VILNIUS UNIVERSITY
MEDICAL FACULTY
INSTITUTE OF DENTISTRY

Winona Brandt
Dentistry 5th year, Group 1

Master's Thesis

Tooth Preservation and Implant Placement - Analysis of Tooth and Implant Survival Rates

Scientistic Supervisor: Dr. Asist. Ruta Rasteniene

Vilnius

2023

Content

Summary

The thesis aims to provide dental practitioners with insights into decision-making for treating questionable teeth. It covers the reasons for tooth loss and the epidemiology of various dental pathologies. The thesis also presents different treatment options, such as periodontal treatment, endodontic treatment, and prosthetics, which can help preserve teeth. Some studies have shown that odontogenic and prosthetic restorations have comparable survival rates to implants, but implant placement is often preferred as the most successful treatment.

Additionally, the discussion will compare the survival rates of both implants and preservative methods with different success criteria set at a time. Factors such as bacterial colonization, systemic health predispositions, and residual bone and tooth structure are crucial for the success of implant survival, the thesis will provide a detailed explanation of these criteria.

Several studies are presented in the thesis to demonstrate the significance of patient motivation, compliance, and oral hygiene instruction in selecting an appropriate treatment option and achieving a successful outcome.

Finally, the evaluation of the advantages and disadvantages of tooth extraction and preservation methods, as well as the factors that must be considered when making these decisions, will be presented.

Keywords

tooth preservation; implant survival rates; tooth survival rates; implant placement

Literature search strategy

PubMed, Clinical Key and google scholar were selected as primary databases to select studies for the thesis. The systematic research with google scholar was restricted to English language studies from 2012 to 2023 and included retrospective, metanalysis as well as longitudinal studies. By utilizing MeSH (Medical subject headings) for indexing articles from PubMed, the primary keywords covered for the present study are “dental prosthesis, implant-supported” and “dental implants”, with an adapted time range from 2010 until 2023, to identify the most recent and relevant studies. In addition to only full-text clinical trials and prospective were selected, as well as retrospective randomized control trials, in which PubMed filtered to 44 results. Screening of titles from the database search resulted in the identification of 86 publications that

were potentially relevant for this review. Evaluation of abstracts yielded nine studies eligible for full-text analysis.

1. Introduction

For the past few years and even decades, dental implantology was seen as a reliable method to replace missing teeth. Either to improve esthetics or seeking to maintain oral health in terms of bone level as well as functional bite. However, there is an increasing trend toward replacing pathologic teeth with dental implants. The long-term survival rates of the implants or success rate of procedures can vary, depending on several factors, such as the patient's systemic health, motivation, the type of procedure performed, and the skills of the dental practitioner (1).

One of the most important factors of either tooth preservation or proper implant integration is having an overall healthy patient. People who on the one hand practice good oral hygiene, consume a nutritious diet, regulating their stress levels and attend regular dental visits, and on the other hand lacking inherent or acquired diseases, are more likely to have positive results. This is, because a healthy body can more effectively fight infection, prevent inflammation, and foster recovery after dental work, significantly increasing the probability of a successful outcome.

Another factor influencing the longevity of tooth preservation or implant placement is the method of treatment. A straightforward cavity filling could be more successful than a more complicated root canal treatment, for instance. Additionally, the quality of the implant and the expertise of the physician who does the placement both influence the success of the treatment. Single implants with high-quality screw threads, set in place by an experienced practitioner are more probable to be enduring than several implants put in place by a doctor lacking experience. Even though within the bibliographic research of this thesis no studies were found, which were considering the skills and experience of the dentist, every patient should keep in mind that their skill set is differing and should choose a specialist fitting their needs.

This applies to tooth preservation too. It is essential to inquire about the knowledge and practice of the dental expert when deciding the long-term success rates of keeping teeth. Practitioners with considerable education and experience in these processes are more likely to produce superior outcomes compared to those who are less experienced. This is because experienced professionals will have a better understanding of the mouth and jaw anatomy and can execute complex procedures with a high degree of precision and proficiency.

Regarding implant placement, it is highly situation dependent if an implant is considered a failure or success. As the setting of the success criteria play an important role in determining if implant placement is perceived as successful, studies with equal clinical parameters were included in the review for this thesis. To start either preservative or implant treatment, the evaluation of tooth prognosis is crucial for treatment planning. Thus, wisely chosen classification systems with several predictors of implant survival rates can be used to examine further success.

The bibliographic review reveals today's prevailing expert opinion within the field of implantology which consider teeth with compromised periodontal support not to remain functional. Therefore, high implant survival rates are combined with other clinical and socio-economic factors, which lead to a positive yet problematic and arguable prognosis to place an implant. Especially physiologic bone resorption cannot always fully be prevented after extraction, even with immediate implantation. Therefore, the question arises, as whether this approach yields the best forecast from a perspective of long-term durability, functionality, chewing ability, and short healing post-operational time. Throughout this thesis, various aspects will be highlighted that must be considered when making a decision on implantation. To date, implants are considered as one of the predictable choices for tooth replacement in edentulous or partially edentulous patients. The survival rates of implants after 5, as well as 10 years, are high and in none of the mentioned studies is dropping below 87.3%. Despite their recognized success, it should be noted, that comparing studies with different implant designs and experimental conditions can be challenging. Studies have shown that conservative treatment options, such as endodontic, prosthetic, or periodontal treatment, can have comparable survival rates to implant placement. However, there are variations in survival rates ranging from 10% to 14% among different studies.

2. Main causes of the tooth loss

2.1. Overview of Odontogenic infections

The main causes of tooth loss are odontogenic infections, which can be classified as endodontic and periodontal (2).

Endodontic infections are caused by caries or microleakage of old restorations. For endodontic infections, inadequate oral hygiene is the main risk factor that leads to plaque accumulation. Bacteria, such as *streptococcus mutans*, metabolize sugar, resulting in higher acidity, and low

pH, followed by demineralization of teeth enamel. If these bacteria are reaching the pulp chamber, they are causing inflammation which can potentially lead to pulp necrosis and apical periodontitis (AP) if left untreated.

An inflammation of the periodontium and surrounding structures caused by bacteria leads to connective tissue and bone loss (3). Periodontal infections are mainly caused by plaque accumulation and calculus (high Oral Hygiene Index), as well as heavy smoking (4). If the afore mentioned risk factors and the biofilm containing anaerobic gram-negative bacteria are not removed, it leads to the periodontal pocket formation and periodontal disease. The cervical epithelium migrates along the root surface and into the periodontal ligament space, and this progression leads to chronic inflammation of the gingiva, periodontal ligament, and underlying alveolar bone. Further signs of periodontal disease are a gingival recession with root exposure, bleeding on probing (BOP), and tooth mobility. Progressing periodontal disease will manifest in persisting bad taste and foul-smelling breath (halitosis). Acute infection of the periodontium is indicated when the infection site exhibits periodontal pockets, decreased bone levels, and destruction that extends through the furcation. An abscess and swelling of the adjacent gingiva may develop (5). Periodontitis can be caused by inherent, acquired, or behavioral factors. Behavioral factors such as tobacco smoking or inadequate oral hygiene are among the most common causes. Genetic susceptibility is an inherent risk factor, while acquired risk factors include systemic inflammatory diseases such as diabetes mellitus (6), rheumatoid arthritis, and atherosclerosis (7). Additionally, preterm birth (8), hyperlipidemia (9), obesity (10), nervous and macular degeneration (11, 12), and malignant and benign solid neoplasms (13) have been shown to be correlated with periodontitis. Periodontitis is broadly divided into aggressive periodontitis and chronic periodontitis (14). Further they may depict as necrotizing ulcerative periodontitis (NUP) and periodontal abscess (14). Aggressive periodontitis refers to an ‘early-onset disease’ in young individuals. Its pathophysiology and disease activity is currently unknown (15). Chronic periodontitis is typically diagnosed in adult individuals. Studies have shown that during the course of the disease, approximately 85% of adult individuals exhibit no further progression, including pocket deepening or bone destruction, for a period of 5 to 6 years even without treatment or with only one instance of scaling (15). Necrotizing ulcerative periodontitis (NUP) is associated with aggressive invasion by diverse spirochetes, *Fusobacterium species*, *Prevotella intermedia* and *Selenomonas* with subsequent bone and clinical attachment loss (16). Usually, it arises from necrotizing ulcerative gingivitis and appears in younger individuals which show immunosuppression or malnutrition (16). Even

though the prevalence of NUP is rare, it is one of the most severe conditions connected with biofilm and tissue destruction (16).

