Survival and marginal bone loss of dental implants placed in sites of previously failed implants: A retrospective study of impacting risk factors

A Thesis

Presented to the Faculty of Tufts University School of Dental Medicine

in Partial Fulfilment of the Requirements for the Degree of

Master of Science in Dental Research

Presented by

Reema Alnuaimi

April 2025

Tufts University School of Dental Medicine

Department of Periodontology

THESIS COMMITTEE MEMBERS

Principal Investigator

Natalie Jeong, DMD, MA

Chair of Department, Professor

Department of Periodontology,

Tufts University School of Dental Medicine

Co-Investigators

Andreas Paraschis DDS, Dr. Odont, FICD

Adjunct Assistant Professor

Department of Periodontology,

Tufts University School of Dental Medicine

Lin-Hsin Chuang, DDS, MS

Assistant Professor

Department of Periodontology,

Tufts University School of Dental Medicine

Zuhair Natto, BDS, MS, MPH, DrPH

Adjunct Assistant Professor

Department of Periodontology,

Tufts University School of Dental Medicine

Nadim Karimbux, DMD, MMSc

Dean, Professor

Department of Periodontology,

Tufts University School of Dental Medicine

ABSTRACT

Background

Implant Survival refers to the continued presence of an implant in the oral cavity. While dental implants generally have a high long-term survival rate, implant failure remains a clinical reality. When an implant fails and requires removal, replacement is often the preferred approach. Previous studies have reported lower survival rates for implants placed in sites of previously failed implants compared to initial placements.

Aim & Hypothesis

This retrospective radiographic study aimed to assess the survival rate and marginal bone loss (MBL) of implants placed in failed sites and to compare it with implants initially integrated. We hypothesize that survival rate and early MBL are similar between implants placed in pristine bone (first attempt) in comparison to implants placed in previously early and late implant failed sites.

Materials and Methods

Implants placed in previously failed sites from January 1, 2014, to January 1, 2024, were included. Implant survival and MBL for both replacement and initially integrated implants were collected. Survival was defined as the presence of the implant, and MBL was measured on radiographs by a calibrated examiner, accounting for radiographic distortion.

Results

A total of 183 replacement implants were analyzed, with a survival rate of 90.16% over a mean follow-up period of 30.81 ± 27.70 months and a mean time to implant failure of 21.66 ± 27.81 months with 9 of the 18 failures occurring within six months. Radiographs one-year post-placement were available for 31 replacement implants with a mean MBL of 1.68 ± 0.98 mm at the deepest site, and 54.8% of sites with more than 2 mm of MBL. There was no significant difference in mean MBL between implants replaced following early versus late failures ($p = 0.786$) nor in the percentage of sites with more than 2 mm of bone loss (55.0% vs. 54.5%, $p = 0.981$). In 19 subjects with both replacement and initial implants, no significant difference in MBL was found (1.70 ± 0.83 mm and 1.81 ± 0.98 mm, respectively, $p = 0.657$) between initially placed or replaced implants.

Conclusions

The survival rate of implants placed in previously failed sites was 90.16%, comparable to rates reported for initial implants. Most implant failures occurred within six months of replacement. These findings suggest implants in previously failed sites can achieve survival rates equivalent to initially placed implants.

DEDICATION

This master's thesis – or may I say, this beautiful journey – is dedicated to a previous version of myself, who dared to believe in a nearly impossible dream. And to all the mentors who supported me along the way.

"Hear the music beneath the noise "

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

MBL – Marginal Bone Loss

ICOI – International Congress of Oral Implantologists

GBR – Guided Bone Regeneration

RI – Replaced Implants

RC – Retrospective Cohort Study

PC – Prospective Case Series Study

SLA – Sandblasted, Large-grit, Acid-etched

FDP – Fixed Partial Denture

ICC – Intraclass Correlation Coefficient

IRB – International Review Board

SD – Standard Deviation

CI – Confidence Interval

SAS - Statistical Analysis System (SAS Institute, Cary, NC)

NA – Not Available / Not Applicable

T1 –Implant re-placement

T2 – Healing abutment connection

T3 – Prosthesis insertion or within 2 months maximum after prosthesis insertion

T4 – At least 1 year after loading (prosthesis insertion)

T5 – Most recent available radiograph

D6100 – CDT Code for Implant Removal

LIST OF SYMBOLS

±: plus-minus

%: percent

>: greater than

<: less than

≥: greater than or equal to

≤: less than or equal to

=: equals

α: alpha

p: p-value

B: regression coefficient

t: t-statistic

Survival and marginal bone loss of dental implants placed in sites of previously failed implants: A retrospective study of impacting risk factors

Introduction

Implant survival refers to the continued presence of a dental implant in the oral cavity. The International Congress of Oral Implantologists (ICOI) Pisa Consensus Conference [(1)] has divided implant survival into two categories: satisfactory survival and compromised survival. Satisfactory survival describes an implant with less-than-ideal conditions that do not require clinical management, including absence of pain on function, 2-4 mm of radiographic bone loss, and absence of mobility or history of exudate. In contrast, compromised survival describes implants with less-than-ideal conditions that require clinical treatment to reduce the risk of implant failure. This case definition usually entails the following conditions: probing depth > 7 mm, radiographic bone loss > 4 mm, absence of mobility, history of exudate, and sensitivity on function.

Albrektsson et al. first outlined implant success criteria in 1986 based on marginal bone loss (MBL) [(2)]. Current definitions expanded on this concept to describe implants with ideal clinical conditions that have served in the mouth for at least 12 months with a prosthetic abutment. Successful implants present with less than 2 mm of radiographic bone loss from the initial surgery and absence of pain, tenderness, mobility, or exudate. Early implant success describes implants that satisfy those conditions during their first 3 years of function in the oral cavity, intermediate success describes implants that maintain ideal health conditions for up to seven years, and long-term success describes implants maintained for more than seven years [(1)]. In the systematic review of Pjetursson et al, the survival rate reported in older publications ranged from 77.4 - 95.2%, with an improvement in newly published studies, especially for screw-retained prostheses, with a five-year survival rate of 96.8% [(3)]. Staedt et al. investigated risk factors associated with early and late implant failure in a retrospective study with 9080 implants that were followed up for five years and reported implant failure in a total of 351 implants, among which the early implant failure rate was 83.48 %. The late dental implant failure rate was 16.52%, and correlated with maxillary implants in older patients, whereas early failure occurred significantly more often in mandibular posterior areas in younger patients (4).

Several local and systemic factors influence both the survival and success rates of dental implants, including smoking, diabetes, previous history of periodontal disease, plaque control, bone quality, loading protocol, and clinician skills. There is currently little evidence on the potential influence of common systemic diseases on implant survival, with only a limited number of randomized controlled trials (5). Zupnik et al. found that diabetes, sex, and implant type produced the strongest correlation with implant failure, reporting an odds ratio of 2.59 for diabetes, 7.84 for implant type, and 4.01 for males (6).

Despite the high rates of reported long-term implant survival, implant failure is still a possibility. According to Esposito et al. (7), implant failure can be classified into biological failure, mechanical failure, iatrogenic failure, and inadequate adaptation. Biological failure further falls into early or late failure depending on the timing of occurrence, with early failures describing cases that failed to achieve osseointegration because of interference with initial bone healing, while late failures describe cases that failed to preserve the achieved osseointegration. In recent studies, the prevalence of implant failures is higher in the early phase than in the late phase, regardless of loading time (8).

The literature describes various methods for the removal of failed dental implants. Trephine burs have been the standard approach for the removal of failed dental implants, with a cutting speed ranging between 1200 and 1500 rpm with maximum water irrigation [(9)]. However, these are an option only if no less invasive alternative methods are applicable. Piezo surgery, in contrast, offers a less invasive method for implant removal and allows for a more precise cutting method that can preserve bone and protect adjacent anatomic structures from injury. Laser surgery offers another less traumatic alternative for implant removal. Hajji et al. reported that laser surgery removes almost half of the bone that is usually removed by trephine burs [(10)]. Tooth extraction instruments (elevators or forceps) remove implants with a high degree of mobility and little implant-to-bone contact. Froum et al [(9)] reported that the counter-torque ratchet technique is the least traumatic approach for the retrieval of failed implants. This technique has two different modalities. The first one loosens the fixture by applying counterclockwise torque, and the second modality is the reverse screw technique usually used for the removal of damaged or fractured implants [(11)].

Following failure and removal, implant replacement may be the only treatment that allows fixed rehabilitation and is the therapy of choice owing to superior occlusal stability, masticatory efficiency, and personal self-esteem without damaging adjacent teeth.

Failed implant sites present a challenging therapeutic dilemma to the clinician because marginal bone resorption usually further reduces the alveolar bone in these sites, resulting in greater difficulties in integrating another implant. It seems that attempts to replace implants in previously failed sites have a lower success rate than first-time operations. Table 1 [(16-25)] summarizes the studies investigating the survival and success rates of dental implants that replaced previously failed implants, as well as the implant characteristics, reasons, and timing of failure of the second implant. Implants placed in sites with a history of implant failures had a weighted survival rate of 88.7% (95% CI 81.7–93.3) [12] with a mean survival rate of 86.3%, with follow-up ranging from less than 1 to over 5 years [13].

Most clinical studies evaluated implants replacing a previously failed site in terms of survival rate (Table 1). However, Oh et al. [14] conducted a retrospective cohort study to compare replaced implants (RI) to pristine implants based on MBL. This was the first study reporting early MBL associated with implants placed at failed sites. Early MBL stability is essential for long-term implant survival and helps in predicting the long-term prognosis of implants. RI showed lower MBL on the distal side because RI was unintentionally placed in a more supra-crestal position on the distal side. All other sides showed no significant difference between the two groups, leading to the conclusion that replaced implants and pristine implants exhibit the same pattern of early MBL.

Several factors may impact the survival of implants replaced following failures, such as age, smoking status, replaced implant surface, implant dimensions, oral hygiene status and maintenance, bone quality, and use of regenerative procedures. Lee et al. [15] reported that being male, history of periodontitis, guided bone regeneration (GBR) at first implant placement, and non-GBR at implant replacement were risk factors affecting the survival of replaced implants. Most studies investigating the survival rate of implants placed at sites with a history of implant failure are retrospective cohort studies with limited numbers of patients and implants, and describe only the survival rates of implants. Only one study [14] evaluated early MBL of surviving and restored implants placed at previously failed sites compared to that of implants initially integrated and restored within the same subjects, and only one study [15] investigated the risk factors affecting the survival of implants replaced following failure.

Aim

The primary aim of this study is to examine the survival of dental implants placed in previously early and late failed implant sites. The secondary aims are (1) to compare early MBL of surviving and restored implants placed at previously failed sites to that of implants initially integrated and restored within the same subjects; (2) to explore the possible subject and implant level-related factors that might affect the survival and early MBL of the replacement implants; and (3) to record late MBL of the replacement implants.

Table (1) – Review of studies investigating survival rates of dental implants that replaced a previously failed implant.

RC = retrospective cohort study; PC = prospective case series study: NR= not reported

Authors and year	Study design	Patients and implants (n) (initial placement)	Timing of initial failure (months)	Failure reason (n) (%)	Survival of initial implants (%)	Patients and implants with replacement (n)	Time interval between removal and second placement (months)	Implant characteristics at replacement	Follow up time of replaced implants (months)	Patients and implants with implant replacement failure (n)	Survival and success rates of replaced implants (%)	Timing of secondary failure (months)	Failure reason
Chrcanovic et al (2017) (16)	RC	2,67 patients 10,096 implants	23.9 ± 32.0	Lack/loss of osseo-integration: 602 (93.8%) Fracture: 40 (6.2%)	93,6%	98 patients 159 implants	13.5 ± 17.3 After removal	Rough (including sandblasted, acid-etched, sandblasted + acid-etched) or machined surface	98.8 ± 84.6	42 implants	73.6% survival rate Success rate NR	29.2 ± 31.3	NR
Manor et al (2009) (17)	RC	NR	NR	Lack of osseo-integration: 35 (87.5%) Early failure: 34 (84%) Late failure: 6 (61%)	NR	40 patients 40 implants	4.7 After removal	Rough surface (sandblasted and acid etched with or without hydroxyapatite)	63	0	100% Survival rate Success rate NR	-	-
Wang et al (2015) (18)	RC	6,456 patients 10,234 implants	NR	Early failure (100%)	99.02%	66 patients 67 implants	6.3 ± 3.1 after removal	Straumann SLA	69.4 ± 27.7	2 patients 2 implants	94.6% survival rate 90.6% success rate	One before prosthesis, One 20 months after loading	Peri-implantitis: 1 (50%) Unknown: 1 (50%) Early failure: 1 (50%) Late failure: 1 (50%)
He et al (2014) (19)	RC	NR	12.9 ± 15.9	NR	NR	12 patients 15 implants	6.8 ± 4.4 after removal	NR	33.5 ± 15.4	0	100% survival rate Success rate NR	-	-
Mardinger et al (2012) (20)	RC	NR	21.25 ± 3.4	Lack of osseo-integration: 54 (37.5%) Infection: 21 (14.6%) Overload: 24 (16.6%) Unknown: 45 (31.3%) Early failure: 94 (65%) Late Failure: 50 (35%)	NR	144 patients 144 implants	4.8 ± 5.45 after removal	NR	48 ± 1.27	11 patients 11 implants	93% survival rate Success rate NR	NR	Lack of osseo-integration: 2 (19%) Overload: 1 (9%) Unknown: 8 (72%) Early failure: 2 (18.2%) Late failure: 9 (81.8%)
Quaranta et al (2012) (21)	PC	NR	NR	Lack of osseo-integration, peri-implant-it is, mal-position	NR	10 patients 16 implants	NR	Winsix immediately loaded, platform-switched SLA	36	0	100% survival rate 93.75% success rate	-	-

				Early failure: 109 (100%)									
Kim et al (2010) (22)	RC	573 patients Implant NR	NR	Lack of osseo-inte-gration: 52 (86.7%) Inflamm-ation / infection: 6 (10%) Fixture fracture: 1 (1.7%) Malposition: 1 (1.7%) Early failure: 41 (68.3%) Late failure: 19 (31.7%)	NR	49 patients 60 implants	2.4 ± 3.06 after removal	NR	22.00 ± 14.56	7 implants	88.3% survival rate Success rate NR	NR	NR
Machtei et al (2008) (23)	RC	NR	8.9 ± 2.1	Lack of osseo-inte-gration: 59 (69.5%) Inflammation: 20 (23.2%) Prolonged pain: 6 (7.3%)	NR	56 patients 79 implants	6.75 ± 1.12 after removal	3i Zimmer Steri-Oss MIS	29.91 ± 2.01	13 implants	83.5% survival rate Success rate NR	NR	NR
Grossman and levin (2007) (24)	RC	1215 patients 1387 implants	5.9 ± 4.4	All during healing or early loading	93.1%	28 patients 31 implants	5.8 ± 5.2 after removal	3i Zimmer MIS	19.4 ± 11.4	8 patients 9 implants	71% survival rate 71% success rate	3.22 ± 2.31	NR
Alsaadi et al (2006) (25)	RC	578 patients Implant NR	NR	Lack of osseo-inte-gration: 58 (100%)	NR	41 patients 58 implants	4 - 6 After removal	Nobel machined (n=29) Nobel TiUnite (N=29)	NR	7 implants	87.9% Survival rate Success rate NR	11.43 ± 6.7	NR

I. Hypothesis

We hypothesize that survival rate and early MBL are similar between implants placed in pristine bone (first attempt) in comparison to implants placed in previously early and late implant failed sites.

Materials and Methods

This study is a retrospective study analyzing the survival rate of implants placed in previously early and late failed sites in the Department of Periodontology at Tufts University School of Dental Medicine from January 1, 2014, to January 1, 2024. The survival rate of replacement implants was determined using Axium records and radiographs. Survival Criteria were defined as simple implant present or absent. In addition to that, early MBL of surviving and restored implants placed at previously failed sites was compared to that of implants initially integrated and restored within the same subjects. Up to 400 records were reviewed for this study.

Radiographic analysis:

Periapical and bitewing radiographs of implants placed in previously early or late failed sites were reviewed in patients' Axium records.

The different time points when radiographic measurements were conducted are the following:

T1- Implant replacement

T2- Healing abutment connection

T3- Prosthesis insertion or within 2 months maximum after prosthesis insertion

T4- At least 1 year after loading (prosthesis insertion)

T5- Most recent available radiograph

The same time points were used for radiographic measurements of implants initially integrated and restored within the same subjects.

Early Marginal Bone loss (up to 1 year after loading or prosthesis insertion) was compared between implants placed in a previously failed site (test) and implants placed in pristine bone (control). Survival implant criteria were defined as a simple implant present or absent.

Linear bone measurements were made on the mesial and distal surfaces of each implant from reproducible reference points – the implant shoulder - to determine bone levels. A horizontal line was drawn through the shoulder of the implant, and the distance from this line to the first bone-to-implant contact was measured at the implant's mesial and distal sites. Radiographic bone level on periapical radiographs was determined after calculating the distortion rate of radiographs using the known length of the implant.

For bitewing radiographs, a line across three threads was drawn and measured, which was used for calculating the distortion rate based on the known distance between implant threads [(26)].

