Article

Long-Term Outcomes of Dental Implants: A Comparative Study of Success Rates Across Different Patient Demographics and Implant Types

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Abstract: Over the years, dentistry research showed that the dental implant operation is the best way to replace missing teeth, because they last a long time due to their longevity. It's functional and it looks nice, over the past forty years the state of the art in implants, in materials, the surface, in devices and in designs for prosthetics is improving the aesthetics and clinical effectiveness. The current review evaluates the long-term outcome of dental implants, survival and success rates by demographic (e.g., patient group, implant classification) level, comprehensively in patients. It also integrates information from long-term cohort studies, systematic reviews, and meta-analyses to examine factors influencing implant survival and potential biological or mechanical complications. This includes demographical differences, systemic issues like diabetes and osteoporosis, tobacco use, implant macro- and micro-design and prosthetic considerations. In addition, it has been shown by this review to have a global survival rate over 90–95% above the benchmark of 10 years post diagnosis. Nevertheless, demographic and implant-specific factors are determinants for complication profiles and marginal bone stability. Tailored treatment planning is also essential for implant longevity.

Keywords: Dental implants, implant survival rate, osseointegration, patient demographics, implant design, long-term outcomes

1. Introduction

For more than fifty years, the dental implant is a technique that improves the rehabilitation of the partially or totally edentulous patient by delivering dependable functional and aesthetic results. Brånemark and associates first mentioned osseointegration in the 1960s. Since then, implant dentistry blossomed into a vigorous evidence-based science, relying on long-term clinical research. Recent implant systems have achieved the survival rate greater than 90–95%, with better performance in multiple clinical applications when compared to fixed or removable systems [1,2]. Osseointegration, which is defined as a direct structural and functional connection between the implant surface and viable bone under load and stress, is regarded as the biological basis for implant success [3]. Also, advancements in implant surface technologies including sandblasted, acid-etched (SLA), anodized, and bioactive coatings improved early bone

healing and long-term durability markedly [4]. Furthermore, advancements in implant macro design such as tapered geometries and platform-switching principles have proved effective in facilitating decreases in marginal bone remodeling and soft tissue stability [5]. Although survival is good, the long-term recovery of the implant is not only a matter of the design, but outcome is affected by some patient-related and environmental variables. Age and sex, smoking and other behaviours, social influences such as smoking, as well as systemic conditions in diabetes mellitus and osteoporosis, have been associated with changes to the ability of wounds to heal and to the stability of the peri-implant area, respectively; each of which has been described by [6, 7]. As an example, smoking has been consistently linked to increased marginal bone loss and increased rates of implant failure due to vascularization failure and immune resistance [8]. Improperly controlled diabetes can contribute to increased resistance to wound healing and predispose individuals to the occurrence of peri-implantitis [9]. Peri-implant diseases have emerged as a serious concern in extended implant therapy of a large proportion of patients has a peri-implant mucositis or peri-implantitis and then, chronic investigations indicated that up to 10% to 25% of the treated patients have peri-implantitis [10]. Without appropriate control of these inflammatory diseases it can lead to bone depletion and later implant failure but anatomic position, and osseous quality are some other key parameters which are also related in prognosis of an implant. Implants in the posterior maxilla have reduced survival compared to anterior mandibular implants due to the differences in bone and occlusal loadings between the implants [2]. Similarly, early loading methods that we once thought were not appropriate now yield comparable long-term outcomes once sufficient primary stability has been developed [11]. Since success of the implant depends on many things, it is necessary to consider long-term results in a large context that covers patient characteristics, systemic health, size of the implant and prosthetic structure. Fostering awareness of these factors permits physicians to intervene by developing targeted treatment plans to prevent or prolong morbidity and mortality. Objective: Long-term success rates determined to measure implant durability and complication risk among diverse population and implant types in an evidence-based manner.

