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# **A RETROSPECTIVE ANALYSIS OF BIOLOGICAL COMPLICATIONS OF IMPLANT-SUPPORTED FIXED DENTAL PROSTHESES**

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## ABSTRACT

### **A retrospective analysis of biological complications of implant-supported fixed dental prostheses**

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**Background:** In the past few decades implant supported fixed dental prostheses has become widely accepted treatment option for replacing missing teeth. Despite their high survival rate, complications such as peri-implant diseases are common.

**Aim:** To evaluate patient-, implant- surgical- and prosthetic-related risk factors that are associated with peri-implant diseases, identify prevalence and predictors of peri-implant diseases.

**Materials and Methods:** A retrospective study of 162 patients who received 301 dental implants was conducted to evaluate the prevalences and risk indicators for peri-implant mucositis and peri-implantitis. The data were analyzed using the binary logistic regression to evaluate different risk indicators peri-implantitis.

**Results:** The prevalence of peri-implant mucositis at the patients and implant levels were 44.4% and 38.2%, respectively. For peri-implantitis, the prevalence at the patient level was 5.6%, while the prevalence at the implant level was 4.0%. Patients diagnosed with peri-implant mucositis were more likely to be irregular attenders of peri-implant maintenance while those diagnosed with peri-implantitis were likely to be smokers, had history of treated periodontitis or did not attend of regular peri-implant maintenance visits.

**Conclusion:** Within the limitations of this retrospective study, the analysis identified plausible risk indicators, namely smoking, history of treated periodontitis and irregular peri-implant

maintenance visits, that would allow clinicians to identify those at risk and ensure continuous peri-implant supportive care.

## DEDICATION

I dedicate this thesis to my paternal grandfather's soul, whose love for me knew no bounds and, who taught me the value of hard work "I will never forget you".

Next, my parents, who have always loved me unconditionally and whose good examples have taught me to work hard for the things that I aspire to achieve.

I also dedicate this to my lovely brothers and sisters for their endless love, support and encouragement.

Finally, to my faculty, colleagues and everyone who supported me during my residency.

## DECLARATION

I declare that all the content of this thesis is my own work. There is no conflict of interest with any other entity or organization

Name: Zainab AlMutairi

Signature:

A handwritten signature in black ink, appearing to be 'Zainab AlMutairi', written over a horizontal line.

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## 1. INTRODUCTION

Implant-supported fixed dental prostheses (FDPs) are currently considered highly accepted treatment option in replacing missing teeth due to the reported long-term high survival rate and predictability (Jung et al., 2008, Lang et al., 2004). High survival rates of 95.4% and 80.1% were reported for implant-supported FDPs after 5 and 10 years, respectively (Pjetursson et al., 2012b). Despite the high survival and success rates of dental implants, biological and technical complications have been observed in 33.6% of patients receiving dental implants during a 5-year follow-up period (Pjetursson et al., 2012b). In particular, the biological complications of dental implants, namely peri-implant mucositis and peri-implantitis, can negatively affect the longevity of dental implants and may ultimately cause implant failure. Peri-implant diseases are common with 63.4% and 18.8% of the patients having peri-implant mucositis and peri-implantitis, respectively (Atieh et al., 2013).

Several risk factors are associated with peri-implant diseases. Of which, history of treated periodontal disease is one of the most documented factors (Ong et al., 2008). Patients who have lost their teeth due to periodontal disease are at high risk of developing peri-implant diseases (Klinge et al., 2005). Implant failure, progressive marginal bone loss and peri-implantitis occur more often in patients with history of treated periodontitis compared to those who had no history of periodontal disease (Ong et al., 2008). Moreover, a recent retrospective study in a university setting showed that patients who previously treated for periodontal disease were at high risk of developing peri-implant mucositis (Atieh et al., 2019). Another well-documented risk factor that has been associated with peri-implant diseases is the absence of regular preventive maintenance (Costa et al., 2012).

Patient-related risk factors also include diabetes mellitus, inadequate plaque control and smoking (Heitz-Mayfield, 2008). In this context, the relationship between implant failure and

smoking has been discussed in several studies. It was concluded that the survival rate of implants can be negatively affected by smoking (Klinge et al., 2005, Chen et al., 2013) with 11.3% failure rate has been noted in smokers compared to only 4.8% in non-smokers (Bain and Moy, 1993). Furthermore, a greater peri-implant marginal bone loss around implants was detected among smokers compared to non-smokers (Karoussis et al., 2004). High risk of peri-implantitis was also shown in smokers who had more than one implant and did not follow a regular peri-implant maintenance program (Atieh et al., 2019).

Implant-related factors such as implant design and surface characteristics and surgically-related factors such as implant site preparation, use of bone grafting materials and immediately placing and loading dental implant may play a role in peri-implant marginal bone loss and hence may contribute to the progression of peri-implant diseases (Atieh et al., 2019, Renvert et al., 2012, Albouy et al., 2008, Rodrigo et al., 2012, Tarnow et al., 2000, Laurell and Lundgren, 2011).

## **2. REVIEW OF THE LITERATURE**

### **2.1 Definition of peri-implant diseases**

There are two common forms of peri-implant diseases: one in which an inflammatory lesion affects only the peri-implant soft tissues, termed peri-implant mucositis, and one which involves loss of hard tissues, termed peri-implantitis. The term “peri-implantitis” was first introduced in 1987 by Mombelli and colleagues to describe the infectious disease around implants (Mombelli et al., 1987). Subsequently, several clinical definitions and treatment protocols for peri-implant diseases have been proposed in the literature.

As peri-implant mucositis is an inflammatory response surrounding a functional osseointegrated dental implant that is limited to the soft tissues (Zitzmann and Berglundh, 2008), the classic sign of inflammation; bleeding on probing (BoP) was identified as the most important characteristic of peri-implant mucositis (Lindhe and Meyle, 2008). In addition, other signs such as erythema, swelling, suppuration and deep probing depths were also reported.

Peri-implant mucositis is a reversible inflammatory response. However, it may progress to an advanced and irreversible stage known as peri-implantitis. Peri-implantitis is an inflammatory response involving both soft and hard tissues surrounding a functional osseointegrated dental implant. Common signs include BoP, suppuration, probing pocket depths (PPDs) of more than 5 mm, and progressive marginal bone loss beyond initial bone remodeling (Berglundh et al., 2018). Peri-implantitis has been reported as one of the causes for late implant failure. Implants with a history of treated peri-implantitis were at higher risk of implant failure compared with those that were free of any peri-implant disease (Brägger et al., 2005).

## **2.2 Prevalence of peri-implant disease**

The approximation of the accurate prevalence of peri-implant disease in the literature is still controversial.

Peri-implant mucositis is common. However, its reported prevalence has been inconsistent in the implant literature, with one study reporting a prevalence of 20.2% and 10.2% for patients and implants, respectively, after an 8-year observation period (Atieh et al., 2019). In contrast, 80% of patients and 50% of implant sites showed signs of peri-implant mucositis in another study (Zitzmann and Berglundh, 2008).

A reported 10% of patients and 9.6% of implants had peri-implantitis after a period of 5 years (Brägger et al., 2005). In a systematic review, a similar prevalence of 5% to 8% of selected implant systems had signs of peri-implantitis over the same time period (Berglundh et al., 2002).

The prevalence rates of peri-implant mucositis ranged between 18.3% to 76.6%, while the prevalence rates of peri-implantitis ranged between 3.7% to 28.7%, after 10 years of function in 218 participants with 999 implants (Roos-Jansåker et al., 2006b). In the same study, the importance of supportive peri-implant care in reducing the prevalence of peri-implant disease was highlighted.

In a retrospective cross-sectional study of 89 patients enrolled from private dental practices (Rinke et al., 2011), the prevalence rates of peri-implant mucositis and peri-implantitis were found to be 44.9% and 11.2%, respectively.

A cross-sectional study found that approximately 40% of patients showed mucositis, while the prevalence of peri-implantitis ranged between 12% to 22% in 245 patients with a total of 964

dental implants attending for periodontal maintenance care in private dental practice between January and June 2010 (Mir-Mari et al., 2012).

In another cross-sectional study, the prevalence and the degree of association between the peri-implant disease and various possible risk factors were investigated in 212 patients rehabilitated with dental implants. The prevalence of peri-implant mucositis was 64.6%, while for peri-implantitis it was 8.9%. Patients with poor plaque control, history of treated periodontitis and poor glycemic control showed a high risk of developing peri-implantitis, while the regularity of peri-implant maintenance visits did not appear to affect peri-implant health (Ferreira et al., 2006).

In a study aimed to assess the frequency of peri-implant diseases in 103 participants with a total of 266 implants in a private clinic during a mean functional time of 8.5 years, the prevalence of mucositis at patient level was 31%, and at implant level was 38%. Similar prevalences for peri-implantitis were reported with 37% at patient level, and 23% at implant level. Patient age, periodontitis, absence of teeth, and rough-surfaced implants were shown to be risk indicators of for peri-implantitis (Marrone et al., 2013).

Another study assessed the prevalence of peri-implant disease and found that the prevalence of peri-implantitis ranged from 11.3% to 47.1% in 109 participants with implants in function for a mean of 8.4 years. A probing pocket depth of  $\geq 4$  or  $\geq 6$  mm with BoP and radiographic peri-implant bone loss of  $\geq 2$  or  $\geq 3$  mm were evaluated to define the severity of peri-implantitis in this study (Koldslund et al., 2010) .

In a retrospective study, the prevalence of peri-implantitis and the incidence of peri-implant bone loss were evaluated in a total of 133 patients with 407 implants. The patients were followed up for 10 years of function. Peri-implantitis was found in 10% of patients, and in 4% of implants (Cecchinato et al., 2014).

Signs of peri-implantitis were detected radiographically in 12.4% of implants in a study involving 662 participants with 3,414 implants after a minimum 5-year period of function. In this study, peri-implantitis was defined as progressive bone loss beyond three threads (Fransson et al., 2005).

The prevalence of peri-implant mucositis and peri-implantitis was also evaluated in 113 subjects with 347 Branemark system implants. The prevalences of peri-implant mucositis and peri-implantitis were 32% and 7.5%, respectively. It was suggested that functional time and periodontal bone loss were associated with the incidence of peri-implant diseases. In contrast, several patient factors, such as the patient's age, gender, and body weight and whether they smoked or had diabetes, were not found to affect peri-implant tissue conditions (Máximo et al., 2008).

In a 9-year retrospective study that involved 47 participants with a total of 237 moderately rough-surface dental implants, peri-implant mucositis was detected in 90% of implants, while peri-implantitis was noted in 2% of implants. Participants with excessive nicotine intake, alcohol abuse, and radiotherapy were at high risk for developing peri-implant diseases (Kaemmerer et al., 2011).

In a 10-year retrospective study, the incidence of peri-implantitis in patients with history of chronic periodontitis was compared to those without a history of periodontitis. In periodontally compromised patients, the incidence of peri-implantitis, survival and success rates were 28.6%, 90.5%, and 71.4%, respectively, while the equivalent incidences and rates in non-periodontitis patients were 5.8%, 96.5%, and 94.5%, respectively (Karoussis et al., 2003).

