

Comprehensive Assessment of Effects of Bone Grafting on Implants' Primary Stability and Associated Bony Transformations in Immediate Implants Placed in the Maxillary Anterior Region: An Original Research Study

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Abstract

Aim: This study aims to assess the effects of bone grafting on implants' primary stability and associated bony transformation, and immediate implants placed in the maxillary anterior region

Materials and Methods: This study focused on 90 patients aged 25 to 50 with decayed teeth seeking natural-looking replacements. After clinical examinations, 80 patients expressed interest in dental implants and implant-supported prostheses. Care was taken to preserve the buccal bone plate, with infraorbital local anaesthesia used for comfort. In cases needing bone augmentation, a hydroxyapatite graft and collagen membrane was applied. The 80 interested patients were split into two groups for analysis: Group 1 received immediate implant placement with bone grafting, and Group 2 received implants without grafting. Effectiveness was assessed by measuring primary stability and osseointegration through the Implant Stability Quotient (ISQ) at 3- and 6-month post-surgery.

Statistical Analysis and Results: Group 1 (40 patients) underwent immediate implant placement with bone grafting, while Group 2 (40 patients) received implants without grafting. After three months, the Implant Stability Quotient (ISQ) was assessed on four surfaces of the implants for each group. Group 1 showed ISQ values of 75.5 ± 5 Ncm (buccal), 79.8 ± 4 Ncm (lingual), 80.4 ± 3 Ncm (mesial), and 69.5 ± 4 Ncm (distal). Conversely, Group 2 had lower ISQ values: 47.6 ± 3 Ncm (buccal), 45.5 ± 3 Ncm (lingual), 43.7 ± 2 Ncm (mesial), and 37.5 ± 3 Ncm (distal). After six months, Group 1's results improved to 77.6 ± 6 Ncm (buccal), 80.5 ± 3 Ncm (lingual), 82.4 ± 4 Ncm (mesial), and 72.5 ± 6 Ncm (distal). In comparison, Group 2's ISQ values increased to 50.5 ± 2 Ncm (buccal), 49.3 ± 2 Ncm (lingual), 55.6 ± 3 Ncm (mesial), and 40.2 ± 2 Ncm (distal). The summarisation of these findings, employing one-way ANOVA for a comprehensive analysis of the effectiveness of immediate implant placement with and without bone grafting, contributes valuable insights for future clinical practice.

Conclusion: This study concluded that immediate implants with bone grafting led to better bone transformation and aesthetics. This technique effectively preserves jawbone shape and enhances long-term cosmetic outcomes.

Keywords: Bone Grafting, Dental Implants, Primary Stability, Immediate Implants

Introduction

A dental implant is a highly advanced dental device, typically crafted from biocompatible materials such as titanium or zirconia. The surgical procedure involves the insertion of the implant into the jawbone, where it serves as an artificial root for a missing tooth. This innovative solution provides a stable foundation for various custom-made dental restorations, including crowns, bridges, and dentures. By doing so, it not only facilitates effective chewing but also helps patients

regain their confidence in their smiles. When dental professionals opt for immediate implant placement, they perform the procedure right after tooth extraction, particularly in the maxillary anterior region, which is often referred to as the "smile zone" because of its visibility in the smile.^{1,2} In this technique, the implant is inserted directly into the socket created by the removed tooth, allowing for optimal integration with the surrounding bone and soft tissue. This immediate approach not only supports the