A periodontal abscess is defined as a localized erythematous gingival enlargement involving periodontal tissue and bone with an accumulation of pus (16). If the abscess occurs near the marginal or interdental gingiva, it is termed a gingival abscess (16).

2.2. Epidemiology of periodontal pathology and periapical pathology

The worldwide prevalence of endodontic infections and apical periodontitis cannot be accurately determined, as these conditions are not solely diagnosed through clinical examination but also require the use of radiographic methods such as periapical and panoramic X-rays or Cone Beam Computer Tomography (CBCT). According to Marcenes *et al.* 2013 (17) and Vos *et al.* 2017 (18), oral conditions such as caries and periodontal diseases are better documented and play a significant role in the global burden of diseases due to their visibly apparent pathology. In contrast, AP is often asymptomatic and underdiagnosed (19), leading to a lack of accurate prevalence data. Studies have reported a global prevalence of 52% for AP based on samples reporting at least one tooth with the condition (19).

Periodontitis is a periodontal disease, which, if left untreated, can lead to furcation development, tooth losing, and loss. In a study from 2020 it was identified that mild periodontitis affects 45% to 50% of adults worldwide, increasing to over 60% in the elderly population of patients more than 65 years (6). The estimated worldwide prevalence of severe periodontitis in 2010, based on data from 170 individuals aged ≥15 years from 37 countries, is 10.8% (95% confidence interval: 10.1-11.6%). This prevalence is higher, up to 20%, in southern Latin America and east Sub-Saharan regions. As shown in Figure 1, the global burden of severe periodontitis increases steadily until adulthood, reaching a plateau at around 40 years of age (20).

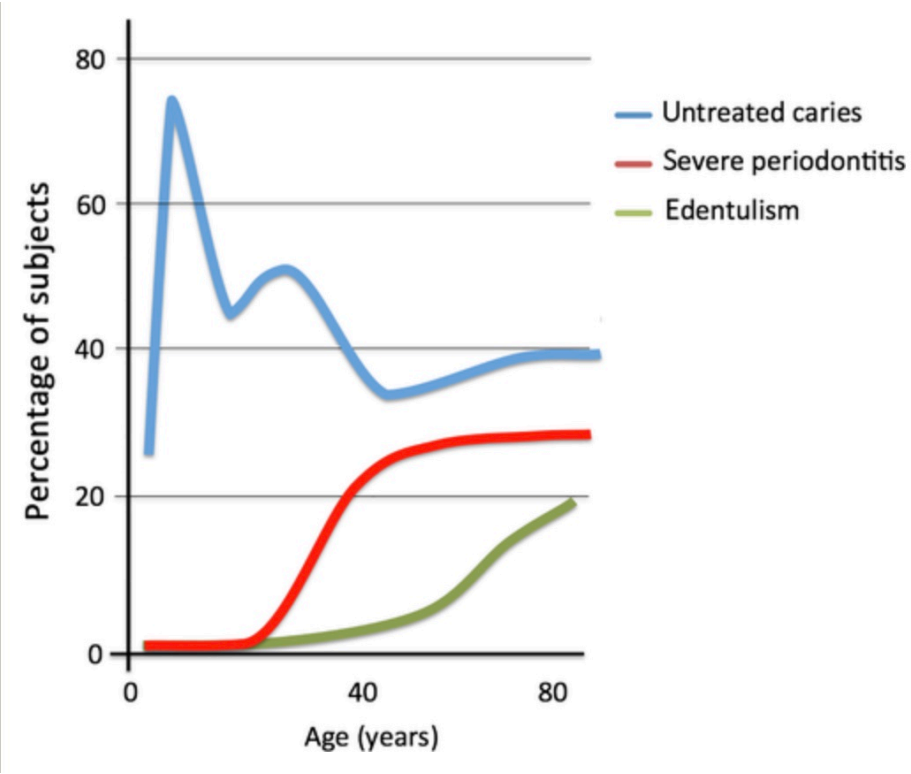

Figure 1: The 2010 global prevalence of subjects with severe periodontitis, untreated caries, and edentulism according to age. Adapted from Kassebaum *et al.* (17).

In 2011, Graetz *et al.* conducted a retrospective study with 68 patients with either aggressive periodontitis or chronic periodontitis (21). Patients were selected under the circumstance of having at least 2 teeth with 50 % of bone loss. With 750 million people affected, chronic periodontitis is among the six most prevalent chronic diseases worldwide (17). Aggressive periodontitis is not as prevalent, affecting only 1.6% (95% CI 1.1–2.3) of the world population (22).

2.3. Socioeconomic age-related aspects of the prevalence of periodontitis and apical periodontitis

A 2015 study conducted by Eke *et al.* focused on US citizens and included six sides of all teeth except the third molars (23). The three-year research aimed to update and identify all stages of periodontitis most accurately. According to the study, 37.4% of teeth had mild periodontitis with Clinical Attachment Loss ≥ 3 mm (CAL), while 10.4% of teeth were identified with CAL ≥ 4 mm. Severe periodontitis was found in 8.9% of American adults. In addition, Eke *et al.* (2015) found the highest prevalence of periodontitis in the Hispanic (63.5%) and non-Hispanic black populations (59.1%) (23). The authors hypothesize that social factors such as socioeconomic status and socio-behavioral factors may contribute to the development of

periodontitis, especially since a higher percentage of the black population comes from developing countries.

Thomson *et al*. (3) took Vietnam as an example of a developing country, and Australia as an already developed country. Their team compared the prevalence of moderate to severe periodontitis among 35 to 44-year-old patients from the low-income country Vietnam to the prevalence of the similarly defined patient group from the developed high-income country Australia. Additionally, they rated the adults in subgroups from highest income to lowest income within the country (Figure 2.) (3). The figure demonstrates notable variances in periodontal health among income groups and countries. However, the underlying reasons for these disparities remain unclear. For instance, why do middle-aged individuals in Australia exhibit better periodontal health than their Vietnamese counterparts? The heightened prevalence of risk factors such as smoking, inadequate access to dental care, and high Oral Hygiene Index (OHI) may partially account for the observed elevated prevalence of periodontitis in Vietnam (3). Nonetheless, as differences also exist between low- and high-income adults, it is uncertain what factors may underlie this social gradient variation.

