THE INITIAL TREATMENT OF PERI-IMPLANT DISEASE

A Thesis

by

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ABSTRACT

In 1952 Per-Ingvar Brånemark discovered the potential of titanium's ability to bond to bone. In 1977 he introduced the concept of the titanium dental implant. Since Dr. Brånemark's discovery the titanium dental implant has revolutionized dentistry, providing treatment options from single tooth to full arch replacement. Implants provide a service to our patients that have the potential to be life changing both functionally and aesthetically. Unfortunately, this progress is lost when dental implants fail, causing emotional and financial distress to the patient. One of the complications that can lead to implant failure is peri-implant disease. Thus far the literature has shown that non-surgical treatment significantly reduces BOP at peri-implant disease sites. Although, complete disease resolution is not commonly observed following therapy. In light of the possible peri-implant disease etiologies of bacterial plaque and foreign material, a peri-implant sulcular debridement via sulcular curettage appears prudent and has been rarely studied. Therefore, the purpose of this study was to investigate the effects of sulcular debridement and chlorhexidine irrigation at peri-implant disease sites.

All implants included in the study were either diagnosed as having peri-implant mucositis or peri-implantitis. Implants will be randomly assigned to two different groups. Group 1 implants initially received debridement of the peri-implant sulcus. While Group 2 implants received sulcular irrigation with 0.12% chlorhexidine gluconate. Four weeks following initial treatment patients from both groups were re-evaluated and measurements were recorded (PD, BOP, Suppuration, GI). Group 1 patients received sulcular irrigation with 0.12% chlorhexidine gluconate, while Group 2 patients received debridement of the peri-implant sulcus. Four weeks following administration of crossover treatment patients were re-evaluated and measurements

were recorded (PD, BOP, Suppuration, GI). 8 weeks following administration of crossover treatment measurements were recorded (PD, BOP, Suppuration, GI).

When comparing the treatment of sulcular debridement to chlorhexidine irrigation (0.08mm, 0%), sulcular debridement (0.73mm, 22%) had greater reductions in PD and BOP, although neither group seemed to make clinically significant reductions. Following the completion of both treatments at 3 months peri-implant mucositis PD improved by 0.58mm, while peri-implantitis PD improved by 0.64mm. Peri-implant mucositis and peri-implantitis BOP reduced by 56% and 12.5%, respectively.

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NOMENCLATURE

PD	Probing Depth
BOP	Bleeding on Probing
GI	Gingival Index
mm	millimeters
CHX	Chlorhexidine 0.12%

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER I

INTRODUCTION AND

LITERATURE REVIEW

In 2005 Dr. Branemark stated that "The edentulous patient is an amputee, an oral invalid, to whom we should pay total respect and rehabilitation ambitions"[1]. In 2011-2012, nearly 19% of U.S. adults aged 65 and over were edentulous. While only 48% of adults (20-64 years of age) had not lost any permanent teeth[2]. Edentulism has been shown to lower an individual's quality of life and has even been shown to predict mortality[3, 4]. The long-term success of dental implants has been an excellent solution to tooth loss, and the physical and emotional morbidity that is associated with it.[5, 6] When dental implants fail this is another source of emotional and financial stress to the patient. While implant failure and disease represent a small percentage of the total implant population, its negative affect on the individual is profound.[6]

History

The search for a cure to edentulism is not new. There is evidence that ancient human populations also struggled with tooth loss. Around 600AD, the Mayans experimented using pieces of shell to replace teeth[7]. At the Peabody Museum of Archaeology and Ethnology at Harvard University a mandible from the 7th to 8th centuries AD is present, containing "three cuneiform shells pieces in place of the three lower incisors". The presence of compact bone osteogenesis was noted around the implant shell teeth[8]. Fast forward to the early 1800s, Maggiolo attempted the first endosseous implant placement[7]. His implant, which he called an artificial root, was constructed of a long thin gold tube whose dimensions correspond to the size of the root being replaced[8]. The artificial root was to be placed in a fresh extraction socket. Following placement of his implant he noted that "It is not a good idea to immediately insert

the… tooth, which should not be fitted to the artificial root until it has achieved maximum stability; otherwise, all of our good work will have been vain."[9]. Around the 1840s, Chapin A. Harris and Horace H. Hayden employed their own tooth replacement procedure. They placed lead-coated platinum posts in prepared artificial sockets. Following splinted healing, a porcelain crown was placed on the implant[8]. In 1913 E.J. Greenfield, of the U.S., presented his basket style implant. The implants were constructed of a hollow latticed iridio-platnium basket soldered with 24-karat gold. His technique included a drill for preparation of the treatment site and a two-stage healing sequence. This was the first time a two-stage healing sequence was suggested[7, 8]. In 1938 a Swedish dentist, Gustav Dahl, presented a tooth replacement device that laid on the bone, the subperiosteal implant. His original design consisted of four metal posts that anchored the framework. Subsequent subperiosteal frameworks were modified by Gershkoff, Goldberg and Weinberg. These U.S. dentists constructed Dahl's subperiosteal framework from cobalt-chromium-molybdenum with posterior extensions to include the external oblique ridge[7, 8]. In Boston, in the year 1939, Drs. Alvin and Moses Stock began human testing of the placement of screw implants made of Vitallium[8]. Vitallium, a chromium-molybdenum-cobalt alloy, was thought to be the first biocompatible material used for dental implants. The screws tested were originally used in orthopedics for fixation[7]. In the 1940s, Italian dentist, Manlio Formiggini created a hollow spiral screw implant made of either stainless steel or tantalum. He named his method "direct endoalveolar infibulation". His implants were inserted into extraction sockets or artificially prepared sockets by "screwing it (the implant) forcefully"[8]. This marked the definitive transition to the era of endosseous implants and for this Formiggini is considered the father of modern implantology[7]. In the 1950s there was unsuccessful attempts of resin implant placement. The failure of this material is most likely do to toxicity of resin[8]. The first self-

threading screw implant was proposed in 1961 by Stefano Tramonte. His implant was made of Vitallium and was considered an elective immediate load implant[8]. In the 1960s and 1970s, Leonard Linkow, created a flat plate made of tantalum which was to be inserted into the bone. A post protruding vertically from the plate was used to support a prosthetic tooth. This was the birth of the blade implant, which was subsequently modified by several other clinicians. In 1975 transosteal implant, also referred to as the mandibular staple implant, was introduced by Dr. Small. This implant differed from other implant designs of its time, such as the subperiosteal implant and blade implant. The mandibular staple implant relied on mechanical retention through a large contact surface area, which was achieved via a bone plate and bicortical screw engagement in the anterior mandible[7, 10, 11]. In 1952 a Swedish orthopedic surgeon, P.I. Branemark, began studying bone marrow circulation by implanting titanium optical chambers in rabbit fibula. Dr. Branemark made an interesting observation while trying to remove the titanium chambers; "the optical chambers could not be removed from the adjacent bone once they had healed in"[12]. He went on to say, "we observed that the titanium chambers were inseparably incorporated with the bone tissue, which actually grew into very thin spaces in the titanium." [12]. These findings separate his implants from all previous dental implant attempts in that he identified a highly biocompatible material, titanium. He termed his discovery osseointegration; "a direct structural and functional connection between ordered, living bone, and the surface of a load carrying implant"[1]. Dr. Branemark first tested his titanium implants intraorally in dogs. Radiographic and histologic analyses illustrated that these implants could be maintained for 10 years without any progressive inflammatory reactions. They treated their first edentulous patient in 1965. The implants were made from pure titanium with a dimension of 3.7mm in width and a length of 10mm[12]. Four implants were placed in the mandible with 6