preservation of these critical structures but also requires a high level of precision in three-dimensional (3D) positioning to ensure that the implant settles correctly within the jawbone. In many cases, a bone graft is employed to augment the structural integrity and aesthetic appeal of the area where the implant is placed.^{3,4} Bone grafting involves transplanting bone material either from another site in the patient's body or from a donor source to fill in any deficits or gaps in the jawbone. The concept of primary stability is essential in ensuring the long-term success of dental implants. Primary stability is characterized by a strong, secure fit that occurs between the implant and the surrounding bone.^{5,6} This is akin to how a screw tightly secures itself within a wooden surface. Achieving excellent primary stability immediately after the implant's placement is primarily dependent on mechanical friction essentially the resistance arising when two surfaces are pressed together. In situations where a bone graft is utilized, the stability of dental implants can be remarkably enhanced.^{7,8} The graft material fills in the gaps and voids that may exist between the implant and the surrounding jawbone, effectively creating a robust and secure foundation that is vital for the healing process that follows the procedure. This is particularly important in the maxillary anterior region the area at the front of the upper jaw where the outer bone wall, known as the buccal plate, is often thinner and more delicate than in other areas of the jaw.^{9,10} When there are gaps exceeding 2 mm in this fragile region, which are frequently referred to as "jumping distances," the body faces challenges in its natural ability to regenerate new bone effectively. By carefully and strategically placing a bone graft in these specific instances, the stability of the dental implant is significantly improved. This added stability not only mitigates the risk of bone loss but also creates an optimal environment for new bone growth, which is crucial for the overall success of the dental implant procedure over time.^{11,12} Thus, meticulous planning and execution in the choice and application of implants and bone grafts are essential for achieving the best possible results for patients who are seeking restorative dental solutions. By ensuring that these components work harmoniously, dental professionals can greatly enhance the likelihood of positive outcomes, leading to healthier and more functional smiles for their patients.¹³ This study aims to assess the effects of bone grafting on implants' primary stability and associated bony transformation, and immediate implants placed in the maxillary anterior region.

Materials and Methods

This comprehensive study focused on a cohort of 90 patients, all aged between 25 and 50 years, who presented with decayed teeth and sought natural-looking replacements for their dental issues.

Following meticulous clinical examinations, it was found that 80 of these patients showed a keen interest in receiving dental implants along with implant-supported prostheses. The study employed stringent inclusion criteria, ensuring that all participants were over 18 years of age and had a single, non-restorable tooth specifically located in the maxillary anterior region, which includes the incisors and canines. These teeth were deemed necessary for extraction in order to facilitate the placement of implants. Furthermore, candidates were required to possess intact or largely preserved extraction socket walls and a substantial amount of healthy native bone—specifically, a minimum of 3 to 4 mm below the tooth root—to ensure both the primary stability of the implant and successful integration into the jawbone. Participants were also required to demonstrate optimal systemic and oral health, as these factors are essential for the healing process following dental procedures. The exclusion criteria were thorough and included factors such as heavy smoking (defined as consumption of more than 10 cigarettes per day), the presence of acute infections, and uncontrolled systemic diseases that might complicate or hinder the healing process. Additionally, individuals with significant bone defects or certain medical histories, including previous head and neck radiation therapy or ongoing treatment with intravenous bisphosphonates, were also excluded from participation. All patients provided informed consent to partake in the study, which adhered to a specific protocol involving the extraction of the affected tooth, followed by precise implant placement. During the extraction procedure, considerable care was taken to remove the damaged tooth while preserving the buccal bone plate, a critical factor for ensuring the success of the subsequent implant. Patients received infraorbital local anaesthesia to minimize discomfort during the surgery. After the careful extraction of the tooth, the dental implant was systematically placed into the prepared socket, achieving robust mechanical fixation within the healthy native bone. In the instances where bone augmentation was deemed necessary, a hydroxyapatite bone graft was employed. This graft filled any gaps that existed between the implant and the extraction socket walls and was combined with a collagen membrane to provide additional protection and support for the healing process. The 80 patients who expressed interest in the procedure were divided into two distinct groups for comparative analysis. Group 1 consisted of 40 patients who underwent immediate implant placement alongside bone grafting procedures, while Group 2 included 40 patients who received immediate implant placement without the aid of bone grafting. The effectiveness of these surgical methods was assessed by measuring primary stability and the process of osseointegration. This evaluation utilized the Implant Stability Quotient (ISQ), which was determined through Resonance Frequency

Analysis (RFA) conducted at 3 and 6 months post-surgery using Cone Beam Computed Tomography (CBCT) imaging. Following a comprehensive six-month healing period, the placement of the implant-supported prostheses was performed. The overarching of this study was to meticulously assess the impact of bone grafting on the primary stability of dental implants and to observe the associated bony transformation that occurs when immediate implants are placed in the maxillary anterior region.

