RISK FACTORS FOR DENTAL IMPLANT FAILURE: A 10-YEAR RETROSPECTIVE STUDY

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ABSTRACT

Risk factors for dental implant failure: a 10-year retrospective study

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Background: Owing to the high long-term survival rates of osseointegrated dental implants it has become increasingly used as the treatment of choice to replace missing teeth in the past few decades. Nevertheless, implant failures and loss may occur as a result of biological and technical complications.

Aim: To identify the risk factors associated with early and late implant failures in patients treated at Dubai Health Authority (DHA) and establish risk assessment model.

Materials and Methods: A total of 645 patients aged ≥18 years had 830 failed implants at DHA between 2010 and 2019. The data was manually collected from records available at DHA and then analyzed using logistic regression analysis. The collected data was divided into two sub-categories; systemic-/patient-related factors, and implant-/site-related factors. The strength of association between the frequency of early and late implant failure and each variable was measured by chi-square analysis. Differences were considered statistically significant at $P < 0.05$. For systemic and patient-related factors, the patient was considered the unit of analysis. For implant-related factors, the implant was considered as the statistical unit.

Results: Out of 14191 implants inserted during the observation period, 721 implants failed before loading (5.1%) and 109 implants failed after loading (0.8%). More than half of late failed implants (59.3%) were single implant and (57.0%) were screw-retained prostheses. A significant association was observed between implant failure and histories of treated periodontitis ($P < 0.0001$), previous implant failure ($P < 0.0001$), and irregular dental attendance ($P = 0.006$). Implants inserted in the posterior region in both arches had a significant impact on implant failure with more early and late implant failures ($P < 0.0001$). The other variables did not influence early or late implant failures.

Conclusion: Within the limitations of this retrospective study, the analysis identified plausible risk factors for early implant failure, namely history of treated periodontitis, previous implant failure and irregular dental attendance that would allow clinicians to identify those at risk and ensure continuous peri-implant supportive care. Further studies are necessary to achieve more robust understanding on potential risk factors for implant failures and to provide effective preventive and therapeutic protocols.

DEDICATION

To my loving and caring husband: **Ibrahim**

My deepest gratitude for your endless support and encouragement when the times got rough. I will not forget the great comfort and relief you have provided by the countless times you took over my role with our children during my hectic schedules. Without you, I would have not been able to complete my dream in being a Prosthodontist. Thank you for your patience, faith and making everything possible.

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You guys are my everything! And everything I do is for you. You are the source of my joy, strength and what kept me going through this journey. I love you to infinity and beyond.

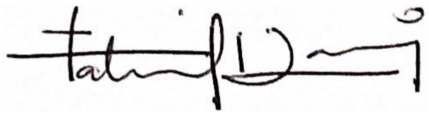
To the sweetest parents: **Dr. Ahmed** and **Sawsan**

Dad, my best friend, no words are enough to describe how grateful I am to you for being my guidance and source of inspiration. You are my first teacher and who led me to this path, so I hope I have made you proud. And to my amazing mom, thank you for nursing me with affection and love. I owe my success to Allah Almighty, Alhamdulillah and of course to you both for your continuous prayers and advice.

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: Fatima AlZarooni

Signature: 

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1. INTRODUCTION

Over the past few decades, the prevalence and incidence of tooth loss that commonly occurs as a result of disease and trauma have reduced (Silva Junior et al., 2019), but still remained amongst the detrimental conditions effecting the health of the world population (Marcenes et al., 2013). Functional and aesthetic problems may arise as a result of tooth loss, and the individual's quality of life can also be affected (Gerritsen et al., 2010, Haag et al., 2017). Hence, a new field of dentistry; dental implantology which involves osseointegrated dental implants has been introduced to replace a missing tooth or teeth. Dental implants have developed from being experimental and an unreliable treatment modality to becoming an important therapeutic tool in the rehabilitation of partially and fully edentulous patients. The reason it is considered the therapy of choice is due to its superior occlusal stability (Quirynen et al., 1992, Goncalves et al., 2015, Fueki et al., 2016), masticatory efficiency, and its ability to restore missing teeth without damaging adjacent teeth (Awad et al., 2000, Tajbakhsh et al., 2013, Gates et al., 2014, Zembic and Wismeijer, 2014).

Osseointegration was first defined as "direct functional and structural connection between living bone and the surface of load-bearing implant" (Albrektsson et al., 1981). Despite the high long-term survival rates (Adell et al., 1990, Lindquist et al., 1996, Roos-Jansaker et al., 2006, Alsaadi et al., 2007); implant failure and loss may occur as a result of biological and technical complications (Berglundh et al., 2002). The incidence of implant failures varies in frequencies from 1% up to 22% (Adell et al., 1990, Lindquist et al., 1996, Roos-Jansaker et al., 2006, Alsaadi et al., 2007).

There are a wide variety of risk factors affecting implant failure and are generally divided into systemic- and patient-related factors (patient systemic status, age, smoking habits, parafunctional habits, oral hygiene maintenance, etc.), site- and implant-related factors (implant location, quantity and quality of bone, implant surface characteristics, implant height and diameter, etc.), prosthesis-related factors (implant-abutment connection, excess cement, etc.) and the operator's experience (Porter and von Fraunhofer, 2005, Levin, 2010).

2. REVIEW OF THE LITERATURE

2.1. Definitions and criteria's

The terms success and survival are commonly misinterpreted and used incorrectly. Pjetursson and colleagues (2014) described the term implant success as a functional implant that does not have clinical symptoms, no signs of inflammation, and limited marginal bone loss (not more 0.2 mm after the first year of function). While implant survival is when an implant is still retained in the oral cavity but with problems, and therefore requiring additional treatment and can be considered nonfunctional.

Several implant success criteria's are available, but the one proposed by Albrektsson and his colleagues (1986) is commonly used. This includes the following characteristics for an individual implant:

- Clinically the implant must be immobile.
- Radiographically there should be no evidence of peri-implant radiolucency.
- Marginal bone loss should not be more than 0.2 mm annually after the first year of function.
- Absence of persistent and/or irreversible signs and symptoms such as infection, pain, paresthesia, anesthesia and violation of the mandibular canal.
- By these criteria, the minimum levels of success rate are (85%) and (80%) at 5 years and 10 years observational periods, respectively.

More recently, esthetics which includes the peri-implant soft tissue have become part of the success criteria of implants inserted in the esthetic zone (Döring et al., 2004). Several studies have discussed this. Belser and colleagues (2004) indicated that harmony must exist between peri-implant soft tissues and healthy surrounding dentition. Buser and colleagues (2004) indicated that an important factor for implant success is patient satisfaction, especially when an implant is in the esthetic zone. A year later, an index termed pink esthetic score (PES) with 7 parameters, was introduced to assess the appearance of peri-implant soft tissue in esthetic zone. (Fürhauser et al., 2005) Belser and colleagues (2009) then modified the esthetic assessment to include a white esthetic score (WES) with 5 parameters to assess the general teeth appearance.

On the other hand, terms such as ailing, failing and failed implant exists and have different descriptions. An ailing implant is when bone loss and pocketing occurs without inflammation or implant mobility. The failing implant is similar but with progressive bone loss and signs of inflammation, such as bleeding on probing and suppuration. While if an implant exhibits mobility, it has to be removed since the implant failed and is no longer functional (Meffert, 1992). In a situation where an implant is part of a multiunit, splinted fixed prosthesis, mobility cannot be detected. Therefore, assessment of bone loss should be achieved by probing and radiographs. A continuous radiolucency around the entire implant is a definitive sign of failure (Esposito et al., 1998a).

On the other hand, some previous studies proposed that regardless of an immobile implant, when (50%) bone loss is observed radiographically, this is considered a failed implant and should be removed (Misch et al., 2008). This concept has recently been challenged due to the advances in treatment of peri-implantitis that may arrests disease progression, thus converting the condition from unfavorable to favorable with respect to implant retention (Khoshkam et al., 2013).

2.2. Classifications of implant failure

Several classifications of implant failure have been proposed by various authors (Kate et al., 2016). However, the most commonly used is the classification of Esposito and co-workers, (1998a) which is based on osseointegration concept and includes four main categories (biological, mechanical, iatrogenic, and inadequate patient adaptation). The biological implant failures are divided into two categories depending on its time of occurrence; early or primary implant failure (before loading) where an implant has failed to establish osseointegration, and late or secondary implant failure (after loading) where an implant failed to maintain previously achieved osseointegration.

In early implant failures the clinically apparent mobility of an implant is a main clinical sign because the failure occurs from lack of osseointegration, rather than other parameters such as; pain or sensitivity during function or percussion, signs of infection, peri-implant radiolucency, and/or dull sounds when percussing (Esposito et al., 1998a).

2.3. Prevalence of implant survival and failure

2.3.1. Implant survival rates

Several controlled clinical trials and systematic reviews are available documenting the survival and complication rates of dental implants. (Jung et al., 2012, Verma et al., 2013, Pjetursson et al., 2014, Hjalmarsson et al., 2016).

In a systematic review by Pjetursson and his colleagues (2014), they reassessed the 5-year survival rate of implant-supported prostheses in comparison with the results of older publications that demonstrated the increasing survival rates, as a result of improvements in implant therapy. The overall survival rate increased from (93.5% to 97.1%); (95.2 to 97.9%) for cemented prostheses, (77.6% to 96.8%) for screw-retained reconstruction, (92.6% to 97.2%) for implant-supported single crowns, and (93.5% to 96.4%) for implant-supported fixed dental prostheses (FDPs) (Pjetursson et al., 2014). Survival rates for telescopic implant-retained removable prostheses were also assessed and found to be (97.9%) and (100%) at 3 years and 10.4 years, respectively (Verma et al., 2013).

Additionally, in a 5-year prospective observational study on 590 patients with 990 implants inserted in a private practice settings, high cumulative survival and success rates were observed after 3 years (> 99%) and 5 years (97%) of loading (Cochran et al., 2007). Another systematic review reported 10-year survival rate of 94.6% and success rates ranging from 34.9% to 100% (Moraschini et al., 2015). In a recent 11-year retrospective study on 1279 implants evaluating the risk factors for implant failure, it was established that the overall success rate of implants was above 95% (Mayta-Tovalino et al., 2019).

Also, multiple authors reviewed the mean survival rates of implants for various procedures with different observational periods. Lang and colleagues (2012) observed survival rate of 94% for immediately placed implants after two years. Corbella and colleagues (2015) reported 5-year implant survival rate in atrophic ridges between 86.5% and 98.2%. Annibali and colleagues (2012) reported survival rate of 99.1% for short dental implants over 3.1 years. Kim and colleagues (2012) found 5-year survival rates between 83.3% and 96.0% in patients treated for aggressive periodontitis, and Romanos and colleagues (2012) reported 7-year survival rate of 95.0% for implants supporting distal cantilevers.

Therefore, survival rates of dental implants are generally considered high with good longevity but that does not necessarily indicate that the peri-implant soft tissues are healthy. The variation in the survival rates between studies is because of the different factors used to assess implant survival (Alsaadi et al., 2007).

2.3.2. Implant failure rates

As mentioned earlier, the failure rates are considered low. The literature available is controversial on whether early or late implant failures is more prevalent than the other. Some studies reported early implant failure rates being somewhat lower than late implant failures, (0.76% to 7.47%) and (2.1% to 11.3%) respectively (Berglundh et al., 2002, Baqain et al., 2012). This evidence is supported in a longitudinal retrospective study by Chrcanovic and his colleagues (2016b), investigating implant-supported prostheses of 10,096 implants placed in 2,670 patients between 1980 and 2014 at one specialist clinic. The overall implant failure rate was 6.36%, of which, 1.74% were early implant failures.

In contrast, several other authors have reported the opposite (Han et al., 2014, Naert et al., 1992, Zarb and Schmitt, 1990). It is also important to bear in mind that different definitions for implant failure were used in the literature. For example, Mardinger and co-workers (2012), defined early implant failure as an implant loss occurring within the first year, while any implant loss after the first year of function was considered a late implant failure.

2.4. Systemic- and patient-related factors

2.4.1. Age

The effect of age on implant failure is controversial. The majority of studies failed to show an association between age of patient at surgery and implant failure (Chrcanovic et al., 2014). However, in a long-term retrospective analysis, it was concluded that implant failure rate was higher among patients aged > 60 years (Moy et al., 2005). The suggested rationale for such observation, was the decreased bone quality and impaired wound healing associated in elder patients that might alter tissue response to implant placement and lead to failure (Shirota et al., 1993). Moreover, the incidence of systemic diseases and medications usage commonly associated in elder patients can act as confounders. On the contrary, recent observations indicated that young patients had an overall significantly higher risk of implant failure than older patients in rehabilitation of fully edentulous jaws (Jemt, 2019). Moreover, middle-aged group of patients had significantly high risk of implant failure in partially edentulous jaws (Jemt, 2019).

2.4.2. Gender

Although, previous studies could not find such an association between gender and higher incidence of implant failures (Smith et al., 1992, Moy et al., 2005). More recently, studies are seeming to correlate male gender as a risk factor for increased implant failure (French et al., 2015, Becker et al., 2016). In a 19-year retrospective study, both early and late implant failures were higher in male patients than females. Where 47% of early failures were due to infection, and 53% of the late failures were due to overloading (Han et al., 2014). These can be attributed to the high incidence of periodontal diseases (Shiau, 2018) and heavy occlusal forces (Koç et al., 2011) experienced among men. This was confirmed in meta-analysis that reported that males were about 1.21 times at higher risk for implant failure than females (Chrcanovic et al., 2015).

2.4.3. Diabetes mellitus

Available evidence in the literature suggests that a bi-directional association between periodontal disease and glycemic control exist, where both diseases can influence each other potentially (Taylor, 2001). Periodontal therapy is less successful in poorly controlled diabetic individuals compared to well-controlled diabetic and non-diabetics individuals (Westfelt et al., 1996). In the past, diabetes was considered a relative risk factor to implants because of their increased susceptibility to infections, impaired wound healing and microvascular complications (Gallacher et al., 1995, McMahon and Bistrian, 1995, Delamaire et al., 1997), thus altering bone healing around implant and affecting osseointegration (Turkyilmaz, 2010). Maintaining a stringent glycemic control is important to minimize some of the most common diabetic comorbidities (Nathan et al., 1993). Complications occur more commonly when plaque and bleeding on probing indices increase. As hemoglobin A1c (HbA1c) level is one of the most important factors affecting post-operative complications in diabetic patients (Tawil et al., 2008) and bone density in diabetic patients does not seem to affect implant survival (Morris et al., 2000), implants can be used successfully in well controlled diabetic patients, with mean HbA1c of 7.2% and high success rates can be achieved provided treatment is properly planned, executed and followed-up (Tawil et al., 2008).

Several studies have specifically addressed implant treatment in well and moderately controlled diabetic patients, and reported success rates of 92.7% (Shernoff et al., 1994), 94.3% (Balshi and Wolfinger, 1999), 100% in well-controlled diabetic and 96.6% in moderately controlled diabetic patients (Gómez-Moreno et al., 2015). A prospective study of implants placed in the mandible of well controlled diabetic patients revealed an early implant failure rate of 2.2% (after implants were uncovered) and late failure rate of 7.3% (one year after implantation) (Shernoff et al., 1994). A five-year survival rate of 90% was also reported (Olson et al., 2000). No differences in survival rate in the first 6 years between diabetic and non-diabetic patients were observed, but diabetic patients had lower implant survival rate than non-diabetic patients in a 20 year follow-up (Naujokat et al., 2016). Various authors reported a higher failure rate after about one year of implant placement (Morris et al., 2000, Sherif et al., 2014). They suggested that failure is associated with uncovering of implants and early phase of implant loading. The microvascular disturbance leading to impaired immune response and reduced bone turnover might be a contributing factor to the implant failure (Olson et al., 2000) and that diabetes is considered a risk factor for implant failure (Morris et al., 2000).

But it is still unclear how the type and level of diabetic control and the duration of the disease is associated with implant failure (Olson et al., 2000, Naujokat et al., 2016). Nevertheless, it has been concluded, that there is no statistical significant difference in the success rate between well controlled diabetic patients and non-diabetic patients (Tawil et al., 2008, Turkyilmaz, 2010, Chen et al., 2013). And it has been reported that immediate loading can be performed safely in moderately HbA1c values (Gómez-Moreno et al., 2015).

Diabetic patients seem to have delayed osseointegration following implantation (Naujokat et al., 2016), are at a significantly increased risk of marginal bone loss and developing peri-implantitis (Gómez-Moreno et al., 2015), and implant failure (Naujokat et al., 2016). Therefore, examining the causative mechanism and having the glycemic control re-assessed and optimized prior surgery is essential (Blanchaert, 1998) It is also recommended to avoid immediate loading (Michaeli et al., 2009, Naujokat et al., 2016).

Furthermore, increased infection risk in diabetic patients can lead to impaired wound healing. Thus local infection post-surgically and decreased immune response, post-operative complications commonly occur (Abiko and Selimovic, 2010, Zupnik et al., 2011).

Controversial suggestions in the literature exist regarding the use of pre- or peri-operative prophylactic antibiotic for placing implants in systemically healthy patients, but there is a general agreement supporting the use of antibiotics for compromised patients such as diabetics undergoing implant placement (Blanchaert, 1998, Balshi and Wolfinger, 1999, Morris et al., 2000). The main pathogens responsible for post-operative impaired wound healing in surgery are, streptococci, anaerobic Gram-positive cocci, and anaerobic Gram-negative rods (Beikler and Flemmig, 2003). Therefore, a low toxicity bactericidal antibiotic should be selected for prophylaxis, such as penicillin or amoxicillin. Clindamycin, metronidazole, or first generation cephalosporin as an alternative in cases of penicillin allergy (Garg, 1992).

Moreover, it has been reported that rinsing with chlorhexidine digluconate (0.12%) mouthwash at the time of implant placement significantly reduced the failure rate from (13.5%) to (4.4%) in type 2 diabetic patients. Therefore, it is recommended for clinicians to use chlorhexidine rinses peri- and post-operatively at time of implant placement. Additionally, the use of HA-coated implants can significantly increase the survival rate from (84.7% to 97.7%) in type 2 diabetics (Morris et al., 2000).

Similar conclusions in a prospective study, that patients with elevated HbA1c levels are at a higher risk of developing peri-implant diseases (Gómez-Moreno et al., 2015). A recent meta-analysis has concluded that diabetic patients are at a (50%) increased risk of developing peri-implant diseases in comparison to healthy patients (Monje et al., 2017a).

2.4.4. Osteoporosis

Osteoporosis is a metabolic disease associated with fragile, low bone mass and low bone mineral content that leads to pain, deformity and bone fracture. It has been shown to be related to gender, age and family incidence. Dobbs and colleagues (1999), have added that other risk can also lead to Osteoporosis, these include; early ovarian failure, low calcium ingestion, smoking, alcohol consumption, and low level of exercise.

Several authors have concluded that patients with osteoporosis are not contraindicated for receiving implant treatment. In a recent meta-analysis, although a direct relationship exists between osteoporosis and implant failure, no clear association and significant inverse impact was found (Chen et al., 2013). Other studies have suggested that although osteoporosis is not an absolute contraindication for implant failure, several measures can be performed to reduce the risk of implant failure, this includes keeping the implant for a longer period of osseointegration and the surgical technique are both necessary before prosthesis insertion (Tsolaki et al., 2009, Gaetti-Jardim et al., 2011). Keller and colleagues (2004), reported reduced bone-implant contact during early bone healing in osteoporosis. At the same time, it is critical to carefully evaluate the bone quality at the implant site, particularly the trabecular bone (Gaetti-Jardim et al., 2011). Likewise, Holahan (2008) and Slagter (2008) and their colleagues, concluded in their studies that osteoporosis and osteopenia does not have an influence on increasing the survival and failure rates of implants, thus implant treatment not being a contraindication for these patients. However, a weak association was found between density of peripheral bone and increased risk of implant failure (Bornstein et al., 2009). Also supporting the previous studies is a cross-sectional study involving 967 implants inserted in 203 women, no relationship was found between osteoporosis and peri-implantitis. Therefore, indicating that osteoporosis is not a risk factor biological complications and implant failure (Dvorak et al., 2011).

Therefore, proper diagnosis and implant treatment planning is critical in patients with osteoporosis. Which is achieved through a thorough history taking, physical examination and a detailed laboratory workup. Treatment of many cases may include physical exercise, adequate calcium intake, and the use of appropriate antiresorptive medications (Dobbs et al., 1999).