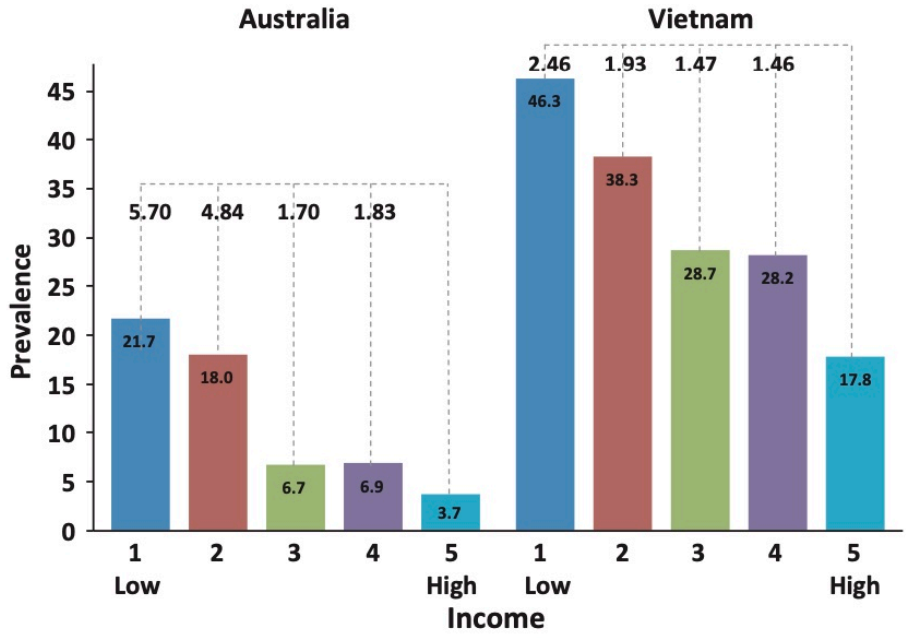

Figure 2: Comparison of prevalence of periodontitis in Australia and Vietnam, as a function of income, performed on a patient test group of ages between 35 to 44 (3).

Four years later after the release of the study of Thomson *et al.,* in 2016, Eke *et al.* focused on periodontitis prevalence in relation to age (5). It was concluded that individuals 65+ years have

a 7 times higher risk for periodontitis, than individuals in the year group 30 to 34. On the other hand, Holtfreter *et al.* (24) found that mild-to-moderate periodontitis is prevalent in a vast majority of adults in Germany, with 95.0% prevalence in adults and 99.2% prevalence in seniors. This suggests that there are no significant differences in the prevalence of mild periodontitis cases between these two age groups in Germany. In a study, conducted by B. Holtfreter's a range between 16.9% to 48% was reported for severe periodontitis due to variation in case definitions (25). However, a systematic analysis published in 2013 estimated the global prevalence of severe generalized periodontitis in all age groups to be 11% (5).

According to a study (26), the peak age for active periodontitis is 38 years old. However, younger patients may not notice much progression if they maintain good oral hygiene, as reported in another study (23). Geriatric patients are less likely to seek professional periodontitis treatment, and there could be several reasons for this phenomenon. One potential explanation is that older individuals tend to have slower and less predictable healing after flap debridement surgery, as suggested by a 2017 study (27). Additionally, older individuals with systemic diseases such as Alzheimer's or dementia may have reduced motivation or psychological abilities to maintain good oral hygiene. Dental geriatric patients are to a lesser extent seeking professional periodontitis treatment. This could be because of several reasons. On the one hand older a study from 2017 (27) suggest that individuals tend to heal slower and less predictable after flap debridement surgery. On the other hand, older individuals with systemic diseases like Alzheimer, dementia etc. demonstrate less motivation or psychologic abilities to maintain a good oral hygiene. Geriatric patients may reside in assisted living communities where access to proper dental care may be limited, which is a contributing factor to their reluctance to seek professional periodontitis treatment. A study suggests that treatment of periodontitis before retirement may prolong life expectancy (27).

Due to the uncertainty regarding periodontitis prevalence, progression, and definition, it is challenging for politicians and the healthcare system to adjust centralized provision regulations accordingly.

3. <u>Short description of tooth preservation and restoration methods- periodontal treatment, endodontic treatment - success criteria, teeth survival rate, long-term results</u>

For nonvital teeth, endodontic treatment is the treatment of choice. According to various studies, the success rates of endodontically treated teeth without periapical lesions range between 82.8% and 97.3% (28, 29, 30). The study conducted by M. Torabinejad *et al.* (31) and S. Friedmann et al. (32) revealed that the survival rate of teeth treated with endodontic therapy

varies between 86% to 92% after a period of 2 to 10 years. Consequently, the study raises the question of identifying the key factors that significantly impact the longevity of teeth treated with endodontic therapy.

For successful endodontic treatment, a lack of periapical pathology is essential, as the survival rate of teeth with apical periodontitis drops to 75.6%–87.77% (28, 29, 30). Additionally, endodontically treated teeth restored with crowns have six times higher survival rates than teeth without prosthetic restorations (33). In addition, a meta-analysis conducted by Ng et al. in 2010 identified several factors that influence the survival of teeth treated with endodontic therapy. These include a proper coronal seal, the time between endodontic treatment and the restoration, proximal contacts, serving as an abutment for fixed or removable partial dentures, the remaining tooth structure with a minimum of 1.5mm ferrule (34), quality of obturation, existing periapical pathology and the type of tooth, as it was observed that molars tend to have lower survival rates (35) than other teeth.

To strengthen the tooth integrity leading to longer survival rates, a porcelain fused metal (PFM) crown is the treatment of choice for most nonvital teeth (36).

The initial treatment of periodontitis is subgingival and supragingival calculus removal, which can be challenging. According to J. Waerhaug, complete deposit removal is only achieved in 11 % of the cases (37). As it not only depends on the experience of the practitioner (38), but as well on the distance of the calculus from the cementoenamel junction and location in a furcation area (39). In order to determine if a tooth is considered for extraction, the extend of the furcation involvement must be evaluated. A Class 3 or Class 4 furcation lesion indicates the need for tooth extraction, and the dental practitioner should discuss further treatment with the patient (40). Additionally, the crown-to-root ratio is an important factor in determining the prognosis of periodontally compromised teeth, as periodontitis often affects this ratio (34). An optimal crown-to-root ratio is 2:3 or 1:2 (41). In cases of severe periodontitis, tooth extraction is a treatment option (42). In addition to the treatment options previously mentioned, there are several other methods available for managing the periodontal disease, including surgical periodontal treatment, defect elimination by resection, regenerative procedures, non-surgical periodontal treatment, and maintenance of the area without or with minimal bone resection (43). Since the level, of the alveolar bone support and remaining supragingival tooth structure play a crucial role in determining the treatment outcome, the initial examination should include a radiographic assessment of the bone and the remaining tooth structure (44).

As discussed in chapter 2.1., maintaining periodontal health is heavily reliant in the patient's oral hygiene motivation and their ability to control supragingival plaque. Achieving and maintaining a low OHI is important for not only slowing the progression of periodontal disease but also for the success of any periodontal therapy (45). In fact, in 2018 Milosavljevic concluded that the patient's self-awareness and oral hygiene practice are factors that are easier to control in comparison to a successful mechanical infection control (46).

4. Short description of main tooth restoration options - fixed partial dentures, removable partial dentures, implants

During the decision-making process which treatment option would be the most favorable, several factors should be taken into consideration. If there is no possibility to preserve at least 1.5 mm of the vertical dentinal wall reaching a ferrule, extraction of the affected tooth is indicated. This can be followed by fixed partial dentures (FPD), removable partial dentures (RPD), or implant placement to restore function and aesthetics (34). To be able to prepare FPD, the abutment teeth should ideally have a crown-to-root ratio 2:3 or 1:2 (41). According to literature, the abutment teeth supporting FPD carry more occlusal load than teeth with only single crowns (47, 48, 49). Though, the highest occlusal load from all prosthetic appliances is carried by abutments of RPD (50). It is important for dental practitioners to be aware that the abutment tooth in bounded edentulous spaces with a distal-extension partial denture design are subjected to higher axial and nonaxial loads (51). As a result, these abutments should be carefully examined both clinically and radiographically to assess their risk of fracture, mobility, or worsening of existing periodontal pathologies (52).

5. Implantation methods: History of Dental Implants

57 years ago, in 1965, Brånemark *et al.* marked a new area in dentistry, by placing the first dental implant in the human oral cavity to improve chewing function and esthetics (53). It was the first well-documented and maintained implant placement by this time. The placement of 4 cylindric titanium screws into the jaw by Brånemark was a significant success as not only were they integrated within a period of 6 months but remained in place for 40 years. He discovered the remarkable integration of titanium into bone accidentally while attempting to remove a titanium chamber that had been placed into a rabbit´s femur (53).