months of two-stage healing. Following implant uncovery, a fixed prosthesis was attached to the integrated implants. These implants remained in place for the next 40 years[13]. In the late 1960s Professor Andre Schroeder, at the University of Bern in Switzerland, began studying the tissue reaction to various implant materials[14]. There preliminary studies led them to focus on a roughened titanium surface. A roughened surface was in line with orthopedic literature; "the adhesion of tissue (bone) to a surface of this type is several orders of magnitude greater than that to a smooth titanium surface"[15]. This type of surface was created by flame-spraying the implants with titanium powder at high temperatures. The result was a rough surface containing crevices and pores[15]. The original design of the Swiss implant was a one-piece transmucosal implant. The implant was designed as a hollow cylinder and had a titanium plasma-sprayed surface. In contrast to Professor Branemark's implant, Dr. Schroeder's design included a transmucosal element while healing. In the late 90s and early twenty first century it became widely agreed that implant healing could predictable be achieved with a non-submerged healing, including Branemark implants[16, 17].

Implant Surfaces

One of the differentiating features between early dental implants is surface characteristics. The original implant had a smooth, machined titanium surface[12]. Subsequent implants were released that featured roughened surfaces[15]. Others were created containing surface modifications including hydroxyapatite (HA). These surface modifications were made in an effort to enhance bone to implant healing. The different implant surfaces are characterized by the amount of bone-to-implant contact and the force required to break the bone-to-implant contact[18]. "A predominant finding has been that roughened implant surfaces have greater amounts of bone-to-implant contact than do smooth surfaces. In addition, greater forces are

required to remove implants with a rougher surface compared to implants with a smoother surface"[18]. One of the original roughened implant surfaces was ITI's (International Team of Implantology) Titanium Plasma Sprayed (TPS) surface. This surface was created by flame-spraying the implants with titanium powder at high temperatures. "During this process the particles of the powder weld to each other and to the implant, producing a rough surface with crevices and pores"[15]. According to orthopedic literature at that time, the adhesion of tissue to this type of titanium surface was significantly stronger compared to a smooth surface[15]. Another modified surface was the titanium implant with a hydroxyapatite coated surface. In animal models the hydroxyapatite surface had greater bone to implant contact compared to machine and roughened titanium surfaces.[19, 20] The disadvantage of this type of implant is the HA coating is prone to failure. Coating failure can either occur through dissolution of the HA coating or, due to a weak HA coating-titanium interface, the coating can fracture from the titanium surface.[21] In 1991 Buser et al conducted a study to evaluate 6 different implant surfaces[22]. The study compared machined implant surfaces, varying degrees of roughened implants and hydroxyapatite coated surfaces. The implants being evaluated were placed in miniature pigs. The study results concluded that roughened surface titanium implants had the greatest bone-to-implant contact. The roughened surface with the greatest bone-to-implant contact was created with large-grit sandblasting and acid attack. In addition, the research team found that hydroxyapatite coated surfaces had a localized resorption of the hydroxyapatite surface coating. They concluded that "the extent of the bone-implant interface is positively correlated with an increasing roughness of the implant surface".[22] These results were confirmed through further clinical research from differing research groups throughout the 1990s.[23, 24] ITI's sandblasting acid attack surface, otherwise known as SLA surface, is

created by sandblasting the titanium surface with a large grit (0.25-0.50 mm) and acid attack with HCL/H_2SO_4.[25] In 1998 further research confirmed that the roughened SLA surface not only had a greater bone-to-implant contact when compared to machine surfaces, but also had significantly greater removal torque values.[25] When testing removal torque in miniature pigs "machined titanium surfaces clearly demonstrated the lowest mean removal torques (0.15-0.25 Nm)" compared to SLA surfaces which exceeded 1.14 Nm (1.14-1.54 Nm).[25] Around this time another method of surface modification arose, anodization. Anodizing is an electrochemical process that thickens and toughens the naturally occurring protective oxide layer on titanium.[26] Anodic coating creates a more porous surface structure. In 1994 Larsson et al found very few difference between implant surfaces, although the machined and anodized surfaces had better bone-to-implant contact compared to the electropolished surfaces.[27] At one year follow-up the same group of researchers found that there was no difference between the test groups when analyzing bone-to-implant contact. "Regardless of surface modifications, a high degree of bone-implant contact was found for all titanium implants studied."[28] Although, the authors admitted that "all surfaces used in this study are still relatively smooth compared to…sandblasted or plasma-sprayed surfaces."[28] In 2003 Zechner et al compared healing of machined, HA coated and anodized implant surfaces (TiUnite) in mini-pigs. They found BIC to be significantly greater in the anodized surfaces compared to the machined surfaces (~30% vs. ~61%). The BIC in the HA coated and anodized implants were similar (~49% vs. ~61%).[29] In the HA coated group resorptive inflammation was observed resulting from HA surface resorption by macrophages, as previously described by Buser et al.[22] Balshi et al conducted a retrospective study evaluating survival rates of TiUnite surface implants in the maxilla of humans, including the pterygomaxillary region.[30] The pterygomaxillary region is a difficult

and problematic area for the treatment of dental implants.[31] This may be because the maxillary posterior quadrant has poor bone quality and decreased bone quantity.[32] In this retrospective study Balshi and colleagues found that the TiUnite surface implants had an overall survival rate of 98%. And for those TiUnite implants placed in the pterygomaxillary regions they reported a survival rate of 94-100%, depending on the implant diameter. In 2004 Buser and colleagues tested a new implant surface, the SLActive surface. Similar to the SLA surface, the SLActive surface is a titanium implant treated with sandblasting with large grits (0.25 to 0.50mm) and acid etched with HCL/H_2SO_4. The SLActive surface is unique in that it is treated under a nitrogen atmosphere, rinsed and stored in an isotonic NaCl solution.[33] When comparing the two surfaces they found that in early healing, at 2 and 4 weeks, the SLActive surfaces had significantly more bone-to-implant contact. At 8 weeks the two surfaces had similar bone-to-implant contact.[33] In 2006 a subsequent study was published comparing the removal torque of the SLA and SLActive surfaces.[34] The removal torque values at 2, 4 and 6 weeks healing were all significantly greater the SLActive group. Surface modification under nitrogen atmosphere reduces atmospheric contamination seen in the SLA surface. By avoiding contamination, a hydrophilic surface is produced rather than the SLA hydrophobic surface.[35] This allows for the more rapid healing observed following implant placement.[33, 34, 36] Current and future endeavors in implant surface research aim to continue enhanced healing, increase implant strength and resistance to implant disease.