Bornstein and colleagues (Bornstein et al., 2009), have discussed the role of bisphosphonate therapy and its effect on bisphosphonate-related osteonecrosis of the jaw and it was found that a significant association is present but dependent on the type of bisphosphonate, duration, drug dose, and route of administration. Whereas, its association with implant survival, there was insufficient data to support the relationship between dental implants and oral bisphosphonate.

2.4.5. Radiotherapy

According to research by Buser and colleagues (2000), patients treated with radiotherapy before or after implant insertion are at an increased risk of implant failure. This is supported in a recent meta-analysis by Chen and co-workers (2013), reporting significant association of implant failure in irradiated jaws. It has been suggested that such conditions could interfere with tissue healing process or increase a patient's susceptibility to other disease, thus reducing implant survivability (Klokkevold and Han, 2007).

Studies have shown that irradiated bone is 2 to 3 times at greater risk of implant failure when compared with non-irradiated bone, and that high radiation doses (> 45 Gy) can significantly decrease survival rate (Ihde et al., 2009, Dholam and Gurav, 2012). On the contrary, one study have reported that radiotherapy has no significant effect on implant survival when compared to non-radiated patients (Jisander et al., 1997). Besides this, higher failure rates are noticed in implants placed in irradiated maxilla compared to those in irradiated mandible (Ihde et al., 2009, Colella et al., 2007). In another study, it has been suggested that location of implant in an irradiated jaw did not seem to effect implant survival rate (Doll et al., 2015).

As with in a previous study by Granström (2005), who retrospectively evaluated implant survival rate in patients treated with radiotherapy. It was shown that these patients had a higher risk of implant failure, particularly those with higher radiation dose (50 Gy) when compared with non-radiated patients. Hence, when treating irradiated patients in specific institutes, implant therapy could be successful and high survival rate can be achieved.

A couple of studies assessed the effect of radiotherapy on late implant failure (Alsaadi et al., 2008a, Doll et al., 2015). When both radiotherapy and chemotherapy are combined together, an implant had 1.9 fold higher risk of implant failure compared to ablative surgery patients (Doll et al., 2015). Alsaadi and colleagues (2008a) reported higher incidence of late implant failure in patients treated with radiotherapy.

During the bone repair and remodeling phase, altered osteoblast and osteoclast function occur, hypoxic-hypocellular and hypovascular tissues breakdown and tissue perfusion and fibrosis decrease as a result of bone response to irradiation. These responses vary widely and can depend on the administered dose of radiation (Dholam and Gurav, 2012). Therefore, recommendations have been proposed for achieving proper osseointegration of implants inserted in irradiated jaws. That would include placing implants at least 1 year after radiotherapy and restore the implant 6 months after implant insertion. Additionally, reduction in the number of implants inserted and selection of hydroxyapatite-coated titanium implants were also suggested (Dholam and Gurav, 2012).

Furthermore, in order to reduce the risks associated with radiotherapy and implant failure, it has been reported that the application of fractionated dose is more tolerable than single exposure at the same level of intensity (Rubin, 1973). As well as the use of hyperbaric oxygen (HBO) as an adjunctive treatment to increase regenerative capacity of tissue; however, it seems to be insignificant in decreasing implant failure in patients treated with radiotherapy (Esposito et al., 2008).

2.4.6. History of periodontitis

The microbiotic flora associated with periodontitis is similar to that of involved in peri-implant disease (Apse et al., 1989, Mombelli and Lang, 1998, Quirynen and Teughels, 2003). That includes; gram-negative anaerobic rods, bacteroids, fusobacterim and spirochetes, all of which can lead to bone destruction and result in marginal bone loss (Mombelli, 1999).

In a recent systematic review and meta-analysis by Ramanauskaite and co-workers (2014) assessing success and survival rates of implants in patients with and without history of periodontitis; they found no difference in the implant survival rate. However, lower success rates were reported in patients with history of periodontitis and therefore, it was concluded that history periodontitis increases the risk of marginal bone loss and incidence of peri-implantitis. This is corresponding with the results of a previous systematic review by Safii and co-workers (2010).

Furthermore, several systematic reviews assessing the relationship between failing implants and history of periodontitis reported no association (Bain et al., 2002, Schou, 2008).

It is well established in the literature that patients with history of treated periodontal disease had an increased frequency of peri-implantitis, but this frequency can be reduced by following regular supportive periodontal care program. Additionally, the frequency of peri-implantitis is significantly high among smokers (36.3%) (Atieh et al., 2013).

2.4.7. Presence of keratinized tissue

Generally, having a wide band of attached keratinized tissue is considered beneficial for its role in maintaining healthy periodontium. That is achieved by providing physical barrier to oral biofilm, protecting periodontium from injury, dissipating masticatory forces (Miyasato et al., 1977) and preventing gingival recession (Agudio et al., 2009). It also facilitates home care and biofilm control in a somewhat painless environment (Esposito et al., 1998b).

Controversy in the literature exists regarding the effect of keratinized mucosa on peri-implant pocket depth, clinical attachment level and marginal bone loss. Multiple clinical trials have found a statistically significant relationship between absence of keratinized mucosa and peri-implant attachment, bone loss and gingival recession (Zigdon and Machtei, 2008, Kim et al., 2009). Schrott and colleagues (2009), reported higher gingival recession on buccal sites of keratinized mucosa < 2mm compared to sites with ≥ 2 mm. In contrast, other studies did not support these findings (Bengazi et al., 1996, Roos-Jansåker et al., 2006b, Chung et al., 2006). Various implant surface characteristics could be the cause of these differences (Adell et al., 1986, Wennström et al., 1994). It was found that smooth surface implants are not negatively affected by the lack of attached gingiva, while rough surface implants are and tend to accumulate more plaque and proinflammatory factors (Quirynen et al., 1993, Abrahamsson et al., 1996).

A possible influence on implant failure has been also discussed (Esposito et al., 1998a, Cochran et al., 2007). However, there seems to be consensus that no correlation between width of keratinized mucosa and implant failure exists. Although, presence of attached keratinized tissue might be beneficial to the patient in some situations (Esposito et al., 1998b).

2.4.8. Smoking habits

Bain and Moy (1993) were the first authors to evaluate the effect of smoking on implant survival and found a relationship between them. This relationship is supported in several prospective studies, including a review by Kasat and Ladda (2012). However, other studies have indicated that smoking and implant survival rate are not associated. (Esposito et al., 1998a, Esposito et al., 1998b, Lambert et al., 2000, Quirynen et al., 2001).

Smoking produces heat and many toxic by-products which includes; nicotine, carbon monoxide, and hydrogen cyanide that binds to the cells involved in wound healing. Nicotine may effect cellular protein synthesis and impair the gingival fibroblast ability to adhere and therefore delay wound healing and/or aggravate periodontal disease (Snyder et al., 2002). Additionally, it is a potent vasoconstrictor that decreases the blood flow and amount of nutrients delivered to the healing site after implant insertion that consequently results in ischemia and decreased blood cells proliferation (Levin et al., 2005). Also, it has a direct influence on increasing the susceptibility to local infections in the surgical site of an implant, through reducing macrophage proliferation that is involved in both specific and nonspecific immune responses during acute phase of cellular injury (Takamiya et al., 2014). On the other hand, carbon monoxide affects the red blood cells by reducing its oxygen carrying capacity, whereas hydrogen cyanide inhibits the enzyme systems responsible for metabolism oxidation resulting in hypoxia. In addition, it was found that high levels of reactive oxygen present in smokers is associated with bone resorption process (Pereira et al., 2008). That being said, these complications are associated with an increased risk of peri-implant bone loss and implant failures (Lindquist et al., 1996, Levin et al., 2005, Strietzel et al., 2007, Schwartz-Arad et al., 2002).

Additionally, several authors have agreed that smoking affects bone quality by decreasing the bone density (Bain and Moy, 1993, De Bruyn and Collaert, 1994). Therefore, it indirectly influences success rate by giving rise to poor quality bone, as observed in the study of Bezerra and co-workers (2016) where two implants placed in the posterior maxilla of smokers did not osseointegrate.

In regards to the smoking cessation protocol established by Bain (1996), the one week smoking cessation prior the implant placement surgery allows decreasing the levels of platelet adhesion and blood viscosity, as well as reversing the nicotine absorption short-term effects. However, continuing smoking cessation for eight weeks after the surgery is necessary to allow bone healing proceed the osteoblastic phase where early osseointegration have been established.

Moreover, in a recent in-vitro study by Yang and colleagues (2019), evaluating the effect of cigarette smoke extract (CSE) exposure on the changes in characteristics of titanium surface and osteoblast-titanium interactions. The CSE intended to mimic the oral liquid environment around the implant under cigarette smoke exposure. It has been observed that immersing titanium samples in CSE has changed the surface characteristic and elemental composition of titanium surface due to the adsorption of the carbon-containing compound thus influencing the osteoblast-titanium interactions. Therefore, the authors concluded that the main cause of smoking-mediated inhibition of osseointegration is because of the adsorbed carbon-containing compounds.

The effect of smoking dose has been evaluated in several studies. In a long-term study, it was found that peri-implant marginal bone loss is influenced by the dose of tobacco used (Lindquist et al., 1996). Similarly, in another study radiographically assessing 646 implants inserted in 161 patients, marginal bone loss was more in smokers than nonsmokers ($P < 0.001$). It was also observed that maxilla had greater marginal bone loss than in mandible ($P < 0.001$). Only 3 implants failed, so the cumulative survival rate was (99.5%) (Nitzan et al., 2005).

Schwartz-Arad and colleagues (2002) compared two groups of smokers who were divided based on number of cigarettes smoked per day (mild smoker ≤10/day; heavy smoker > 10/day) and the duration of smoking (mild smoker ≤10 years; heavy smoker > 10 years). It was concluded that there is a significant increase in complications in both groups compared to nonsmokers, and that the complication increases as the number of years smoking increases. Complications include cover screw exposure during early healing.

In a retrospective analysis looking at the association between duration of smoking and long-term implant survival, implant failure rate was 15% in current smokers, 9.6% in former smokers and 3.6% in nonsmokers. Similar to the previous study, it was found that a statistically significant association exists between the number of years smoking and increased risk of implant failure. The hazard ratio of implant failure increased from 1.5 for smokers who smoked <10 years to 5.36 for patients who smoked for >40 years (Mundt et al., 2006).

In another study by Sanchez-Perez and co-workers (2007) patients were divided into four categories (never smoked or quit at least 10 years' prior; light smoker <10/day; moderate smoker 10-20/day; heavy smoker >20/day). The risk of implant failure in smokers was 15.8% with an odds ratio of 13.1. The relative risk of implant failure in light or moderate smokers was 10.1% whereas in heavy smokers it was 30.8%.

Therefore, a thorough smoking history should be obtained when planning for an implant therapy and should include the current status of smoking, the duration and the past and current smoking intensities (Kasat and Ladda, 2012).

Giving to the available evidence that smoking reduces the success rate of dental surgical procedures, the operator should encourage smoker patients to cease smoking and emphasize on its ability of reducing implant complications. In high-risk patients, the dentist has to decide whether or not to perform the dental implant treatment, and if it was decided to be commenced, the patient's informed consent is essentially required (Kasat and Ladda, 2012)

In a prospective study investigating the early outcomes of Brånemark implants, patients were divided into three groups: nonsmokers, smokers who followed a smoking cessation protocol, and smokers who continued smoking. The cessation protocol was to cease smoking 1 week prior and 8 weeks after initial implant placement surgery. The author concluded that implant failure rates were significantly higher in the smokers who continued to smoke (38.46%) compared to the patients who followed the cessation protocol (11.76%) and nonsmokers (5.68%). No significant difference present between patients who quit smoking and nonsmokers. Therefore, it is recommended to follow smoking cessation protocol which can considerably improve success rate of implants osseointegration in smokers (Bain, 1996).

Besides smoking cessation in reducing post-operative and soft tissue complications, it can be beneficial to use peri-operative antibiotics (Gorman et al., 1994)as well as high cover screw rather than flat cover screw to eliminate local risk factors associated with it (Schwartz-Arad et al., 2002).

There are no other studies in the literature investigating the effect of smoking cessation and implant failure. However, a 1-year prospective study have assessed the adjunctive effect of smoking cessation in non-surgical periodontal therapy on patients with severe chronic periodontitis. The subjects were enrolled from a smoking cessation clinic, and have received periodontal maintenance every 3 months. It was concluded in a 1-year follow-up, that clinical attachment gain was improved significantly in patients who quit smoking. But further studies with longer observation period are required to establish the effect of smoking cessation on periodontal status (Rosa et al., 2011).

2.4.9. Bruxism

Prevalence of bruxism is common among general adult population. It is considered a risk factor for temporomandibular pain, tooth wear and implant failure.

The rationale for implant failure associated with bruxism is the occurrence of excessive occlusal overload on the implant and it's suprastructure, which can further lead to marginal bone loss and hence possibly implant failure. For this reason, bruxism is often considered a cause of concern or even a contraindication for implant therapy. Consequently, in the selection of participants in many clinical studies concerned with implant therapy, researchers tend to exclude patients with bruxism (Lobbezoo et al., 2006).

Manor and colleagues (2009) found no association between bruxism and late implant failure. In contrast, Chrcanovic and his colleagues (2016a) evaluated late failure rates in bruxer and non-bruxer patients, (13%) and (4.6%), respectively ($P < 0.001$). They concluded that bruxism was a significant risk factor for late failure.

Recently, a meta-analysis was performed to evaluate the effect of bruxism on implant failure. It was found that prostheses in bruxers had higher failure rate than non-bruxer patients. This suggests that bruxism is a risk factor for both technical and biological complications of implant and plays a role in implant failure (Zhou et al., 2016) On the contrary, in another more recent systematic-review, no definitive conclusion could be established on whether bruxism is significant risk factor for implant failure (Do et al., 2020).

In order to reduce the risk of implant failure associated with bruxism, studies have recommended to insert more implants than necessary in full mouth rehabilitation of bruxer patients to obtain favorable biomechanics (Narita et al., 2009, Sarmento et al., 2012). The reduction of forces received on each implant individually when number of implants increase justifies this recommendation (Lindquist et al., 1988).

Moreover, a number of authors reported that hard occlusal stabilization devices are effective in minimizing the damage caused by parafunction on the oral tissues, clinical results have shown no differences compared to other types of devices (Türp et al., 2004). Soft splints are the only exception because it is indicated that soft splints can increase muscular activity in some bruxer patients (Okeson, 1987).

2.4.10. History of previous implant failure

An implant- and site-related factor that has not been thoroughly explored in the literature is the failure rate of implants inserted in sites of previously failed implants. Such failure rate varies across different studies. Overall, success rates of implant retreatment were relatively higher in later studies (93% to 95%) (Mardinger et al., 2012, Wang et al., 2015) than in earlier studies (71% to 84%) (Alsaadi et al., 2006, Grossmann and Levin, 2007, Machtei et al., 2008). In one report (Mardinger et al., 2012), the survival rate was 93% but reduced to 85% in cases that received a third implant placement. In contrast, a systematic review (Quaranta et al., 2014) demonstrated low survival rates of implants inserted in sites of previously failed implants. In a more recent systematic review (Gomes et al., 2018), the authors concluded that the survival rate of implants inserted in sites of previously failed implants cannot be precisely estimated due to the limited number of patients. Hence, more studies are required to explore this factor and its association with overall implant failure rate.

It has been observed that alveolar bone loss is more severe following late failure rather than early failure (Alsaadi et al., 2008b). Therefore, suggesting that the timing of implant failure may affect the survival of retreated implants. Interestingly, it was reported in two studies that late implant failure occurred in retreated patients with at least one initial early failed implant. Therefore, a strong correlation exists between initial early implant failure and second late implant failure. However, no statistical analysis was performed (Koldsland et al., 2009, Jemt et al., 2017).

2.4.11. Peri-implant maintenance

Post-surgery follow-up for maintenance sessions and compliance is critical to prevent late implant failure and ensure better outcomes. Studies have reported that most patients receiving implants, report signs of mucosa inflammation before failure occurs. If such symptoms are observed at the implant site during the first year, it can significantly increase the risk of late implant failure (Do et al., 2020). Similarly, a meta-analysis reported that supportive peri-implant care can reduce the incidence of peri-implant disease from (14.3% to 18.8%) (Atieh et al., 2013).

Costa and co-workers (2012), found of peri-implantitis occurrence to be significantly associated to the lack of peri-implant maintenance therapy. This is supported in a recent meta-analysis, that reported the median prevalence of peri-implantitis in patients who did attend regular peri-implant maintenance sessions and those who did not, it was (9.0%) and (18.8%), respectively (Dreyer et al., 2018).

A significant association exists between implant survival and regular strict supportive periodontal programs (Anner et al., 2010). In Roccuzzo and his colleagues (2018) recent meta-analysis, the implementation of peri-implant supportive care in patients with peri-implantitis helped implants to prevent implant failure, with a 7-year survival rates approximately (70%). Nonetheless, compliance is also important to avoid peri-implant disease. This was observed in healthy patients who attended 2 or more peri-implant maintenance treatment sessions annually (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). In another study, the incidence of implant failure has decreased for patients regularly attending peri-implant maintenance sessions (90%) and in patients who attended with less than 1-year maintenance sessions (60%) (Gay et al., 2016). However, it has been reported that patients who are smokers or have history of periodontitis, are unlikely to comply with peri-implant maintenance sessions (Monje et al., 2017b, Hu et al., 2017).

Fox and colleagues (1990), discussed professional peri-implant care, they observed that corrosion and increase in implant surface roughness could be effected with the use of titanium-alloy scalers and stainless-steel scalers to even a higher extent, while plastic scalers resulted in the least damage, therefore making it the instrument of choice for routine maintenance therapies, despite their weaker efficiency in plaque and calculus removal (Meschenmoser et al., 1996). Moreover, sonic and ultrasonic scalers seemed to be more destructive to the implant surface than metal scalers. Air powder abrasion as well showed minor implant surface alterations. However, polishing with a rubber cup which demonstrated minimal harmful effect. (Thomson-Neal et al., 1989). Nevertheless, subgingival debridement with the use of chlorhexidine showed uncertain outcomes in treating peri-implant mucositis (Thöne-Mühling et al., 2010).

Moreover, in a recent systematic review about homecare device, different types of toothbrushes were evaluated and did not have different effect on reducing gingival inflammation and plaque accumulation (Rösing et al., 2019).

2.5. Implant- and site-related factors

2.5.1. Implant location

Evidence available in the literature have demonstrated that posterior maxilla tends to be the most prevalent area for implant failure due to poor bone quality (Attard and Zarb, 2003, Pabst et al., 2015). As well, it was reported that implants located in the maxilla are at 3-folds higher failure rate (Esposito et al., 1998a). Poor bone quality has been considered a risk factor for early implant failure in some studies (Van Steenberghe et al., 2002, Noguerol et al., 2006, Alsaadi et al., 2007).

When comparing implants inserted in edentulous sites versus adjacent to natural dentition, it has been reported that failure rates were similar in both maxilla and mandible for the partially edentulous jaw, whereas in edentulous maxilla, the failure rate was 3-folds higher (Esposito et al., 1998a).

More specifically, in regards to location association with early implant failure different results are available in the literature. In a 5-year retrospective study involving 276 implants with external connection placed in 142 patients, no difference was found between early failures in maxilla and mandible (Olmedo-Gaya et al., 2016). In agreement with these findings, Alsaadi and colleagues (Alsaadi et al., 2007) initially reported higher failure rates in posterior mandible and maxilla than anterior mandible, but after one year found no association between location and early implant failure (Alsaadi et al., 2008b). Consistent with the findings of a recent meta-analysis, the odds ratio for early implant failure was unfavorable for implants placed in the maxilla (Manzano et al., 2016). However, in a recent retrospective analysis, the mandibular region posed a higher risk for early implant failure (Kang et al., 2019).

Likewise, in late implant failure several controversial reports were documented. Several authors agreed that an implant placed in the maxilla had significantly greater risk of late failure than those placed in the mandible. Alsaadi and colleagues (2008a), reporting (HR = 2.59, $P < 0.001$) while Noda and colleagues (2015), reporting (HR = 4.19, $P = 0.02$). In contrast, other studies found that implants placed in the mandible significantly increases late faillure rate (Jemt, 2017), HR = 2.03 ($P < 0.05$) (Jemt et al., 2017). While various other studies found that no significant difference between maxilla or mandible can influence late failure (Dvorak et al., 2011, Strietzel et al., 2011, Doll et al., 2015).

Considering late implant failure in either anterior or posterior regions, several studies investigate this factor and found the posterior region a greater risk for late failure than the anterior region (Alsaadi et al., 2008a, Manor et al., 2009, Noda et al., 2015). Moreover, in two other studies, the authors failed to find a significant association between them (Dvorak et al., 2011, Strietzel et al., 2011) However, Alsaadi (2007, 2008b) observed a significant failure increase in implants inserted in the jaw adjacent to natural teeth versus edentulous area.

