INCIDENCE OF DENTAL IMPLANT FAILURE IN AN ACADEMIC SETTING - A CLINICAL RETROSPECTIVE STUDY
PART TWO: IMPLANT LEVEL ANALYSIS

OMAR. A. A. MOHAMMAD, DDS

A THESIS PRESENTED TO THE GRADUATE SCHOOL OF THE UNIVERSITY OF PENNSYLANIA FOR THE DEGREE OF MASTER OF SCIENCE IN ORAL BIOLOGY.

University of Pennsylvania Dental Medicine

INCIDENCE OF DENTAL IMPLANT FAILURE IN ACADEMIC SETTING – A CLINICAL RETROSPECTIVE STUDY

PART TWO: IMPLANT LEVEL

THESIS

Presented to the Faculty of Penn Dental Medicine in Fulfillment of the Requirements for the Degree of Master of Science in Oral Biology

Joseph Fiorellini DMD DMSc

Jonathan Korostoff DMD PhD

Dumitru Gogarnoiu DMD

Yu (Taylor) Wang DDS MS DMD

To my parents, my brothers, my sisters, and my loving wife, thank you for supporting, guiding, and inspiring me to reach my dreams in life.

ACKNOWLEDGEMENTS

First, special thanks to my committee chair and adviser Dr. Jonathan Korostoff, who had met with me numerous times during work hours and over the weekends to help me finishing this project without any confusions. Many thanks to my committee members Dr. Joseph P. Fiorellini who always offered support and encouragement, Dr. Dumitru Gogarnoiu for his inspiration that took this project to another level, and Dr. Yu (Taylor) Wang who was always there to review every part of this study and provide me with the guidance. Also, this project would not be done and completed without the support of my co-residents Dr. Reza Hakim Shoushtari, Dr. Thomas Yoo, and the help of the dental student Viviana Portillo. Finally, I would like to thank my family and friends for their support throughout my journey in the United States.

LIST OF ABBREVIATIONS

1. PDM	Penn Dental Medicine	**21. PS**	Platform Switch
2. PDFP	Penn Dental Faculty Practice	**22. NPS**	Non-Platform Switch
3. EMR	Electronic medical records.	**23. Perio-Prosth**	Periodontal prosthesis
4. AAID	American Academy of Implant Dentistry	**24. Perio-Ortho**	Periodontal Orthodontal
5. ADA	American Dental Association	**25. TiUnite**	Titanium Oxide
6. ASA	American Society of Anesthesiologists	**26.HA**	Hydroxyapatite
7. TiO_2	Titanium Dioxide	**27. TiPS**	Titanium plasma spraying
8. PMN	polymorphonuclear leukocyte	**28.SCs**	Single crowns
9. BMP	Bone morphogenic proteins	**29. FDPs**	Fixed dental prosthesis
10. AKT	Absence of keratinized gingiva	**30. OR**	Odds Ratio
11. PHI	Protected health information.	**31. Adj OR**	Adjusted Odds Ratio
12. SPSS/IBM	Software platform for advanced statistical analysis	**32. SE**	Standard Error.
13. Wnt	Wingless-related integration site	**33. Cl**	Confidence Interval
14. GBR	Guided bone regeneration	**34. BOP**	Bleeding on probe
15. BL	Bone Level	**35. PD**	Probing depth
16. BLT	Bone Level Tapered	**36. DO**	Distraction osteogenesis
17. TL	Tissue Level	**37. MBL**	Mean marginal bone loss
18. TLS	Tissue Level Standard		
19. TLSP	Tissue Level Standard Plus		
20. SLA	Sandblasted, Large Grit, Acid-Etched		

TABLE OF CONTENTS

ABSTRACT

Background:

Partial or complete edentulism can have a huge impact on an individual's life due to functional and/ or esthetic consequences. From ancient records dating to 2500 BC and up to the eighteenth century, missing teeth were replaced with animal teeth, human teeth, or "artificial" teeth made from melted wax, gold, or metal alloys. Although considered "state of the art" at the time, these approaches were fraught with problems. A dramatic change occurred with the introduction of root form osseointegrated dental implants into the clinical armamentarium. Today, such implants are used routinely to replace missing teeth in a highly successful and predictable manner. However, in a small percentage of patients, clinical failures do occur. Research has shown that the etiology of failures is multifactorial and can be due to patient-related and/or exogenous factors.

Aim:

The aim of this retrospective study was to evaluate the incidence of failure and the associated co-contributing factors of implants placed and restored in an academic setting.

Materials and Methods:

The electronic dental records of all patients who had implants placed and restored in the pre- and post-doctoral clinics or the faculty practice of the University of Pennsylvania School of Dental Medicine between June 1st, 2016 to August 31st, 2019 and explanted before February 29th, 2020, were identified using the implant placement procedure code D6010. From this group, patients that

experienced an implant failure were then identified using the implant removal procedure code, D6100.

Results:

In total, 1609 patients received 3,180 dental implants during the timeframe of the study, 883 patients treated at PDM (total of 2162 implants) and 726 (total of 1018 implants) at PDFP. The overall percentage of patients who experienced failures was 4.9% (X/1609), 6.0% of patients treated at PDM (X/883) and 3% (X/726) treated at PDFP. At the implant level, the school-wide failure rate was 3.49%, 3.7% for implants placed at PDM and 3.0% for PDFP.

Implant-related variables that were significantly over-represented in the failure group (combined data for both PDM and PDFP) showed that some variables were significantly overrepresented in the failure group such as Active Nobel BioCare (21.1%, P-value<0.001) and Straumann tissue level (27.8, P-value<0.001). In term of surfaces, both SLA and osseotite surfaces were overrepresented with P-value=0.001 and <0.001 respectively. 8-10 mm length (6.6%, P-value=0.021) and 4-4.7 mm width (6.7%, P-value=0.040), No Implant Restoration (14.6%, P-value<0.001), No Ridge Preservation (11.8%, P-value=0.006), Perio-Prosth Resident clinicians (29.2%, P-value<0.001), and Maxillary Anterior site (13.4%, P-value<0.001) were significantly overrepresented in the failure as well.

Based on the multivariate conditional logistic regression results in Table 3C, estimated odds of implant failure in people with multiple implants was about 4 times than people with single implant (Adj OR=4.04, P-value=0.004); estimated odds of implant failure in people who received bone

graft “before and during” the implant was about 5.6 times than people with no bone graft (Adj OR=5.57, P-value=0.012); estimated odds of implant failure in people with no restored implant was about 33 times than people with restored implant (Adj OR=0.03, P-value<0.001); Other variables did not show any significant association with implant failure (with P-values>0.05).

Conclusion:

Implant therapy is viable option for replacing missing teeth. This retrospective study showed that incidence of implant failure in academic setting was not significant. Multiple implants, bone grafting during implant placement in previously grafted site, and non-restored implant showed significant association with implant failure.

INTRODUCTION

Maintaining the health of the structures within the oral cavity, including the dentition, has been recognized as an important issue since the beginning of civilization. In particular, replacement of missing teeth to address functional and esthetic deficits, and for religious purposes in certain situations has been practiced throughout human history.[1] As early as 2500 BC, ancient Egyptians used gold ligature wires to stabilize periodontally involved teeth while ancient Chinese used carved bamboo pegs to replace missing teeth.[1,2] The most ancient and first "alloplastic implant" was discovered by Dr. Bobbio when he examined the remains of ancient Mayans and confirmed the presence of bone around wedges prepared from seashells.[3] During the Middle Ages, specifically in the 10th century, Abu Calsis wrote a book "Kitab al Tasrif" in which he explained the procedure of replacing missing teeth with artificial ones made of mammals' bones.[4] In the 18th century, edentulous sites were replaced using animal teeth, human teeth, melted wax and other materials. The first gold implant was used in 1809 by Maggiolo.[5] This was followed by the use of implants made from a diverse array of materials including vitallium, cobalt-chromium-molybdenum, vitreous carbon, and aluminum. [6] [7] Although considered "state of the art" at the time, these approaches were fraught with problems. A dramatic change occurred with Dr. P.-I. Brånemark's accidental discovery of the process of osseointegration[8] and the subsequent introduction of root form osseointegrated dental implants into the clinical armamentarium.

Dr. Brånemark defined osseointegration as a direct structural and functional contact at the microscopic level between bone and a load-carrying endosseous implant. [9] In addition the American Academy of Implant Dentistry (AAID) in 2016 explained osseointegration as the

osseous contact to the surface of a dental implant through osseous cellular hemidesmosomes in which cells are engaged by titanium dioxide (TiO_2).[10] The mechanism of osseointegration has been studied and described to resemble the healing of primary fractured bone. Moreover, it is a dynamic process wherein molecular and cellular activity involved in bone formation that might depend on implants characteristics. The presence of a blood clot at the interface between the bone and implant initiates a complex cascade of activity.[11] It leads to phagocytic activity through neutrophils (PMNs) and monocytes/macrophages followed by the release of a variety of growth factors including bone morphogenetic proteins (BMP) that facilitate migration of the osteoprogenitor cells to the site through chemotaxis.[12] [13] This is followed by proliferation and differentiation of these cells into osteoblasts that participate in osseous healing through distance and contact osteogenesis.[12] Histological studies of samples derived from both animals and humans confirmed that osseointegration occurs in stages involving woven bone formation within 4-6 weeks, lamellar bone deposition by 8 weeks, and adaptation of bone structure to load through bone remodeling after 16 weeks.[13,14]

Today, such implants are used routinely to replace missing teeth in a highly successful and predictable manner. Numerous longitudinal studies have reported implant survival rates of 91-95%.[15,16] However, in a small percentage of patients, clinical failures do occur. Severe bone loss, and severe mobility are considered failed implants. Research has shown that the etiology of failures is multifactorial and can be due to patient-related and/or exogenous factors. Esposito and colleagues classified implant failures as either biological early or late failures. Early biological failure (primary, before loading) is defined as a failure to achieve osseointegration while late failure (secondary, after loading) is defined as a failure to maintain osseointegration. Beyond the

distinction between early and late biological failures, numerus other types of failures have been described in the literature. For example, mechanical failures include fracture of implants, screws, and prostheses. Iatrogenic failures have been described such as stably osseointegrated implant that is mispositioned and non-restorable. Inadequate, or insufficient patient adaptation to an implant-supported restoration due to psychological, aesthetical, and phonetical issues represent another type of failure.[15,16] It should be stressed that early failure is not synonymous with periimplantitis. This condition is described as an inflammatory reaction to the structure around a stable osseointegrated implant leading to hard and soft tissue loss. [17] Multiple factors appear to influence the early implant failure. Amongst others, examples include the extent of surgical trauma, improper site preparation, microbial contamination, lack of primary stability, malpositioning of fixtures, type of implant, and quality of the adjacent bone. Due to a paucity of studies in the existing literature, the impact of these factors on implant failure remains unclear.

Factors Potentially Contributing to Enhanced Risk of Implant Failure

Clinicians are faced with another dilemma in implant dentistry. It has been documented that there are more than 600 implant systems sold around the world. The literature suggests that most of these manufactures have zero scientific evidence to support the efficacy of their system while the little scientific evidence that does exist supports the effectiveness of a limited number of systems. Furthermore, there is a lack of well-designed clinical publications comparing different implant systems under relevant circumstances. However, one published clinical study compared the success rates of three different implant systems in 14 patients and found that the success rates were the same.[18] The author's concluded that implant design is not a factor that affects success rates.