Since then, several aspects integral to osseointegration and bone preservation have been developed, such as surface coatings, implant shape, and soft and hard tissue biology. As osseointegration is crucial for implant success, the purpose of the materials used is to connect

as much bone to the implant surface. Titanium is currently the most commonly used material for dental implants. Once inserted, osteoclasts begin to resorb the existing osteons, and osteoblasts begin to grow the next generation of osteons, leading to osseointegration. In addition, titanium screws can be coated with nanocomposites, which contribute to bioactivity and anti-infectious osseointegration (54).

6. Clinical presentation of pathology or condition

6.1. Physiologic Bone loss vs. Bone loss after implantation

Physiologic bone loss after extraction is an inevitable biologic process, which is influencing the success rates of dental implants. The prevalence of bone loss around preserved teeth are significantly lower, which may be a factor to consider tooth extraction and implant placement versus tooth preservation. However, implant placement has become a common practice. To define a successful implantation, two criteria are commonly used in studies: the physical stability of the implant and a stable bone level over time (55).

In 2003, a prospective cohort study (56) was conducted with 112 implants to determine the success of an implant placement based on specific criteria. The criteria for successful implant included a pocket probing depth, (PPD) ≤ 5mm, no bleeding on probing (BOP) and an annual bone loss of < 0.2 mm. The study found that 52.4% of implants in patients with a history of periodontitis (A) and 79.1% of implants in patients without periodontitis (B) were successful. However, determining whether an implant is considered a success or failure can be highly subjective. The study also found that the success rate increased significantly to 81% (A) and 96.7% (B) when the threshold was set at a PPD ≤ 6mm and no BOP. Therefore, the criteria used to define a successful implant placement play an important role in determining its success (56).

In their study, M. Dierens and colleagues (57) conducted a retrospective analysis of 134 patients in the control group and 50 patients in the investigation group who were clinically examined. The research team defined treatment success as having a probing depth of ≤ 5 mm and ≤ 2nd thread. Their analysis revealed that 76.3% of patients met both success criteria. In 2010, Bergenblock *et al.* (57) carried out a study on 57 patients with Brånemark system implants (Nobel Biocare, Zurich) over a 5-year prospective and 15-year retrospective period. The success of the implants was evaluated solely based on their physical survival in the oral cavity, resulting in a high success rate of 96.8%. In contrast, J. Da Silva (1) conducted a study on 922 patients with a mean follow-up time of 4 years, which showed a lower physical survival rate of

93% (CI: 91.4% to 94.7%). This difference in survival rates may be attributed to the larger number of implants included in Da Silva's study and the fact that it was conducted in general dental practices rather than academic or specialty dental offices. Furthermore, B. Pjetursson's study in 2012 (58) with a 5-year follow-up time demonstrated significantly higher ($p > 0.01$) survival rates of 95.6% (CI: 94.4% to 96.6%) in academic research-based settings compared to Da Silva's results.

To evaluate the long-term survival rate of implants over a 10-year period, numerous studies have been conducted, using the criterium of an implant remaining in place to define success. For this thesis, three systematic reviews published between 2004 and 2016 were chosen (58, 59, 60). The drawback of conducting long-term studies is the significant reduction in the number of participants over time, a phenomenon referred to as attrition. This can lead to a decrease in the informative value of the study, and studies with missing follow-up data exceeding 20% are more likely to be biased in their results (61). However, the three systematic reviews selected for this thesis reported missing data as "missing at random", which makes them less prone to bias

Pjetursson *et al.* 2012 (58), reported a 10-year implant survival rate of 93.1% (95% CI: 90.5% to 95.5%). It is noteworthy that their previous systematic review (Pjetursson *et al.,* 2004) showed a slightly lower success rate of 92.8% (95% CI: 90% to 94.8%). However, the difference in success rates was not statistically significant ($p < 0.001$).

In one of the more recent systematic reviews from 2016, the long-term survival rate of the implants was 95% (95% CI: 91.8 % to 100.0%) (60). During the bibliographic review conducted for this thesis, the only long-term study that reported significantly lower survival rates was conducted by D. Schwartz-Arad in 2005 (61). This study analyzed implant-supported maxillary overdentures and reported a survival rate of 87.3%.

6.2 Peri-implant Mucositis and Peri-implantitis

In addition to the favorable survival rates of dental implants, pathologic conditions such as peri-implant mucositis and peri-implantitis can occur after implant placement. Peri-implant mucositis is characterized by a plaque-related inflammatory soft tissue infiltration, without concomitant loss of peri-implant bone tissue, and can be assessed by BOP (62). Peri-implantitis is an “irreversible inflammatory disease that leads to the destruction of the supporting tissues around implants” (62). The supporting tissues are hard tissue (bone) and soft tissue (mucosa). It combines mucosal inflammation with detectable bone loss over 0.5mm; exceeding the

measurement error (63). To differentiate peri-implantitis from perimucositis, it is necessary to identify any hard tissue loss through radiographic examination, as both diseases are characterized by soft tissue swelling, redness, and bleeding on probing (BOP). Scientific studies both preclinical and clinical, indicate that an alteration in crestal bone level is a characteristic of peri-implantitis, often coinciding with an increase in probing depth (64,65). A systematic review conducted in 2015 demonstrated that over 50% of patients exhibited mucositis, and peri-implantitis affected 28% to 56% of patients (55). Moreover, this study suggested that the duration of implant function is positively correlated with the likelihood of developing peri-implantitis (55). In a Swedish study by Derks *et al.* conducted in 2016, 32% of implants developed peri-implant mucositis, 45% developed peri-implantitis and 14.5% developed moderate to severe peri-implantitis with bone loss of more that 2 mm. Derks *et al.* conducted a 9-year study and estimated that patients with periodontitis, more than 4 implants, implants of certain brands, and prosthetic therapy delivered by general practitioners have a higher probability of developing moderate to severe peri-implantitis. The study found that the Straumann Dental Implant System had the best outcome in terms of periodontal health (odds ratio 1), followed by the Astra Tech Implant System (odds ratio 3.55) and the Brånemark System, Replace Select (odds ratio 3.77) (63).

7. Discussion

7.1. Tooth preservation studies vs implant placement

Currently, dental implant placement is a commonly accepted treatment option, supported by evidence-based high survival rates (55). The standard conservative treatment options for nonvital teeth are endodontic treatment, endodontic retreatment, or implant placement. During primary evaluation and subsequent treatment recommendations, the dentist should propose a treatment option based on cost efficacy (66), the amount of tooth structure left (67) and the patient's preferences. As periapical pathology is influencing the treatment outcome and success rate of the treated teeth, it is integral to eliminate the periapical inflammation while removing the pulp in time (55). As previously stated, the success rates of teeth without periapical lesions range from 82.8% to 97.3% (28, 29, 30). On the other hand, teeth with apical periodontitis have a success rate of 75.6% to 87.77% (28, 29, 30). Several studies have compared the success rates of implants and endodontically treated teeth, revealing similar success rates (68, 69). Hannahan and Eleazar estimated the success rate for implant treatment to be 87.5 % and the success rate for endodontic treatment to be 90.2 % (68). The study by Doyle *et al.* showed similar results

(69). Therefore, it appears that there are comparable clinical outcomes between endodontic treatment and implant placement in terms of success, survival, and failure rates (67). However, two studies conducted by M. Torabinejad *et al.* (31) and S. Friedman (32) compared the survival rates of implants and endodontically treated teeth and reported significantly higher survival rates for implants: 97% (31) and 99% (32), respectively. In their studies, the survival rate for endodontically treated teeth without periapical pathology was reported to be 92%. Thus, the lack of standardized assessment criteria among articles seems to be the primary issue.