Another 5-year retrospective study evaluated the relationship between the periodontal condition and the prevalence of peri-implantitis in 66 well-maintained patients with a total of 177 dental implants. The results showed that implants inserted in patients with a history of

periodontitis and persistent residual pockets of  $\geq 6$  mm were more prone to have bone loss than those with history of treated periodontitis but no residual pockets (Cho-Yan Lee et al., 2012).

In another retrospective study of 10-16 years, the prevalence of peri-implant mucositis and peri-implantitis were evaluated in 55 subjects with 131 implants. The history of treated periodontitis was again associated with high risk of developing peri-implantitis and implant failure (Simonis et al., 2010).

### **2.3 Systemic and Patient-related factors**

The association between smoking, diabetes, radiotherapy, and osteoporosis and peri-implant diseases is still controversial. Many studies have investigated the influence of these potential risk factors on peri-implant tissues and provided insight into implant treatment prognosis and strategies (Bornstein et al., 2009).

### **2.4 Diabetes mellitus**

Diabetes mellitus is defined as a “group of metabolic diseases characterized by hyperglycemia resulting from defects in insulin secretion, insulin action or both” (Puavilai et al., 1999, Retzepi and Donos, 2010). Diabetes mellitus is categorized into two main groups; type 1 (insulin deficiency) and type 2 (impaired insulin function which is combination of resistance to insulin action and inadequate insulin secretion). Up-to-date Hemoglobin A1c (HbA1c), also known as glycated hemoglobin, is considered the test of choice for diagnosing and monitoring diabetes mellitus since it measures the blood glucose levels over 2-3 months (Gómez-Moreno et al., 2015). The recommended cut-off point HbA1c level for diagnosing diabetes is  $\geq 48$  mmol/mol ( $\geq 6.5\%$ ) (Organization, 2011).

The global prevalence of diabetes in 2019 was estimated to be 9.3% (463 million individuals) according to International Diabetes Federation. It is expected to rise to 10.2% by 2030 and 10.9% by 2045. Furthermore, the prevalence of diabetes among adults (20-79 years) in the Middle East and North Africa (MENA) region is 12.8% for diagnosed cases and 44.7% for undiagnosed cases. According to the International Diabetes Federation, the national prevalence of diabetes in the United Arab Emirates accounts for 15.4%. This high prevalence can be associated to multiple risk factors, namely, age, gender, hypertension, body mass index, education, family history. Type 2 diabetes mellitus can be prevented by adjusting some of the risk factors, providing regular screenings and prevention strategies for individuals at risk (Awadi et al., 2020).

Diabetes mellitus is a complex disease that raises numerous complications caused by micro- and macroangiopathy. Due to the increased susceptibility to infections and altered wound healing in diabetic patients, periodontal diseases and oral infections are common risk factors, where the risk of developing periodontitis in diabetics is 2.9-3.4 times more than in non-diabetics (Beikler and Flemmig, 2003). Other complications in the oral cavity include xerostomia, increased levels of salivary glucose, swelling of the parotid gland, and increased incidence of caries and periodontitis (Murray, 1985, Mellitus, 1997).

Evidence from the literature found that diabetes and periodontitis have a direct relationship (Kinane and Chestnutt, 1997). Studies suggest that patients with poorly controlled diabetes have less successful response to periodontal therapy in comparison to patients who have well controlled diabetes or are not diabetic (Westfelt et al., 1996, Tervonen and Karjalainen, 1997).

Diabetes cannot be cured, but it can be controlled (Van Dyke and Sheilsh, 2005) Therefore, poorly-controlled diabetic patients who would like to undergo dental implant placement should first get the glycemic levels controlled.

In the past, implants were contraindicated in diabetic patients because of their increased susceptibility to infections, delayed wound healing and microvascular complications (Tawil et al., 2008a) However, today, studies suggest that diabetic patients can benefit from having implant supported prosthesis. Diabetic patients with tooth loss may avoid food that need effort to masticate leading to adverse nutrition with poor metabolic control. Hence, placing dental implants can be beneficial to improve nutrition and metabolic control (Chrcanovic et al., 2014).

Dental implants can be placed successfully in diabetic patients with controlled blood sugar levels with an average glycosylated hemoglobin level of 7 mg/% (Blanchaert, 1998). HbA1c is the main factor affecting post-operative implant complications. Increased PI and BOP can increase risk of complications (Tawil et al., 2008a). Bone density is not necessarily influence implant failure (Morris and Ochi, 2000). High success rates can be achieved when proper treatment plan, execution and follow-up are done (Abdulwassie and Dhanrajani, 2002). Such success rates were observed by several studies, Shernoff et al reported 92.7% (Shernoff et al., 1994) Balshi and Wolfinger reported 94.3% success rates (Balshi and Wolfinger, 1999) and Fiorellini et al reported 85.6% success rates (Fiorellini et al., 2000) No evidence regarding bone augmentation procedures are available to whether it can lead to complications and increased failure rates (Naujokat et al., 2016). It has relatively safe to perform immediate loading in well and moderately controlled diabetic patients (Aguilar-Salvatierra et al., 2016a).

Management of poorly controlled diabetic patients is difficult. Delayed osseointegration following implantation (Naujokat et al., 2016) and greater chance of developing peri-implantitis are common in these patients (Ferreira et al., 2006). Therefore, immediate loading of implants should be avoided (Naujokat et al., 2016) and surgery should be delayed until better control is achieved. Therefore, regular screening for diabetes and ensuring patients are under good metabolic control are recommended to increase success rates of osseointegration since definitive guidelines with objective criteria, including type of diabetes, age of onset, and level

of long-term metabolic control have not yet been determined (Smith et al., 1992). And It has been concluded that placing implants in well controlled diabetic patients is just as successful as in non-diabetic patient (Proceedings of the 1996 World Workshop in Periodontics. Lansdowne, 1996, Tawil et al., 2008b, Chen et al., 2013). However, several studies have reported increased failure rate at about one year after implant placement (Fiorellini et al., 2000, Morris et al., 2000, Shernoff et al., 1994).

Moreover, Diabetic patients have decreased ability to fight post-operative local infections because of their immunosuppressed state. Thus, negative outcomes are common (Abiko and Selimovic, 2010, Zupnik et al., 2011). Several studies have agreed that the use of pre- and peri-operative antibiotic prophylaxis in implant dentistry for compromised patients such as diabetics is necessary. (Blanchaert, 1998, Balshi and Wolfinger, 1999, Morris et al., 2000). The antibiotic to be used should be bactericidal and of low toxicity, such as penicillin or amoxicillin, alternatively, in the case of penicillin allergy, clindamycin, metronidazole or a first generation cephalosporin can be used (Garg, 1992, Sbordone et al., 1995). Because the pathogens that are most likely to cause post-operative wound healing problems are streptococci, anaerobic Gram-positive cocci and anaerobic Gram-negative rods (Dent et al., 1997).

Besides the use of antibiotic prophylaxis, it is advised to use chlorhexidine digluconate (0.12%) rinse peri- and post-operatively at the time of implant placement, due to the evidence available on its ability to significantly reduce failure rate in type 2 diabetic patients from 13.5% to 4.4%. As well as the use of hydroxyapatite coated implants which can increase success rate of implant in type 2 diabetic patients from 84.7% to 97.9% (Morris et al., 2000).

In the literature, several similar evidence on the influence of diabetes of peri-implant diseases exist. In a cross-sectional study the author reported that patients with elevated glycemic levels are at increased risk of peri-implant diseases and that being diabetic with periodontitis has a significant influence on developing peri-implantitis. Non-smoking diabetic subjects (14.2% of

them had periodontitis) were observed, the author reported 64.6% peri-implant mucositis and 8.9% peri-implantitis 8.9%. Risk factors for these peri-implant diseases included: gender, plaque score, and bleeding on probing (Ferreira et al., 2006). Two prospective studies have agreed that patients with elevated HbA1c levels are at a higher risk of developing peri-implant diseases.(Aguilar-Salvatierra et al., 2016b) (Gómez-Moreno et al., 2015). However, in the study by (Gómez-Moreno et al., 2015) the effect is not significant where only increased bleeding on probing was present but not necessarily increased pocket depth. Recently, a meta-analysis reported that diabetic patients are at a 50% higher risk of developing peri-implant diseases versus healthy patients (Monje et al., 2017b).

The association between smoking, diabetes, radiotherapy and osteoporosis and the risk of dental implant survival rate and failure is controversial. Many studies investigated the influence of these potential risk factors on dental implants and provided an insight for implant treatment prognosis and treatment strategies.

Studies that considered these systemic conditions as a potential risk factors or as absolute and relative contraindications for oral implant therapy are sparse due to low level of evidence (Bornstein et al., 2009).

## **2.5 Osteoporosis**

Osteoporosis is a metabolic disease characterized by fragility, low bone mass, and a generalized decrease in bone mineral content, which may lead to pain, deformity, or bone fracture. Osteoporosis is a physiological condition related to gender, age and family incidence (Osteoporosis, 1984). Other risks include early ovarian failure, low calcium ingestion, smoking, alcohol consumption, and low level of exercise (Dobbs et al., 1999).

Osteoporosis is classified into two categories: primary and secondary. Primary osteoporosis includes Type I, which is postmenopausal osteoporosis associated with increased bone

resorption exceeding bone formation due to loss of androgen and estrogen, and it is reported to be the most common form. Secondary osteoporosis, or Type II, is senile osteoporosis, gradual age-related bone loss found in both genders and caused by systemic aging. Secondary osteoporosis has a clear etiological mechanism (Riggs and MELTON III, 1983).

In women, postmenopausal osteoporosis can lead to pathological bone fractures due to reduced osteoblastic activity rather than increasing the number of osteoclasts within 15 to 20 years after starting menopause. This may cause less bone-implant contact with lower torque resistance. It was also reported that women suffer a bone mineral loss rate two times greater than that of men (Osteoporosis, 1984).

A complete history and physical examination and a thorough laboratory workup are important in patients with low bone density or an osteoporotic fracture. Hence, the proper diagnosis and implant treatment in patients with osteoporosis are critical. Treatment of many cases may include physical exercise, adequate calcium intake, and the use of appropriate antiresorptive medications (Dobbs et al., 1999).

There is no clear association and significant inverse impact between dental implant failures and osteoporosis, although the association was direct (Chen et al., 2013). However, no available data contraindicate the implant surgery in osteoporotic patients, but a longer period of implant osseointegration and surgical technique is essential before prosthesis insertion (Tsolaki et al., 2009, Gaetti-Jardim et al., 2011). Additionally, the bone quality at the implant site should be carefully evaluated, mainly the trabecular bone (Gaetti-Jardim et al., 2011). Hence, further investigations are needed to elucidate the role of osteoporosis in the long-term success of dental implants (Chen et al., 2013).

The bone-to-implant contact in a patient diagnosed with Type 1 osteoporosis was evaluated in a case report and the results suggest that osteoporosis may not present as a contraindication of

implant placement, at least when osseointegration has been established (Shibli et al., 2008). However, osteoporosis would reduce bone–implant contact during early bone healing (Keller et al., 2004).