2.5.2. Implant system and surface characteristics

Karoussis and co-workers (2004), prospectively assessed the success rate and incidence of peri-implantitis in hollow screw and cylindrical designed ITI implants after 10 years of service. The success rate was (95.4% vs. 85.7%) and incidence of peri-implantitis was (10% vs. 29%).

The association between different implant designs and implant surface characteristics and peri-implant disease have been reviewed in various studies, where no association was found (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). Zetterqvist and co-workers (2010), discussed that in order to maintain esthetics through preserving marginal bone and a stable soft tissue, it is necessary to use an implant with roughened surface at the collar.

It has been suggested that implant surface treatment is not significantly associated with late implant failure (Alsaadi et al., 2008a, Dvorak et al., 2011, Strietzel et al., 2011). However, machined (Alsaadi et al., 2008a) and moderate rough implant surfaces (Dvorak et al., 2011) showed a tendency for late failure. On the contrary, Kermalli and colleagues (2014), reported significantly higher late failure in press-fit implant design with sintered porous surface than in threaded implant design with a sandblasted-acid-etched surface.

Additionally, it was observed that early failure rates can be reduced dramatically (from 17.2% to 3.8%) when moderately rough surface implants are used ($P < 0.5$) (Jemt et al., 2016).

Furthermore, a recent meta-analysis reported that moderately rough and rough implant surfaces are at a significantly increased risk of peri-implantitis than machined surface implants. But they did conclude that the impact of surface roughness is of minimal clinical relevance (Doornewaard et al., 2017) This is consistent with previous reviews that have shown greater tendency for marginal bone loss and implant failure around rough surface implants (Quirynen et al., 2007, Esposito et al., 2007).

Moreover, Bain and colleagues (2002) reviewed the success rates of different implant surface roughness in smokers. Clinically significant difference was observed between smooth surface implants (93.5%) and rough surface implants (98.7%). However, among for the rough surface implants, no difference in success rates between smokers and nonsmokers was found. This is consistent with the findings of Balshe and colleagues (2008), where long-term survival of 2,182 smooth-surface implants placed in 593 patients and 2,425 rough-surface implants placed in 905 patients were evaluated. And it was observed that smoking is significantly associated with implant failure in smooth-surface implants ($P < 0.001$) but not significantly with rough-surface implants ($P = 0.86$). In particular, implant anatomic location is significantly associated with implant failure among smokers with smooth-surface implants ($P = 0.004$), but not patients with rough-surface implants ($P = 0.45$) or nonsmokers with smooth-surface implants ($P = 0.17$).

2.5.3. Implant height and diameter

It is well known that implant height has less effect on dispersing occlusal loads than an implant diameter does (Guan et al., 2009). Similarly, there are studies that found no association between implant height and late implant failure (Alsaadi et al., 2008a, Vercruyssen et al., 2010, Noda et al., 2015). A definition of short implant can differ in different studies depending on the author. Strietzel and Reichart (2007), defined it as ≤ 11 mm, while other authors considered < 10 mm (Mezzomo et al., 2014, Telleman et al., 2014) and < 8 mm (Fan et al., 2017). Other authors also defined an implant as extra-short when the height was ≤ 6.5 mm (Anitua et al., 2014, Ravidà et al., 2019).

Additionally, short implants (< 8mm) appear to have predictable outcomes as those of standard height implants inserted in sites of augmented bone. A short implant will simplify surgical procedure by reducing the degree of invasion into surrounding anatomical structures and the need for regenerative procedures (Thoma et al., 2017). Moreover, in a study of immediately loaded implants, short implants were significantly associated with late implant failure (P = 0.029) (Strietzel et al., 2011).

Considering implant diameter, numerous studies have shown that narrow and wider diameter implants have equivalent survival rates (Klein et al., 2014). Equally, other studies did show no association between implant diameter and late implant failure (Strietzel et al., 2011, Noda et al., 2015, Jemt, 2017). While Alsaadi and colleagues, found that wide implants (5 mm) had significantly higher rate of late implant failure compared to regular (4 mm) and narrow (≤ 3.75 mm) implants (Alsaadi et al., 2008a). Also, Renouard and Nisand (2006), supported this finding and demonstrated that wide diameter implants are at an increased risk of implant failure, and that can be attributed to several reasons which might include; inferior surgical skills, inferior implant design, inadequate site preparation and poor bone quality. Another reason could be because primary stability of standard diameter implants cannot be achieved.

Moreover, in a retrospective to determine the influence of implant height ranging from 6 to 16 mm and diameter ranging from 3.25 to 6 mm on implant success. It was reported that no significant association between implant dimensions and higher failure. Other published data outcomes were in agreement to this finding (Arlin, 2006, Annibali et al., 2012, Omran et al., 2015, Lemos et al., 2016b).

2.5.4. Use of grafting materials

The effect of bone grafting on increasing the risk of implant failure in the literature is still controversial. According to a recent meta-analysis, this can be correlated to the bone remodeling and resorption involved in bone grafting procedures, which can result in significant late graft resorption, therefore, compromising the peri-implant bone of osseointegrated implant and lead to implant dehiscence, peri-implant disease, and late implant failure. The extent of resorption can be affected by several factors, this includes; alveolar defect configuration, patient factors, and technique and grafting materials chosen (Elnayef et al., 2018). Yet, another study found other factors such as age, osteoporosis, uncontrolled diabetes and use of certain medications to correlate with delayed or poor graft healing after bone augmentation(Granate-Marques et al., 2019)

Additionally, no evidence in the literature was found about having higher complications and failure rate when bone augmentation procedures such as; guided bone regeneration and sinus lifts were performed in well and moderately controlled diabetic patients (Naujokat et al., 2016). Moreover, it has been reported that sinus augmentation does not affect early implant failure, but because of the complications that arise during surgery, early implant failure might increase (Huynh-Ba et al., 2008). However, a 2.5-fold higher failure risk with sinus augmentation, bone expansion and graft treatment was described in a retrospective cohort study of 5787 implants (Anitua and Orive, 2010).

In regards to late implant failure, several studies found bone augmentation was not a significant risk factor (Arbes et al., 1999, Bornstein et al., 2008, Bornstein et al., 2009).

Moreover, it was found that bone augmentation is likely to increase the success rate of an implant. Another protective effect demonstrated is the significant reduction of peri-implantitis and the higher survival rate. (Bornstein et al., 2009).

2.6. Prosthetic-related factors

The term complication distinctly differs from failure. Complications indicate an increased risk for failure, but are either of temporary impact or can be treated (Esposito et al., 1998a). The literature has documented several complications that can occur after implant loading and might lead to implant failure. They can be divided into two main categories; biological and technical complications. Biological complications are those that involve pathology of the surrounding peri-implant soft tissue and bone. While technical complications are those associated with implant mechanics or prosthesis as a result of the material's strength inability to longer withstand applied forces (Ravidà et al., 2018). Esthetic and phonetic complications also exists (Pjetursson et al., 2004).

Pjetursson and colleagues (2012) observed overall (66.4%) of implant success without complications. It was concluded that technical complications were more likely to happen. That being said so, veneer fractures accounted for (13.5%), peri-implantitis (8.5%), abutment screw loosening (5.3%) and cement failure (4.7%).

In a systematic review reporting on the incidence of implant complications, it was observed that implant failure was most frequently described in about (100%) of the studies, while biological and technical complications were not considered in most studies, (40-60%) and (60-80%), respectively. Therefore, indicating that the incidence of complications may be underestimated and should be interpreted with caution (Berglundh et al., 2002).

2.6.1. Biological complications

Late implant failures are mainly associated with biological complications, namely peri-implant diseases (Zandim-Barcelos et al., 2019). Peri-implant diseases are inflammatory conditions of soft and hard tissues. While peri-implant mucositis is the reversible inflammation of soft tissues without bone loss, peri-implantitis is a pathological plaque-associated inflammatory response that involves both soft and hard tissues surrounding a functional osseointegrated implant. Diagnosis of peri-implantitis is detected through clinical signs that includes mucosa swelling and redness, presence of bleeding and/or suppuration on gentle probing, probing pocket depths of ≥ 6 mm and the radiographic bone loss of ≥3 mm apical to the most coronal portion of the intraosseous part of the implant (Quirynen et al., 1991, Berglundh et al., 2018).

The prevalence of biological complications and implant failures for implants inserted in pristine sites and augmented sites with at least 10-years observation period have been assessed in a recent meta-analysis by Salvi and his colleagues (2018) They reported prevalence of peri-implant mucositis (21.2% and 24.6%) and peri-implantitis (7.5% and 6.5%) in pristine and augmented sites, respectively. While failure rates were (2.4%) in pristine sites and (6.5%) in augmented sites. Therefore, demonstrating no significant difference between pristine and augmented sites.

Cement-retained implant prostheses are frequently used for its simplicity, passive fit, easy adjustment of occlusion, and cheaper cost compared to screw-retained implant prosthesis (Wilson, 2009). However, in the case of retained residual excess cement at the time of cementation, the health of the implant and peri-implant soft and hard tissues can become compromised, since these remnants of cement may advocate marginal bone loss and peri-implant disease (Renvert and Quirynen, 2015, Atieh et al., 2019).

Moreover, the difference between annual rate of peri-implantitis in cement- and screw-retained fixed complete implant prostheses was analyzed in a recent retrospective cohort study (Papaspyridakos et al., 2019). It was found to be (1.5%) for cement-retained group and (2.5%) for screw-retained group with no significant difference observed. However, the cement-retained group has a 4.6 times higher risk of peri-mucositis (Papaspyridakos et al., 2019). Other studies have also evaluated the biological complications associated with implant survival rate in cement- and screw-retained implant prosthesis, no significant difference was found and it was observed that cement-retained developed more biological and technical complications (Sherif et al., 2014, Wittneben et al., 2014).

2.6.2. Technical complications

The technical complications associated with an implant prosthesis are cement debonding, veneer chipping/fracture and framework fracture. While the ones associated with the implant suprastructure are abutment loosening, abutment fracture, implant fracture and loss of implant suprastructure. All of which can be classified as minor, medium and major complications (Pjetursson et al., 2004).

Technical complications were also estimated in a recent 12-year retrospective study. It reported veneer chipping to be the most frequent minor complication with an estimated 5-year rate of (49.0%), while the most frequent major complication was veneer fracture with an estimated 5-year (9.5%). It was observed that in the presence of bruxism and absence of occlusal appliance, these complications are at an increased risk of occurrence. It was concluded that cumulative rates of prosthesis that are free of major technical complications at 5- and 10-years were (85%) and (30.1%), respectively (Papaspyridakos et al., 2020). Additionally, implant fracture was reported to range between (0.0% and 7.5%) of implants overall (Sánchez-Pérez et al., 2010).

2.7. Operator-related factors

Despite this being considered as a risk factor in various studies investigating risk factors of implant failure, there is a lack of information about it, with only brief discussion on this topic.

2.7.1. Operator experience

In a retrospective study assessing implant survival rates based on an operator's experience at a clinical training center, no association was found (Minsk et al., 1996). Meanwhile, the learning curve of an operator was associated with a 2-fold higher risk of early implant failure when the operator has placed fewer than 50 implants versus those who place more than 50 implants (Lambert et al., 1997).

Additionally, it has been suggested that well-developed operator surgical skills can increase survival rate of implants, irrelative of implant height or diameter when inserted in location of good bone density (Renouard and Nisand, 2006).

2.7.2. Surgical technique and protocol

Some of the surgical errors that may arise when inserting an implant due to lack of operator's experience, is underpreparing the implant site, which will further lead to surgically overheating the bone, thus causing bone necrosis if temperature exceeds 47°C which is the critical threshold of greater than is reached by the surgical drills or dental implant (Esposito et al., 1998a) Another issue that can also occur during surgery, is contamination of the surgical site or contamination of the implant surface during fixture placement and thus might lead to no osseointegration and implant failure.

2.7.3. Prosthetic technique and protocol

Whereas, having uncleaned excess cement in the cement-retained prosthesis can lead to the biological complications mentioned above, and possibly implant failure (Chee et al., 2013). Additionally, heavy occlusion on prosthesis can lead to implant overloading which is found to be a risk factor associated with late implant failure (van Steenberghe et al., 1990, Manor et al., 2009, Sakka et al., 2012). Moreover, in a longitudinal retrospective study by Noda and colleagues (2015) the design of prosthesis in fully edentulous patients was in favor of implant-supported overdenture over implant-fixed prosthesis since it provides easier maintenance.

3. AIM

The aim of this study is to identify prevalence and risk factors associated with early and late implant failures.

3.1. Specific objectives

- To evaluate the prevalence of early implant failure
- To evaluate the prevalence of late implant failure
- To identify systemic- and patient-related factors that had an impact on the early implant failure
- To identify implant-, site-, prosthetic- and surgical-related factors that had an impact on late implant failure
- To establish a logistic regression model to assess potential predictors related to implant failures

3.2. Research question

Are there any potential associations of systemic-, patient-, implant-, site- and surgical-related factors with risk for implant failure?

4. MATERIALS AND METHODS

4.1. Study design and participants

This is a retrospective study which included patients aged ≥18 years who presented with at least one failed implant at DHA between 2010 and 2019. All the patients had periodontal and radiographic assessment prior to dental implant placement. The patient records at DHA include demographic data, medical and dental history as well as number of follow-up and maintenance visits.

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-2020-011) (Appendix 1) and DHA (USREC06-19/PG/2020) (Appendix 2) in accordance with the Declaration of Helsinki of ethical human research practice.

4.3. Data collection

Data were collected by the principal investigator (F.A.) using dental practice management software (D4W, Australia), Salama software and explanted implant records available at DHA. A data collection form (Appendix 3) was used to collect relevant information. The data were collated into four main domains:

1. Demographic data
2. Systemic and patient-related outcomes
3. Implant-, site-, and surgical 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-, site-, and surgical-related factors, such as implant system, location, surface roughness, height, diameter, shape, placement protocol; prosthesis-related factors such as type of retention were also collected and analyzed as possible risk factors for peri-implantitis.

Systemic- and patient-related factors

- Gender
- Cardiovascular disease
- Diabetes Mellitus
- Osteoporosis
- Hypothyroidism
- Use of antidepressants
- Use of vitamin supplements
- History of radiotherapy
- Smoking habits
- History of treated periodontal disease
- History of regular dental attendance (defined as at least one dental check-up per year)
- History of previous implant failure

Implant- and site-related factors

- Implant surface characteristics
- Implant shape
- Implant height
- Implant diameter
- Implant location
- Implant placement protocol
- Implant surgical protocol

- Use of grafting material at the time of implant placement
- Operator

4.4. Case definition

In this study, implant failure is considered a biological failure in which the implant has to be removed either due to failure to establish osseointegration (i.e. early implant failure) or maintain an established osseointegration (i.e. late implant failure). Early and late implant failures are also known as primary where an implant failure is removed before loading and secondary where implants are removed after loading (Esposito et al., 1998a).

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, an intra-examiner reliability test was performed by selecting five files form pool of retrieved patient files. Data were collected by the principal investigator (F.A.) with two weeks apart and cross-checked by an experienced clinician (M.A.) The strength of intra-examiner reliability was 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. Statistical analyses

Data were analyzed using the Statistical Package for Social Sciences (SPSS) Version 27. The strength of association between the frequency of early and late implant failure 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 failed implant per patient was included in the analysis to enhance statistical accuracy (Herrmann et al., 1999). For implant- and site-related factors, the implant was considered as the statistical unit.

Risk factors for early and late implant failure were estimated by a binary logistic regression, which is the appropriate model for a categorical dichotomous outcome (early implant failure was coded 0 while late implant failure was coded 1). 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 830 implants failed out of 14191 placed implants. Of which, 721 implants failed before loading (5.1%) and 109 implants failed after loading (0.8%). Only 645 patients with reported 721 early and 109 late failed implants between 2010 and 2019 were included in the analysis. The age of the patients ranged between 18 and 85 with mean age of 47.11 ± 14.66 at the time of implant placement. In late implant failure group, almost one third of the implants failed in the first two years of function. Biological and technical complications accounted for (59.3%) and (40.7%) of late implant failures, respectively. More than half of late failed implants (59.3%) were single implant and (57.0%) were screw-retained prostheses. There were relatively more reports of late implant failures reported between 2015 and 2019 (68.6%) compared to reports of early failed implants during the same period (49.9%).

5.1. Systemic- and patient-related factors

Females lost more implants before loading than males (88.0% *vs*. 84.9%) but the difference was not statistically significant. No significant differences were observed between implant failure and presence of systemic conditions (such as cardiovascular disease, diabetes mellitus, osteoporosis, hypothyroidism), smoking, history of radiotherapy, use of antidepressants or vitamin supplement. There were significant associations between implant failure and histories of treated periodontitis, previous implant failure and irregular dental attendance. A total of 60 (9.3%) patients with history of previous implant failure and 99 (15.3%) patients with history of treated periodontitis had reported an early implant failure. More incidents of early implant failures were reported in 310 (48.0%) irregular dental attendants. The systemic- and patient-related factors are summarized in (Table 1).

Table 1 Characteristics of patients diagnosed with early and late implant failure (n = 645)

Systemic and patient-related factors:	N (%) EIF	N (%) LIF	EIF Relative risk (95% CI)*	*P* value†
Gender				
Male	241 (84.9)	43 (15.1)	0.97 (0.91, 1.03)	0.25
Female	314 (88.0)	43 (12.0)		
Presence of cardiovascular disease				
Yes	35 (89.7)	4 (10.3)	0.96 (0.86, 1.10)	0.56
No	513 (86.5)	80 (13.5)		
Presence of diabetes mellitus				
Yes	112 (83.6)	22 (16.4)	1.05 (0.97, 1.14)	0.23
No	436 (87.6)	62 (12.4)		
Presence of osteoporosis				
Yes	5 (83.3)	1 (16.7)	1.04 (0.73, 1.49)	0.81
No	543 (86.7)	83 (13.3)		
Presence of hypothyroidism				
Yes	25 (83.3)	5 (16.7)	1.04 (0.89, 1.23)	0.58
No	523 (86.9)	79 (13.1)		
Use of antidepressants				
Yes	7 (70.0)	3 (30.0)	1.24 (0.83, 1.87)	0.12
No	541 (87.0)	81 (13.0)		

Use of vitamin supplements				
Yes	37 (88.1)	5 (11.9)	0.99 (0.88, 1.12)	0.80
No	511 (86.8)	78 (13.2)		
History of radiotherapy				
Yes	3 (60.0)	2 (40.0)	1.45 (0.71, 2.97)	0.08
No	545 (86.9)	82 (13.1)		
Smoking habits				
Smokers	60 (84.5)	11 (15.5)	1.03 (0.93, 1.14)	0.57
Non-smokers	440 (87.0)	66 (13.0)		
History of treated periodontitis				
Yes	99 (75.6)	32 (24.4)	1.19 (1.07, 1.32)	< 0.0001
No	441 (89.8)	50 (10.2)		
History of regular dental attendance**				
Yes	239 (82.7)	50 (17.3)	1.09 (1.02, 1.16)	0.006
No	310 (90.1)	34 (9.9)		
History of implant failure				
Yes	60 (71.4)	24 (28.6)	1.25 (1.09, 1.43)	< 0.0001
No	467 (89.1)	57 (10.9)		

EIF: early implant failure; LIF: late implant failure; CI: confidence interval
*Computed only for 2x2 tables
**Regular attendance of general dental practioner and dental hygienist or periodontist at least twice annually
†Chi-square test

5.2. Implant- and site-related factors

Rough-surface implants were associated with more early implant failures than moderately rough-surface implants (666 *vs*. 47; p = 0.24). More early implant failures were also reported amongst implants which were cylindrical, had a height of less than 11 mm and a diameter of 3.5 mm or less, but the difference was not statistically significant. Implant location had a significant impact on implant failure with more early and late implant failures reported in the posterior region compared with the anterior region in both arches. However, the use of grafting materials, implant placement and surgical protocols did not have any significant influence on the number of early or late failed implants. In terms of the operator, the differences in early and late implant failures were not significant. Nevertheless, implants were more likely to fail before loading when placed by oral and maxillofacial surgeons than periodontists (437 *vs*. 281; p = 0.08). The implant- and site-related factors are summarized in (Table 2).