Statistical Analysis

In this research study, all statistical analyses were conducted utilizing SPSS version 31.0, which is a comprehensive software package for statistical computing and data analysis within the social sciences. This versatile tool provides a wide array of functions, including advanced statistical methods, data management capabilities, allowing for in-depth exploration and interpretation of the data collected. The choice of SPSS was made to ensure rigorous and reliable analysis, enabling the researchers to derive insights and conclusions from study's findings.

Results

This comprehensive study focuses on a cohort of 80 patients, consisting of both males and females aged between 25 to 50 years. A detailed statistical analysis of the age and gender distribution of these patients is presented in Table 1, providing critical insights into the demographics of the participants. Additionally, Graph 1 visually illustrates the demographic distribution, highlighting essential characteristics of the patient population. The study participants were motivated individuals who expressed a clear interest in undergoing dental procedures; they were systematically divided into two distinct groups for the purpose of conducting a comparative analysis. Group 1 consisted of 40 patients who underwent immediate implant placement in conjunction with bone grafting procedures. In contrast, Group 2, which also included 40 patients, received immediate implant placement without the enhancement of bone grafting techniques. Table 2 outlines the classification of these groups with precise categorizations, ensuring clarity in the grouping of the participants. Subsequent evaluations focused on Group 1 (N=40), where the patients received immediate implant placement supplemented by bone grafting. After a follow-up period of three months, the Implant Stability Quotient (ISQ) was

methodically assessed on all four surfaces of the implants—buccal, lingual, mesial, and distal. The statistical evaluation relied on the Pearson Chi-Square test, which yielded the following detailed measurements for Group 1: the buccal surface exhibited an ISQ of 75.5 ± 5 Ncm, the lingual surface measured 79.8 ± 4 Ncm, the mesial surface showed an ISQ of 80.4 ± 3 Ncm, and the distal surface recorded a lower stability at 69.5 ± 4 Ncm. These findings are meticulously presented in Table 3. In the same vein, Table 4 delineates the results for Group 2 (N=40), where patients underwent immediate implant placement without the benefit of bone grafting. The ISQ measurements for Group 2, assessed after an identical three-month period, revealed notably lower values on all implant surfaces. The buccal surface registered an ISQ of 47.6 ± 3 Ncm, the lingual surface recorded 45.5 ± 3 Ncm, the mesial surface presented an ISQ of 43.7 ± 2 Ncm, and the distal surface showed a further decrease to 37.5 ± 3 Ncm. Further analysis is provided in Table 5, focusing on Group 1 (N=40) patients after an extended six-month duration following their immediate implant placement and bone grafting procedures. The ISQ was diligently re-evaluated across all four surfaces, with statistical assessment conducted via the Pearson Chi-Square test once again. The results illustrated an increase in stability, with the buccal surface showing an ISQ of 77.6 ± 6 Ncm, the lingual surface measuring 80.5 ± 3 Ncm, the mesial surface achieving a higher ISQ of 82.4 ± 4 Ncm, and the distal surface measuring 72.5 ± 6 Ncm. Finally, Table 6 presents the results for Group 2 (N=40) patients after a six-month timeframe following immediate implant placement without bone grafting. The ISQ assessments across the four surfaces indicated a distinct pattern: the buccal surface achieved an ISQ of 50.5 ± 2 Ncm, the lingual surface was registered at 49.3 ± 2 Ncm, the mesial surface at 55.6 ± 3 Ncm, and the distal surface at a lower measurement of 40.2 ± 2 Ncm. To synthesize all findings, Table 7 summarizes the estimation results across all studied groups, employing one-way ANOVA to facilitate a robust analysis of the data. This thorough and multifaceted approach provides an in-depth understanding of the comparative effectiveness of immediate implant placement with and without the application of bone grafting procedures in the examined patient population, paving the way for future studies and clinical practices.

