UIC College of Dentistry Implants Outcome Study

BY

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THESIS

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ANN	Artificial neural network analysis
BOP	Bleeding of probing
PPD	Periodontal probing depth

SUMMARY

Introduction: Every year millions of dental implants are placed, and these add to the several millions of implants that are in use. Dental implants though are not immune to complications. These complications can be biological or biomechanical.

Objectives: This study proposed to follow up and evaluate the biological and biomechanical status of implants placed in the UIC COD clinics and assess the various factors that could have resulted in or predicted the health outcome of the implants. The main objectives of the study were to evaluate outcomes of the implants placed at UIC College of Dentistry and identify factors associated with peri-implant diseases and implant failure. The study also aimed to introduce the use of a novel artificial neural model analysis to predict the most important factors affecting implant survival and implant success.

Methods: (I) A retrospective component which included evaluation of implants placed between January 1, 2012 to October 31, 2018 at UIC College of Dentistry. (II) A prospective component where the data from the retrospective study was utilized to identify a select set of subjects who received Dentsply OsseoSpeed EV implants during January 1, 2015 to December 31, 2016. Out of this dataset, 36 subjects were randomly selected to perform clinical and radiographic evaluation of the implant(s).

Results: The multivariate analysis showed that tobacco smoking, diabetes, history of periodontitis and bone grafting simultaneously with implant placement were significantly associated with peri-implant mucositis (P value <0.05).

SUMMARY (continued)

Results of the artificial neural network model analysis showed that tobacco smoking, patient's age at the time of implant installation, history of periodontitis and bone grafting at the time of or prior to implant installation are the most important variables predicting implant outcomes (>97% mode accuracy).

Conclusion: Patient's age at the time of implant placement, tobacco smoking status history of periodontitis and bone grafting either prior to or at the time of implant installation are the most important predictors for development of peri-implant diseases and implant survival. Therefore, patient education on smoking cessation, meticulous oral hygiene, regular periodontal maintenance compliance and influence of age should be an important part of informed consent discussion.

I. INTRODUCTION

A. Background

The use of dental implants has become increasingly prevalent in the past couple of decades for the restoration of partially or fully edentulous maxilla and mandible. There has been a remarkable surge in the use of dental implants from less than 1% in 1999-2000 to about 6% in 2015-2016 and it is projected to increase to almost 25% by 2026 (Elani et al., 2018). The overall success rate of dental implants have been shown to be higher than 90% by many long-term studies (Buser et al., 2012; Albrektsson et al., 1986; Adell et al., 1981). An osseointegrated functional implant is exposed to the oral cavity. Therefore, oral commensal bacteria can colonize on dental implant surface and restoration and form dysbiotic biofilm which can lead to inflammation in peri-implant tissues. With the rise in use of dental implants, prevalence of peri-implant diseases, implant failure and implant redo at the previously failed sites are also increasing. There is varying evidence in the literature regarding prevalence of peri-implant mucositis and peri-implantitis depending on the definitions used to diagnose peri-implant mucositis and peri-implantitis. A long-term implant success and survival rate study showed that overall survival rate of dental implants was about 83% and overall complication rate among these implants was almost 50%. Out of which, about 17% implants showed peri-implant disease (Simonis et al., 2010). This long-term study also evaluated the patients' satisfaction level via a questionnaire regarding the implant treatment where more than 90% expressed satisfaction with the function of the implant (Simonis et al., 2010). According to Daubert et al, 50% of the patients who received dental implants had peri-implant mucositis and almost 25% patients and about 17%

implants presented with peri-implantitis after 10 years of implant placement (Daubert et al., 2015). Another systematic review and meta-analysis showed that the patient-level prevalence of peri-implant mucositis was about 46% and peri-implantitis was about 20% (Lee et al., 2017). A review article published by Zitzmann and Berglundh showed that the subject-specific prevalence of peri-implant mucositis was 80% and implant-specific prevalence of peri-implant mucositis was about 50%. Whereas about 30% study participants and almost 40% implants had peri-implantitis (Zitzmann & Berglundh, 2008). Another long-term study published by Mir-Mari et al showed that patient-level prevalence of peri-implantitis was around 10% to 20% and patient-level prevalence of peri-implant mucositis was around 40% (Mir-Mari et al., 2012). A 3.5 years follow up study published by Ferreira et al showed that the prevalence of peri-implantitis was almost 9% (Ferreira et al., 2006). Similarly, another 5-year follow up study showed a 8.6% prevalence rate for peri-implantitis (Kourtis et al., 2004).

B. Review of literature

There are a number of local, systemic and prosthetic risk factors for peri-implant diseases. At the time of implant surgery and during healing phase post implant placement, dynamic and active remodeling processes occur in peri-implant tissues. 1-2 mm marginal bone loss after implant placement occurs as a normal physiological response (Albrektsson et al., 1986). However, increased bone loss can happen due to host related systemic factors such as smoking, diabetes mellitus, history of periodontitis, excessive surgical trauma, poor quality of peri-implant soft tissue, absence of adequate keratinized gingiva, presence of subgingival biofilm, and implant related factors such as subgingival inflammation caused by excessive subgingival cement in cement-retained prostheses, type of implant-abutment connection, frequent abutment disconnection and reconnection, abutment mobility resulting from screw loosening or fracture, presence of microgap between abutment and implant and implant malpositioning etcetera (Romanos et al., 2019). A retrospective study completed by Kumar et al showed that higher than 1.6 plaque index, history of periodontal disease and tooth loss due to periodontal disease, periodontitis on adjacent teeth, and apical implant placement were implant related risk factors predisposing the patients to peri-implantitis (Kumar et al., 2018). Another study reported by Wilson showed that out of all implants presenting signs of peri-implantitis, 81% of implants had cement-retained restorations with residual subgingival cement (Wilson, 2009).

The most commonly identified host systemic risk factor is uncontrolled diabetes. Diabetic patients have impaired wound healing due to immune response alterations and microvascular changes. These patients may also have decreased bone density and decreased osteoblastic activity. The advanced glycation end-products present in patients with uncontrolled diabetes can decrease the production of matrix proteins by gingival fibroblasts which can lead to periodontal bone loss and attachment loss. The increased number of cytokines including IL-6, IL-1B and TNF-a can cause exaggerated inflammatory response and bone loss around dental implants in diabetic patients (Al Zahrani & Al Mutairi, 2019)(Al Zahrani & Al Mutairi, 2018). Therefore, thorough medical history and medical consultation are necessary before treatment to make sure that patient’s glycemic control is within normal limits (Moy & Aghaloo, 2019). Implant therapy should be postponed for patients with poorly controlled diabetes until physiologic glycemic control is achieved. Additionally, patient education on adverse effects of poor glycemic control on healing after implant placement and increased susceptibility to subsequent peri-implant diseases is very important. Regular periodontal maintenance appointments and medical check-ups are critical to maintain patients physical and oral health (Moy & Aghaloo, 2019) (Romanos et al., 2019)(Javed & Romanos, 2019). A systematic review and meta-analysis published in 2017 compared the results of implant outcome in patients with euglycemia and hyperglycemia. The results of the study showed that diabetic patients had 50% increased risk for peri-implantitis as compared to non-diabetic patients. The risk for peri-implantitis increased with increasing HbA1c (Monje et al., 2017).

The second most commonly identified host systemic risk factor is tobacco smoking. Chronic exposure to nicotine can adversely affect molecular functions, immune response, periodontal health and systemic health. A number of studies have shown that chronic tobacco use can lead to altered immune response, affect proliferation of fibroblasts in periodontal tissues, damage clinical attachment levels, can lead to attachment loss and alveolar bone loss. Many research articles have shown increased incidence and prevalence of peri-implant diseases and implant failure in chronic smokers (Chrcanovic et al., 2015). Multiple research studies have shown that smoking significantly increases the risk for peri-implant diseases and implant failure (Moimaz et al., 2009)(Bain & Moy, 1993) (Lindquist et al., 1997). Lindquist et al, 1997 also found that the risk for developing peri-implant complications and bone loss increased with the increased number of cigarettes smoked daily. Another retrospective analysis showed similar results where patients who smoke cigarettes and waterpipes had a significantly greater prevalence of peri-implantitis as compared to non-smokers (ALHarthi et al., 2018). The likelihood for implant failure among smokers was 2.92 times higher than non-smokers ($P < .001$) (Alfadda, 2018).

History of periodontal disease also has been considered a major risk factor for peri-implant diseases. Multiple studies have shown that patients with the periodontitis, who received dental implants to restore their missing teeth, had an increased risk of developing peri-implant mucositis and peri-implantitis as compared to the patients with periodontal health (Safii et al., 2009) (Klinge et al., 2005). A 10-year prospective analysis showed that peri-implantitis was significantly associated with clinical attachment loss, increasing probing depth and smoking (Karoussis et al., 2004). Similarly, a Belgian study analyzing the prevalence and risk factors for peri-implantitis showed that patients with periodontitis had almost 2 times higher odd of developing peri-implantitis when compared to the patients with periodontal health (Marrone et al., 2013).

Poor patient's oral hygiene and poor compliance have been identified as very important risk factors for peri-implant diseases. Similar to periodontal disease, plaque is considered the primary etiological factor for peri-implant diseases as well (Berglundh et al., 2018). The research suggests that healthy implant sites have more numbers of gram-positive rods and cocci while peri-implant disease sites have more gram-negative bacteria, spirochetes, and anaerobes which are associated with chronic periodontitis. The evidence shows that these periodontal pathogenic bacteria may persist in oral cavity even after extraction of teeth. Hence, edentulous patients can also develop peri-implantitis if proper home care and professional care are not monitored. Peri-implant sulcus provide a unique niche for bacterial colonization. Therefore, regular periodontal maintenance and meticulous oral hygiene are the main concept to avoid transition from peri-implant mucositis to peri-implantitis (Daubert & Weinstein, 2019) (Romanos et al., 2019). Elderly patients often have impaired dexterity making meticulous oral hygiene difficult to maintain.