2. Methodology

A comprehensive literature review approach was used to assess the long-term implant outcomes and factors affecting implant survival and success rates for various population groups and implant types. A systematic review of the relevant scientific literature was performed using peer-reviewed journals, clinical cohort studies, systematic reviews, and meta-analyses documenting clinical data related to dental implantology. Studies that evaluate implant survival or success criteria as well as biological stability or complications of dental implants with long follow-up (greater than five to ten years) were included. Studies that were included comprised patient-related factors like age, sex, smoking and systemic factors such as diabetes and osteoporosis, which were evaluated for their impact on implant outcomes. Also, literature pertaining to implant-related properties (implant materials, surface modification technologies, macro-design aspects, and loading protocols) was also explored for their contribution to osseointegration and long-term clinical stability. Data from relevant studies were systematically assessed and pooled to enable a comparison of survival and success rates of implants according to implant position and type of patients. The methodology was further associated with the biological factors that are related to bone quality, peri-implant tissue quality, and marginal bone loss, as well as mechanical complications that have an impact on the longevity of the implant. Extracted data were analyzed comparatively and descriptively in order to reveal commonalities, risk factors, and determinants of long implant longevity. The purpose of this study was to combine evidence from distinct clinical investigations to provide a comprehensive account of the role played by patient characteristics, implant design and treatment protocols on long-term outcomes of dental implants and evidence-based

guidance to improve clinical decision-making and personalized planning of dental implant treatment.

3. Results and Discussion

What it means to survive and succeed:

People often use the terms survival and success to describe how well dental implants perform; Implant survival means the implant stays in the jaw despite problems. Success from implants, however, is built on certain criteria. [3] claim success depends on parameters such as lack of discomfort, mobility, and infection, and that marginal bone loss should be kept within an acceptable range. Specifically, marginal bone loss must not exceed 1.5 mm in the first-year post implantation and stay below 0.2 mm per year thereafter. These criteria have become widely accepted in the implant community, and their application in clinical studies, where testing can determine the effectiveness of implants [1, 2]. It is important to understand the distinction between survival and success since an implant has the potential to survive but will still be viewed as a failure if it leads to complications, such as infection, implant movement, or excessive bone loss [3]. Longitudinal studies report implant survival rates typically from 90% to 98% at 5 years, and from 85% to 95% at 10 years [12]. Success rates are often reduced due to issues of, e.g., peri-implantitis, mechanical failure, and soft tissue issues. In fact, in long-term studies peri-implantitis is reported at a rate within 10%-25% and hence there is a drop in the success rate compared to survival rate [10].

Biological basis for long-term implant stability:

To explain, osseointegration is the biological basis of long-term dental implant stability; the direct, solid contact that forms between the implant surface and surrounding bone tissue. Osseointegration allows dental implants to act like natural teeth; providing mechanical support, and also biological connectivity of the process [13]. The surface properties of the implant, bone density at the implant site, and load applied to the implant determines the quality of osseointegration. Big improvements have been made to implant surfaces to improve osseointegration; roughened surfaces (sandblasted and acid-etched (SLA) titanium) give the bone a larger surface area in which to develop and help osteoblasts to adhere to the surface, resulting in faster and more stable integration [9]. Moreover, technologies such as plasma-sprayed coatings and bioactive surface treatments have been adapted to improve osteoconductivity and speed up the healing of the bone [14]. Considering the biologic as well as mechanical aspects, bone resorption might occur at the contact point of implants during the first stage of healing, as remodeling of bone around implants is dynamic. However, over time growth of bone can frequently be a counterbalance to resorption and keep the connective tissue solid. An over-stress or low-quality bone may not be conducive to this balance and lead to problems like marginal bone loss, which is a clear warning of implant failure [15]. Finally, one of the key aspects in ensuring long-term stability of the implants is the peri-implant soft tissue seal, which is well developed such that germs do not enter as peri-implant illnesses such as peri-implant mucositis and peri-implantitis [10] would be unlikely. If, and only if dental implants are properly osseointegrated, bones are remodeled, and soft tissues are healthy, dental implants are effective for a long time.