The diagnoses of osteoporosis and osteopenia did not increase the risk of implant failure or the survival rate of osseointegrated dental implants and were not contraindications to dental implant therapy, based on a retrospective study done on 192 women at least 50 years of age at the time of implant placement (Holahan et al., 2008). Holahan et al. (Holahan et al., 2008) and Slagter et al. (Slagter et al., 2008) also agreed that osteoporosis does not contraindicate implant placement. However, the density of peripheral bone presented a weak association with the risk of implant failure in two case-control studies (Bornstein et al., 2009).

The relationship between peri-implantitis and postmenopausal osteoporosis in 203 adult females with 967 dental implants was evaluated in a cross-sectional study. The results showed that there is no significant association between osteoporosis and peri-implantitis, it was also suggested that postmenopausal osteoporosis in adult women is not a risk indicator for developing peri-implantitis or implant loss (Dvorak et al., 2011).

Regarding bisphosphonate therapy, bisphosphonate-related osteonecrosis of the jaw was significantly associated with the type of bisphosphonate, duration, drug dose, and route of administration. However, regarding the risk of taking oral bisphosphonate on dental implant surgery, there is insufficient data to support the relationship between dental implants and oral bisphosphonate (Bornstein et al., 2009).

## **2.6 Radiotherapy**

Patients treated with radiotherapy may have a higher risk of dental implant failure (Chen et al., 2013). It has been shown that the failure rate was 2 to 3 times greater in implants inserted in irradiated bone when compared with non-irradiated bone, while higher radiation doses of more

than 45 Gy significantly reduced the implant survival rate (Ihde et al., 2009, Dholam and Gurav, 2012). Additionally, implants placed in the maxilla have a higher failure rate than those placed in the mandible (Ihde et al., 2009, Colella et al., 2007). On the other hand, one study showed that the location of dental implants in patients with radiotherapy has no effect on implant survival rate (Doll et al., 2015).

The survival rate of 103 dental implants inserted in 17 oral cancer patients treated with radiotherapy and followed up from 1 to 5 years was evaluated. The results showed that the survival rate of implants placed in the maxilla was 92%, while for those placed in the mandible it was 97%. However, it has been reported that radiotherapy of oral cancer has no significant effect on implant survival rate when comparing radiotherapy patients with those who have not undergone radiotherapy (Jisander et al., 1997).

The implant survival rate was also evaluated in a retrospective study of 631 dental implants placed in patients who received cancer radiation therapy over a 25-year period. Although it was shown that the implant failure rate was higher in patients who received previous irradiation and a higher radiation dose (50 Gy) when compared with non-irradiated patients, implants could be successfully placed in patients with irradiated jaws with a very high survival rate. However, cancer patients should be carefully treated in specific institutes (Granström, 2005).

The implant survival rate was reported in patients who had undergone resection surgery. The results showed that after up to 20 years, the implant survival rate was significantly higher (90.8%), whereas the implants placed in patients treated with ablative surgery combined with radiochemotherapy showed a lower survival rate (Doll et al., 2015).

To achieve proper osseointegration in irradiated patients, dental implants are recommended to be placed after 1 year of radiotherapy, while the prosthesis part should be placed 6 months after the implant placement. Furthermore, choosing hydroxyapatite-coated titanium implants and

reducing the number of implants was also suggested. However, an improved implant survival rate was observed in non-smoking irradiated patients (Dholam and Gurav, 2012).

## **2.7 Smoking habits**

Cigarette smoking is a primary risk factor to the general health. Many life-threatening health conditions are associated with smoking, such as lung cancers (90%), chronic lung diseases (70%), myocardial infarctions in patients below the age of 50 (80%), and chronic ischemic heart diseases and strokes (30%) (Fielding, 1985, Peto et al., 1996, La Vecchia et al., 1991). It is also associated with several problems in the oral cavity, which includes; increased incidence of tongue and throat cancer (Saha et al., 2007) increased risk of peri-implant bone loss and implant failure (Haas et al., 1996, Lindquist et al., 1996, Lemons et al., 1997), increased plaque accumulation, higher incidence of gingivitis and periodontitis, higher risk of bone loss and tooth loss and wound healing complications as a result of the heat as well as toxic by-products such as nicotine, carbon monoxide, and hydrogen cyanide (Levin and Schwartz-Arad, 2005). Smoking is a risk factor for implant failure, but not an absolute contraindication. Therefore, a smoking history taking is important when an implant treatment is being planned, and it should include duration, intensity and present status of smoking (Kasat and Ladda, 2012).

### **2.7.1 Smoking dose**

The evidence in the literature about duration of smoking suggests that a significant relationship between number of years of smoking and risk of implant failure exist (Schwartz-Arad et al., 2002, Mundt et al., 2006).

Schwartz-Arad et al compared number of cigarettes smoked per day and number of years of smoking in mild smokers ( $\leq 10$  cigarettes per day and  $\leq 10$  years of smoking) and heavy smokers ( $> 10$  cigarettes per day and  $> 10$  years of smoking). Both groups had significantly more

complications than nonsmokers. Such complications include exposure of cover screw during early healing after implantation (Schwartz-Arad et al., 2002).

Another study compared smokers according to never smoker or quit smoking (over 10 years), light smoker (<10 cigarettes per day), moderate smoker (10 to 20 cigarettes per day), and heavy smoker (>20 cigarettes per day). The results were conclusive that dose of smoking is influential on increasing the risk of implant failure. Where light and moderate smokers had 10.1% relative risk of implant failure, while this risk was increased in heavy smokers to 30.8%. (Sánchez-Pérez et al., 2007). Additionally, Lindquist et al. (Lindquist et al., 1997) reported that the dose of tobacco use has an effect on peri-implant marginal bone loss over a 10-year period.

Moreover, in a study analyzing duration of smoking and its relation to long-term implant survival. The outcomes were that current smokers had a 15% implant failure rate, while the rate for former smokers was 9.6% and for nonsmokers 3.6%. Therefore, duration of smoking is significantly associated with increased risk of implant failures (Mundt et al., 2006).

### 2.7.2 Smoking and treated periodontitis

Krall et al. (Krall et al., 1997) studied the effect of smoking on tooth loss in adult population in a 10-year prospective study. The authors reported that smoking resulted in greater loss of teeth than in non-smokers, 3.3 and 1.3 folds, respectively. It was also reported that among men, smoke quitting decreases the rate of edentulism. Also, a positive association between the number of smoked cigarettes per day among men increasing and tooth was observed. However, association between the number of smoked cigars or pipe per day in men was not relevant to cause an increased risk of tooth loss in men who smoked cigarettes. The results can conclude that smoke quitting can significantly reduce the risk of tooth loss among adults.

In a study assessing reduction in pocket depth and gain in clinical attachment level after mechanical debridement based on smoking status. It was found that the least results were in the current smokers' groups compared to the former smokers or nonsmokers. In the current

smokers, the reduced healing was independent of the amount of supragingival plaque and was mainly in deep pockets (PPD 5 mm) and less gingival bleeding was observed. (Grossi et al., 1997) These results match the proposal of Danielsen et al. (Danielsen et al., 1990) that smokers "have a reduced capacity to mount and maintain an effective defense reaction to a given plaque challenge."

It was also observed that former smokers had similar response in periodontal therapy to nonsmokers. Therefore, it is currently suggested that smoking cessation may reverse the effect smoking poses on periodontal healing and subgingival microflora (Grossi et al., 1997).

The effect of smoking in patients who have a history of treated periodontitis have been evaluated in several studies (Baelum and Ellegaard, 2004, Ellegaard et al., 2006, Jansson et al., 2005, Feloutzis et al., 2003, Machtei et al., 2008, Machtei et al., 2007, Malo et al., 2007, Wennström et al., 2004, Chuang et al., 2002).

Several authors reported that the risk for implant failure was 3.1 (Chuang et al., 2002), 2.6 (Baelum and Ellegaard, 2004) and 2.2 (Ellegaard et al., 2006) folds higher in smokers with a history of treated periodontitis. And therefore, there is a statistical significance relation between smokers and higher early implant failure compared to nonsmokers (Jansson et al., 2005). Similarly, statistically significant greater bone loss in patients with history of treated periodontitis was observed in patients who smoked more than 20 cigarettes per day compared to non-smokers or former smokers (Feloutzis et al., 2003).

### 2.7.3 Smoking cessation

Smokers undergoing surgical dental procedures including implants must be encouraged by their clinician to cease smoking in order to reduce the risk of complications and failure rate. That being said, the clinician must be able to decide whether an implant treatment can be performed in high-risk situations, and once the decision is to proceed with the procedure, an

informed consent signed by the patient is necessary before starting the treatment (Kasat and Ladda, 2012).

Only one study in the literature exists regarding the influence of smoking cessation on implants osseointegration. Bain (Bain, 1996) reported in a prospective study the early outcomes of Brånemark implants in three groups of patients: nonsmokers (NS), smokers following a smoking cessation protocol (SQ), and smokers who continue to smoke (SNQ). The aim was to compare whether the smoking cessation protocol which is to cease smoking 1 week before initial implant placement and 8 weeks after that, can improve success rates for osseointegration of implants in smokers. The results showed that a statistically significant difference between failure rates in the NS and SNQ groups ( $P < .005$ ) and between the SQ and SNQ groups ( $P < .05$ ), but not between the NS and SQ groups. Hence, it is concluded that smoking cessation can significantly lower the risk of early implant failure.

Similarly, Rosa (Rosa et al., 2011) assessed the influence of smoking cessation in patients enrolled from a smoking cessation clinic. The patients involved had severe chronic periodontitis and undergone non-surgical periodontal therapy every 3 months. At the end of 1-year prospective study, there was a significant increase in clinical attachment for patients who ceased smoking. Although, studies with longer follow-up periods are required for a definitive effect.

#### 2.7.4 Smoking with rough and smooth surface implants

In a retrospective study evaluating the long term survival rates of smooth- and rough-surfaced implants, the outcomes of several factors were considered, this includes: age, gender, smoking habits, implant diameter, implant length, and anatomic location of implant. The study involved 593 patients receiving 2,182 smooth-surface implants and 905 patients receiving 2,425 implants. The results were that smoking is significant risk factor for implant failure in smooth-surface implants only; and among these high risk patients, the implant anatomic location

increases the risk of implant failure, with the maxillary posterior having the highest failure rates (Balshe et al., 2008).

In the systematic review of Bain et al. (Bain, 2003), success rate of smooth- and rough-surface implants were evaluated. Rough-surface implants had clinically significant success rates compared to smooth-surface implants 98.7% and 93.5%, respectively. However, it was found that only 0.3% difference in success rate between smokers and non-smokers in rough-surface implants group.

#### 2.7.5 Smoking and genetic factors:

The effect of smoking on implant outcome in patients with interleukin-1 (IL-1) polymorphism have been investigated by several authors. (Laine et al., 2006, Jansson et al., 2005, Feloutzis et al., 2003, Gruica et al., 2004) In a retrospective study, the relationship between IL-1 polymorphism and marginal bone loss and peri-mucositis was investigated in patients according to smoking status which involved: heavy smokers (20 cigarettes per day), moderate smokers (5-19 cigarettes per day), former smokers (quit >5 years), and non-smokers. 31.1% of the 90 candidates are IL-1 genotype positive. It was reported that significant difference in marginal bone loss between heavy smokers and nonsmokers was present in the patients who had IL-1 polymorphism. Therefore, the combination of both risk factors increases the risk for marginal bone loss around an implant (Feloutzis et al., 2003).