Therefore, strategic treatment planning to avoid too many implants should be considered. For completely edentulous patients, mandibular 2-implant supported overdenture opposed by maxillary conventional denture or implant supported overdenture if conventional in not tolerated should be considered. Dentures may favor colonization by candida; *C.albicans* biofilms containing mixed bacteria species can upregulate putative virulence factors and hyphal production. These microorganisms can attract other periodontal pathogenic bacteria making implants susceptible to peri-implant inflammation and subsequent bone loss. Proper oral hygiene instructions, powered toothbrushes instead of manual toothbrushes have shown superior results in reducing plaque and bleeding on probing. Patients should be properly educated on interdental cleaning using dental floss, superfloss, interdental brushes, and wooden toothpicks (Daubert & Weinstein, 2019).

Other host systemic risk factors for peri-implant diseases include history of radiation therapy where often occlusion of small blood vessels is seen which can limit blood flow to the surgical site. This can in turn delay wound healing and can lead to unfavorable outcomes. Similarly, patients with a history of chemotherapy should be carefully evaluated keeping xerostomia and mucositis in mind. Patients receiving anti-resorptive medications should also be carefully evaluated for the risk of medication related osteonecrosis of the jaw (Moy & Aghaloo, 2019).

Multiple studies have compared outcomes between implants placed in previously hard tissue- augmented site and implants placed in native bone. However, the evidence regarding this matter is inconclusive. A systematic review published by (Hämmerle et al., 2002) showed that the implant survival rate did not have any difference between implant placed in grafted bone or implants placed in pristine bone. Another retrospective study similar results where implants placed with simultaneous bone grafting showed similar implant success rate and implant survival rate as implants placed in pristine bone (Bazrafshan & Darby, 2014).

Trauma from occlusion and excessive occlusal forces have also been identified as potential risk factor for peri-implantitis. Occlusal forces on implants are multidirectional. Overload strains more than 3000 micro strains can affect the weakest part of the implant-abutment connection and can cause structural and/or biological complications (Delgado-Ruiz et al., 2019)**.** Experimental studies have shown that axial loads produce compressive stress at the implant apex and generate minimal stress at implant-bone interface. Whereas off axial and transverse forces can produce compressive stresses where the load is applied and tensile stresses on the other side of the load at the transition between cortical and cancellous bone in peri-implant tissues (Delgado-Ruiz et al., 2019). Compressive forces can increase bone density and shear forces are associated with bone resorption. Therefore, there needs to be an equilibrium between compressive and tensile forces and sheer forces should be minimized to maintain the stability of bone-implant interface(Delgado-Ruiz et al., 2019). On the contrary, a systemic review by Manfredini, et al did not find any impact of bruxism on development of peri-implant diseases or implant failure (Manfredini et al., 2014).

Quality and quantity of peri-implant mucosa are also very important factors in sustaining peri-implant health. The results of research studies have demonstrated that when implant is placed in a thin mucosa with minimal to no keratinized gingiva, there is a higher risk of crestal resorption and recession of marginal gingiva. Inadequate keratinized tissue may cause gingival recession and gingival inflammation in peri-implant tissues. Thin gingival phenotype, inadequate width of keratinized tissue, height and thickness of buccal bone, and malpositioning of implant in bucco-lingual direction, (implant placed too facially), angle of implant fixture, and implant-abutment, and prosthesis connection are some of the factors that increase the susceptibility to peri implant diseases (Chackartchi et al., 2019).

Apart from host related factors, there are a number of prosthetic factors that can increase the susceptibility to peri-implantitis. Microgap between implant and abutment can attract oral bacteria which can increase microbial colonization and establish a bacterial niche, causing inflammation in peri-implant tissues near the implant-abutment connection. The presence of microgap in implant-abutment connection near to the bone also increases the susceptibility for peri-implant inflammation and bone resorption. Therefore, minimizing this microgap is very important to prevent inflammation in peri-implant mucosa and maintain crestal bone stability. Research shows that implants having internal conical connection have decreased bacterial challenge than external and internal clearance-fit abutment interfaces (Koutouzis, 2019).

Thus, clinicians should consider all patient related risk factors, biological and prosthetic risk factors before treatment planning for dental implants. Patient education on the pros and cons of implant therapy, complications related to implant therapy, meticulous oral hygiene, maintaining physical health, smoking cessation and compliance with regular periodontal maintenance is key in preventing peri-implant diseases. Recognizing the patients at risk for peri-implantitis and identifying the severity of potential risk factors for peri-implantitis is an imperative aspect of patient education, informed consent, treatment planning and long-term maintenance.

C. Purpose of the study

The primary objective of the study was to evaluate implant survival for implants placed at UIC College of Dentistry. The secondary aim of the study was to assess the factors associated with peri-implant diseases including peri-implant mucositis and peri-implantitis, and implant failure. Additionally, the study also aimed to introduce the use of a novel artificial neural model analysis to predict the most important factors affecting implant survival and implant success.

D. Null hypotheses

Patients with smoking habit, history of periodontitis, uncontrolled diabetes and bruxism are not at a higher risk of developing peri-implant diseases or implant failure. Artificial neural network analysis is not a reliable statistical method in predicting the most important variables for peri-implant diseases and implant failure.

E. Significance of the study

The statistical analysis utilized in this study is novel artificial machine learning technique which uses complex algorithms to analyze large datasets. ANNs function on a continuous feedback loop that allows the algorithm to constantly learn and improve its pattern recognition, generating outcome data that can be utilized in patient education and treatment planning (Allareddy, 2019). Artificial neural network models are statistical algorithms that function similar to the human brain (Hinton, 1992). ANNs consist of an input layer, hidden layer(s) and an output layer. Hidden layers extrapolate additional information and affect the value of inputs (independent variables) in predicting the output (dependent variable). ANNs can determine the importance of each independent variable in contributing to the outcome compared to other variables. The key advantage of ANNs is their ability to model non-linear and complex relationships, as in real-life, the relationships between predictor and outcome variables are often non-linear and complex and it is difficult to always normally distribute the data (Tu, 1996) (Allareddy et al, 2019) (Park & Lek, 2016).

II. METHODS

A. <u>Eligibility</u>

For the retrospective component of the study:

Individuals, between the ages of 18 and 99, who received endosseous dental implants at UIC College of Dentistry from January 1, 2012 to October 31, 2018, and have their records present in the Axium patient database at the College of Dentistry, UIC.

For the prospective component of the study:

The inclusion criteria included: subject ≥ 18 years at time of implant placement; informed consent for implant placement was signed on the day of implant placement surgery; and subject had installed one or more Dentsply OsseoSpeed EV implants between January 1, 2015 and December 31, 2016.

The exclusion criteria included: subject not willing to partake in the study or not able to comprehend the content of the study or non-compliance to the clinical investigational plan (CIP) as judged by the Investigator.

B. <u>Excluded or Vulnerable Populations</u>

Non-English-speaking individuals were excluded from the study to facilitate study required communication and for purposes of informed consent. As the investigators involved in the study were English speaking only and the study materials including the consent form were in English. Minors, pregnant women and prisoners were also excluded from the study.

C. Study Design and procedures

The study had a retrospective component and a prospective component. For the retrospective component of the study, College of Dentistry Axium database was utilized to identify patients who received endosseous dental implants at UIC College of Dentistry from January 1, 2012 to October 31, 2018. The eligible subjects were identified from Axium database and data were exported in Microsoft Excel format and analyzed as per the study protocol.

The following data were extracted for the retrospective component: age, gender, race, ethnicity, medical history (diabetes), periodontitis diagnosis, smoking status (smoker or non-smoker), implant position, date of implant placement, history of implant removal by using ADA dental code for implant removal D6100, and history of treatment for peri-implant mucositis and peri-implantitis by using ADA dental codes D6101 – “debridement of implant defect”, D6102 – “debridement and osseous contouring of a peri-implant defect” and D6103 – “bone graft for repair of peri-implant defect”. Out of this dataset, 36 individuals with one or more OsseoSpeed Astra EV implants placed between January 1, 2015 and December 31, 2016 were separately identified for the prospective component of the study. In order to avoid bias in subject selection for the prospective clinical component, all subjects identified in the retrospective study, and noted to be eligible for the prospective component, were listed and coded. The coded list, without any identifiers, was sent to the project sponsor, DENTSPLY IH AB d.b.a., Dentsply Sirona Implants, Mölndal, Sweden for randomization. The eligible participants were contacted following a specific order as specified on the randomized list.

These subjects were contacted via telephone to provide the opportunity to participate in the study. For prospective clinical component of the study, informed consents were obtained from the study participants before the initiation of the visit. The data for demographics and other patient related details such as participant's gender, race, ethnicity, medical history (diabetes), periodontitis diagnosis, smoking status (current smoker, former smoker or non-smoker), implant position, date of implant placement, history of implant failure, peri-implant mucositis and peri-implantitis were collected. Oral examination was conducted to assess periodontal and peri-implant soft tissue status around each study implants. The soft tissue response around study implant was evaluated by assessing presence of plaque, periodontal probing depth (PPD), bleeding on probing (BOP) for each implant on the day of clinical evaluation. The presence of suppuration upon palpation or probing was also evaluated. Plaque, BOP and suppuration were evaluated at four surfaces (mesial, buccal, distal and lingual/palatal) around each implant. Plaque was recorded as presence or absence of plaque by visual inspection. PPD, BOP and suppuration were evaluated using a periodontal probe. PPD was calculated from the gingival margin to the bottom of the probable pocket in whole millimeters. BOP was recorded as present or absent when probing to the base of the probable periodontal pocket. Radiographic examination was completed by obtaining peri-apical and bitewing (where needed) radiographs at the time of their visit. Additionally, the overall status of dentition for the presence of caries, full coverage restoration, missing teeth, removable prosthesis, presence of implants, presence of tooth supported fixed partial dentures, implant supported single tooth restorations, implant supported fixed restorations and implant supported removable prosthesis were also assessed during this visit. Implant specific study details regarding implant study position, date of implant installation, implant details (length/width, reference number and/or product name), bone substitutes (Yes/No and material), last drill used (if available), bone quality (if available), date of implant loading, date when implant was lost/removed (if applicable), implant abutment and prosthesis in situ at time of dental appointment, restoration type: Single/Bridge (If bridge, the implant and/or tooth positions included in bridge), retention type: Cemented/Screw-retained/Other and prosthesis material: All metal/ Porcelain fused to metal/ All ceramic/ Other were collected for the purpose of the study. All study participants received a no-cost basic dental cleaning (dental prophylaxis, not a deep cleaning) at the end of the visit. The clinical and radiographic evaluation of implants at the time of the prospective study visit were also provided at no cost to the participant.