Table 1: Age & Gender based Statistical Description of Contributing Patients

Age Group (Yrs)	Male	Female	Total	P value
25-30	5	6	11	0.03
31-35	7	8	15	0.40
36-40	9	6	15	0.02*
41-45	9	7	16	0.60
46-50	14	9	23	0.50
Total	44	36	80	*Significant
*p<0.05 significant				

Graph 1: Patients Demographic Distribution and Associated Details

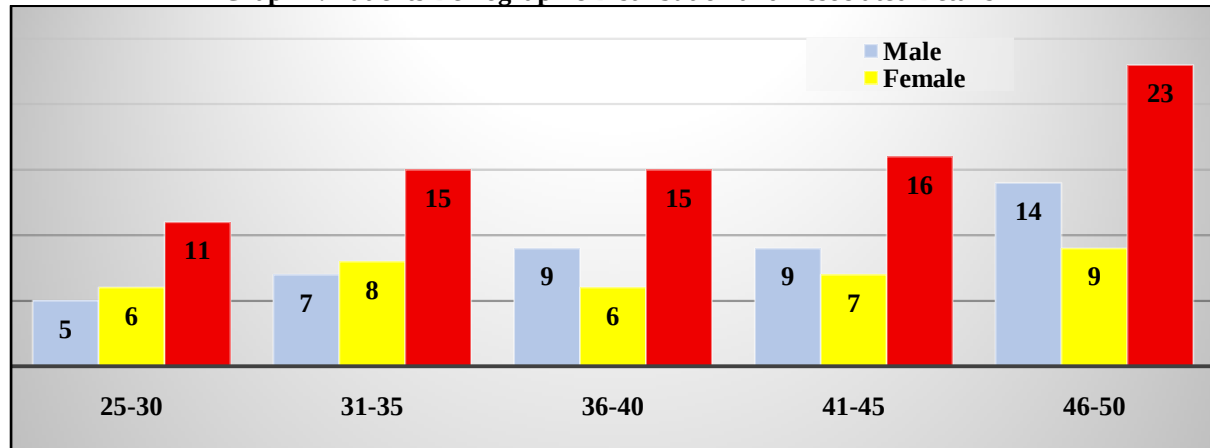


Table 2: The Classification of the Groups into Two Distinct Categories

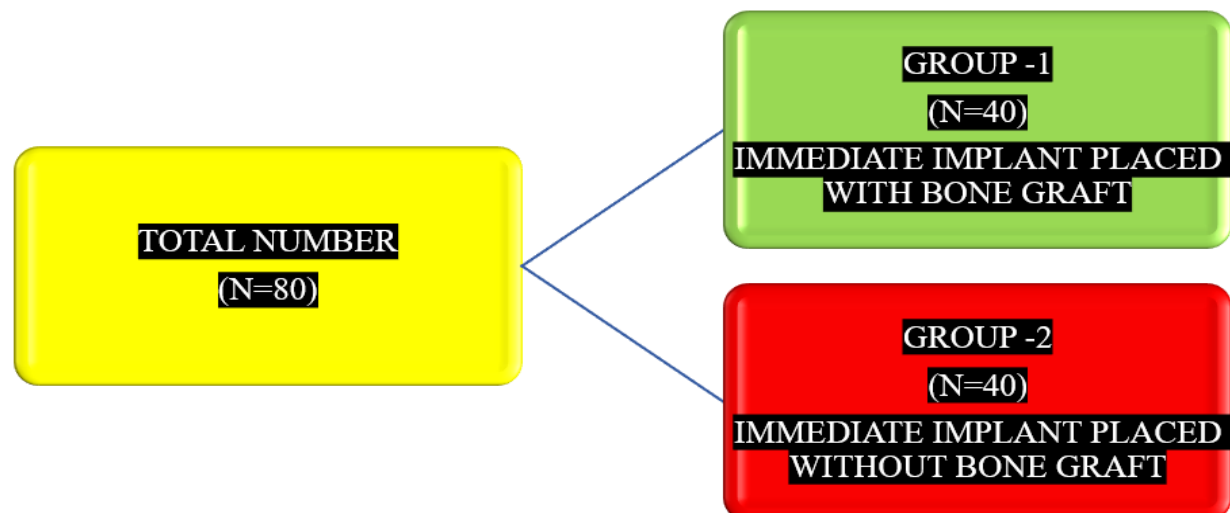


Table 3: Group 1 (N= 40) patients who underwent immediate implant placement and bone grafting procedures. The Implant Stability Quotient (ISQ) was assessed on all four surfaces after 3 months. Statistical assessment was conducted using the Pearson Chi-Square test

SURFACES	ISQ value	Stat. Mean	Std. Dev.	Std. Error	95% CI	Pearson Chi-Square Value	df	p value
Buccal	75.5±5Ncm	2.26	2.087	2.075	2.16	2.383	1.01	0.01*
Lingual	79.8±4Ncm	2.89	1.065	1.242	2.76	2.086	1.03	0.60
Mesial	80.4±3Ncm	1.12	0.273	0.029	1.08	1.098	1.02	0.06
Distal	69.5±4Ncm	1.09	0.034	0.065	1.01	1.036	1.04	0.76
*p<0.05 significant								

Table 4: Group 2 (N= 40) patients who underwent immediate implant placement without bone grafting procedures. The Implant Stability Quotient (ISQ) was assessed on all four surfaces after 3 months. Statistical assessment was conducted using Pearson Chi-Square test

SURFACES	ISQ value	Stat. Mean	Std. Dev.	Std. Error	95% CI	Pearson Chi-Square Value	df	p value