Longitudinal Implant Studies

Early implant designs were plagued with unpredictability and poor implant survival.[11, 37] Clinicians were taking them out quicker than they could put them in. For the most part, dental implants were seen as experimental. Many of the shortcomings can be attributed to the

use of materials with low biocompatibility such as lead, gold, resins and others.[8] In 1952, when Prof. Branemark discovered osseointegration, a new chapter of implant dentistry began. With the discovery of a highly biocompatible material, titanium, dental professionals could place implants with a degree of predictability that was previously unknown. In 1965, Dr. Branemark treated his first patient with four titanium implants. These implants remained in place for the next 40 years, until the patient passed. Adell et al published data on Branemark's original group of implant patients. This included 1,997 fixtures placed between 1965 and1980. They reported 5-9 year survival rates in upper jaws of 81% and 91% in lowers jaws.[5] Adell et al in 1985 published 5-12 year Branemark implant survival rates of 93%.[38] In 1990, the same group published 10 year data with mandibular implant survival rates of 95%, while maxillary implant survival rates were 81%.[13] At the same time a group from Toronto, Zarb et al, reported 5-9 year survival rates of 85%.[39] Both Zarb and Adell, reported lower survival rates in the maxilla. The maxilla, especially the posterior maxilla, can be a difficult area for the treatment of dental implants.[31] In some cases this could be due to poor bone quality and decreased bone density.[32] Jaffin et al followed 1,054 Branemark implants for 5 years. They reported a 97% survival rate of implants in Type I, II, III bone.[40, 41] They observed a 65% survival rate of implants placed in Type IV bone. The authors discussed that "while compiling statistics, it became evident that Type IV bone was the single greatest determinant in predicting fixture failure." New surfaces were developed in the 1990s that enhanced wound healing and increased bone-to-implant contact.[22, 27, 29, 33, 42] Following these developments an increase in survival of implants, in less than ideal bone quality, have been observed.[43] In 2014 a systematic review reported on 19 prospective and retrospective implant survival studies.[43] The review included both machined and surface treated implants. Implants placed in Type I, II,

III bone had a survival rate of greater than 95%. Implants place in Type IV bone had an 88% survival rate. While the implants placed in less dense bone did not reach the survival rates of implants placed in denser bone, this is certainly an improvement from previous reports and a successful outcome according to Albrektsson et al.[37] Other reports have shown similar survival rates amongst implants placed in all 4 bone quality types.[44-46]

Definition of Peri-implant Disease

The term peri-implantitis first appears in the literature in 1965, by Levignac et al, and again in the 1980s, by Mombelli et al.[47-50] The First European Workshop on Periodontology agreed that the term should be used to specify destructive inflammation around osseointegrated implants that lead to peri-implant pocket formation and loss of supporting bone.[48] In 1994, Mombelli et al stated that peri-implant "pockets 5 or more millimeters deep can be viewed as protected habitats for putative pathogens and are a sign of peri-implantitis."[51] Recent meetings and publications on peri-implant disease reported numerous conflicting definitions of peri-implantitis in the literature.[49, 52, 53] In 2002 Berglundh et al, defined peri-implantitis as implants demonstrating "probing depths of >6mm in combination with bleeding on probing/suppuration and attachment loss/bone loss of 2.5mm."[54] According to an AAP 2013 report, "Peri-implant diseases present in two forms – peri-implant mucositis and peri-implantitis."[55] The report defines peri-implant mucositis as being characterized by inflammation limited to the soft tissues surrounding an implant, but not involving supporting bone tissue. While peri-implantitis involves inflammation of the peri-implant soft tissues and evidence of loss of implant supporting hard tissue. These definitions of implant disease are in agreement with other groups world-wide.[49, 56, 57] A recent international meeting, in Roma, stresses the importance of baseline radiographs. These baseline radiographs should be "taken at

or within weeks after the installation of the prosthetic suprastructure."[56] The baseline radiograph is critical in that it will serve to detect any future marginal bone loss. Early healing bone loss, as defined by Albrektsson and Zarb in 1986, is excluded from the definition of peri-implantitis.[37, 49] This early bone loss definition, modified in 1991, includes 1mm of acceptable bone remodeling and an additional 0.2mm of bone loss during subsequent years.[58] Although relaying solely on clinical measurements to diagnose peri-implantitis is not advised, clinical measurements should not be overlooked. If gentle probing (<0.25 N) elicits BOP this is a sign of peri-implant soft tissue inflammation.[49, 56] While peri-implant mucositis is not always a precursor to peri-implantitis, in 2012 Costa et al published evidence showing lack of annual supportive therapy in peri-implant mucositis resulted in 43.9% of implants converting from mucositis to peri-implantitis.[59] Increased probing depths and bleeding is not a diagnosis of peri-implantitis, but an indicator for supplementary radiographic examination.[49, 56] In comparison to peri-implantitis definitions that rely on clinical indicators[60, 61], a diagnosis of peri-implantitis based upon a series of comparative radiographs over time appears to be a more reliable method.[49, 56, 57]

Prevalence of Peri-implant Disease

In 1990 a group from Toronto, Zarb et al, published implant survival data on a collection of Branemark implants in place for 5-9 years.[39] Over the 5-9-year study period, 8 (3.29%) out of 253 successfully integrated implants did not meet the criteria for success[37] and were removed. More recent investigations have reported conflicting rates of peri-implant disease. Fransson et al, in 2005, reported on 662 patients treated with Branemark implants with radiographic follow-up of at least 5 years.[62] The authors reported 28% of patients and 12.4% of implants demonstrated progressive bone loss. They also reported that 32% of the 3,413

implants illustrated bone loss up to the third implant thread at one year. Jemt et al continued to follow the progressive bone loss patient population in this study.[63] They followed these patients for an average total follow-up time of 9.1 years. They reported that, in a patient population defined as having progressive bone loss, the average bone loss for the current follow-up period was 0.3mm. 91.4% of the followed implants showed no or smaller annual bone loss than <0.2mm during follow-up. Which argues that in a machined implant surface population defined as having progressive bone loss, future bone loss is not a certainty. In 2016 Derks et al reported on the prevalence of peri-implant disease.[64] The authors found that only 23% of the implant patients were free of implant disease. While 32 % exhibited peri-implant mucositis and 45% showed signs of peri-implantitis. They defined peri-implantitis as "BoP/suppuration and detectable bone loss (>0.5mm; exceeding the measurement error)". In response to these recently published articles suggesting higher rates of peri-implantitis[62, 65, 66], a group of clinicians met in Rome to review the current implant literature.[52] They found that a lack of homogeneity when reporting on the condition may in fact be leading to higher reported occurrence of peri-implantitis compared to what clinicians see in everyday practice. For example, there is a lack of consensus for the definition of peri-implantitis. Depending on how liberal or conservative the authors definition is this will affect the reported prevalence of the problem. Also, publishing data at the patient level versus the implant level can artificially inflate the rate of occurrence of a condition such as peri-implantitis. Lastly, in some articles the lack of baseline radiographs makes it impossible to accurately diagnosis peri-implantitis. Other, more recent, longitudinal implant publications have reported a rather low occurrence of peri-implantitis.[6, 67] Chrcanovic et al reported-on a group on 300 implants that were followed radiographically for a minimum of 20 years.[6] They found that over 2 decades only 11.7% of the implants exhibited