Additionally, a patient satisfaction questionnaire was provided to the study participants to collect data for patient reported outcomes.

Assessment of patient reported outcomes:

Participants were asked to complete a simple questionnaire to state their opinion about:

1) chewing function and 2) esthetics and 3) overall level of treatment satisfaction.

For question 1) the scale ranges from Very bad (1), Bad (2), Neither bad or good (3), Good (4) and Very good (5). For questions 2) and 3) the scale ranges from Very dissatisfied (1), Dissatisfied (2), Neither dissatisfied nor satisfied (3), Satisfied (4) and Very satisfied (5).

Authorized study site personnel provided the questionnaire during the study visit. The participant was instructed to complete it, one per study position, and return the form for data entry by site personnel.

American Academy of Periodontology 2017 World workshop defined criteria were used to diagnose peri-implant health, peri-implant mucositis and peri-implantitis. Peri-implant health is defined as "Visual inspection demonstrating the absence of peri- implant signs of inflammation:

pink, no swelling, firm tissue consistency; Lack of profuse (line or drop) bleeding on probing; and absence of further bone loss following initial healing, which should not be ≥2 mm" (Renvert et al., 2018)**.** Peri-implant mucositis is defined as "Visual inspection demonstrating the presence of peri-implant signs of inflammation: red, swollen tissues, soft tissue consistency; Presence of profuse (line or drop) bleeding and/or suppuration on probing; an increase in probing depths compared to baseline; and absence of bone loss beyond crestal bone level changes resulting from the initial remodeling"(Renvert et al., 2018). And Peri-implantitis is defined as "Evidence of visual inflammatory changes in the peri- implant soft tissues combined with bleeding on probing and/or suppuration; increasing probing pocket depths as compared to measurements obtained at placement of the supra-structure; and progressive bone loss in relation to the radiographic bone level assessment at 1 year following the delivery of the implant-supported prosthetics reconstruction; and In the absence of initial radiographs and probing depths, radiographic evidence of bone level ≥3 mm and/or probing depths ≥6 mm in conjunction with profuse bleeding" (Renvert et al., 2018).

D. Data Collection and Management Procedures

All raw data including patient reported outcome were stored in a locked filing cabinet in the office of the clinical research coordinator, which is a locked room within a limited access facility. All computer data were stored under password protection and were coded and de-identified. Study data from evaluation of the Osseospeed implants were entered into electronic Case Report Forms (eCRFs) using Viedoc™, a web based Electronic Data Capture (EDC) system. Viedoc is compliant with good practices and regulatory requirements for clinical trials issued by e.g. FDA, EMA and PMDA. Trained and authorized study site personnel were responsible for entering the study data into Viedoc. Data entered into Viedoc were immediately saved to a central database, hosted by a 3rd party, PCG Solutions AB. Data entered into this system were accessible by Dentsply Sirona Implants. The company had access to review the data and data queries were raised for inconsistent, missing, unclear or questionable data. The study personnel were required to resolve any such queries.

E. Data analysis

Data analysis for retrospective component:

Primary outcome variables

Implant removal: Implant removal was identified when implant removal code ADA D6011 was used.

Data regarding codes D6101 (debridement at implant defect), D6102 (osseous recontouring at implant defect) and D6103 (bone grafting at implant defect) were also collected to gather information regarding peri-implantitis treatment rendered at the college.

Data analysis for prospective component:

Primary outcome variable:

Implant survival: When study position implant was in situ at the time of evaluation. Each implant was categorized as implant survival (Yes/No).

Secondary outcome variables:

Implant success: Implant success was considered when the study position implant was in situ at the time of clinical evaluation and there were no (Adverse Device Effect) ADE(s) related to the implant or adjacent peri-implant tissues reported from the day when the study position(s) was permanently included in a prosthetic restoration until the end of the study.

Assessment of implant success:

The presence and position of the implant in the mouth was recorded. It was categorized as success = Yes when the implant was in situ at time of the study visit and no ADE(s) related to implant or adjacent peri-implant tissues were reported from the day when the study position(s) was permanently included in a prosthetic restoration until the end of the study. It was categorized as success=No when the implant has been lost and/or when ADE(s) related to implant or adjacent peri-implant tissues from the day when the study position(s) was permanently included in a prosthetic restoration until the end of the study.

Peri-implant mucositits: The implant was diagnosed as having peri-implant mucositis when there were signs of peri-implant mucositis including inflammation in peri-implant mucosa, bleeding on probing, and increased probing depth compared to baseline in the absence of radiographic bone changes as defined by Renvert et al., 2018.

Assessment of peri-implant mucositis:

The implant was categorized as peri-implant mucositis (No/Yes). It was categorized as peri-implant mucositis = Yes when the implant was in situ at time of the study visit and there were signs of peri-implant mucositis as described above. It was categorized as peri-implant mucositis =No when there were no signs of peri-implant mucositis as described above.

Peri-implantitis: The implant was diagnosed as having peri-implantitis when there were signs of peri-implantitis including inflammation in peri-implant mucosa, bleeding on probing, suppuration, increased probing depth and evidence of progressive bone loss compared to baseline as defined by Renvert et al., 2018.

Assessment of peri-implantitis:

The implant was categorized as peri-implantitis (No/Yes). It was categorized as peri-implantitis = Yes when the implant was in situ at time of the study visit and there were signs of peri-implantitis as described above. It was categorized as peri-implant mucositis = No when there were no signs of peri-implant mucositis as described above.

Prosthetic success: Implant, abutment and permanent restoration in situ and no ADE(s) related to implant, abutment, or restoration reported from the day when the study position(s) was permanently included in a prosthetic restoration until the end of the study.

Marginal Bone Level: The hard tissue response for each implant was evaluated by measuring Marginal Bone Levels (MBL) on radiographs.

Assessment of Marginal Bone Level:

The parallel technique was utilized to obtain radiographs at the time of prospective study visit. The bone levels at this visit were compared with the radiographs taken at the time of restoration delivery. When a radiograph at the time of delivery of restoration was not available, radiographs obtained at the uncovery visit when healing abutment was placed or at the time of implant placement were used. We used the implant length as a standardization process and accounted for image magnification in Dexis while calculating the relative bone loss in percentage.

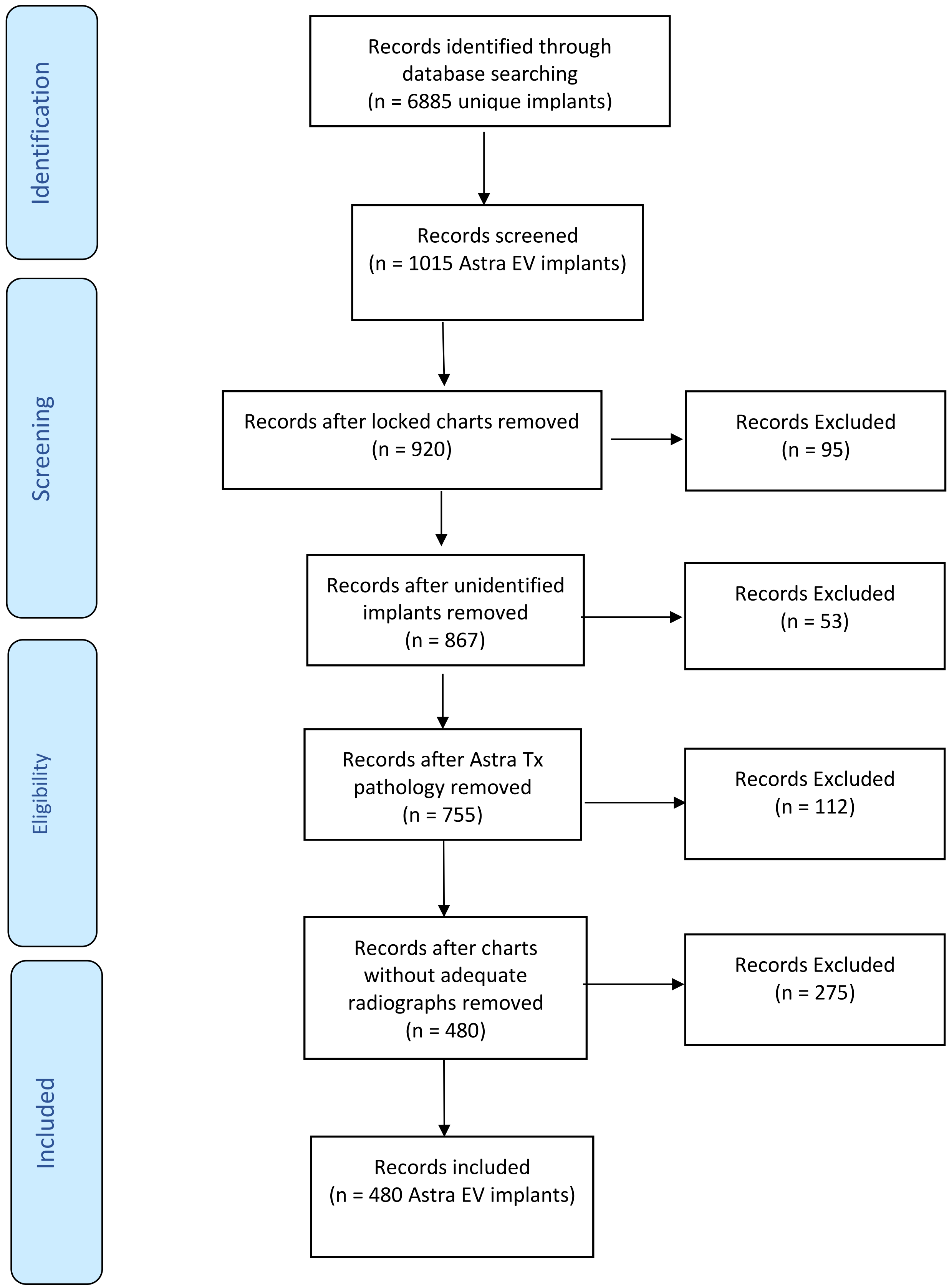
F. Statistical Analysis

The SPSS statistical software (SPSS, version 20.0 for Windows, IBM, Chicago, IL, USA) was utilized for data analysis. Each variable was analyzed using descriptive and/or frequency analysis for each variable in the study for both retrospective and prospective components. All categorical variables were explained as frequency and percentage and continuous variable – age as mean, minimum and maximum range and standard deviation. Additionally, the artificial neural network model was used to predict risk factors for implant failure (implant removal) for retrospective component of the study. In addition to the descriptive analysis, logistic regression analysis was used to assess the relationship between various independent and dependent variables for prospective component of the study. Furthermore, artificial neural network models were used to predict risk factors for peri-implant mucositis, peri-implantitis, implant survival in the prospective component. Four Neural Network models were developed to test the hypotheses of this study. The first model for retrospective study had implant removal as an output variable and patient's age, smoking history, diabetes and other demographic variables were used as input variables. The rest of the models for prospective study had peri-implant mucositis, peri-implantitis and implant survival as output variables and patient's age, demographic variables, smoking, diabetes, type of implant restoration retention, grafting prior to or at the time of implant placement and bruxism as input variables. These models were developed using Multilayer Perception. Normalized importance was calculated for each independent variable in input layer.