Dental implant surfaces have been studied and modified over time. It has been proven that the surface characteristics of a particular implant play a major role in osseointegration in the context of contact osteogenesis. The main reason is that certain surface characteristics decrease healing time by improving hemostasis and promoting bone apposition; thus, improve osseointegration.[2] Nasatzky et al [19] showed that osteoblasts are sensitive to rough surfaces and induces them to undergo differentiation. He concluded that instead of the conventional 12 week healing time allowed for osseointegration, titanium implants with rough surfaces require a shorter healing period before loading (6 to 8 weeks) and this includes shorter (6- to 8-mm) roughened implants. According to Albertson and Wennerberg (2004) implants can be divided into four different categories, depending on roughness value of Sa: smooth (Sa<0.5 μm); minimally rough (Sa between 0.5-1.0 μm), moderately rough (Sa between 1.0-2.0 μm); rough (Sa>2.0 μm) and based on the scale of features it can be divided into Macro, Micro, and Nano roughness. [20]

Implant surfaces have been further classified based on the type of treatment: ablative/subtractive (sand blasting, acid etching, anodization, laser etching) versus additive processes (plasma spraying, sol gel coating). These processes result in different surface textures which are classified as concave produced by additive processes (hydroxy apatite or titanium plasma spraying) or convex created by subtractive processes (etching and sandblasting). The orientation of surface irregularities has also been used to categorize implant surfaces as either Isotropic (irregularities oriented in the same direction) or Anisotropic (irregularities oriented in different directions. Finally, surface modifications can be classified as physicochemical, morphological, or biochemical.[20-23]

Machined (turned) implants surfaces are considered the first generation of dental implants in which Brånemark conducted his studies. It shows no surface features other than marks from the manufacturing process. [24] On the other hand, etched implants surfaces resulting from treatment with both hydrochloric and sulfuric acid exhibited a micro complexity that provide the roughness for better adhesion. [25] In a comparative study, Lazzara (2003) found that the value of bone-implant contact was 34% for machined and 73% for the dual acid etched surface. [26] Also, he reported a high success rate of >98% and survival rate ranging from 96.5% to 99.4% for acid etched surfaces. [26]

In clinical scenarios of limited vertical bone height and/or proximity to vital anatomic structures, shorter implants are becoming of greater interest. Fuggazzotto (2008) in his retrospective study evaluating 2073 implants varying in length (6, 7, 8, or 9 mm) reported a high survival rate ranging from 89.1% to 99.7% for the four lengths and concluded that the survival rates of "shorter" implants were comparable to those of longer implants. [27] Another study reported that short (5 to 8 mm) implants had low complication rates and are a viable option for resorbed posterior mandibles. [28] In contrast, in one study evaluating factors that contribute to early implant loss the author concluded that the use of shorter implants (< 10 mm) had a 5.8-fold greater risk of early implant failure relative to the risk for longer implants ($p = 0.0230$). [29]

Implant diameter has been evaluated as a risk factor for failure in a number of studies. We know from different numerous consensus statements in our literature that narrower implants are the selection of choice when it comes to esthetic cases. However, most of these statements are based

on case reports with minimal clinical research to support a definitive conclusion. One study showed that implants narrower than 4 mm were not a relevant risk factor for early implant failure. [30]Similarly, Olate et al [31] concluded that there is not a relationship between early failure and implant diameter. Regarding wide diameter implants, meta-analysis concluded that wide-diameter implants have survival rates similar to that of narrower implants.[32]

Technological advances in implant dentistry and along with our enhanced understating of the biology underlying bone remodeling led to an evolution in implant placement protocols. One example is the immediate placement of implants into extraction sockets. This approach has been evaluated in both animal and human studies. Histological animal studies proved that immediate implants placed in extracted socket reduced the amount of remodeling but did not prevent it.[33,34] In addition, these studies showed that osseointegration can be achieved around immediately placed implants. [35] Comparative studies have shown that immediate and delayed implants are equally effective. However, the advantages of immediate implants are reducing treatment time, reducing surgical procedures, preserving soft and hard tissues, and more effectively meeting patients' expectations. With a reported mean survival rate of 97% as a mean survival rate and 98.4% overall success rate, immediate implant placement is a viable treatment for replacing missing teeth. [36]

Advances in periodontal bone regenerative surgical techniques have made it possible to augment deficient areas of the jaws to facilitate implant placement. Currently there a number of different surgical approaches to enhancing bone volume. A variety of distinct materials have been

developed for use in these procedures including bone grafts (autografts, allografts, xenografts, and alloplasts), growth factors, and a diverse array of barrier membranes. Since a large number of patients present with atrophic ridges unsuitable for implant placement, bone augmentation procedures are becoming a routine component of clinical practice. Thus, it is imperative that we know whether the success rate of implants placed in grafted bone is equivalent to that of fixtures placed in native bone. In Fiorellini and Nevins's [41] systematic review (2003), it was reported that the survival rate for implants placed in augmented bone was comparable to implants placed in non-grafted sites. Another retrospective stud7 showed that survival rate of implants in grafted healed sites was 97.3%, compared to 98.5% in non-grafted healed sites [42].The influence of bone grating on early implant failure has not been adequately reported in the literature and is still being studied.

Another potential factor that can contribute to risk of implant failure is bone quality. Anatomic studies have clearly shown difference in bone quality and quantity between the maxilla and mandible as well as the anterior and posterior aspects of each jaw. Lekholm *et al* [43] classified bone quality based on radiographic appearance into four types: Type 1 composed of homogenous compact bone; Type 2 made up of thick compact bone surrounding a dense trabecular bone; Type 3 comprised of thin cortical bone surrounding a dense trabecular bone; and Type 4 exhibiting thin cortical bone surrounding low density trabecular bone. *In vivo* studies showed that osteotomies made in different bone type healed differently and revealed strong correlation between these sites and Wnt signaling. [44] The existing literature indicates that mandibular implants are superior and have a higher success rate than maxillary implants. [45,46] In addition, Fouda *et al* showed that early implant failure is more critical in anterior maxillary sites compared to other aspects of the jaws. [47]

Today, implant dentistry is being practiced by clinicians with different educational backgrounds and years of experience. One would expect that implants placed by experienced surgeons have a superior outcome compared to those placed by less experienced clinicians. According to Kang (2019), implants placed by faculty members showed a significantly lower early implant failure rate compared to fixtures placed by residents.[37] Another study showed that the early failure rate was 2 folds higher for inexperienced surgeons. [48] Thus, the extent of a clinician's experience placing implants does impact the relative success and survival rates of the fixtures they place.

The dental profession now appreciates that implant failures are not due to a single issue. Instead, a multitude of factors acting alone or in combination with one another can contribute to the rate of implant failures. Additional well-designed clinical studies are needed to clarify key factors that lead to increased failure rates. This will enable clinicians to take appropriate steps to mitigate these factors and enhance the success rate of the implants they place. It is important to appreciate that factors at every stage (diagnostic, treatment planning, treatment and maintenance) of a patient's treatment have the potential to act as risk factors for implant failure.

AIM AND STUDY OBJECTIVES

The aim of this retrospective study was to evaluate the incidence of dental implant failure and the associated co-contributing factors in an academic setting by evaluating the outcomes of implant placed in the pre-doctoral and resident clinics of Penn Dental Medicine (PDM) and faculty practice clinics (PDFP) from 06/01/2016 to 02/29/2020.

The primary objective was to determine the implant failure rate of fixtures placed in PDM and PDFP.

The secondary objective was to identify key factors contributing to the rate of implant failures in the two patient cohorts at the level of the patient (age, gender, past medical history, smoking, history of periodontal disease, and maintenance regimen) and the implant level (implant systems, implant design, surface characteristics, length, width, immediate implants, implants in grafted/non-grafted sites, anatomic site, and type of prosthesis.

The tertiary objective was to determine whether clinical experience affects implant survival rates.

MATERIALS AND METHODS

This clinical retrospective study was conducted using Axium electronic health records for all patients who received dental implants at University of Pennsylvania School of Dental Medicine (PDM and PDFP) between 06/01/2016 to 02/29/2020.

Data from both practices "Patient level" and "Implant level" was categorized as "Patient count" and "Implant count". All data were reviewed by two examiners (R.H and O.M) after Institutional review board approval was obtained. Implant placement (ADA CodeD6010) defined as timeline A from 06/01/2016 to 08/31/2019 and implant removal (ADA Code D6100) as timeline B from 06/01/2016 to 02/29/2020. All date were confirmed through Axium reports using ADA codes, implant checklist, hard copies, and clinical notes. All date and information were collected without any link to the subject's identity.

Inclusion criteria consisted of any patients older than 18 years and received implant(s) at PDM and PDFP, medical conditions of diabetes, bisphosphonate (IV and Oral), smoking, penicillin allergy.

Exclusion criteria consisted of any patients younger than 18 years old, patient who received implant outside Penn Dental, and who received/removed implant at Penn Dental not within the timeframe of this study.

These criteria were included for both implant level and patient level analysis.

A-Patient Count:

1 - Implant placement and implant removal

1-1: Total number of patients who had implants placed (D6010) during timeline A.

1-2: Total number of patients who had implants placed during time line A and removed (D6100) during time line B (the patients in this category should have codes D6100 in addition to code D6010 during the dates mentioned above).

1-3: The number of patients who received implants (D6010) during time line A in each of the following categories:

- Female
- Male
- Age (18-30 y/o)
- Age (31-50 y/o)
- Age (51-70 y/o)
- Age (70<)
- Medical condition: Diabetes
- Medical condition: Smoking
- Medical condition: Bisphosphonate (IV, oral
- Allergy: Penicillin allergy

1-4: The number of patients who had implants removed (D6100) during time line B in each of the following categories:

- Female
- Male

- Age (18-30 y/o)
- Age (31-50 y/o)
- Age (51-70 y/o)
- Age (70 < years)
- Medical condition: Diabetes
- Medical condition: Smoking
- Medical condition: Bisphosphonate (IV, oral)
- Allergy: Penicillin allergy

2 - Implants placed in the grafted sites

2-1: The number of patients who had implants placed (D6010) with bone graft (D7953, D4263.1, D4263.2, D4263.E, D4263.H, D4263.4, D4263.5, D4263.6, D4263.7, D4263.D, D4263.F, D7950) *before* implant placement (the time of bone graft can be outside of timeline A. However, the time of implant placement should be within time line A).

2-2: The number of patients who had implants placed (D6010) with bone graft (D7953, D4263.1, D4263.2, D4263.E, D4263.H, D4263.4, D4263.5, D4263.6, D4263.7, D4263.D, D4263.F, D7950) *same day* as the implant placement.

2-3: The number of patients who had implants placed (D6010) with bone graft (D7953, D4263.1, D4263.2, D4263.E, D4263.H, D4263.4, D4263.5, D4263.6, D4263.7, D4263.D, D4263.F, D7950) *after* implant placement.

2-4: The number of patients who had implants removed (D6100) during time line B for category.

2-5: Each patient in this category should have code D6010 during timeline A, as well as one of the following codes D7953, D4263.1, D4263.2, D4263.E, D4263.H, D4263.4, D4263.5, D4263.6, D4263.7, D4263.D, D4263.F, D7950. The timeline for bone graft can be out of time line A or B, however, must be placed before implant placement)

2-6- The number of implants removed (D6100) during time line B for category 2-3. (Each implant in this category should have code D6010 during timeline A, as well as one of the following codes D7953, D4263.1, D4263.2, D4263.E, D4263.H, D4263.4, D4263.5,D4263.6, D4263.7, D4263.D, D4263.F, D7950. The timeline for bone graft has to be placed after implant placement)

2-7: Each patient in this category should have code D6010 during timeline A, as well as one of the following codes D7953, D4263.1, D4263.2, D4263.E, D4263.H, D4263.4, D4263.5, D4263.6, D4263.7, D4263.D, D4263.F, D7950. The timeline for bone graft is the same day as implant placement).

2-8: Each patient in this category should have code D6010 during timeline A, as well as one of the following codes D7953, D4263.1, D4263.2, D4263.E, D4263.H, D4263.4, D4263.5, D4263.6, D4263.7, D4263.D, D4263.F, D7950. The timeline for bone graft must be placed after implant placement)

3 - Implants placed augmented sinus sites

3-1: The number of patients who had implants placed (D6010) with sinus augmentation (D7951, D7952) *before* implant placement (the time of sinus augmentation can be before timeline A) However, the time of implant placement should be within time line A.

3-2: The number of patients who had implants placed (D6010) with sinus augmentation (D7951, D7952) *same day* as implant placement.

3-3: The number of patients who had implants removed (D6100) during time line B for the category 3-1. (Each patient in this category should have code D6010 during timeline A as well as one of the following codes D7951, D7952 performed *before* implant placement date)

3-4: The number of patients who had implants removed (D6100) during time line B for the category 3-2. (Each patient in this category should have code D6010 during timeline A as well as one of the following codes D7951, D7952 performed *at the same day* of implant placement)

4 - Immediate implants

4-1: The number of patients who had immediate implants placed during timeline A: code D7140/D7210 and D6010 should be performed the same day.

4-2: The number of patients who had immediate implants removed (D6100) during time line B for category 4-1. (Each patient in this category should have code D6010 and D7140/D7210 performed the same day and during timeline A, and code D6100 during timeline B).

5 - Restored implants

5-1: Number of patients who had implants placed during time line A and restored within timeline B. Each patient in this category should have the code D6010 during time line A, as well as one of the following codes (D6058, D6057, D6057Z (D6058, D6058A, D6059, D6061, D6062, D6064), D6064Z (D6065, D6065A, D6066, D6067), D6067Z (D6068, D6069, D6071, D6072, D6074), D6074Z (D6075, D6076, D6077), D6052 during time line B.

5-2: Number of patients who had implants removed (D6100) during timeline B for category 5-1.

6 - Periodontal Disease and Periodontal Maintenance

6-1: Total number of patients who received implants (D6010) during time line A, who also have a history of periodontal disease (codes D499T2, D499T3, D499T4, D4999.1) within no specific time line (since the beginning of becoming a patient at PDM until now).

6-1-1: Total number of patients in category 6-1, who also have been coming for their periodontal maintenance (any of the following codes D110, D4910, D4910.2, D4910.3, D4910.4) during time line B, and please specify the number of times these codes (D110, D4910, D4910.2, D4910.3, D4910.4) were completed (to determine if they were coming for regular maintenance and follow ups or not).

6-2: Total number of patients who received implant (D6010) during time line A and had that implant removed (D6100) during time line B, who also have a history of periodontal disease (codes D499T2, D499T3, D499T4, D4999.1) within no specific time line (since the beginning of becoming a patient at PDM until now).

6-2-2: Total number of patients in category 6-2, who also have been coming for their periodontal maintenance (any of the following codes D110, D4910, D4910.2, D4910.3, D4910.4) during time line B, and please specify the number of times these codes (D110, D4910, D4910.2, D4910.3, D4910.4) were completed (to determine if they were coming for regular maintenance and follow ups or not).