Periodontal health is a significant factor in maintaining tooth stability in a healthy environment, and different types of periodontitis are considered risk factors for tooth preservation. Periodontitis is a chronic, multifactorial inflammatory disease associated with dysbiotic plaque biofilms, leading to non-resolving and destructive inflammatory responses that progress through periodontal attachment and bone loss (6). From an epidemiological perspective, periodontitis is a leading cause of tooth loss (20) and is particularly prevalent in individuals aged 65-74 years (70). In general, it has been reported that 35% of adults will develop periodontitis at some point in their lifetime, and a subset of 10% to 15% will experience severe periodontitis resulting in significant clinical attachment loss (62). As such, identifying and addressing factors that contribute to the development of periodontitis is a public health concern. During a 16-year period of supportive periodontal therapy (SPT), Graetz *et al.* (21) conducted a study to determine the survival rates of hopeless teeth (70% bone loss) or questionable teeth (50 to less than 70% bone loss). The team evaluated the pocket probing depth (PPD), radiographic tooth loss, and reasons for extraction. Data analysis revealed no significant differences between mean tooth loss per year for aggressive periodontitis (AgP) and chronic periodontitis (0.14 and 0.16 teeth/year, respectively). However, the tooth loss rate of patients with AgP was 11.8% (89.2% success rate) for questionable teeth and 40.5% (59.5% success rate) for hopeless teeth. Quite similar results were seen in patients with chronic periodontitis (CP) around 20.4% of questionable teeth and 34.3% of hopeless teeth were lost (21).
Hence, the results suggest that with situation-dependent appropriate treatment, it is possible to preserve hopeless and questionable teeth in cases of severe chronic or aggressive periodontitis over 15 years. This is especially true for questionable teeth, with a higher chance of success. Supportive periodontal treatment options such as subgingival scaling, root planning, and open flap debridement could be considered. These results would indicate a higher success rate of implant placement compared with conservative treatment of periodontitis patients. A more

recent study published in 2017 by the same research team confirmed the previous findings of Graetz *et al.* and suggested that extraction of teeth with advanced bone loss should be postponed. This is because early extraction reduces the likelihood of prosthetic treatment, which subsequently increases the risk of further tooth loss. The study found that teeth treated with prosthetic devices are at a higher risk of being lost during supportive periodontal therapy compared to non-prosthetically treated teeth (71).

From a general perspective, strategic and proactive tooth extraction can be considered as a preventive approach to avoid further bone loss. However, N. Donos and colleagues (72) pointed out that even with preventive measures such as alveolar bone preservation techniques or immediate implant placement, tooth extraction can result in alveolar bone resorption.

An alternative treatment option for periodontally affected teeth would be extraction followed by dental implant placement. However, the question arises as to whether periodontitis patients should be treated with implants, given the potential risk factors for implant failure mentioned earlier (63).

7.2. Reason for implant failure

In 2013, Koyanagi *et al.* conducted a bacteriological study and found that periodontitis and periimplantitis have similar microbial colonization (73). Both periodontal pockets around implants and teeth provide a suitable environment for microbial growth and differentiation. The study collected subgingival biofilm samples from the deepest pockets in periodontitis and periimplantitis and identified 333 species, with 192 from periimplantitis sites and 148 from periodontitis sites. Although periimplantitis had a more diverse and complex microbiota than periodontitis, *Fusobacterium spp. and Streptococcus spp*. were the predominant bacteria found in both diseases. Two studies conducted in 2010 indicated that there was no significant difference in rates of periimplantitis and dental implant failure between patients with or without periodontitis (74, 75). However, bacterial colonization is not the only factor that can contribute to the development of periimplantitis in the long run. Host response can also play a role, as a 2013 study found that it could lead to lower implant survival rates (76). Furthermore, one year before, in 2012, two studies from M. Laine *et al.* and W. Luo *et al.* (77, 78) identified a correlation between periodontitis and several host susceptible genes as interleukin-1, interleukin-6, tumor necrosis factor-alpha and transforming growth factor beta 1 (77, 78). In addition, researchers investigated the connection between these specific genes and implant failure. They stated that these genes could be linked with periimplantitis too (79, 80, 81). Considering the findings of M. Laine *et al.* (77) and W. Luo *et al.* (78) and Koyanagi *et al*. (73),

it is imperative to perform a comprehensive and precise evaluation of patients with a history of periodontitis to identify their likelihood of experiencing implant loss in the future. Furthermore, it is crucial to determine the rate and timeline of potential implant loss, as well as the expected periodontal stability following implant placement. Additionally, it is important to consider if the type of periodontitis they have may affect the likelihood of implant survival. Hence, X. Wen *et al.* (62) conducted a meta-analysis to figure out the effect of a history of different periodontitis types on implant survival rates. After analyzing the gathered data, the researcher determined that the long-term outcome of dental implants is significantly impacted by aggressive periodontitis, particularly within 101 to 200 months of follow-up, as compared to a healthy periodontium (Risk ratio = 1.03, Confidence interval 0.99 to 1.06). However, no significant difference between healthy and pathologic periodontium was observed after a 100-month follow-up. Although the effect of periodontitis on implant survival rate remains a controversial topic, the current meta-analysis conducted by X. Wen *et al.* (62) is considered a reliable source due to its inclusion of 13 publications and sufficient follow-up periods, ranging from 24 months to 192 months. This study provides valuable information for dental professionals to evaluate the implant survival rate for specific cases by comparing and differentiating between various types of periodontitis (chronic, aggressive, moderate, severe, treated or history). Using a meta-analysis approach to analyze the effect of periodontitis on implant survival rates is appropriate because it allows for the inclusion of a large number of studies and the ability to update data over time.

Based on current research, it appears that managing the expectations of patients with aggressive periodontitis regarding implant survival is important.

Given the ongoing bone loss that is associated with periodontitis, researchers have investigated the potential risks of infrabony defects and their impact on tooth survival. One of the key concerns is whether the bone level will continue to decrease with disease progression and whether this affects the survival of the tooth. In retrospective studies conducted by Muzzi *et al.* (82) and Samet *et al.* (83), it was suggested that the preservation of hard tissues is an important factor in successful tooth retention. They predicted tooth loss by comparing radiographic and clinical data, with Muzzi *et al.* also examining the influence of the infrabony component of the defect. They found that higher levels of bone regeneration during implant placement can serve as a preventive method to tooth loss.

7.3. New predictors of implant survival rates

Besides the most known and previously analyzed factors causing periodontitis and periimplantitis, some newer studies focused on co-factors, which can be described as the phenomena of our time. They were discovered recently in 2022 by F. D'Ambrosio *et al.* such factors are stress and depression (84).

Nowadays burnouts, constant comparison via social media, and permanent availability are yet the order of the day. As a result, depressive disorders are among the most common psychiatric diseases (85). According to a study conducted in 2015 by the American Psychological Association, 25% to 28% of the American population experience chronic stress (86). If stress occurs over a long period of time or very frequently, the human "system" becomes exhausted. This can result in inter alias in depression. As rising evidence implies this chronic stress behavior can not only have neurobiological and neurobehavioral pathogenic implications but can putatively lead to a periodontal immune-microbiome unbalance (86).

Some studies had a hypothesis that during COVID-19 times, the manifestations of oral diseases such as necrotizing periodontal and mucosal lesions increased, due to the unclear straining situation with consequently raised stress levels (84). The elevated stress levels are followed by a change of neurobiological, neurobehavioral, and microbial processes. Consequently, raised glucocorticoids, especially cortisol levels, lead to the activation of pathological processes and disturbed homeostasis in the body and similarly delay periodontal wound healing. Therefore, it can lead to even worse periodontal pathology due to cytokine modulation (87). In addition to that, Cirillo *et al.* (38) discovered the physiological secretion of cortisol from keratinocytes originally from periodontal and peri-implant tissue as their autocrine agent for soft tissue homeostasis. Besides increased cortisol levels, stress interferes psychologically in adrenergic nerve signaling processes which decrease the vascularization of smooth muscles of periodontal tissue, reducing wound healing and nutrient supply (86, 89). Neurobehavioral changes of depression are poor oral hygiene (90) and lead to anxiety which is connected to health-damaging behaviors like tobacco smoking, diets with high carbohydrate load, and alcohol consumption starting a cascade of inflammatory processes like the onset, progression of periodontitis, microbiome dysbiosis, and tooth loss (90, 91, 92, 93).