All measurements were made by a single investigator (RA) and verified by another investigator (LC). A previously calibrated investigator (AP) measured the MBL on 10 randomly selected radiographs and compared them to the measurements by the two investigators in the same radiographs. To test intra-investigator variability, the MBL on another 10 randomly selected radiographs was measured twice, within a 1-week interval. The inter-investigator variability of the two investigators was evaluated using the same radiographs. The statistical significance of the differences between measurements was assessed using the paired t-test. Pearson correlation coefficients and Intraclass correlation (ICC) were calculated to analyze the correlation between the sets of measurements.

Inclusion criteria

1. Single or multiple non-adjacent implants in the maxilla or mandible that were placed in previously early or late failed sites.
2. Single or multi-unit implant-supported restorations in patients with periapical and bitewing radiographs that permit analysis of MBL around replacement implants. For the primary analysis, radiographs at implant replacement, radiographic measurements at the time of prosthesis insertion or within a maximum period of 2 months after prosthesis insertion, at least 1 year after loading, and from the most recent radiograph on file were used, as derived from Axium records of each patient. All other radiographs available in Axium records between the above periods were also collected and recorded for use in a possible secondary analysis.

Exclusion criteria:

1. Replacement implants without any periapical or bitewing radiographs at implant replacement, prosthesis insertion, or within 2 months maximum after prosthesis insertion and at least one year after loading.
2. Replacement implants without implant-supported restoration within 12 months after implant placement.
3. Replacement implants with radiographs that do not permit analysis of MBL around implants (for instance, radiographs with a very high distortion or a poor diagnostic quality, or bitewing radiographs that do not capture the MBL).

Data collection from clinical records:

All available information from Axium patients' records regarding the subject- and failed implant-related factors, as well as replacement implant-related factors that could be possible risk indicators for survival and MBL of replacement implants, was collected.

Patient factors:

1. Gender
2. Age based on T1
3. Medical Status (diabetes, cardiovascular diseases, ..etc.) within 1 year of initial implant placement and re-placement time
4. Medications based on the most recent records of the patient within 1 year from T1 and T4
5. Smoking status based on the most recent records of the patient within 1 year from T1 and T4
6. Periodontal diagnosis (Gingivitis, Periodontitis, Treated Periodontitis) based on the most recent diagnosis on record of the patient within 1 year from T1 and T4

Failed Implant related factors (First implant):

1. Implant site (anterior or posterior, maxilla or mandible)
2. Implant system
3. Implant dimensions (Height and Diameter)
4. Guided bone regeneration at the time of implant placement
5. Date of implant placement and loading
6. Type of implant loading (immediate, early, or delayed)

7. Duration of loading
8. Type of restoration (Screw-retained, Cement-retained)
9. Type of failure (Early vs late)
10. Reason for failure (biological, mechanical, esthetic, or iatrogenic)
11. Date of removal
12. Way of removal
13. Guided bone regeneration and materials used at the failed site

Replacement Implant Related Factors:

1. Implant system
2. Implant dimensions (Height and Diameter)
3. Placement protocol (Guided vs non-guided)
4. Duration from first implant failure to placement of second implant (replacement implant)
5. Guided bone regeneration and materials used at the time of implant replacement
6. Date of implant replacement and loading
7. Type of implant loading (Immediate, early, or delayed)
8. Type of restoration (Screw-retained, cement-retained)
9. MBL one year after replacement
10. Failure of replacement implant (Date)
11. Survival of the replacement implant
12. Replacement of the second implant

Sample size calculation and statistical analysis:

Sample size was calculated using GPower (Version 3.1). Assuming that the effect size is 0.32 based on the average mean survival of study groups (94, 95, and 98%) which was calculated from several studies (16-25), and a type I error rate of 1%, a power of 80% would be achieved with n=47 subjects per group (141 total).

Mean and median or frequency and percentage were used. Chi square of Fischer exact test was used for categorical variables Independent or paired t test was used for continuous variables. The survival of implants or subsets of implants grouped based on early failed sites, late failed, and implants placed in pristine bone will be displayed by using Kaplan-Meier survival curves with clustering (frailty model analysis) if there were failures. The significance of differences between survival curves will be determined by using the log-rank test (α=.05). The total time at risk will be computed as the sum of the censoring and survival times for each group. Estimated risk will be computed as the number of failures in that group divided by the corresponding total time at risk. Multiple linear regression was used to identify the significant predictor variables. The analyses will be performed using the statistical program SAS Version 9.4 (SAS Institute, Cary, NC). P value less than 0.05 will be considered significant.

Results

IRB approval was obtained from the Tufts Health Sciences Institutional Review Board (IRB ID: STUDY00005101). A total of 419 patient records were retrieved from the Department of Periodontology at Tufts University School of Dental Medicine from January 1st, 2014, to January 1st, 2024. Axium records were identified using the implant removal code (D6100) following the study's inclusion criteria. Following the application of the exclusion criteria, 232 files were excluded due to the absence of attempts to replace the failed implants, resulting in 183 replacement implants available for analysis.

Patient Demographics

The average patient age at the time of implant replacement was 59.7 ± 11.2 years, ranging from 27 to 79 years. Gender distribution was balanced with males at 51.9% and females at 48.1% (Figure 1).

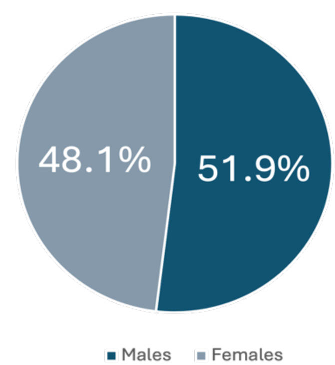

Figure (1): Gender Characteristics of Study Sample

Implant replacements were evenly distributed between the maxillary and mandibular arches, with 54.1% occurring in the maxilla and 45.9% in the mandible. The majority of implants were placed in the posterior region (74.9%), while only 25.1% were in the anterior region. The posterior region was the most commonly treated segment in both arches. However, the maxilla had a notably higher proportion of anterior implant placements compared to the mandible (34.3% vs. 14.3%, respectively). This difference resulted in a statistically significant correlation between the arch (maxilla or mandible) and implant placement segment (anterior or posterior), with a p-value of 0.0032. Table (2) describes patient demographics, Periodontal diagnosis, Smoking status, and distribution of initial implant location.

Table (2): Patient Demographics, Periodontal Diagnosis, Smoking Status, and Distribution of Initial Implant Location

Variable	Total N=183 (Frequency/%)	Survived N=165 (Frequency/%)	Failed N=18 (Frequency/%)	P Value
Age (mean ±SD)	59.7±11.2	60.0 ±11.0	57.0±12.5	0.276
Gender				0.244
Male	95(51.9)	88(53.3)	7(38.9)	
Female	88(48.1)	77(46.7)	11(61.1)	
Periodontal diagnosis				0.611
Gingivitis	32 (17.5)	29 (17.6)	3 (16.7)	
Periodontitis	123 (67.2)	112 (67.9)	11 (61.1)	
Treated Periodontitis	24 (13.1)	20 (12.1)	4 (22.2)	
First presented as edentulous	4(2.2)	4(2.4)		
Smoking Status				0.304
None	127(69.4)	113(68.5)	14(77.8)	
Current	22(12.0)	19(11.5)	3(16.7)	
Past	34(18.6)	33(20.0)	1(5.6)	
Arch				0.713
Maxilla	99 (54.1)	90 (54.5)	9 (50.0)	
Mandible	84 (45.9)	75 (45.5)	9 (50.0)	
Segment				0.399
Anterior teeth	46 (25.1)	40 (24.2)	6 (33.3)	
Posterior teeth	137 (74.9)	125 (75.8)	12 (66.7)	

*P value < 0.05

Medical and Periodontal Conditions

Cardiovascular conditions were the most prevalent, affecting 37.2% of the study population. The most frequently documented cardiovascular diagnosis was hypertension, reported in 31.7% of cases. Metabolic disorders appeared in 23% of patients, with diabetes being the most common, affecting 13.1% of subjects. Mental health conditions were present in 18.6% of patients, followed by a history of cancer at 16.4%. Gastrointestinal conditions were present in 9.3% of the cohort, while endocrine disorders were present in 8.2%. Respiratory conditions affected 7.7% of patients, with asthma representing the most common diagnosis within this group. Infectious diseases were reported in 3.3% of patients, autoimmune conditions in 2.7%, and both neurological and musculoskeletal disorders in 2.2% of the sample. Alcohol and opioid abuse disorders were the least prevalent, reported in 1.6% of patients. Overall, 26.2% of individuals were classified as medically healthy (Figure 2).

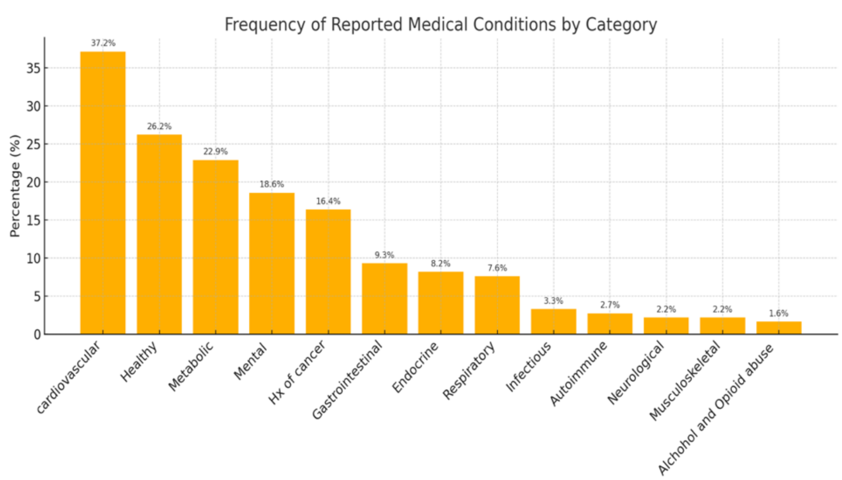

Figure (2): Frequency of Reported Medical Conditions

Most of the patients were non-smokers (69.4%), while past smokers comprised 18.6%, and current smokers comprised 12.0%. Regarding the use of systemic medication among study subjects, antihypertensive drugs were the most frequently prescribed, as reported by 35.0% of patients, with Lisinopril being the most common (45.3%). Lipid-lowering medications were used by 24.6% of patients, with Atorvastatin being the most commonly reported (48.9%). Antidepressants were prescribed in 21.3% of patients, with the majority taking Effexor. Anticoagulants were reported in 13.7%, and gastrointestinal medications in 9.3% of patients. Anti-diabetic medications were used by 6.6%, with Metformin being the most frequently reported agent. Corticosteroids and bisphosphonates were documented in 2.7% and 1.1% of patients, respectively. Finally, 33.3% of patients did not report taking any medications (Figure 3).

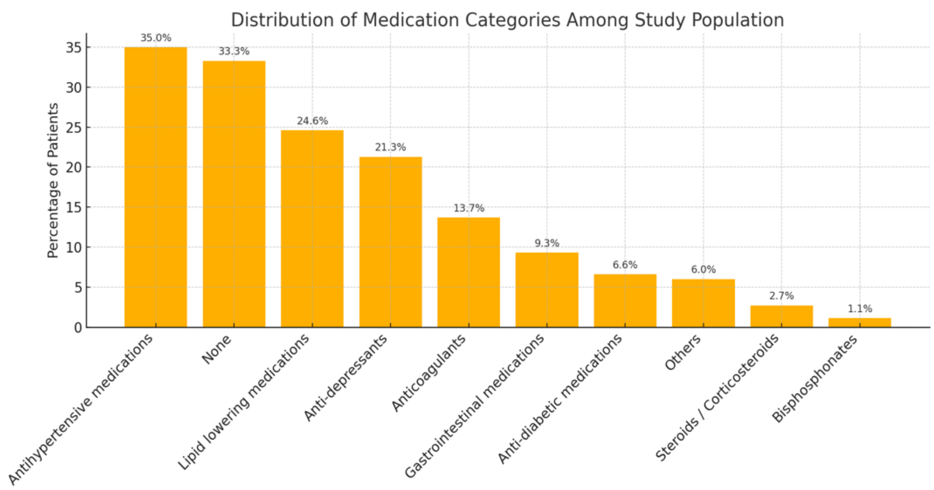

Figure (3): Distribution of Medication Categories Among Study Population

The most frequently reported periodontal diagnosis was active periodontitis (67.2%), followed by gingivitis (17.5%) and treated periodontitis (13.1%). 2.2% of patients initially presented to the clinic as edentulous, with no prior periodontal diagnosis documented in their records. Table (3) describes the medical status and medication intake in our patient population.

Table (3): Medical Status and Medication Intake.

Variable	Total N=183 (Frequency/%)	Survived N=165 (Frequency/%)	Failed N=18 (Frequency/%)	P Value
Medical status				
Healthy	48(26.2)	41(24.8)	7(38.9)	0.316
Respiratory	14(7.7)	13(7.9)	1(5.6)	0.725
cardiovascular	68(37.2)	61(37.0)	7(38.9)	0.873
History of Cancer	30(16.4)	28 (17.0)	2 (11.1)	0.524
Gastrointestinal	17 (9.3)	15 (9.1)	2 (11.1)	0.676
Neurological	4 (2.2)	2 (1.2)	2 (11.1)	0.049*
Endocrine	15 (8.2)	13 (7.9)	2 (11.1)	0.646
Metabolic	42(23.0)	40(24.2)	2(11.1)	0.254
Musculoskeletal	4(2.2)	4(2.4)	0	0.707
Autoimmune	5 (2.7)	5(3.0)	0	0.454
Mental	34(18.6)	32(19.4)	2(11.1)	0.533
Infectious	6(3.3)	5(3.0)	1(5.6)	0.468
Alcohol and Opioid Abuse	3(1.6)	0	3(16.7)	<0.001*
Medications				
None	61(33.3)	56(33.9)	5(27.8)	0.598
Anti-depressants	39(21.3)	36(21.8)	3(16.7)	0.768
Gastrointestinal Medications	17(9.3)	14(8.5)	3(16.7)	0.225
Anti-coagulants	25(13.7)	25(15.2)	0	0.139
Corticosteroids	5 (2.7)	5 (3.0)	0	0.454
Anti-hypertensive Medications	64 (35.0)	59 (35.8)	5 (27.8)	0.500
Lipid Lowering Medications	45(24.6)	41(24.8)	4(22.2)	0.806
Anti-diabetic Medications	12 (6.6)	11 (6.7)	1 (5.6)	0.857
Bisphosphonates	2 (1.1)	2 (1.2)	0	0.639

Others	11(6.0)	7(4.2)	4(22.2)	0.014*

Statistical comparison performed using Chi chi-square or Fischer exact test. *P value < 0.05

Implant Survival Analysis

Of 183 replacement implants 165 survived, yielding a survival rate of 90.2% during the follow-up period. The mean follow-up duration was 30.81 ± 27.70 months, and the mean time to implant failure was 21.66 ± 27.81 months. Of the 18 implants that failed (9.8%), nine occurred within the first six months, accounting for 50% of all failures. Of the 18 failures, eight implants underwent a second replacement attempt.

Of the 183 replacement implants, only 31 qualified for the analysis. Reasons for exclusion included: absence of periapical radiographs at one year post loading (37 files), restorations placed after more than 12 months following implant replacement (36 files), implants not restored (25 files), absence of restoration radiographs (22 files), absence of radiographs of implant replacement surgery (11 files), implant failure before restoration (12 implants), surgeries outside the inclusion timeframe (8 files), and poor-quality radiographs (1 file). Nineteen files were available for an intra-subject analysis, which compared early MBL of surviving and restored implants placed at previously failed sites to that of implants initially integrated and restored within the same subjects (Figure 4).