7 - Recall

7-1: Total number of patients who received implant (D6010) during time line A and their history of recalls (codes D110, D4910, D4910.2, D4910.3, D4910.4) during time line B. As well as the number of the times these codes (D110, D4910, D4910.2, D4910.3, D4910.4) were completed (to determine if they were coming for regular maintenance and follow ups or not).

7-2: Total number of patients who received implant (D6010) during time line A and had the implant removed (D6100) during timeline B, and their history of recalls (codes D110, D4910, D4910.2, D4910.3, D4910.4) during time line B. As well as the number of the times these codes (D110, D4910, D4910.2, D4910.3, D4910.4) were completed (to determine if they were coming for regular maintenance and follow ups or not).

8 – Anatomic Site

8-1: Total number of patients who had implants placed (D6010) based on tooth number, during time line A.

8-2: Total number of patients who had implants placed during time line A and removed (D6100) during time line B, based on tooth number (The implants in this category should have codes D6100 in addition to code D6010 during the dates mentioned above.)

8-3: The number of patients who had implants placed (D6010) based on tooth number, during time line A in each of the following categories:

- Female
- Male
- Age (18-30 y/o)

- Age (31-50 y/o)
- Age (51-70 y/o)
- Age (70<)
- Medical condition: Diabetes
- Medical condition: Smoking
- Medical condition: Bisphosphonate (IV, oral)
- Allergy: Penicillin allergy

8-4: The number of patients who had implants removed (D6100) based on tooth number, during time line B in each of the following categories:

- Female
- Male
- Age (18-30 y/o)
- Age (31-50 y/o)
- Age (51-70 y/o)
- Age (70<)
- Medical condition: Diabetes
- Medical condition: Smoking
- Medical condition: Bisphosphonate (IV, oral)
- Allergy: Penicillin allergy

9 - Implant System

9-1: Total number of patients who had implants placed (D6010) during time line A, for each of the following brands: Astra, Nobel Biocare (Replace, Active, Parallel CC), Straumann (SLA active, SLA), Biomet 3i (T3, Nanotite, osseotite).

9-2: Total number of patients who had implant placed during time line A and removed (D6100) during time line B for each of the following brands: Astra, Nobel Biocare (Replace, Active, Parallel CC), Straumann (SLA active, SLA), Biomet 3i (T3, Nanotite, osseotite).

10 - Implant Length and Width

10-1: Total number of patients who had implant placed (D6010) during time line A, for each of the following categories: Length: < 8 mm, 8 mm – 10 mm, >10 mm and Width: < 4 mm, 4 mm-4.7 mm, > 4.7mm.

10-2 Total number of patients who had implant placed during time line A and removed (D6100) during time line B for each of the following categories: Length: < 8 mm, 8 mm – 10 mm, >10 mm and Width: < 4 mm, 4 mm-4.7 mm, > 4.7mm.

B - Implant Count

1 - Implant placement and implant removal

1-1: Total number of implants placed (D6010) during timeline A.

1-2: Total number of implants placed during time line A and removed (D6100) during time line B (Implants in this category should have codes D6100 in addition to code D6010 during the dates mentioned above.)

1-3: The number of implants placed (D6010) during time line A in each of the following categories:

- Female
- Male
- Age (18-30 y/o)
- Age (31-50 y/o)
- Age (51-70 y/o)
- Age (70<)
- Medical condition: Diabetes
- Medical condition: Smoking
- Medical condition: Bisphosphonate (IV, oral
- Allergy: Penicillin allergy

1-4: The number of implants removed (D6100) during time line B in each of the following categories:

- Female
- Male
- Age (18-30 y/o)
- Age (31-50 y/o)

- Age (51-70 y/o)
- Age (> 70)
- Medical condition: Diabetes
- Medical condition: Smoking
- Medical condition: Bisphosphonate (IV, oral)
- Allergy: Penicillin allergy

2 - Implants placed in the grafted sites

2-1: The number of implants placed (D6010) with bone graft (D7953, D4263.1, D4263.2, D4263.E, D4263.H, D4263.4, D4263.5, D4263.6, D4263.7, D4263.D, D4263.F, D7950) *before* implant placement (the time of bone graft can be outside of timeline A. However, the time of implant placement should be within time line A)

2-2: The number of implants placed (D6010) with bone graft (D7953, D4263.1, D4263.2, D4263.E, D4263.H, D4263.4, D4263.5, D4263.6, D4263.7, D4263.D, D4263.F, D7950) *same day* as the implant placement.

2-3: The number of implants placed (D6010) with bone graft (D7953, D4263.1, D4263.2, D4263.E, D4263.H, D4263.4, D4263.5, D4263.6, D4263.7, D4263.D, D4263.F, D7950) *after* implant placement.

2-4: The number of implants removed (D6100) during time line B for category 2-1. (Each implant in this category should have code D6010 during timeline A, as well as one of the following codes D7953, D4263.1, D4263.2, D4263.E, D4263.H, D4263.4, D4263.5, D4263.6, D4263.7, D4263.D, D4263.F, D7950. The timeline for bone graft can be out of time line A or B, however, must be placed before implant placement).

2-5: The number of implants removed (D6100) during time line B for category 2-2. (Each implant in this category should have code D6010 during timeline A, as well as one of the following codes D7953, D4263.1, D4263.2, D4263.E, D4263.H, D4263.4, D4263.5, D4263.6, D4263.7, D4263.D, D4263.F, D7950. The timeline for bone graft is the same day as implant placement).

2-6: The number of implants removed (D6100) during time line B for category 2-3. (Each implant in this category should have code D6010 during timeline A, as well as one of the following codes D7953, D4263.1, D4263.2, D4263.E, D4263.H, D4263.4, D4263.5, D4263.6, D4263.7, D4263.D, D4263.F, D7950. The timeline for bone graft must be placed after implant placement)

3 - Implants placed in augmented sinus sites

3-1: The number of implants placed (D6010) with sinus augmentation (D7951, D7952) *before* implant placement (the time of sinus augmentation can be before timeline A) However, the time of implant placement should be within time line A.

3-2: The number of implants placed (D6010) with sinus augmentation (D7951, D7952) *same day* as implant placement.

3-3: The number of implants removed (D6100) during time line B for the category 3-1. (Each implant in this category should have code D6010 during timeline A as well as one of the following codes D7951, D7952 performed *before* implant placement date).

3-4-: The number of implants removed (D6100) during time line B for the category 3-2. (Each implant in this category should have code D6010 during timeline A as well as one of the following codes D7951, D7952 performed *at the same day* of implant placement).

4 - Immediate implants

4-1: The number immediate implants placed during timeline A: code D7140/D7210 and D6010 should be performed the same day.

4-2: The number of immediate implants removed (D6100) during time line B for category 4-1. (Each implant in this category should have code D6010 and D7140/D7210 performed the same day and during timeline A, and code D6100 during timeline B).

5 - Restored implants

5-1: Number of implants placed during time line A and restored within timeline B. Each implant in this category should have the code D6010 during time line A, as well as one of the following codes D6058, D6057, D6057Z (D6058, D6058A, D6059, D6061, D6062, D6064), D6064Z (D6065, D6065A, D6066, D6067), D6067Z (D6068, D6069, D6071, D6072, D6074), D6074Z (D6075, D6076, D6077), D6052 during time line B.

5-2: Number of implants removed (D6100) during timeline B for the category 5-1.

6 - Periodontal Disease and follow ups/Periodontal Maintenance

6-1: Total number of implants (D6010) during time line A, in a patient with a history of periodontal disease (codes D499T2, D499T3, D499T4, D4999.1) within no specific time line (since the beginning of becoming a patient at PDM until now).

6-1-1: Total number of implants in category 6-1, in the above patients who have been coming for their periodontal maintenance (any of the following codes D110, D4910, D4910.2, D4910.3, D4910.4) during time line B, and please specify the number of times these codes (D110, D4910, D4910.2, D4910.3, D4910.4) were completed (to determine if they were coming for regular maintenance and follow ups or not).

6-2: Total number of implants (D6010) during time line A and had that implant removed (D6100) during time line B, in a patient with a history of periodontal disease (codes D499T2, D499T3, D499T4, D4999.1) within no specific time line (since the beginning of becoming a patient at PDM until now).

6-2-2: Total number of implants in category 6-2, in the above patients who have been coming for their periodontal maintenance (any of the following codes D110, D4910, D4910.2, D4910.3, D4910.4) during time line B, and please specify the number of times these codes (D110, D4910, D4910.2, D4910.3, D4910.4) were completed (to determine if they were coming for regular maintenance and follow ups or not).

7- Recall

7-1: Total number of implants placed (D6010) during time line A and their history of recalls (codes D110, D4910, D4910.2, D4910.3, D4910.4) during time line B. As well as the number of the times these codes (D110, D4910, D4910.2, D4910.3, D4910.4) were completed (to determine if they were coming for regular maintenance and follow ups or not).

7-2: Total number of implants received (D6010) during time line A and the implant removed (D6100) during timeline B, and the history of recalls (codes D110, D4910, D4910.2, D4910.3, D4910.4) during time line B. As well as the number of the times these codes (D110, D4910, D4910.2, D4910.3, D4910.4) were completed (to determine if they were coming for regular maintenance and follow ups or not).

8 – Anatomic Site

8-1: Total number of implants placed (D6010) based on tooth number, during time line A

8-2: Total number of implants placed during time line A and removed (D6100) during time line B, based on tooth number (The implants in this category should have codes D6100 in addition to code D6010 during the dates mentioned above.)

8-3: The number of implants placed (D6010) based on tooth number, during time line A in each of the following categories:

- Female
- Male
- Age (18-30 y/o)
- Age (31-50 y/o)
- Age (51-70 y/o)
- Age (>>70<)
- Medical condition: Diabetes
- Medical condition: Smoking
- Medical condition: Bisphosphonate (IV, oral)
- Allergy: Penicillin allergy

8-4: The number of implants removed (D6100) based on tooth number, during time line B in each of the following categories:

- Female
- Male

- Age (18-30 y/o)
- Age (31-50 y/o)
- Age (51-70 y/o)
- Age (> 70)
- Medical condition: Diabetes
- Medical condition: Smoking
- Medical condition: Bisphosphonate (IV, oral)
- Allergy: Penicillin allergy

9 - Implant System

9-1: Total number of implants placed (D6010) during time line A, for each of the following brands: Astra, Nobel Biocare (Replace, Active, Parallel CC), Straumann (SLA active, SLA), Biomet 3i (T3, Nanotite, osseotite).

9-2: Total number of implants removed (D6100) during time line B for each of the following brands: Astra, Nobel Biocare (Replace, Active, Parallel CC), Straumann (SLA active, SLA), Biomet 3i (T3, Nanotite, osseotite).

10 - Implant Length and Width

10-1 Total number of implants placed_(D6010) during time line A, for each of the following categories: Length: < 8 mm, 8 mm – 10 mm, > 10 mm and Width: < 4 mm, 4 mm - 4.7 mm, > 4.7 mm.

10-2 Total number of implants placed during time line A and removed (D6100) during time line B for each of the following categories: Length: < 8 mm, 8 mm – 10 mm, > 10 mm and Width: < 4 mm, 4 mm - 4.7 mm, > 4.7 mm.

STATISTICAL ANALYSIS

In this study, data were analyzed using SPSS v.24 (IBM Corp. Released 2016. IBM SPSS Statistics for Windows, Version 24.0. Armonk, NY: IBM Corp.), and Stata v.15 (Stata Corp. 2017. Stata Statistical Software: Release 15. College Station, TX: Stata Corp LLC.).

We first reported the descriptive statistics to explain the data, including, number and percentage. The overall incidence of failure was calculated in both patient-level and implant-level separately at PDM and PDFP and totally combined.

A chi-square test was used to compare the implant failure distribution between the different categories of potential risk factors (a P-value ≤ 0.05 was considered as significant). The null hypothesis (H_0) was that the implant failure rate is independent from the potential risk factors, i.e., the different level of a particular risk factor does not change the implant failure ratio. The Chi-square test was used in both patient-level and implant-level.

This was a matched-case-control study with a 1:3 ratio where 1 failure case matched to 3 controls. It consisted of 79 patients with implant failures and 237 matched controls. Age, gender, trainee group/clinician, and implant site were used to match the cases.

First, we applied a univariate conditional logistic regression as a feature selection method to select the most relevant factors affecting the implant failure - to be considered in the final multivariate logistic regression model. Variables with a univariate P-value < 0.2 were considered as important variables and got selected as the covariate for the final multivariate conditional logistic regression.

We then applied the multivariate conditional logistic regression to find the potential risk factors affecting the implant failure and report the odds ratios, called adjusted odds ratio (Adj. ORs). Covariates with a multivariate P-value ≤ 0.05 were considered as significant potential risk factors.

One patient was excluded from the matching due to limited control group which was less than 3.

RESULTS

This clinical retrospective study evaluated both patient and implant level from PDM and PDFP separately and categorized them as patient count and implant count. Patient level was discussed in part one of this study. These results focused primarily on implant level.

Patient count

In total, 1609 patients received dental implant during the timeframe of the study, 883 patients at PDM and 726 at PDFP. The total rate of patients with failed implants was 4.9%, 6% for PDM and 3.7% for PDFP.