Table 2 Characteristics of implants diagnosed with early and late implant failure (n = 830)

Implant-, site-, and surgical-related outcomes	N (%) EIF	N (%) LIF	EIF Relative risk (95% CI)*	*P* value†
Implant surface characteristics				
Moderately rough (Astra Tech, Neoss)	47 (92.2)	4 (7.8)	1.07 (0.98, 1.16)	0.24
Rough (Ankylos, Friadent, Xive)	666 (86.4)	105 (13.6)		
Implant shape				
Cylindrical	513 (88.1)	69 (11.9)	1.06 (0.99, 1.13)	0.06
Tapered	199 (83.3)	40 (16.7)		

Implant height (mm)				
< 11	362 (87.9)	50 (12.1)	1.02 (0.97, 1.08)	0.38
≥ 11	357 (85.8)	59 (14.2)		
Implant diameter (mm)				
≤ 3.5	498 (88.0)	68 (12.0)	1.04 (0.98, 1.11)	
> 3.5	221 (84.4)	41 (15.6)		0.15
Implant location				
Anterior maxilla	82 (73.9)	29 (26.1)	NA	< 0.0001
Posterior maxilla	263 (88.6)	34 (11.4)		
Anterior mandible	58 (93.5)	4 (6.5)		
Posterior mandible	312 (88.6)	40 (11.4)		
Implant placement protocol**				
Type I	68 (89.5)	8 (10.5)	NA	0.54
Type II	24 (92.3)	2 (7.7)		
Type III	41 (91.1)	4 (8.9)		
Type IV	534 (86.1)	86 (13.9)		
Implant surgical protocol				
One-stage	252 (87.8)	35 (12.2)	0.99 (0.94, 1.05)	0.72
Two-stage	412 (86.9)	62 (13.1)		
Bone augmentation procedure at the time of implant placement				
Yes	181 (84.6)	33 (15.4)	1.04 (0.97, 1.11)	0.22
No	487 (87.9)	67 (12.1)		

Operator				
Periodontist	281 (84.4)	52 (15.6)	1.05 (0.99, 1.11)	0.08
Oral and maxillofacial surgeon	437 (88.5)	57 (11.5)		

EIF: early implant failure; LIF: late implant failure; CI: confidence interval
*Computed only for 2x2 tables
**(Hämmerle et al., 2004)
†Chi-square test

The binary logistic regression showed that histories of treated periodontitis and implant failure reached statistical significance in the final model. The two 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 those with history of treated periodontitis were 2.6 times at risk of early implant failure, while those with history of previous implant failure were 2.9 times at risk of implant failure. The overall accuracy of the model to predict early implant failure (with predicted probability of 0.5 or greater) is (87.0%). The estimates of the logistic regression model, the adjusted odds ratios for the two risk factors and their 95% Cis are summarized in (Table 3).

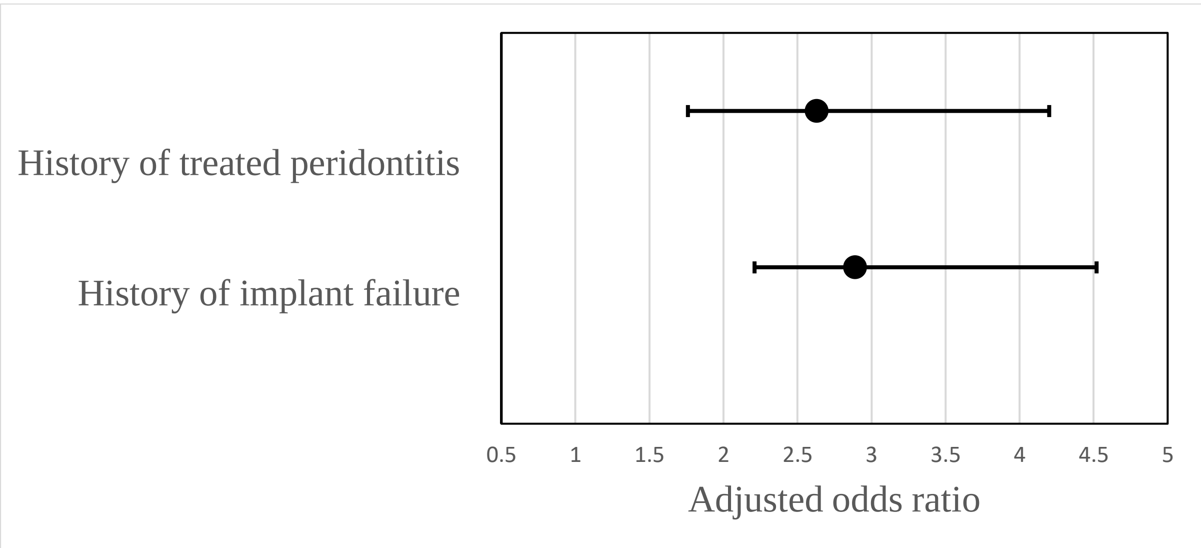

Figure 1 Adjusted odds ratios and 95% confidence intervals for the independent risk factors

Table 3 Results of logistic regression analysis

Predictor variable	Early implant failure		
	B coefficient (SE)	*P* value	Odds ratio (95% CI)
History of treated periodontitis (Yes = 0, No = 1)	0.97	< 0.0001	2.63 (1.57, 4.39)
History of implant failure (Yes = 0, No = 1)	1.06	< 0.0001	2.89 (1.63, 5.10)
Model Chi-square = 201.07; df = 1; *P* < 0.0001			

6. DISCUSSION

The present 10-year retrospective study assessed the prevalence and risk factors for early and late implant failures amongst group of patients that received implants in DHA. The study identified two risk factors for early implant failure; history of treated periodontitis and previous implant failure.

6.1. Prevalence of early implant failure

Several retrospective studies have investigated patient-related factors (Van Steenberghe et al., 2002, Costa-Junior et al., 2013, Brügger et al., 2015, Derks et al., 2015, Chrcanovic et al., 2016b, Chrcanovic et al., 2017a, Chrcanovic et al., 2017b, Grisar et al., 2017, Antoun et al., 2017), and implant-related factors (Olate et al., 2010, Pommer et al., 2011, Derks et al., 2015, Grisar et al., 2017, Antoun et al., 2017) to identify potential risk factors for early implant failure. The variability in the reported findings amongst those studies is mostly related to the use of various implant systems with different designs.

Nevertheless, low implant failure rates (Nixon et al., 2009, Al-Nawas et al., 2012) has been generally reported in the literature and some have showed that early implant failures are more prevalent than late ones (Friberg and Jemt, 2015, Jemt et al., 2015). The results of the present study are in agreement with the previous reports, where early failure rate of (5.1%) is within the reported range (1.3%–6.36%) (Roos-Jansåker et al., 2006a, Derks et al., 2015, Chrcanovic et al., 2016b, Labriaga et al., 2017).

6.2. Prevalence of late implant failure

Late failure rates were comparably lower than early failures in this study, with only 109 late failed implants observed. Biological complications accounted for more than half of these failures. In a recent meta-analysis including 57 studies, peri-implantitis prevalence at implant level ranged between (1.1% to 85.0%) (Dreyer et al., 2018). However, it is suggested that presence of inflammation at implant site during the first year significantly increases the risk of late failure (Jemt et al., 2017). Late implant failure can also be attributed to excess stress created at the implant-bone interface which can lead to marginal bone loss (Misch, 1996, Crupi et al., 2004, Misch et al., 2005). A combined occurrence of occlusal overload and infectious etiologies is possible, thus giving rise to a mixed etiology (Esposito et al., 1998b) and it is suggested that this can be the main reason for late failures (Newman and Flemmig, 1988).

In the present study, 59.3% of the implant-supported prostheses that failed were single implant crowns. This is in agreement with the findings of the study by Kim and co-workers (2010) who reported that single implant crown (18%) was the most common type of failed implant prostheses. However, Mardinger and co-workers (2012) reported that late implant failures were more common amongst implant-supported fixed prostheses (61%). Yet, both studies concluded that implant-retained fixed prostheses had higher failure rates than implant-retained removable prostheses (Kim et al., 2010, Mardinger et al., 2012). The authors speculate that it can be related to that patients presenting with missing single teeth tend to restore it with dental implant rather than other prostheses such as fixed bridge or removable partial denture.

In a systematic review comparing survival and success of screw- *versus* cement-retained implant supported crowns, the cement-retained group had a higher failure rate, but no significant difference exists (Sherif et al., 2014). On the contrary, the results of the present study revealed that 57.0% of the late failures were screw-retained prostheses. Despite no consensus being established on which retention system improves clinical success and reduces peri-implant mucositis and peri-implantitis, several studies, including a recent meta-analysis, concluded that the choice of retention system is mainly influenced by the clinician’s personal preference (Lee et al., 2010, Wittneben et al., 2014, Lemos et al., 2016a). The choice of screw-retained prostheses in this study is partly related to the preference of experienced and trained clinicians who tend to use screw- rather than cement-retained prostheses to facilitate maintenance and reduce biological complications.

Moreover, the present study reported higher incidence of late failures in the second half of the observational period than the first half but the difference was not significant. One could assume that a higher prevalence of late implant failure can be expected in the future since implants treatment services were only introduced in DHA in late 2008.

6.3. Systemic- and patient-related factors

The variables in this section were analyzed at patient level. There was no association between patient's gender and implant failures. Similarly, previous studies evaluating risk factors for implant failures did not find a significant association with gender in either early failures (Mohajerani et al., 2017, Mayta-Tovalino et al., 2019) or late failures (Manor et al., 2009, Noda et al., 2015, Doll et al., 2015). However, Manor et al. (2009) reported that late failures were more common in males than females.

With regard to patient lifestyle and habits, smoking has always been considered a primary risk factor for early implant failure because osseointegration is affected by insufficient bone healing as a result of compromised blood circulation (Kasat and Ladda, 2012, Chen et al., 2013, Chrcanovic et al., 2016b, Grisar et al., 2017). On the contrary, the association between smoking and implant failure was not observed in other studies (Zupnik et al., 2011, Borba et al., 2017, Krisam et al., 2019). In the present study, early implant failure was not associated with smoking when compared to late implant failure. This, however, does not preclude the deleterious effects of smoking on early healing and osseointegration. The insufficient number of smokers included in this study and the lack of assessment of frequency of smoking might have reduced the power to detect any association between smoking and implant failures.

The collected and analyzed data on several systemic conditions showed no significant association between implant failure and any systemic condition. This could be partly related to the small number of patients with systemic conditions and self-reported medical history obtained at consultation. Self-reporting can be considered as a limitation since it may not include all the necessary details (Anitua and Orive, 2010).

Despite that diabetes is a metabolic condition that affects wound healing, diabetes was not associated with implant failure in this study. This might be related to patients' compliance with anti-diabetic medication (Balshi and Wolfinger, 1999) which they usually receive in the DHA diabetes center. Additionally, the dental department in DHA has set a strict protocol where dental implants are only placed in diabetic patients with controlled glycemic levels. Furthermore, a recent systematic review and meta-analysis showed that diabetes is not a significant risk factor for implant failure (Chen et al., 2013).

Several studies have also found that osteoporosis has a direct but insignificant influence on increasing the risk of implant failure (Chen et al., 2013, Alsaadi et al., 2007). Again, the results for this variable were inconclusive in the present study because of a small number of patients. The results in the present study analyzing the two variables; presence of cardiovascular diseases and presence of osteoporosis as risk factors for implant failure showed no statistically significant difference among patients with or without these conditions. The literature available on long-term success and survival of implants in patients with cardiovascular diseases supports the present study. That being said, as long as cardiovascular conditions is controlled by medications, it is not considered a contraindication to implant insertion (Javed and Romanos, 2018). Relatively, in a cohort study comparing success rate of implants placed in treated hypothyroid female patients, no statistically significant difference in implant failures existed between the two groups examined (P = 0.781). However, more soft tissue complications post-surgery (P = 0.018) and more marginal bone loss after 1 year of loading (P = 0.017) were observed. Therefore, suggesting that medically controlled hypothyroidism is also not a contraindication for implant insertion (Attard and Zarb, 2002).

In a 5-year retrospective study which assessed the effects of different groups of antidepressants, the use of antidepressants was considered risk factor for implant failure with odds ratio of 4.285. Use of serotonin-norepinephrine reuptake inhibitors (SNRI) and tricyclic antidepressants (TCA) was associated with higher implant failure rates than the other groups of antidepressants (Hakam et al., 2021). This could not be assessed in the present study, because of the small number of patients reporting on the use of anti-depressants. Despite the results from the recent retrospective study, very few literature and studies are available regarding antidepressants and implant failure so further studies should be done to investigate the dose-effect relationship and duration of consumption and its effect on implants (Mishra et al., 2016). During some nutritional deficiencies, oxidative stress and inflammation increase, hence affecting collagen structure and bone mineralization. Several micronutrients can affect bone metabolism and reduce risk of bone fractures. This includes, calcium, fluorides, magnesium, potassium, vitamin B6, vitamin D, and zinc (Iolascon et al., 2017). Data from previous studies revealed that although vitamin D is highly correlated with bone metabolism which is expected to improve success rates of implant, contradictory results have been reported, where no significant relationship was observed (Guido Mangano et al., 2018, Karaoglu et al., 2019), which is similar to the outcome of the present study.

It is evident in the present study that both histories of treated periodontitis and previous implant failure established a highly significant association with implant failures. An association was also observed in patients with irregular dental attendance. This is consistent with multiple studies demonstrating an association between history of periodontitis and early implant failure (Van Steenberghe et al., 2002, Chrcanovic et al., 2016b, Grisar et al., 2017). Late implant failures were also associated with history of periodontitis (Heitz-Mayfield, 2008, Do et al., 2020), as history of periodontitis is associated with increased risk of peri-implantitis which is associated with marginal bone loss (Roos-Jansåker et al., 2006a, Ong et al., 2008, Roccuzzo et al., 2012, Renvert et al., 2012, Monje et al., 2016, Schwarz et al., 2017, Atieh et al., 2019).

However, Leonhardt and colleagues (1993) suggested that micro-organisms do not play a decisive role on implant failure. The previous study was corroborated by Becker and co-workers (1990) who investigated the correlation between the presence of particular bacterial species and failure of Brånemark implants and could not establish a relationship. Few other studies concluded that history of treated periodontitis was not a risk factor for implant failure (Gianserra et al., 2010, Krisam et al., 2019).

The results of this retrospective analysis confirmed the detrimental effect that previously failed implant has on retreated implant. Supporting the observations that survival rate of retreated implants is lower than initial implant placement (Park, 2011). In a recent meta-analysis, Gomes and colleagues (2018) reported the survival rates of implants after first retreatment and second retreatment, (86.7% and 67.1%) respectively. In a more recent systematic review, survival rate of (86.3%) was reported after retreatment. It was reported that smooth-surfaced implants had lower survival rates than rough-surfaced implants. Therefore, suggesting that the initial implant failure can be due to factors such as implant architecture, anatomic site, infection and occlusal overload (Oh et al., 2020).

In addition to the above, it has been observed in the present study that patients who did not attend their twice a year general dental practitioner and hygienist appointments regularly, were at a significantly increased risk of implant failure. The reason behind it remains unclear. However, one of the contributing factors can be that the adjacent teeth might become carious and develop a periapical lesion, which will eventually travel to the neighboring implant leading to bone loss around the implant in a short period of time (Esposito et al., 1998a). Therefore, it is important to consider emphasizing and educating the patient on the necessity of regular follow-up and compliance to avoid complications that may arise and ensure better outcomes. Future well-controlled studies are necessary to clarify this finding.

6.4. Implant- and site-related factors

In this section, the variables were analyzed on an implant-level. Five different implant systems were analyzed in the present study, having either rough or moderately rough surfaces. It has been observed that rough surface implants had much higher failure rates, but these results were insignificant. In the author’s opinion, this has been established because the two main implant systems used in DHA throughout 2010 up to 2018 were Ankylos and Xive, and sometimes Astra, while Neoss was only introduced in DHA in January 2019. Friadent was used before the observational period, but implants that failed during the observational period were included. Likewise, this has been observed in previous reviews by Quirynen et al. and Esposito et al., where higher incidence of marginal bone loss and implant failure around rough surface implants have been reported (Quirynen et al., 2007, Esposito et al., 2007). More recently, an updated review of 27 randomized controlled trials in 1512 patients and 3230 implants, it was not evident that an association between implant type and its effect on improved long-term success (Esposito et al., 2014).

In regards to the implant selection, which included shape and size (both height and diameter); relatively higher incidences of early failure rates were observed in implants that were cylindrical, < 11 mm long and ≤ 3.5 mm in diameter. These observed results in the present study were insignificant.

In a retrospective study evaluating 1093 implants by Mohajerani and co-workers (2017), it has been reported that (6.68%) early implant failures were observed, while implant height and implant shape (cylindrical or conical) were not significant risk factors for implant failure. Conversely, several other studies did not find cylindrical implants affecting survival rate of implants (Lazzara et al., 1996, Heydenrijk et al., 2002, Lemmerman and Lemmerman, 2005, Meijer et al., 2004). Additionally, according to Karoussis and his colleagues (2004) the rationale for lower survival rates associated with cylindrical implants opposed to threaded implants remains unknown and can only be speculated upon.

In the literature, a controversy on the association between short implants and increased risk of implant failure. However, there are studies that support the negative effect height of implant has on implant survival (Olate et al., 2010), while other studies did not find an increased risk of failure due to short implants (Grisar et al., 2017, Borba et al., 2017). In a recent retrospective study (Krisam et al., 2019) analyzing 106 patients receiving 186 implants, shorter implants (< 10 mm) had significantly more early failures than implants ≥10 mm long ($P = 0.010$). Therefore, short implants being at a 5.8-fold greater risk of early failures (95% CI 1.3–26.4). This can be explained to the fact that longer implants have a larger contact surface with bone and greater stability in sites with compromised bone quality and hence increasing the likelihood of bone cells growing into the surface (Krisam et al., 2019).

Olate and co-workers (2010), retrospectively analyzed 1,649 implants inserted in 650 patients and observed a significant relationship of early implant loss with implant height but not with diameter, where short implants (6 - 9 mm) had higher failure rates. An increase early failures in narrow implants was also observed in a previous retrospective study (Noguerol et al., 2006). On the contrary, Degidi and his colleagues (2008), have also retrospectively compare between delayed and immediate loading in 510 narrow implants inserted in anterior and posterior regions. The survival rate was (99.4%) after a mean follow-up of 20 months. However, several studies have also associated wide implants with early implant failure, since it might increase the risk of buccal bone dehiscence (Noguerol et al., 2006, Urban et al., 2012).

Location of implant has always been known for being a significant risk factor for both early and late implant failure. The results of the present study, is in agreement with this, since implants placed in both posterior maxilla and mandible had a significant association with implant failure ($P < 0.0001$). According to several reports, early implant failure is significantly higher in posterior regions of both jaws (Jaffin and Berman, 1991, Chuang et al., 2002, Alsaadi et al., 2007, Degidi et al., 2009, Sánchez-Garcés et al., 2012). This can be attributed to multiple conditions which can be present in posterior regions, such as insufficient bone volume, poor bone quality and heavy occlusal forces (Glauser et al., 2001).

Alsaadi (2008a) and Noda (2015) with their co-workers have found implants placed in the posterior region to be a significant risk factors for late implant failure ($P < 0.001$) and ($P < 0.01$), respectively.

No association between bone grafting materials and implant failure were seen in the present study. This might be contributed to the protective effect bone grafting has on improving bone quantity and enhancing the success rates of implants (Dvorak et al., 2011). However, in a more recent report, higher failure rates are observed in implants placed with bone grafting (Borba et al., 2017).

No association could be found between implant placement and surgical protocols and higher implant failure. This is in agreement with a recent meta-analysis result (Bassir et al., 2019).

Finally, it was observed that more implant failures that occurred before loading were placed by oral surgeons rather than periodontists, but the results were not significant. No clear evidence for this is available in the literature since all the operators in the present study were specialists and experienced. However, it can be suggested that implant survival rates might be negatively influenced by the operator's surgical technique, skills and clinical judgement. Moreover, a contributing factor that might somehow correspond to this finding, is that Periodontist are more thorough in maintenance therapy for implant patients who are being followed-up in that department (Sonkar et al., 2019). Evidence in the literature demonstrated that regular maintenance 3 to 4 times in the first year followed by 1 to 2 times annually is necessary for implant survival (Lang and Nyman, 1994, Wilson et al., 2014, Gay et al., 2016).