III. RESULTS

The total number of implants placed were 6885 in 2498 patients between January 1, 2012 to October 31, 2018. Out of which, a total number of 1015 Dentsply Astra implants were placed in total 504 patients between January 1, 2015 and December 31, 2016. Four hundred and eighty (480) Dentsply Astra EV implants were identified placed in total 255 patients after removing Astra Tx implants, charts with missing information, unidentifiable implant system, and charts without having initial periapical radiograph at the time of implant placement (figure 1).

Figure 1. Prisma flow chart for selection of participants (Moher et al., 2009)



A. <u>Results for retrospective component:</u>

1. Descriptive statistics:

The results found a total number of 2498 patients who received a total number of 6885 implants between January 1, 2012 and October 31, 2018. The average age for the patients was 58.04 years with minimum age 18 years and maximum age 98 years. These patients included 1411 females, 1086 males and 1 unspecified patient. Among them, 1507 were White, 428 were Black, 8 were American Indians or Alaska natives, 1 was pacific islander, 160 were Asian patients and 394 patients did not have data for race. For ethnicity, 436 identified as Hispanics, 1345 identified as other (or non-Hispanic), 267 patients declined to disclose their ethnicity and there was missing data for 450 patients. Two hundred and eighty-three 283 patients who had reported smoking habit, 204 patients had reported diabetes type-2 in their medical history and 780 charts showed either history of periodontitis or having chronic/aggressive periodontitis (TABLE I).

TABLE I

DEMOGRAPHIC INFORMATION FOR RETROSPECTIVE COMPONENT: PATIENT LEVEL RESULTS

Demographic variable	Frequency N= 2498 patients	Percentage
Gender		
• Female	1411	56.5
• Male	1086	43.5
• Unspecified	1	0.0
Race		
• White	1507	60.3
• Black	428	17.1
• American Indians or Alaska Natives	8	0.3
• Pacific islanders	1	0.0
• Asian	160	6.4
• Missing	394	15.8
Ethnicity		
• Hispanic	436	17.5
• Other	1345	53.8
• Declined	267	10.7
• Missing	450	18.0
Tobacco Use		
• Smokers	283	11.3
• Missing	2215	88.7
Diabetes type 2		
• Yes	204	8.2
• Missing	2294	91.8
History of periodontitis		
• Yes	780	31.2
• Missing	1718	68.8

Retrospective component: Implant specific results:

Out of the total 6885 implants, 61 implants were removed using the ADA implant removal code D6100. Fifteen (15) implants were treatment for peri-implant diseases using the ADA code D6101 for debridement at implant defect and ADA code D6102 for osseous contouring at implant defect. Seventy-one (71) implants received bone grafting treatment at implant defect using ADA code D6103. Due to incorrect use of dental codes and missing information, we could not run any additional statistical analyses to make any inferences on our data (TABLE II).

TABLE II

DESCRIPTIVE ANALYSIS FOR RETROSPECTIVE COMPONENT: IMPLANT LEVEL RESULTS

Implant level variables	Frequency N= 6885 implants	Percentage
Implant Removal (D6100) • Yes • Missing	 61 6824	 0.9 99.1
Debridement at implant defect (D6101) • Yes • Missing	 15 6870	 0.2 99.8
Osseous contouring at implant defect (D6102) • Yes • Missing	 15 6870	 0.2 99.8
Grafting at implant defect (D6103) • Yes • Missing	 71 6814	 1.0 98.9

2. Artificial neural network analysis:

Implant removal:

Artificial neural network model for implant removal had accuracy of 99.1% and 0.9% incorrect predictions (Figure 2). Figure 3 demonstrates the normalized importance of all independent variables on implant removal where patient's age on implant placement was the most important variable predicting implant removal or in other words, implant failure. The other variables in chronological order were race, history of periodontitis, tobacco use, diabetes mellitus type-2, ethnicity and patient's sex being the least important predictor.

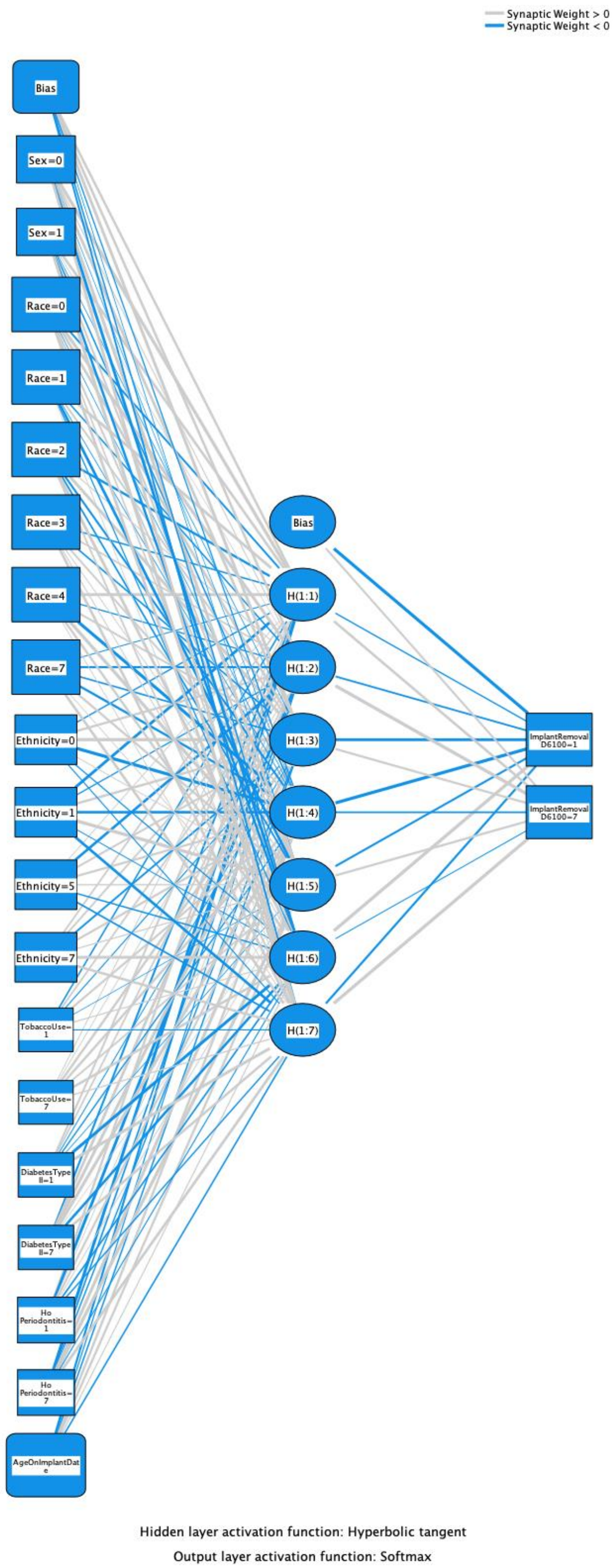


Figure 2. Artificial neural network for the prediction of implant removal consisting of 7 input variables, a hidden layer with 7 nodes, and 1 output variable.

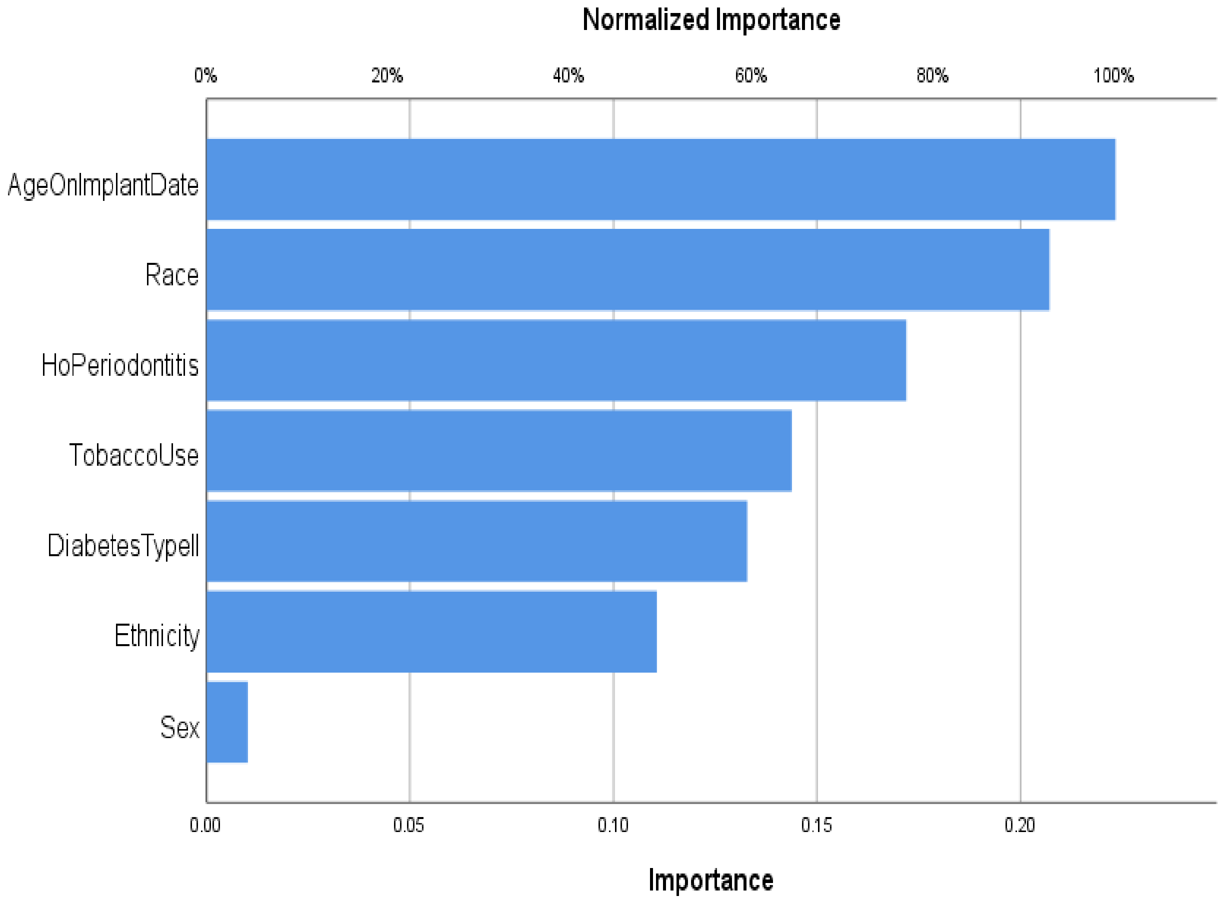


Figure 3. Normalized importance of all independent variables for implant removal.