Based on the chi-square test results in Table 1A evaluating the data from PDM, it showed that patients with Nobel BioCare Replace implants(2.0%, P-value = 0.002), Biomet 3i implant system (44.4%, P-value < 0.001), Osseotite surface (3.8%, P-value < 0.001), 8-10 mm length (8.7%, P-value = 0.038), none restored implants (14.8%, P-value < 0.001), no ridge preservation (17.5%, P-value = 0.001), none grafted sites (12.5%, P-value < 0.001), periodontal prosthesis resident clinicians (29.9%, P-value = 0.001), maxillary anterior sites (18.9%, P-value < 0.001), and mandibular anterior sites (13.2%, P-value = 0.009) were significantly overrepresented in the failure group.

In contrast, patients with Nobel BioCare Active implants (27.3%, P-value < 0.001), Nobel BioCare All implant system (3.8%, P-value<0.001), TiUnite surface (3.8%, P-value < 0.001), >10 mm length (4.8%, P-value = 0.020), implant restoration (0.2%, P-value < 0.001), no sinus

augmentation (4.5%, P-value = 0.001), grafted sites (2.9%, P-value < 0.001), periodontal resident clinicians (14.3%, P-value = 0.008), and maxillary posterior sites (3.6%, P-value = 0.008) were significantly underrepresented in the failure group.

Based on the chi-square test results in Table 1B evaluating the data from PDFP, it showed that patients with Nobel BioCare Replace implants (12.9%, P-value < 0.001), Straumann tissue level implants (75%, P-value < 0.001), Biomet 3i implants (29.4%, P-value < 0.001), SLA surface (66.7%, P-value = 0.004), Osseotite surface (29.4%, P-value < 0.001), no implant restoration (13.9%, P-value < 0.001), none grafted sites (6.5%, P-value = 0.002) were significantly overrepresented in the failure group.

On the other hand, patients with Nobel BioCare Parallel CC implants (1.2%, P-value < 0.001), Straumann bone level implants (1.6%, P-value = 0.047), restored implants (1.7%, P-value < 0.001), Grafted (2.0%, P-value=0.002), Others clinicians (0.0%, P-value=0.026) were significantly underrepresented in the failure group.

Based on the chi-square test results in Table 1C, evaluating total combined data for both PDM and PDFP showed that patients with Nobel BioCare Active implants (21.1%, P-value < 0.001), Straumann tissue level implants (27.8, P-value < 0.001), SLA surface (60%, P-value = 0.001), Osseotite surface (34.6%, P-value < 0.001), 8-10 mm length implants (6.6%, P-value = 0.021), 4 - 4.7 mm width implants (6.7%, P-value = 0.040), none restored implants (14.6%, P-value < 0.001), no ridge preservation (11.8%, P-value=0.006), periodontal prosthesis resident clinicians (29.2%, P-value<0.001), none grafted sites (9.6%, P-value < 0.001), and maxillary anterior sites (13.4%, P-value < 0.001) were significantly overrepresented in the failure group.

In contrast, patients with Straumann bone level implants (3.2%. P-value = 0.007), all Nobel BioCare implants (3.6%, P-value = 0.001), all Biomet 3i implants (34.6%, P-value < 0.001), TiUnite surface (3.6%, P-value = 0.001), >10 mm length implants (3.9%, P-value = 0.013), restored implants (1.0%, P-value < 0.001), no sinus augmentation (4.2%, P-value = 0.006), grafted sites (2.5%, P-value < 0.001), other clinicians (0%, P-value = 0.01) were significantly underrepresented in the failure group.

Implant count

During the timeframe of this study, a total of 3180 dental implants were placed: 2162 implants were placed at PDM while 1018 were placed at PFDP. The total rate of implant failure was 3.49%, 3.7% for PDM and 3% for PDFP.

Based on the chi-square test results in Table 2A, evaluating the data from PDM, it showed that patients with Parallel Nobel BioCare (8%, P-value=0.009), Active Nobel BioCare (50%, P-value<0.001), Straumann all implant system (11%, P-value=0.002), Biomet 3i all implant system (18.4%, P-value=0.010), Osseotite surface (18.4%, P-value=0.010), no implant restoration (6.9%, P-value<0.001), no sinus augmentation (7.4%, P-value=0.024), grafted (4.9%, P-value=0.016), perio-prosth resident clinicians (32.1%, P-value=0.022), and mandibular anterior site (8.1%, P-value<0.001) were significantly overrepresented in the failure group.

In contrast, patients with Replace Nobel BioCare (1.6%, P-value<0.001), Nobel BioCare all implant system (4.1%, P-value<0.001), TiUnite surface (4.1%, P-value<0.001), >4.7 mm width (3.9%, P-value=0.001), implant restoration (50%, P-value<0.001), no ridge preservation (2.6%, P-

value=0.024), none grafted (2.9%, P-value=0.016), periodontal resident clinicians (18.8%, P-value=0.008), maxillary posterior site (2.3%, P-value=0.007) were significantly underrepresented in the failure group.

Based on the chi-square test results in Table 2B, evaluating the data from PFDP, it showed that patients with Replace Nobel BioCare (11.5%, P-value<0.001), Straumann tissue level (42.9%, P-value<0.001), Biomet 3i all implant system (13.6%, P-value<0.001), Osseotite surface (13.6%, P-value<0.001), 8-10 mm length (5.5%, P-value<0.001), 4-4.7 mm width (6.1%, P-value=0.014), no implant restoration (9.8%, P-value<0.001), and grafted (4.1%, P-value=0.090) were significantly overrepresented in the failure group.

While patients with Parallel Nobel BioCare (1.1%, P-value<0.001), Active Nobel BioCare (50%, P-value<0.001), >10 mm length (1.7%, P-value=0.003), >4.7 mm width (2.2%, P-value=0.006), implant restoration (1.2%, P-value<0.001), none grafted (2.2%, P-value=0.090), Other clinicians (0%, P-value=0.002) were significantly underrepresented in the failure group.

Based on the chi-square test results in Table 2C, evaluating total combined data for both PDM and PDFP showed that patients with Active Nobel BioCare (31.8%, P-value=0.009), Straumann tissue level (23.1%, P-value<0.001), Astra all implant system (11.9%, P-value=0.044), Straumann all implant system (7.2%, P-value=0.042), Biomet 3i all implant system (15.9%, P-value<0.001), Osseospeed surface (11.9%, P-value=0.044), SLA surface (25%, P-value=0.020), Osseotite surface (15.9%, P-value<0.001), 8-10 mm length (7.1%, P-value=0.007), <4.7 mm width (8.8%, P-value=0.042), 4-4.7 mm width (8.1%, P-value<0.001), no implant restoration (7.4%, P-

value<0.001), grafted (4.6%, P-value=0.002), perio-Pprosth resident clinicians (32.1%, P-value=0.043), and mandibular anterior site (6.4%, P-value=0.005) were significantly overrepresented in the failure group.

However, patients with Straumann bone level (4.8%, P-value=0.027), Nobel BioCare all implant system (3.7%, P-value<0.001), TiUnite surface (3.7%, P-value<0.001), >10 mm length (4.1%, P-value=0.005", >4.7 mm width (2.9%, P-value<0.001), implant restoration (0.8%, P-value<0.001), none grafted (2.6%, P-value=0.002), periodontal resident clinicians (18.8%, P-value=0.017), and others clinicians (0%, P-value=0.004) were significantly underrepresented in the failure group.

Conditional Logistic Regression

Based on the frequency distributions of the variables (Table 3A), the number of Straumann Tissue level Standard and Standard Plus (n = 7), SLA surface (n = 7), T3 surface (n = 2), < 8 mm length (n=2) were very low which may result in unreliable odds ratios (ORs) in the conditional logistic regression.

We first applied a univariate conditional logistic regression as a variable-selection step. Variables with univariate P-value $\leq$ 0.2 are selected to be entered into the final multivariate logistics regression model. As shown in Table 3B, total implant (OR = 3.15, P-value = 0.001), bone graft (OR = 2.16, P-value = 0.093), immediate implants (OR = 0.49, P-value = 0.076), restored implants (OR = 0.05, P-value<0.001), implant system (OR = 2.07, P-value = 0.145), width (OR = 0.32, P-value = 0.027), and type of restoration (OR=1.85, P-value = 0.086) were selected (with P-value $\leq$ 0.2) as the final variables to be entered into the multivariate conditional logistic regression.

Based on the multivariate conditional logistic regression results in Table 3C, estimated odds of implant failure in people with multiple implants was about 4 times than people with single implants (Adj OR = 4.04, P-value = 0.004). The estimated odds of implant failure in people who received bone grafts before and during the implant surgery was about 5.6 times greater than that for people with no bone grafts (Adj OR = 5.57, P-value = 0.012). The estimated odds of implant failure in people with none restored implants was about 33 times that of people with restored implants (Adj OR = 0.03, P-value < 0.001); Other variables did not show any significant association with implant failure (with P-values > 0.05).

Both implant type and clinician variables were removed from the multivariate logistic regression model due to non-convergency because of their multiple categories.

DISCUSSION

The discovery of osseointegration caused a revolution in implant dentistry. Since the first placement of titanium implants in a human volunteer in 1965, dental implants have become a common component of dental practice. This causes a dilemma because implants do fail. It is thought that a major cause of implant failure is peri-implantitis. To date, there is insufficient evidence to understand the precise mechanism of peri-implantitis. However, one classification based on causative etiology was proposed. Sarmiento *et al*.[49] classified periimplantitis as induced by; pathogenic/bacteria biofilm; iatrogenic factors; exogenous irritants; extrinsic pathology; and AKT. In the consensus report from the American Academy of Periodontology 2017 world workshop, periimplantitis was defined as pathological inflammatory process causing progressive loss of supporting bone.[50] In addition to radiographic bone loss, clinical characteristics exhibit inflammation, BOP and/or suppuration, increased PD and/or loss of soft tissue. [50] It has been reported that implant failures have also been associated with various non-microbial factors such as systemic diseases, alcohol use, bone quality, loss or primary stability, high torque, overload, surface texture, and surgical trauma.

Failure of implant was classified according to the osseointegration concept into early or late failure depending on before or after occlusal load. Early failure (before loading) described as inability to establish bone to implant contact leading to lack of osseointegration and possible mobility. Late failure (after loading) explained as achieved osseointegration was not maintained due to inflammatory process. [15,16]

The current study has categorized data into patient count and implant count in order to evaluate the incidence of implant failure and associated factors in an academic setting. It focused primarily on implant level factors. The failure rate in the patient count at PDM was 3.7% while at PDFP it was 3%. The total rate of failure for both practices was 4.9% (95% CI: 3.90, 6.03). The failure rate in the implant count was 6% and 3.7%, at PDM and PDFP, respectively. The total failure rate for both practices was 3.49% (95% CI: 2.85, 4.13). The early failure rate determined in this study is similar that reported in the literature ranging from 0.7% to 3.8% and 4%.[51,52]

Variables that were investigated included: Implant system such as Astra, Nobel BioCare, Straumann, and Biomet 3i; Implant type/Design (EVS, TXS, Parallel, Replace, Active, BL, BLT, TL, TLSP, PS, NPS); Surface texture (Osseospeed, TiUnite, SLA, SLActive, Osseotite); Length (<8mm, 8-10mm, >10mm); Width (<4mm, 4-4.7mm, >4.7mm); Immediate implants; Restoration; Grafted and Non-grafted site; Implant site (Maxillary Anterior/Posterior, Mandibular Anterior/Posterior); and clinicians (Periodontal resident, Perio-Prosth, Perio-Orth, Periodontist, Oral surgeon, Others) Some of these variables showed to be overrepresented and/or underrepresented in the failure group.

Implant System:

It has been documented in the literature that comparison between implant systems is very limited Despite the limitation, 5 years survival rates extracted from 17 different articles showed no difference between different implant systems.[53] The results of the current study showed that Nobel BioCare (3.6%, P-value = 0.001) and Biomet (34.6%, P-value < 0.001) were significantly

underrepresented in the failure group. In contrast, Astra (11.9%, P-value = 0.044), Straumann (7.2%, P-value = 0.042), and Biomet 3i (15.9%, P-value < 0.001) were significantly overrepresented in the failure group while Nobel BioCare implant system (3.7%, P-value<0.001) was significantly underrepresented in the failure group.

It is very important to realize that different implant systems were used at variable frequencies at different times. For example, some systems were used more than others. Therefore, the association between failures and implant systems are descriptive in nature. In addition, based on the multivariate conditional logistic regression it did not show any significant association with implant failure (with P-values > 0.05).

Implant Type/Design

Implant design has been always modified to achieve better outcomes. According to the literature, there is no statistically significant differences between bone level and tissue level implants regarding survival rates. [54] Another study reported slightly greater marginal bone loss around tissue level implants (P-value < 0.001). [55]However, our results regarding both patient and implant demographics showed that Nobel BioCare Active implants (21.1%, P-value < 0.001) (31.8%, P-value=0.009), and TL (27.8, P-value<0.001) (23.1%, P-value<0.001), respectively were significantly overrepresented in the failure group. While BL at patient demographics and implant demographics (3.2%. P-value=0.007) (4.8%, P-value=0.027), respectively was significantly underrepresented in the failure group.