Buccal	47.6±3Ncm	2.09	1.054	2.007	2.09	2.071	1.01	0.08
Lingual	45.5±3Ncm	2.05	1.034	1.095	2.06	2.004	1.02	0.70
Mesial	43.7±2Ncm	1.06	0.212	0.0984	1.05	1.003	1.01	0.05
Distal	37.5±3Ncm	1.04	0.006	0.074	1.01	1.093	1.01	0.07
*p<0.05 significant								

Table 5: Group 1 (N= 40) patients who underwent immediate implant placement and bone grafting procedures. The Implant Stability Quotient (ISQ) was assessed on all four surfaces after 6 months. Statistical assessment was conducted using the Pearson Chi-Square test

SURFACES	ISQ value	Stat. Mean	Std. Dev.	Std. Error	95% CI	Pearson Chi-Square Value	df	p value
Buccal	77.6±6Ncm	2.32	2.098	2.078	2.20	2.385	1.03	0.70
Lingual	80.5±3Ncm	2.93	1.076	1.250	2.79	2.089	1.05	0.02*
Mesial	82.4±4Ncm	1.18	0.056	0.032	1.10	1.112	1.05	0.98
Distal	72.5±6Ncm	1.14	0.076	0.069	1.02	1.052	1.02	0.80
*p<0.05 significant								

Table 6: Group 2 (N= 40) patients who underwent immediate implant placement without bone grafting procedures. The Implant Stability Quotient (ISQ) was assessed on all four surfaces after 3 months. Statistical assessment was conducted using Pearson Chi-Square test

SURFACES	ISQ value	Stat. Mean	Std. Dev.	Std. Error	95% CI	Pearson Chi-Square Value	df	p value
Buccal	50.5±2Ncm	2.10	2.060	2.085	2.10	2.067	1.02	0.10
Lingual	49.3±2Ncm	2.07	2.039	1.096	2.07	2.030	1.0	0.60
Mesial	55.6±3Ncm	1.09	0.222	0.0784	1.04	1.089	1.0	0.04*
Distal	40.2±2Ncm	1.06	0.098	0.084	1.02	1.098	1.02	0.06
*p<0.05 significant								