more than 3mm of bone loss and 100% of the 300 implants were still surviving. In 2017 Rakic published a systematic review that included 29 articles on the prevalence of peri-implantitis.[67] The articles included all agreed on the following definition of peri-implantitis: ≥2mm of implant bone loss, BOP and probing depth ≥5mm. They observed that the prevalence of peri-implantitis at the patient level was often higher when compared to the implant level. Following a meta-analysis peri-implantitis was estimated at 12.8% and 18.5%, at the implant level and patient level respectively. While peri-implantitis is suspected to be less prevalent than some recent studies have suggested, most clinicians would agree that this condition still plagues our patients.

Etiology of Peri-implant Disease

Bacterial Plaque

It has been suggested that peri-implantitis may be a site-specific infection similar to the ecosystem encountered in periodontal diseases.[47] In 1987 Mombelli et al observed bacteria samples in successful implants and peri-implantitis sites.[47] The predominant bacteria morphology found at successful sites, including successful implant sites within patients containing peri-implantitis sites, were coccoid. No presence of spirochetes and very low percentage of motile and fusiform organism were present at successful sites. Conversely, peri-implantitis sites had a regular presence of gram negative, spirochetes, fusiform and motile bacteria. Berglundh and Lindhe et al studied the effect of plaque formation around implants in a dog model.[68, 69] They found that the amount of plaque formation upon termination of oral hygiene was similar when comparing natural tooth to implant tooth surfaces. Similar findings have occurred when studying plaque accumulation in humans at teeth and implants sites.[70] Upon histomorphometric analysis, Lindhe et al observed both tooth and implant tissues responded to plaque accumulation with a connective tissue inflammatory infiltrate. Although the

peri-implant inflammatory infiltrate was significantly larger. When cotton ligatures where used to induce disease, bone loss was observed at both teeth and implants. Although implants showed more severe bone loss. It was observed that in teeth the connective tissue inflammatory infiltrate always terminated before reaching the alveolar crest. The inflammatory infiltrate was separated from the bone crest with a zone of structurally intact tissue between the inflammatory infiltrate and the alveolar bone crest. This zone of structurally intact tissue was not present at implant sites. Thus, the inflammatory infiltrate extended to the alveolar bone crest at implant sites. The authors hypothesized that at the implant a "lack of cementum with inserting collagen fibers might have enabled a more rapid downgrowth of plaque than at the teeth."[69]

History of Periodontitis

In more recent publications, a history of periodontitis has been associated with peri-implantitis.[64, 71-73] Roos-Jansaker et al reported on long-term follow-up on a group of 1,057 Branemark implants.[71] A significant relationship was found between peri-implantitis and bone loss around other teeth in the same patient. Specifically, patients who had teeth with ≥4mm of bone loss had a significant association with peri-implantitis at their implant sites. Swierkot et al found that in a group of implant patients with a treatment history of aggressive periodontitis, 26% of their implants were diagnosed with peri-implantitis.[72] While healthy individuals illustrated peri-implantitis in 10% of implants. It was calculated that patients with aggressive periodontitis had a 14 times greater risk of peri-implantitis. In 2015 and 2016 publications by Derks et al reported that a previous diagnosis of periodontitis had an odds ratio of 3.3 for early implant loss and an odds ratio of 4.08 for peri-implant bone loss of >2mm. In light of these publications it appears prudent to discuss this risk factor with appropriate patients and treat their periodontal disease prior to implant placement.

Excess Cement

In 1999 Pauletto et al published on 4 cases in which they observed implant complications that seemed to be associated with excess dental luting cement at the crown-abutment interface.[74] The complications always resulted in soft tissue inflammation and edema, and in some cases marginal bone loss. Removal of the excess cement by way of a gingival flap procedure resolved the signs and symptoms, except in cases that included marginal bone loss. In the cases with marginal bone loss, removing excess cement resolved gingival inflammation, but following healing gingival recession was noted. A decade later Wilson et al reported on 42 implants that exhibited signs of peri-implant disease.[75] The authors found excess cement at 34 of the 42 implants exhibiting signs of disease. Twelve control implants, in the same patient population and without signs of inflammation, had no excess cement. Following removal of the excess peri-implant cement, 75% of the originally diseased implants were without signs of inflammation. The same research group has reported on histologic and elemental analysis of a cohort of 19 peri-implantitis lesions.[76] All 19 specimens had elements of commonly used dental cements. Sailer et al reviewed screw retained versus cement retained implant crowns.[77] The authors found that cemented retained crowns had significantly more biologic complications (implant loss, bone loss >2mm) compared to screw retained implant crowns. In 2015 Rodriguez et al investigated cellular viability response to commonly used dental cements.[78] They found that osteoblast proliferation was much less affected by dental cements compared to gingival fibroblasts. On the other hand, fibroblast cell viability was significantly reduced by dental cement exposure. While implant crown cementation cannot always be avoided, thorough removal of excess cement is critical.

Titanium/Corrosion

Since the advent of titanium in the biomedical world, this metal has been viewed and accepted as a biologically inert material. This view is substantiated by years of research and clinical success.[5, 6, 13, 39, 79, 80] Particles of titanium identified in peri-implantitis lesions has led some researchers to question if these particles are possibly causing a host reaction.[81-83] It has been suggested that these metallic particles may be involved in a cytotoxic and inflammatory process. These "metal ions and debris are recognized as foreign bodies by the immune system, stimulating the migration of polymorphonuclear leukocytes and macrophages, and then activating biochemical mediators associated with bone resorption and peri-implant disease."[84] One way these titanium particles may be introduced to the peri-implant surrounding tissues is through titanium implant degradation via corrosion.[85] Implant corrosion can be stimulated in the presence of an acidic environment. The etiology of the acidic environment can be brought on by an inflammatory process, bacterial biofilm, or acidic solutions introduced to the implant surface. Mechanical factors such as cyclical loading may lead to corrosion as well. And the combination of an acidic environment and mechanical loading can cause a synergistic action leading to corrosion.[85]