These overrepresentation in the failure group could be related to the total number of implants used in this study. The number and shape of the implant threads could play a role in the failure of the active implants. Another factor is the quality of bone and the anatomical location of these implants.

Additionally, Implant type/design variable was removed from the multivariate logistic regression model due to non-convergency because of its multiple categories.

Surface Texture:

Khang *et al* [56] found that at 36 months the collective success rates were 86.7% for machined surface implants and 95% for dual acid- etched implants. In addition, another study showed that regardless of location, rough surface implants had a higher success rate than smooth surface fixutres.[57] Surface texture has no association with implant failure in our study. However, our patient count showed SLA and Osseotite (60%, P-value = 0.001) (34.6%, P-value < 0.001), respectively, were significantly overrepresented in the failure group while TiUnite surface (3.6%, P-value = 0.001) was significantly underrepresented. In addition, our implant count revealed that Osseospeed (11.9%, P-value=0.044), SLA (25%, P-value=0.020) and Osseotite surfaces (15.9%, P-value<0.001) were significantly overrepresented. In contrast, TiUnite surface (3.7%, P-value<0.001) was significantly underrepresented in the failure group

This topic has become of increasing interest in our literature since animal studies reported that susceptibility to progression of periimplantitis may be higher for some moderately rough implant

surfaces than others. Lang et al[13] found that peri-implantitis is more likely to occur following exposure of rough surfaces to the oral environment.

It is very important to understand the surface modifications played a role in primary stability; However, these failures might be related to patient related factors such as smoking, diabetes, and oral hygiene.

Length:

Implant selection is another important factor to consider when placing implants. Renouard reported that there was a tendency towards an increased failure rate with short and wide-diameter machined-surface implants. [58] Another study revealed that short implants (6 - 9 mm) showed an association with early loss. [59] In addition, Misch *et al* [60] observed a low success rate (85.3%) for implants less than 10 mm in length.

Unexpectedly, our results regarding both patient and implant demographics showed that 8-10 mm (6.6%, P-value = 0.021 and 7.1%, P-value = 0.007, respectively) were significantly overrepresented in the failure group while implants >10 mm in length for both patient and implant demographics (3.9%, P-value = 0.013, 4.1%, P-value = 0.005, respectively) were significantly underrepresented. Implants > 8 mm were not overrepresented or underrepresented in the failure group. However, conditional logistic regression provided multivariate adjusted odds ratios and yielded no significant association with implant failure (with P-values > 0.05).

Width:

According to a prospective study evaluating early loss and the potential risk factors, the author concluded that early loss of dental implants was significantly associated with the use of narrow implants (p = 0.035). [61] In addition, another study reported that early survival rate for all 1,649 implants was 96.2%. while the largest loss was observed in narrow implants (5.1%). [31]

Surprisingly, our study showed that narrow implant width < 4 mm was not overrepresented or underrepresented in the failure group for both patient count and implant count. However, 4 - 4.7 mm width respectively were significantly overrepresented in the failure group for both groups with (6.7%, P-value = 0.040) and (8.1%, P-value < 0.001). Yet, multivariate adjusted odds ratios provided no significant association with implant failure (with P-values>0.05).

Immediate Implants:

The frequency of immediate implant placement has increased dramatically since the scientific approval of its predictability. It is comparable to early implant placement with a survival rate of 96.2%. [62] According to Becker (1998), evaluated implant placed at the time of extraction and showed that the success rate for 5 years follow up was 93.3%. [63] In addition, Covani et al [64] concluded that the success rate for 10 years follow-up was 91.8% for immediate implants. Our studies yielded the same results. Immediate implants were neither underrepresented nor overrepresented in the failure group. Moreover, conditional logistic regression provided

multivariate adjusted odds ratios (OR = 0.51, P-value = 0.242) and yielded no significant association with implant failure (with P-values > 0.05).

Restored implants/single and multiple:

According to the literature, implant supported single crown showed survival rate of 94.5% at 5 years while implant support fixed dental prosthesis was 95.2%. [39] On the other hand, a meta-analysis showed that early implant failure for partially and fully edentulous was 3.8% and 2%, respectively. [40] Our study showed that non-restored implants were significantly overrepresented in the failure group with (14.6%, P-value<0.001) for patient demographics and (7.4%, P-value<0.001) for implant demographics. Moreover, conditional logistic regression yielded a significant association with implant failure (Adj OR=0.03, P-value<0.001).

Additionally, participants with multiple implants were associated with implant failure about three times more than participants with single implant (Adj OR=2.99, P-value=0.002). While type of restoration showed no association (OR=1.85, P-value=0.086).

These early failures of single and multiple implants might be related to many factors such as inadequate implant selection, impaired site, unexperienced clinician, and surgical trauma. In addition, some of these patients showed inadequate oral hygiene and were not compliance with their recall appointment.

Grafted vs Non grafted:

This factor has been widely investigated in the literature. The usage of different material could have influenced the process off osseointegration and delayed healing of the sites. One retrospective study in 2009 showed that survival rate of implants placed in grafted and non-grafted were 99.1% and 98.9% respectively. [42] Jung et al. [65] reported a survival rate of 91.9% to 92.6% for implants placed after guided bone regeneration in 12-year follow up study

In contrast, our study showed estimated odds of implant failure in people who received bone grafts at the time of implant placement in already grafted sites was about 5.6 times greater than that of people who do not have bone grafts (Adj OR=5.57, P-value=0.012). This agrees with Sesma et al [66] that reported more implant failure in the grafted sites compared to non-grafted site. It is very important to understand that healing of bone grafting material could rely and depends on the quality of the existing bone of the sockets. These failures might be related to the amount of the residual bone graft that remained in the sites. The amount of non-vital bone residual may affect the migration of the osteoprogenitor cells and the release of growth factors. These biological interreference might lead to delayed or no osseous healing.

Clinicians:

Surgeon experiences play a role in the outcome of the procedure. One study showed that residents had significantly higher hazard ratios than faculty and suggested that personality or attitude of the

surgeon can affect the implant outcome. [67] Another study showed that failure rate was 5.9% for the inexperienced residents while 2.4% for more experienced residents. Our study showed that implants placed by periodontal prosthesis residents (29.2%, P-value<0.001) were significantly overrepresented in the failure group while fixtures inserted by periodontics residents (18.8%, P-value=0.017), and other clinicians (0%, P-value=0.004) were significantly underrepresented in the failure group. However, periodontal prosthesis residents placed more implants compared to periodontics residents and other clinicians. Therefore, the association between failures and clinicians are descriptive in nature and do not contribute to etiologic reasoning.

Additionally, clinician variable was removed from the multivariate logistic regression model due to non-convergency because of multiple categories.

Sites:

Human anatomy and skeletal system have been studied and we learned that the density of bone vary in our jaw comparing to our maxilla. Therefore, implant placement in maxillary anterior/posterior and mandibular anterior/posterior were investigated. According to multiple studies, failure rates of maxillary implants is higher relative to mandibular implants. [46,68] Our study showed the same result, maxillary anterior sites (13.4%, P-value<0.001) were significantly overrepresented in the failure group. Similarly, another study reported that the anterior maxilla is more susceptible to early implant loss than other alveolar bone sites.[69]

CONCLUSIONS

Osseointegration concept led to the true discovery of implant dentistry. Different materials have been investigated and implant therapy became a viable treatment for restoring edentulous sites. Electronic health records and hard copy were used to conduct this project. This retrospective study evaluated the incidence of implant failure in an academic setting as a primary objective. It concluded that the total failure rate at PDM and PDFP were 4.9% 3.49%, respectively. This study showed that experienced clinician has roughly the same failure rate and this could be related to different in number of implants placed between PDM and PDFP.

The secondary objective investigated the co-contributing actors which have been categorized into patient level and implant level. This study only focused on implant level which included: Implant system, Implant type/design, Surface texture, Length, Width, Immediate implants, Restored Implant/Non-restored, Grafted vs Non grafted site, Clinicians, and site.

It concluded that patients with multiple implants, non-restored implants, and using graft in already grafted site showed significant contribution to implant failure. Other factors were not significantly related to implant failure.

LIMITATIONS

This retrospective study provides an understanding of the incidence of implant failure in an academic setting. However, it is important to consider some of the limitation of this study such as inconsistency in some charts due to missing codes. Limited access to patient information due to school policy was another issue that resulted in an incomplete data set and therefore, subject to confounding. The incidence of some variables was very low such that a larger sample size is needed to avoid unreliable odds ratios (ORs) in the conditional logistic regression. In addition, both implant type and clinician variables were eliminated from the multivariate logistic regression model due to non-convergency. These variables could be organized and categorized better in future studies. This study only showed association and not causation of early implant failure.

TABLES

Table 1A. Patients with failed implants (**PDM**).

Variable	Patients Who Received Implants	Patients with Failures	% of Patients with Failures (Under H_0)	Expected Patients with Failures (Under H_0)	P-value
Entire sample	883	53	-	-	
Gender					
Male	382	18	4.70%	22.9	0.159
Female	500	35	7%	30.0	0.154
Unknown	1	0			
Age (in years)					
18-30	33	1	3%	2.0	0.464
31-50	161	8	5%	9.7	0.542
51-70	468	31	6.60%	28.1	0.409
70<	221	13	5.90%	13.3	0.931
Astra					
Astra EVS	15	3	20.0%	2.2	0.634
Astra TXS	19	2	10.50%	2.8	0.634
Nobel BioCare					
Parallel	110	7	6..40%	4.2	0.099
Replace	302	6	2.00%	11.4	**0.002***
Active	11	3	27.30%	0.4	**<0.001***
Straumann					
Straumann bone level	88	6	6.80%	7.6	0.482
Straumann bone level tapered	223	20	9.00%	19.2	0.737
Straumann tissue level	14	2	14.30%	1.2	0.440
Biomet 3i					
Platform switch	6	2	33.30%	2.7	0.343
Non platform switch	3	2	66.70%	1.3	0.343
Implant system					
Astra All	34	5	14.70%	2.3	0.056
Nobel BioCare All	423	16	3.80%	28.3	**<0.001***
Straumann All	325	28	8.60%	21.8	0.072
Biomet 3i All	9	4	44.40%	0.6	**<0.001***
Surface					
Osseospeed	34	5	14.70%	2.3	0.056
TiUnite	423	16	3.80%	28.3	**<0.001***
SLA	2	1	50.00%	0.1	0.130
SLActive	323	27	8.40%	21.6	0.121

Osseotite	9	4	44.40%	0.6	**<0.001***
Length					
<8 mm	2	1	50.00%	0.1	0.132
8-10 mm	390	33	8.7%	26.6	**0.038***
>10 mm	399	19	4.8%	27.2	**0.020***
Width					
<4 mm	248	14	5.60%	16.6	0.422
4-4.7 mm	375	31	8.30%	25.1	0.097
>4.7 mm	168	8	4.80%	11.3	0.257
Implant					
Immediate implant	164	8	4.90%	9.8	0.502
No Immediate implant	719	45	6.30%	43.2	0.502
Implant					
Implant restoration	532	1	0.20%	31.9	**<0.001***
No Implant restoration	351	52	14.80%	21.1	**<0.001***
Grafted Site					
Ridge Preservation	523	15	2.90%	14.9	0.951
Sinus Augmentation	73	2	2.70%	2.1	0.951
None Grafted Site					
No Ridge Preservation	177	31	17.50%	22.2	**0.001***
No Sinus Augmentation	110	5	4.50%	13.8	**0.001***
Graft					
Grafted	596	17	2.90%	35.8	**<0.001***
None Grafted	287	36	12.50%	17.2	**<0.001***
Clinicians					
Periodontal Resident	133	19	14.30%	28.7	**0.008**
Perio-Prosth Resident	168	49	29.90%	36.3	**0.001**
Perio-Ortho Resident	28	3	10.70%	6.0	0.144
Periodontist	0	0	-	-	-
Oral Surgeon	0	0	-	-	-
Others	4	0	0	0.9	0.291
Site					
Maxillary Posterior	387	14	3.60%	23.2	**0.008***
Maxillary Anterior	74	14	18.90%	4.4	**<0.001***
Mandibular Posterior	354	16	4.50%	21.2	0.129
Mandibular Anterior	68	9	13.2%	4.1	**0.009***

* Significant with P-value<0.05. P-values are based on a chi-square test.

Table 1B. Patients with failed implants (**PDFP**).