6.5. Future research directions

The limitations of this study should be noted to be addressed in the future. The lack of data that is usually associated with retrospective studies such as documentation about presence of 2mm thickness of keratinized tissue around the implant, parafunctional habits, oral hygiene habits and providing occlusal splints should be considered, and future long-term prospective research with larger samples is encouraged to verify these associations. Besides this, the present study did not contain a wide variety of implant system designs and surface characteristics. Therefore, the outcomes of this study cannot be applied to all implant systems. In addition, several variables which were not evaluated in this study such as oral hygiene status and drilling speed could be considered as limitations owing to the fact that implant failure has a multifactorial etiology, thus require strict control on variables. Another limitation was the lack of a control group of patients without any implant failure. Nevertheless, the present study had a relatively large sample size of implants which were placed in a standardized clinical setting. Future studies may include control group to achieve more robust understanding of the potential risk factors for implant failure and provide effective preventive and therapeutic protocols.

7. CONCLUSIONS

Within the limitations of this retrospective study, the analysis identified plausible risk factors for early implant failure, namely history of treated periodontitis, previous implant failure and irregular dental attendance that would allow clinicians to identify those at risk and ensure continuous peri-implant supportive care.

In order to prevent the occurrence of implant failures, it is necessary to adopt strict guidelines for implant placement and identify those who are at high risk of implant failures. That being said so, it is necessary to educate and emphasize to the patient the importance of regular follow-ups and implement a strict and effective peri-implant care program particularly for patients with a history of treated periodontitis to reduce the incidence of biological complications and risk of early implant failure.

Further studies are necessary to achieve more robust understanding on potential risk factors for implant failures and to provide effective preventive and therapeutic protocols.

8. REFERENCES

- ABIKO, Y. & SELIMOVIC, D. 2010. The mechanism of protracted wound healing on oral mucosa in diabetes. Review. *Bosn J Basic Med Sci,* 10**,** 186-91.
- ABRAHAMSSON, I., BERGLUNDH, T., WENNSTRÖM, J. & LINDHE, J. 1996. The peri-implant hard and soft tissues at different implant systems. A comparative study in the dog. *Clin Oral Implants Res,* 7**,** 212-9.
- ADELL, R., ERIKSSON, B., LEKHOLM, U., BRANEMARK, P. I. & JEMT, T. 1990. Long-term follow-up study of osseointegrated implants in the treatment of totally edentulous jaws. *Int J Oral Maxillofac Implants,* 5**,** 347-59.
- ADELL, R., LEKHOLM, U., ROCKLER, B., BRÅNEMARK, P. I., LINDHE, J., ERIKSSON, B. & SBORDONE, L. 1986. Marginal tissue reactions at osseointegrated titanium fixtures (I). A 3-year longitudinal prospective study. *Int J Oral Maxillofac Surg,* 15**,** 39-52.
- AGUDIO, G., NIERI, M., ROTUNDO, R., FRANCESCHI, D., CORTELLINI, P. & PINI PRATO, G. P. 2009. Periodontal conditions of sites treated with gingival-augmentation surgery compared to untreated contralateral homologous sites: a 10- to 27-year long-term study. *J Periodontol,* 80**,** 1399-405.
- AL-NAWAS, B., KÄMMERER, P. W., MORBACH, T., LADWEIN, C., WEGENER, J. & WAGNER, W. 2012. Ten-year retrospective follow-up study of the TiOblast dental implant. *Clin Implant Dent Relat Res,* 14**,** 127-34.
- ALBREKTSSON, T., BRANEMARK, P. I., HANSSON, H. A. & LINDSTROM, J. 1981. Osseointegrated titanium implants. Requirements for ensuring a long-lasting, direct bone-to-implant anchorage in man. *Acta Orthop Scand,* 52**,** 155-70.
- ALBREKTSSON, T., ZARB, G., WORTHINGTON, P. & ERIKSSON, A. R. 1986. The long-term efficacy of currently used dental implants: A review and proposed

criteria of success. *The International journal of oral & maxillofacial implants,* 1**,** 11-25.

- ALSAADI, G., QUIRYNEN, M., KOMAREK, A. & VAN STEENBERGHE, D. 2007. Impact of local and systemic factors on the incidence of oral implant failures, up to abutment connection. *J Clin Periodontol,* 34**,** 610-7.
- ALSAADI, G., QUIRYNEN, M., KOMÁREK, A. & VAN STEENBERGHE, D. 2008a. Impact of local and systemic factors on the incidence of late oral implant loss. *Clin Oral Implants Res,* 19**,** 670-6.
- ALSAADI, G., QUIRYNEN, M., MICHILES, K., TEUGHELS, W., KOMÁREK, A. & VAN STEENBERGHE, D. 2008b. Impact of local and systemic factors on the incidence of failures up to abutment connection with modified surface oral implants. *J Clin Periodontol,* 35**,** 51-7.
- ALSAADI, G., QUIRYNEN, M. & VAN STEENBERGHE, D. 2006. The importance of implant surface characteristics in the replacement of failed implants. *Int J Oral Maxillofac Implants,* 21**,** 270-4.
- ANITUA, E., ALKHRAIST, M. H., PIÑAS, L., BEGOÑA, L. & ORIVE, G. 2014. Implant survival and crestal bone loss around extra-short implants supporting a fixed denture: the effect of crown height space, crown-to-implant ratio, and offset placement of the prosthesis. *Int J Oral Maxillofac Implants,* 29**,** 682-9.
- ANITUA, E. & ORIVE, G. 2010. Short implants in maxillae and mandibles: a retrospective study with 1 to 8 years of follow-up. *J Periodontol,* 81**,** 819-26.
- ANNER, R., GROSSMANN, Y., ANNER, Y. & LEVIN, L. 2010. Smoking, diabetes mellitus, periodontitis, and supportive periodontal treatment as factors associated with dental implant survival: a long-term retrospective evaluation of patients followed for up to 10 years. *Implant Dent,* 19**,** 57-64.

- ANNIBALI, S., CRISTALLI, M. P., DELL'AQUILA, D., BIGNOZZI, I., LA MONACA, G. & PILLONI, A. 2012. Short dental implants: a systematic review. *J Dent Res,* 91**,** 25-32.
- ANTOUN, H., KAROUNI, M., ABITBOL, J., ZOUITEN, O. & JEMT, T. 2017. A retrospective study on 1592 consecutively performed operations in one private referral clinic. Part I: Early inflammation and early implant failures. *Clin Implant Dent Relat Res,* 19**,** 404-412.
- APSE, P., ELLEN, R. P., OVERALL, C. M. & ZARB, G. A. 1989. Microbiota and crevicular fluid collagenase activity in the osseointegrated dental implant sulcus: a comparison of sites in edentulous and partially edentulous patients. *J Periodontal Res,* 24**,** 96-105.
- ARBES, S. J., JR., SLADE, G. D. & BECK, J. D. 1999. Association between extent of periodontal attachment loss and self-reported history of heart attack: an analysis of NHANES III data. *J Dent Res,* 78**,** 1777-82.
- ARLIN, M. L. 2006. Short dental implants as a treatment option: results from an observational study in a single private practice. *Int J Oral Maxillofac Implants,* 21**,** 769-76.
- ATIEH, M. A., ALSABEEHA, N. H., FAGGION, C. M., JR. & DUNCAN, W. J. 2013. The frequency of peri-implant diseases: a systematic review and meta-analysis. *J Periodontol,* 84**,** 1586-98.
- ATIEH, M. A., PANG, J. K., LIAN, K., WONG, S., TAWSE-SMITH, A., MA, S. & DUNCAN, W. J. 2019. Predicting peri-implant disease: Chi-square automatic interaction detection (CHAID) decision tree analysis of risk indicators. *J Periodontol,* 90**,** 834-846.
- ATTARD, N. J. & ZARB, G. A. 2002. A study of dental implants in medically treated hypothyroid patients. *Clin Implant Dent Relat Res,* 4**,** 220-31.

- ATTARD, N. J. & ZARB, G. A. 2003. Implant prosthodontic management of partially edentulous patients missing posterior teeth: the Toronto experience. *J Prosthet Dent,* 89**,** 352-9.
- AWAD, M. A., LOCKER, D., KORNER-BITENSKY, N. & FEINE, J. S. 2000. Measuring the effect of intra-oral implant rehabilitation on health-related quality of life in a randomized controlled clinical trial. *J Dent Res,* 79**,** 1659-63.
- BAIN, C. A. 1996. Smoking and implant failure--benefits of a smoking cessation protocol. *Int J Oral Maxillofac Implants,* 11**,** 756-9.
- BAIN, C. A. & MOY, P. K. 1993. The association between the failure of dental implants and cigarette smoking. *Int J Oral Maxillofac Implants,* 8**,** 609-15.
- BAIN, C. A., WENG, D., MELTZER, A., KOHLES, S. S. & STACH, R. M. 2002. A meta-analysis evaluating the risk for implant failure in patients who smoke. *Compend Contin Educ Dent,* 23**,** 695-9, 702, 704 passim; quiz 708.
- BALSHE, A. A., ECKERT, S. E., KOKA, S., ASSAD, D. A. & WEAVER, A. L. 2008. The effects of smoking on the survival of smooth- and rough-surface dental implants. *Int J Oral Maxillofac Implants,* 23**,** 1117-22.
- BALSHI, T. J. & WOLFINGER, G. J. 1999. Dental implants in the diabetic patient: a retrospective study. *Implant Dent,* 8**,** 355-9.
- BAQAIN, Z. H., MOQBEL, W. Y. & SAWAIR, F. A. 2012. Early dental implant failure: risk factors. *Br J Oral Maxillofac Surg,* 50**,** 239-43.
- BASSIR, S. H., EL KHOLY, K., CHEN, C. Y., LEE, K. H. & INTINI, G. 2019. Outcome of early dental implant placement versus other dental implant placement protocols: A systematic review and meta-analysis. *J Periodontol,* 90**,** 493-506.
- BECKER, S. T., BECK-BROICHSITTER, B. E., ROSSMANN, C. M., BEHRENS, E., JOCHENS, A. & WILTFANG, J. 2016. Long-term Survival of Straumann Dental

Implants with TPS Surfaces: A Retrospective Study with a Follow-up of 12 to 23 Years. *Clin Implant Dent Relat Res,* 18**,** 480-8.

- BECKER, W., BECKER, B. E., NEWMAN, M. G. & NYMAN, S. 1990. Clinical and microbiologic findings that may contribute to dental implant failure. *Int J Oral Maxillofac Implants,* 5**,** 31-8.
- BEIKLER, T. & FLEMMIG, T. F. 2003. Implants in the medically compromised patient. *Crit Rev Oral Biol Med,* 14**,** 305-16.
- BELSER, U., BUSER, D. & HIGGINBOTTOM, F. 2004. Consensus statements and recommended clinical procedures regarding esthetics in implant dentistry. *Int J Oral Maxillofac Implants,* 19 Suppl**,** 73-4.
- BELSER, U. C., GRÜTTER, L., VAILATI, F., BORNSTEIN, M. M., WEBER, H. P. & BUSER, D. 2009. Outcome evaluation of early placed maxillary anterior single-tooth implants using objective esthetic criteria: a cross-sectional, retrospective study in 45 patients with a 2- to 4-year follow-up using pink and white esthetic scores. *J Periodontol,* 80**,** 140-51.
- BENGAZI, F., WENNSTRÖM, J. L. & LEKHOLM, U. 1996. Recession of the soft tissue margin at oral implants. A 2-year longitudinal prospective study. *Clin Oral Implants Res,* 7**,** 303-10.
- BERGLUNDH, T., ARMITAGE, G., ARAUJO, M. G., AVILA-ORTIZ, G., BLANCO, J., CAMARGO, P. M., CHEN, S., COCHRAN, D., DERKS, J., FIGUERO, E., HAMMERLE, C. H. F., HEITZ-MAYFIELD, L. J. A., HUYNH-BA, G., IACONO, V., KOO, K. T., LAMBERT, F., MCCAULEY, L., QUIRYNEN, M., RENVERT, S., SALVI, G. E., SCHWARZ, F., TARNOW, D., TOMASI, C., WANG, H. L. & ZITZMANN, N. 2018. Peri-implant diseases and conditions: Consensus report of workgroup 4 of the 2017 World Workshop on the Classification of Periodontal and Peri-Implant Diseases and Conditions. *J Periodontol,* 89 Suppl 1**,** S313-S318.

- BERGLUNDH, T., PERSSON, L. & KLINGE, B. 2002. A systematic review of the incidence of biological and technical complications in implant dentistry reported in prospective longitudinal studies of at least 5 years. *J Clin Periodontol,* 29 Suppl 3**,** 197-212; discussion 232-3.
- BEZERRA FERREIRA, J. D., RODRIGUES, J. A., PIATTELLI, A., IEZZI, G., GEHRKE, S. A. & SHIBLI, J. A. 2016. The effect of cigarette smoking on early osseointegration of dental implants: a prospective controlled study. *Clin Oral Implants Res,* 27**,** 1123-8.
- BLANCHAERT, R. H. 1998. Implants in the medically challenged patient. *Dent Clin North Am,* 42**,** 35-45.
- BORBA, M., DELUIZ, D., LOURENÇO, E. J. V., OLIVEIRA, L. & TANNURE, P. N. 2017. Risk factors for implant failure: a retrospective study in an educational institution using GEE analyses. *Brazilian oral research,* 31.
- BORNSTEIN, M. M., CIONCA, N. & MOMBELLI, A. 2009. Systemic conditions and treatments as risks for implant therapy. *Int J Oral Maxillofac Implants,* 24 Suppl**,** 12-27.
- BORNSTEIN, M. M., HALBRITTER, S., HARNISCH, H., WEBER, H. P. & BUSER, D. 2008. A retrospective analysis of patients referred for implant placement to a specialty clinic: indications, surgical procedures, and early failures. *Int J Oral Maxillofac Implants,* 23**,** 1109-16.
- BRÜGGER, O. E., BORNSTEIN, M. M., KUCHLER, U., JANNER, S. F., CHAPPUIS, V. & BUSER, D. 2015. Implant therapy in a surgical specialty clinic: an analysis of patients, indications, surgical procedures, risk factors, and early failures. *Int J Oral Maxillofac Implants,* 30**,** 151-60.
- BUSER, D., JANNER, S. F., WITTNEBEN, J. G., BRÄGGER, U., RAMSEIER, C. A. & SALVI, G. E. 2012. 10-year survival and success rates of 511 titanium implants with

a sandblasted and acid-etched surface: a retrospective study in 303 partially edentulous patients. *Clin Implant Dent Relat Res,* 14**,** 839-51.

- BUSER, D., MARTIN, W. & BELSER, U. C. 2004. Optimizing esthetics for implant restorations in the anterior maxilla: anatomic and surgical considerations. *Int J Oral Maxillofac Implants,* 19 Suppl**,** 43-61.
- BUSER, D., VON ARX, T., TEN BRUGGENKATE, C. & WEINGART, D. 2000. Basic surgical principles with ITI implants. *Clin Oral Implants Res,* 11 Suppl 1**,** 59-68.
- CHEE, W. W., DUNCAN, J., AFSHAR, M. & MOSHAVERINIA, A. 2013. Evaluation of the amount of excess cement around the margins of cement-retained dental implant restorations: the effect of the cement application method. *J Prosthet Dent,* 109**,** 216-21.
- CHEN, H., LIU, N., XU, X., QU, X. & LU, E. 2013. Smoking, radiotherapy, diabetes and osteoporosis as risk factors for dental implant failure: a meta-analysis. *PLoS One,* 8**,** e71955.
- CHRCANOVIC, B. R., ALBREKTSSON, T. & WENNERBERG, A. 2014. Reasons for failures of oral implants. *J Oral Rehabil,* 41**,** 443-76.
- CHRCANOVIC, B. R., ALBREKTSSON, T. & WENNERBERG, A. 2015. Dental implants inserted in male versus female patients: a systematic review and meta-analysis. *J Oral Rehabil,* 42**,** 709-22.
- CHRCANOVIC, B. R., KISCH, J., ALBREKTSSON, T. & WENNERBERG, A. 2016a. Bruxism and dental implant failures: a multilevel mixed effects parametric survival analysis approach. *J Oral Rehabil,* 43**,** 813-823.
- CHRCANOVIC, B. R., KISCH, J., ALBREKTSSON, T. & WENNERBERG, A. 2016b. Factors Influencing Early Dental Implant Failures. *J Dent Res,* 95**,** 995-1002.

- CHRCANOVIC, B. R., KISCH, J., ALBREKTSSON, T. & WENNERBERG, A. 2017a. Intake of Proton Pump Inhibitors Is Associated with an Increased Risk of Dental Implant Failure. *Int J Oral Maxillofac Implants,* 32**,** 1097–1102.
- CHRCANOVIC, B. R., KISCH, J., ALBREKTSSON, T. & WENNERBERG, A. 2017b. Is the intake of selective serotonin reuptake inhibitors associated with an increased risk of dental implant failure? *Int J Oral Maxillofac Surg,* 46**,** 782-788.
- CHUANG, S. K., WEI, L. J., DOUGLASS, C. W. & DODSON, T. B. 2002. Risk factors for dental implant failure: a strategy for the analysis of clustered failure-time observations. *J Dent Res,* 81**,** 572-7.
- CHUNG, D. M., OH, T. J., SHOTWELL, J. L., MISCH, C. E. & WANG, H. L. 2006. Significance of keratinized mucosa in maintenance of dental implants with different surfaces. *J Periodontol,* 77**,** 1410-20.
- COCHRAN, D., OATES, T., MORTON, D., JONES, A., BUSER, D. & PETERS, F. 2007. Clinical field trial examining an implant with a sand-blasted, acid-etched surface. *Journal of periodontology,* 78**,** 974-982.
- COLELLA, G., CANNAVALE, R., PENTENERO, M. & GANDOLFO, S. 2007. Oral implants in radiated patients: a systematic review. *Int J Oral Maxillofac Implants,* 22**,** 616-22.
- CORBELLA, S., TASCHIERI, S. & DEL FABBRO, M. 2015. Long-term outcomes for the treatment of atrophic posterior maxilla: a systematic review of literature. *Clin Implant Dent Relat Res,* 17**,** 120-32.
- COSTA-JUNIOR, F. R., ALVIM-PEREIRA, C. C., ALVIM-PEREIRA, F., TREVILATTO, P. C., DE SOUZA, A. P. & SANTOS, M. C. 2013. Influence of MMP-8 promoter polymorphism in early osseointegrated implant failure. *Clin Oral Investig,* 17**,** 311-6.

- COSTA, F. O., TAKENAKA-MARTINEZ, S., COTA, L. O., FERREIRA, S. D., SILVA, G. L. & COSTA, J. E. 2012. Peri-implant disease in subjects with and without preventive maintenance: a 5-year follow-up. *J Clin Periodontol,* 39**,** 173-81.
- CRUPI, V., GUGLIELMINO, E., LA ROSA, G., VANDER SLOTEN, J. & VAN OOSTERWYCK, H. 2004. Numerical analysis of bone adaptation around an oral implant due to overload stress. *Proc Inst Mech Eng H,* 218**,** 407-15.
- DE BRUYN, H. & COLLAERT, B. 1994. The effect of smoking on early implant failure. *Clin Oral Implants Res,* 5**,** 260-4.
- DEGIDI, M., IEZZI, G., PERROTTI, V. & PIATTELLI, A. 2009. Comparative analysis of immediate functional loading and immediate nonfunctional loading to traditional healing periods: a 5-year follow-up of 550 dental implants. *Clin Implant Dent Relat Res,* 11**,** 257-66.
- DEGIDI, M., PIATTELLI, A. & CARINCI, F. 2008. Clinical outcome of narrow diameter implants: a retrospective study of 510 implants. *J Periodontol,* 79**,** 49-54.
- DELAMAIRE, M., MAUGENDRE, D., MORENO, M., LE GOFF, M. C., ALLANNIC, H. & GENETET, B. 1997. Impaired leucocyte functions in diabetic patients. *Diabet Med,* 14**,** 29-34.
- DERKS, J., HÅKANSSON, J., WENNSTRÖM, J. L., TOMASI, C., LARSSON, M. & BERGLUNDH, T. 2015. Effectiveness of implant therapy analyzed in a Swedish population: early and late implant loss. *J Dent Res,* 94**,** 44s-51s.
- DHOLAM, K. P. & GURAV, S. V. 2012. Dental implants in irradiated jaws: a literature review. *J Cancer Res Ther,* 8 Suppl 1**,** S85-93.
- DO, T. A., LE, H. S., SHEN, Y. W., HUANG, H. L. & FUH, L. J. 2020. Risk Factors related to Late Failure of Dental Implant-A Systematic Review of Recent Studies. *Int J Environ Res Public Health,* 17.