The etiology of peri-implant disease is not completely understood. It appears that the cause may be multi-factorial. In the fight against peri-implant disease, prevention maybe our best tool. Prevention calls for a well-planned surgical and restorative treatment plan, along with an adequate maintenance protocol.[86, 87]

Treatment of Peri-implant Disease

In 1987, Mombelli et al, introduced the term "peri-implantitis" and illustrated similarities between disease around implants and periodontitis.[47] The authors found that the bacterial population of periodontally involved teeth were similar to those found around implants with peri-implantitis. Mousques et al reported that subgingival instrumentation of periodontally involved teeth was able to return the subgingival bacterial population back to those found around teeth with a healthy periodontium.[88] It would seem logical that similar subgingival instrumentation treatment around implants could achieve a similar affect to those observed around teeth. In the 1990s several articles were published that observed deleterious implant surface alterations caused by metal scalers and ultrasonic instruments.[89-91] These authors suggested the use of plastics scalers, as these instruments caused the least implant surface alterations. Other authors have found that plastic instruments leave behind plastic debris, that is difficult to remove, following instrumentation of titanium.[92, 93] Still other clinicians have found that an array of instruments, from glycine powder air-polishing to metallic instruments, are safe to use on titanium implants.[94, 95] In 2017 Hoerler et al published data on a large group of implant patients receiving implant hygiene instrumentation with several different types of instruments ranging from plastic, titanium, stainless steel curettes to ultrasonic devices.[86] The authors found that "more consistent dental hygiene therapy increases the median in years of which soft tissue pathology or implant failure present", regardless of the type of instrument used. Porras et al compared mechanical debridement alone or mechanical debridement plus chlorhexidine irrigation in the treatment of peri-implant mucositis.[96] They found that both treatments were effective at reducing BOP, but did not eradicate disease at all sites. In 2017 John et al treated peri-implant mucositis and peri-implantitis with non-surgical treatment. They compared

treatment with carbon fiber curettes plus chlorhexidine irrigation to Er.YAG laser treatment. The authors observed disease resolution in 54.2% of peri-implant mucositis sites and 50% of peri-implantitis sites, regardless of the treatment modality.[97] Sahm et al observed non-surgical treatment of peri-implantitis with an air-abrasive device or mechanical debridement.[98] The air-abrasive device used an amino acid glycine powder, while the mechanical debridement group was completed using carbon fiber curettes followed by irrigation with chlorhexidine. At 6 months the air-abrasive treatment group revealed significantly greater reduction of BOP when compared to the mechanical debridement group. Although both groups exhibited comparable probing depth reductions at around 0.6mm. Thus far the literature has shown that non-surgical treatment significantly reduces BOP at peri-implant mucositis sites with both conventional debridement and debridement plus adjunctive therapy. Complete disease resolution is not commonly observed following therapy.[99-101] In light of the possible peri-implant disease etiologies of bacterial plaque and foreign material, a peri-implant sulcular debridement via sulcular curettage appears prudent and has been rarely studied. Therefore, the purpose of this study was to investigate the effects of sulcular debridement and chlorhexidine irrigation at peri-implant disease sites.

CHAPTER II

MATERIALS AND METHODS

Patients were recruited from the Departments of Periodontics and Hygiene at Texas A&M College of Dentistry. All patients had at least one or more dental implants with peri-implant disease. Peri-implant disease was defined as the following:

- Peri-implant mucositis – Dental implants exhibiting bleeding following gentle probing with a UNC-15 periodontal probe and no evidence of radiographic bone loss.[55]
- Peri-implantitis – Dental implants exhibiting bleeding and/or suppuration following gentle probing with a UNC-15 periodontal probe and radiographic bone loss following initial bone remodeling after implant placement.[55]

Patients were excluded if they met at least one of the following criteria: Pregnant or lactating females, individuals younger than 18 years of age, non-English speakers, patients with an ASA 3 classification, diabetic patients with HbA1c > 7, History of tobacco, alcohol or drug dependency, patients taking anti-resorptive or immunosuppressive agents and/or allergy to chlorhexidine. Patients had a one-hour clinical appointment. During this period of time, the patient signed an informed consent and had a clinical and radiographic evaluation. The clinical records of the patients were reviewed to obtain the dental implant(s) and medical history.

The following baseline clinical parameters were evaluated. The probing depth (PD) were evaluated in 6 sites per implant with a UNC-15mm periodontal probe and were defined as the distance in mm from the gingival marginal to the tip of the probe. The presence of bleeding on probing (BOP) and suppuration was recorded immediately afterward probing and was defined as present or absent. A vertical bite wing radiograph was obtained from the areas of the patient's mouth that have a dental implant (if the patient file had a recent periapical radiograph i.e. taken

no more than one month prior to entering the study, that radiograph will be used for the present study and no additional radiographs will be taken as long as radiographs on file are of diagnostic quality).

Following the baseline evaluation described above, implants will undergo an initial treatment phase. Implants will be randomly assigned to two different groups. Group 1 implants initially received debridement of the peri-implant sulcus. While Group 2 implants received sulcular irrigation with 0.12% chlorhexidine gluconate. Four weeks following initial treatment patients from both groups were re-evaluated and measurements were recorded (PD, BOP, Suppuration, GI). Group 1 patients received sulcular irrigation with 0.12% chlorhexidine gluconate, while Group 2 patients received debridement of the peri-implant sulcus. Four weeks following administration of crossover treatment patients were re-evaluated and measurements were recorded (PD, BOP, Suppuration, GI). 8 weeks following administration of crossover treatment measurements were recorded (PD, BOP, Suppuration, GI).

CHAPTER III

RESULTS

Included in this study were 12 patients and 25 implants. All implants included were of the roughened surfaced type. 36% of implants exhibited peri-implant mucositis. While 64% of implants were defined as having peri-implantitis. Implant average baseline PD was 4.8mm, with a range of 1mm to 12mm (Table 1). 100% of sites bled upon probing, while suppuration was detected at 12% of sites (Figure 2). The average baseline GI was 1.8 (Figure 3). At the end of the 3 month follow-up the average PD was 4.2mm (Figure 1).