B. Results for prospective component

1. Descriptive statistics:

The total number of Dentsply Astra implants placed were 1015 in total 504 patients between January 1, 2015 and December 31, 2016. Out of the 1015 Astra implants, 112 were Astra Tx. A total number of 480 Dentsply Astra EV implants placed in total 255 patients were identified after removing Astra Tx implants, charts with missing information, unidentifiable implant system, and charts without having initial periapical radiograph at the time of implant placement. Out of these 255 patients, 36 patients were randomly selected for a clinical and radiographic examination visit. The selected 36 patients had received a total number of 53 Dentsply Astra EV implants between January 1, 2015 and December 31, 2016 (figure 1).

According to the patient satisfaction survey 21 (58.33%) participants reported the chewing function to be very good, 12 (33.33%) reported it to be good and 3 (8.33%) reported it to be neither good nor bad. Regarding implant restoration esthetics 18 (50%) participants reported that they were very satisfied, 16 (44.44%) were satisfied, 2 (5.55%) were neither satisfied nor dissatisfied and 1 participant was dissatisfied with the restoration esthetics. Regarding the overall level of treatment satisfaction, 27 (75%) participants reported that they were very satisfied with the treatment, 7 (19.44%) were satisfied and 2 (5.55%) were neither satisfied nor dissatisfied.

The average age for the study participants was 61.64 years with minimum age 35 years and maximum age 81 years. There were 19 female and 17 male participants. Out of the 36 participants, 20 were White, 9 were Black, and 1 was Asian. Six participants declined to disclose their race. Seven identified as Hispanics and 23 identified as other (or non-Hispanic). Six participants declined to disclose their ethnicity. Out of 36 participants, 5 were current smokers, 18 former smokers and 13 who never smoke. Four (4) participants were diabetic and 32 were non-diabetic. Fourteen participants reported a history of periodontitis, whereas 22 participants presented with periodontal health and 1 participant reported bruxism. Implant related information such as implant diameter, length, quality of the bone, grafting prior to implant installation and grafting at the time of implant installation were collected from Axium chart surgical notes. Out of 53 implants, 12 implants had bone grafting done prior to implant installation in the form of site preservation after extraction, guided bone regeneration, sinus augmentation via crestal or lateral approach. Twelve implants received bone grafting at the time of implant installation. After the clinical examination, 15 out of 53 implants presented as peri-implant mucositis, whereas 4 implants presented as having peri-implantitis. Three out of 53 implants had prosthetic complications where the prosthetic screw had become loose. One out of 53 implants had failed that was placed during the study duration. The overall implant survival rate was 98.1% and implant failure rate was 1.9%. The overall implant success rate was 90.6%. Two implants had prosthetic complications where the prosthetic screw became loose. One patient had received a screw retained crown with a UCLA castable abutment and the second implant was restored using an Atlantis custom abutment. These patients were referred to the department of prosthodontics for evaluation and management. The results of the study showed that 100% of implants diagnosed with peri-implantitis had received cement-retained restorations (TABLE III,IV).

TABLE III

DEMOGRAPHIC INFORMATION FOR PROSPECTIVE COMPONENT: PATIENT LEVEL RESULTS

Demographic variable	Frequency N= 36 patients	Percentage
Gender		
• Female	19	52.77
• Male	17	47.22
Race		
• White	20	55.6
• Black	9	25.0
• Asian	1	2.8
• Declined	6	16.7
Ethnicity		
• Hispanic	7	19.4
• Other	23	63.9
• Declined	6	16.7
Tobacco Use		
• Current smokers	5	13.9
• Former smokers	13	36.1
• Non-smokers	18	50.0
Diabetes type 2		
• Diabetic	4	11.1
• Non-diabetic	32	88.9
History of periodontitis		
• Yes	14	38.9
• No	22	61.1
Bruxism		
• Yes	1	2.8
• No	35	97.2

TABLE IV

DESCRIPTIVE ANALYSIS FOR PROSPECTIVE COMPONENT: IMPLANT LEVEL RESULTS

Implant level variables	Frequency N= 53 implants	Percentage
Grafting prior to implant installation • Yes • No	 12 41	 22.6 77.4
Grafting at implant installation • Yes • No	 12 41	 22.6 77.4
Prosthesis Retention • Cement retained • Screw retained • Other	 41 9 2	 78.8 17.3 3.8
Peri-implant mucositis • Yes • No	 15 38	 28.3 71.7
Peri-implantitis • Yes • No	 4 49	 7.5 92.5
Implant survival • Yes • No	 52 1	 98.1 1.9
Implant success • Yes • No	 48 5	 90.6 9.4
Prosthetic complications • Yes • No	 2 51	 3.7 96.2

Changes in the marginal bone levels:

Four out of fifty-three implants were diagnosed as peri-implantitis. One out of those four implants had 60% progressive relative bone loss when compared to the baseline bone levels after accounting for image distortion in Dexis. The other 3 implants had =< 20% progressive relative bone loss since baseline. All patients with peri-implantitis were referred to the department of Periodontics for further evaluation and management.

2. Multivariate regression analysis:

Multivariate logistic regression models were used to assess the relationship between smoking habit, diabetes and history of periodontitis and peri-implant diseases and implant failure. At the patient level, the study did not find any statistically significant difference in terms of implant outcomes when considering smoking habit, diabetes, history of periodontitis and bruxism at the patient level. At the implant level, having diabetes was significantly associated with peri-implant mucositis (P value 0.022). History of periodontitis was significantly associated with increased odds of developing peri-implant mucositis (P value 0.017). Bone grafting at the time of implant installation was also significantly associated with development of peri-implant mucositis (P value 0.011). Additionally, being current smoker was also significantly associated with peri-implant mucositis (P value 0.011) (TABLE V). Other variables such as age, sex, race, ethnicity, bruxism, and grafting prior to implant installation were not significantly associated with peri-implant mucositis. Regression analysis for peri-implantitis, implant success, implant survival and prosthetic complications for both patient-level and implant-level did not provide any statistically significant differences (TABLE VI, VII, VIII, IX).

TABLE V

LOGISTIC MULTIVARIATE ANALYSIS FOR PERI-IMPLANT MUCOSITIS

Peri-implant mucositis					
	B	S.E.	Wald	df	Sig.
age	-.005	.036	.019	1	.890
Sex	-.161	.981	.027	1	.870
Race	-2.036	1.373	2.196	1	.138
Ethnicity	2.415	1.546	2.439	1	.118
diabetes	-4.310	1.886	5.223	1	.022
H/o periodontitis	3.675	1.546	5.654	1	.017
smoking	-2.366	.936	6.390	1	.011
Bruxism	-14.340	40192.970	.000	1	1.000
Grafting prior to implant installation	-3.458	1.894	3.333	1	.068
Grafting at implant installation	3.991	1.578	6.401	1	.011
Prosthesis retention	-.278	1.140	.059	1	.807
Constant	-2.066	2.493	.687	1	.407

TABLE VI

LOGISTIC MULTIVARIATE ANALYSIS FOR PERI-IMPLANTITIS

Peri-implantitis					
	B	S.E.	Wald	df	Sig.
age	-8.340	438.529	.000	1	.985
Sex	33.929	4802.667	.000	1	.994
Race	-55.491	9634.333	.000	1	.995
Ethnicity	83.623	10181.180	.000	1	.993
diabetes	239.795	19799.891	.000	1	.990
H/o periodontitis	170.791	11825.067	.000	1	.988
smoking	21.050	9627.776	.000	1	.998
Bruxism	215.583	45153.531	.000	1	.996
Grafting	27.753	4703.513	.000	1	.995
Constant	134.448	9999.249	.000	1	.989

TABLE VII

LOGISTIC MULTIVARIATE ANALYSIS FOR IMPLANT SURVIVAL

Implant Survival					
	B	S.E.	Wald	df	Sig.
age	.135	854.251	.000	1	1.000
Sex	-5.216	27799.642	.000	1	1.000
Race	-.228	15100.800	.000	1	1.000
Ethnicity	.366	14305.829	.000	1	1.000
diabetes	-4.501	33210.715	.000	1	1.000
H/o periodontitis	35.323	7832.189	.000	1	.996
smoking	-34.063	11964.400	.000	1	.998
Bruxism	38.885	42824.605	.000	1	.999
Grafting	.414	17066.306	.000	1	1.000
Constant	47.855	45910.512	.000	1	.999

TABLE VIII

LOGISTIC MULTIVARIATE ANALYSIS FOR IMPLANT SUCCESS

Implant success					
	B	S.E.	Wald	df	Sig.
age	29.110	770.722	.001	1	.970
Sex	-200.135	6331.309	.001	1	.975
Race	349.903	10078.740	.001	1	.972
Ethnicity	-331.863	9622.008	.001	1	.972
diabetes	-.526	12670.924	.000	1	1.000
H/o periodontitis	-42.976	1282.794	.001	1	.973
smoking	43.202	3656.630	.000	1	.991
Bruxism	-445.835	42249.396	.000	1	.992
Grafting	-216.073	6649.002	.001	1	.974
Constant	-1096.559	29478.648	.001	1	.970

TABLE IX

LOGISTIC MULTIVARIATE ANALYSIS FOR PROSTHETIC COMPLICATIONS

Prosthetic complications					
	B	S.E.	Wald	df	Sig.
age	-.955	783.276	.000	1	.999
Sex	-6.940	16042.010	.000	1	1.000
Race	-7.795	3817.643	.000	1	.998
Ethnicity	5.145	9183.739	.000	1	1.000
diabetes	-.674	20766.633	.000	1	1.000
H/o periodontitis	-2.515	27323.917	.000	1	1.000
smoking	-32.803	12409.954	.000	1	.998
Bruxism	79.785	50731.198	.000	1	.999
Grafting prior to implant installation	52.858	10678.213	.000	1	.996
Grafting at implant installation	16.186	14027.888	.000	1	.999
Constant	28.662	62646.020	.000	1	1.000

3. Artificial neural network analysis:

Peri-implant mucositis

Artificial neural network model for peri-implant mucositis had accuracy of 97.3% and 2.7% incorrect predictions (Figure 4). Figure 5 demonstrates the normalized importance of all independent variables on peri-implant mucositis where smoking, history of periodontitis and patient's age on implant placement were the most important variables.