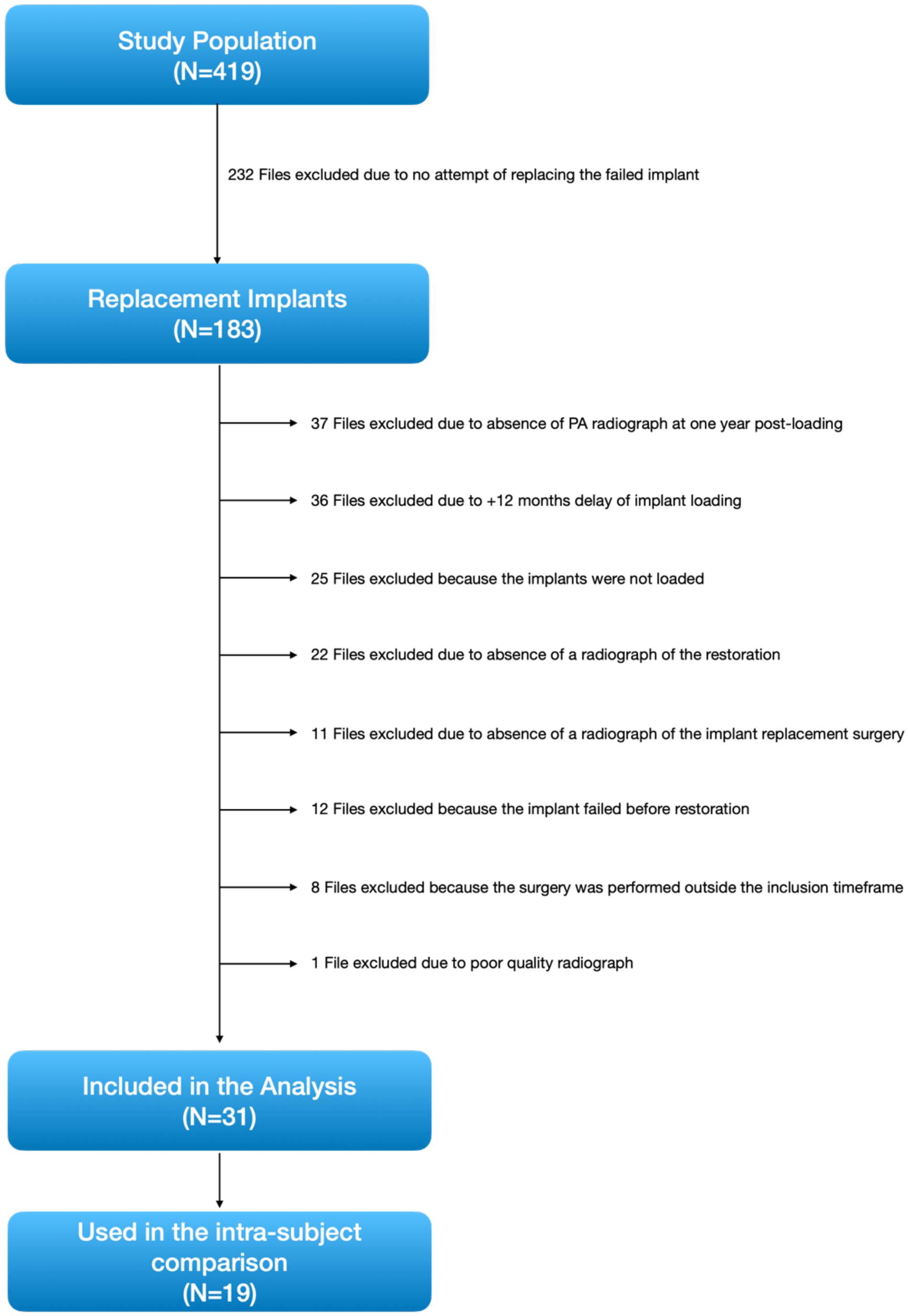

Figure (4): Flowchart of Study Population Selection and Inclusion Criteria

The analysis presented in Table (4) summarizes the clinical variables associated with early and late implant failures of the initial implant. A total of 31 implant cases were analyzed, comprising 20 cases (64.5%) of early failure (within the first six months) and 11 cases (35.5%) of late failure (after six months). Statistical significance was considered at a p-value < 0.05.

Table (4): Clinical Variables Associated with Early and Late Implant Failure of Initial Implant

Variable	Total N=31 (Frequency/%)	Early N=20 (Frequency/%)	Late N=11 (Frequency/%)	P Value
Implant system of initial implant				0.024*
Nobel	24 (77.4)	18 (90.0)	6 (54.5)	
Others	7 (22.6)	2 (10.0)	5 (45.5)	
Implant Diameter				0.030*
< 5.0mm	19(67.9)	16(80.0)	3(37.5)	
≥ 5.0mm	9(32.1)	4(20.0)	5(62.5)	
Implant Length				0.190
< 10.0mm	6(21.4)	3(15.0)	3(37.5)	
≥ 10.0mm	22(78.6)	17(85.0)	5(62.5)	
GBR at Initial Implant Placement				0.008*
Yes	4 (12.9)	2 (10.0)	2 (18.2)	
No	23(74.2)	18 (90.0)	5(45.5)	
Not mentioned	4 (12.9)	0	4 (36.4)	
Was the Implant loaded?				<0.001*
Yes	11 (35.5)	0 (0.0)	11 (100.0)	
Prosthesis Type				<0.001*
Screw retained	6 (19.4)	0 (0.0)	6 (54.5)	
Cement retained	3 (9.6)	0 (0.0)	3 (27.3)	
NA	22(71.0)	20(100.0)	2 (18.2)	
Crown/FPD				<0.001*
Crown	10 (32.3)	0 (0.0)	10 (90.9)	
FPD	1 (3.2)	0 (0.0)	1 (9.1)	
NA	20 (64.5)	20(100.0)	0 (0.0)	

Variable	Total N=31 (Frequency/%)	Early N=20 (Frequency/%)	Late N=11 (Frequency/%)	P Value
Reason for Initial Implant Failure				0.174
Biological	27(87.1)	17(85.0)	10(90.9)	
Mechanical	1(3.2)	0(0.0)	1(9.1)	
Iatrogenic	3(9.7)	3(15.0)	0(0.0)	
Way of Initial Implant Removal				0.487
Forceps	9(29.0)	4 (20.0)	5(45.0)	
Trephine	2(6.5)	1(5.0)	1(9.1)	
De-torque	11(35.5)	9(45.0)	2(18.2)	
Nobel retrieval kit	4(12.9)	3(15.0)	1(9.1)	
No mentioned	5(16.1)	3(15.0)	2(18.2)	
Was GBR Performed at Time of Implant Removal				0.282
Yes	21(67.7)	12(60.0)	9(81.8)	
No	8(25.8)	7(35.0)	1(9.1)	
Not mentioned	2(6.5)	1(5.0)	1(9.1)	
Type of Bone Graft				0.054
Autogenous	6 (19.4)	5(25.0)	1(9.1)	
Allograft	12 (38.7)	7(35.0)	5(45.5)	
Xenograft	3 (9.7)	0	3(27.3)	
NA	10(32.3)	8(40.0)	2(18.2)	
Type of Membrane				0.469
Resorbable	16 (51.6)	10(50.0)	6(54.5)	
Non-resorbable	3 (9.7)	1(5.0)	2(18.2)	
Collagen plug	2 (6.5)	1(5.0)	1(9.1)	
NA	10 (32.3)	8(40.0)	2(18.2)	

Statistical comparison performed using Chi square or Fischer exact test. *P value < 0.05

Implant System and Initial Implant Dimensions

The most commonly used implant system for the first implant placement was Nobel BioCare, accounting for 77.4% of cases, followed by 3i (6.5%), Straumann (6.6%), and Keystone (3.2%), with 6.5% of cases with unspecified implant systems. A statistically significant difference was discernible between early and late failures (p = 0.024). Nobel BioCare implants were more prevalent in cases of early failure (90.0%) than late failure (54.5%).

Regarding implant dimensions, the most common implant height was 10 mm (64.3%), followed by 8 mm (14.3%), 13 mm, 11.5 mm, and 8.5 mm (7.1% each). The most frequent implant diameters were 4.3 mm and 5.0 mm (32.1% each), followed by 3.5 mm (25.0%), 4.2 mm, 4.8 mm, and 4.1 mm (3.6% each) (Figure 5).

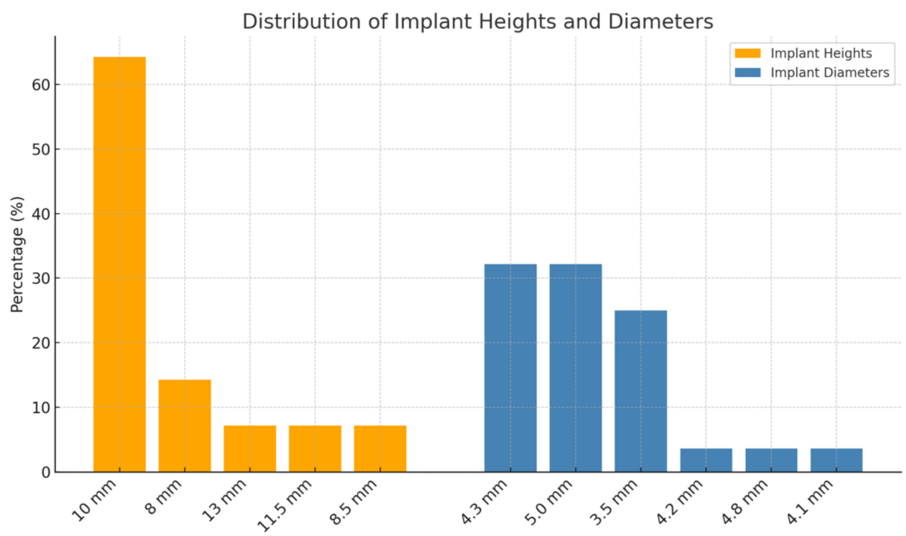

Figure (5): Distribution of Initial Implant Heights and Diameters

Implant diameter also showed a significant association with failure timing (p=0.030). Implants with diameters smaller than 5.0 mm were more likely to correlate with early failure (80.0%) than late failure (37.5%), whereas implants measuring 5.0 mm or greater were more common among late failures (62.5%) than early failures (20.0%). Although implant length did not demonstrate statistical significance (p=0.190), implants measuring 10 mm or more were more frequently observed in cases of early failure (85.0%) than late failure (62.5%). Conversely, shorter implants (under 10 mm) were relatively more common among late failures (37.5%) than early failures (15.0%).

Bone Augmentation in Initial Implant Site

GBR was only performed in 12.9% of initial implant placements, whereas the majority of cases (74.2%) did not receive GBR. This suggests that GBR was performed based on individual clinical needs, including selective application based on the patient's bone quality and surgical requirements. However, 6.5% of cases had missing information regarding GBR performance.

GBR performed at initial implant placement exhibited a statistically significant difference between the two groups (P=0.008). The majority of early failure cases (90.0%) had no GBR performed initially, whereas only 45.5% of late failure cases reported no GBR at initial placement.

Initial Implant Loading Protocol and Restoration

A significant portion of implants (64.5%) were not loaded, while 35.5% were functionally loaded. The average duration from initial implant placement to implant loading was 22.44 ± 7.60 months. This considerable variation suggests that some implants were loaded much earlier than others, possibly because of differences in healing responses, surgical approaches, or patient-specific factors. Implant loading status highly and significantly correlated with the timing of implant failure ($p < 0.001$). Remarkably, all implants that failed early (100%) were never loaded, whereas all implants that failed late (100%) were loaded. This finding emphasizes that loading protocols can critically increase the risk of implant failure and highlights the need for careful patient selection and timing during implant loading.

When analyzing restoration types, crowns accounted for 90.9% of restorations, while 9.1% were fixed dental prostheses (FDPs). The majority of restoration retention methods were not reported in 71.0% of cases. Among the recorded cases, 19.4% of restorations were screw-retained, while 9.7% were cement-retained. Restoration type also demonstrated significant differences between early and late failures ($p<0.001$). In cases of late failure, 54.5% of restorations were screw-retained, and 27.3% were cement-retained, whereas all early failure cases (100%) lacked restorations. Similarly, crowns were present in 90.9% of late failures, and Fixed Partial Dentures (FPDs) accounted for 9.1%, contrasting sharply with early failures, which did not have any restorations placed.

Initial Implant Failure Analysis

Failure analysis indicated that 64.5% of failures were early and occurred within the first six months of placement, underscoring this period as critical for implant survival. The remaining 35.4% were late failures. The majority of implant failures were biological (87.1%), followed by iatrogenic (9.7%), and mechanical failures (3.2%), as shown in Figure 6.

The analysis of reasons for implant failure did not yield statistical significance ($p=0.174$). However, biological failures were predominant across both early (85.0%) and late (90.9%) failure groups. Mechanical failures exclusively occurred in the late group (9.1%), whereas iatrogenic causes occurred solely in the early group (15.0%), suggesting distinct underlying mechanisms associated with different failure timings.

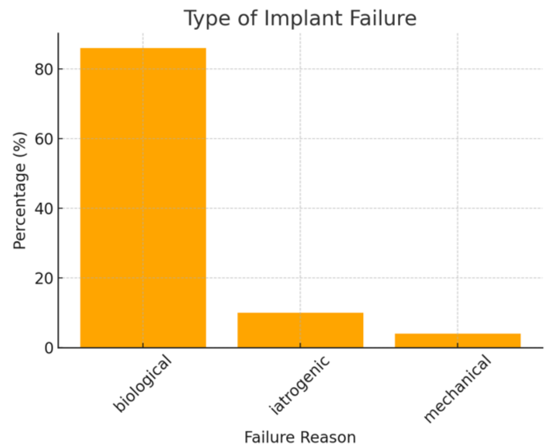

Figure (6): Type of Initial Implant Failure

Implant Removal

The average time from the first implant placement to removal was 29.60 ± 39.70 months. The large standard deviation suggests variability in implant longevity, with some implants failing much earlier than others. The most common method of implant removal was reverse torquing, accounting for 32.3% of cases. This method may have been preferable because of its effectiveness in preserving surrounding bone structure while minimizing trauma to the site. Extraction forceps were used in 29.0% of cases, most likely for implants with limited osseointegration or where a more mechanical approach was necessary for removal. The Nobel retrieval kit was utilized in 12.9% of cases. Trephine drills were used in 6.5% of cases, typically in situations requiring more invasive bone removal to extract an integrated implant. Additionally, 3.2% of cases involved a combination of forceps and de-torque, suggesting that a multi-step approach was sometimes necessary for successful removal. In 16.1% of cases, the method of implant removal was not specified (Figure 7).

Methods of implant removal showed no significant differences between groups (p = 0.487). However, de-torque was the most prevalent in early failures (45.0%), compared to late failures (18.2%). Removal with extraction forceps occurred more frequently in late failure cases (45.0%) than in early failure cases (20.0%).

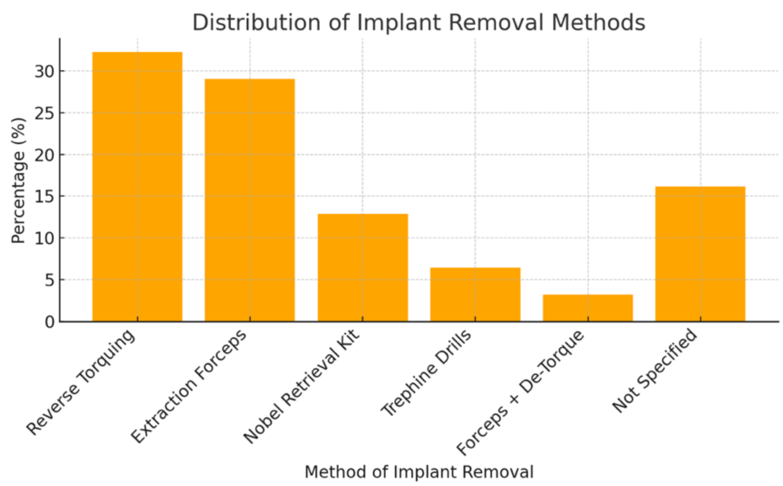

Figure (7): Distribution of Implant Removal Methods

GBR was performed at the time of implant removal in 67.7% of cases. In 25.8% of cases, GBR was not performed, likely due to sufficient existing bone volume or clinical decisions favoring alternative treatment strategies. Additionally, 6.5% of cases had missing information. GBR performed at the failed site showed no statistically significant difference (p=0.282). Nevertheless, GBR was more frequently performed in late failure cases (81.8%) compared to early failure cases (60.0%), potentially indicating greater bone loss or compromised conditions necessitating regeneration in late failures.

Regarding materials selection, the most commonly used bone graft was allograft (57.1%), followed by a combination of autogenous and xenograft materials (23.8%). Other combinations included xenograft alone, allograft and xenograft, and autogenous with allograft at 4.8% each (Figure 8).

Graft materials showed a trend nearing statistical significance (p=0.054). Autogenous grafts were more common in early failure cases (25.0%) than in late cases (9.1%). Xenografts, however, were exclusively used in late failures (27.3%), potentially reflecting differences in clinician preferences or clinical situations influencing graft material selection.

For membrane selection, the most frequently used type was resorbable membranes (76.2%), followed by non-resorbable membranes (14.3%) and collagen plugs (9.5%), as shown in Figure 8. The type of membrane selected for GBR did not differ significantly between groups (p=0.469). Resorbable membranes were slightly more frequent in late (54.5%) than in early failure cases (50.0%). Non-resorbable membranes and collagen plugs were less frequent used methods, with no clear differences between early and late failure groups.

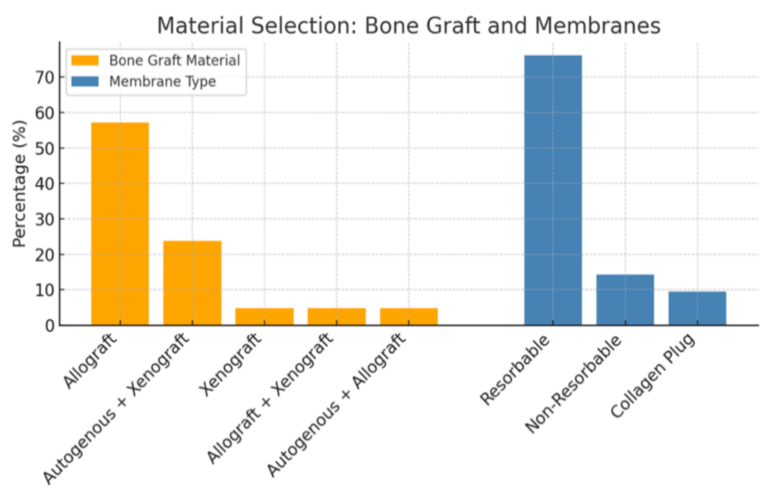

Figure (8): Material Selection (Bone Graft and Membrane) for Guided Bone Regeneration at The Time of Initial Implant Removal

Timing of Implant Replacement

The average time from first implant removal to implant replacement was 11.16 ± 7.31 months. This significant variability in timing suggests that some patients underwent implant replacement shortly after removal, whereas others experienced extended healing periods, possibly because of bone regeneration needs or patient-specific factors.