- DOBBS, M. B., BUCKWALTER, J. & SALTZMAN, C. 1999. Osteoporosis: the increasing role of the orthopaedist. *Iowa Orthop J,* 19**,** 43-52.
- DOLL, C., NACK, C., RAGUSE, J. D., STRICKER, A., DUTTENHOEFER, F., NELSON, K. & NAHLES, S. 2015. Survival analysis of dental implants and implant-retained prostheses in oral cancer patients up to 20 years. *Clin Oral Investig,* 19**,** 1347-52.
- DOORNEWAARD, R., CHRISTIAENS, V., DE BRUYN, H., JACOBSSON, M., COSYN, J., VERVAEKE, S. & JACQUET, W. 2017. Long-Term Effect of Surface Roughness and Patients' Factors on Crestal Bone Loss at Dental Implants. A Systematic Review and Meta-Analysis. *Clin Implant Dent Relat Res,* 19**,** 372-399.
- DÖRING, K., EISENMANN, E. & STILLER, M. 2004. Functional and esthetic considerations for single-tooth Ankylos implant-crowns: 8 years of clinical performance. *J Oral Implantol,* 30**,** 198-209.
- DREYER, H., GRISCHKE, J., TIEDE, C., EBERHARD, J., SCHWEITZER, A., TOIKKANEN, S. E., GLÖCKNER, S., KRAUSE, G. & STIESCH, M. 2018. Epidemiology and risk factors of peri-implantitis: A systematic review. *J Periodontal Res,* 53**,** 657-681.
- DVORAK, G., ARNHART, C., HEUBERER, S., HUBER, C. D., WATZEK, G. & GRUBER, R. 2011. Peri-implantitis and late implant failures in postmenopausal women: a cross-sectional study. *J Clin Periodontol,* 38**,** 950-5.
- ELNAYEF, B., PORTA, C., SUÁREZ-LÓPEZ DEL AMO, F., MORDINI, L., GARGALLO-ALBIOL, J. & HERNÁNDEZ-ALFARO, F. 2018. The Fate of Lateral Ridge Augmentation: A Systematic Review and Meta-Analysis. *Int J Oral Maxillofac Implants,* 33**,** 622-635.

- ESPOSITO, M., ARDEBILI, Y. & WORTHINGTON, H. V. 2014. Interventions for replacing missing teeth: different types of dental implants. *Cochrane Database Syst Rev***,** Cd003815.
- ESPOSITO, M., GRUSOVIN, M. G., PATEL, S., WORTHINGTON, H. V. & COULTHARD, P. 2008. Interventions for replacing missing teeth: hyperbaric oxygen therapy for irradiated patients who require dental implants. *Cochrane Database Syst Rev***,** Cd003603.
- ESPOSITO, M., HIRSCH, J. M., LEKHOLM, U. & THOMSEN, P. 1998a. Biological factors contributing to failures of osseointegrated oral implants. (I). Success criteria and epidemiology. *Eur J Oral Sci,* 106**,** 527-51.
- ESPOSITO, M., HIRSCH, J. M., LEKHOLM, U. & THOMSEN, P. 1998b. Biological factors contributing to failures of osseointegrated oral implants. (II). Etiopathogenesis. *Eur J Oral Sci,* 106**,** 721-64.
- ESPOSITO, M., MURRAY-CURTIS, L., GRUSOVIN, M. G., COULTHARD, P. & WORTHINGTON, H. V. 2007. Interventions for replacing missing teeth: different types of dental implants. *Cochrane Database Syst Rev***,** Cd003815.
- FAN, T., LI, Y., DENG, W. W., WU, T. & ZHANG, W. 2017. Short implants (5 to 8 mm) versus longer implants (> 8 mm) with sinus lifting in atrophic posterior maxilla: a meta-analysis of RCTs. *Clinical implant dentistry and related research,* 19**,** 207-215.
- FOX, S. C., MORIARTY, J. D. & KUSY, R. P. 1990. The Effects of Scaling a Titanium Implant Surface With Metal and Plastic Instruments: An in Vitro Study. *Journal of Periodontology,* 61**,** 485-490.
- FRENCH, D., LARJAVA, H. & OFEC, R. 2015. Retrospective cohort study of 4591 Straumann implants in private practice setting, with up to 10-year follow-up. Part 1: multivariate survival analysis. *Clin Oral Implants Res,* 26**,** 1345-54.

- FRIBERG, B. & JEMT, T. 2015. Rehabilitation of edentulous mandibles by means of osseointegrated implants: a 5-year follow-up study on one or two-stage surgery, number of implants, implant surfaces, and age at surgery. *Clin Implant Dent Relat Res,* 17**,** 413-24.
- FUEKI, K., IGARASHI, Y., MAEDA, Y., BABA, K., KOYANO, K., SASAKI, K., AKAGAWA, Y., KUBOKI, T., KASUGAI, S. & GARRETT, N. R. 2016. Effect of prosthetic restoration on masticatory function in patients with shortened dental arches: a multicentre study. *J Oral Rehabil,* 43**,** 534-42.
- FÜRHAUSER, R., FLORESCU, D., BENESCH, T., HAAS, R., MAILATH, G. & WATZEK, G. 2005. Evaluation of soft tissue around single-tooth implant crowns: the pink esthetic score. *Clin Oral Implants Res,* 16**,** 639-44.
- GAETTI-JARDIM, E. C., SANTIAGO-JUNIOR, J. F., GOIATO, M. C., PELLIZER, E. P., MAGRO-FILHO, O. & JARDIM JUNIOR, E. G. 2011. Dental implants in patients with osteoporosis: a clinical reality? *J Craniofac Surg,* 22**,** 1111-3.
- GALLACHER, S. J., THOMSON, G., FRASER, W. D., FISHER, B. M., GEMMELL, C. G. & MACCUISH, A. C. 1995. Neutrophil bactericidal function in diabetes mellitus: evidence for association with blood glucose control. *Diabet Med,* 12**,** 916-20.
- GARG, A. 1992. Pharmacological agents used in implant dentistry. *Implant Soc,* 3**,** 1, 5-7, 16.
- GATES, W. D., 3RD, COOPER, L. F., SANDERS, A. E., RESIDE, G. J. & DE KOK, I. J. 2014. The effect of implant-supported removable partial dentures on oral health quality of life. *Clin Oral Implants Res,* 25**,** 207-13.
- GAY, I. C., TRAN, D. T., WELTMAN, R., PARTHASARATHY, K., DIAZ-RODRIGUEZ, J., WALJI, M., FU, Y. & FRIEDMAN, L. 2016. Role of supportive maintenance therapy on implant survival: a university-based 17 years retrospective analysis. *Int J Dent Hyg,* 14**,** 267-271.

- GERRITSEN, A. E., ALLEN, P. F., WITTER, D. J., BRONKHORST, E. M. & CREUGERS, N. H. 2010. Tooth loss and oral health-related quality of life: a systematic review and meta-analysis. *Health Qual Life Outcomes,* 8**,** 126.
- GIANSERRA, R., CAVALCANTI, R., OREGLIA, F., MANFREDONIA, M. F. & ESPOSITO, M. 2010. Outcome of dental implants in patients with and without a history of periodontitis: a 5-year pragmatic multicentre retrospective cohort study of 1727 patients. *Eur J Oral Implantol,* 3**,** 307-14.
- GLAUSER, R., RÉE, A., LUNDGREN, A., GOTTLOW, J., HÄMMERLE, C. H. & SCHÄRER, P. 2001. Immediate occlusal loading of Brånemark implants applied in various jawbone regions: a prospective, 1-year clinical study. *Clin Implant Dent Relat Res,* 3**,** 204-13.
- GOMES, G. H., MISAWA, M. Y. O., FERNANDES, C., PANNUTI, C. M., SARAIVA, L., HUYNH-BA, G. & VILLAR, C. C. 2018. A systematic review and meta-analysis of the survival rate of implants placed in previously failed sites. *Braz Oral Res,* 32**,** e27.
- GÓMEZ-MORENO, G., AGUILAR-SALVATIERRA, A., RUBIO ROLDÁN, J., GUARDIA, J., GARGALLO, J. & CALVO-GUIRADO, J. L. 2015. Peri-implant evaluation in type 2 diabetes mellitus patients: a 3-year study. *Clin Oral Implants Res,* 26**,** 1031-5.
- GONCALVES, T. M., CAMPOS, C. H. & GARCIA, R. C. 2015. Effects of implant-based prostheses on mastication, nutritional intake, and oral health-related quality of life in partially edentulous patients: a paired clinical trial. *Int J Oral Maxillofac Implants,* 30**,** 391-6.
- GORMAN, L. M., LAMBERT, P. M., MORRIS, H. F., OCHI, S. & WINKLER, S. 1994. The effect of smoking on implant survival at second-stage surgery: DICRG

Interim Report No. 5. Dental Implant CLinical Research Group. *Implant Dent,* 3**,** 165-8.

- GRANATE-MARQUES, A., POLIS-YANES, C., SEMINARIO-AMEZ, M., JANÉ-SALAS, E. & LÓPEZ-LÓPEZ, J. 2019. Medication-related osteonecrosis of the jaw associated with implant and regenerative treatments: Systematic review. *Med Oral Patol Oral Cir Bucal,* 24**,** e195-e203.
- GRANSTRÖM, G. 2005. Osseointegration in irradiated cancer patients: an analysis with respect to implant failures. *J Oral Maxillofac Surg,* 63**,** 579-85.
- GRISAR, K., SINHA, D., SCHOENAERS, J., DORMAAR, T. & POLITIS, C. 2017. Retrospective Analysis of Dental Implants Placed Between 2012 and 2014: Indications, Risk Factors, and Early Survival. *Int J Oral Maxillofac Implants,* 32**,** 649–654.
- GROSSMANN, Y. & LEVIN, L. 2007. Success and survival of single dental implants placed in sites of previously failed implants. *J Periodontol,* 78**,** 1670-4.
- GUAN, H., VAN STADEN, R., LOO, Y. C., JOHNSON, N., IVANOVSKI, S. & MEREDITH, N. 2009. Influence of bone and dental implant parameters on stress distribution in the mandible: a finite element study. *Int J Oral Maxillofac Implants,* 24**,** 866-76.
- GUIDO MANGANO, F., GHERTASI OSKOUEI, S., PAZ, A., MANGANO, N. & MANGANO, C. 2018. Low serum vitamin D and early dental implant failure: Is there a connection? A retrospective clinical study on 1740 implants placed in 885 patients. *Journal of dental research, dental clinics, dental prospects,* 12**,** 174-182.
- HAAG, D. G., PERES, K. G., BALASUBRAMANIAN, M. & BRENNAN, D. S. 2017. Oral Conditions and Health-Related Quality of Life: A Systematic Review. *J Dent Res,* 96**,** 864-874.
- HAKAM, A. E., VILA, G., DUARTE, P. M., MBADU, M. P., AI ANGARY, D. S., SHUWAIKAN, H., AUKHIL, I., NEIVA, R., DA SILVA, H. D. P. & CHANG, J. 2021.

Effects of different antidepressant classes on dental implant failure: A retrospective clinical study. *Journal of Periodontology,* 92**,** 196-204.

- HÄMMERLE, C. H., CHEN, S. T. & WILSON, T. G., JR. 2004. Consensus statements and recommended clinical procedures regarding the placement of implants in extraction sockets. *Int J Oral Maxillofac Implants,* 19 Suppl**,** 26-8.
- HAN, H. J., KIM, S. & HAN, D. H. 2014. Multifactorial evaluation of implant failure: a 19-year retrospective study. *Int J Oral Maxillofac Implants,* 29**,** 303-10.
- HEITZ-MAYFIELD, L. J. 2008. Peri-implant diseases: diagnosis and risk indicators. *J Clin Periodontol,* 35**,** 292-304.
- HERRMANN, I., LEKHOLM, U., HOLM, S. & KARLSSON, S. 1999. Impact of implant interdependency when evaluating success rates: a statistical analysis of multicenter results. *Int J Prosthodont,* 12**,** 160-6.
- HEYDENRIJK, K., RAGHOEBAR, G. M., MEIJER, H. J., VAN DER REIJDEN, W. A., VAN WINKELHOFF, A. J. & STEGENGA, B. 2002. Two-stage IMZ implants and ITI implants inserted in a single-stage procedure. A prospective comparative study. *Clin Oral Implants Res,* 13**,** 371-80.
- HJALMARSSON, L., GHEISARIFAR, M. & JEMT, T. 2016. A systematic review of survival of single implants as presented in longitudinal studies with a follow-up of at least 10 years. *Eur J Oral Implantol,* 9 Suppl 1**,** S155-62.
- HOLAHAN, C. M., KOKA, S., KENNEL, K. A., WEAVER, A. L., ASSAD, D. A., REGENNITTER, F. J. & KADEMANI, D. 2008. Effect of osteoporotic status on the survival of titanium dental implants. *Int J Oral Maxillofac Implants,* 23**,** 905-10.
- HU, K. F., LIN, Y. C., HO, K. Y. & CHOU, Y. H. 2017. Compliance with Supportive Periodontal Treatment in Patients with Dental Implants. *Int J Oral Maxillofac Implants,* 32**,** 1364–1370.

- HUYNH-BA, G., FRIEDBERG, J. R., VOGIATZI, D. & IOANNIDOU, E. 2008. Implant failure predictors in the posterior maxilla: a retrospective study of 273 consecutive implants. *J Periodontol,* 79**,** 2256-61.
- IHDE, S., KOPP, S., GUNDLACH, K. & KONSTANTINOVIĆ, V. S. 2009. Effects of radiation therapy on craniofacial and dental implants: a review of the literature. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod,* 107**,** 56-65.
- IOLASCON, G., GIMIGLIANO, R., BIANCO, M., DE SIRE, A., MORETTI, A., GIUSTI, A., MALAVOLTA, N., MIGLIACCIO, S., MIGLIORE, A., NAPOLI, N., PISCITELLI, P., RESMINI, G., TARANTINO, U. & GIMIGLIANO, F. 2017. Are Dietary Supplements and Nutraceuticals Effective for Musculoskeletal Health and Cognitive Function? A Scoping Review. *J Nutr Health Aging,* 21**,** 527-538.
- JAFFIN, R. A. & BERMAN, C. L. 1991. The excessive loss of Branemark fixtures in type IV bone: a 5-year analysis. *J Periodontol,* 62**,** 2-4.
- JAVED, F. & ROMANOS, G. 2018. Dental Implants in Patients with Cardiovascular Disorders.
- JEMT, T. 2017. A retro-prospective effectiveness study on 3448 implant operations at one referral clinic: A multifactorial analysis. Part II: Clinical factors associated to peri-implantitis surgery and late implant failures. *Clin Implant Dent Relat Res,* 19**,** 972-979.
- JEMT, T. 2019. Implant failures and age at the time of surgery: A retrospective study on implant treatment in 2915 partially edentulous jaws. *Clin Implant Dent Relat Res,* 21**,** 686-692.
- JEMT, T., KAROUNI, M., ABITBOL, J., ZOUITEN, O. & ANTOUN, H. 2017. A retrospective study on 1592 consecutively performed operations in one private referral clinic. Part II: Peri-implantitis and implant failures. *Clin Implant Dent Relat Res,* 19**,** 413-422.

- JEMT, T., OLSSON, M. & FRANKE STENPORT, V. 2015. Incidence of First Implant Failure: A Retroprospective Study of 27 Years of Implant Operations at One Specialist Clinic. *Clin Implant Dent Relat Res,* 17 Suppl 2, e501-10.
- JEMT, T., OLSSON, M., RENOUARD, F., STENPORT, V. & FRIBERG, B. 2016. Early Implant Failures Related to Individual Surgeons: An Analysis Covering 11,074 Operations Performed during 28 Years. *Clin Implant Dent Relat Res,* 18, 861-872.
- JISANDER, S., GRENTHE, B. & ALBERIUS, P. 1997. Dental implant survival in the irradiated jaw: a preliminary report. *Int J Oral Maxillofac Implants,* 12, 643-8.
- JUNG, R. E., ZEMBIC, A., PJETURSSON, B. E., ZWAHLEN, M. & THOMA, D. S. 2012. Systematic review of the survival rate and the incidence of biological, technical, and aesthetic complications of single crowns on implants reported in longitudinal studies with a mean follow-up of 5 years. *Clin Oral Implants Res,* 23 Suppl 6, 2-21.
- KANG, D. Y., KIM, M., LEE, S. J., CHO, I. W., SHIN, H. S., CABALLÉ-SERRANO, J. & PARK, J. C. 2019. Early implant failure: a retrospective analysis of contributing factors. *J Periodontal Implant Sci,* 49, 287-298.
- KARAOGLU, A., PEKÇETIN, Z., KORAY, E., SOYER, H. & KORAY, M. 2019. The Role of Vitamin D in Implant Success. *Open Journal of Stomatology,* 09, 260-269.
- KAROUSSIS, I. K., BRÄGGER, U., SALVI, G. E., BÜRGIN, W. & LANG, N. P. 2004. Effect of implant design on survival and success rates of titanium oral implants: a 10-year prospective cohort study of the ITI Dental Implant System. *Clin Oral Implants Res,* 15, 8-17.
- KASAT, V. & LADDA, R. 2012. Smoking and dental implants. *Journal of International Society of Preventive & Community Dentistry,* 2, 38-41.
- KATE, M., PALASKAR, S. & KAPOOR, P. 2016. Implant failure: A dentist's nightmare. *Journal of Dental Implants,* 6, 51-56.

- KELLER, J. C., STEWART, M., ROEHM, M. & SCHNEIDER, G. B. 2004. Osteoporosis-like bone conditions affect osseointegration of implants. *Int J Oral Maxillofac Implants,* 19**,** 687-94.
- KERMALLI, J. Y., DEPORTER, D. A., ATENAFU, E. G. & LAM, E. W. 2014. A retrospective report on three implant devices used to restore posterior partial edentulism: overall performance and changes in crestal bone levels. *Int J Periodontics Restorative Dent,* 34**,** 225-31.
- KHOSHKAM, V., CHAN, H. L., LIN, G. H., MACEACHERN, M. P., MONJE, A., SUAREZ, F., GIANNOBILE, W. V. & WANG, H. L. 2013. Reconstructive procedures for treating peri-implantitis: a systematic review. *J Dent Res,* 92**,** 131s-8s.
- KIM, B. S., KIM, Y. K., YUN, P. Y., YI, Y. J., LEE, H. J., KIM, S. G. & SON, J. S. 2009. Evaluation of peri-implant tissue response according to the presence of keratinized mucosa. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod,* 107**,** e24-8.
- KIM, K. K. & SUNG, H. M. 2012. Outcomes of dental implant treatment in patients with generalized aggressive periodontitis: a systematic review. *J Adv Prosthodont,* 4**,** 210-7.
- KIM, Y. K., PARK, J. Y., KIM, S. G. & LEE, H. J. 2010. Prognosis of the implants replaced after removal of failed dental implants. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod,* 110**,** 281-6.
- KLEIN, M. O., SCHIEGNITZ, E. & AL-NAWAS, B. 2014. Systematic review on success of narrow-diameter dental implants. *Int J Oral Maxillofac Implants,* 29 Suppl**,** 43-54.
- KLOKKEVOLD, P. R. & HAN, T. J. 2007. How do smoking, diabetes, and periodontitis affect outcomes of implant treatment? *Int J Oral Maxillofac Implants,* 22 Suppl**,** 173-202.

- KOÇ, D., DOĞAN, A. & BEK, B. 2011. Effect of gender, facial dimensions, body mass index and type of functional occlusion on bite force. *J Appl Oral Sci,* 19**,** 274-9.
- KOLDSLAND, O. C., SCHEIE, A. A. & AASS, A. M. 2009. Prevalence of implant loss and the influence of associated factors. *J Periodontol,* 80**,** 1069-75.
- KRISAM, J., OTT, L., SCHMITZ, S., KLOTZ, A.-L., SEYIDALIYEVA, A., RAMMELSBERG, P. & ZENTHÖFER, A. 2019. Factors affecting the early failure of implants placed in a dental practice with a specialization in implantology – a retrospective study. *BMC Oral Health,* 19**,** 208.
- LABRIAGA, W., HONG, J.-H., PARK, J.-H., SHIN, S.-W. & LEE, J.-Y. 2017. A 5-year prospective clinical study of Neobiotech implants for partially edentulous patients. *J Korean Acad Prosthodont,* 55**,** 272-278.
- LAMBERT, P. M., MORRIS, H. F. & OCHI, S. 1997. Positive effect of surgical experience with implants on second-stage implant survival. *J Oral Maxillofac Surg,* 55**,** 12-8.
- LAMBERT, P. M., MORRIS, H. F. & OCHI, S. 2000. The influence of smoking on 3-year clinical success of osseointegrated dental implants. *Ann Periodontol,* 5**,** 79-89.
- LANDIS, J. R. & KOCH, G. G. 1977. The measurement of observer agreement for categorical data. *Biometrics,* 33**,** 159-74.
- LANG, N. P. & NYMAN, S. R. 1994. Supportive maintenance care for patients with implants and advanced restorative therapy. *Periodontol 2000,* 4**,** 119-26.
- LANG, N. P., PUN, L., LAU, K. Y., LI, K. Y. & WONG, M. C. 2012. A systematic review on survival and success rates of implants placed immediately into fresh extraction sockets after at least 1 year. *Clin Oral Implants Res,* 23 Suppl 5**,** 39-66.
- LAZZARA, R., SIDDIQUI, A. A., BINON, P., FELDMAN, S. A., WEINER, R., PHILLIPS, R. & GONSHOR, A. 1996. Retrospective multicenter analysis of 3i

endosseous dental implants placed over a five-year period. *Clin Oral Implants Res,* 7**,** 73-83.