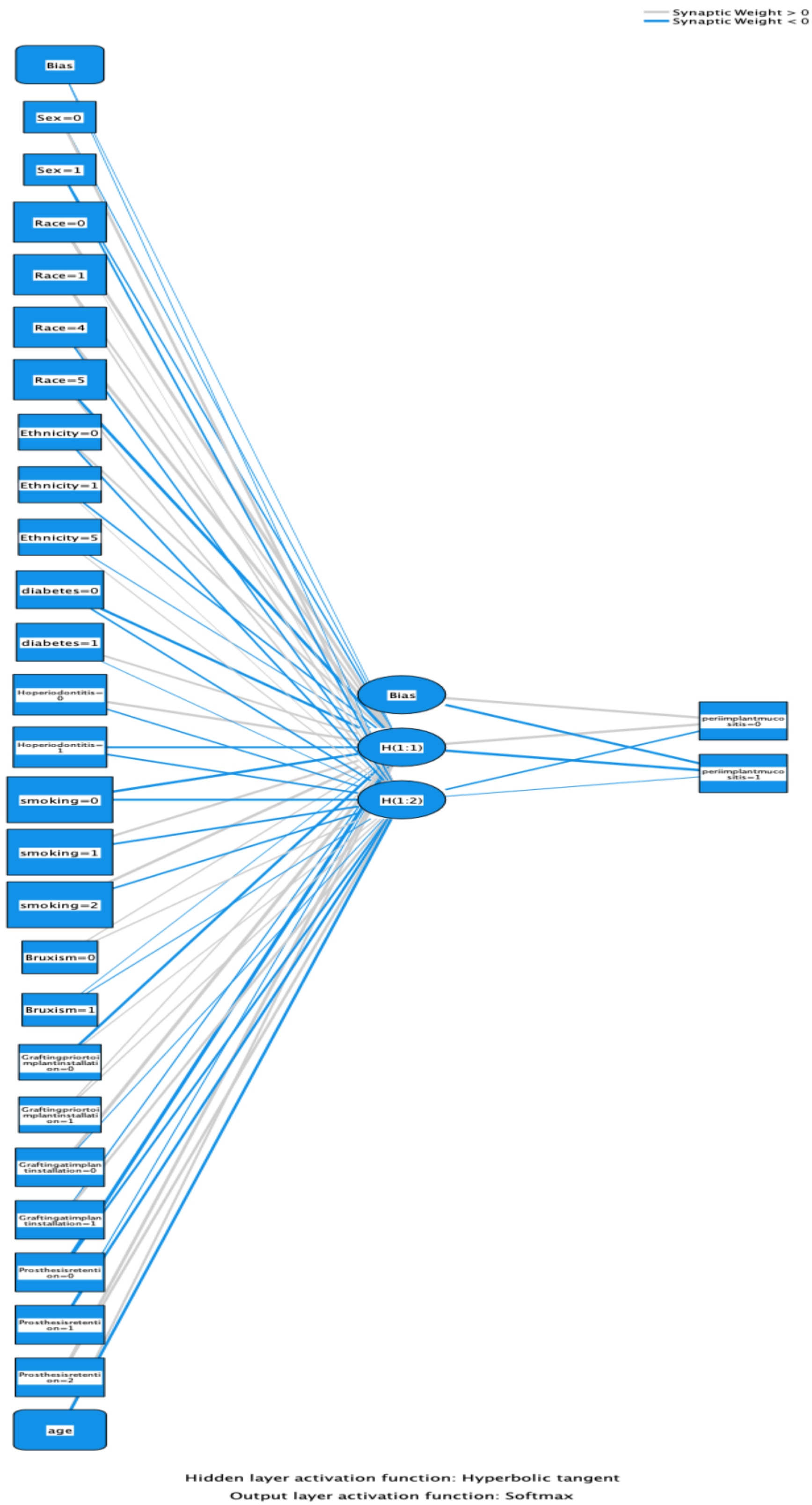


Figure 4. Artificial neural network for prediction of peri-implant mucositis consisting of 11 input variables, a hidden layer with 6 nodes, and 1 output variable.

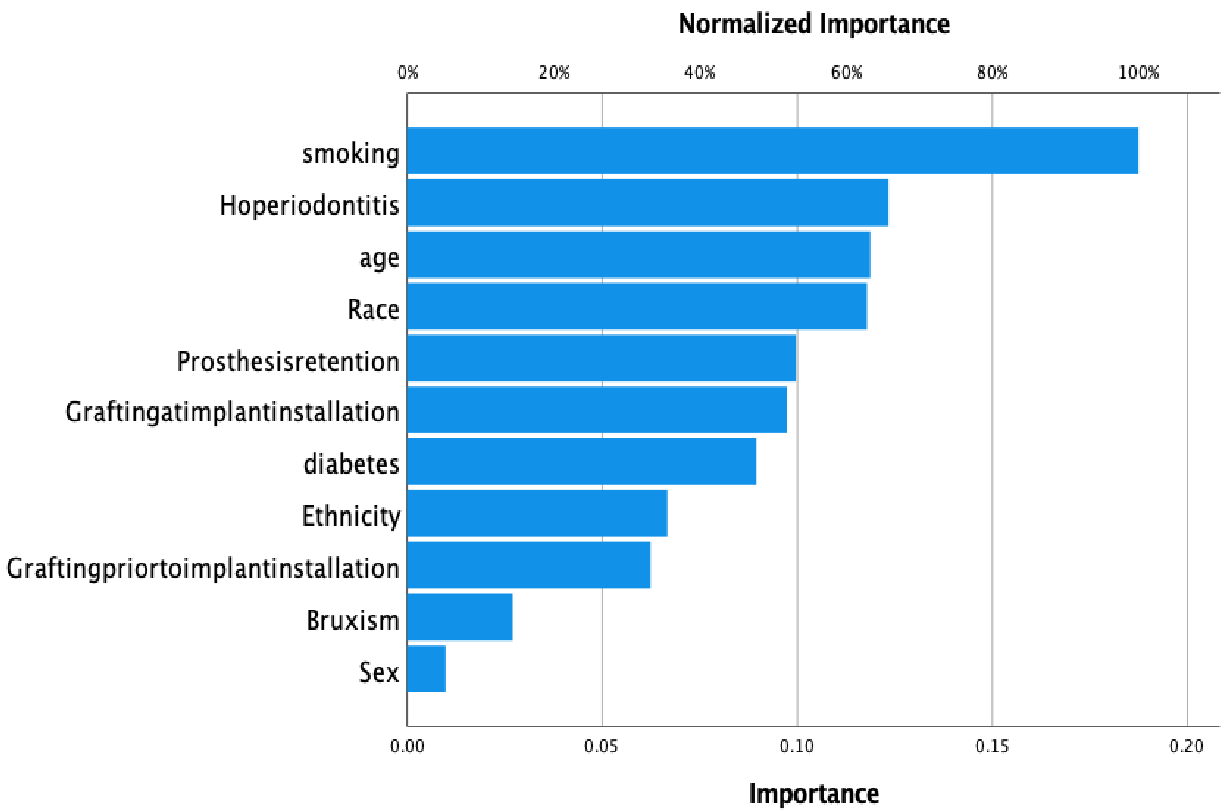


Figure 5. Normalized importance of all independent variables for peri-implant mucositis where smoking and history of periodontitis are the most important factors followed by patient's age on implant placement, race, prosthesis retention and grafting at implant placement.

Peri-implantitis:

Artificial neural network model for peri-implantitis had accuracy of 97.1% and 2.9% incorrect predictions (Figure 6). Figure 7 demonstrates the normalized importance of all independent variables on peri-implantitis where patient's age on implant placement was the most important variable, followed by smoking, history of periodontitis and bone grafting prior to and at the time of implant placement.