8. Conclusion

Within the limitations of this thesis, the results of this systematic review show, that in most chosen studies, implant survival rates exceed those of compromised teeth. When treated and maintained adequately, teeth without periapical pathology have in some studies almost the same

successful outcomes as implants. The lack of consistency in the literature can be attributed to variations in research settings. Nevertheless, these findings support the notion that the decision to extract a tooth and place a dental implant should be made with caution. Even when a tooth seems to be compromised and requires treatment to be maintained, implant treatment also might require additional surgical procedures followed by the possibility of peri-mucositis or periimplantitis. Additionally, it should be noted that while teeth can be extracted and replaced with dental implants at any time, extraction is a definitive and irreversible procedure. Therefore, it is important to carefully consider all treatment options, including endodontic, prosthetic, and/or periodontal treatments, before making a decision. However, it should be noted that preserving teeth for a longer period of time may come with an increased cost and time commitment, as well as potentially decreased patient motivation.

Preventing periodontitis is crucial for tooth preservation, as it is a leading cause of tooth loss and a global public health issue that affects 1 out of 10 adults. Dental practitioners need to increase patient awareness of periodontal pathology and strategies for prevention, as there is currently limited political engagement on this issue. Not only do individuals have to raise their awareness of their actions and the periodontal health implications, but the public health system should foster more systematic prevention and education and investigate this issue further. Several actions could be applicable. Among others, good initial documentation with regular X-rays and annual probing are important components of supportive aftercare for periodontitis and implant patients. In this way, progressing diseases like periodontitis or peri-implant inflammation can be recognized and treated as early as possible. Additionally, it should be mentioned that shared decision making is significant as it brings both the parties on the same page through negotiation.

9. Bibliography

(1) Da Silva J, Kazimiroff J. Outcomes of implants and restorations placed in general dental practices: a retrospective study by the Practitioners Engaged in Applied Research and Learning (PEARL) Network. J. Am. Dent. Assoc. 2014 Jul;145(7):704–713.

(2) Seerig LM, Nascimento GG, Peres MA, Horta BL, Demarco FF Tooth loss in adults and income: systematic review and meta-analysis. Journal of Dentistry. 2015 Sep;43(9):1051–1059.

(3) Thomson WM, Sheiham A, Spencer AJ. Sociobehavioral aspects of periodontal disease. Periodontology 2000. 2012 Aug 22;60(1),54–63.

(4) Anner R, Grossmann Y, Anner Y. 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. 2010 Feb ;19(1):7–64.

(5) Eke PI, Wei L, Borgnakke WS, Thornton-Evans G, Zhang X, Lu H, McGuire LC, Genco RJ. Periodontitis prevalence in adults ≥ 65 years of age, in the USA. Periodontol 2000. 2016 Aug 16;72(1):76–95.

(6) Genco R. Clinical and public health implications of periodontal and systemic diseases: An overview. Periodontology 2000. 2020 May 08; 81(1):7–13.

(7) Soory M. Association of periodontitis with rheumatoid arthritis and atherosclerosis: Novel paradigms in etiopathogeneses and management? Open Access Rheumatol. 2010 Dec 21; 2:1–16.

(8) Sert T, Kırzıoğlu FY, Fentoğlu O, Aylak F, Mungan T. Serum placental growth factor, vascular endothelial growth factor, soluble vascular endothelial growth factor receptor-1 and -2 levels in periodontal disease, and adverse pregnancy outcomes. J.Periodontol. 2011 Dec 01;82(12):1735–1748.

(9) Di Spirito F, Schiavo L, Pilone V, Lanza A, Sbordone L, D'Ambrosio F. Periodontal and peri-implant diseases and systemically administered statins: A systematic review. Dent. J. 2021 Sep 04; 9(9):100.

(10) Di Spirito F, Sbordone L, Pilone V, D'Ambrosio F. Obesity and Periodontal Disease: A Narrative Review on Current Evidence and Putative Molecular Links. Open Dent. J. 2019 Dec 12;13:526–536.

(11) Elemek E, Almas K, Multiple sclerosis and oral health: An update. N. Y. State Dent. J. 2013 Apr:79:16–21.

(12) Di Spirito F, La Rocca M, De Bernardo M, Rosa N, Sbordone C, Sbordone L. Possible Association of Periodontal Disease and Macular Degeneration: A Case-Control Study. Dent. J. 2020;9(1):1.

(13) Di Spirito F, Toti P, Pilone V, Carinci F, Lauritano D, Sbordone L. The Association between Periodontitis and Human Colorectal Cancer: Genetic and Pathogenic Linkage. Life. 2020 Dec 22;10(1):211.

(14) Mehrotra N, Singh S. Periodontitis. StatPearls Publishing. 2022 May 08.

(15) Jørgen Slots Periodontitis: facts, fallacies and the future Periodontology 2000. 2017 Jul 31;75(1):7–23.

(16) Herrera D, Retamal-Valdes B, Alonso B, Feres M. Acute periodontal lesions (periodontal abscesses and necrotizing periodontal diseases) and endo-periodontal lesions. Journal of Clinical Periodontology. 2018 Jun 20;45(S20):S78-S94.

(17) Marcenes W, Kassebaum NJ, Bernabé E, Flaxman A, Naghavi M, Lopez A, Murray CJL. Global burden of oral conditions in 1990–2010: a systematic analysis. Journal of Dental Research. 2013 Apr 20;92(7):592–597.

(18) Vos T, Abajobir AA, Abate KH. Global, regional, and national incidence, prevalence, and years lived with disability for 328 diseases and injuries for 195 countries, 1990–2016: a systematic analysis for the Global Burden of Disease Study 2016. The Lancet. 2017 Sep 16;390(10100):1211–1259.

(19) Tiburcio-Machado C, Michelon C, Zanatta FB, Gomes MS, Marin JA, Bier CA. The global prevalence of apical periodontitis: a systematic review and meta-analysis Internat. Endodontic Journal. 2021 Dec 30;54(5):715–735.

(20) Papapanou P, Susin C. Periodontitis epidemiology: Is periodontitis underrecognized, over-diagnosed, or both? Periodontol. 2000. 2017 July 31;75(1):45–51.

(21) Graetz C, Dörfer CE, Kahl M, Kocher T, Fawzy El-Sayed K, Wiebe J, Gomer K, Rühling A. Retention of questionable and hopeless teeth in compliant patients treated for aggressive periodontitis Jour Clinic Periodontology. 2011;38(8):707–714.

(22) Bouziane A. Global prevalence of aggressive periodontitis: A systematic review and meta-analysis. JOP. 2020;47(4):406–428.

(23) Eke PI, Dye BA, Wei L, Slade GD, Thornton-Evans GO, Borgnakke WS, Taylor GW, Page RC, Beck JD, Genco RJ. Update on prevalence of periodontitis in adults in the United States: NHANES 2009 to 2012. J Periodontol. 2015 May 01;86(5):611–622.

(24) Holtfreter B, Kocher T, Hoffmann T, Desvarieux M, Micheelis W. Prevalence of periodontal disease and treatment demands based on a German dental survey (DMS IV). J Clin Periodontol. 2010 Feb 01;37(3):211–219.

(25) Zhan Y, Holtfreter B, Meisel P, Hoffmann T, Micheelis W, Dietrich T, Kocher T. Prediction of periodontal disease: modelling and validation in different general German populations. J Clin Periodontol 2014 Dec 06; 41(3):224–231.