Table 1 Baseline Measurements

	PD (mm)	BOP	Suppuration	GI
All implants	4.84	100%	12%	1.80
Peri-implant mucositis implants	3.80	100%	0%	1.87
Peri-implantitis implants	5.43	100%	18.8%	1.81

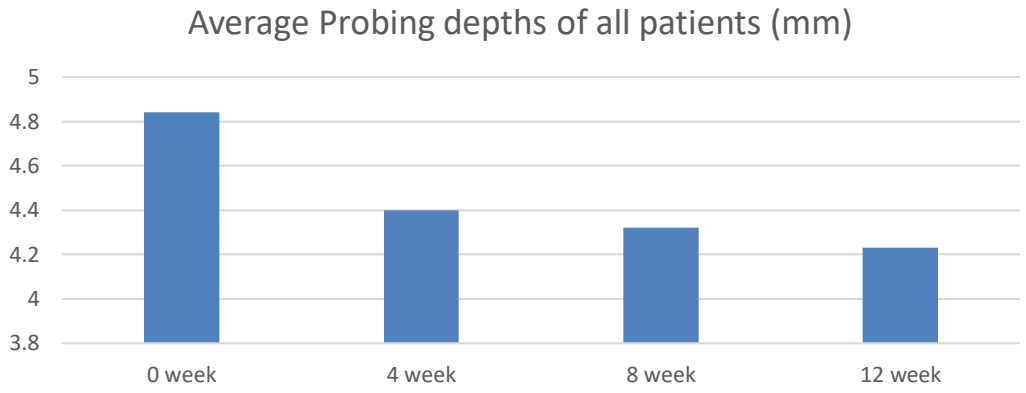

Figure 1 Average Probing Depth of all Patients

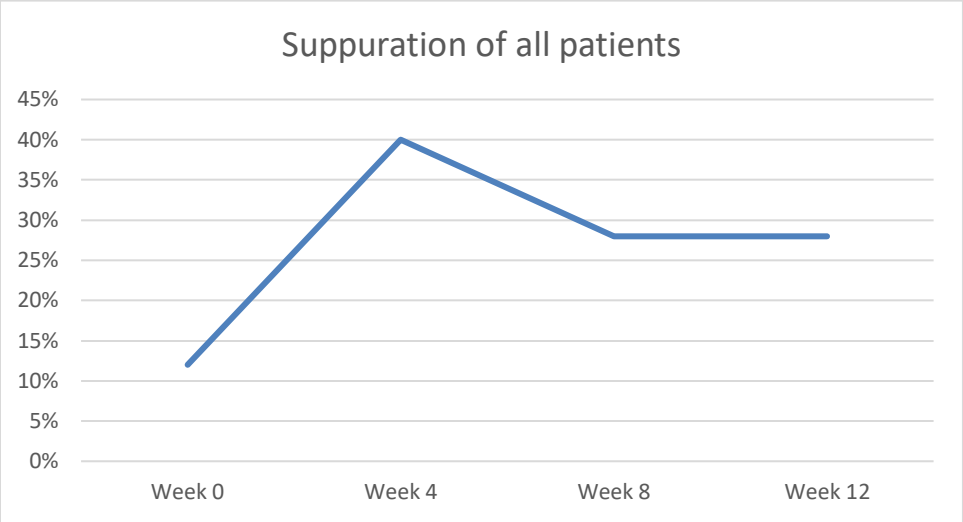

Figure 2 Suppuration of all Patients

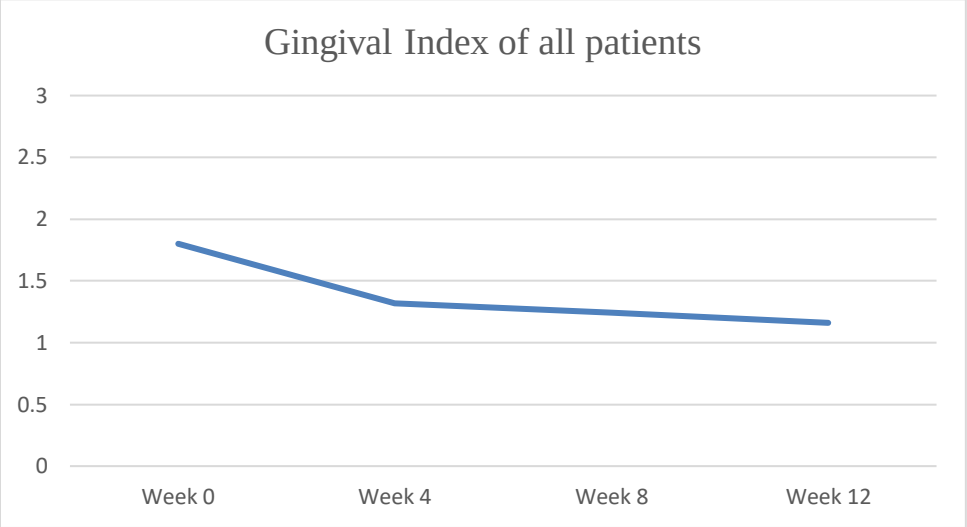

Figure 3 Gingival Index of all Patients

72% of sites bled upon probing, while at 28% of sites suppuration was detected. The average GI at 3 months was 1.16 (Figure 3). When comparing peri-implantitis mucositis versus peri-implantitis sites baseline PD were 3.8mm and 5.43mm, respectively (Figure 4).