Additionally, Gruica et al. also evaluated the impact of IL-1 polymorphism and smoking status on peri-implant tissues of implants that have been in function for a minimum of 8 years. 17.4% implants had late biological complications. Concluding that an association between heavy smokers with IL-1 polymorphism and peri-implantitis exist (Gruica et al., 2004). Agreeing to the previous studies, a statistically significant combined effect of IL-1 polymorphism and smoking results in increased risk of early implant failure (Jansson et al., 2005). Also, a

statistically significant association between IL-1 polymorphism with peri-implantitis was found (Laine et al., 2006).

#### 2.7.6 Smoking effect on osseointegration

Bain & Moy (Bain and Moy, 1993) and De Bruyn & Collaert (De Bruyn and Collaert, 1994) have concluded that smoking does not only influence wound healing, but also reduces bone density.

Corresponding to the smoke cessation protocol introduced by Bain (Bain, 1996), the cessation 1 week before the implant placement is responsible in reversing the increased levels of platelet adhesion and blood viscosity, and also the short term effects of nicotine absorption. While the 8 week cessation after implant placement is responsible for improving early osseointegration without influencing the osteoblastic phase (Barzanji et al., 2018).

Gaining osseointegration in smokers receiving surface-modified implants have been evaluated in an 18-month retrospective study. It included 461 patients and in the smoker group, patients included in this study were those who smoked at least half a pack of cigarettes per day. The overall success rate of the 1,183 placed implants was 98.1%. 97% implants successfully osseointegrated in smokers and 98.4% in non-smokers ( $P < .05$ ). Therefore, no statistical significance was found in the relation of smoking with surface-modified implants effecting osseointegration. The authors suggest that using surface-modified implants can have an influence on achieving osseointegration in smoking patients (Kumar et al., 2002).

### **2.8 Lack of regular peri-implant maintenance**

The patient risk factor evaluation and effective supportive maintenance protocol should be initiated before implant placement to avoid the risk of biological complications, and patients should be motivated regarding the importance of peri-implant maintenance before implant placement. The present evidence shows that peri-implant diseases would be prevented with

regular dental visits and proper plaque control. Therefore, the impact of supportive periodontal therapy in periodontal health was emphasized in several studies. Even in patients with advanced forms of periodontal disease, periodontal health could be maintained in most patients and sites for 14 years and treatment was equally effective in both younger and older patients (Lindhe and Nyman, 1984).

Another study showed that the bone and attachment levels were stable and maintained in 80% of patients with high susceptibility to periodontal disease over a 12-year period with a regular supportive periodontal care program and subgingival debridement (Rosling et al., 2001). Although there have been reports of increased failure rates in periodontitis patients who received implants, these implants could function successfully for a long period of time in the presence of a strict periodontal maintenance program (Quirynen et al., 2007). Nevertheless, even with regular supportive periodontal therapy, the prevalence of inflammatory diseases in periodontal settings presents significant clinical and therapeutic challenges that will be developed with time (Aguirre-Zorzano et al., 2013).

Regarding the influence of supportive care on peri-implant tissues, a meta-analysis found that the rate of occurrence of peri-implant diseases appeared to be reduced when supportive periodontal care was performed. Furthermore, the incidence of peri-implant diseases reduced to 14.3% when general and high-risk patients obtained supportive care, compared to 18.8% among general patients (Atieh et al., 2013).

A systematic review concluded that the implementation of peri-implant supportive therapy may prevent biologic complications and hence increase the long-term implant success rate. However, the incidence of peri-implantitis was expected to be reduced in 25% of patients receiving maintenance care compared to patients without peri-implant supportive therapy. It was also mentioned that patients not under maintenance care showed higher mucositis and peri-implantitis incidences. Hence, a minimum peri-implant maintenance recall interval of 5 to 6 months was advised in this study (Monje et al., 2016). Another systematic review of the

literature found that patients with a diagnosis of periodontitis who complied with appropriate and regular periodontal maintenance had comparable periodontal and peri-implant conditions to those of healthy patients, and implant therapy could be used successfully in these patients. Moreover, the mean peri-implant bone loss was significantly less in treated periodontitis patients with a regular periodontal maintenance program than in noncompliant patients (Zangrando et al., 2015). Moreover, low rates of peri-implant bone loss were found in patients with 10-mm-long implants who had regular peri-implant maintenance (De la Rosa et al., 2013).

The occurrence of peri-implantitis was strongly related to the lack of peri-implant maintenance therapy (Costa et al., 2012). A recent meta-analysis showed that the median prevalence of peri-implantitis in patients who implemented regular peri-implant preventive maintenance was 9.0%, while it was 18.8% for patients without maintenance (Dreyer et al., 2018). Moreover, in a 5-year follow-up study, the results showed that the risk of peri-implantitis was higher in patients with previous peri-implant mucositis and a lack of preventive maintenance (Costa et al., 2012). The survival of implants was found to be highly associated with implant patients under a strict continuous supportive periodontal program (Anner et al., 2010). A recent meta-analysis reported approximately 70% survival rates 7 years after implants were placed in patients treated for peri-implantitis who received peri-implant supportive care (Roccuzzo et al., 2018). In regard to compliance, it was reported that attendance of two or more peri-implant maintenance therapy treatments per year in healthy patients appears to be important to avoid peri-implant disease (Monje et al., 2017a). It was also suggested that peri-implant maintenance recalls in patients with a history of susceptibility to disease should continue for at least 1 year to decrease the progression of disease (Rosén et al., 1999). The frequency of professional peri-implant maintenance recalls showed a significant role in longevity and success of dental implants. It was found that periodic peri-implant maintenance appointments reduced the incidence of implant failure in 90% of patients, including in 60% of patients with less than a 1-year maintenance recall (Gay et al., 2016). However, patients with a history of periodontitis

and smokers showed lower compliance with peri-implant maintenance (Monje et al., 2017b, Hu et al., 2017). Nevertheless, to date, there is no consensus regarding the ideal PIMT interval for adequate care of dental implants.

For the ideal peri-implant maintenance program, no strong critical maintenance protocol is described in the literature. However, several measures may be considered to maintain the health of peri-implant tissue and minimize the incidence of peri-implant diseases, such as oral hygiene instruction and professional mechanical plaque removal.

A recent systematic review showed no major difference between the different types of toothbrushes with respect to the reduction of gingival inflammation and dental plaque. Hence, patient preference in choosing the proper dental devices should be taken into consideration (Rösing et al., 2019). However, many studies confirmed the systemic use of home care devices such as toothbrushes, floss, and interdental brushes to reduce gingival inflammation (Robinson et al., 2005, Slot et al., 2008, Berchier et al., 2008) and the incidence of peri-implant mucositis and control clinical attachment loss (Corbella et al., 2011).

Regarding professional peri-implant care, it was demonstrated that stainless-steel scalers could affect the rate of corrosion and increase implant surface roughness of implants to a greater extent than titanium-alloy scalers, while plastic scalers caused the least damage to implant surfaces (Fox et al., 1990). Therefore, due to their minimal alterations of the implant surface, plastic curettes were recommended for routine maintenance although their efficiency at removal of plaque and calculus has not been confirmed (Meschenmoser et al., 1996). It also stated that the sonic and ultrasonic scalers had a more destructive effect on the implant surface than the metal scalers, while polishing with a rubber cup showed the least harmful effect. Moreover, the air powder abrasive treatment showed minor alterations to the implant surface (Thomson-Neal et al., 1989). Nevertheless, regarding the effect of chlorhexidine on

improvement of peri-implant mucositis, it was found that subgingival debridement with or without chlorhexidine has an uncertain outcome (Thöne-Mühling et al., 2010).

In conclusion, regular supportive care should be provided for patients who have received dental implants in order to maintain peri-implant health and minimize peri-implant inflammation.

## **2.9 Implant- and site-related factors**

### **2.9.1 Implant system and Surface characteristics**

Several studies and systematic reviews found no association between surface characteristics or implant design and peri-implant diseases (Renvert et al., 2012). These findings agreed with previous studies, which showed that the incidence of peri-implantitis did not increase with acid-etched implants (Buser et al., 2012, Zetterqvist et al., 2010). Moreover, the results of a randomized controlled study of 102 subjects with a total of 304 implants, followed up for 5 years, suggested that the fully etched implants do not adversely affect mucosal health or increase the risk of peri-implant diseases compared to hybrid-designed implants. It also emphasized the importance of the roughened surface at the collar in maintaining aesthetics due to persevering crestal bone and therefore the stability of soft tissue (Zetterqvist et al., 2010).

This is consistent with the outcomes of a review of 13 studies done in 2011, which showed a lack of evidence for the association between implant surface characteristics and peri-implantitis (Renvert et al., 2011). A comparative study in dogs showed that the host's response to a bacterial challenge is not related to that of the implant system. A similar composition of inflammatory lesions was observed around the implant mucosa in three different implant systems (Abrahamsson et al., 1998). This was in accordance with the results of a recent retrospective analysis of 200 patients who received implant-supported prostheses between 1998 and 2011. It showed that the type of implant system did not appear to be a risk indicator

for peri-implant diseases (Atieh et al., 2019). In contrast, (Becker et al., 2000) found significant marginal bone loss around plasma-sprayed implants when compared with minimally rough implants placed in one and two stages over a period up to 3 years. Similarly, Astrand et al. (Astrand et al., 2004) in a randomized-controlled trial (RCT), showed that implants with a rough surface significantly increase the occurrence of peri-implantitis compared to minimally rough implants. This was also confirmed by a systematic review (Esposito et al., 2007). Another experimental animal study conducted in 2013 showed that bone loss occurred more often in implants with modified surfaces following ligature removal compared with machine-surfaced implants, which considered a significant association between changes in peri-implant marginal bone level and implant surface characteristics (Carcuac et al., 2013). Quirynen et al. (Quirynen et al., 2007) verified the effects of regular periodontal maintenance and implant surface roughness. He considered implant surface roughness a co-factor in peri-implantitis and late implant loss, the review also showed that peri-implantitis or late implant loss is more likely in patients with aggressive periodontitis and/or with very rough implants and may decrease in the presence of a strict periodontal maintenance program.

A cross-sectional analysis of 512 implants, which were screened after a median function time of almost 2 years, found that the prevalence of peri-implant mucositis and peri-implantitis amounted to 41.6% and 13.9%, corresponding to 35.6% and 7.6% at the implant level, respectively, for a two-piece implant system with a tube-in-tube internal connection. The study concluded that the prevalence of peri-implant diseases among this kind of implant system significantly correlated with patient-specific factors ((Schwarz et al., 2017). Two other types of dental implants, Brånemark Nobel Biocare® (NB) and AstraTech TiOblast™ (AT) were studied over a period of 13 years, the incidence rate of peri-implantitis varied between 39% for NB implants and 32% for AT implants. The same study also confirmed the results of previous studies, which reported that the effects of implant surface and design make no difference in the

incidence of peri-implantitis and that the level of bone loss was greater during the first 7 years after implant placement (Renvert et al., 2012).