(26) Lamster IB, Asadourian L, Del Carmen T, Friedman PK. The aging mouth: differentiating normal aging from disease. Periodontol 2000. 2016 Aug 08;72(1):96–107.

(27) Persson GR. Dental geriatrics and periodontitis. Periodontol 2000. 2017 Apr 21;74(1):102–115.

(28) Ng YL, Mann V, Gulabivala K. A prospective study of the factors affecting outcomes of nonsurgical root canal treatment: part 1: periapical health. Int Endod J. 2011 Mar 02;44(7):583–609.

(29) Ricucci D, Russo J, Rutberg M, Burleson J. A prospective cohort study of endodontic treatments of 1,369 root canals: results after 5 years. Oral Surg Oral Med Oral Pathol Oral Radiol Endod. 2011 Dec;112 (6):825-842.

(30) Ferrari M, Vichi A, GM Fadda GM. A randomized controlled trial of endodontically treated and restored premolars. J Dent Res. 2012 Jul;91:72–78.

(31) Torabinejad M, Charles J. Endodontic or dental implant therapy: the factors affecting treatment planning. J Am Dent Assoc. 2006;137:973–977.

(32) Friedman S, Abitbol S, Lawrence HP. Treatment outcome in endodontics. J Endod. 2003;29:787–793.

(33) Moghaddam A, Radafshar G. Long-term survival rate of teeth receiving multidisciplinary endodontic, periodontal and prosthodontic treatments. Jour Oral Rehabilitation. 2014 Feb 02;41(3):236–242.

(34) Sayed ME, Jurado1 CA, Tsujimoto A. Factors Affecting Clinical Decision-Making and Treatment Planning Strategies for Tooth Retention or Extraction: An Exploratory Review Nigerian Journal of Clinical Practice. 2020;23(12):1629–1638.

(35) Ng YL, Mann V, Gulabivala K. Tooth Survival after root canal treatment. Int Endod J. 2010 Feb 08;43(3):171–189.

(36) Herbert TS, David AS, Edvin LW, Joseph RC, Donald LM, Louis JB, James CK. Fundamentals of Fixed Prosthodontics, 4th ed. New Malden, Surrey, UK: Quintessence Pub. Co; 2012.

(37) Waerhaug J. Healing of the dento-epithelial junction following subgingival plaque control. II: As observed on extracted teeth. J Periodontol. 1978;49:119–134.

(38) Brayer WK, Mellonig JT, Dunlap RM, Marinak KW, Carson RE. Scaling and root planing effectiveness: the effect of root surface access and operator experience. J Periodontol. 1989;60:67–72.

(39) Richardson AC, Chadroff B, Bowers GM. The apical location of calculus within the intrabony defect. J Periodontol. 1990;61:118–122.

(40) Avila G, Galindo-Moreno P, Soehren S, Misch CE, Morelli T, Wang HL. A novel decision-making process for tooth retention or extraction. J Periodontol. 2009;80:476–491.

(41) Tada S, Allen PF, Ikebe K, Zheng H, Shintani A, Maeda Y. The impact of the crown-root ratio on survival of abutment teeth for dentures. J Dent Res. 2015;94(9 Suppl):220S-5S.

(42) Nemovsky CE, Sculean A. Evidence-based decision making in periodontal tooth prognosis and maintenance of the natural dentition. Evidence-Based Decision Making in Dentistry. Springer. 2017:39-59.

(43) Sayed ME. Clinical Decision Support System for Tooth Retention or Extraction. The State University of New Jersey; 2017.

(44) Lang-Hua BH, McGrath CPJ, Lo ECM, Lang NP. Factors influencing treatment decision-making for maintaining of extracting compromised teeth. Clin Oral Implants Res. 2014;25(1):59-66.

(45) Deas DE, Moritz AJ, Sagun SR, Gruwell SF, Charles A. Powell Scaling and root planing vs. conservative surgery in the treatment of chronic periodontitis. Periodontology 2000. 2016;71(1):128-139.

(46) Milosavljevic A. Periodontal treatment strategies in general dentistry. Malmö university; 2018.

(47) Shillingburg HI, Hobo S, Whitsett LD, Brackett SE. Fundamentals of Fixed Prosthodontics, ed, St. Louis, MO. Elsevier Mosby.1997;10:40.

(48) Shillingburg HI, Hobo S, Whitsett LD, Brackett SE. Fundamentals of Fixed Prosthodontics, ed, St. Louis, MO. Elsevier Mosby.1997;10:40.

(49) Pol CW, Raghoebar GM, Kerdijk W, Boven GC, Cune MS, Meijer HJA. A systematic review and meta-analysis of 3-unit fixed dental prostheses: Are the results of 2 abutment implants comparable to the results of 2 abutment teeth? J Oral Rehabil. 2018;45:147–60.

(50) Liang S, Zhang Q, Witter DJ, Wang Y, Creugers NH. Effects of removable dental prostheses on masticatory performance of subjects with shortened dental arches: A systematic review. J Dent. 2015;43:1185–94.

(51) Mizuuchi W, Yatabe M, Sato M, Nishiyama A, Ohyama T. The effects of loading locations and direct retainers on the movements of the abutment tooth and denture base of removable partial dentures. J Med Dent Sci. 2002;49:11-18.

(52) Ettinger RL, Qian F. Abutment tooth loss in patients with overdentures. J Am Dent Assoc. 2004;135:739-46; quiz 795-6.

(53) Abraham C. A Brief Historical Perspective on Dental Implants, Their Surface Coatings and Treatments. Open dent Journal. 2014 May 16;8(1):50–55.

(54) Kandavalli S. A Brief Review on the Evolution of Metallic Dental Implants: History, Design, and Application. Frontiers in materials. Frontiers. 2021 May 13;8, 646383.

(55) Chercoles-Ruiz A, Sanchez-Torres A, Gay-Escoda C. Endodontics, Endodontic Retreatment, and Apical Surgery Versus Tooth Extraction and Implant Placement: A Systematic Review. J Endodontics. 2017 May;43(5):679–686.

(56) Karoussis I, Salvi GE, Heitz-Mayfield LJA. Long-term implant prognosis in patients with and without a history of chronic periodontitis: a 10-year prospective cohort study of the ITI® Dental Implant System. Clinical Oral implant research. 2003 May 20;14(3):329-339.

(57) Dierens M, Vandeweghe M, Kisch J, Nilner K, De Bruyn H. Long-term follow-up of turned single implants placed in periodontally healthy patients after 16–22 years: radiographic and peri-implant outcome. Clin Oral Implant Research. 2011;23(2):197–204.

(58) Pjetursson BE, Thoma D, Jung R, Zwahlen M, Zembic A. 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. 2012 Oct 12;23(1):22–38.

(59) Pjetursson BE, Tan K, Lang NP, Bragger U, Egger M, Zwahlen M. A systematic review of the survival and complication rates of fixed partial dentures (FPDs) after an observation period of at least 5 years. I. Implant-supported FPDs. Clin. Oral Implants Res. 2004 Oct 12;15(6):625–642.

(60) Hjalmarsson JT, Gheisarifar M. 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 Implant. 2016;9(Suppl1):155–163.

(61) Heneghan C, Goldacre B, Mahtani KR. Why clinical trial outcomes fail to translate into benefits for patient trials, Trials. 2017 Mar 14;18(122):122.

(62) X. Wen, R Lui, G Li, M Deng, L Liu, XT Zeng, X Nie. History of Periodontitis as a Risk Factor for Long-Term Survival of Dental Implants: A Meta-Analysis. International journal of oral and maxillofacial implants. 2014;29(6):1271–1280.

(63) Derks J, Schaller D, Håkansson J, Wennstöm JL, Tomasi C, Berglundh T. Effectiveness of implant therapy analyzed in a Swedish population: prevalence of peri-implantitis. J Dent Res. 2016;95(1):43–49.