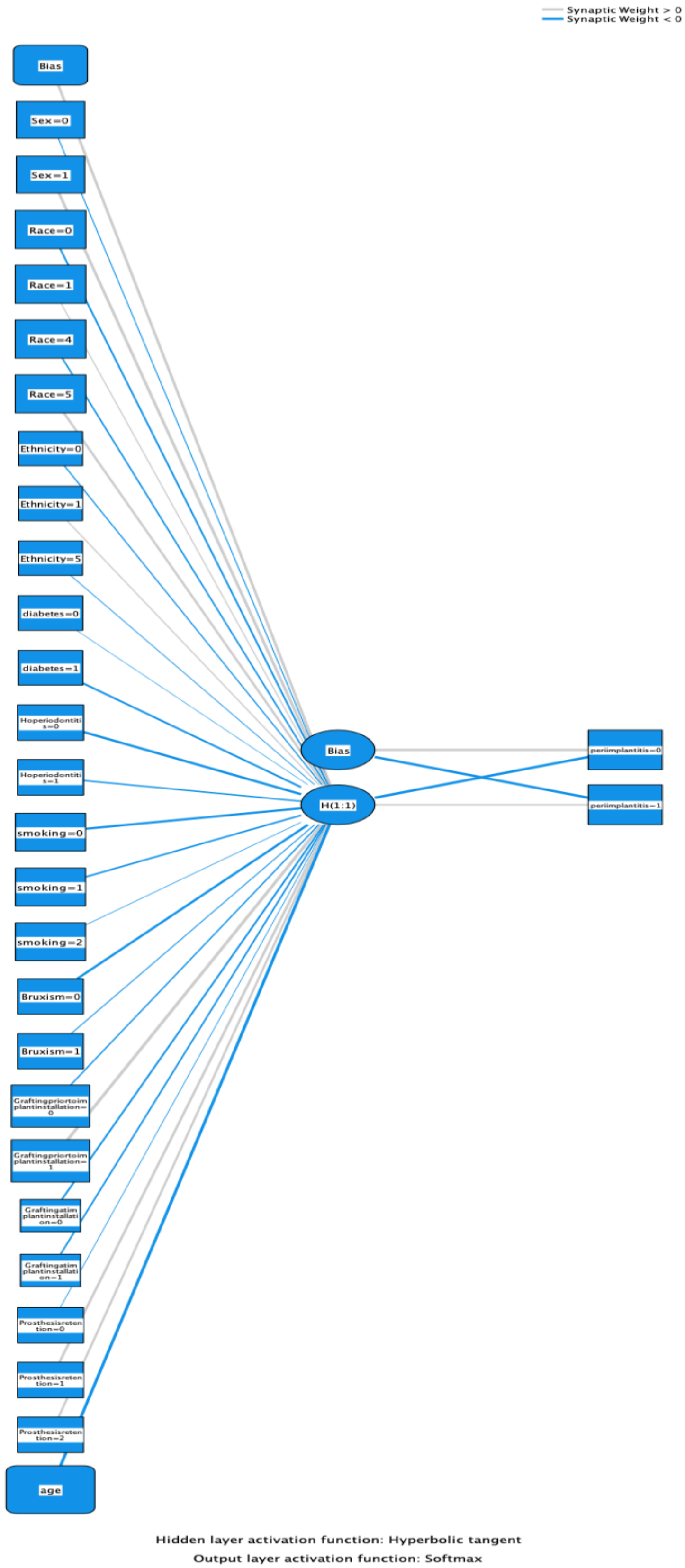


Figure 6. Artificial neural network for prediction of peri-implantitis consisting of 11 input variables, a hidden layer with 1 node, and 1 output variable.

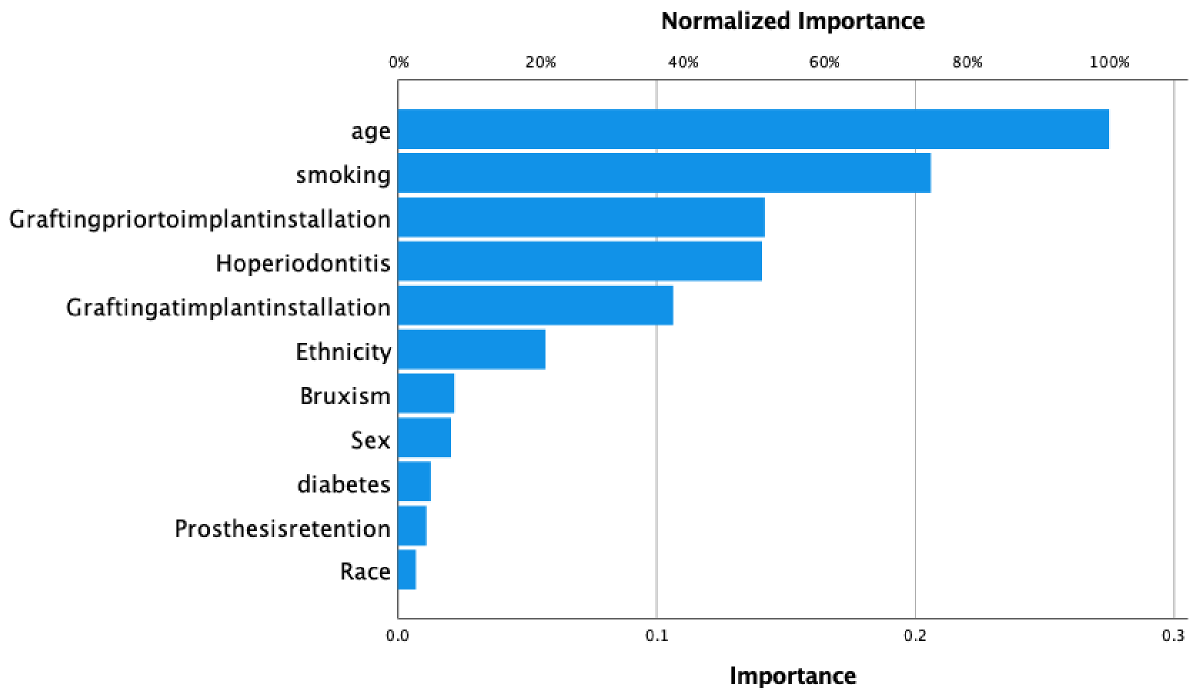


Figure 7. Normalized importance of all independent variables for peri-implantitis where patient's age on implant placement was the most important variable, followed by smoking, bone grafting and history of periodontitis.

Implant survival:

Artificial neural network model for implant survival had accuracy of 100% (Figure 8). Figure 9 demonstrates the normalized importance of all independent variables on implant survival where patient's age on implant placement was the most important variable, followed by history of periodontitis, smoking, ethnicity, race, sex, grafting either prior to or at the time of implant installation, diabetes mellitus type-2 and bruxism.

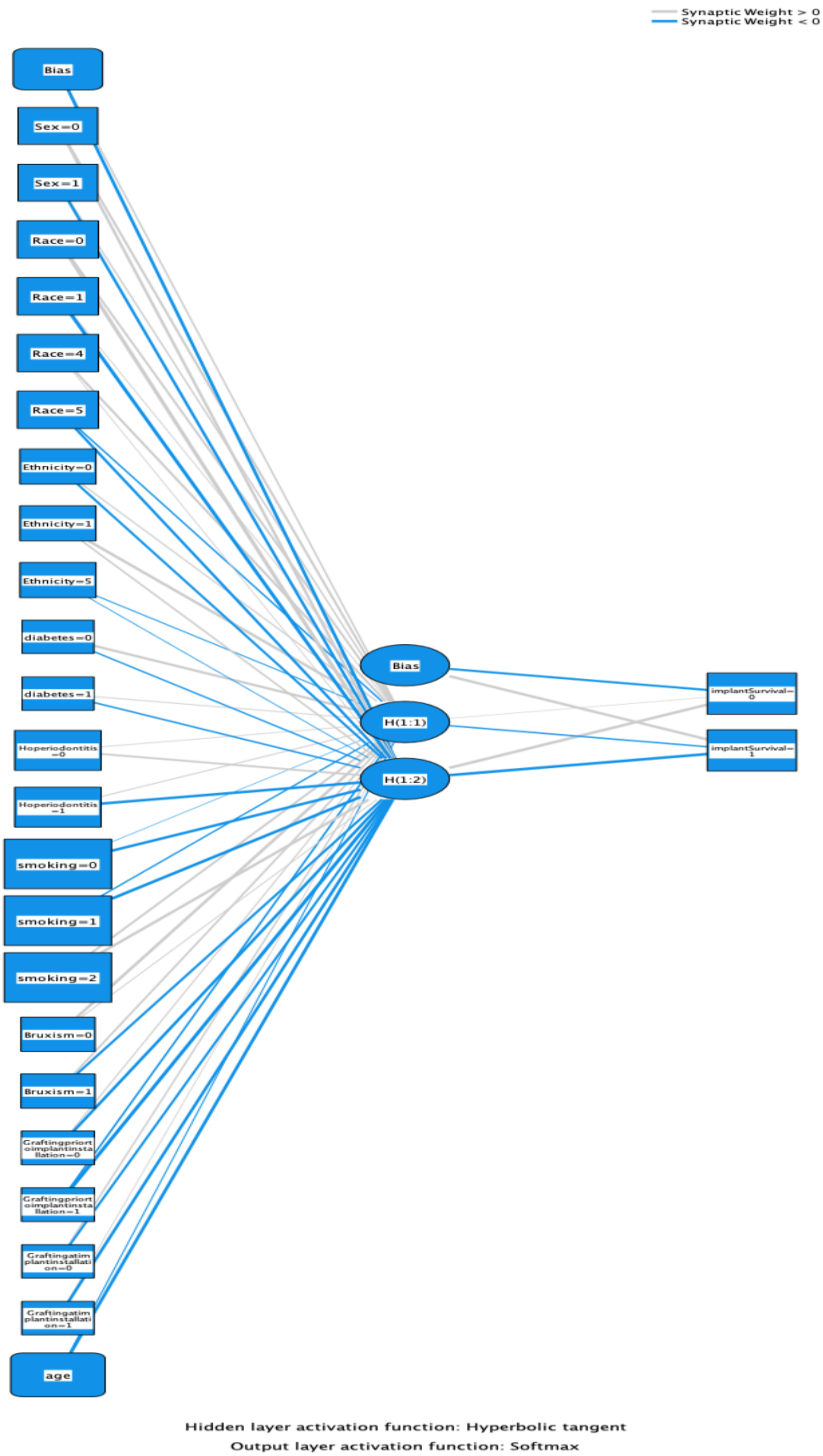


Figure 8. Artificial neural network for prediction of implant survival consisting of 11 input variables, a hidden layer with 2 nodes, and 1 output variable.