Survival rates down the line over the long term:

Dental implants are a widely accepted treatment for dental problems. In many studies, the long-term survival rates of implants are also high. Survival rates are defined as the presence of an implant embedded into the bone; independent of any natural (biological) or mechanical deficits. It has been studied for long time duration of dental implants (typically over 10 years) as well and the common endpoint is 90% survival or more [16]. These remarkable health features have contributed to making dental implants the go-to and most preferred treatment for partly or totally edentulous patients for tooth replacement [11]. Survival rates of implants are influenced by several factors including

the type of implant, the quality of the bone, the surgical procedure, and the patient's health. For instance, implants at the rear part of the maxilla do not last as long as in the jaws where bone quality and density is better [2]. In contrast, implants placed in the front mandible typically have higher survival rates because the bone is denser [1]. Another determinant of survival is loading. Immediate loading, when the implants are repaired with a prosthesis within days or weeks, has become routine. If primary stability is good, several studies observed that immediate and delayed loading regimens have similar survival rates [12]. Even though quick loading is advantageous under certain conditions, delayed loading is much more common, especially when the quality of the bone is less good. The two most serious long-term reasons for implant failure will always be peri-implantitis and mechanical failure; both issues can be prevented by selecting the right patient, planning the right therapy, and caring for the patient after the operation [10].

The effects of patient demographics:

1. Age:

In testing for implant longevity and efficacy, age is often used as a gauge; in previous times, younger people were given preference for implant placement because their bones were denser, healed faster and tended to work much better in general health. However, recent scientific studies suggest that age alone does not have a significant effect on implant lifespan; implants in older patients may have excellent success rates when the treatment has been provided, particularly of implant placement [7].

[16] conducted a study to confirm this conclusion, as an older patient; particularly 65 years and older, with similar implant survival to younger patients, but conditional upon the treatment of systemic health problems.

2. Gender

The role of gender in implant success has been disputable, with some investigations suggesting that women have only slightly higher risk of complications associated with hormonal activity, particularly post-menopausal women and a higher risk of osteopenia and/or osteoporosis [6]. However, gender does not in itself appear to be an influential risk factor for implant failure. According to research by [8], the survival and success of male and female patients in general after controlling for age and systemic disease levels and treatment is quite similar in general.

3. Smoking

Smoking is probably the largest factor in reducing your chances of failure of an implant. It decreases the flow of blood and the activity of the osteoblasts, both key in effective osseointegration [8]. A great deal of literature suggests that smokers have a correspondingly higher risk of implant failure, peri-implantitis, and more bone loss surrounding the implant than nonsmokers [6]. Smokers have a higher risk of problems, and there is usually a 2 to 3 times greater chance of implant failure than patients who do not smoke. Therefore, stopping smoking usually means before an implant to get the best results.

4. Full body diseases

Patients with uncontrolled systemic disorders, including diabetes mellitus, are more likely to have problems with implants because their wounds don't heal properly and their immune system doesn't work as well [9]. However, controlled diabetes seems not to make such big a difference in success of implants [8]. Osteoporosis and other disorders can also impact the quality of bones. However, implants in individuals with controlled osteoporosis generally have good long-term results [6].

Actions related to implant design and materials

The long-term consequences of dental implants are closely tied to the implants design and materials selection. The evolution of titanium implants revolutionized the field of dental implantology forever. This is due to their very biocompatible, good mechanics properties, and osseointegrate capabilities. In the end, both ceramic alternatives that look good (Zirconia) have been available in the implant materials over the years [17]. Zirconia offers decent short- to medium-term results, and titanium seems to hold out the best advantage as it's the one with the more durable and predictable data and more consistent results in a clinical setting [16].