Implant System and Dimensions of the Replacement Implant

The most commonly used implant system for replacement implants was Nobel, accounting for 64.5% of cases, followed by Straumann (35.5%). Analysis of implant system selection revealed that in 64.5% of cases, clinicians chose the same implant system as the initial implant, whereas in 35.5% of cases, they selected a different implant system. There was no statistically significant difference between early and late failure groups ($P = 0.390$). Nobel implants were more frequently used in early failures (70.0%) than in late failures (54.5%). Conversely, clinicians chose Straumann implants slightly more often in cases of late failure (45.5%) than early failure (30.0%), although this trend was not statistically significant.

The most common replaced implant length was 10 mm, accounting for 61.3% of cases. Other commonly used implant lengths included 8 mm (32.3%) and 11.5 mm (6.5%), as shown in Figure 9. indicating that while 10 mm was the preferred choice, clinicians also frequently used shorter implants. Implant length did not show statistical significance between groups ($P = 0.660$). Implants measuring 10 mm or longer were slightly more prevalent among late failures (72.7%) compared to early failures (65.0%). Shorter implants (<10 mm) were slightly more common in early failures (35.0%) than in late failures (27.3%).

The most common replaced implant diameter was 4.3 mm, which was used in 32.3% of cases. However, clinicians selected a variety of implant diameters based on clinical needs, using 4.8 mm, 5.0 mm, and 3.5 mm implants in 16.1% of cases each. Additionally, clinicians used 4.1 mm implants in 12.9% of cases, and 3.3 mm implants in 6.5% (Figure 9), indicating that narrower implants were less common but still used in specific clinical situations. Implant diameter did not significantly differ between groups ($p = 0.211$). Implants with diameters less than 5.0 mm were somewhat more common among early failures (90.0%) than late failures (72.7%). Conversely, larger implants (≥5.0 mm diameter) were relatively more frequent among late failures (27.3%) than early failures (10.0%).

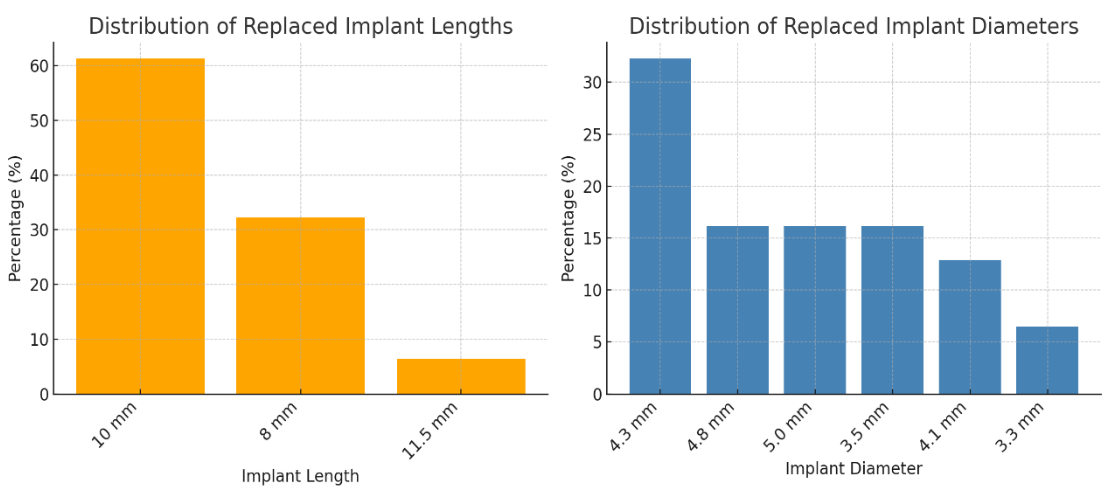

Figure (9): Distribution of Replaced Implants Lengths and Diameter

Placement Protocols of Replacement Implants

Regarding placement protocols, clinicians placed the majority of implants (80.7%) using a guided approach, whereas they placed 19.4% free hand. This data suggests that guided placement was the preferred method, likely due to its increased precision and predictable outcomes, though free-hand placement was still used in certain cases. Guided placement was slightly more frequent in late failures (90.9%) compared to early failures (75.0%), whereas free-hand placement was more common among early failures (25.0%) compared to late failures (9.1%). However, these differences were not statistically significant (p = 0.283).

Bone Augmentation at the Time of Implant Replacement

Clinicians performed GBR at the time of implant replacement in 22.6% of cases, indicating that bone augmentation selectively enhanced site conditions for the new implant. In contrast, 77.4% of cases did not undergo GBR at replacement, suggesting that in many instances, clinicians deemed the existing bone volume sufficient for implant placement without additional grafting. GBR performed during replacement implant surgery did not significantly differ between early and late failure groups (p = 0.664). GBR was slightly more frequent in early failures (25.0%) than in late failures (18.2%).

Regarding the type of bone graft material used at replacement, the most commonly selected material was xenograft (57.1%), followed by allograft (28.6%). Additionally, 14.3% of cases used a combination of autogenous bone and allograft, indicating that in select cases, clinicians opted for an additional autogenous component to enhance bone regeneration (Figure 10). There was no statistically significant difference between early and late failure cases (p = 0.560). Xenografts had an equal distribution between early (10.0%) and late (18.2%) failures. Clinicians employed autogenous grafts and allografts exclusively in early failure cases (5.0% and 10.0%, respectively).

For membrane selection at replacement, the majority of cases (80.0%) utilized a resorbable membrane, whereas 20.0% of cases did not use a membrane (Figure 10). The type of membrane used during replacement procedures also showed no significant differences between groups ($p = 0.656$). Although resorbable membranes were slightly more common in early failures (15.0%) compared to late failures (9.1%), only one early failure case showed no membrane usage.

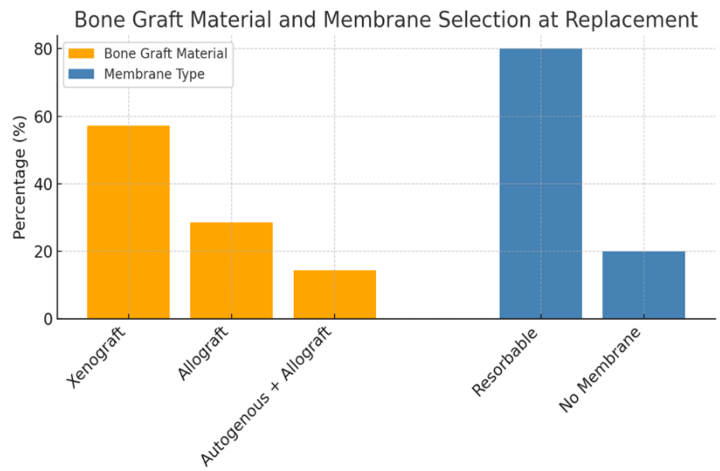

Figure (10): Bone Graft Materia and Membrane Selection at Time of Implant Replacement

Out of all analyzed sites, 28% underwent guided bone regeneration (GBR) at both the removal of the failed implant and the replacement implant placement, indicating persistent or recurring bony defects. 28% underwent GBR only at the time of the failed implant removal, and 14% underwent GBR exclusively at the time of implant replacement.

Timing of Replacement Implant Loading

The average time from implant replacement to implant loading was 7.79 ± 6.10 months. This variability suggests that while some implants were loaded relatively soon after placement, others required extended healing periods before functional restoration, likely due to site-specific factors, bone healing progress, and clinical judgment.

Table (5) summarizes the clinical characteristics associated with replacement implants placed in sites of previously early or late failed implants, Statistical significance was determined at a p-value < 0.05.

Table (5): Clinical Characteristics Associated with Replacement Implants Placed in Sites of Previously Early or Late Failed Implants

Variable	Total N=31 (Frequency/%)	Early N=20 (Frequency/%)	Late N=11 (Frequency/%)	P Value
Implant system of replacement implant				0.390
Straumann	11 (35.5)	6(30.0)	5(45.5)	
Nobel	20 (64.5)	14(70.0)	6(54.5)	
Implant Diameter				0.211
< 5.0mm	26 (83.9)	18(90.0)	8(72.7)	
≥ 5.0mm	5 (16.1)	2(10.0)	3(27.3)	
Implant Length				0.660
< 10.0mm	10(32.3)	7(35.0)	3(27.3)	
≥ 10.0mm	21(67.7)	13(65.0)	8(72.7)	
Implant Placement protocol				0.283
Guided	25(80.6)	15(75.0)	10(90.9)	
Free hand	6(19.4)	5(25.0)	1(9.1)	
GBR at time of replacement				0.664
Yes	7(22.6)	5(25.0)	2(18.2)	
No	24(77.4)	15(75.0)	9(81.8)	
Type of Bone Graft				0.560
Autogenous	1(3.2)	1(5.0)	0	
Allograft	2(6.5)	2(10.0)	0	
Xenograft	4(12.9)	2(10.0)	2(18.2)	
NA	24(77.4)	15(75.)	9(81.8)	
Type of Membrane				0.656
Resorbable	4(12.9)	3(15.0)	1(9.1)	

Variable	Total N=31 (Frequency/%)	Early N=20 (Frequency/%)	Late N=11 (Frequency/%)	P Value
None	1(3.2)	1(5.0)	0	
NA	26(83.9)	16(80.0)	10(90.9)	

Statistical comparison performed using Chi square or Fischer exact test. *P value < 0.05

Radiographic Evaluation

Radiographic calibration demonstrated high reproducibility, with measurement variations consistently within 0.2 mm across all samples. Radiographic evaluation at one-year post-placement was possible for 31 implants, revealing an overall mean marginal bone loss (MBL) of 1.68 ± 0.98 mm (mesial 1.54 ± 1.07 mm, distal 1.82 ± 1.05 mm). More than half of the sites (54.8%) exhibited MBL ≥ 2 mm at one or more sites, raising concerns about early peri-implant bone remodeling and potential long-term stability. Statistical analysis showed no significant difference in mean MBL between implants that were replaced following early failures versus those replaced after late failures (mesial: 1.58 ± 0.99 mm vs. 1.46 ± 1.24 mm, p = 0.763; distal: 1.85 ± 1.02 mm vs. 1.77 ± 1.16 mm, p = 0.840; average: 1.72 ± 0.91 mm vs. 1.62 ± 1.15 mm, p = 0.786). The proportion of implants exhibiting ≥ 2 mm bone loss at either mesial or distal sites did not differ significantly between early and late failure groups (mesial: 35.0% early vs. 36.4% late, p = 0.939; distal: 50.0% early vs. 54.5% late, p = 0.809). Furthermore, the combined analysis for implants demonstrating >2 mm MBL at any evaluated site showed virtually identical proportions between early and late failure groups (55.0% early vs. 54.5% late, p = 0.981). These findings suggest that marginal bone remodeling patterns at one-year post-replacement are not significantly influenced by the timing of the previous implant failure (Figure 11).

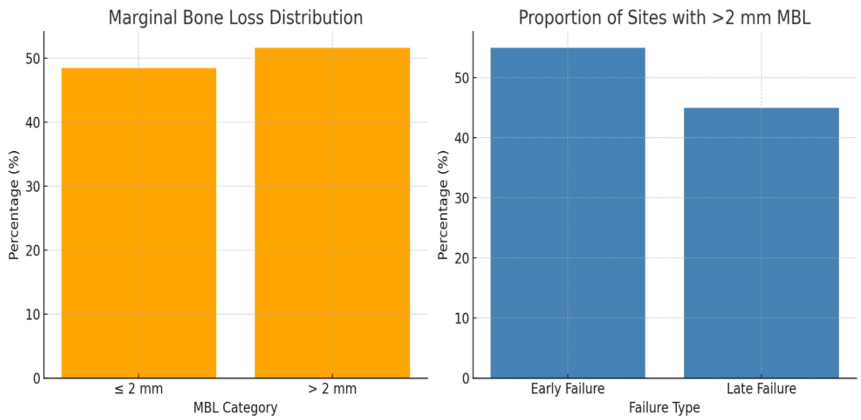

Figure (11): Marginal Bone Loss Distribution One Year After Loading of Replacement Implant and Proportion of Sites with > 2 mm MBL

Tables (6) and (7) summarize the radiographic outcomes associated with marginal bone loss (MBL) measured one year after replacement implant placement. The analyses compared cases that replaced implants following early failure (within six months following replacement) versus late failure (occurring after six months). Statistical significance was considered at a p-value < 0.05.

Table (6): Marginal Bone Loss Measured One Year After Replacement Implant Placement

Variables	Total N=31	Early N=20	Late N=11	P Value
MBL at one year after replacement				
Mesial	1.54 ± 1.07	1.58 ± 0.99	1.46 ± 1.24	0.763
Distal	1.82 ± 1.05	1.85 ± 1.02	1.77 ± 1.16	0.840
Average	1.68 ± 0.98	1.72 ± 0.91	1.62 ± 1.15	0.786

Statistical comparison performed using independent t-test. *P value < 0.05 between Early and Late

Table (7): Number and percentage of implants with site MBL ≥ 2mm or more

Variables	Total N=31	Early N=20	Late N=11	P Value
MBL at one year after replacement				
Mesial	11(35.5)	7(35.0)	4(36.4)	0.939
Distal	16(51.6)	10(50.0)	6(54.5)	0.809

Any	17(54.8)	11(55.0)	6(54.5)	0.981

Statistical comparison performed using independent t-test. *P value < 0.05 between Early and Late

Radiographic analysis was conducted for 19 subjects who had replacement implants placed at previously failed sites, as well as initially successful implants placed in the pristine bone, with both implants having comparable follow-up periods. The purpose was to compare marginal bone loss (MBL) between replacement implants and initially successful implants. Marginal bone loss at the mesial aspect was slightly lower in replacement implants (1.49 ± 0.94 mm) compared to initially successful implants (1.56 ± 1.08 mm), though this difference was not statistically significant ($p = 0.784$). Similarly, distal MBL showed slightly lower values in replacement implants (1.91 ± 0.85 mm) compared to initially successful implants (2.05 ± 1.06 mm), but this difference was also not statistically significant ($p = 0.589$). The overall average MBL across mesial and distal sites was comparable between replacement implants (1.70 ± 0.83 mm) and initially successful implants (1.81 ± 0.98 mm), without significant differences detected ($p = 0.657$). Table (8) presents mean MBL values at mesial and distal sites.

Table (8): Mean Marginal Bone Loss Values in Replacement Implants vs. Successful Implants

Variables	Replaced implant N=19	Successful implant N=19	P Value
MBL			
Mesial	1.49 ± 0.94	1.56 ± 1.08	0.784
Distal	1.91 ± 0.85	2.05 ± 1.06	0.589
Average	1.70 ± 0.83	1.81 ± 0.98	0.657

Statistical comparison performed using Paired t-test. *P value < 0.05 between replaced versus successful

Table (9) evaluates the frequency of implants with MBL ≥ 2mm or more. At mesial sites, replacement implants showed slightly lower rates (26.3%) compared to initially successful implants (31.6%), with no statistically significant difference ($p = 0.721$). For distal sites, replacement implants showed slightly higher rates of significant bone loss (57.9%) compared to initially successful implants (52.6%), though again the difference was not statistically significant ($p = 0.744$). When analyzing implants with MBL ≥ 2 mm at any site, identical proportions were observed in both groups (57.9%), confirming no statistically significant difference ($p = 1.000$).

Table (9): Number and percentage of implants with site MBL ≥ 2mm or more

Variables	Replaced implant N=19	Successful implant N=19	P Value
MBL			
Mesial	5(26.3)	6(31.6)	0.721
Distal	11(57.9)	10(52.6)	0.744
Any	11(57.9)	11(57.9)	1.000

Statistical comparison performed using Paired t-test. *P value < 0.05 between replaced versus successful

Factors Influencing MBL One Year After Implant Replacement: Regression Analysis

This study performed two regression analyses to identify factors influencing average marginal bone loss (MBL) one year after dental implant replacement. MBL serves as a critical indicator of implant survival, and understanding its contributing factors helps clinicians enhance treatment outcomes.

Model 1: Impact of Implant Brand, Failure Reason, and Implant Diameter (Table 10)

The initial regression analysis examined three main predictors: the brand of implant used for replacement (Straumann vs. Nobel), the reason behind the original implant's failure, and implant diameter (narrow or wide).

- **Implant Brand (Straumann vs. Nobel):**

Replacement with Straumann implants significantly increased MBL by about 1.03 mm compared to Nobel implants (B = 1.026, p = 0.001). This suggests Nobel implants may be more favorable to marginal bone preservation.