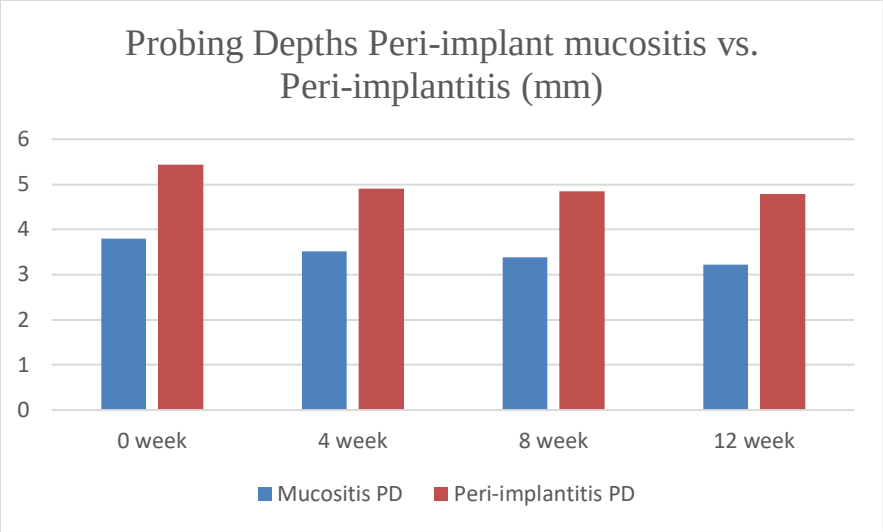

Figure 4 Probing Depth Peri-implant Mucositis vs. Peri-implantitis

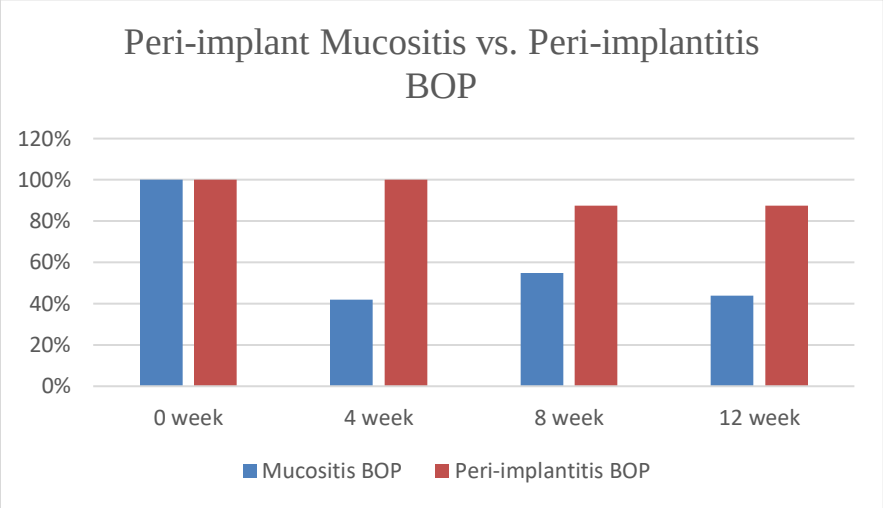

Figure 5 Peri-implantitis vs. Peri-implant mucositis BOP

Both groups initially exhibited 100% BOP (Figure 5). Peri-implant mucositis sites had no suppurating sites, while the peri-implantitis group exhibited suppuration of 18.8% of implants. Average GI for peri-implant mucositis sites was 1.9. Peri-implantitis sites had an average GI of 1.8. At 3 months peri-implant mucositis implants had an average PD 3.2mm and peri-implantitis implants had an average PD of 4.8mm. This is an improvement of 0.58mm and 0.64mm at peri-

implant mucositis and peri-implantitis sites, respectively. At 3 months BOP was recorded at 33.3% and 81% for peri-implant mucositis implants and peri-implantitis implants, respectively. Suppuration at peri-implant mucositis implants remained at 0% of implants, while peri-implantitis group exhibited suppuration at 43.7% of implants. GI at 3 months was 0.67 and 1.44 at peri-implant mucositis and peri-implantitis implants, respectively. When comparing the two treatment modalities, Group 1 patients, initially receiving debridement treatment, had an average PD of 4.56mm, 100% of implants exhibited BOP and 14% of implants recorded suppuration (Figure 6, 7).

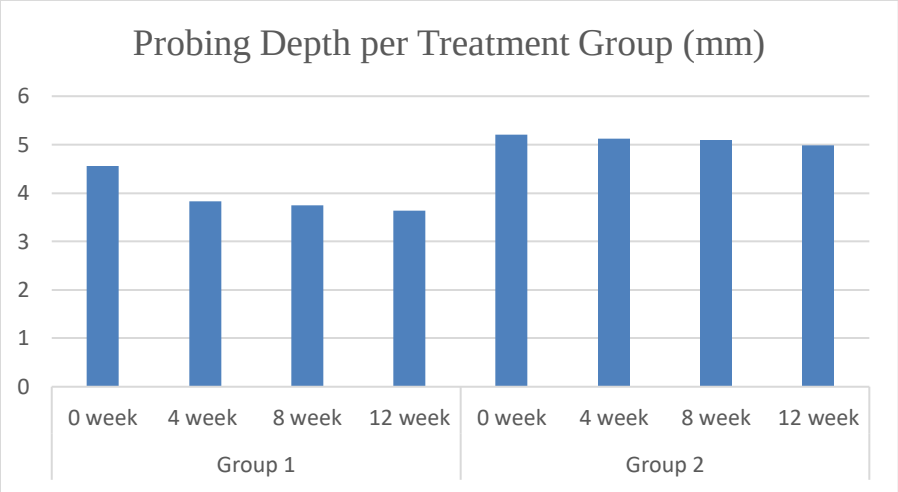

Figure 6 Probing Depth per Treatment Group
Group 1 received debridement at Week 0 & CHX irrigation at Week 4
Group 2 received CHX irrigation at Week 0 & debridement at Week 4

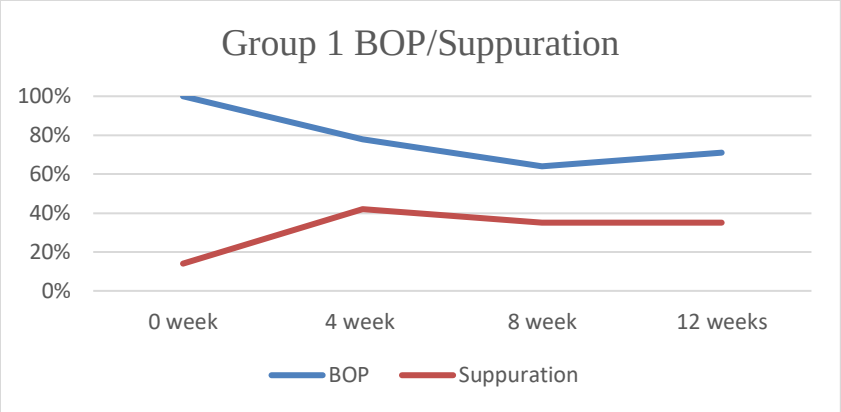

Figure 7 Group 1 BOP/Suppuration
Group 1 received debridement at Week 0 & CHX irrigation at Week 4
Group 2 received CHX irrigation at Week 0 & debridement at Week 4

An average GI of 1.5 was recorded. 4 weeks following peri-implant sulcular debridement the average PD measured was 3.83mm, with 78% of sites exhibiting BOP, 42% of sites showed suppuration and an average GI of 1.21 was recorded. Group 2 patients, initially receiving chlorhexidine irrigation, had a baseline average PD of 5.2mm, BOP at 100% of implants, suppuration at 10% of implants and average GI of 2.1 (Figure 5, 7). 4 weeks following chlorhexidine irrigation the average PD was 5.1mm, BOP was still 100%, 36% of implants exhibited suppuration and the average GI was 1.3. At 4 weeks both groups received crossover treatment. Group 1 patients 4 weeks following the crossover treatment of chlorhexidine irrigation had an average PD of 3.74mm. BOP was exhibited at 64% of implants, suppuration was recorded at 35% and an average GI of 1.21 was recorded. Group 2 patients 4 weeks following the crossover treatment of sulcular debridement had an average PD of 5.1mm. BOP was exhibited at 90% and suppuration at 9% of implants and an average GI of 1.1 was recorded (Figure 7, 8, 9).