Table 7: Estimation amongst all studied groups using one-way ANOVA

Variables	Degree of Freedom	Sum of Squares Σ	Mean Sum of Squares $m\Sigma$	F	Level of Sig. (p)
Between Groups	9	2.890	2.432	1.4	0.02*
Within Groups	26	2.322	2.054		—
Cumulative	492.16	2.933	*p<0.05 significant		

Discussion

Carvalho PHA et al reviewed in their study that dental implants represent a highly effective and permanent solution for individuals with missing tooth roots. These implants are surgically embedded into the jawbone, functioning as robust anchors that support custom-designed artificial teeth. One of the key advantages of dental implants over traditional dental solutions, such as bridges or dentures, is their ability to closely mimic the look and functionality of natural teeth. This not only enhances the patient's smile but also eliminates concerns about slippage or damage to adjacent teeth that can occur with removable prosthetics.^{14,15} Carvalho PHA et al showed in their study a particularly promising technique in the field of implant dentistry is known as immediate implant placement (IIP), which is often employed in the maxillary anterior region, the front part of the mouth. Clinical studies have indicated that when performed with stringent adherence to 3D positioning protocols and careful case selection, the survival rate of these implants can reach an impressive 98.4%. This approach not only increases the efficiency of treatment but also plays a crucial role in preserving the integrity of the extraction socket, which is vital for

both function and aesthetics.^{16,17} Donker VJJ et al included in their study that however, it is essential that surgeons execute this technique with precision, especially in the aesthetic zone where even small discrepancies can significantly impact visual outcomes. Bone grafting is another critical component in the successful placement of dental implants, particularly in scenarios where there is insufficient bone volume or where teeth have recently been extracted. The primary stability of an implant defined as the initial support it receives to prevent any movements that could jeopardize osseointegration is heavily influenced by the use of bone grafts. Various mechanisms contribute to the enhancement of primary stability through bone grafting.^{18,19} Atieh MA et al included in their study that for instance, these grafts fill in gaps, commonly referred to as "jumping gaps," that may exist between the implant and the walls of the socket. By doing so, they provide crucial lateral resistance that is necessary for the implant's success. Additionally, the application of dense graft materials can significantly enhance cortical engagement, which is vital for reconstructing thin or weak bone walls.^{20,21} Schiegnitz E et al reviewed in their study that a secure fit around the implant threads ensures that even in areas where the bone is thin, the implant remains

stable and minimizes the risk of complications associated with gap issues. Specifically, if a gap exceeds 2 mm, a graft is essential, as it acts like a wedge, substantially improving stability and thereby increasing the likelihood of successful integration. The healing phase following implant placement is characterized by a process known as "bony transformation." During this period, the graft material acts as a scaffold, facilitating the growth of new bone around the implant.^{22,23} Tokuc B et al reviewed in their study that over time, the graft material gradually dissolves, allowing the jawbone to replace it with living bone tissue. This natural replacement process is critical, as it helps to minimize the shrinkage of the socket that could potentially lead to gum recession. Given the visibility of anterior teeth, even slight shifts in the levels of bone or gum tissue can have a pronounced impact on a person's smile. Consequently, utilizing a bone graft not only promotes optimal implant-to-bone contact but also supports robust osseointegration. Furthermore, it aids in stabilizing the surrounding gum tissue, ultimately contributing to a more aesthetically pleasing and natural-looking outcome that enhances both functionality and confidence in patients.^{24,25}

Conclusion

The authors conducted a thorough investigation into the impact of bone grafting on the primary stability of dental implants and the resulting changes in surrounding bone structure. Focusing on immediate implants placed in the maxillary anterior region, their findings concluded that such procedures, particularly when combined with bone grafting, yield superior outcomes in terms of both bone transformation and aesthetic appearance. Bone grafting serves as a crucial technique during the immediate placement of implants in the anterior maxilla, effectively addressing any gaps that may arise. This strategy not only helps maintain the natural contour of the jawbone but also enhances the long-term cosmetic results for patients. However, the authors note that further studies are necessary to deepen the understanding of these findings and to explore additional implications for future dental practices..

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