### 2.9.2 Implant height and diameter

Despite the high success rates of dental implants, implant length and diameter may play a role in the implant survival rate. However, in some circumstances, such as bone atrophy or reduced bone height, the placement of standard-length implants ( $\geq 10$  mm) may not always be possible. Hence, the use of short or nonstandard-diameter implants could be an effective solution to overcome more invasive techniques such as guided bone regeneration (GBR) or maxillary sinus floor elevation. A short dental implant can be defined as any implant with a length of  $\leq 11$  mm (Strietzel and Reichart, 2007), while some authors consider short to be  $< 10$  mm (Mezzomo et al., 2014, Telleman et al., 2014) or  $< 8$  mm (Fan et al., 2017) and extra-short to be a length of  $\leq 6.5$  mm (Anitua et al., 2014, Ravidà et al., 2019).

A previous meta-analysis showed that short ( $< 10$  mm) implants supporting single crowns in the posterior areas present minimal bone loss, low prosthetic/biologic complications, and low failure rates (Mezzomo et al., 2014). Another meta-analysis, also reported that the placement of short ( $< 10$  mm or  $< 8$  mm) rough-surfaced implants has similar outcomes compared to conventional ( $\geq 10$  mm) rough-surfaced implants (Kotsovilis et al., 2009, Monje et al., 2013). Similarly, a recent systematic review evaluating the mean survival rate and marginal bone loss (MBL) of dental implants of  $\leq 6$  mm in length over a period of 5 years concluded that extra-short implants show an acceptable survival rate, with a low rate of prosthetic and biologic complications, and can be used as an alternative treatment option in atrophic ridges (Ravidà et al., 2019). Additionally, comparable survival rates have been demonstrated between short and wide-diameter implants and between longer implants and standard-diameter implants in the

presence of good bone density and well-developed surgical skills in the surgeon (Renouard and Nisand, 2006).

Considering implant diameter, a clinical and radiographic retrospective study of 316 narrow-diameter implants evaluated and followed patients over a 10-year period. It was concluded that when the buccolingual width of the edentulous ridge is inadequate to replace missing incisor teeth, narrow-diameter implants (NDIs; diameter 4.75 mm) can be used with confidence. Minimal MBL around NDIs was observed, mostly within 2 years of loading, with no implant fractures discovered over this period (Arisan et al., 2010). In regard to implant diameter, a few published studies have reported an increased failure rate of wide-diameter implants for many reasons, such as inferior surgical skills, inferior implant design, inadequate site preparation, and poor bone quality. Failure rate also increased when a wide implant was used because the primary stability of a standard-diameter implant could not be achieved. However, in some older studies, the increased failure rates of wide-diameter implants were mostly related to inferior surgical skill, inadequate site preparation, inferior implant design and poor bone density (Renouard and Nisand, 2006).

### 2.9.3 Use of grafting material

Regarding the association between bone grafting and peri-implant diseases, a retrospective analysis of 3,082 implants placed in 1,017 subjects showed that using non-autogenous bone grafting materials with immediate implant placement would increase the risk of early inflammation and peri-implantitis. Furthermore, the biological complications could be related to the surgical protocols and grafting procedures (Jemt et al., 2017).

This was consistent with the results of a recent published retrospective analysis of 200 patients who received implant-supported prostheses and followed for a functional time of 10 years, that the rate of peri-implantitis was increased with the use of bone grafting and immediate implant

placement. However, the same study showed that the use of grafting material was a significant risk factor for peri-implant mucositis in patients with a history of treated periodontitis and a lack of supportive peri-implant maintenance, but did not detect any association between peri-implantitis and the use of grafting material or surgical protocols (Atieh et al., 2019). A recent meta-analysis compared the prevalence of biological complications and failure of implants placed in pristine sites vs. augmented sites after at least a 10-year follow-up period. The results showed that the prevalence of peri-implant mucositis, peri-implantitis, and implant failure at the implant level presented weighted mean values of 21.2%, 7.5%, and 2.4% for pristine sites and of 24.6%, 6.5%, and 6.5% for augmented sites respectively. Nevertheless, no statistically significant differences were found in this meta-analysis between implants placed in pristine and augmented sites at both the implant and patient levels (Salvi et al., 2018) . A 10-year retrospective study concluded that 72.1% of the implants showed no bone loss with implants immediately placed into extraction sockets grafted with tri-calcium phosphate, which were highly comparable to implants placed without grafting material in favorable conditions. However, no statistical association was found between the time of implant placement either delayed or immediate, the amount of bone loss, and the use of bone graft material (Harel et al., 2013).

## **2.10 Prosthesis-related factors**

### **2.10.1 Superstructure retention**

Cement-retained implant-supported restorations are frequently used in dental implants due to their simplicity, passivity of fit, ease of controlling occlusion, prevention of prosthesis screw loosening, and lower cost compared with screw-retained implant-supported restorations (Wilson, 2009). Nevertheless, the implant and the health of soft tissue surrounding the implant may be affected due to the possibility of retaining residual excess cement at the time of cementation. Moreover, the remnants of cement might lead to advanced marginal bone loss

and peri-implant disease (Renvert and Quirynen, 2015). It was noted that after the cementation of fixed dental prostheses, the appearance of early signs of inflammation and peri-implant disease varied from as early as 4 months to > 9 years (Wilson, 2009, Pauletto et al., 1999). Hence, the positive relationship between peri-implant disease and excess dental cement was documented in several studies. In a previous prospective clinical endoscopic study of 39 patients who had clinical and/or radiographic signs of peri-implant disease during a 5-year period, the results showed that 81% of the patients who demonstrated signs of peri-implant disease were accompanied by subgingival retained excess cement. Signs of inflammation were reduced after 4 weeks in most of the treated cases when the retained excess cement was removed by using either the dental endoscope or a surgical flap procedure when needed. Additionally, around 74% of the test implants showed no signs of peri-implant disease after removal of the excess cement (Wilson, 2009).

A very recent retrospective study found that the estimated annual rate of peri-implantitis at the implant level was 1.5% for cement-retained implant-supported fixed complete dental prostheses (IFCDPs) and 2.5% for screw-retained IFCDPs, but the difference is not statistically significant. Nevertheless, the cement-retained fixed dental prosthesis has a 4.6 times greater risk of gingival inflammation than the screw-retained fixed dental prosthesis (Papaspyridakos et al., 2019). However, regarding the biological complication and implant survival rates, although the difference is not statistically significant between screw- and cement-retained prostheses, the cement-retained prosthesis presented a higher occurrence of biological and technical complications (Sherif et al., 2014, Wittneben et al., 2014).

### **3. AIM**

To evaluate prevalence and risk indicators that are associated with peri-implant diseases.

#### **3.1 Specific objectives**

1. Evaluate the prevalence of peri-implant mucositis
2. Evaluate the prevalence of peri-implantitis.
3. Identify systemic- and patient-related factors that had an impact on peri-implant diseases.
4. Identify implant-, site- and surgical-related factors that had an impact on peri-implant diseases.
5. Identify prosthesis-related factors that had an impact on peri-implant diseases.

#### **3.2 Research question**

What is the prevalence and risk indicators for peri-implant diseases in dental implants placed at Dubai Health Authority (DHA) in United Arab Emirates (UAE)?

### **4. MATERIALS AND METHODS**

#### **4.1 Study design and participants**

This is a retrospective study of patients aged  $\geq 18$  years and had dental implants placed at DHA in 2010. All the patients had periodontal and radiographic assessment prior to dental implant placement and during the follow-up visits up to 2019. The patients' electronic records at DHA included demographic data, medical and dental history, and clinical notes including information on the number of follow-up and maintenance visits between 2010 and 2019.

#### **4.2 Ethical approval**

The study was approved by the institutional review board of Mohammed Bin Rashid University of Medicine and Health Sciences (MBRU-IRB-2020-014) and DHA in accordance with the Declaration of Helsinki of ethical human research practice.

### 4.3 Data collection

Data were collected by the principal investigator (Z.A.) using dental practice management software (D4W, Australia), Salama (electronic medical record system) software and explanted implant records available at Dubai Health Authority. A structured data collection form (Appendix I) was used to collect relevant information. The data were collated into four main domains:

Demographic data

Systemic and patient-related outcomes

Implant-, site-, and surgical related outcomes

Prosthesis-related outcomes

Patients were not recalled for examination. The information related to the clinical assessment, implant system and radiographic marginal bone level changes were obtained from patients' electronic records. Data collection were divided into several sub-categories: Systemic-related factors such as medical and social history were collected retrospectively when the health status was assessed at the time of implant placement. Implant-, surgical- and prosthesis-related factors, such as implant system, location, surface roughness, height, diameter, shape, placement protocol, number of functional years prior to peri-implant diseases, use of grafting materials at the time of implant placement, type of retention, screw loosening, number of maintenance visits were also collected and analyzed as possible risk indicators for peri-implantitis.

*Systemic- and patient-related factors*

- Gender.
- Systemic conditions.
- Diabetes Mellitus.
- Dyslipidemia.

- Hypertension.
- Osteoporosis.
- Anemia.
- Hypothyroidism.
- Smoking habits.
- Parafunctional habits.
- History of treated periodontitis.
- Lack of regular dental attendance (regular attendance was defined as at least one dental check-up per year).
- Lack of regular peri-implant maintenance (regular maintenance was defined as at least one dental visit for peri-implant maintenance per year)

*Implant- and site-related factors*

- Implant system.
- Implant shape.
- Implant height
- Implant diameter.
- Implant location.
- Implant placement protocols (Hammerle et al., 2004).
- Use of grafting material at the time of implant placement.
- Operator.

*Prosthesis-related factors*

- Type of prosthesis.
- Superstructure retention.
- Number of functional years prior to diagnosis.

- Prosthetic complications: screw loosening.
- Prosthetic complications: crown chipping.
- Prosthetic complications: crown debonding.

Records with missing data on more than 50% of the follow-up time were excluded.

#### **4.4 Case definition**

Peri-implant mucositis was defined as an osseointegrated functional implant which demonstrated bleeding and/or suppuration on probing, absence of increasing probing depths and bone loss beyond initial remodeling of crestal bone levels. Peri-implantitis was defined as an osseointegrated functional implant which demonstrated bleeding and/or suppuration on probing, increased probing depths and bone loss beyond initial remodeling of crestal bone levels or > 2 mm in the absence of baseline clinical parameters. A healthy implant was defined as one which showed no clinical signs of inflammation, absence of increased probing depths and bone loss beyond initial remodeling of crestal bone levels (Araujo and Lindhe, 2018, Renvert et al., 2018).

#### **4.5 Reliability study**

An experienced clinician (M.A.) conducted a training session on the data collection which included running a practice exercise using a predetermined collection form from an actual patient file. To produce stable and consistent results, inter- and intra-examiner reliability tests were performed by selecting five files from pool of retrieved patient files. Data were collected by the principal investigator (Z.A.) with two weeks apart and cross-checked by an experienced clinician (M.A.) The strengths of inter- and intra-examiner reliability were assessed by calculating Cohen kappa coefficients for selected items with two or more categories. Kappa scores of 0.21-0.40 indicated fair reliability; 0.41-0.60 indicated moderate reliability; 0.61-0.80 indicated substantial reliability; and 0.81-1.0 indicated excellent reliability (Landis and Koch, 1977).

#### **4.6 Power analysis**

The determination of the sample size needed was based on adopting 95% power and 5% error using Gpower software, version 3.1.9.4. A representative sample size of 262 implants was calculated for the inclusion of at least 15 risk indicators. To account for possible exclusions, a total of 300 implants were included.