- LEE, A., OKAYASU, K. & WANG, H. L. 2010. Screw- versus cement-retained implant restorations: current concepts. *Implant Dent,* 19**,** 8-15.
- LEMMERMAN, K. J. & LEMMERMAN, N. E. 2005. Osseointegrated dental implants in private practice: a long-term case series study. *J Periodontol,* 76**,** 310-9.
- LEMOS, C. A., DE SOUZA BATISTA, V. E., ALMEIDA, D. A., SANTIAGO JÚNIOR, J. F., VERRI, F. R. & PELLIZZER, E. P. 2016a. Evaluation of cement-retained versus screw-retained implant-supported restorations for marginal bone loss: A systematic review and meta-analysis. *J Prosthet Dent,* 115**,** 419-27.
- LEMOS, C. A., FERRO-ALVES, M. L., OKAMOTO, R., MENDONÇA, M. R. & PELLIZZER, E. P. 2016b. Short dental implants versus standard dental implants placed in the posterior jaws: A systematic review and meta-analysis. *J Dent,* 47**,** 8-17.
- LEONHARDT, A., ADOLFSSON, B., LEKHOLM, U., WIKSTRÖM, M. & DAHLÉN, G. 1993. A longitudinal microbiological study on osseointegrated titanium implants in partially edentulous patients. *Clin Oral Implants Res,* 4**,** 113-20.
- LEVIN, L. 2010. Dealing with dental implant failures. *Refuat Hapeh Vehashinayim (1993),* 27**,** 6-12, 60.
- LEVIN, L., SCHWARTZ-ARAD, D. & NITZAN, D. 2005. [Smoking as a risk factor for dental implants and implant-related surgery]. *Refuat Hapeh Vehashinayim (1993),* 22**,** 37-43, 85.
- LINDQUIST, L. W., CARLSSON, G. E. & JEMT, T. 1996. A prospective 15-year follow-up study of mandibular fixed prostheses supported by osseointegrated implants. Clinical results and marginal bone loss. *Clin Oral Implants Res,* 7**,** 329-36.

- LINDQUIST, L. W., ROCKLER, B. & CARLSSON, G. E. 1988. Bone resorption around fixtures in edentulous patients treated with mandibular fixed tissue-integrated prostheses. *J Prosthet Dent,* 59**,** 59-63.
- LOBBEZOO, F., BROUWERS, J. E., CUNE, M. S. & NAEIJE, M. 2006. Dental implants in patients with bruxing habits. *J Oral Rehabil,* 33**,** 152-9.
- MACHTEI, E. E., MAHLER, D., OETTINGER-BARAK, O., ZUABI, O. & HORWITZ, J. 2008. Dental implants placed in previously failed sites: survival rate and factors affecting the outcome. *Clin Oral Implants Res,* 19**,** 259-64.
- MANOR, Y., OUBAID, S., MARDINGER, O., CHAUSHU, G. & NISSAN, J. 2009. Characteristics of early versus late implant failure: a retrospective study. *J Oral Maxillofac Surg,* 67**,** 2649-52.
- MANZANO, G., MONTERO, J., MARTÍN-VALLEJO, J., DEL FABBRO, M., BRAVO, M. & TESTORI, T. 2016. Risk Factors in Early Implant Failure: A Meta-Analysis. *Implant Dent,* 25**,** 272-80.
- MARCENES, W., KASSEBAUM, N. J., BERNABÉ, E., FLAXMAN, A., NAGHAVI, M., LOPEZ, A. & MURRAY, C. J. 2013. Global burden of oral conditions in 1990-2010: a systematic analysis. *J Dent Res,* 92**,** 592-7.
- MARDINGER, O., BEN ZVI, Y., CHAUSHU, G., NISSAN, J. & MANOR, Y. 2012. A retrospective analysis of replacing dental implants in previously failed sites. *Oral Surg Oral Med Oral Pathol Oral Radiol,* 114**,** 290-3.
- MAYTA-TOVALINO, F., MENDOZA-MARTIARENA, Y., ROMERO-TAPIA, P., ÁLVAREZ-PAUCAR, M., GÁLVEZ-CALLA, L., CALDERÓN-SÁNCHEZ, J., BOLAÑOS-CARDENAS, R. & DIAZ-SARABIA, A. 2019. An 11-Year Retrospective Research Study of the Predictive Factors of Peri-Implantitis and Implant Failure: Analytic-Multicentric Study of 1279 Implants in Peru. *International journal of dentistry,* 2019**,** 3527872-3527872.

- MCMAHON, M. M. & BISTRIAN, B. R. 1995. Host defenses and susceptibility to infection in patients with diabetes mellitus. *Infect Dis Clin North Am,* 9**,** 1-9.
- MEFFERT, R. M. 1992. How to treat ailing and failing implants. *Implant Dent,* 1**,** 25-33.
- MEIJER, H. J., RAGHOEBAR, G. M., VAN'T HOF, M. A. & VISSER, A. 2004. A controlled clinical trial of implant-retained mandibular overdentures: 10 years' results of clinical aspects and aftercare of IMZ implants and Brånemark implants. *Clin Oral Implants Res,* 15**,** 421-7.
- MESCHENMOSER, A., D'HOEDT, B., MEYLE, J., ELSSNER, G., KORN, D., HÄMMERLE, H. & SCHULTE, W. 1996. Effects of various hygiene procedures on the surface characteristics of titanium abutments. *J Periodontol,* 67**,** 229-35.
- MEZZOMO, L. A., MILLER, R., TRICHES, D., ALONSO, F. & SHINKAI, R. S. 2014. Meta-analysis of single crowns supported by short (<10 mm) implants in the posterior region. *J Clin Periodontol,* 41**,** 191-213.
- MICHAELI, E., WEINBERG, I. & NAHLIELI, O. 2009. Dental implants in the diabetic patient: systemic and rehabilitative considerations. *Quintessence Int,* 40**,** 639-45.
- MINSK, L., POLSON, A. M., WEISGOLD, A., ROSE, L. F., SANAVI, F., BAUMGARTEN, H. & LISTGARTEN, M. A. 1996. Outcome failures of endosseous implants from a clinical training center. *Compend Contin Educ Dent,* 17**,** 848-50, 852-4, 856 passim.
- MISCH, C. E. 1996. Early bone loss etiology and its effect on treatment planning. *Dent Today,* 15**,** 44-51.
- MISCH, C. E., PEREL, M. L., WANG, H. L., SAMMARTINO, G., GALINDO-MORENO, P., TRISI, P., STEIGMANN, M., REBAUDI, A., PALTI, A., PIKOS, M. A., SCHWARTZ-ARAD, D., CHOUKROUN, J., GUTIERREZ-PEREZ, J. L.,

MARENZI, G. & VALAVANIS, D. K. 2008. Implant success, survival, and failure: the International Congress of Oral Implantologists (ICOI) Pisa Consensus Conference. *Implant Dent,* 17**,** 5-15.

- MISCH, C. E., SUZUKI, J. B., MISCH-DIETSH, F. M. & BIDEZ, M. W. 2005. A positive correlation between occlusal trauma and peri-implant bone loss: literature support. *Implant Dent,* 14**,** 108-16.
- MISHRA, S., P, H. & CHOWDHARY, R. 2016. Do antidepressant drugs leads to dental implant failure. *European Journal of Prosthodontics,* 4**,** 42.
- MIYASATO, M., CRIGGER, M. & EGELBERG, J. 1977. Gingival condition in areas of minimal and appreciable width of keratinized gingiva. *J Clin Periodontol,* 4**,** 200-9.
- MOHAJERANI, H., ROOZBAYANI, R., TAHERIAN, S. & TABRIZI, R. 2017. The Risk Factors in Early Failure of Dental Implants: a Retrospective Study. *Journal of dentistry (Shiraz, Iran),* 18**,** 298-303.
- MOMBELLI, A. 1999. In vitro models of biological responses to implant microbiological models. *Adv Dent Res,* 13**,** 67-72.
- MOMBELLI, A. & LANG, N. P. 1998. The diagnosis and treatment of peri-implantitis. *Periodontol 2000,* 17**,** 63-76.
- MONJE, A., ARANDA, L., DIAZ, K. T., ALARCÓN, M. A., BAGRAMIAN, R. A., WANG, H. L. & CATENA, A. 2016. Impact of Maintenance Therapy for the Prevention of Peri-implant Diseases: A Systematic Review and Meta-analysis. *J Dent Res,* 95**,** 372-9.
- MONJE, A., CATENA, A. & BORGNAKKE, W. S. 2017a. Association between diabetes mellitus/hyperglycaemia and peri-implant diseases: Systematic review and meta-analysis. *J Clin Periodontol,* 44**,** 636-648.

- MONJE, A., WANG, H. L. & NART, J. 2017b. Association of Preventive Maintenance Therapy Compliance and Peri-Implant Diseases: A Cross-Sectional Study. *J Periodontol,* 88**,** 1030-1041.
- MORASCHINI, V., POUBEL, L. A., FERREIRA, V. F. & BARBOZA EDOS, S. 2015. Evaluation of survival and success rates of dental implants reported in longitudinal studies with a follow-up period of at least 10 years: a systematic review. *Int J Oral Maxillofac Surg,* 44**,** 377-88.
- MORRIS, H. F., OCHI, S. & WINKLER, S. 2000. Implant survival in patients with type 2 diabetes: placement to 36 months. *Ann Periodontol,* 5**,** 157-65.
- MOY, P. K., MEDINA, D., SHETTY, V. & AGHALOO, T. L. 2005. Dental implant failure rates and associated risk factors. *Int J Oral Maxillofac Implants*, 20**,** 569-77.
- MUNDT, T., MACK, F., SCHWAHN, C. & BIFFAR, R. 2006. Private practice results of screw-type tapered implants: survival and evaluation of risk factors. *Int J Oral Maxillofac Implants,* 21**,** 607-14.
- NAERT, I., QUIRYNEN, M., VAN STEENBERGHE, D. & DARIUS, P. 1992. A six-year prosthodontic study of 509 consecutively inserted implants for the treatment of partial edentulism. *J Prosthet Dent,* 67**,** 236-45.
- NARITA, N., FUNATO, M., ISHII, T., KAMIYA, K. & MATSUMOTO, T. 2009. Effects of jaw clenching while wearing an occlusal splint on awareness of tiredness, bite force, and EEG power spectrum. *J Prosthodont Res,* 53**,** 120-5.
- NATHAN, D. M., GENUTH, S., LACHIN, J., CLEARY, P., CROFFORD, O., DAVIS, M., RAND, L. & SIEBERT, C. 1993. The effect of intensive treatment of diabetes on the development and progression of long-term complications in insulin-dependent diabetes mellitus. *N Engl J Med,* 329**,** 977-86.
- NAUJOKAT, H., KUNZENDORF, B. & WILTFANG, J. 2016. Dental implants and diabetes mellitus-a systematic review. *Int J Implant Dent,* 2**,** 5.

- NEWMAN, M. G. & FLEMMIG, T. F. 1988. Periodontal considerations of implants and implant associated microbiota. *J Dent Educ,* 52**,** 737-44.
- NITZAN, D., MAMLIDER, A., LEVIN, L. & SCHWARTZ-ARAD, D. 2005. Impact of smoking on marginal bone loss. *Int J Oral Maxillofac Implants,* 20**,** 605-9.
- NIXON, K. C., CHEN, S. T. & IVANOVSKI, S. 2009. A retrospective analysis of 1,000 consecutively placed implants in private practice. *Aust Dent J,* 54**,** 123-9.
- NODA, K., ARAKAWA, H., KIMURA-ONO, A., YAMAZAKI, S., HARA, E. S., SONOYAMA, W., MAEKAWA, K., OKURA, K., SHINTANI, A., MATSUKA, Y. & KUBOKI, T. 2015. A longitudinal retrospective study of the analysis of the risk factors of implant failure by the application of generalized estimating equations. *J Prosthodont Res,* 59**,** 178-84.
- NOGUEROL, B., MUÑOZ, R., MESA, F., DE DIOS LUNA, J. & O'VALLE, F. 2006. Early implant failure. Prognostic capacity of Periotest: retrospective study of a large sample. *Clin Oral Implants Res,* 17**,** 459-64.
- OH, S. L., SHIAU, H. J. & REYNOLDS, M. A. 2020. Survival of dental implants at sites after implant failure: A systematic review. *J Prosthet Dent,* 123**,** 54-60.
- OKESON, J. P. 1987. The effects of hard and soft occlusal splints on nocturnal bruxism. *J Am Dent Assoc,* 114**,** 788-91.
- OLATE, S., LYRIO, M. C., DE MORAES, M., MAZZONETTO, R. & MOREIRA, R. W. 2010. Influence of diameter and length of implant on early dental implant failure. *J Oral Maxillofac Surg,* 68**,** 414-9.
- OLMEDO-GAYA, M. V., MANZANO-MORENO, F. J., CAÑAVERAL-CAVERO, E., DE DIOS LUNA-DEL CASTILLO, J. & VALLECILLO-CAPILLA, M. 2016. Risk factors associated with early implant failure: A 5-year retrospective clinical study. *J Prosthet Dent,* 115**,** 150-5.

- OLSON, J. W., SHERNOFF, A. F., TARLOW, J. L., COLWELL, J. A., SCHEETZ, J. P. & BINGHAM, S. F. 2000. Dental endosseous implant assessments in a type 2 diabetic population: a prospective study. *Int J Oral Maxillofac Implants,* 15**,** 811-8.
- OMRAN, M. T., MILEY, D. D., MCLEOD, D. E. & GARCIA, M. N. 2015. Retrospective assessment of survival rate for short endosseous dental implants. *Implant Dent,* 24**,** 185-91.
- ONG, C. T., IVANOVSKI, S., NEEDLEMAN, I. G., RETZEPI, M., MOLES, D. R., TONETTI, M. S. & DONOS, N. 2008. Systematic review of implant outcomes in treated periodontitis subjects. *J Clin Periodontol,* 35**,** 438-62.
- PABST, A. M., WALTER, C., EHBAUER, S., ZWIENER, I., ZIEBART, T., AL-NAWAS, B. & KLEIN, M. O. 2015. Analysis of implant-failure predictors in the posterior maxilla: a retrospective study of 1395 implants. *J Craniomaxillofac Surg,* 43**,** 414-20.
- PAPASPYRIDAKOS, P., BORDIN, T. B., KIM, Y. J., EL-RAFIE, K., PAGNI, S. E., NATTO, Z. S., TEIXEIRA, E. R., CHOCHLIDAKIS, K. & WEBER, H. P. 2020. Technical Complications and Prosthesis Survival Rates with Implant-Supported Fixed Complete Dental Prostheses: A Retrospective Study with 1- to 12-Year Follow-Up. *J Prosthodont,* 29**,** 3-11.
- PAPASPYRIDAKOS, P., BORDIN, T. B., NATTO, Z. S., EL-RAFIE, K., PAGNI, S. E., CHOCHLIDAKIS, K., ERCOLI, C. & WEBER, H. P. 2019. Complications and survival rates of 55 metal-ceramic implant-supported fixed complete-arch prostheses: A cohort study with mean 5-year follow-up. *J Prosthet Dent,* 122**,** 441-449.
- PARK, J. B. 2011. Replacing a failed implant adjacent to the implant-supported restoration in the anterior region after ridge augmentation procedure. *Gerodontology,* 28**,** 238-42.

- PEREIRA, M. L., CARVALHO, J. C., PERES, F., GUTIERRES, M. & FERNANDES, M. H. 2008. Behaviour of human osteoblastic cells cultured on plasma-sprayed titanium implants in the presence of nicotine. *Clin Oral Implants Res,* 19**,** 582-9.
- PJETURSSON, B. E., ASGEIRSSON, A. G., ZWAHLEN, M. & SAILER, I. 2014. Improvements in implant dentistry over the last decade: comparison of survival and complication rates in older and newer publications. *Int J Oral Maxillofac Implants,* 29 Suppl**,** 308-24.
- PJETURSSON, B. E., TAN, K., LANG, N. P., BRÄGGER, U., EGGER, M. & ZWAHLEN, M. 2004. A systematic review of the survival and complication rates of fixed partial dentures (FPDs) after an observation period of at least 5 years. *Clin Oral Implants Res,* 15**,** 625-42.
- PJETURSSON, B. E., THOMA, D., JUNG, R., ZWAHLEN, M. & ZEMBIC, A. 2012. A systematic review of the survival and complication rates of implant-supported fixed dental prostheses (FDPs) after a mean observation period of at least 5 years. *Clin Oral Implants Res,* 23 Suppl 6**,** 22-38.
- POMMER, B., FRANTAL, S., WILLER, J., POSCH, M., WATZEK, G. & TEPPER, G. 2011. Impact of dental implant length on early failure rates: a meta-analysis of observational studies. *J Clin Periodontol,* 38**,** 856-63.
- PORTER, J. A. & VON FRAUNHOFER, J. A. 2005. Success or failure of dental implants? A literature review with treatment considerations. *Gen Dent,* 53**,** 423-32; quiz 433, 446.
- QUARANTA, A., PERROTTI, V., PIATTELLI, A., PIEMONTESE, M. & PROCACCINI, M. 2014. Implants placed in sites of previously failed implants: a systematic review. *Implant Dent,* 23**,** 311-8.
- QUIRYNEN, M., ABARCA, M., VAN ASSCHE, N., NEVINS, M. & VAN STEENBERGHE, D. 2007. Impact of supportive periodontal therapy and implant

surface roughness on implant outcome in patients with a history of periodontitis. *J Clin Periodontol,* 34**,** 805-15.

- QUIRYNEN, M., NAERT, I. & VAN STEENBERGHE, D. 1992. Fixture design and overload influence marginal bone loss and fixture success in the Brånemark system. *Clin Oral Implants Res,* 3**,** 104-11.
- QUIRYNEN, M., PEETERS, W., NAERT, I., COUCKE, W. & VAN STEENBERGHE, D. 2001. Peri-implant health around screw-shaped c.p. titanium machined implants in partially edentulous patients with or without ongoing periodontitis. *Clin Oral Implants Res,* 12**,** 589-94.
- QUIRYNEN, M. & TEUGHELS, W. 2003. Microbiologically compromised patients and impact on oral implants. *Periodontol 2000,* 33**,** 119-28.
- QUIRYNEN, M., VAN DER MEI, H. C., BOLLEN, C. M., SCHOTTE, A., MARECHAL, M., DOORNBUSCH, G. I., NAERT, I., BUSSCHER, H. J. & VAN STEENBERGHE, D. 1993. An in vivo study of the influence of the surface roughness of implants on the microbiology of supra- and subgingival plaque. *J Dent Res,* 72**,** 1304-9.
- QUIRYNEN, M., VAN STEENBERGHE, D., JACOBS, R., SCHOTTE, A. & DARIUS, P. 1991. The reliability of pocket probing around screw-type implants. *Clin Oral Implants Res,* 2**,** 186-92.
- RAMANAUSKAITE, A., BASEVICIENE, N., WANG, H. L. & TÖZÜM, T. F. 2014. Effect of history of periodontitis on implant success: meta-analysis and systematic review. *Implant Dent,* 23**,** 687-96.
- RAVIDÀ, A., BAROOTCHI, S., ASKAR, H., SUÁREZ-LÓPEZ DEL AMO, F., TAVELLI, L. & WANG, H. L. 2019. Long-Term Effectiveness of Extra-Short (≤ 6 mm) Dental Implants: A Systematic Review. *Int J Oral Maxillofac Implants,* 34**,** 68-84.

