases; cyst or benign tumor operation in six cases, failed implant extraction in three, and trauma in six. Sixty-three point six percent had two-walled defects while thirty-six point four percent had three-walled defects. In the upper canine region, implants were placed at a rate of 72.7%, and 27.3% in the upper premolar region. Cemented types of restoration accounted for 36.4%, whereas screwed types represented 63.6% (Table 1). Therefore, these demographics indicate that we covered a wide range of defect types and implant locations.

Table 1. Descriptive Statistics

Variables	Statistical Data
D2	21(63.6)
D1	12(36.4)
Maxilla Canine	24(72.7)
Maxilla Premolar	9(27.3)
Cemente	12(36.4)
Screw	21(63.6)
Bleeding on Probing: Yes	3(9.1)
Bleeding on Probing: No	30(90.9)
D1 Gained Bone (mm) (Avg. ± SD)	4.82 ± 1.17
D2 Gained Bone (mm) (Avg. ± SD)	4.09 ± 1.97
Total Gained Bone (mm) (Avg. ± SD)	8.91 ± 1.30
Avg. Probing Depth (mm) (Avg. ± SD)	3.18 ± 0.75

D1: three-walled bone defect D2: double-walled bone defect Avg: average

In D1, defective single wall showed an average bone gain of 4.82 ± 1.17 mm, while the defective second wall (D2) showed an average bone gain of 4.09 ± 1.97 mm. The total bone height increase was on average 8.91 ± 1.30 mm. The mean pocket depth was found to be 3.18 ± 0.75 mm (Table 2). This means that the GBR technique is highly efficient for the regeneration of alveolar bone with defects as shown by these findings.

Table 2. Bone Heights Measured Before and After the Operation

Variables	Average (SD)	Median [Min-Max]	p valuea
D1- T0 (mm)	4.64(1.21)	5[3-6]	0.003*
D1- T1 (mm)	9.45(0.69)	10[8-10]	
D2- T0 (mm)	5.55(2.01)	4[4-9]	0.003*
D2- T1 (mm)	9.64(0.51)	10[9-10]	

*p<0.05 level of significance , a: Wilcoxon Signed Rank test
D1- T0: three-walled bone defect, pre- operation
D1- T1: three-walled bone defect, post- operation
D2- T0: double-walled bone defect, pre- operation
D2- T1: double-walled bone defect, post- operation

There was a significant bone gain in both types of defect (p=0.003). Cemented or screwed restorations did not affect bone gain (p=0.927), whereas pocket depth was significantly higher in cemented restorations (p=0.006) (Table 3). These results may indicate that screw retention will give more benefits in peri-implant health.

Table 3. Comparison of bone gain and mean pocket depth measurements between restoration types

Variables	Cemente (n=12) Median [Min-Max]	Screw (n=21) Median [Min-Max]	*p* value[b]
D1 Gained Bone (mm)	4.50[4-6]	5.00[3-7]	0.788
D2 Gained Bone (mm)	5.00[1-6]	5.00[1-6]	>0.999
Total Gained (mm)	9.50[7-10]	9.00[7-11]	0.927
Average Pocket Depth (mm)	4.00[4-4]	3.00[2-3]	**0.006***

*p<0.05 level of signifiance, b: Mann Whitney U test

In the first 6 months, an average loss of 0.32 ± 0.18 mm was observed during marginal bone loss assessment after implant placement. An additional loss of 0.15 ± 0.09 mm occurred between 6 months and a year later. The overall average marginal bone loss for the one-year period was 0.47 ± 0.22 mm (Table 4). These findings are under acceptable limits for marginal bone loss, suggesting that this technique has potential with respect to long-term implant stability.