#### **4.7 Statistical analyses**

Data were analyzed using the Statistical Package for Social Sciences (SPSS) Version 27. The strength of association between the frequency of peri-implant diseases and each variable was measured by chi-square analysis. Differences were considered statistically significant at  $P < 0.05$ . Estimates of relative risk were also calculated for all variables. For systemic and patient-related factors, the patient was considered the unit of analysis. Therefore, one only one event of peri-implant mucositis or peri-implantitis per patient was included in the analysis to enhance statistical accuracy (Herrmann et al., 1999). For implant-, site-, and prosthesis-related factors, the implant was considered as the statistical unit.

Risk indicators for peri-implantitis were estimated by a binary logistic regression, which is the appropriate model for a categorical dichotomous outcome (peri-implantitis was coded 0 if no events occurred and 1 if peri-implantitis was reported). A backward stepwise method was selected. All predictor variables which had  $P$ -values of less than 0.05 or relative risk of 1.5 or greater were entered into the analysis and coded in a binary format 0 or 1. Then, at each step, the variable with a significance level equal to or larger than 0.05 was removed, until the final model was obtained.

## 5. RESULTS

A total of 162 patients with 301 implant-supported restorations were included in the study. The age of the patients ranged between 19 and 72 with mean age of  $46.4 \pm 11.7$  years. The prevalence of peri-implant mucositis at the patients and implant levels were 44.4% and 38.2%, respectively. For peri-implantitis, the prevalence at the patient level was 5.6%, while the prevalence at the implant level was 4.0%. The kappa values for the inter- and intra-examiner agreement ranged from 0.88 and 0.94, indicating excellent agreement in data collection.

### 5.1 Peri-implant mucositis

Patients diagnosed with peri-implant mucositis were more likely to be irregular attender of peri-implant maintenance visits as 55.4% of irregular attenders were diagnosed with peri-implant mucositis compared to 35.2% of regular attenders diagnosed with peri-implant mucositis ( $p = 0.01$ ), while there were no significant association between history of treated periodontitis or lack of regular dental attendance and peri-implant mucositis. Gender, presence of any systemic conditions, smoking and parafunctional habits had no significant impact on the prevalence of peri-implant mucositis (Table 1). All the placed implants were either Ankylos, Xive or Friadent and all had rough surfaces. Therefore, it was not possible to compare the impact of implant surface characteristics on the prevalence of peri-implant mucositis. Single implant restorations that were cemented were more likely to be associated with increased prevalence of peri-implant mucositis. However, the difference was not statistically significant when compared with fixed implant-supported prostheses or screw-retained restorations. The implant dimensions, implant location, implant placement protocol, use of grafting materials, operator or any prosthesis-related factors did not have any significant influence on the prevalence of peri-implant mucositis (Table 2).

## 5.2 Peri-implantitis

The prevalence of peri-implantitis was statistically significant among smokers, those who had history of treated periodontitis or did not attend of regular peri-implant maintenance visits as all these variables showed significant associations. Gender, presence of any systemic conditions, parafunctional habits or lack of regular dental attendance had no significant impact on the prevalence of peri-implantitis (Table 3). Likewise, implant-, site-, surgical- and prosthesis-related factors did not have any significant influence the prevalence of peri-implantitis (Table 4).

The binary logistic regression showed that smoking habits, history of treated periodontitis and lack of peri-implant maintenance reached statistically significant association with the onset of peri-implantitis in the final model. The three variables had low standard errors implying a statistically stable model and did not contain a value of 1.00 representing useful and independent predictor variables (Figure 1). The odds ratios showed that smokers, those with history of treated periodontitis or those that did not attend regular peri-implant maintenance were eight, seven and ten times at risk of peri-implantitis, respectively. The overall accuracy of the model to predict peri-implantitis (with predicted probability of 0.5 or greater) is 96.3%. The estimates of the logistic regression model, the adjusted odds ratios for the three risk indicators and their 95% confidence intervals are summarized in Table 5.

**Table 1** : Characteristics of patients diagnosed with peri-implant mucositis (n = 162)

Systemic and patient-related factors:	N (%) diagnosed peri-implant mucositis	Relative risk (95% CI) *	P value <sup>†</sup>
<b>Gender</b>			
Male	34 (52.3)	1.34 (0.95, 1.88)	0.10
Female	38 (39.2)		
<b>Presence of systemic conditions</b>			
Yes	22 (43.1)	1.04 (0.72, 1.52)	0.82
No	50 (45.0)		
<b>Presence of diabetes mellitus</b>			
Yes	15 (51.7)	1.43 (0.64, 3.20)	0.38
No	57 (42.9)		
<b>Presence of dyslipidemia</b>			
Yes	7 (50.0)	1.28 (0.43, 3.82)	0.66
No	65 (43.9)		
<b>Presence of hypertension</b>			
Yes	10 (43.5)	1.03 (0.62, 1.70)	0.92
No	62 (44.6)		
<b>Presence of osteoporosis</b>			
Yes	1 (14.3)	3.21 (0.52, 19.84)	0.10
No	71 (45.8)		
<b>Presence of anemia</b>			
Yes	2 (50.0)	1.26 (0.17, 9.15)	0.82
No	70 (44.3)		
<b>Presence of hypothyroidism</b>			
Yes	3 (37.5)	1.20 (0.48, 2.97)	0.69
No	69 (44.8)		
<b>Smoking habits</b>			
Smokers	10 (43.5)	1.01 (0.61, 1.67)	0.98
Non-smokers	60 (43.8)		
<b>Parafunctional habits</b>			
Yes	2 (18.2)	2.55 (0.72, 9.04)	0.07
No	70 (46.4)		

<b>History of treated periodontitis</b>			
Yes	20 (50.0)	1.35 (0.66, 2.76)	0.42
No	52 (42.6)		
<b>Lack of regular dental attendance</b>			
Yes	16 (55.2)	1.31 (0.89, 1.92)	0.20
No	56 (42.1)		
<b>Lack of regular peri-implant maintenance</b>			
Yes	41 (55.4)	2.28 (1.21, 4.31)	0.01
No	31 (35.2)		

CI: confidence interval

\*Computed only for 2x2 tables

†Chi-square test

**Table 2** : Characteristics of implants diagnosed with peri-implant mucositis (n = 301)

Implant-, site-, and surgical-related outcomes	N (%) diagnosed peri-implant mucositis	Relative risk (95% CI)*	P value†
<b>Implant system</b>			
Ankylos	48 (38.7)	NA	0.39
Xive	66 (39.1)		
Friadent	0 (0.0)		
<b>Implant shape</b>			
Cylindrical	48 (38.7)	1.01 (0.75, 1.35)	0.95
Tapered	66 (38.4)		
<b>Implant height (mm)</b>			
< 11	72 (38.9)	1.05 (0.65, 1.70)	0.84
≥ 11	43 (37.7)		
<b>Implant diameter (mm)</b>			
< 4.5	65 (39.4)	1.09 (0.68, 1.75)	0.71
≥ 4.5	50 (37.3)		
<b>Implant location</b>			
Anterior maxilla	8 (25.0)	NA	0.31
Posterior maxilla	40 (36.7)		
Anterior mandible	4 (50.0)		
Posterior mandible	63 (41.4)		
<b>Implant placement protocol</b>			
Type I		NA	0.54
Type II	7 (43.8)		
Type III	3 (30.0)		
Type IV	6 (26.1)		
	99 (39.3)		
<b>Bone augmentation procedure at the time of implant placement</b>			
Yes	21 (34.4)	1.14 (0.78, 1.67)	0.50
No	94 (39.2)		
<b>Operator</b>			
Periodontist	76 (39.8)	1.20 (0.74, 1.96)	0.46
	39 (35.5)		

Oral and maxillofacial surgeon			
Prosthesis-related outcomes	N (%) diagnosed peri-implant mucositis	Relative risk (95% CI)*	P value†
<b>Type of Prosthesis</b>			
Single implant crown	96 (40.3)	1.34 (0.89, 2.01)	0.14
Fixed implant-supported prosthesis	19 (30.2)		
<b>Superstructure retention</b>			
Screw-retained	40 (35.7)	1.17 (0.72, 1.91)	0.52
Cement-retained	71 (39.4)		
<b>Number of functional years prior to diagnosis</b>			
< 5 years	59 (43.1)	1.26 (0.95, 1.68)	0.11
≥ 5 years	56 (34.1)		
<b>Prosthetic complications</b>			
<b>Screw loosening</b>			
Yes	11 (40.7)	1.12 (0.50, 2.52)	0.78
No	104 (38.0)		
<b>Prosthetic complications</b>			
<b>Crown chipping</b>			
Yes	5 (33.3)	1.15 (0.56, 2.40)	0.69
No	110 (38.5)		
<b>Prosthetic complications</b>			
<b>Crown debonding</b>			
Yes	18 (38.3)	1.01 (0.53, 1.91)	0.99
No	97 (38.2)		

CI: confidence interval

\*Computed only for 2x2 tables

†Chi-square test

**Table 3:** Characteristics of patients diagnosed with peri-implantitis (n = 162)

Systemic and patient-related factors:	N (%) diagnosed peri-implantitis	Relative risk (95% CI)*	P value†
<b>Gender</b>			
Male	2 (3.1)	2.45 (0.49, 12.19)	0.26
Female	7 (7.2)		
<b>Presence of systemic conditions</b>			
Yes	3 (5.9)	1.09 (0.26, 4.56)	0.90
No	6 (5.4)		
<b>Presence of diabetes mellitus</b>			
Yes	2 (6.9)	1.33 (0.26, 6.78)	0.73
No	7 (5.3)		
<b>Presence of dyslipidemia</b>			
Yes	1 (7.1)	1.35 (0.16, 11.62)	0.79
No	8 (5.4)		
<b>Presence of hypertension</b>			
Yes	1 (4.3)	0.74 (0.09, 6.25)	0.79
No	8 (5.8)		
<b>Presence of osteoporosis</b>			
Yes	1 (14.3)	3.06 (0.33, 28.58)	0.30
No	8 (5.2)		
<b>Presence of anemia</b>			
Yes	1 (25.0)	6.25 (0.58, 67.01)	0.09
No	8 (5.1)		
<b>Presence of hypothyroidism</b>			
Yes	1 (12.5)	2.61 (0.29, 23.83)	0.38
No	8 (5.2)		
<b>Smoking habits</b>			
Smokers	5 (21.7)	9.24 (2.26, 37.60)	< 0.0001
Non-smokers	4 (2.9)		
<b>Parafunctional habits</b>			
Yes	1 (9.1)	1.79 (0.20, 15.74)	0.60
No	8 (5.3)		

<b>History of treated periodontitis</b>			
Yes	6 (15.0)	7.00 (1.66, 29.47)	0.003
No	3 (2.5)		
<b>Lack of regular dental attendance</b>			
Yes	1 (3.4)	1.79 (0.22, 14.91)	0.59
No	8 (6.0)		
<b>Lack of regular peri-implant maintenance</b>			
Yes	8 (10.8)	10.55 (1.29, 86.40)	0.007
No	1 (1.1)		