(64) Renvert S, Persson G, Pirih FQ, Camargo MP. Peri-implant health, peri-implant mucositis, and peri-implantitis: Case definitions and diagnostic considerations. J. Clin. Periodontol. 2018 Jun 20;45(S20):S278–S285.

(65) Berglundh T, Armitage G, Araujo M. 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. Clin. Periodontol. 2018 Jun 21;89(S1):286–291.

(66) Torabinejad M, Lozada J, Puterman I, White SN. Endodontic therapy or single tooth implant? A systematic review. J Calif Dent Assoc. 2008 Jun 1;36(6):429–437.

(67) Vozza I, Barone A, Quaranta M, De Paolis G, Covani U, Quaranta A. A comparison between endodontics and implantology: an 8-year retrospective study. Clin Implant Dent Relat Res. 2013 Nov 14;15(1):29–36.

(68) Hannahan JP, Eleazer PD. Comparison of success of implants versus endodontically treated teeth. J Endod. 2008 Nov;34 (11):1302–1305.

(69) Doyle SL, Hodges JS, Pesun IJ, Law AS, Bowles WR. Retrospective cross sectional comparison of initial nonsurgical endodontic treatment and single-tooth implants. J Endod. 2006 Sept;32(9):822-827.

(70) World Health Organization. World Oral Health Report 2018/2019; World Health Organization: Geneva, The Switzerland; Available online: (accessed on 31 December 2022)

(71) Graetz C, Sälzer S, Plaumann A, Schlattmann P, Kahl M. Springer C, Dörfer C, Schwendicke F. Tooth loss in generalized aggressive periodontitis: Prognostic factors after 17 years of supportive periodontal treatment. J. Clin. Periodontol. 2017 Mar 27;44(6):612–619.

(72) Donos N, Laurell L, Mardas N. Hierarchical decisions on teeth vs. implants in the periodontitis-susceptible patient: The modern dilemma. Periodontol. 2000. 2012 Apr 17;59(1):89–110.

(73) Koyanagi T, Sakamoto M, Takeuchi Y. Comprehensive microbiological findings in peri-implantitis and periodontitis. J Clin Periodontol. 2013 Nov 26;40(3):218–226.

(74) García-Bellosta S, Bravo M, Subirá C, Echeverría JJ. Retrospective study of the long-term survival of 980 implants placed in a periodontal practice. Int J Oral Maxillofac Implants. 2010;25(1):613–619.

(75) Anner R, Grossmann Y, Anner Y. 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. 2010 Feb ;19(1):7–64.

(76) Costa FR, Alvim-Pereira CC, Alvim-Pereira F. Influence of MMP-8 prompter polymorphism in early osseointegrated implant failure. Clin Oral Investig. 2013 Mar 02;17:311–316.

(77) Luo W, Wang CY, Jin L. Baicalin Porphyromonas gingivalis lipopolysaccharide-unregulated IL-6 and IL-8 expression in human oral keratocytes by negative regulation of TLR signaling. PLoS One. 2012 Dec 11;7:e51008.

(78) Laine ML, Crielaard W, Loos BG Genetic susceptibility to periodontitis. Periodontol 2000. 2012 Dec 01;58(1):37–68.

(79) Dos Santos MC, Campos MI, Souza AP. Analysis of the transforming growth factor-beta 1 gene promoter polymorphisms in early osseointegrated implant failure. Implant Dent. 2004 Sep;13(3):262–269.

(80) Campos MI, Godoy dos Santos MC, Trevilatto PC. Interleukin-2 and gene promoter polymorphisms, and early failure of dental implants. Implant Dent. 2005 Dec;14(4):391–396.

(81) Hamdy AA, Ebrahem MA. The effect of interleukin-1 allele 2 genotype (IL-1a(-889) and IL-1b (+3954) on the individual's susceptibility to peri-implantitis: Case-control study. J Oral Implantol. 2011;37(3):325–334.

(82) Muzzi L, Nieri M, Cattabriga M, Rotundo R, Cairo F, Prato Gpp. The Potential Prognostic Value of Some Periodontal Factors for Tooth Loss: A Retrospective Multilevel Analysis on Periodontal Patients Treated and Maintained Over 10 Years. Journal of Periodontology. 2006 Dec 01;77(12):2084–2089.

(83) Samet N, Jotkowitz A. Classification and prognosis evaluation of individual teeth – a comprehensive approach. Quintessence international. 2009 May;40(5):377–387.

(84) D'Ambrosio F, Caggiano M. Chronic Stress and Depression in Periodontitis and Peri-Implantitis: A Narrative Review on Neurobiological, Neurobehavioral and Immune–Microbiome Interplays and Clinical Management Implications. Dentistry Journal. 2022 March 18;10(3):49.

(85) Beurel E, Toups M, Nemeroff C The Bidirectional Relationship of Depression and Inflammation: Double Trouble. Neuron. 2020 July 22;107(2): 234–256.

(86) Decker A, Kapila YL, Wang HL. The psychobiological links between chronic stress-related diseases, periodontal/peri-implant diseases, and wound healing. Periodontol. 2000. 2021 Aug 31; 87(1):94–106.

(87) Warren K, Postolache TT, Goer ME, Pinjari O, Kelly DL, Reynolds MA. Role of chronic stress and depression in periodontal diseases. Periodontol. 2000. 2014 Dec 09; 64(1):127–138.

(88) Cirillo N, Prime SS. Keratinocytes synthesize and activate cortisol. J. Cell. Biochem. 2011 Feb 22; 112(6):1499–1505.

(89) Prete A, Taylor AE, Bancos I, Smith DJ, Foster MA, Kohler S, Fazal-Sanderson V, Komninos J, O'Neil DM, Vassiliadi DA Prevention of adrenal crisis: Cortisol responses to major stress compared to stress dose hydrocortisone delivery. J. Clin. Endocrinol. Metab. 2020 Mar 14;105(7):2262–2274.

(90) Dumitrescu AL. Depression and Inflammatory Periodontitis Considerations. Front.Psychol. 2016:7:347.

(91) Costa FO, Cota LOM Cumulative smoking exposure and cessation associated with the recurrence of periodontitis in periodontal maintenance therapy: A 6-year follow-up. J. Periodontol. 2019 Feb 22;90(8):856–865.

(92) Copeland LB, Krall EA, Brown LJ, Garcia RI, Streckfus CF. Predictors of tooth loss in two US adult populations. J. Public Health Dent. 2004 May 01;64(1):31–37.

(93) Foster JA, Rinaman L, Cryan JF. Stress & the gut-brain axis: Regulation by the microbiome. Neurobiol. Stress. 2017 Dec;7:124–136.

10. Warranty of Vilnius University Student Thesis

Name, Surname: Winona, Brandt-Peukert

Faculty: Medical Faculty

Study program: Integrated studies of dentistry

Thesis topic: Tooth preservation and implant placement - Analysis of long-term tooth and implant survival rates

Thesis type: Narrative Review

I guarantee that my thesis is prepared in good faith and independently, there is no contribution to this work from other individuals. I have not made any illegal payments related to this work. Quotes from other sources used in this thesis, directly or indirectly, are indicated in literature references.

I, [Winona Brandt-Peukert], confirm (check)

I declare that this thesis is submitted to the Vilnius University Study Information System.

(vardas, pavardė / *name, surname*) (parašas / *signature*) (data / *date*)

Embargo period

I am requesting an embargo of this thesis for the period indicated below:

-An *embargo period shall not exceed 60 months];*

-*No embargo requested.*

Reason for embargo period:

.....

.....

(vardas, pavardė / *name, surname*) (parašas / *signature*) (data / *date*)

-Katedros (Padalinio) patvirtinimas, kad atspausdintas baigiamasis darbas buvo pateiktas ir užregistruotas:

(vardas, pavardė) (parašas) (data)