- **Reason for Implant Failure:**

A biologically driven failure (e.g., peri-implantitis) was associated with less MBL than mechanical failures (B = -0.389, p = 0.009). This highlights that biologically related failures may have a less detrimental impact on bone preservation after replacement.

- **Implant Diameter:**

Narrower implants showed significantly lower marginal bone loss compared to wider implants (B = -0.608, p = 0.035). This finding supports the potential advantages of narrower implants for bone preservation.

Table (10): Regression analysis without type of failure (early vs late) of average MBL one-year after replacement

Variables	B	Std. Error	t	*P* value
Constant	1.868	.423	4.420	<.001*
Implant replaced (Straumann vs Nobel)	1.026	.260	3.951	.001*
Reason for failure	-.389-	.136	-2.852-	.009*
Implant diameter	-.608-	.271	-2.239-	.035*

Statistical comparison performed using multiple linear regression. *P value < 0.05.

Model 2: Including Timing of Failure (Early vs. Late) (Table 11)

The second regression model added the timing of implant failure (early vs. late) to assess its influence on marginal bone loss.

- **Implant Brand (Straumann vs. Nobel):**

  Consistent with the first model, Straumann implants remained significantly associated with higher marginal bone loss compared to Nobel implants (B = 0.981, p = 0.002).

- **Reason for Implant Failure:**

  The significance and direction remained stable (B = -0.408, p = 0.009), reinforcing the finding that biological failures generally result in less marginal bone loss.

- **Implant Diameter:**

  When accounting for the timing of implant failure, implant diameter was no longer statistically significant (B = -0.537, p = 0.090). This suggests other factors, potentially related to failure timing, may mediate the relationship between diameter and bone loss.

- **Timing of Failure (Early vs. Late):**

  No significant relationship was found between the timing of implant failure and marginal bone loss (B = -0.185, p = 0.588). This indicates that marginal bone loss is independent of whether the implant failure occurred early or late.

Table (11): Regression analysis with type of failure (early vs late) of average MBL one-year after replacement

Variables	B	Std. Error	t	*P* value
Constant	1.861	.429	4.337	<.001*
Implant replaced (Straumann vs Nobel)	.981	.276	3.555	.002*
Reason for failure	-.408-	.143	-2.860-	.009*
Implant diameter	-.537-	.304	-1.769-	.090
Type of failure	-.185-	.336	-.550-	.588

Statistical comparison performed using multiple linear regression. *P value < 0.05.

Kaplan Meier Survival Analysis

- **Overall Implant Survival (Figure 12)**

The Kaplan-Meier survival curve illustrates the cumulative survival rate of implants over a follow-up period extending up to 120 months. The curve indicates very few implant failures, with an overall survival rate of 96.8%, highlighting the effectiveness and reliability of implant replacement at sites of previous implant failure.

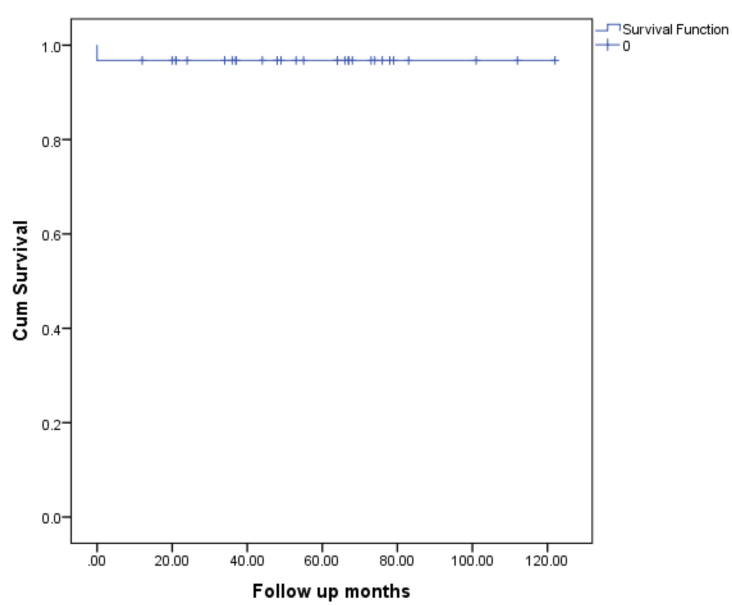

Figure (12): Kaplan Meier Survival Analysis of Replacement Implants

- **Implant Survival by Timing of Initial Implant Failure (Figure 13)**

The second Kaplan-Meier graph presents a comparison of implant survival according to the timing of the initial implant failure (early vs. late). Both groups demonstrated excellent survival outcomes throughout the follow-up period. However, implants replaced after early failures exhibited slightly better survival outcomes compared to those replaced following late failures. Despite this subtle difference, survival rates remained consistently high in both groups (above 90%), indicating favorable long-term implant performance regardless of the timing of the initial implant failure.

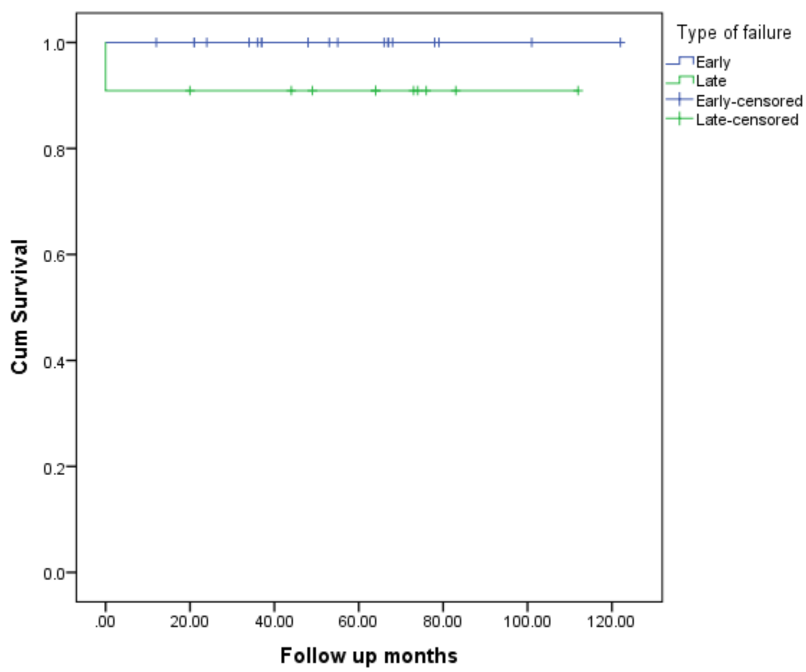

Figure (13): Kaplan Meier Survival Analysis of Replacement Implants According to Type of Failure of Initial Implant

Discussion

In this retrospective study, we investigated the survival rate and MBL of dental implants placed in previously failed sites, offering insights into the clinical and surgical considerations associated with re-implantation procedures. The study yielded a survival rate of replacement implants of 90.2%, which is higher than the survival rates reported in previous studies, in which replacement implant survival rates ranged from 73% to 88.7%. Chrcanovic et al. (30) reported a replacement implant survival rate of approximately 85.5%, noting that replacement implants had generally lower survival rates compared to initial implants because of site-specific bone conditions and prior complications. Manor et al. (35) similarly documented an 88.7% survival rate, emphasizing the impact of site healing time and initial bone quality on outcomes. Wang et al. (42) observed a relatively lower survival rate of 73%, attributed to the complex clinical scenarios of replacement sites and the variability in regenerative procedures. The higher survival rate observed in the current study may be attributable to several factors inherent to the treatment protocol. All replacement implants followed a delayed placement approach, with an average healing period of 11.16 months between implant removal and replacement. Additionally, clinicians placed 80.7% of replacement implants using guided surgical protocols, promoting precision and optimal positioning.

Furthermore, 70% of cases received GBR at one or more stages—during initial implant removal, at the time of re-implantation, or both—thereby enhancing site quality and ensuring favorable conditions for implant success. Additionally, 69.4% of the patient population were non-smokers, which may have further contributed to the high implant survival rate, as smoking is a well-documented risk factor for impaired osseointegration and peri-implant complications (31). This affirms the clinical viability of re-implantation in previously failed sites when strategic planning, thorough assessment, and control of local and systemic risk factors, and appropriate surgical techniques are applied.

A notable observation in this study was the prevalence of early implant failures among initial implants, with 64.5% of all initial implant placement failures occurring within the first six months. This critical period is particularly sensitive to host and site-related variables such as primary implant stability, bone quality, and healing capacity. Staedt et al. (41) similarly noted that early failures constitute the majority of implant failures, often occurring in younger patients and posterior mandibular regions. In this study, however, the majority of initial implant placement failures occurred in the maxillary posterior region. We may attribute this observation to the anatomical and histological characteristics of the posterior maxilla, which is known for its lower bone density and higher trabecular content, making it less favorable for achieving primary stability and osseointegration (33)(36). Clinicians often attribute the early failure to micromovement, insufficient primary stability, bacterial contamination, or inadequate vascular supply to the surgical site (32)(40). In our cohort, implants with diameters below 5.0 mm and those placed without GBR significantly correlated with early failure, indicating the need for enhanced mechanical and biological support in compromised sites.

This high early failure rate at initial implant placement observed also highlights the need for clinicians to reevaluate surgical protocols for high-risk sites. Factors such as poor primary stability, premature loading, or inappropriate implant selection (e.g., immediate placement in compromised bone) must receive closer scrutiny. Delaying implant placement or using staged

GBR and selecting wider or shorter implants may mitigate risks in certain situations, as indicated in the literature [39].

The survival of replacement implants was not significantly attributable to most systemic factors, although hypertension and diabetes were relatively prevalent (16.13% and 13.1%, respectively). While there was no significant correlation, clinicians have linked systemic diseases such as diabetes to impaired osseointegration and delayed healing in several studies [28][43]. The potential impact of antihypertensive and antidiabetic medications on osseous remodeling and implant integration also warrants further investigation. Angiotensin-converting enzyme inhibitors and statins may have osteo-modulatory effects, which could influence peri-implant healing.

Interestingly, alcohol and opioid abuse, while rare (1.6%), correlated with a disproportionately high rate of implant failure (16.7%), reinforcing the need for thorough medical screening and behavioral assessment prior to implant therapy. Neurological disorders are also significantly correlated with significantly higher failure rates, potentially reflecting challenges in oral hygiene, medications used, or neuromuscular control affecting implant success.

Methods of implant removal showed no significant differences between early and late failure of initially placed implants. However, reverse torque (de-torque) was the most frequently used method for implant removal (35.5%), particularly in early failures, where osseointegration was likely insufficient. Clinicians more commonly used extraction forceps in late failures, suggesting greater fixture integration. The variation in removal techniques indicates the importance of selecting removal strategies that preserve the bone architecture to facilitate future implant placement [40]. Clinically, the choice of atraumatic methods like de-torque can influence the need for secondary augmentation and ultimately the success of re-implantation.

Following initially placed implant removal, clinicians performed GBR at the time of implant removal in 67.7% of cases, with allografts being the most commonly used graft material (57.1%), and resorbable membranes used in 76.2% of cases. These findings reflect a clinical preference for biologically favorable and less invasive regenerative materials. A detailed breakdown of GBR usage in all cases revealed that 28% received GBR at both the time of implant removal and implant replacement, 28% received GBR only during implant removal, and 14% received GBR only at the time of implant replacement. This distribution suggests that clinicians applied GBR selectively based on individual site conditions, healing response, and surgical objectives. The remaining 30% of replacement cases did not undergo GBR at any stage, likely because of atraumatic removal techniques or sufficient pre-existing bone volume. The variability in GBR usage suggests that clinicians selectively applied GBR based on individual site conditions, healing responses, and surgical objectives, highlighting the importance of personalized treatment planning and comprehensive site assessment both before and after explantation.

Regarding implant selection, Nobel BioCare was the most utilized implant system for both initial and replacement implants, used in 64.5% of re-implantations. This consistency likely reflects institutional preferences, availability, and possibly sponsorship agreements, rather than solely clinician trust in system performance. However, the use of different systems in 35.5% of cases underscores the importance of adaptive planning. Changes in bone morphology, implant availability, or evolving clinical philosophy may justify a switch in systems. Such flexibility reflects a clinician's strategic response to site-specific challenges.

Implant dimensions were also subject to change, reflecting adaptive surgical decision-making in response to site-specific conditions encountered during re-implantation. In our study, 48.4% of cases maintained the same implant length between the initial and replacement procedures, suggesting a preference for preserving anatomical consistency when site conditions permitted. However, 38.7% of cases required the use of shorter implants, which may be attributed to residual bone loss following implant failure, anatomical limitations such as sinus proximity or nerve location, or the desire to minimize surgical invasiveness in compromised sites. Chrcanovic et al. [30] also reported the tendency to use shorter implants in replacement procedures because of reduced available bone after initial implant failures. Conversely, clinicians used longer implants in 12.90% of the replacement cases, possibly reflecting improved site conditions following regenerative procedures, a change in angulation or implant trajectory to engage more apical bone, or an intentional effort to enhance primary stability in areas with compromised bone quality. These variations underscore the necessity of adapting implant dimensions based on individual clinical circumstances and highlight the importance of thorough preoperative site evaluation to guide appropriate implant selection.

In terms of implant diameter, 45.2% of replacement implants were narrower than their predecessors. Chrcanovic et al. [30] noted a similar pattern, indicating that clinicians frequently selected narrower implants for replacement procedures due to altered anatomical conditions or residual bone limitations following previous implant failure. This trend highlights a conservative approach that aligns with contemporary philosophies favoring less aggressive osteotomy preparation and reduced cortical stress, particularly in ridges that may have undergone remodeling or resorption post-explantation. Narrower implants also allow for placement in more confined ridges while preserving vital structures and facilitating soft tissue adaptation.

We also examined early MBL in replacement implants, with a mean value of 1.68 mm at one-year post-loading. This level of bone remodeling falls within the range considered clinically acceptable in the literature. Previous studies, such as those by Atieh et al.[(29)], report average MBL values for replacement implants between 1.8 and 2.2 mm during the first year, suggesting that our results are consistent with broader clinical findings. Zhou et al.[(46)] reported a similar range of 1.5 to 2.1 mm, while Lee et al.[(15)] documented a five-year MBL range of 1.6 to 2.3 mm, depending on implant site and regenerative approach. These outcomes indicate that with proper timing and regenerative procedures, replacement implants can achieve more favorable bone stability than that of initial implants in non-compromised sites.

Additionally, we compared MBL in replacement implants to that of initial implants placed in pristine bone within the same subjects. The mean MBL of replacement implants was 1.70 mm, while implants in pristine bone showed a mean MBL of 1.81 mm, with no significant difference between the two groups. These findings align with those of prior studies by Quaranta et al. [(38)] and Oh et al. [(37)], which also found no significant differences in crestal bone remodeling between implants placed in previously failed sites and those in pristine bone, assuming appropriate protocols. In contrast, Chrcanovic et al. [(30)] reported higher MBL in re-implanted sites compared to initial placements (1.47 mm vs 1.10 mm) but concluded that these numbers are within clinically acceptable thresholds. This suggests that a history of implant failure does not inherently predispose a site to greater mean MBL, reinforcing that replacement implants can yield better peri-implant bone stability than that of primary placements when planned and executed meticulously.

Despite the overall favorable mean MBL outcomes, it is noteworthy that over half (51.6%) of the replacement implants exhibited MBL greater than 2 mm—an established threshold for increased risk of peri-implantitis and long-term implant complications [34] with an equal number (57.9% of implants with MBL greater than 2 mm) in replacement and initially placed implants. Windael et al. [44] demonstrated that early peri-implant bone loss serves as a strong predictor for future peri-implantitis, particularly in the absence of a rigorous maintenance protocol. Similarly, Galindo-Moreno et al. [45] proposed that exceeding a 2 mm MBL threshold should prompt clinical concern, emphasizing that peri-implant health may be at risk, even in the absence of overt clinical symptoms. These findings highlight the need for vigilant long-term follow-up, including regular radiographic monitoring to detect early signs of peri-implant bone loss. Clinicians should be prepared to implement individualized maintenance strategies and initiate timely interventions, when necessary, particularly in patients presenting with systemic risk factors, history of periodontal disease, or suboptimal plaque control. Proactive management remains essential to maintaining peri-implant health and supporting the long-term success of re-implantation therapies.

The mean time between implant removal and re-implantation in this study was 11.16 months. While there is no definitive consensus on the optimal timing, a delayed approach appears to support improved outcomes by allowing sufficient time for adequate bone healing and remodeling [27][46]. Our data supports the notion that a healing period of approximately 9–12 months after implant removal provides favorable conditions for re-implantation. This interval provides a favorable window for bone remodeling, soft tissue maturation, and comprehensive re-evaluation of the site. This approach may enhance the biological environment by reducing residual inflammation and improving vascularity, ultimately contributing to greater implant success. Furthermore, the delay allows time for any necessary regenerative or preparatory procedures and offers an opportunity to optimize patient-specific factors prior to re-entry.