CI: confidence interval

\*Computed only for 2x2 tables

†Chi-square test

**Table 4:** Characteristics of implants diagnosed with peri-implantitis (n = 301)

Implant-, site-, and surgical-related outcomes	N (%) diagnosed peri-implantitis	Relative risk (95% CI)*	P value†
<b>Implant system</b>			
Ankylos	6 (3.6)	NA	0.81
Xive	6 (4.8)		
Friadent	0 (0.0)		
<b>Implant shape</b>			
Cylindrical	6 (4.8)	1.39 (0.46, 4.20)	0.56
Tapered	6 (3.5)		
<b>Implant height (mm)</b>			
< 11	6 (3.2)	1.62 (0.54, 4.91)	0.39
≥ 11	6 (5.3)		
<b>Implant diameter (mm)</b>			
< 4.5	9 (5.5)	2.52 (0.67, 9.50)	0.16
≥ 4.5	3 (2.2)		
<b>Implant location</b>			
Anterior maxilla	1 (3.1)	NA	0.69
Posterior maxilla	3 (2.8)		
Anterior mandible	0 (0.0)		
Posterior mandible	8 (5.3)		
<b>Implant placement protocol</b>			
Type I		NA	0.76
Type II	0 (0.0)		
Type III	0 (0.0)		
Type IV	1 (4.3)		
	11 (4.4)		
<b>Bone augmentation procedure at the time of implant placement</b>			
Yes	2 (3.3)	1.27 (0.29, 5.65)	0.75
No	10 (4.2)		
<b>Operator</b>			
Periodontist	5 (2.6)	2.43 (0.79, 7.48)	0.11
Oral and maxillofacial surgeon	7 (6.4)		

Prosthesis-related outcomes	N (%) diagnosed peri-implant mucositis	Relative risk (95% CI)*	P value†
<b>Type of Prosthesis</b>			
Single implant crown	9 (3.8)	1.27 (0.33, 4.85)	0.72
Fixed implant-supported prosthesis	3 (4.8)		
<b>Superstructure retention</b>			
Screw-retained	5 (4.5)	1.15 (0.37, 3.53)	0.81
Cement-retained	7 (3.9)		
<b>Number of functional years prior to diagnosis</b>			
< 5 years	8 (5.8)	2.39 (0.74, 7.78)	0.13
≥ 5 years	4 (2.4)		
<b>Prosthetic complications</b>			
<b>Screw loosening</b>			
Yes	1 (3.7)	1.08 (0.15, 8.08)	0.94
No	11 (4.0)		
<b>Prosthetic complications</b>			
<b>Crown chipping</b>			
Yes	1 (6.7)	1.79 (0.22, 14.82)	0.59
No	11 (3.8)		
<b>Prosthetic complications</b>			
<b>Crown debonding</b>			
Yes	2 (4.3)	1.08 (0.23, 5.12)	0.92
No	10 (3.9)		

CI: confidence interval

\*Computed only for 2x2 tables

†Chi-square test

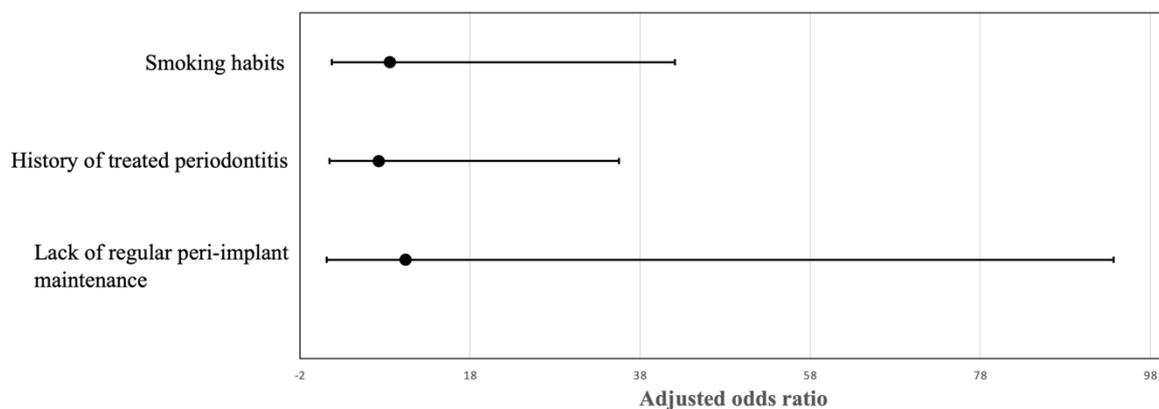
**Table 5:** Results of logistic regression analysis

Predictor variable	Peri-implantitis		
	<i>B</i> coefficient (SE)	<i>P</i> value	Odds ratio (95% CI)
Smoking habits (Yes = 0, No = 1)	2.15	0.008	8.55 (1.75, 42.10)
History of treated periodontitis (Yes = 0, No = 1)	1.98	0.01	7.26 (1.48, 35.52)
Lack of regular peri- implant maintenance (Yes = 0, No = 1)	2.34	0.04	10.41 (1.15, 93.69)

Model  
Chi-square = 22.88; df = 3;  $P < 0.0001$

CI: confidence interval

**Figure 1:** Adjusted odds ratios and 95% confidence intervals for the independent risk indicators



## 6. DISCUSSION

The present study retrospectively investigated the prevalence and factors that are mostly associated with the development of peri-implant diseases amongst group of patients that received implants in DHA.

The study identified the main risk indicators for peri-implant mucositis and peri-implantitis. For peri-implant mucositis, the most significant variable was irregular participation in a supportive peri-implant maintenance program. For peri-implantitis, the most significant variables were tobacco smokers, history of treated periodontitis, and lack of regular supportive peri-implant therapy.

### 6.1 The prevalence of peri-implant disease

The prevalence of peri-implant mucositis was 44.4% at the patient level and 38.2% at the implant level, during an implant functional time of up to 10 years. This was significantly higher than the recently published retrospective study by Atieh and coworkers (Atieh et al., 2019), In that recent 8-year retrospective analysis of 188 patients with 423 implant-supported protheses, the estimated frequency of peri-implant mucositis was 20.2% at the patient level and 10.2% at the implant level, while the frequency of peri-implantitis was 10.1% and 5.4% at patient and implant levels, respectively. However, the result of the present study was almost comparable with two previously reported studies (French et al., 2019, Daubert et al., 2015). In one of those studies, the estimated frequency of peri-implant mucositis amongst a total of 4591 dental implants, performed in private practice and followed up for 5 to 10 years, was 38.6% at the implant level, while the frequency of peri-implantitis was 4.7% (French et al., 2019). Similarly, a cross-sectional study of 96 patients with 225 implants reported an 11-year prevalence of 48% for peri-implant mucositis at patient level and 33% at implant level. The prevalence of peri-implantitis was 26% at patient level and 16% at the implant level (Daubert et al., 2015).

When compared with systematic reviews, the results of the current study were significantly lower than previously reported in systematic reviews (Atieh et al., 2019, Zitzmann and Berglundh, 2008). Atieh and co-workers conducted a systematic review and meta-analysis which included 1497 patients and 6283 implants. A prevalence of 63.4% was estimated for peri-implant mucositis at patient level and 30.7% at implant level. The corresponding prevalences for peri-implantitis were 18.8% and 9.6% at patient and implant levels, respectively (Atieh et al., 2013). In another systematic review, the prevalences of peri-implant mucositis at patients and implant levels were reported as 80% and 50%, respectively. The incidence of peri-implantitis ranged between 28% and 56% at patient level and between 12% and 43% at implant level (Zitzmann and Berglundh, 2008). In contrast, the prevalences of peri-implantitis in the present study were lower with 5.6% at the patient level and 4.0% at the implant level. Likewise, the reported prevalences in the present study were also lower than two recently published retrospective studies (Atieh et al., 2019, Kordbacheh Changi et al., 2019). One of those retrospective studies included a total of 188 patients with 423 implant-supported protheses. During 8-year functional follow-up period, the estimated frequencies of peri-implantitis were 10.1% and 5.4% at patient and implant levels, respectively (Atieh et al., 2019). The other study evaluated the prevalence of peri-implantitis in 2,127 patients and 6,129 implants over an average follow-up of 2 years. Prevalences of 34% and 21% at patient and implant levels, respectively, were reported (Kordbacheh Changi et al., 2019). The observed differences in results can be accounted for by the different follow-up periods reported in the forementioned studies.

## **6.2 Systemic and behavioral risk indicators**

Our data analyses showed that gender, presence of any systemic conditions, lack of regular dental attendance and parafunctional habits had no significant impact on the prevalence of peri-implant diseases. Furthermore, no significant relation was found between history of treated

periodontitis and smoking and peri-implant mucositis. This was consistent with another retrospective analysis (Atieh et al., 2019).

One of the most significant risk factors for developing peri-implant diseases is a lack of regular peri-implant maintenance visits. The results obtained in the present study showed that the absence of supportive peri-implant maintenance care was significantly associated with the development of peri-implant diseases. Patients that did not undergo regular peri-implant maintenance had a ten times higher risk of peri-implantitis. This strong association is in accordance with what has been previously reported in several studies (Costa et al., 2012, Atieh et al., 2019, Pjetursson et al., 2012a). In agreement with the current study, it was reported in a retrospective study that the prevalence of peri-implant mucositis in the absence of regular supportive peri-implant maintenance was 63.3%, while the prevalence of peri-implantitis was 40.0% (Atieh et al., 2019). In a systematic review and meta-analysis, the prevalence of peri-implantitis was 9.0% for patients in a regular peri-implant maintenance program and 18.8% for patients with irregular supportive maintenance (Dreyer et al., 2018). Furthermore, the prevalence of peri-implantitis for patients under supportive peri-implant care was 18.0%, while this prevalence was 43.9% in patients with irregular supportive maintenance care (Costa et al., 2012). It was also confirmed by Monje et al. in a meta-analysis of the importance of peri-implant maintenance, the incidence of mucositis and peri-implantitis was higher in patients without regular peri-implant maintenance. However, patients who received regular maintenance care showed a 25% reduction of the incidence of peri-implantitis when compared to those not under regular maintenance (Monje et al., 2016). Similarly, in a previously published meta-analysis, it was reported that the number of patients with peri-implantitis was reduced in those who participated in a regular peri-implant supportive care program (Atieh et al., 2013).

Furthermore, the results of the present study suggest that patients with a history of treated periodontitis were found to have a seven times higher risk of peri-implantitis than periodontally healthy patients. This significant relation is agreed with the previously described by several authors (Roos-Jansåker et al., 2006a, Karoussis et al., 2007, Quirynen et al., 2007, Ong et al., 2008, Simonis et al., 2010, Rocuzzo et al., 2012, Renvert et al., 2012, Dalago et al., 2017, Monje et al., 2017b, Schwarz et al., 2018, Atieh et al., 2019). The association between patients with a history of chronic periodontitis and an absence of maintenance care and an increased rate of peri-implantitis was strongly evident in the last review of the 2017 World Workshop (Schwarz et al., 2018).