- RAVIDÀ, A., SALEH, M. H. A., MURIEL, M. C., MASKA, B. & WANG, H. L. 2018. Biological and Technical Complications of Splinted or Nonsplinted Dental Implants: A Decision Tree for Selection. *Implant Dent,* 27**,** 89-94.
- RENOUARD, F. & NISAND, D. 2006. Impact of implant length and diameter on survival rates. *Clin Oral Implants Res,* 17 Suppl 2**,** 35-51.
- RENVERT, S., LINDAHL, C. & RUTGER PERSSON, G. 2012. The incidence of peri-implantitis for two different implant systems over a period of thirteen years. *J Clin Periodontol,* 39**,** 1191-7.
- RENVERT, S. & QUIRYNEN, M. 2015. Risk indicators for peri-implantitis. A narrative review. *Clin Oral Implants Res,* 26 Suppl 11**,** 15-44.
- ROCCUZZO, M., BONINO, F., AGLIETTA, M. & DALMASSO, P. 2012. Ten-year results of a three arms prospective cohort study on implants in periodontally compromised patients. Part 2: clinical results. *Clin Oral Implants Res,* 23**,** 389-95.
- ROCCUZZO, M., LAYTON, D. M., ROCCUZZO, A. & HEITZ-MAYFIELD, L. J. 2018. Clinical outcomes of peri-implantitis treatment and supportive care: A systematic review. *Clin Oral Implants Res,* 29 Suppl 16**,** 331-350.
- ROMANOS, G. E., GUPTA, B. & ECKERT, S. E. 2012. Distal cantilevers and implant dentistry. *Int J Oral Maxillofac Implants,* 27**,** 1131-6.
- ROOS-JANSAKER, A. M., LINDAHL, C., RENVERT, H. & RENVERT, S. 2006. Nine- to fourteen-year follow-up of implant treatment. Part I: implant loss and associations to various factors. *J Clin Periodontol,* 33**,** 283-9.
- ROOS-JANSÅKER, A. M., LINDAHL, C., RENVERT, H. & RENVERT, S. 2006a. Nine- to fourteen-year follow-up of implant treatment. Part II: presence of peri-implant lesions. *J Clin Periodontol,* 33**,** 290-5.

- ROOS-JANSÅKER, A. M., RENVERT, H., LINDAHL, C. & RENVERT, S. 2006b. Nine- to fourteen-year follow-up of implant treatment. Part III: factors associated with peri-implant lesions. *J Clin Periodontol,* 33**,** 296-301.
- ROSA, E. F., CORRAINI, P., DE CARVALHO, V. F., INOUE, G., GOMES, E. F., LOTUFO, J. P., DE MICHELI, G. & PANNUTI, C. M. 2011. A prospective 12-month study of the effect of smoking cessation on periodontal clinical parameters. *J Clin Periodontol,* 38**,** 562-71.
- ROSÉN, B., OLAVI, G., BADERSTEN, A., RÖNSTRÖM, A., SÖDERHOLM, G. & EGELBERG, J. 1999. Effect of different frequencies of preventive maintenance treatment on periodontal conditions. 5-Year observations in general dentistry patients. *J Clin Periodontol,* 26**,** 225-33.
- RÖSING, C. K., FIORINI, T., HAAS, A. N., MUNIZ, F., OPPERMANN, R. V. & SUSIN, C. 2019. The impact of maintenance on peri-implant health. *Braz Oral Res,* 33**,** e074.
- RUBIN, P. 1973. Regeneration of bone marrow in rabbits following local, fractionated irradiation. *Cancer,* 32**,** 847-52.
- SAFII, S. H., PALMER, R. M. & WILSON, R. F. 2010. Risk of implant failure and marginal bone loss in subjects with a history of periodontitis: a systematic review and meta-analysis. *Clin Implant Dent Relat Res,* 12**,** 165-74.
- SAKKA, S., BAROUDI, K. & NASSANI, M. Z. 2012. Factors associated with early and late failure of dental implants. *J Investig Clin Dent,* 3**,** 258-61.
- SALVI, G., MONJE, A. & TOMASI, C. 2018. Long-term biological complications of dental implants placed either in pristine or in augmented sites: A systematic review and meta-analysis. *Clinical Oral Implants Research,* 29**,** 294-310.

- SÁNCHEZ-GARCÉS, M. A., COSTA-BERENGUER, X. & GAY-ESCODA, C. 2012. Short implants: a descriptive study of 273 implants. *Clin Implant Dent Relat Res,* 14**,** 508-16.
- SÁNCHEZ-PÉREZ, A., MOYA-VILLAESCUSA, M. J. & CAFFESSE, R. G. 2007. Tobacco as a risk factor for survival of dental implants. *J Periodontol,* 78**,** 351-9.
- SÁNCHEZ-PÉREZ, A., MOYA-VILLAESCUSA, M. J., JORNET-GARCIA, A. & GOMEZ, S. 2010. Etiology, risk factors and management of implant fractures. *Med Oral Patol Oral Cir Bucal,* 15**,** e504-8.
- SARMENTO, H. R., DANTAS, R. V., PEREIRA-CENCI, T. & FAOT, F. 2012. Elements of implant-supported rehabilitation planning in patients with bruxism. *J Craniofac Surg,* 23**,** 1905-9.
- SCHOU, S. 2008. Implant treatment in periodontitis-susceptible patients: a systematic review. *J Oral Rehabil,* 35 Suppl 1**,** 9-22.
- SCHROTT, A. R., JIMENEZ, M., HWANG, J. W., FIORELLINI, J. & WEBER, H. P. 2009. Five-year evaluation of the influence of keratinized mucosa on peri-implant soft-tissue health and stability around implants supporting full-arch mandibular fixed prostheses. *Clin Oral Implants Res,* 20**,** 1170-7.
- SCHWARTZ-ARAD, D., SAMET, N., SAMET, N. & MAMLIDER, A. 2002. Smoking and complications of endosseous dental implants. *J Periodontol,* 73**,** 153-7.
- SCHWARZ, F., BECKER, K., SAHM, N., HORSTKEMPER, T., ROUSI, K. & BECKER, J. 2017. The prevalence of peri-implant diseases for two-piece implants with an internal tube-in-tube connection: a cross-sectional analysis of 512 implants. *Clin Oral Implants Res,* 28**,** 24-28.
- SHERIF, S., SUSARLA, H. K., KAPOS, T., MUNOZ, D., CHANG, B. M. & WRIGHT, R. F. 2014. A systematic review of screw- versus cement-retained implant-supported fixed restorations. *J Prosthodont,* 23**,** 1-9.

- SHERNOFF, A. F., COLWELL, J. A. & BINGHAM, S. F. 1994. Implants for type II diabetic patients: interim report. VA Implants in Diabetes Study Group. *Implant Dent,* 3**,** 183-5.
- SHIAU, H. J. 2018. Periodontal Disease in Women and Men. *Current Oral Health Reports,* 5**,** 250-254.
- SHIROTA, T., OHNO, K., SUZUKI, K. & MICHI, K. 1993. The effect of aging on the healing of hydroxylapatite implants. *J Oral Maxillofac Surg,* 51**,** 51-6.
- SILVA JUNIOR, M. F., BATISTA, M. J. & DE SOUSA, M. D. L. R. 2019. Risk factors for tooth loss in adults: A population-based prospective cohort study. *PLOS ONE,* 14**,** e0219240.
- SLAGTER, K. W., RAGHOEBAR, G. M. & VISSINK, A. 2008. Osteoporosis and edentulous jaws. *Int J Prosthodont,* 21**,** 19-26.
- SMITH, R. A., BERGER, R. & DODSON, T. B. 1992. Risk factors associated with dental implants in healthy and medically compromised patients. *Int J Oral Maxillofac Implants,* 7**,** 367-72.
- SNYDER, H. B., CAUGHMAN, G., LEWIS, J., BILLMAN, M. A. & SCHUSTER, G. 2002. Nicotine modulation of in vitro human gingival fibroblast beta1 integrin expression. *J Periodontol,* 73**,** 505-10.
- SONKAR, J., MANEY, P., YU, Q. & PALAIOLOGOU, A. 2019. Retrospective study to identify associations between clinician training and dental implant outcome and to compare the use of MATLAB with SAS. *Int J Implant Dent,* 5**,** 28.
- STRIETZEL, F. P., KARMON, B., LOREAN, A. & FISCHER, P. P. 2011. Implant-prosthetic rehabilitation of the edentulous maxilla and mandible with immediately loaded implants: preliminary data from a retrospective study, considering time of implantation. *Int J Oral Maxillofac Implants,* 26**,** 139-47.

- STRIETZEL, F. P. & REICHART, P. A. 2007. Oral rehabilitation using Camlog screw-cylinder implants with a particle-blasted and acid-etched microstructured surface. Results from a prospective study with special consideration of short implants. *Clin Oral Implants Res,* 18**,** 591-600.
- STRIETZEL, F. P., REICHART, P. A., KALE, A., KULKARNI, M., WEGNER, B. & KÜCHLER, I. 2007. Smoking interferes with the prognosis of dental implant treatment: a systematic review and meta-analysis. *J Clin Periodontol,* 34**,** 523-44.
- TAJBAKHSH, S., RUBENSTEIN, J. E., FAINE, M. P., MANCL, L. A. & RAIGRODSKI, A. J. 2013. Selection patterns of dietary foods in edentulous participants rehabilitated with maxillary complete dentures opposed by mandibular implant-supported prostheses: a multicenter longitudinal assessment. *J Prosthet Dent,* 110**,** 252-8.
- TAKAMIYA, A. S., GOIATO, M. C. & GENNARI FILHO, H. 2014. Effect of smoking on the survival of dental implants. *Biomed Pap Med Fac Univ Palacky Olomouc Czech Repub,* 158**,** 650-3.
- TAWIL, G., YOUNAN, R., AZAR, P. & SLEILATI, G. 2008. Conventional and advanced implant treatment in the type II diabetic patient: surgical protocol and long-term clinical results. *Int J Oral Maxillofac Implants,* 23**,** 744-52.
- TAYLOR, G. W. 2001. Bidirectional interrelationships between diabetes and periodontal diseases: an epidemiologic perspective. *Ann Periodontol,* 6**,** 99-112.
- TELLEMAN, G., RAGHOEBAR, G. M., VISSINK, A. & MEIJER, H. J. 2014. Impact of platform switching on peri-implant bone remodeling around short implants in the posterior region, 1-year results from a split-mouth clinical trial. *Clin Implant Dent Relat Res,* 16**,** 70-80.

- THOMA, D. S., CHA, J. K. & JUNG, U. W. 2017. Treatment concepts for the posterior maxilla and mandible: short implants versus long implants in augmented bone. *J Periodontal Implant Sci,* 47**,** 2-12.
- THOMSON-NEAL, D., EVANS, G. H. & MEFFERT, R. M. 1989. Effects of various prophylactic treatments on titanium, sapphire, and hydroxyapatite-coated implants: an SEM study. *Int J Periodontics Restorative Dent,* 9**,** 300-11.
- THÖNE-MÜHLING, M., SWIERKOT, K., NONNENMACHER, C., MUTTERS, R., FLORES-DE-JACOBY, L. & MENGEL, R. 2010. Comparison of two full-mouth approaches in the treatment of peri-implant mucositis: a pilot study. *Clin Oral Implants Res,* 21**,** 504-12.
- TSOLAKI, I. N., MADIANOS, P. N. & VROTSOS, J. A. 2009. Outcomes of dental implants in osteoporotic patients. A literature review. *J Prosthodont,* 18**,** 309-23.
- TURKYILMAZ, I. 2010. One-year clinical outcome of dental implants placed in patients with type 2 diabetes mellitus: a case series. *Implant Dent,* 19**,** 323-9.
- TÜRP, J. C., KOMINE, F. & HUGGER, A. 2004. Efficacy of stabilization splints for the management of patients with masticatory muscle pain: a qualitative systematic review. *Clin Oral Investig,* 8**,** 179-95.
- URBAN, T., KOSTOPOULOS, L. & WENZEL, A. 2012. Immediate implant placement in molar regions: risk factors for early failure. *Clin Oral Implants Res,* 23**,** 220-227.
- VAN STEENBERGHE, D., JACOBS, R., DESNYDER, M., MAFFEI, G. & QUIRYNEN, M. 2002. The relative impact of local and endogenous patient-related factors on implant failure up to the abutment stage. *Clinical oral implants research,* 13**,** 617-622.
- VAN STEENBERGHE, D., LEKHOLM, U., BOLENDER, C., FOLMER, T., HENRY, P., HERRMANN, I., HIGUCHI, K., LANEY, W., LINDEN, U. &

ASTRAND, P. 1990. Applicability of osseointegrated oral implants in the rehabilitation of partial edentulism: a prospective multicenter study on 558 fixtures. *Int J Oral Maxillofac Implants,* 5**,** 272-81.

- VERCRUYSSEN, M., MARCELIS, K., COUCKE, W., NAERT, I. & QUIRYNEN, M. 2010. Long-term, retrospective evaluation (implant and patient-centred outcome) of the two-implants-supported overdenture in the mandible. Part 1: survival rate. *Clin Oral Implants Res,* 21**,** 357-65.
- VERMA, R., JODA, T., BRÄGGER, U. & WITTNEBEN, J. G. 2013. A systematic review of the clinical performance of tooth-retained and implant-retained double crown prostheses with a follow-up of ≥ 3 years. *J Prosthodont,* 22**,** 2-12.
- WANG, F., ZHANG, Z., MONJE, A., HUANG, W., WU, Y. & WANG, G. 2015. Intermediate long-term clinical performance of dental implants placed in sites with a previous early implant failure: a retrospective analysis. *Clin Oral Implants Res,* 26**,** 1443-9.
- WENNSTRÖM, J. L., BENGAZI, F. & LEKHOLM, U. 1994. The influence of the masticatory mucosa on the peri-implant soft tissue condition. *Clin Oral Implants Res,* 5**,** 1-8.
- WESTFELT, E., RYLANDER, H., BLOHMÉ, G., JONASSON, P. & LINDHE, J. 1996. The effect of periodontal therapy in diabetics. Results after 5 years. *J Clin Periodontol,* 23**,** 92-100.
- WILSON, T. G., JR. 2009. The positive relationship between excess cement and peri-implant disease: a prospective clinical endoscopic study. *J Periodontol,* 80**,** 1388-92.
- WILSON, T. G., JR., VALDERRAMA, P. & RODRIGUES, D. B. 2014. The case for routine maintenance of dental implants. *J Periodontol,* 85**,** 657-60.

- WITTNEBEN, J. G., MILLEN, C. & BRÄGGER, U. 2014. Clinical performance of screw- versus cement-retained fixed implant-supported reconstructions--a systematic review. *Int J Oral Maxillofac Implants,* 29 Suppl**,** 84-98.
- YANG, J., SHAO, S. Y., CHEN, W. Q., CHEN, C., ZHANG, S. M. & QIU, J. 2019. Cigarette Smoke Extract Exposure: Effects on the Interactions between Titanium Surface and Osteoblasts. *Biomed Res Int,* 2019**,** 8759568.
- ZANDIM-BARCELOS, D. L., CARVALHO, G. G., SAPATA, V. M., VILLAR, C. C., HAMMERLE, C. & ROMITO, G. A. 2019. Implant-based factor as possible risk for peri-implantitis. *Braz Oral Res,* 33**,** e067.
- ZARB, G. A. & SCHMITT, A. 1990. The longitudinal clinical effectiveness of osseointegrated dental implants: the Toronto Study. Part II: The prosthetic results. *J Prosthet Dent,* 64**,** 53-61.
- ZEMBIC, A. & WISMEIJER, D. 2014. Patient-reported outcomes of maxillary implant-supported overdentures compared with conventional dentures. *Clin Oral Implants Res,* 25**,** 441-50.
- ZETTERQVIST, L., FELDMAN, S., ROTTER, B., VINCENZI, G., WENNSTRÖM, J. L., CHIERICO, A., STACH, R. M. & KENEALY, J. N. 2010. A prospective, multicenter, randomized-controlled 5-year study of hybrid and fully etched implants for the incidence of peri-implantitis. *J Periodontol,* 81**,** 493-501.
- ZHOU, Y., GAO, J., LUO, L. & WANG, Y. 2016. Does Bruxism Contribute to Dental Implant Failure? A Systematic Review and Meta-Analysis. *Clin Implant Dent Relat Res,* 18**,** 410-20.
- ZIGDON, H. & MACHTEI, E. E. 2008. The dimensions of keratinized mucosa around implants affect clinical and immunological parameters. *Clin Oral Implants Res,* 19**,** 387-92.

- ZUPNIK, J., KIM, S. W., RAVENS, D., KARIMBUX, N. & GUZE, K. 2011. Factors associated with dental implant survival: a 4-year retrospective analysis. *J Periodontol,* 82**,** 1390-5.

9. APPENDICES

APPENDIX 1:

MBRU-IRB approval letter

MBRU

11 April 2020

Fatima AlZarooni
Resident - Prosthodontics
HBMCDM

RE: MBRU-IRB-2020-011

Dear Dr Fatima,

Thank you for submitting clarifications to the observations on the study titled "Risk factors for implant failure". 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.

Thank you for your interest in MBRU-IRB.

Sincerely,

Alex Milosevic

Professor Alexander Milosevic
Deputy Chairman, MBRU-IRB

لجنة أخلاقيات البحوث
INSTITUTIONAL REVIEW BOARD

MBRU/IRB/2020/015 Page **1** of **1**

APPENDIX 2:

DHA-USREC approval letter

حكومة دبي
GOVERNMENT OF DUBAI

هيئة الصحة بدبي
DUBAI HEALTH AUTHORITY

UNIVERSITY STUDENT RESEARCH EVALUATION COMMITTEE

APPROVAL LETTER

Reference: USREC06-19/PG/2020 **Date**: 02 June 2020

Dear Dr. Fatima AlZarooni,

Title of Project: "Risk factors for implant failure"

Thank you for submitting the mentioned study.

University Student Research Evaluation Committee has reviewed your research Proposal and supporting documents and I am pleased to inform you that your research proposal has been approved to be conducted in Al Badaa Health care center (dental department).

Please note that the following standard requirements are integral part of the approval:

1. This approval will be for a period of 1 year. At the end of this period, if the project has been completed, abandoned, discontinued or not completed for any reason you are required to inform the University Students Research Evaluation Committee.
2. Please remember that you must notify the Committee via email regarding any alteration to the Project protocol.
3. Please apply for ethical approval through DSREC@dha.gov.ae . After getting your ethical committee approval, you can officially start your research and data assembly.
4. Please provide a copy of the research results to the committee following the completion of the study.

We wish you every success with your studies and beyond.

Yours sincerely

University Student Research Evaluation Committee
Medical Education Department

Dr. Hamda Hassan Khansaheb

Acting Chair, University Student Research Evaluation Committee

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APPENDIX 3:

Data collection form

1. **Demographic data:**
   - Gender: Male / Female
   - Age (at implant failure): __________ years.
   - Operator placed dental implant: Maxillofacial and oral surgeon / Periodontist
2. **Systemic and patient-related outcomes:**
   - Presence of systemic condition(s): _______________
   - Medications: Yes / No
   - Radiation therapy: Yes / No
   - Chemotherapy: Yes / No
   - Smoking habits: Non-smoker / Current smoker
   - Parafunctional habits: Yes / No
   - History of treated periodontitis: Yes / No
   - History of regular dental attendance: Yes / No
   - Regular peri-implant maintenance care: Yes / No
3. **Implant-, site-, and surgical-related outcomes:**
   - Implant system:
     - Astra
     - Xive
     - Ankylos
     - Friadent
     - Neoss

- Implant surface characteristics: Moderately roughened / Roughened
- Implant shape: Cylindrical / Tapered
- Implant height: <11mm / ≥11mm
- Implant diameter: ≤3.5mm (narrow) / >3.5mm (standard)
- Implant location:
    - Anterior maxilla
    - Posterior maxilla
    - Anterior mandible
    - Posterior mandible
- Presence of keratinized tissue of ≥2mm: Yes / No
- Implant placement protocol:
    - Type 1
    - Type 2
    - Type 3
    - Type 4
- Use of grafting materials: Yes / No
- Number of placed implants: No additional implants / ≥ 2 implants
- Timing of implant failure: Early / Late
- Reason for late implant failure: Biological complications / Technical complications
- Type of dental implant prosthesis:
    - No prosthesis
    - Single crown
    - Fixed bridge (splinted / cantilever)
    - Removable denture

- History of previous implant failure: Yes / No

4. **Prosthesis-related outcomes:**

- History of Screw fracture: Yes / No
- History of coronal fracture: Yes / No
- Type of retention: Screwed / Cemented
- Numbers of years in function (≥ 2 years): Yes / No