The findings of this investigation also carry important implications for patient communication and education. A survival rate of 90.2% for implants placed in previously failed sites enables clinicians to confidently reassure patients that implant failure is not necessarily the end of treatment. Instead, with appropriate planning and tailored interventions, successful re-implantation is a highly realistic outcome with well-controlled and executed protocols. This perspective is crucial in reducing the psychological burden and stigma often associated with implant failure. Evidence-based discussions can help patients understand the factors contributing to the original failure and highlight how these are addressed in the future treatment plan. Transparent communication, reinforced by clinical data, fosters informed decision-making, enhances patient confidence, and supports stronger clinician–patient trust throughout the treatment process.

Limitations of the present study include its retrospective nature, potential documentation inconsistencies, and a relatively small sample size for MBL analysis because of radiographic limitations in the records reviewed. The sample size included for radiographic analysis was substantially smaller than the calculated requirement, rendering the study underpowered for detecting smaller effects or differences. Additionally, all radiographic measurements were performed by a single (albeit calibrated) investigator, which may introduce observer-related variability. The single-center design may also introduce a degree of selection bias. Future prospective studies should aim to assess standardized surgical protocols and, radiographic assessments, evaluating the impact of specific local and systemic factors on re-implantation success. Additionally, there is a need for further investigation of the biological mechanisms underlying early failures in previously compromised sites, including bone cell signaling, angiogenesis, and the role of biomaterials.

Conclusion

In conclusion, this study provides valuable evidence supporting the clinical feasibility of re-implanting dental implants in previously failed sites, achieving survival and MBL outcomes comparable to implants placed in pristine bone. Careful patient selection, comprehensive risk assessment, customized implant planning, and adherence to evidence-based surgical protocols are paramount to optimizing outcomes in re-implantation therapy. These findings reinforce that implant failure does not preclude successful re-treatment when appropriate measures are taken. Rather, failure can serve as a diagnostic opportunity, prompting further refinements in technique, material choice, and interdisciplinary care.

References

1) Misch, C., Perel, M., Wang, H., Sammartino, G., Galindo-Moreno, P., Trisi, P., Steigmann, M., Rebaudi, A., Palti, A., Pikos, M., Schwartz-Arad, D., Choukroun, J., Gutierrez-Perez, J., Marenzi, G., Valavanis, D. (2008). Implant success, survival, and failure: the International Congress of Oral Implantologists (ICOI) Pisa Consensus Conference. Implant Dent, 17(1):5-15. doi: 10.1097/ID.0b013e3181676059. PMID: 18332753.

2) Albrektsson, T., Zarb, G., Worthington, P., Eriksson, A. (1986) The long-term efficacy of currently used dental implants: A review and proposed criteria of success. Int JOral Maxillofac Implants, 1:11-25.

3) Pjetursson, B., Asgeirsson A., Zwahlen M., Sailer I. (2014) Improvements in Implant Dentistry over the Last Decade: Comparison of Survival and Complication Rates in Older and Newer Publications. International Journal of Oral & Maxillofacial Implants. 29 (Suppl):308-324. doi: 10.11607/jomi.2014suppl.g5.2. PMID: 24660206.

4) Staedt H, Rossa M, Lehmann KM, Al-Nawas B, Kämmerer PW, Heimes D. (2020). Potential risk factors for early and late dental implant failure: a retrospective clinical study on 9080 implants. Int J Implant Dent.;6(1):81. doi: 10.1186/s40729-020-00276-w. PMID: 33251566; PMCID: PMC7701040.

5) Diz, P., Scully, Sanz. (2013) Dental implants in the medically compromised patient. J Dent, 41, pp. 195-206.

6) Zupnik, J., Kim, S., Ravens, D., Karimbux, N., Guze K., (2011) Factors Associated with Dental Implant Survival: A 4-year Retrospective Analysis. J Periodontal 82(10):1390-1395.

7) Esposito M., Hirsch J., Lekholm U., Thomsen P. (1998) Biological factors contributing to failures of osseointegrated oral implants (I). Success criteria and epidemiology. Eur J Oral Sci 106: 527–551.

8) Friberg, B., Jemt, T. (2015) Rehabilitation of edentulous mandibles by means of osseointegrated implants: a 5-year follow-up study on one or two-stage surgery, number of implants, implant surfaces, and age at surgery. Clin Implant Dent Relat Res. 17:413–424.

9) Froum, S., Yamanaka, T., Cho, S. C., Kelly, R., James, S. S., & Elian, N. (2011). Techniques to remove a failed integrated implant. Compendium of Continuing Education in Dentistry, 32(22–26), 28.

10) Hajji, M., Franzen, R., Grumer, S., Modabber, A., Nasher, R., Prescher, A., & Gutknecht, N. (2016). Removal of dental implants using the erbium, chromium: Yttrium-

scandium-gallium-garnet laser and the conventional trephine bur: An in vitro comparative study. Photomedicine and Laser Surgery, 34, 61–67.

11) Solderer, A., Al-Jazrawi, A., Sahrmann, P., Jung, R., Attin, T., Schmidlin, P. (2019) Removal of failed dental implants revisited: Questions and answers. Clin Exp Dent Res. 5(6):712-724. doi: 10.1002/cre2.234. PMID: 31890309; PMCID: PMC6934347.

12) Gomes GH, Misawa MYO, Fernandes C, Pannuti CM, Saraiva L, Huynh-Ba G, Villar CC. (2018) A systematic review and meta-analysis of the survival rate of implants placed in previously failed sites. Braz Oral Res. 2018;32: e27. doi: 10.1590/1807-3107bor-2018.vol32.0027. Epub. PMID: 29723338.

13) Oh SL, Shiau HJ, Reynolds MA. (2019) Survival of dental implants at sites after implant failure: A systematic review. J Prosthet Dent. 2020 Jan;123(1):54-60. doi: 10.1016/j.prosdent.2018.11.007. Epub. PMID: 31027959.

14) Oh, S., Shiau, H., Ashour, I., Chen, H., Cruz, C. (2022) Early crestal bone loss around implants placed at previously failed sites compared with initially integrated implants: A retrospective cohort study. Clin Implant Dent Relat Res. 1-9. doi:10.1111/cid.13076

15) Lee, D., Ko, Y., Seol, Y., Koo, K., Lee, Y., Lee, J. (2023) Risk factors impacting the survival of implants replaced following failure: A retrospective study. Clin Implant Dent Relat Res. 2023;1-11. doi:10.1111/cid.13265

16) Chrcanovic, B., Kisch, J., Albrektsson, T., Wennerberg, A. (2017) Survival of dental implants placed in sites of previously failed implants. Clin Oral Implants Res. 28(11):1348-1353. https://doi.org/10.1111/clr.12992

17) Manor, Y., Oubaid, S., Mardinger, O., Chaushu, G., Nissan, J. (2009) Characteristics of early versus late implant failure: a retrospective study. J Oral Maxillofac Surg. 67(12):2649-2652. https://doi.org/10.1016/j.joms.2009.07.050

18) Wang, F., Zhang, Z., Monje, A., Huang, W., Wu, Y., Wang, G. (2015) Intermediate long-term clinical performance of dental implants placed in sites with a previous early implant failure: a retrospective analysis. Clin Oral Implants Res. 26(12):1443-1449. https://doi.org/10.1111/clr.12485

19) He, J., Shang, Y., Deng, C., Shang, D., Zhang, C., Wang, D. et al. (2014) A clinical retrospective analysis of dental implants replaced in previously failed sites]. Shanghai Kou Qiang Yi Xue. 23(2):196-200. Chinese.

20) Mardinger, O., Ben, Zvi Y., Chaushu, G., Nissan, J.,
Manor, Y. (2012) A retrospective analysis of replacing dental implants in previously failed sites. Oral Surg Oral Med Oral Pathol Oral Radiol. 114(3):290-293. https://doi.org/10.1016/j.tripleo.2011.07.010

21) Quaranta, A., Cicconetti, A., Battaglia, L., Piemontese, M., Pompa, G., Vozza, I. (2012) Crestal bone remodeling around platform switched, immediately loaded implants placed in sites of previous failures. Eur J Inflamm. 10(2):115-22. https://doi.org/10.1177/1721727X120100S222

22) Kim, Y., Park, J., Kim, S., Lee, H. (2010) Prognosis of the implants replaced after removal of failed dental implants. Oral Surg Oral Med Oral Pathol Oral Radiol Endod. 110(3):281-286. https://doi.org/10.1016/j.tripleo.2010.01.031

23) Machtei, E., Horwitz, J., Mahler, D., Grossmann, Y., Levin, L. (2011) Third attempt to place implants in sites where previous surgeries have failed. J Clin Periodontol. 38(2):195-198. https://doi.org/10.1111/j.1600-051X.2010.01629.x

24) Grossmann, Y., Levin, L. (2007) Success and survival of single dental implants placed in sites of previously failed implants. J Periodontol. 78(9):1670-1674. https://doi.org/10.1902/jop.2007.060516

25) Alsaadi, G., Quirynen, M., van Steenberghe, D. (2006) The importance of implant surface characteristics in the replacement of failed implants. Int J Oral Maxillofac Implants. 21(2):270-274.

26) Aghazadeh, A., Persson, G. R., Stavropoulos, A., & Renvert, S. (2022). Reconstructive treatment of peri-implant defects-Results after three and five years. Clinical oral implants research, 33(11), 1114–1124.

27. Adell, R., Lekholm, U., Rockler, B., & Brånemark, P. I. (1981). A 15-year study of osseointegrated implants in the treatment of the edentulous jaw. *International Journal of Oral Surgery, 10*(6), 387–416. https://doi.org/10.1016/S0300-9785(81)80077-4

28. Alsaadi, G., Quirynen, M., Komárek, A., & van Steenberghe, D. (2006). Impact of local and systemic factors on the incidence of late oral implant loss. *Clinical Oral Implants Research, 17*(6), 670–676. https://doi.org/10.1111/j.1600-0501.2006.01378.x

29. Atieh, M. A., Alsabeeha, N. H., Faggion, C. M., Duncan, W. J., & Payne, A. G. (2022). Marginal bone loss around dental implants placed in smokers and non-smokers: A systematic review and meta-analysis. *Clinical Implant Dentistry and Related Research, 24*(1), 1–12. https://doi.org/10.1111/cid.13042

30. Chrcanovic, B. R., Kisch, J., Albrektsson, T., & Wennerberg, A. (2017). Factors influencing early dental implant failures. *Journal of Dental Research, 96*(9), 995–1002. https://doi.org/10.1177/0022034517708553

31. Chrcanovic, B. R., Kisch, J., Albrektsson, T., & Wennerberg, A. (2021). Smoking and dental implants: A systematic review and meta-analysis. *Journal of Dentistry, 103*, 103497. https://doi.org/10.1016/j.jdent.2020.103497

32. Esposito, M., Hirsch, J. M., Lekholm, U., & Thomsen, P. (1998). Biological factors contributing to failures of osseointegrated oral implants: I. Success criteria and epidemiology. *European Journal of Oral Sciences, 106*(1), 527–551. https://doi.org/10.1046/j.0909-8836.1998.eos106105.x

33. Javed, F., & Al-Hezaimi, K. (2014). Do implant surface characteristics influence peri-implant bone loss? A systematic review. *Journal of Periodontology, 85*(9), 1211–1221. https://doi.org/10.1902/jop.2014.130688

34. Lang, N. P., Berglundh, T., & Working Group 4 of the Seventh European Workshop on Periodontology. (2004). Peri-implant diseases: Where are we now? Consensus of the Seventh European Workshop on Periodontology. *Journal of Clinical Periodontology, 31*(Suppl. 3), 282–285. https://doi.org/10.1111/j.1600-051X.2004.00388.x

35. Manor, Y., Oubaid, S., Mardinger, O., Chaushu, G., Nissan, J., & Chaushu, S. (2009). Characteristics of early versus late implant failure: A retrospective study. *Journal of Oral and Maxillofacial Surgery, 67*(12), 2649–2652. https://doi.org/10.1016/j.joms.2009.07.019

36. Misch, C. E. (1999). *Contemporary Implant Dentistry* (2nd ed.). Mosby.

37. Oh, T. J., Shotwell, J. L., Billy, E. J., & Wang, H. L. (2019). Survival of dental implants at sites after implant failure: A systematic review. *Journal of Prosthetic Dentistry, 121*(4), 658–666. https://doi.org/10.1016/j.prosdent.2018.06.010

38. Quaranta, A., Piemontese, M., Rappelli, G., Sammartino, G., & Procaccini, M. (2012). Clinical evaluation of implant-supported overdentures and periodontal parameters in patients with history of periodontitis. *Clinical Oral Implants Research, 23*(3), 330–335. https://doi.org/10.1111/j.1600-0501.2011.02267.x

39. Sakkas, A., Wilde, F., Heufelder, M., Winter, K., & Schramm, A. (2022). Implant survival and success rates in patients with systemic diseases: A retrospective study. *Clinical Oral Investigations, 26*(2), 1473–1481. https://doi.org/10.1007/s00784-021-04103-3

40. Solderer, A., Al-Jazrawi, A., Sahrmann, P., Jung, R. E., Attin, T., & Schmidlin, P. R. (2019). Removal of failed dental implants revisited: Questions and answers. *Clinical and Experimental Dental Research, 5*(6), 712–724. https://doi.org/10.1002/cre2.234

41. Staedt, H., Rossa, M., Lehmann, K. M., Heimes, D., Kämmerer, P. W., & Al-Nawas, B. (2020). Potential risk factors for early and late dental implant failure: A retrospective clinical study on 9,080 implants. *International Journal of Implant Dentistry, 6*, 81. https://doi.org/10.1186/s40729-020-00276-w

42. Wang, H. L., Boyapati, L. (2005). "PASS" principles for predictable bone regeneration. *Implant Dentistry, 14*(1), 8–17. https://doi.org/10.1097/01.id.0000148557.76743.0e

43. Zupnik, J., Kim, S., Ravens, D., Karimbux, N., & Guze, K. (2011). Factors associated with dental implant survival: A 4-year retrospective analysis. *Journal of Periodontology, 82*(10), 1390–1395. https://doi.org/10.1902/jop.2011.100621

44. Windael, S., Collaert, B., De Buyser, S., De Bruyn, H., Vervaeke, S.. (2021). Early peri-implant bone loss as a predictor for peri-implantitis: A 10-year prospective cohort study. Clin Implant Dent Relat Res., Jun (23(3)), 298-308.

45. Galindo-Moreno, P., Leon-Cano, A., Ortega-Oller, I., Monje, A., F, O. V., & Catena, A. (2015). Marginal bone loss as success criterion in implant dentistry: beyond 2 mm. Clin Oral Implants Res, 26(4), e28-e34.

46. Zhou, X., Wu, T., Guo, Y., & Duan, X. (2017). Marginal bone loss around non-submerged implants is associated with salivary microbiome during bone healing. *International Journal of Oral Science, 9*(2), e13. https://doi.org/10.1038/ijos.2017.18

Appendix A

Table (1) – Review of studies investigating survival rates of dental implants that replaced a previously failed implant.