Variable	Patients Who Received Implants	Patients with Failures	% of Patients with Failures (Under H_0)	Expected Patients with Failures (Under H_0)	P-value
Entire sample	726	27	-	-	-
Gender					
Male	309	10	3.20%	11.9	0.452
Female	392	17	4.30%	15.1	0.452
Unknown	0	0			
Age (in years)					
18-30	30	0	0%	1.1	0.272
31-50	218	4	1.80%	8.1	0.079
51-70	348	17	4.90%	12.9	0.111
70<	130	6	4.60%	4.8	0.551
Astra					
Astra EVS	6	0	-	-	-
Astra TXS	4	0	-	-	-
Nobel BioCare					
Parallel	343	4	1.20%	11.4	**<0.001***
Replace	70	9	12.90%	2.3	**<0.001***
Active	8	1	12.50%	0.3	0.144
Straumann					
Straumann bone level	193	3	1.60%	5.6	**0.047***
Straumann bone level tapered	81	2	2.50%	2.3	0.794
Straumann tissue level	4	3	75.00%	0.1	**<0.001***
Biomet 3i					
Platform switch	9	3	33.30%	2.6	0.707
Non platform switch	8	2	25.50%	2.4	0.707
Implant system					
Astra All	10	0	0.00%	0.4	0.531
Nobel BioCare All	421	14	3.30%	15.7	0.345
Straumann All	278	8	2.90%	10.3	0.345
Biomet 3i All	17	5	29.40%	0.6	**<0.001***
Surface					
Osseospeed	10	0	0.00%	0.4	0.531
TiUnite	421	14	3.30%	15.7	0.510
SLA	3	2	66.70%	0.1	**0.004***
SLActive	275	6	2.20%	10.2	0.087
Osseotite	17	5	29.40%	0.6	**<0.001***
Length					
<8 mm	3	0	0.00%	0.1	>0.999

8-10 mm	349	15	4.3%	12.5	0.317
>10 mm	374	11	2.9%	13.4	0.339
Width					
<4 mm	209	5	2.40%	7.8	0.230
4-4.7 mm	254	11	4.30%	9.4	0.523
>4.7 mm	263	11	4.20%	9.8	0.619
Implant					
Immediate implant	40	0	0.00%	1.5	0.201
No Immediate implant	686	27	3.90%	25.5	0.201
Implant					
Implant restoration	604	10	1.70%	25.5	**<0.001***
No Implant restoration	122	17	13.90%	4.5	**<0.001***
Grafted Site					
Ridge Preservation	421	8	1.90%	8.4	0.541
Sinus Augmentation	28	1	3.60%	0.6	0.541
None Grafted Site					
No Ridge Preservation	222	16	7.20%	14.4	0.267
No Sinus Augmentation	55	2	3.60%	3.6	0.267
Graft					
Grafted	449	9	2.00%	16.7	**0.002***
None Grafted	277	18	6.50%	10.3	**0.002***
Clinicians					
Periodontal Resident	0	0	-	-	-
Perio-Prosth Resident	0	0	-	-	-
Perio-Ortho Resident	0	0	-	-	-
Periodontist	106	20	18.90%	17.5	0.293
Oral Surgeon	48	9	18.80%	7.9	0.619
Others	22	0	0.00%	3.6	**0.026***
Site					
Maxillary Posterior	288	12	4.20%	10.7	0.605
Maxillary Anterior	53	3	5.70%	2.0	0.438
Mandibular Posterior	329	12	3.60%	12.2	0.926
Mandibular Anterior	56	0	0.00%	2.1	0.126

* Significant with P-value<0.05. P-values are based on a chi-square test.

Table 1C. Patients with failed implants (**Total**).

Variable	Patients Who Received Implants	Patients with Failures	% of Patients with Failures (Under H_0)	Expected Patients with Failures (Under H_0)	P-value
Entire sample	1609	80	-	-	-
Gender					
Male	691	28	4.10%	34.9	0.110
Female	892	52	5.80%	45.1	0.108
Unknown	1	0	-	-	-
Age (in years)					
18-30	63	1	1.60%	3.1	0.207
31-50	379	12	3.20%	18.8	0.064
51-70	816	48	5.90%	40.6	0.088
70<	351	19	5.40%	17.5	0.667
Astra					
Astra EVS	21	3	14.30%	2.4	0.658
Astra TXS	23	2	8.70%	2.6	0.658
Nobel BioCare					
Parallel	453	11	2.40%	16.1	0.057
Replace	372	15	4.00%	13.2	0.506
Active	19	4	21.10%	0.7	**<0.001***
Straumann					
Straumann bone level	281	9	3.20%	16.8	**0.007***
Straumann bone level tapered	304	22	7.20%	18.1	0.186
Straumann tissue level	18	5	27.80%	1.1	**<0.001***
Biomet 3i					
Platform switch	15	5	33.30%	5.2	0.873
Non platform switch	11	4	36.40%	3.8	0.873
Implant system					
Astra All	44	5	11.40%	2.3	0.067
Nobel BioCare All	844	30	3.60%	44.5	**0.001***
Straumann All	603	36	6.00%	31.8	0.324
Biomet 3i All	26	9	34.60%	1.4	**<0.001***
Surface					
Osseospeed	44	5	11.40%	2.3	0.067
TiUnite	844	30	3.60%	44.5	**0.001***
SLA	5	3	60.00%	0.3	**0.001***
SLActive	598	33	5.50%	31.5	0.731
Osseotite	26	9	34.60%	1.4	**<0.001***
Length					
<8 mm	5	1	20.00%	0.3	0.140

8-10 mm	739	49	6.60%	39.0	**0.021***
>10 mm	773	30	3.90%	40.8	**0.013***
Width					
<4 mm	457	19	4.20%	24.1	0.202
4-4.7 mm	629	42	6.70%	33.2	**0.040***
>4.7 mm	431	19	4.40%	22.7	0.342
Implant					
Immediate implant	204	8	3.90%	10.1	0.460
No Immediate implant	1405	72	5.10%	69.9	0.460
Implant					
Implant restoration	1136	11	1.00%	56.5	**<0.001***
No Implant restoration	473	69	14.60%	23.5	**<0.001***
Grafted Site					
Ridge Preservation	944	23	2.40%	23.5	0.743
Sinus Augmentation	101	3	3.00%	2.5	0.743
None Grafted Site					
No Ridge Preservation	399	47	11.80%	38.2	**0.006***
No Sinus Augmentation	165	7	4.20%	15.8	**0.006***
Graft					
Grafted	1045	26	2.50%	52	**<0.001***
None Grafted	564	54	9.60%	28	**<0.001***
Clinicians					
Periodontal Resident	133	19	14.30%	26.1	0.070
Perio-Prosth Resident	168	49	29.20%	33.0	**<0.001***
Perio-Ortho Resident	28	3	10.70%	5.5	0.221
Periodontist	106	20	18.90%	20.8	0.821
Oral Surgeon	48	9	18.80%	9.4	0.870
Others	26	0	0.00%	5.1	**0.010***
Site					
Maxillary Posterior	675	26	3.90%	33.6	0.079
Maxillary Anterior	127	17	13.40%	6.3	**<0.001***
Mandibular Posterior	683	28	4.10%	34.0	0.167
Mandibular Anterior	124	9	7.30%	6.2	0.223

* Significant with P-value<0.05. P-values are based on a chi-square test.

Table 2A. Implant's demographics (**PDM**).

Variable	Patients Who Received Implants	Patients with Failures	% of Patients with Failures (Under H_0)	Expected Patients with Failures (Under H_0)	P-value
Entire sample	2162	80	-	-	-
Gender					
Male	947	28	3.00%	35.1	0.104
Female	1214	52	4.30%	45.0	0.109
Unknown	1	0			
Age (in years)					
18-30	70	1	1.40%	2.6	0.306
31-50	325	10	3.10%	12.0	0.518
51-70	1235	51	4.10%	45.7	0.222
70<	467	18	3.90%	17.3	0.842
Astra					
Astra EVS	28	4	14.30%	4	>0.999
Astra TXS	21	3	14.30%	3	>0.999
Nobel BioCare					
Parallel	138	11	8.00%	5.7	**0.009***
Replace	435	7	1.60%	17.8	**<0.001***
Active	12	6	50.00%	0.5	**<0.001***
Straumann					
Straumann bone level	104	10	9.60%	11.4	0.598
Straumann bone level tapered	259	29	11.20%	28.5	0.855
Straumann tissue level	19	3	15.80%	2.1	0.493
Biomet 3i					
Platform switch	29	6	20.70%	5.3	0.517
Non platform switch	9	1	11.10%	1.7	0.517
Implant system					
Astra All	49	7	14.30%	3.7	0.070
Nobel BioCare All	585	24	4.10%	44.4	**<0.001***
Straumann All	382	42	11.00%	29	**0.002***
Biomet 3i All	38	7	18.40%	2.9	**0.010***
Surface					
Osseospeed	49	7	14.30%	3.7	0.070
TiUnite	585	24	4.10%	44.4	**<0.001***
SLA	3	1	33.30%	0.2	0.092
SLActive	379	41	10.80%	28.8	0.003
Osseotite	38	7	18.40%	2.9	**0.010***
Length					
<8 mm	2	1	50.00%	0.2	0.146

8-10 mm	618	51	8.30%	46.9	0.334
>10 mm	434	28	6.50%	32.9	0.243
Width					
<4 mm	126	15	11.90%	9.6	0.051
4-4.7 mm	572	51	8.90%	43.4	0.077
>4.7 mm	356	14	3.90%	27	**0.001***
Implant					
Immediate implant	281	9	3.20%	10.4	0.636
No Immediate implant	1881	71	3.80%	69.5	0.636
Implant					
Implant restoration	1070	5	0.50%	39.6	**<0.001***
No Implant restoration	1092	75	6.90%	40.4	**<0.001***
Grafted Site					
Ridge Preservation	701	38	5.40%	34.2	0.139
Sinus Augmentation	181	5	2.80%	8.8	0.139
None Grafted Site					
No Ridge Preservation	1212	32	2.60%	35	**0.024***
No Sinus Augmentation	68	5	7.40%	2	**0.024***
Graft					
Grafted	882	43	4.90%	32.6	**0.016***
None Grafted	1280	37	2.90%	47.4	**0.016***
Clinicians					
Periodontal Resident	128	24	18.80%	34	**0.008***
Perio-Prosth Resident	159	51	32.10%	42.3	**0.022***
Perio-Ortho Resident	14	5	35.70%	3.7	0.428
Periodontist	0	0	-	-	-
Oral Surgeon	0	0	-	-	-
Others	4	0	0	0.9	0.291
Site					
Maxillary Posterior	822	19	2.30%	30.4	**0.007***
Maxillary Anterior	402	21	5.20%	14.9	0.073
Mandibular Posterior	704	21	3.00%	26	0.220
Mandibular Anterior	234	19	8.10%	8.7	**<0.001***

* Significant with P-value<0.05. P-values are based on a chi-square test.

.

Table 2B. Implant's demographics (**PDFP**).

Variable	Patients Who Received Implants	Patients with Failures	% of Patients with Failures (Under H_0)	Expected Patients with Failures (Under H_0)	P-value
Entire sample	1018	31			
Gender					
Male	444	12	2.70%	13.5	0.576
Female	574	19	3.30%	17.5	0.576
Unknown	0	0			
Age (in years)					
18-30	40	0	0.00%	1.2	0.253
31-50	270	5	1.90%	8.2	0.183
51-70	512	17	3.30%	15.6	0.607
70<	196	9	4.60%	6.0	0.161
Astra					
Astra EVS	7	0	-	-	-
Astra TXS	3	0	-	-	-
Nobel BioCare					
Parallel	357	4	1.10%	11.2	**<0.001***
Replace	78	9	11.50%	2.5	**<0.001***
Active	10	1	10.0%	0.3	0.209
Straumann					
Straumann bone level	211	5	2.40%	6.5	0.337
Straumann bone level tapered	137	3	2.20%	4.2	0.433
Straumann tissue level	7	3	42.90%	0.2	**<0.001***
Biomet 3i					
Platform switch	31	2	6.50%	4.2	0.053
Non platform switch	13	4	30.80%	1.8	0.053
Implant system					
Astra All	10	0	0.00%	0.4	0.537
Nobel BioCare All	445	14	3.10%	16.2	0.430
Straumann All	355	11	3.10%	12.9	0.484
Biomet 3i All	44	6	13.60%	1.6	**<0.001***
Surface					
Osseospeed	10	0	0.00%	0.4	0.537
TiUnite	445	14	3.10%	16.2	0.430
SLA	5	1	20.00%	0.2	0.050
SLActive	350	10	12.90%	12.7	0.314
Osseotite	44	6	13.60%	1.6	**<0.001***
Length					
<8 mm	4	0	0.00%	0.1	>0.999

8-10 mm	435	24	5.5%	14.3	**<0.001***
>10 mm	415	7	1.7%	15.1	**0.003***
Width					
<4 mm	102	5	4.90%	3.7	0.464
4-4.7 mm	246	15	6.10%	8.9	**0.014***
>4.7 mm	506	11	2.20%	18.4	**0.006***
Implant					
Immediate implant	42	0	0.00%	1.3	0.241
No Immediate implant	976	31	3.20%	29.7	0.241
Implant					
Implant restoration	804	10	1.20%	24.5	**<0.001***
No Implant restoration	214	21	9.80%	6.5	**<0.001***
Grafted Site					
Ridge Preservation	383	15	3.90%	15.7	0.632
Sinus Augmentation	57	3	5.30%	2.3	0.632
None Grafted Site					
No Ridge Preservation	364	11	3.00%	8.2	0.102
No Sinus Augmentation	214	2	0.90%	4.8	0.102
Graft					
Grafted	440	18	4.10%	13.4	**0.090***
None Grafted	578	13	2.20%	17.6	**0.090***
Clinicians					
Periodontal Resident	0	0	-	-	-
Perio-Prosth Resident	0	0	-	-	-
Perio-Ortho Resident	0	0	-	-	-
Periodontist	68	22	32.40%	17.9	0.080
Oral Surgeon	28	9	32.10%	7.4	0.419
Others	22	0	0.00%	5.8	**0.002***
Site					
Maxillary Posterior	411	15	3.60%	12.5	0.356
Maxillary Anterior	126	3	2.40%	3.8	0.643
Mandibular Posterior	419	13	3.10%	12.8	0.929
Mandibular Anterior	62	0	0.00%	1.9	0.150

* Significant with P-value<0.05. P-values are based on a chi-square test.