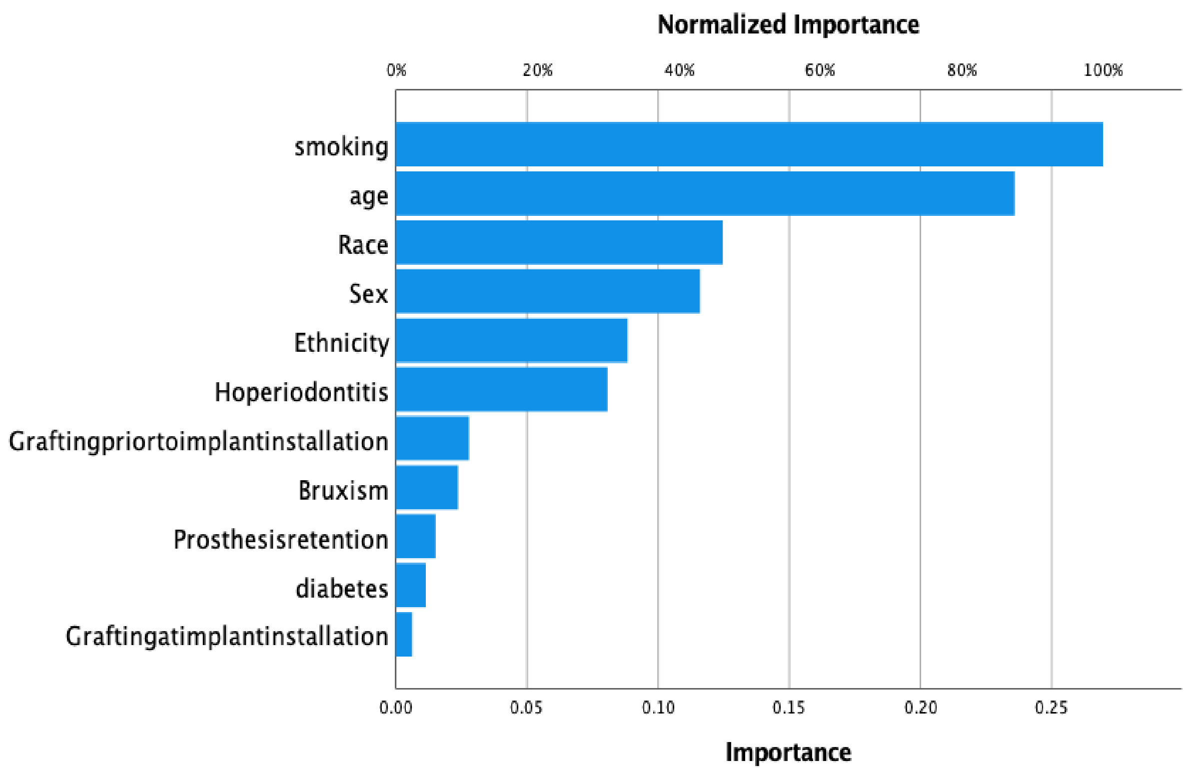


Figure 9. Normalized importance of all independent variables for implant survival where smoking is the most important factor, followed by patient's age on implant placement, race and sex.

IV. DISCUSSION

A. Discussion

The primary aim of the study was to assess the outcome of implants and factors associated with outcomes of the implants placed at UIC College of Dentistry. In the current study, the results of multivariate regression analysis found that diabetes, smoking habit, history of periodontitis and bone grafting at the time of implant placement were significantly associated with peri-implant mucositis. Multiple studies have shown that peri-implant mucositis, if left untreated, can lead to peri-implantitis (Costa et al., 2012; Heitz-Mayfield & Salvi, 2018). A study conducted by Jepsen et al, 2015 showed that smoking was one of the most significant risk factors for peri-implant mucositis along with poor oral hygiene (Jepsen et al., 2015). Research has also shown that peri-implant mucositis is a reversible process similar to gingivitis and establishment of proper oral hygiene practices and regular professional implant maintenance can resolve the peri-implant inflammation and prevent further progression (Salvi et al., 2012). However, research has shown that implant therapy can be successfully carried out in patients with controlled diabetes (Costa et al., 2012). Hence, identifying possible risk factors for peri-implant mucositis and timely treatment for it are importance for prevention of peri-implantitis. This study did not show significant impact of tobacco smoking, diabetes, history of periodontitis, bruxism, bone grafting and other patient demographic factors on development of peri-implantitis or implant failure in logistic regression model. On the contrary, multiple studies have shown the influence of these factors on implant success and survival. A systematic review and meta-analysis showed that smokers had double the odds of having implant failure when compared to non-smokers. Additionally, when the implants are placed in augmented bone in smokers, the odds of implant failure is increased threefold (P value <0.05) (Strietzel et al., 2007). Similarly, Moy et al showed about one and a half times increased risk for implant failure in smokers than non-smokers(P value <0.05) (Moy et al., 2005). A cross-sectional study showed that history of periodontitis and bruxism doubled the risk for peri-implantitis; cement- retained prostheses increased the risk of peri-implantitis by three-fold; and full-arch implant retained prosthesis increased the risk by about sixteen times (P value < 0.05) (Dalago et al., 2017). Another review article showed similar results where history of periodontitis, smoking, over-retained subgingival cement and lack of regular periodontal maintenance were significant risk indicators for peri-implantitis (P value <0.05) (Renvert & Quirynen, 2015). The lack of significant impact of the above-mentioned variables on implant outcomes can be explained by the small sample size. The studies included in Renvert & Quirynen, 2015 review article had 500 to 999 total number of implants. Additionally, the study participants were followed up long term to determine implant outcome.

Furthermore, the regression analysis did not find any significant impact of bone grafting, whether before implant placement as site development or at the time of implant placement, on peri-implantitis and implant success. This finding is comparable to previously published studies. A 5-year follow up study showed that implant placed with bone grafting on the buccal surface simultaneously had similar success rate as implants placed in native bone (94-100%, P value > 0.05) (Benić et al., 2009). Similarly, another 5-year follow up study showed that implants placed in grafted bone had a success rate of around 96% and implants placed in native bone had a success rate about 97% (P value > 0.05) (Hong et al., 2020). A systematic review published by (Hämmerle et al., 2002) showed similar results where bone grafting did not have any significant impact on implant survival or success as compared to implants placed in native bone. Bazrafshan

& Darby, 2014 found in their retrospective study that implant survival rate for both grafted and non-grated groups was about 97% and implant success rate was about 90% with no significant difference. Hence, the results of this study in agreement with existing literature found that implant placement in augmented bone or bone grafting simultaneously with implant placement does not affect implant outcome.

According to the artificial neural network model analysis, smoking history, age of the patient at the time of implant placement, history of periodontitis, and bone grafting, either prior to or at the time of implant placement are the most important variables predicting implant outcomes. Multivariate regression analysis, although widely used, can only predict linear relationships between the predictor and outcome variables. Therefore, it is difficult to get comprehensive results with regression models when there are nonlinear and complex relationships present. Neural network models can identify all possible interactions between independent variables and provide their influence on the dependent variable using an artificial intelligence-like algorithms (Tu, 1996). Additionally, artificial neural networks can perform better when there is incomplete data and still make inferences (Greenwood, 1991). Therefore, ANNs can often include variables that may not reach significance using conventional statistical methods. Hence, with the utilization of the artificial neural network analysis, this study was able to predict the most important factors for peri-implant diseases and implant failure when the multivariate regression analysis failed to demonstrate any significant association.

B. Limitations of the study:

One of the critical limitations of this study was missing data. Because of the lack of standardization with use of ADA of codes, it was difficult to accurately acquire information regarding treatment rendered at UIC college of dentistry in terms of implant removal and treatment for peri-implantitis. Additionally, due to the lack of standardized documentation regarding peri-implant disease diagnosis, it was not feasible to collect accurate data regarding prevalence of peri-implant mucositis and peri-implantitis for retrospective component of the study. Due to a small sample size in the prospective component of this study, establishment of any significant association between some of the most researched risk indicators such as history of periodontitis, smoking, bruxism and bone grafting; and peri-implantitis was not possible. However, the utilization of the artificial neural network model analysis enabled us to predict the most important risk indicators for implant survival, peri-implant mucositis and peri-implantitis despite having incomplete data and small sample size. Additionally, the prospective component of this study is a part of a multi-center international study, therefore, complying the final data from all study centers would provide more useful information for future research.

C. Directions for future research:

UIC College of Dentistry Axium database is an excellent resource for conducting various research studies. However, due to the lack of standardized documentation procedures, we were not able to utilize the data to its fullest potential. Therefore, the future directions should focus on standardization of ADA coding for treatment and utilizing designated forms and codes for various diagnoses. This way data collection and analysis can become more efficient and easier, and we can more accurately present prevalence of implant related complications and other various study topics. Additionally, integration of UI Health database Epic with college of dentistry would allow us to further our abilities to study the effect of the patient's general health and related conditions on periodontal and peri-implant health. Furthermore, the utilization of the novel artificial neural model analysis will add more value for statistical analysis in the future. The artificial neural network models are widely used statistical analysis method in financial marketing and trading and are now becoming popular in the field of medicine as well. This novel statistical approach would allow to explore relationships between predictor and outcome variables that are nonlinear and complex and facilitate making inferences and generalizations in the field of dentistry (Terrin et al., 2003)(Allareddy et al., 2019). A critical limitation of ANNs is that cause-effect relationship cannot be established using this model. A neural network model is a relative "black box" in comparison to a logistic regression model. Researchers have been working to improve their performance and to understand the effect of each input variable on outcome to explain causality. Reducing the "black box nature" of ANN n will likely facilitate their acceptance within the healthcare field (Tu, 1996). Hence, the future prospective longitudinal studies should focus on determining cause-effect relationship in various fields of implant dentistry.

V. Conclusion

Patient's tobacco smoking history, age at the time of implant placement, history of periodontitis and bone grafting prior to or at the time of implant placement are the most important predictors for development of peri-implant diseases and implant survival. Therefore, patient education on smoking cessation, meticulous oral hygiene, regular periodontal maintenance compliance and influence of age should be an important part of informed consent discussion.

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APPENDIX

Patient satisfaction questionnaire:

Subject ID: Consent signed date:

Question 1: How is your chewing function after implant installation?

1. Very bad
2. Bad
3. Neither bad nor good
4. Good
5. Very good

Question 2: Are you satisfied with the esthetics of the implant restoration?

1. Very dissatisfied
2. Dissatisfied
3. Neither dissatisfied nor satisfied
4. Satisfied
5. Very satisfied

Question 3: How was your overall level of satisfaction with the treatment?

1. Very dissatisfied
2. Dissatisfied
3. Neither dissatisfied nor satisfied
4. Satisfied
5. Very satisfied

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