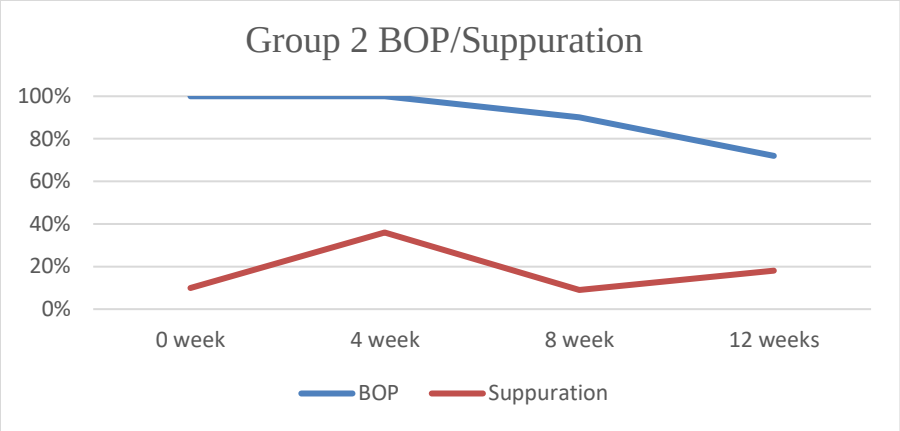

Figure 8 Group 2 BOP/Suppuration
Group 1 received debridement at Week 0 & CHX irrigation at Week 4
Group 2 received CHX irrigation at Week 0 & debridement at Week 4

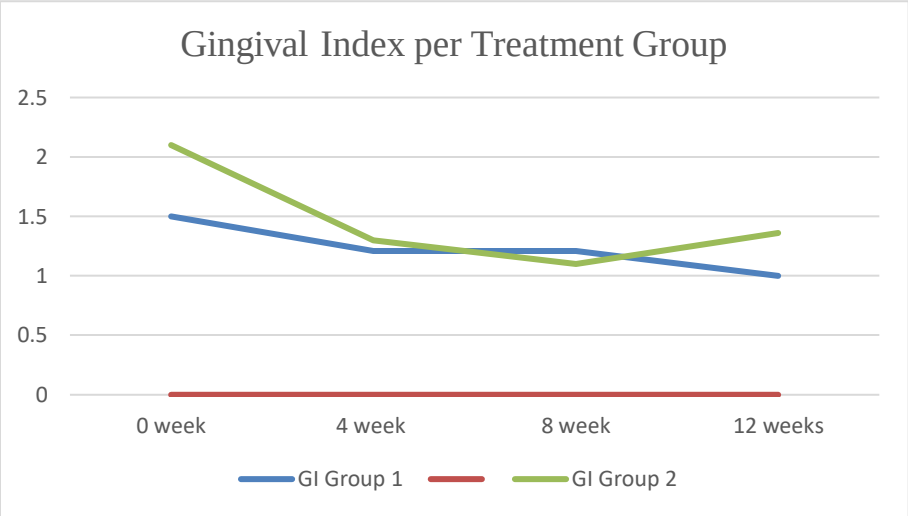

Figure 9 Gingival Index per Treatment Group
Group 1 received debridement at Week 0 & CHX irrigation at Week 4
Group 2 received CHX irrigation at Week 0 & debridement at Week 4

CHAPTER IV

DISCUSSION

The purpose of this study was to investigate an initial therapy for the treatment of peri-implant disease. When choosing our ideal initial treatment, we tried to avoid cumbersome treatment that would require special instrumentation that may not be readily available in a general dental practice. In light of past and recent literature linking the possible etiology of peri-implant disease to plaque and foreign materials, we chose to utilize treatment via a peri-implant sulcular debridement.[47, 70, 75, 76, 82] In this case a conventional stainless-steel curette, found in every dental practice, was used to complete a sulcular curettage which avoided contact with the implant surface. In doing this, it was our goal to remove bacterial plaque and inflamed sulcular tissue which may contain foreign debris such as cement and titanium. If any cement or calculus was detected on the implant surface a titanium curette would be utilized to remove this debris from the implant surface. In our observed patient population this circumstance did not present itself. Although this was not observed in our study the literature clearly supports that this can occur with some frequency and the effects can be deleterious.[75, 76] We may not have observed excess cement in our study due to the fact that this treatment was carried out non-surgically. Studies reporting on excess cement have used surgical access or enhanced visualization techniques.[75] Although we did not detect excess cement around the studied implants there could have still have been residual cement particles in the peri-implant soft tissues, as found in current literature.[76] A sulcular curettage may help remove these retained cement particles.

The current study found an average PD improvement of 0.73mm and BOP reduction of 22% a month following sulcular debridement. The chlorhexidine irrigation group had PD reduction of 0.08mm and no improvement in the BOP parameter. At 3 months, once all implants received both treatments, the peri-implant mucositis and peri-implantitis implants had a PD reduction of 0.58mm and 0.64mm, respectively. Percent BOP reduction at 3 months was 66.7% and 19% at peri-implant mucositis and peri-implantitis implants, respectively. Sahm et al reported on 43 implants all suffering from peri-implantitis.[98] One group received non-surgical treatment by mechanical debridement with carbon curettes and irrigation with chlorhexidine. The second group received non-surgical treatment by a glycine powder airflow device. At three months post treatment PD reduction of 0.8mm was observed in both groups. BOP reduction of 24.8% was observed in the mechanical debridement group while a reduction of 51.6% was observed in the glycine powder treatment group. Menezes et al studied a group 119 implants diagnosed with peri-implant mucositis.[102] The test group implants were treated with mechanical debridement plus chlorhexidine irrigation while the control implants were treated with mechanical debridement alone. At 3 months the test implants exhibited PD reduction of 0.51mm while the control's PD improved by 0.35mm. The test and control groups exhibited BOP reduction of 35.4% and 23%, respectively. Both of these studies offered similar results to the current study. The present results suggest that disease resolution is not commonly observed following non-surgical treatment of peri-implant mucositis and peri-implantitis. This conclusion is in alignment with a 2016 consensus paper published following a meeting on non-surgical treatment of peri-implant disease at the EUROPERIO 8 conference.[99]

There were some limitations to the current study. The study population was quite small. This led to the study being underpowered. In 2017 Stein et al studied are larger implant

population. He observed 164 implants with peri-implantitis treated with non-surgical therapy.[103] Non-surgical therapy consisted of "submucosal depuration of the implant surfaces with piezoelectric ultrasonic device" with a metal tip, removal of sulcular granulation tissue via tissue curettage with a metal curette and subgingival cleaning of the implant surface with a glycine air polishing device plus submucosal application of 10% PVP-iodine solution. At 12 months follow-up the authors observed a reduction in PD of 1.3mm and BOP reduction of 36.5%. Compared to the current study, these authors found a greater reduction in PD and BOP in a large implant population with peri-implantitis. Another limitation to the current study is the limited amount of follow-up time. While other recent studies have utilized a 3 month observation period, others have extended this period of observation. Extending the follow-up period is advantageous in that you can observe whether the results sustain themselves, improve or deteriorate.

CHAPTER V

CONCLUSION

When comparing the treatment of sulcular debridement to chlorhexidine irrigation, sulcular debridement had greater reductions in PD and BOP, although neither group seemed to make clinically significant reductions. Following the completion of both treatments at 3 months peri-implant mucositis PD improved by 0.58mm, while peri-implantitis PD improved by 0.64mm. Peri-implant mucositis and peri-implantitis BOP reduced by 56% and 12.5%, respectively. These results are similar to other recently published literature and a consensus report that concluded that complete disease resolution is not commonly observed following non-surgical therapy of peri-implant disease.[98, 99]

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