Table 4. Marginal Bone Loss

Time Interval	Average Marginal Bone Loss (mm) ± SD	Range (mm)
Baseline - 6 months	0.32 ± 0.18	0.1 - 0.7
6 months - 1 year	0.15 ± 0.09	0.0 - 0.3
Total (1 year)	0.47 ± 0.22	0.2 - 0.9

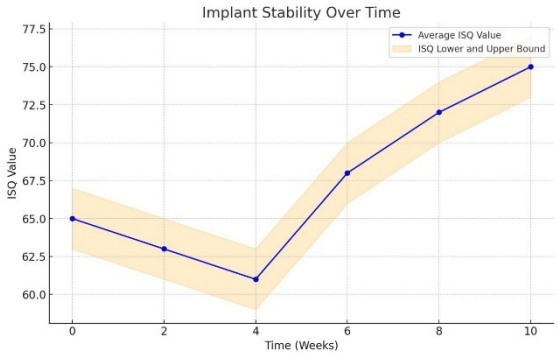
The mean PES total score was measured as 12.3 ± 1.8 and the mean WES total score as 8.4 ± 1.5 using the Pink Esthetic Score (PES) and White Esthetic Score (WES), respectively, to evaluate aesthetic outcomes (Table 5). These scores support the recommended aesthetic success criteria; hence, applying this technique provides good aesthetic outcomes as required by patients' expectations.

Table 5. Pink Esthetic Score (PES) / White Esthetic Score (WES)

Esthetic Parameter	Average Score ± SD	Range
Mesial papilla	1.8 ± 0.4	1 - 2
Distal papilla	1.7 ± 0.5	1 - 2
Soft tissue level	1.9 ± 0.3	1 - 2
Soft tissue contour	1.8 ± 0.4	1 - 2
Alveolar process	1.6 ± 0.5	1 - 2
Soft tissue color	1.7 ± 0.5	1 - 2
Soft tissue texture	1.8 ± 0.4	1 - 2
PES Total	12.3 ± 1.8	9 - 14
Tooth form	1.7 ± 0.5	1 - 2
Tooth volume/outline	1.8 ± 0.4	1 - 2
Color	1.6 ± 0.5	1 - 2
Surface texture	1.7 ± 0.5	1 - 2
Translucency	1.6 ± 0.5	1 - 2
WES Total	8.4 ± 1.5	6 - 10

Mean ISQ of 65 was recorded at the time of insertion during implant stability measurements. There was a slight decrease in the first 4 weeks, and at week 4, the lowest value of 61 ISQ was reached. From week 8, stability started to increase, and osseointegration was completed with an ISQ value of 75 (Figure 4) by week 16. This stability curve is typical for osseointegration and shows that the technique used is associated with successful implant stability.

Figure 4. Implant Stability Graphic



DISCUSSION

In this study, we evaluated whether the GBR technique using a titanium reinforced PTFE membrane combined with single-stage implant placement would be effective in Type I.-I and Type II-0 alveolar bone defects. Our results showed that this method ensures efficient bone regeneration, maintains implant reliability, and affords acceptable marginal bone loss values.

Bone augmentation procedures, especially in the vertical direction, involve a high risk of complications. Distraction osteogenesis and autogenous block graft application are still practiced in vertical bone deficiency. However, among these procedures, the GBR technique has been reported to have the lowest risk of complications.[16] We aimed to contribute to the literature by discussing a new material for material selection used in the GBR technique.

The mean bone gain obtained (8.91 ± 1.30 mm) is an extremely good result when compared to what has been reported in the literature.[16] For instance, Meloni et al.[17] observed a mean vertical bone gain of 3.71 ± 1.24 mm in GBR procedures involving titanium mesh and collagen membrane use. The high level of bone gain noted in our study, on the other hand, promotes the efficiency of the titanium reinforced PTFE membrane employed here as opposed to other studies which used different material types such as collagen membranes.[18]

Marginal bone loss results we obtained (0.47 ± 0.22 mm) were considerably within acceptable limits reported in the literature. Galindo-Moreno et al. [18] reported 0.71 ± 0.76 mm mean marginal bone loss after an implant has been in place for 18 months. In a recent clinical study on the subject, the mean bone loss in the study group with 94% survival was calculated as 0.81 mm. [19] In line with these studies, it can be said that our preferred technique is promising in terms of long-term implant stability because it has less percentage bone loss.