A retrospective study also showed that the prevalence of peri-implant diseases was significantly high in patients with a previous history of treated periodontitis (Atieh et al., 2019). Similarly, a cross-sectional study of 183 patients with 916 implants showed that the risk of peri-implantitis increased 2.2 times in patients with a history of periodontal disease (Dalago et al., 2017). According to a retrospective study of 109 patients with mean functional time of 8.4 years, history of periodontitis was identified as a risk indicator for peri-implantitis (Koldsland et al., 2011). Another study of 70 periodontally-treated patients with 165 dental implants who were followed-up for 3 to 23 years, the risk of development of peri-implantitis was significantly high in patients with a history of periodontitis and residual pocket depth of  $\geq 5$ mm (Pjetursson et al., 2012a). This was in accordance with our results.

The prevalence of peri-implantitis for periodontally-compromised patients was also reported in an earlier study of 112 dental implants placed in 53 participants with a 10-year follow-up period. The results showed that the prevalence of peri-implantitis for patients with a history of periodontitis was 28.6%, while for non-periodontitis patients this prevalence was 5.8% (Karoussis et al., 2003). Also, Quirynen and colleagues evaluated the relationship between peri-implantitis and several factors such as history of treated periodontitis and supportive periodontal therapy. The results showed that minimally/moderately rough implants can be

placed effectively in periodontally-compromised patients when regular supportive periodontal maintenance is followed (Quirynen et al., 2007). The strong association between previous history of periodontitis and increased risk for peri-implantitis can be partly explained by the similarities in microbial composition and patient susceptibility. Such association can also be compounded by the overlapping in risk factors for peri-implantitis and periodontitis.

The negative effect of smoking on peri-implant diseases was discussed in several studies. Similarly, the present study showed that an increased rate of peri-implantitis was significantly associated with smoking and smoking was identified as a risk indicator for peri-implantitis that is eight times higher than that of non-smokers. This observation agrees with several studies that evaluated the association between smoking and peri-implantitis (Heitz-Mayfield, 2008, Atieh et al., 2013, Chrcanovic et al., 2015, Atieh et al., 2019).

In a recent retrospective study, Atieh and co-workers (2019) reported that smokers have more risk of developing peri-implantitis. This risk is also higher when smoking is in conjunction with irregular supportive peri-implant maintenance care (Atieh et al., 2019). Similar association was also reported in a systematic review by the same research group (Atieh et al. 2013), where the occurrence of peri-implantitis was significantly associated with smoking, with an estimated prevalence of peri-implantitis of 36.3% recorded for smokers (Atieh et al., 2013).

In a meta-analysis of a total of 19,836 implants placed in smokers, the results showed that incidence of postoperative infections and implant failure rates were negatively affected by smoking (Chrcanovic et al., 2015). Furthermore, in a retrospective study, 148 implants placed in 104 subjects and maintained for at least 3 years were examined. The results reported that peri-implant bone loss was significantly increased in smokers (De la Rosa et al., 2013). Similarly, current and former smokers showed higher marginal bone loss than nonsmokers (Levin et al., 2008). In a 10-year retrospective analysis that compared tobacco smokers with and without a history of treated periodontitis, it was also reported that implants placed in smokers with a history of treated periodontitis and lack of supportive care were associated with

higher marginal bone loss rates and lower implant survival rates (Aglietta et al., 2011). Conversely, other studies did not detect any association between smoking and peri-implantitis (Koldsland et al., 2011, Renvert et al., 2014).

### **6.3 Prosthesis-related risk indicators**

The relation between retained cement in cement-retained implant-supported restorations and peri-implant diseases was documented in several studies (Wilson, 2009, Papaspyridakos et al., 2019, Pauletto et al., 1999, Gapski et al., 2008).

In a prospective study of 39 patients with cement-retained dental restorations during a 5-year period, it was found that 81% of patients with excess cement showed signs of peri-implant disease (Wilson, 2009).

The survival and success of cement-retained crowns were compared with screw-retained crowns in a systematic review. The results showed that the failure rate was slightly higher in the cement-retained group, however the difference was not statically significant (Sherif et al., 2014). In another review, it was also concluded that excess cement could increase the risk of developing peri-implantitis (Renvert and Quirynen, 2015).

These results were confirmed in a recent retrospective study of a total of 249 implants placed in 19 subjects, those with a cement-retained fixed dental prosthesis had a 4.6 times higher risk of gingival inflammation compared to those with a screw-retained fixed dental prosthesis (Papaspyridakos et al., 2019). Conversely, in another recently published retrospective study of 200 subjects with a functional time of 10 years, it was reported that the risk of developing peri-implant disease was not associated with the type of retention (Atieh et al., 2019). Nevertheless, the results of our study found that the prevalence of peri-implant mucositis was slightly associated with cement-retained single restorations, but the difference between the two types of retention was not statistically significant. However, the prevalence of peri-implantitis was not significantly related to the type of retention. The lack of such a significant association might be related to the placement of the cement-retained implant crown margins at mucosal levels

which would have allowed early detection and removal of excess cement. Nevertheless, this cannot be confirmed as none of the participants were recalled to assess the position of the crown margins.

#### **6.4 Implant- and site-related risk indicators**

In the current study, the relation between the implant surface characteristics and the prevalence of peri-implant disease could not be detected since all of the placed implants had rough surface characteristics. However, several reported studies found that the implant system did not appear to be a risk indicator for peri-implant diseases. (Zetterqvist et al., 2010, Renvert et al., 2011, Atieh et al., 2019). In contrast, Becker et al. (Becker et al., 2000) found significant marginal bone loss around plasma-sprayed implants when compared with minimally rough implants placed in one and two stages over periods of up to 3 years.

The present study showed that implant placement protocol and use of grafting materials did not have any significant influence on the prevalence of peri-implant disease. In contrast, a recent retrospective analysis (Atieh et al. 2019) showed that the rate of peri-implantitis was increased in immediate implant placement and when bone grafting material was used. However, the use of grafting material and the surgical protocol were significantly associated with peri-mucositis but were not considered risk factors for peri-implantitis (Atieh et al., 2019). However, in another retrospective analysis of 3,082 implants placed in 1,017 subjects, the risk of early inflammation and peri-implantitis was increased with the use of non-autogenous bone grafting materials with immediate implant placement (Jemt et al., 2017).

The present study had several limitations. As a retrospective study, the loss of specific data is not uncommon. In addition, the sample size can be considered small which might affected the statistical power. Further well-designed retrospective and prospective studies with larger sample size and longer follow-up periods are required to estimate prevalences and risk indicators for peri-implant diseases.

## **7. CONCLUSIONS**

Within the limitations of this retrospective study, the analysis identified plausible risk indicators, namely smoking, history of treated periodontitis and irregular peri-implant maintenance visits, that would allow clinicians to identify those at risk and ensure continuous peri-implant supportive care.

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## 9. APPENDICES

### APPENDIX 1

<b><i>Systemic and patient-related factors</i></b>	
Age (at the time of implant placement)	_____
Gender	<input type="checkbox"/> Male <input type="checkbox"/> Female
Presence of systemic disease	<input type="checkbox"/> Yes <input type="checkbox"/> No
Presence of diabetes mellitus	<input type="checkbox"/> Yes <input type="checkbox"/> No
Smoking habits	<input type="checkbox"/> Never <input type="checkbox"/> Former <input type="checkbox"/> Current
Parafunctional habits	<input type="checkbox"/> Yes <input type="checkbox"/> No
History of treated periodontitis	<input type="checkbox"/> Yes <input type="checkbox"/> No
History of regular dental attendance	<input type="checkbox"/> Yes <input type="checkbox"/> No
Regular periodontal/peri-implant maintenance	<input type="checkbox"/> Yes <input type="checkbox"/> No
<b><i>Implant, site and surgical-related outcomes</i></b>	
Implant system	<input type="checkbox"/> Straumann <input type="checkbox"/> Brånemark System <input type="checkbox"/> Nobel Biocare <input type="checkbox"/> Neoss System <input type="checkbox"/> Southern Implants <input type="checkbox"/> Biomet-3i <input type="checkbox"/> Astra Tech <input type="checkbox"/> Others: _____
Implant surface characteristics	<input type="checkbox"/> Machined <input type="checkbox"/> Moderately roughened Or _____
Implant shape	<input type="checkbox"/> Cylindrical <input type="checkbox"/> Tapered

Implant height (mm)	_____
Implant diameter (mm)	_____
Implant sites	<input type="checkbox"/> Anterior maxilla <input type="checkbox"/> Posterior maxilla <input type="checkbox"/> Anterior mandible <input type="checkbox"/> Posterior mandible
Implant placement protocol (ITI)	<input type="checkbox"/> Type I <input type="checkbox"/> Type II <input type="checkbox"/> Type III <input type="checkbox"/> Type IV
Bone augmentation procedure or using grafting materials	<input type="checkbox"/> Yes <input type="checkbox"/> No
Number of implants	<input type="checkbox"/> Single implant <input type="checkbox"/> $\geq 2$ implants Or _____
Mobility of implant	<input type="checkbox"/> Yes <input type="checkbox"/> No
Presence of marginal bone loss	<input type="checkbox"/> Yes <input type="checkbox"/> No
Presence of peri-implant mucositis	<input type="checkbox"/> Yes <input type="checkbox"/> No Or previous -never -current
Peri-implantitis	<input type="checkbox"/> Yes <input type="checkbox"/> No
<b><i>Prosthesis-related outcomes</i></b>	
Implant connection	<input type="checkbox"/> Internal <input type="checkbox"/> External
Superstructure retention	<input type="checkbox"/> Screwed retained <input type="checkbox"/> Cement retained
Number of functional years before diagnosis	<input type="checkbox"/> $\leq 5$ <input type="checkbox"/> $> 5$ or _____
<b><i>Prosthetic complications</i></b>	
Crown chipping	<input type="checkbox"/> Yes <input type="checkbox"/> No
Screw loosening	<input type="checkbox"/> Yes <input type="checkbox"/> No

## APPENDIX 2



8 April 2020

**Zainab Almutairi**

**Resident - Prosthodontics**

**HBMCDM**

RE: MBRU-IRB-2020-014

Dear Dr Zainab,

Thank you for submitting clarifications to the observations on the study titled "A retrospective analysis of biological complications of implant-supported fixed dental prostheses". The Board has reviewed the same and agreed to approve the study.

The study can now commence; any change to the protocol has to be communicated to the Board on the appropriate documentation.

For any questions, please contact the Institutional Review Board [irb@mbru.ac.ae](mailto:irb@mbru.ac.ae).

Thank you for your interest in MBRU-IRB.

Sincerely,

**Professor Alexander Milosevic**

*Deputy Chairman, MBRU-IRB*



04 May 2020

To,  
University Student Research Evaluation Committee  
Medical Education Department  
Dubai Health Authority.

Sub: Research co-supervision letter

In response to the following Student:

**Dr Zainab Al Mutairi**  
**Student, MBRU**  
**Resident in Master Program in Prosthodontics**

who is, working on a research study titled :

**“A retrospective analysis of biological complications of implant-supported fixed dental prostheses”**

I hereby declare the approval of the Dental Services Department for the above-mentioned student to conduct the study and research.

**The student/ requester will review the draft of said study/research with the Dental Services Department-DHA co-supervisor and Director and/or assigned member prior to finalizations and publications”.**

Sincerely,



Dr Hamda AlMesmar  
Director of Dental Services Department  
Primary Health Care SectorDubai Health Authority