Table 2C. Implant's demographics (**Total**).

Variable	Patients Who Received Implants	Patients with Failures	% of Patients with Failures (Under H_0)	Expected Patients with Failures (Under H_0)	P-value
Entire sample	3180	111			
Gender					
Male	1391	40	2.90%	48.6	0.094
Female	1788	71	4.00%	62.4	0.096
Unknown	1	0			
Age (in years)					
18-30	110	1	0.90%	3.8	0.133
31-50	595	15	2.50%	20.8	0.153
51-70	1787	68	3.80%	62.4	0.273
70<	663	27	4.10%	23.1	0.359
Astra					
Astra EVS	35	4	11.40%	4.2	>0.999
Astra TXS	24	3	12.50%	2.8	>0.999
Nobel BioCare					
Parallel	495	15	3.00%	18.3	0.280
Replace	513	16	3.10%	18.9	0.333
Active	22	7	31.80%	0.8	**<0.001***
Straumann					
Straumann bone level	315	15	4.80%	22.7	**0.027***
Straumann bone level tapered	396	32	8.10%	28.5	0.314
Straumann tissue level	26	6	23.10%	1.9	**<0.001***
Biomet 3i					
Platform switch	60	8	13.30%	9.5	0.302
Non platform switch	22	5	22.70%	3.5	0.302
Implant system					
Astra All	59	7	11.90%	3.4	**0.044***
Nobel BioCare All	1030	38	3.70%	59.9	**<0.001***
Straumann All	737	53	7.20%	42.9	**0.042***
Biomet 3i All	82	13	15.90%	4.8	**<0.001***
Surface					
Osseospeed	59	7	11.90%	3.4	**0.044***
TiUnite	1030	38	3.70%	59.9	**<0.001***
SLA	8	2	25.00%	0.5	**0.020***
SLActive	729	51	7.00%	42.4	0.084
Osseotite	82	13	15.90%	4.8	**<0.001***
Length					
<8 mm	6	1	16.70%	0.3	0.256

8-10 mm	1053	75	7.10%	61.3	**0.007***
>10 mm	849	35	4.10%	49.4	**0.005***
Width					
<4 mm	228	20	8.80%	13.3	**0.042***
4-4.7 mm	818	66	8.10%	47.6	**<0.001***
>4.7 mm	862	25	2.90%	50.1	**<0.001***
Implant					
Immediate implant	323	9	2.80%	11.3	0.467
No Immediate implant	2857	102	3.60%	99.7	0.467
Implant					
Implant restoration	1874	15	0.80%	65.4	**<0.001***
No Implant restoration	1306	96	7.40%	45.6	**<0.001***
Grafted Site					
Ridge Preservation	1084	53	4.90%	50	0.309
Sinus Augmentation	238	8	3.40%	11	0.309
None Grafted Site					
No Ridge Preservation	1576	41	2.60%	40.7	>0.999
No Sinus Augmentation	282	7	2.50%	7.3	>0.999
Graft					
Grafted	1322	61	4.60%	45.3	**0.002***
None Grafted	1858	48	2.60%	63.7	**0.002***
Clinicians					
Periodontal Resident	128	24	18.80%	33.9	**0.017***
Perio-Prosth Resident	159	51	32.10%	42.1	**0.043***
Perio-Ortho Resident	14	5	35.70%	3.7	0.426
Periodontist	68	22	32.40%	18	0.231
Oral Surgeon	28	9	32.10%	7.4	0.483
Others	22	0	0.00%	5.8	**0.004***
Site					
Maxillary Posterior	1233	34	2.80%	43.4	0.063
Maxillary Anterior	528	25	4.70%	118.6	0.098
Mandibular Posterior	1123	34	3.00%	39.6	0.264
Mandibular Anterior	64	19	6.40%	10.4	**0.005***

* Significant with P-value<0.05. P-values are based on a chi-square test.

Table 3A. Frequency of variables

Variable	Level	Number	%
Outcome	Fail	99	25.0
	Success	297	75.0
Site	Max Post	124	31.3
	Max Ant	84	21.2
	Mand Post	128	32.3
	Mand Ant	60	15.2
Arch	Mandibular	188	47.5
	Maxillary	208	52.5
Location	Posterior	252	63.3
	Anterior	144	36.4
Trainee group	PDM	280	70.7
	PDFP	116	29.3
Total Implant	Single	117	29.5
	Multiple	279	70.5
Bone Graft	No	194	49.1
	Before placement	105	26.5
	During placement	72	18.2
	After placement	1	0.3
	Before and During	24	6.1
Immediate implants	No	343	86.6
	Yes	53	13.4
Restored Implants	No	200	50.5
	Yes	196	49.5
Number of attempts in site	Once	374	94.4
	Twice	22	5.6
Failed in site	None	297	75.0
	Once	88	22.2
	Twice	11	2.8
Implant System	Straumann	211	53.3
	Nobel BioCare	124	31.3
	Astra	19	4.8
	Biomet 3i	42	10.6
Implant type	Straumann Bone level	46	11.6
	Straumann bone level tapered	157	39.6
	Straumann Tissue level Standard and standard plus	7	1.8
	Nobel Active	12	3.0
	Nobel parallel	46	11.6
	Nobel Replace	67	16.9
	Astra EVS	14	3.5
	Astra TX S	5	1.3
	Biomet 3i platform switch	34	8.6
	Biomet 3i non platform switch	8	2.0
Surfaces	SLA	7	1.8
	SLActive	204	51.5
	TiUnite	124	31.3
	T3	2	0.5
	Osseotite	42	10.6
	Osseospeed	17	4.3
Width	< 4 mm	65	16.4
	4-4.7 mm	219	55.3
	> 4.7 mm	112	28.3
Length	< 8 mm	2	0.5
	8-10 mm	237	59.8
	> 10 mm	157	39.6

Type of restoration	Single	259	65.4
	Full mouth fixed	88	22.2
	Removable	49	12.4
Clinicians (Expertise)	Periodontal resident	117	29.5
	Perio-Prosth resident	147	37.1
	Perio-Ortho resident	14	3.5
	Periodontist	68	17.2
	Oral surgeon	28	7.1
	Others	22	5.6

Table 3B. Results of the univariate conditional logistic regression. Variables with univariate P-value≤0.2 are selected to be entered into the final multivariate logistics regression.

Variable	Category	Univariate Analysis		
		OR*	95% CI	P-value
Bone Graft	No		*ref*	
	Before placement	1.06	0.60-1.87	0.835
	During placement	0.76	0.38-1.53	0.452
	After placement	-	-	-
	Before and During	2.16	0.87-5.34	**0.093**
Immediate implants	No		*ref*	
	Yes	0.49	0.22-1.08	**0.076**
Restored Implants	No		*ref*	
	Yes	0.05	0.02-0.12	**<0.001**
Number of attempts in site		-	-	-
Failed in site		-	-	-
Implant System	Straumann		*ref*	
	Nobel BioCare	1.36	0.82-2.24	0.229
	Astra	2.07	0.78-5.54	**0.145**
	Biomet 3i	1.57	0.77-3.18	0.211
Implant type	Straumann Bone level		*ref*	
	Straumann bone level tapered	0.57	0.26-1.25	**0.158**
	Straumann Tissue level and standard plus	2.24	0.38-13.18	0.373
	Nobel Active	1.92	0.52-7.16	0.326
	Nobel parallel	0.77	0.29-2.08	0.608
	Nobel Replace	1.14	0.49-2.69	0.758
	Astra EVS	0.98	0.26-3.67	0.980
	Astra TX S	4.68	0.67-32.88	**0.120**
	Biomet 3i platform switch	0.80	0.29-2.19	0.672
	Biomet 3i non platform switch	4.76	1.01-22.35	**0.048**
Surfaces	SLA		*ref*	
	SLActive	0.60	0.10-3.52	0.575
	TiUnite	0.95	0.16-5.53	0.956
	T3	-	-	-
	Osseotite	1.12	0.18-6.82	0.898
	Osseospeed	1.24	0.17-8.95	0.827
Width	Less than 4 mm		*ref*	
	4-4.7 mm	0.77	0.40-1.48	0.440

	Greater than 4.7 mm	0.32	0.12-0.881	**0.027**
Length	Less than 8 mm		*ref*	
	8-10 mm	0.34	0.21-5.49	0.450
	Greater than 10 mm	0.28	0.01-4.69	0.379
Type of restoration	Single		*ref*	
	Full mouth fixed	1.85	0.92-3.74	**0.086**
	Removable	0.82	0.28-2.40	0.724
Expertise	Periodontal resident		*ref*	
	Perio-Prosth resident	2.79	1.47-5.32	**0.002**
	Perio-Ortho resident	1.37	0.33-5.76	0.666
	Periodontist	-	-	-
	Oral surgeon	-	-	-
	Others	-	-	-

* Odds Ratio

** Adjusted Odds Ratio

Table 3C. Results of the multivariate conditional logistic regression. P-value≤0.05 are significant.

Variable	Category	Univariate Analysis		
		OR*	95% CI	P-value
Total Implant	Single		*ref*	
	Multiple	4.04	1.56-10.44	**0.004**
Bone Graft	No		*ref*	
	Before placement	2.04	0.88-4.79	0.097
	During placement	0.86	0.33-2.26	0.764
	After placement	-	-	-
	Before and During	5.57	1.45-21.37	**0.012**
Immediate implants	No		*ref*	
	Yes	0.51	0.17-1.57	0.242
Restored Implants	No		*ref*	
	Yes	0.03	0.01-0.09	**<0.001**
Implant System	Straumann		*ref*	
	Nobel BioCare	1.19	0.58-2.46	0.626
	Astra	1.88	0.48-7.42	0.366
	Biomet 3i	1.85	0.72-4.73	0.200
Width	Less than 4 mm		*ref*	
	4-4.7 mm	0.66	0.26-1.69	0.391
	Greater than 4.7 mm	0.59	0.17-2.08	0.413
Type of restoration	Single		*ref*	
	Full mouth fixed	0.68	0.24-1.94	0.469
	Removable	0.75	0.19-2.87	0.671

* Odds Ratio

** Adjusted Odds Ratio

REFRENCES

1. Asbell milton B. dentistry. a historical perspective- being a historical account of the history of dentistry from ancient times.with emphasis upon the united states from the colonial to the present period. bryn mawr pa dorrance & co. 1988- 1–256. .

2. Abraham CM. A brief historical perspective on dental implants, their surface coatings and treatments. *Open Dent J*. 2014;8:50-55. doi: 10.2174/1874210601408010050 [doi].

3. Bobbio A. the first endosseous alloplastic implant in the history of man. bull hist dent. 1972 jun;20(1)-1-6. PMID- 4505221. .

4. Abdul quasim al-zahrawi, latinized as abulcasis, was one of the first to propose appropriate instrumentation for dental surgery, which he described extensively in his richly illustrated work; many of the drawings were done by the author. .

5. Maggiolo manuel de l'art dentaire [manuel of dental art]. nancy france C.le seure. 1809 .

6. Implantology in dentistry. A brief historical perspective. linkow LI, dorfman JD N Y state dent J. 1991 jun-jul; 57(6)-31-5. .

7. [Technic and instrumentation of the implant C.B.S. (cristalline bone screw)]. sandhaus S inf odontostomatol. 1968; 4(3)-19-24. .

8. Brånemark PI. osseointegration and its experimental background. J prosthet dent. 1983 sep;50(3)-399-410. doi- 10.1016:s0022-3913(83)80101-2. PMID- 6352924. .

9. Jayesh RS, Dhinakarsamy V. Osseointegration. *J Pharm Bioallied Sci*. 2015;7(Suppl 1):226. doi: 10.4103/0975-7406.155917 [doi].

10. Glossary of terms. JOI 2016;48-49 .

11. Schenk RK, Buser D. Osseointegration: A reality. *Periodontology 2000*. 1998;17(1):22-35.. doi: 10.1111/j.1600-0757.1998.tb00120.x.

12. Parithimarkalaignan S, Padmanabhan T. Osseointegration: An update. *J Indian Prosthodont Soc*. 2013;13(1):2-6.. doi: 10.1007/s13191-013-0252-z.

13. Sakka S, Coulthard P. Bone quality: A reality for the process of osseointegration. *Implant dentistry*. 2009;18(6):480-485. doi: 10.1097/ID.0b013e3181bb840d.

14. Albrektsson.1994.biological aspects of implant dentistry osseointegration. . 1064.

15. Esposito M, Hirsch J, Lekholm U, Thomsen P. Biological factors contributing to failures of osseointegrated oral implants, (I). success criteria and epidemiology. *European journal of oral sciences*. 1998;106(1):527-551. doi: 10.1046/j.0909-8836..t01-2-.x.