RC = retrospective cohort study; PC = prospective case series study: NR= not reported

Authors and year	Study design	Patients and implants (n) (initial placement)	Timing of initial failure (months)	Failure reason (n) (%)	Survival of initial implants (%)	Patients and implants with replacement (n)	Time interval between removal and second placement (months)	Implant characteristics at replacement	Follow up time of replaced implants (months)	Patients and implants with implant replacement failure (n)	Survival and success rates of replaced implants (%)	Timing of secondary failure (months)	Failure reason
Chrcanovic et al (2017) (16)	RC	2,67 patients 10,096 implants	23.9 ± 32.0	Lack/loss of osseo-inte-gration: 602 (93.8%) Fracture: 40 (6.2%)	93,6%	98 patients 159 implants	13.5 ± 17.3 After removal	Rough (including sandblasted, acid-etched, sandblasted + acid-etched) or machined surface	98.8 ± 84.6	42 implants	73.6% survival rate Success rate NR	29.2 ± 31.3	NR
Manor et al (2009) (17)	RC	NR	NR	Lack of osseo-inte-gration: 35 (87.5%) Early failure: 34 (84%) Late failure: 6 (61%)	NR	40 patients 40 implants	4.7 After removal	Rough surface (sandblasted and acid etched with or without hydroxyapatite)	63	0	100% Survival rate Success rate NR	-	-
Wang et al (2015) (18)	RC	6,456 patients 10,234 implants	NR	Early failure (100%)	99.02%	66 patients 67 implants	6.3 ± 3.1 after removal	Straumann SLA	69.4 ± 27.7	2 patients 2 implants	94.6% survival rate 90.6% success rate	One before prosthesis, One 20 months after loading	Peri-implantitis: 1 (50%) Unknown: 1 (50%) Early failure: 1 (50%) Late failure: 1 (50%)
He et al (2014) (19)	RC	NR	12.9 ± 15.9	NR	NR	12 patients 15 implants	6.8 ± 4.4 after removal	NR	33.5 ± 15.4	0	100% survival rate Success rate NR	-	-
Mardinger et al (2012) (20)	RC	NR	21.25 ± 3.4	Lack of osseo-inte-gration: 54 (37.5%) Infection: 21 (14.6%) Overload: 24 (16.6%) Unknown: 45 (31.3%) Early failure: 94 (65%) Late Failure: 50 (35%)	NR	144 patients 144 implants	4.8 ± 5.45 after removal	NR	48 ± 1.27	11 patients 11 implants	93% survival rate Success rate NR	NR	Lack of osseo-inte-gration: 2 (19%) Overload: 1 (9%) Unknown: 8 (72%) Early failure: 2 (18.2%) Late failure: 9 (81.8%)

Quaranta et al (2012) (21)	PC	NR	NR	Lack of osseo-inte-gration, peri-implant-it is, mal-position Early failure: 109 (100%)	NR	10 patients 16 implants	NR	Winsix immediately loaded, platform-switched SLA	36	0	100% survival rate 93.75% success rate	-	-
Kim et al (2010) (22)	RC	573 patients Implant NR	NR	Lack of osseo-inte-gration: 52 (86.7%) Inflamm-ation / infection: 6 (10%) Fixture fracture: 1 (1.7%) Malposition: 1 (1.7%) Early failure: 41 (68.3%) Late failure: 19 (31.7%)	NR	49 patients 60 implants	2.4 ± 3.06 after removal	NR	22.00 ± 14.56	7 implants	88.3% survival rate Success rate NR	NR	NR
Machtei et al (2008) (23)	RC	NR	8.9 ± 2.1	Lack of osseo-inte-gration: 59 (69.5%) Inflammation: 20 (23.2%) Prolonged pain: 6 (7.3%)	NR	56 patients 79 implants	6.75 ± 1.12 after removal	3i Zimmer Steri-Oss MIS	29.91 ± 2.01	13 implants	83.5% survival rate Success rate NR	NR	NR
Grossman and levin (2007) (24)	RC	1215 patients 1387 implants	5.9 ± 4.4	All during healing or early loading	93.1%	28 patients 31 implants	5.8 ± 5.2 after removal	3i Zimmer MIS	19.4 ± 11.4	8 patients 9 implants	71% survival rate 71% success rate	3.22 ± 2.31	NR
Alsaadi et al (2006) (25)	RC	578 patients Implant NR	NR	Lack of osseo-inte-gration: 58 (100%)	NR	41 patients 58 implants	4 - 6 After removal	Nobel machined (n=29) Nobel TiUnite (N=29)	NR	7 implants	87.9% Survival rate Success rate NR	11.43 ± 6.7	NR

Table (2): Patient Demographics, Periodontal Diagnosis, Smoking Status and Distribution of Initial Implant Location

Variable	Total N=183 (Frequency/%)	Survived N=165 (Frequency/%)	Failed N=18 (Frequency/%)	P Value
Age (mean ±SD)	59.7±11.2	60.0 ±11.0	57.0±12.5	0.276

Gender				0.244
Male	95(51.9)	88(53.3)	7(38.9)	
Female	88(48.1)	77(46.7)	11(61.1)	
Periodontal diagnosis				0.611
Gingivitis	32 (17.5)	29 (17.6)	3 (16.7)	
Periodontitis	123 (67.2)	112 (67.9)	11 (61.1)	
Treated Periodontitis	24 (13.1)	20 (12.1)	4 (22.2)	
First presented as edentulous	4(2.2)	4(2.4)		
Smoking Status				0.304
None	127(69.4)	113(68.5)	14(77.8)	
Current	22(12.0)	19(11.5)	3(16.7)	
Past	34(18.6)	33(20.0)	1(5.6)	
Arch				0.713
Maxilla	99 (54.1)	90 (54.5)	9 (50.0)	
Mandible	84 (45.9)	75 (45.5)	9 (50.0)	
Segment				0.399
Anterior teeth	46 (25.1)	40 (24.2)	6 (33.3)	
Posterior teeth	137 (74.9)	125 (75.8)	12 (66.7)	

*P value < 0.05

Table (3): Medical Status and Medication Intake.

Variable	Total N=183 (Frequency/%)	Survived N=165 (Frequency/%)	Failed N=18 (Frequency/%)	P Value
Medical status				
Healthy	48(26.2)	41(24.8)	7(38.9)	0.316
Respiratory	14(7.7)	13(7.9)	1(5.6)	0.725
cardiovascular	68(37.2)	61(37.0)	7(38.9)	0.873
History of Cancer	30(16.4)	28 (17.0)	2 (11.1)	0.524

Gastrointestinal	17 (9.3)	15 (9.1)	2 (11.1)	0.676
Neurological	4 (2.2)	2 (1.2)	2 (11.1)	0.049*
Endocrine	15 (8.2)	13 (7.9)	2 (11.1)	0.646
Metabolic	42(23.0)	40(24.2)	2(11.1)	0.254
Musculoskeletal	4(2.2)	4(2.4)	0	0.707
Autoimmune	5 (2.7)	5(3.0)	0	0.454
Mental	34(18.6)	32(19.4)	2(11.1)	0.533
Infectious	6(3.3)	5(3.0)	1(5.6)	0.468
Alcohol and Opioid Abuse	3(1.6)	0	3(16.7)	<0.001*
Medications				
None	61(33.3)	56(33.9)	5(27.8)	0.598
Anti-depressants	39(21.3)	36(21.8)	3(16.7)	0.768
Gastrointestinal Medications	17(9.3)	14(8.5)	3(16.7)	0.225
Anti-coagulants	25(13.7)	25(15.2)	0	0.139
Corticosteroids	5 (2.7)	5 (3.0)	0	0.454
Anti-hypertensive Medications	64 (35.0)	59 (35.8)	5 (27.8)	0.500
Lipid Lowering Medications	45(24.6)	41(24.8)	4(22.2)	0.806
Anti-diabetic Medications	12 (6.6)	11 (6.7)	1 (5.6)	0.857
Bisphosphonates	2 (1.1)	2 (1.2)	0	0.639
Others	11(6.0)	7(4.2)	4(22.2)	0.014*

Statistical comparison performed using Chi square or Fischer exact test. *P value < 0.05

Table (4): Clinical Variables Associated with Early and Late Implant Failure of Initial Implant

Variable	Total N=31 (Frequency/%)	Early N=20 (Frequency/%)	Late N=11 (Frequency/%)	P Value
Implant system of initial implant				0.024*
Nobel	24 (77.4)	18 (90.0)	6 (54.5)	

Variable	Total N=31 (Frequency/%)	Early N=20 (Frequency/%)	Late N=11 (Frequency/%)	P Value
Others	7 (22.6)	2 (10.0)	5 (45.5)	
Implant Diameter				0.030*
< 5.0mm	19(67.9)	16(80.0)	3(37.5)	
≥ 5.0mm	9(32.1)	4(20.0)	5(62.5)	
Implant Length				0.190
< 10.0mm	6(21.4)	3(15.0)	3(37.5)	
≥ 10.0mm	22(78.6)	17(85.0)	5(62.5)	
GBR at Initial Implant Placement				0.008*
Yes	4 (12.9)	2 (10.0)	2 (18.2)	
No	23(74.2)	18 (90.0)	5(45.5)	
Not mentioned	4 (12.9)	0	4 (36.4)	
Was the Implant loaded?				<0.001*
Yes	11 (35.5)	0 (0.0)	11 (100.0)	
Prosthesis Type				<0.001*
Screw retained	6 (19.4)	0 (0.0)	6 (54.5)	
Cement retained	3 (9.6)	0 (0.0)	3 (27.3)	
NA	22(71.0)	20(100.0)	2 (18.2)	
Crown/FPD				<0.001*
Crown	10 (32.3)	0 (0.0)	10 (90.9)	
FPD	1 (3.2)	0 (0.0)	1 (9.1)	
NA	20 (64.5)	20(100.0)	0 (0.0)	
Reason for Initial Implant Failure				0.174
Biological	27(87.1)	17(85.0)	10(90.9)	
Mechanical	1(3.2)	0(0.0)	1(9.1)	
Iatrogenic	3(9.7)	3(15.0)	0(0.0)	
Way of Initial Implant Removal				0.487
Forceps	9(29.0)	4 (20.0)	5(45.0)	
Trephine	2(6.5)	1(5.0)	1(9.1)	
De-torque	11(35.5)	9(45.0)	2(18.2)	
Nobel retrieval kit	4(12.9)	3(15.0)	1(9.1)	
No mentioned	5(16.1)	3(15.0)	2(18.2)	
Was GBR Performed at Time of Implant Removal				0.282

Variable	Total N=31 (Frequency/%)	Early N=20 (Frequency/%)	Late N=11 (Frequency/%)	P Value
Yes	21(67.7)	12(60.0)	9(81.8)	
No	8(25.8)	7(35.0)	1(9.1)	
Not mentioned	2(6.5)	1(5.0)	1(9.1)	
Type of Bone Graft				0.054
Autogenous	6 (19.4)	5(25.0)	1(9.1)	
Allograft	12 (38.7)	7(35.0)	5(45.5)	
Xenograft	3 (9.7)	0	3(27.3)	
NA	10(32.3)	8(40.0)	2(18.2)	
Type of Membrane				0.469
Resorbable	16 (51.6)	10(50.0)	6(54.5)	
Non-resorbable	3 (9.7)	1(5.0)	2(18.2)	
Collagen plug	2 (6.5)	1(5.0)	1(9.1)	
NA	10 (32.3)	8(40.0)	2(18.2)	

Statistical comparison performed using Chi square or Fischer exact test. *P value < 0.05

Table (5): Clinical Characteristics Associated with Replacement Implants Placed in Sites of Previously Early or Late Failed Implants

Variable	Total N=31 (Frequency/%)	Early N=20 (Frequency/%)	Late N=11 (Frequency/%)	P Value
Implant system of replacement implant				0.390
Straumann	11 (35.5)	6(30.0)	5(45.5)	
Nobel	20 (64.5)	14(70.0)	6(54.5)	
Implant Diameter				0.211
< 5.0mm	26 (83.9)	18(90.0)	8(72.7)	
≥ 5.0mm	5 (16.1)	2(10.0)	3(27.3)	
Implant Length				0.660
< 10.0mm	10(32.3)	7(35.0)	3(27.3)	
≥ 10.0mm	21(67.7)	13(65.0)	8(72.7)	
Implant Placement protocol				0.283
Guided	25(80.6)	15(75.0)	10(90.9)	
Free hand	6(19.4)	5(25.0)	1(9.1)	
GBR at time of replacement				0.664
Yes	7(22.6)	5(25.0)	2(18.2)	

Variable	Total N=31 (Frequency/%)	Early N=20 (Frequency/%)	Late N=11 (Frequency/%)	P Value
No	24(77.4)	15(75.0)	9(81.8)	
Type of Bone Graft				0.560
Autogenous	1(3.2)	1(5.0)	0	
Allograft	2(6.5)	2(10.0)	0	
Xenograft	4(12.9)	2(10.0)	2(18.2)	
NA	24(77.4)	15(75.)	9(81.8)	
Type of Membrane				0.656
Resorbable	4(12.9)	3(15.0)	1(9.1)	
None	1(3.2)	1(5.0)	0	
NA	26(83.9)	16(80.0)	10(90.9)	

Statistical comparison performed using Chi square or Fischer exact test. *P value < 0.05

Table (6): Marginal Bone Loss Measured One Year After Replacement Implant Placement

Variables	Total N=31	Early N=20	Late N=11	P Value
MBL at one year after replacement				
Mesial	1.54 ± 1.07	1.58 ± 0.99	1.46 ± 1.24	0.763
Distal	1.82 ± 1.05	1.85 ± 1.02	1.77 ± 1.16	0.840
Average	1.68 ± 0.98	1.72 ± 0.91	1.62 ± 1.15	0.786

Statistical comparison performed using independent t-test. *P value < 0.05 between Early and Late

Table (7): Number and percentage of implants with site MBL ≥ 2mm or more

Variables	Total N=31	Early N=20	Late N=11	P Value
MBL at one year after replacement				
Mesial	11(35.5)	7(35.0)	4(36.4)	0.939
Distal	16(51.6)	10(50.0)	6(54.5)	0.809
Any	17(54.8)	11(55.0)	6(54.5)	0.981

Statistical comparison performed using independent t-test. *P value < 0.05 between Early and Late

Table (8): Mean Marginal Bone Loss Values in Replacement Implants vs. Successful Implants

Variables	Replaced implant N=19	Successful implant N=19	P Value
MBL			
Mesial	1.49 ± 0.94	1.56 ± 1.08	0.784
Distal	1.91 ± 0.85	2.05 ± 1.06	0.589
Average	1.70 ± 0.83	1.81 ± 0.98	0.657

Statistical comparison performed using Paired t-test. *P value < 0.05 between replaced versus successful

Table (9): Number and percentage of implants with site MBL ≥ 2mm or more

Variables	Replaced implant N=19	Successful implant N=19	P Value
MBL			
Mesial	5(26.3)	6(31.6)	0.721
Distal	11(57.9)	10(52.6)	0.744
Any	11(57.9)	11(57.9)	1.000

Statistical comparison performed using Paired t-test. *P value < 0.05 between replaced versus successful

Table (10): Regression analysis without type of failure (early vs late) of average MBL one-year after replacement

Variables	B	Std. Error	t	*P* value
Constant	1.868	.423	4.420	<.001*
Implant replaced (Straumann vs Nobel)	1.026	.260	3.951	.001*
Reason for failure	-.389-	.136	-2.852-	.009*
Implant diameter	-.608-	.271	-2.239-	.035*

Statistical comparison performed using multiple linear regression. *P value < 0.05.

Table (11): Regression analysis with type of failure (early vs late) of average MBL one-year after replacement

Variables	B	Std. Error	t	*P* value
Constant	1.861	.429	4.337	<.001*
Implant replaced (Straumann vs Nobel)	.981	.276	3.555	.002*

Reason for failure	-.408-	.143	-2.860-	.009*
Implant diameter	-.537-	.304	-1.769-	.090
Type of failure	-.185-	.336	-.550-	.588

Statistical comparison performed using multiple linear regression. *P value < 0.05.