In terms of aesthetic results, we had good Pink Aesthetic Score (PES) and White Aesthetic Score (WES). The reason behind this is that these scores are in agreement with the suggested Belser et al.'s [20] aesthetic success criteria: They have similar PES and WES values to those recorded by Cosyn et al. [21] for early implant placement cases with soft tissue augmentation. In addition, PES and WES serve as tools that can be used in clinical practice to objectively evaluate the outcome of treatment using implants and they indicate that it has a positive effect on patient satisfaction. Moreover, the reliability and reproducibility of the scores in a digital environment have been supported by a recent study.[22] According to this result, the clinical observation-based scoring applied in this study is considered to provide a reliable and objective result.

In our study, screw-retained restorations were observed to be more advantageous in terms of peri-implant health. This finding is consistent with the results of the systematic review by Sailer et al. [23] The authors reported that screw-retained restorations had lower biologic complication rates compared to cemented restorations. Screw-retained restorations are also known to be more advantageous in terms of retrievability, passive placement and ease of repair.[24] Considering the biological usefulness, it is thought that screw-retained restorations should replace cemented restorations.

The titanium reinforced PTFE membrane we used had the advantage of being biocompatible, stable, and easy to shape. These properties are in line with the ideal barrier membrane properties emphasized by Ronda et al.[25] Furthermore, a randomized clinical trial by Cucchi et al. [13] showed that the use of titanium mesh resulted in higher bone gain compared to resorbable membranes. This result can be explained by the longer stability of titanium and its ability to be a durable barrier for bone formation.

It has been reported that the incidence of impacted canines is 2.7% in the population, and 78.4% of cases are unilateral.[26] The success of implant treatment in such cases is of critical importance in terms of esthetic and functional aspects. The results obtained in our study show that successful outcomes can be achieved in these challenging cases.

In addition to the materials used, the surgical technique is also of great importance in the success of the GBR technique. The surgical protocol applied in our study was performed in accordance with the principles recommended by Urban et al.[27] Especially flap design and primary closure were effective in the successful results obtained. In addition to the surgical technique, waiting long enough for bone maturation after surgery and controlling the surgical field during this process significantly affect the success of the procedure.[28] This important point was taken into consideration in patient follow-up.

One of the strengths of our study is that detailed radiographic and clinical evaluations were performed. CBCT images allowed an objective evaluation of bone gain. In addition, standardized aesthetic evaluation criteria such as PES and WES scores were used.[29]

However, our study also has some limitations. The relatively small sample size and short follow-up period limit the generalizability of the results. In future studies, it is important to evaluate the efficacy of this technique with larger patient groups and longer follow-up periods.

Furthermore, comparison of different membrane and graft materials would also be useful.[30,31] In particular, investigating the effectiveness of newly developed bioactive materials in the GBR technique may be an important topic for future studies.[32,33]

CONCLUSIONS

In Type I.-I and Type II-0 alveolar bone defects, single-stage implant placement can be successfully achieved with the GBR technique using a titanium reinforced PTFE membrane. This approach provides effective bone regeneration and acceptable marginal bone loss values. Good postoperative oral care and preservation of the augmented site are critical for long-term success. The use of screw retainers in prosthetic restorations provides better peri-implant health outcomes than cemented restorations. The aesthetic results are also satisfactory. However, these findings need to be confirmed in larger patient groups and with long-term follow-up.

Ethical Approval

This study has been approved by Nigde University Non-Interventional Clinical Research Ethics Committee on 25/01/2024 with protocol number 2024/14.

Financial Support

The authors declare that this study received no financial support.

Conflict of Interest

The authors deny any conflicts of interest related to this study.

Author Contributions

Design: NG, Data collection or access: NG, Analysis and comments: NG, Literature search: NG, Writing: NG.

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