16. Berglundh T, Persson L, Klinge B. A systematic review of the incidence of biological and technical complications in implant dentistry reported in prospective longitudinal studies of at least 5 years. *Journal of clinical periodontology*. 2002;29(s3):197-212. doi: 10.1034/j.1600-051X.29.s3.12.x.

17. Schwarz F, Derks J, Monje A, Wang H. Peri-implantitis. *J Periodontol*. 2018;89(1):S267. doi: 10.1002/jper.16-0350.

18. Du Preez L, Bütow K, Benninghoff W, Bütow K. A comparison of three different implant systems in the same patient. .

19. Nasatzky E, gultchin J, schwartz Z. [the role of surface roughness in promoting osteointegration]. refuat hapeh vehashinayim (1993). 2003 jul;20(3)-8-19, 98. hebrew. PMID-14515625. .

20. Albrektsson T, Zarb G, Worthington P, Eriksson AR. The long-term efficacy of currently used dental implants: A review and proposed criteria of success. *The International journal of oral and maxillofacial implants*. 1986;1(1):11-25.

21. Ting M, Jefferies SR, Xia W, Engqvist H, Suzuki JB. Classification and effects of implant surface modification on the bone: Human Cell–Based in vitro studies. *The Journal of oral implantology*. 2017;43(1):58-83. doi: 10.1563/aaid-joi-D-16-00079.

22. Wennerberg A, Albrektsson T. Effects of titanium surface topography on bone integration: A systematic review. *Clinical Oral Implants Research*. 2009;20:172. doi: 10.1111/j.1600-0501.2009.01775.x.

23. Albrektsson T, Wennerberg A, Schwartz Filho HO, Francischone CE, Rosa MB. The influence of surface treatment on the implant roughness pattern. *Journal of Applied Oral Science*. 2012;20(5).

24. Albrektsson T, Wennerberg A, Schwartz Filho HO, Francischone CE, Rosa MB. The influence of surface treatment on the implant roughness pattern. *Journal of Applied Oral Science*. 2012;20(5).

25. Eroglu CN, Ertugrul AS, Eskitascioglu M, Eskitascioglu G. Changes in the surface of bone and acid-etched and sandblasted implants following implantation and removal. *European journal of dentistry*. 2016;10(1):077-081. doi: 10.4103/1305-7456.175679.

26. Trisi P, Lazzara R, Rebaudi A, Rao W, Testori T, Porter SS. Bone-Implant contact on machined and dual Acid-Etched surfaces after 2 months of healing in the human maxilla. *Journal of periodontology (1970)*. 2003;74(7):945-956.. doi: 10.1902/jop.2003.74.7.945.

27. Fugazzotto PA. Shorter implants in clinical practice: Rationale and treatment results. *The International journal of oral and maxillofacial implants*. 2008;23(3):487-496.

28. Camps-Font O, Burgueño-Barris G, Figueiredo R, Jung RE, Gay-Escoda C, Valmaseda-Castellón E. Interventions for dental implant placement in atrophic edentulous mandibles: Vertical bone augmentation and alternative treatments. A Meta-Analysis of randomized clinical trials. *Journal of periodontology (1970)*. 2016;87(12):1444-1457. doi: 10.1902/jop.2016.160226.

29. Krisam J, Ott L, Schmitz S, et al. Factors affecting the early failure of implants placed in a dental practice with a specialization in implantology - a retrospective study. *BMC oral health*. 2019;19(1):208. doi: 10.1186/s12903-019-0900-8.

30. Manzano G, Montero J, Martín-Vallejo J, Del Fabbro M, Bravo M, Testori T. Risk factors in early implant failure: A meta-analysis. *Implant Dent*. 2016;25(2):272-280.

31. Olate S, Lyrio MCN, de Moraes M, Mazzonetto R, Moreira RWF. Influence of diameter and length of implant on early dental implant failure. *Journal of Oral and Maxillofacial surgery*. 2010;68(2):414-419.

32. Ting M, Palermo M, Donatelli D, Gaughan J, Suzuki J, Jefferies S. A meta-analysis on the effect of implant characteristics on the survival of the wide-diameter implant. *Int J Implant Dent*. 2015;1(1):1-8.. doi: 10.1186/s40729-015-0030-2.

33. Araújo MG, Sukekava F, Wennström JL, Lindhe J. Ridge alterations following implant placement in fresh extraction sockets: An experimental study in the dog. *Journal of clinical periodontology*. 2005;32(6):645-652.. doi: 10.1111/j.1600-051X.2005.00726.x.

34. Volume 71 • number 12 academy report. .

35. Wilson TG jr, schenk R, buser D, cochran D. implants placed in immediate extraction sites: A report of histologic and histometric analyses of human biopsies. int J oral maxillofac implants 1998;13:333–341.

36. Lang NP, Pun L, Lau KY, Li KY, Wong MC. A systematic review on survival and success rates of implants placed immediately into fresh extraction sockets after at least 1 year. *Clinical oral implants research*. 2012;23(s5):39-66. doi: 10.1111/j.1600-0501.2011.02372.x.

37. Kang D, Kim M, Lee S, et al. Early implant failure: A retrospective analysis of contributing factors. *Journal of periodontal & implant science*. 2019;49(5):287-298. doi: 10.5051/jpis.2019.49.5.287.

38. Berglundh T, Persson L, Klinge B. A systematic review of the incidence of biological and technical complications in implant dentistry reported in prospective longitudinal studies of at least 5 years. *Journal of clinical periodontology*. 2002;29(s3):197-212.. doi: 10.1034/j.1600-051X.29.s3.12.x.

39. Pjetursson BE, Bragger U, Lang NP, Zwahlen M. Comparison of survival and complication rates of tooth-supported fixed dental prostheses (FDPs) and implant-supported FDPs and single crowns (SCs). *Clinical oral implants research*. 2007;18(s3):97-113. doi: 10.1111/j.1600-0501.2007.01439.x.

40. Esposito M, Hirsch J, Lekholm U, Thomsen P. Biological factors contributing to failures of osseointegrated oral implants, (I). success criteria and epidemiology. *European journal of oral sciences*. 1998;106(1):527-551. doi: 10.1046/j.0909-8836..t01-2-.x.

41. Fiorellini JP, Nevins ML. Localized ridge augmentation/preservation. A systematic review. *Annals of Periodontology*. 2003;8(1):321-327.

42. Bakhshalian N, Freire M, Min S, Wu I, Zadeh HH. Retrospective analysis of the outcome of ridge preservation with anorganic bovine bone minerals: Microcomputed tomographic assessment of wound healing in grafted extraction sockets. *Int J Periodontics Restorative Dent*. 2018;38(1).

43. Lekholm U, zarb GA, albrektsson T. patient selectino and preparation. tissue integrated prostheses. chicago- quintessence publishing co. inc., 1985;199-209. .

44. Li J, yin X, huang L, et al. relationships among bone quality, implant osseointegration, and wnt signaling. J dent res. 2017;96(7):822-831. doi:10.1177/0022034517700131

. .

45. Cochran DL. A comparison of endosseous dental implant surfaces. *J Periodontol*. 1999;70(12):1523-1539.

46. Becker W, Becker BE, Alsuwyed A, Al-Mubarak S. Long-term evaluation of 282 implants in maxillary and mandibular molar positions: A prospective study. *J Periodontol*. 1999;70(8):896-901.

47. Gaviria L, Salcido JP, Guda T, Ong JL. Current trends in dental implants. *J Korean Assoc Oral Maxillofac Surg*. 2014;40(2):50-60. doi: 10.5125/jkaoms.2014.40.2.50 [doi].

48. Lambert PM, morris HF, ochi S. positive effect of surgical experience with implants on second-stage implant survival. J oral maxillofac surg 1997;55-12-8. .

49. Sarmiento HL, Norton MR, Fiorellini JP. A classification system for peri-implant diseases and conditions. *The International journal of periodontics & restorative dentistry*. 2016;36(5):699-705. doi: 10.11607/prd.2918.

50. Berglundh T, Armitage G, Araujo MG, et al. Peri-implant diseases and conditions. . 2018;45:S286. doi: 10.1111/jcpe.12957.

51. Baqain ZH, Moqbel WY, Sawair FA. Early dental implant failure: Risk factors. *British journal of oral & maxillofacial surgery*. 2011;50(3):239-243. doi: 10.1016/j.bjoms.2011.04.074.

52. Bornstein MM, cionca N, mombelli A. systemic conditions and treat- ments as risks for implant therapy. int J oral maxillofac implants 2009;24(suppl.):12–27.

. .

53. Eckert SE, Choi Y, Sánchez AR, Koka S. Comparison of dental implant systems: Quality of clinical evidence and prediction of 5-year survival. *Int J Oral Maxillofac Implants*. 2005;20(3).

54. Vouros ID, kalpidis CD, horvath A, petrie A, donos N. systematic assessment of clinical outcomes in bone-level and tissue-level endosseous dental implants. int J oral maxillofac implants. 2012 nov-dec;27(6):1359-74. PMID: 23189285.

. .

55. Kumar VV, Sagheb K, Kämmerer PW, Al-Nawas B, Wagner W. Retrospective clinical study of marginal bone level changes with two different screw-implant types: Comparison between tissue level (TE) and bone level (BL) implant. *J Maxillofac Oral Surg*. 2013;13(3):259. doi: 10.1007/s12663-013-0532-5.

56. Khang W, Feldman S, Hawley CE, Gunsolley J. A Multi-Center study comparing dual Acid-Etched and Machined-Surfaced implants in various bone qualities. *Journal of periodontology (1970)*. 2001;72(10):1384-1390. doi: 10.1902/jop.2001.72.10.1384.

57. Cochran DL, Periodontol J. A comparison of endosseous dental implant surfaces* state of the art review. . 1999.

58. Renouard F, Nisand D. Impact of implant length and diameter on survival rates. *Clin Oral Implants Res*. 2006;17(S2):35-51.

59. Olate, Sergio, DDS, MSc, Lyrio, Mariana Camilo Negreiros, DDS, MSc, de Moraes, Márcio, DDS, MSc, PhD, Mazzonetto, Renato, DDS, MSc, PhD, Moreira, Roger William Fernandes, JD, DDS, MSc, PhD. Influence of diameter and length of implant on early dental implant failure. *Journal of oral and maxillofacial surgery*. 2010;68(2):414-419. doi: 10.1016/j.joms.2009.10.002.

60. Misch CE, Steigenga J, Barboza E, Misch-Dietsh F, Cianciola LJ, Kazor C. Short dental implants in posterior partial edentulism: A multicenter retrospective 6-year case series study. *J Periodontol*. 2006;77(8):1340-1347.

61. Baqain ZH, Moqbel WY, Sawair FA. Early dental implant failure: Risk factors. *British journal of oral & maxillofacial surgery*. 2011;50(3):239-243. doi: 10.1016/j.bjoms.2011.04.074.

62. Moraschini V, Poubel LdC, Ferreira VF, dos Sp Barboza E. Evaluation of survival and success rates of dental implants reported in longitudinal studies with a follow-up period of at least 10 years: A systematic review. *Int J Oral Maxillofac Surg*. 2015;44(3):377-388.

63. Becker BE, Becker W, Ricci A, Geurs N. A prospective clinical trial of endosseous Screw-Shaped implants placed at the time of tooth extraction without augmentation. *Journal of periodontology (1970)*. 1998;69(8):920-926. doi: 10.1902/jop.1998.69.8.920.

64. Covani U, Chiappe G, Bosco M, Orlando B, Quaranta A, Barone A. A 10-Year evaluation of implants placed in fresh extraction sockets: A prospective cohort study. *Journal of periodontology (1970)*. 2012;83(10):1226-1234.. doi: 10.1902/jop.2012.110583.

65. Jung RE, Fenner N, Hämmerle CH, Zitzmann NU. Long-term outcome of implants placed with guided bone regeneration (GBR) using resorbable and non-resorbable membranes after 12–14 years. *Clin Oral Implants Res*. 2013;24(10):1065-1073.

66. Sesma N, Pannuti CM, Cardaropoli G. Retrospective clinical study of 988 dual acid-etched implants placed in grafted and native bone for single-tooth replacement. *Int J Oral Maxillofac Implants*. 2012;27(5).

67. Jemt T, Olsson M, Renouard F, Stenport V, Friberg B. Early implant failures related to individual surgeons: An analysis covering 11,074 operations performed during 28 years. *Clinical implant dentistry and related research*. 2016;18(5):861-872. doi: 10.1111/cid.12379.

68. Pommer B, Frantal S, Willer J, Posch M, Watzek G, Tepper G. Impact of dental implant length on early failure rates: A meta-analysis of observational studies. *Journal of clinical periodontology*. 2011;38(9):856-863. doi: 10.1111/j.1600-051X.2011.01750.x.

69. Fouda AAH. The impact of the alveolar bone sites on early implant failure: A systematic review with meta-analysis. *Journal of the Korean Association of Oral and Maxillofacial Surgeons*. 2020;46(3):162-173.. doi: 10.5125/jkaoms.2020.46.3.162.