Appendix B

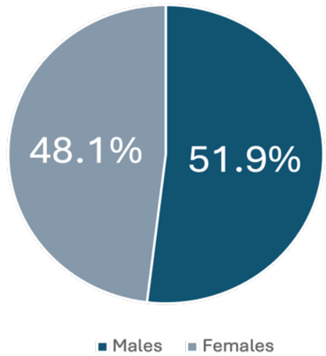

Figure (1): Gender Characteristics of Study Sample

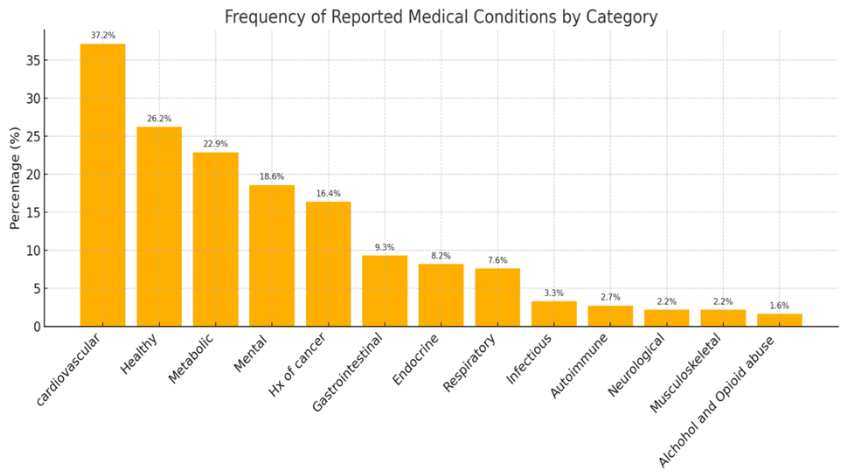

Figure (2): Frequency of Reported Medical Conditions

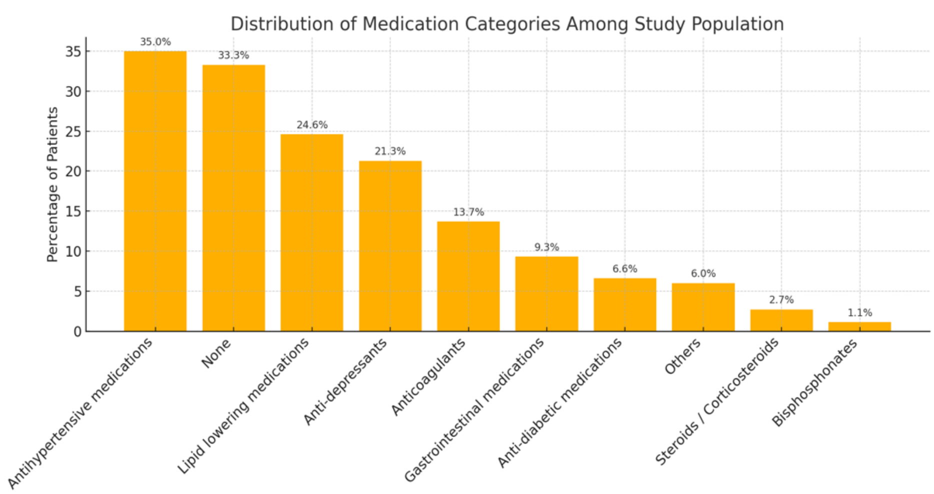

Figure (3): Distribution of Medication Categories Among Study Population

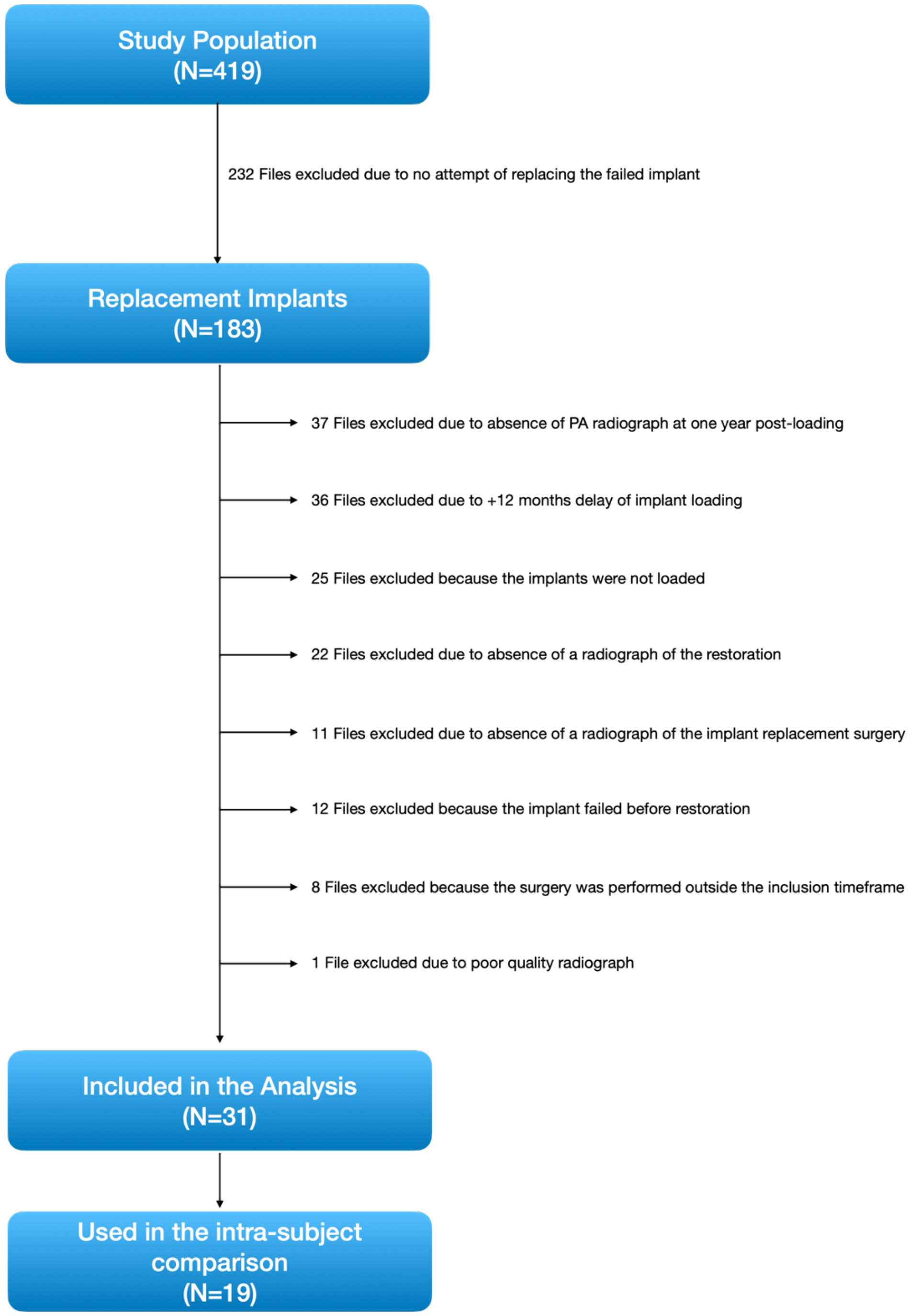

Figure (4): Flowchart of Study Population Selection and Inclusion Criteria

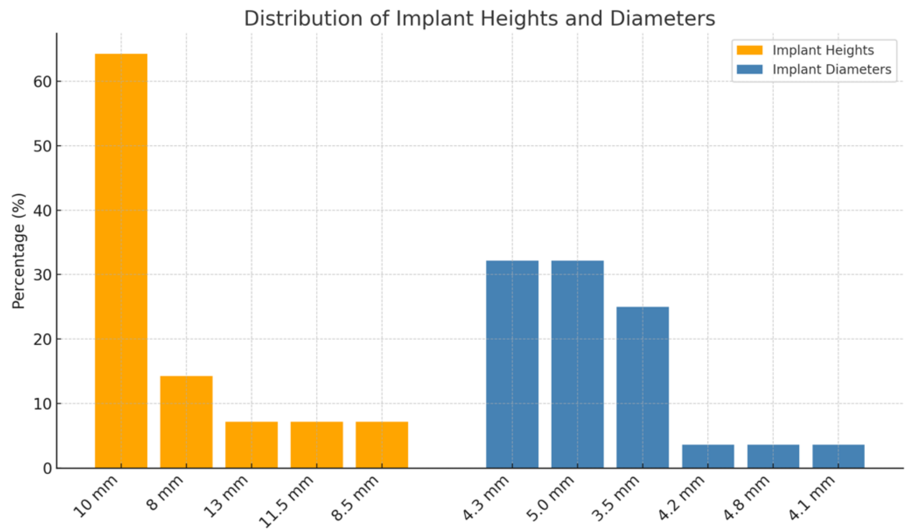

Figure (5): Distribution of Initial Implant Heights and Diameters

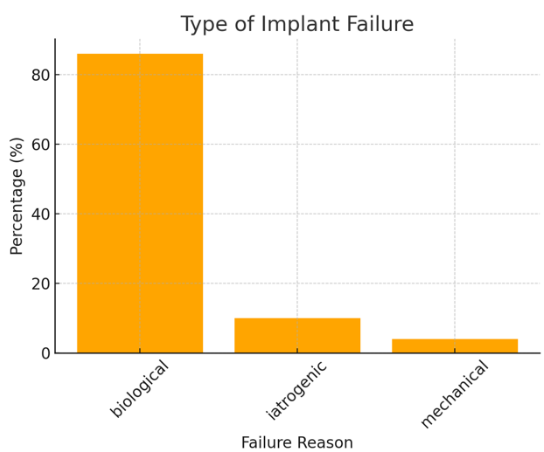

Figure (6): Type of Initial Implant Failure

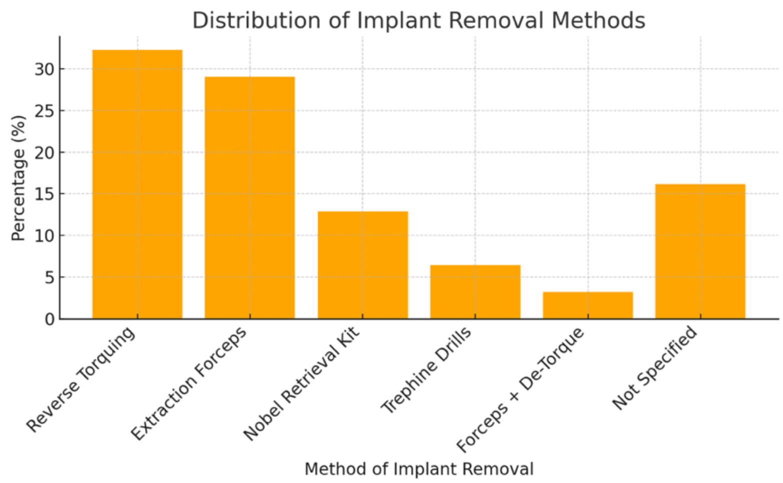

Figure (7): Distribution of Implant Removal Methods

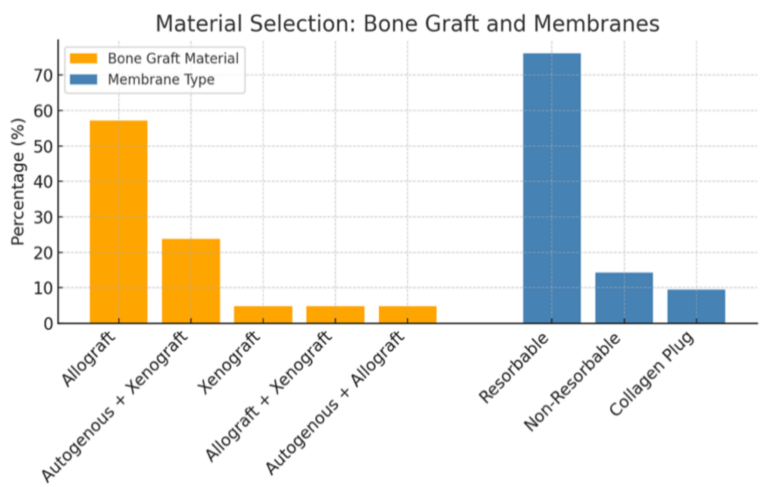

Figure (8): Material Selection (Bone Graft and Membrane) for Guided Bone Regeneration at The Time of Initial Implant Removal

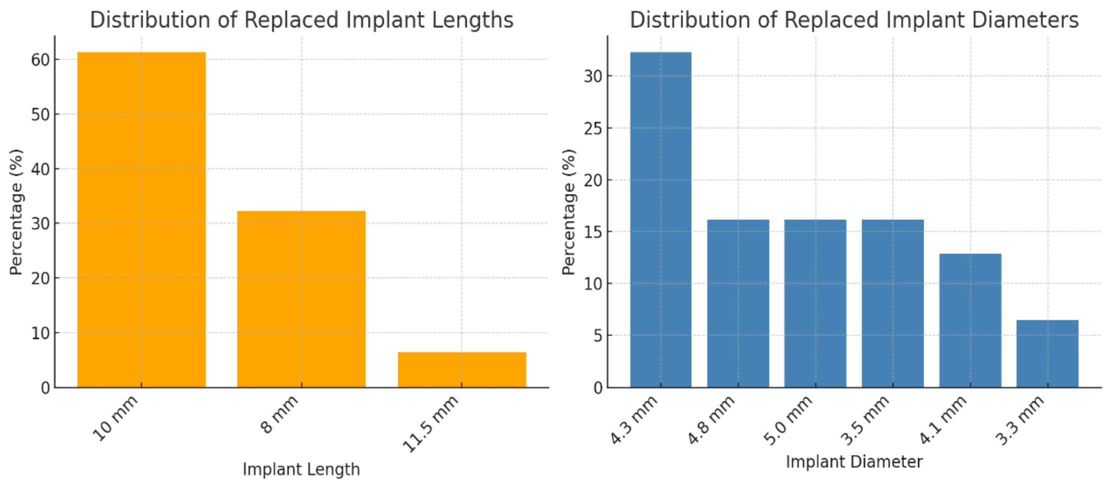

Figure (9): Distribution of Replaced Implants Lengths and Diameter

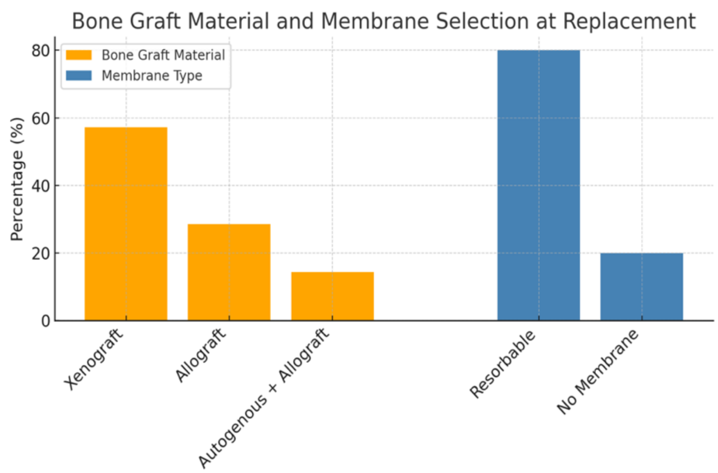

Figure (10): Bone Graft Materia and Membrane Selection at Time of Implant Replacement

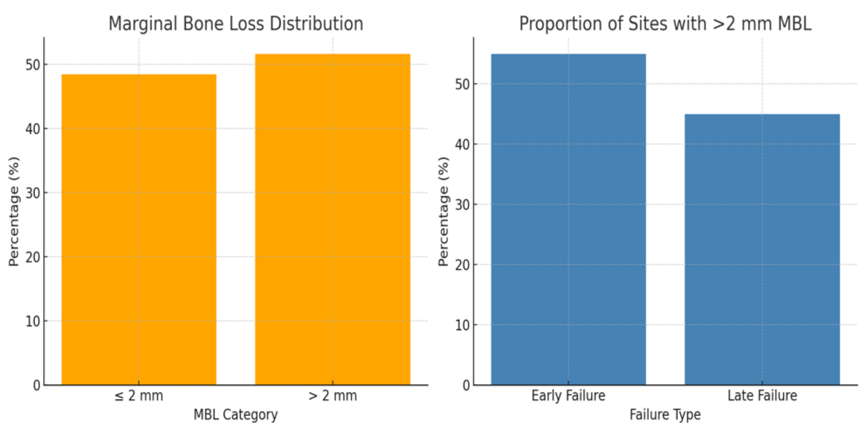

Figure (11): Marginal Bone Loss Distribution One Year After Loading of Replacement Implant and Proportion of Sites with > 2 mm MBL

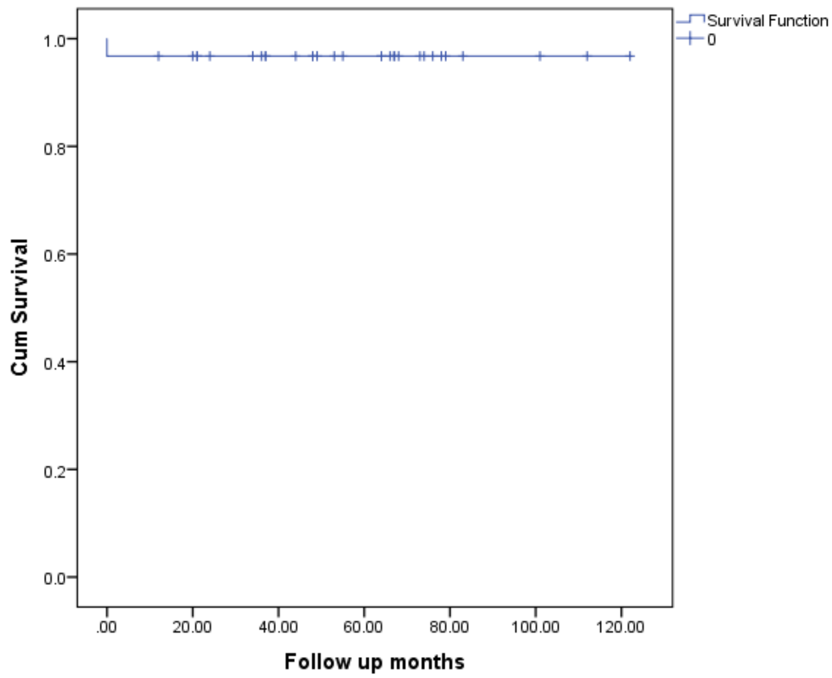

Figure (12): Kaplan Meier Survival Analysis of Replacement Implants

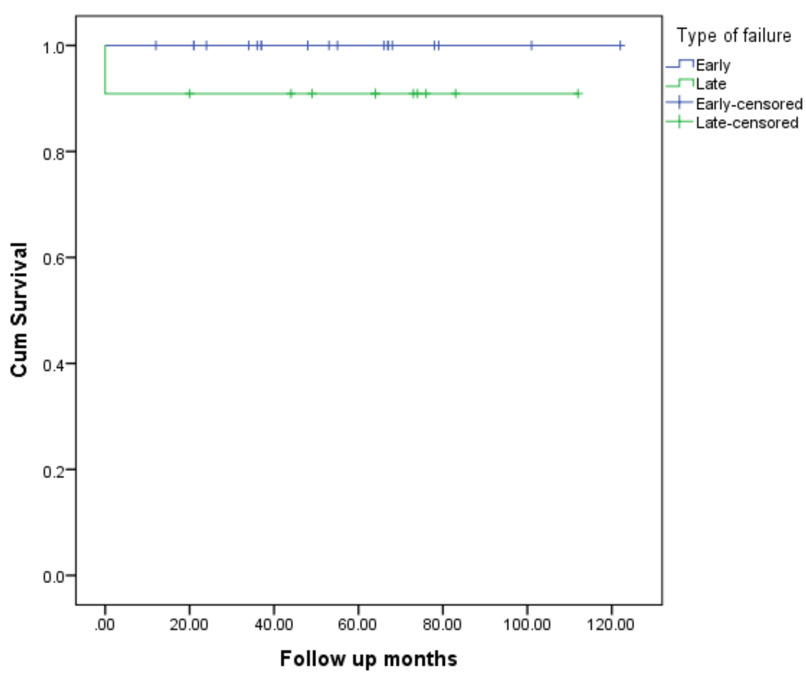

Figure (13): Kaplan Meier Survival Analysis of Replacement Implants According to Type of Failure of Initial Implant