1. Changes to the Surface

Material properties affect the degree to which implants can combine with bone. Harsh surfaces like this sandblasted and acid-etched (SLA) titanium, give the cells more surface to stick to that helps promote bone growth early on and ensures the stability of the implant in the future [4]. Studies consistently show that rough surfaces achieve excellent osseointegration than smooth surfaces, particularly among individuals with bone density reduction patients [18].

2. Macro-Design of the Implant

The macro-design for implant such as shape, size; and threaded design, has proven to be vital to ensure that they remain stable and operate well in the long run. Tapered implants, for example, are commonly used in areas where bone density is low because they improve primary stability through higher bone-to-bone contact. Additionally, the concept of platform switching (the diameter of the restorative platform is less than the diameter of the body of the implant) has been associated with better bone stability and less loss of crestal bone [6].

3. Different Materials

Zirconia implants have many advantages like better cosmetic results especially in the front areas, and lesser plaque buildup. They have not been well studied so far as titanium, and the mechanical properties below high occlusal forces are not particularly strong [17]. They would have limited application due to this restriction for full-arch restorations, or in individuals with high occlusal forces.

Loading Rules

How quickly or quickly to load or delay implant may heavily impact the longevity of dental implants. Installing a prosthesis on an implant within 48 to 72 hours of placement is becoming an increasingly routine behavior in clinical practice. This is known as immediate loading and when primary stability is reached, immediate loading has shown survival in the same manner as delayed loading procedures [11]. The quick loading may shorten the time of treatment for a patient leading to greater satisfaction. But the efficacy of rapid loading crucially hinges on stability of implant, typically measured by torque values. It is widely assumed that implants whose primary stability has reached or exceeded 35 Ncm [12] can be loaded immediately. Delayed loading is still the standard procedures and requires waiting 3 to 6 months for implants to heal before loading them. This approach allows for complete osseointegration before functional loading can be performed on the implant, which is less demanding and more secure, especially in circumstances where the first level of stability is compromised or its integrity is not high [11]. Although both regimens worked, the overall long-term success of dental implants depends on factors such as quality of the bone; type of implant, and whether the patient has more systemic diseases, such as diabetes or osteoporosis. Research shows implants placed in regions with poor bone quality or poor healing conditions may fare best when loaded later to decrease the risk of failure [12].

How well does a patient maintain bones and where in the body is their implant.

The success of dental implants is inextricably linked to the nature and position of bone as well as the surrounding space where dental implants are placed. Bone quality refers to how thick; large or small all around one can be situated around implant bones; their structure and volume. This may seriously affect the main stability and long-term results of the implant [19]. In 1985, Lekholm and Zarb devised a four-types model for bone quality, distinguishing between Type I (high-density and cortical bone) and Type IV (poor-quality trabecular bone). Implants of Type I bone generally outperform those in Type IV bone because they do not provide as much initial support and take longer to connect with the bone. The anatomical layout of an implant has also proved extremely important; implants in the maxillary posterior area often survive significantly worse than the anterior area, much of which is attributed to inferior bone quality in the maxilla [2]. The posterior maxilla tends to have weaker bone with diminished density which leads to a more risk of implant failure, resulting in perforation or loss of volume of bone, including sinus perforation. On an opposing side, the front of the mandible commonly has denser bone which provides implants improved primary stability and increases the chances of success in a long-term perspective [2]. For people who have a deficit of bone volume in important regions; processes to increase the quantity of bone (particularly in the hands and feet) and quality of bone (including bone grafting) in need of an implant are also available [11].

Diseases around implants.

Multiple determinant factors in the outcome of dental implant wear in the long term are known as peri-implant diseases, for instance the peri-implant mucositis and peri-implantitis. Peri-implant mucositis (PM) is a chronic inflammatory condition of the soft structures of the implant that is relatively benign, although preserving proper bone structure and function. If left untreated, however, it could become aggressive and transform to peri-implantitis, which is irreversible and characterised by inflammation of soft tissue and loss of bone which can eventually progress to implant failure [10]. Researchers studied the prevalence of peri-implant diseases as peri-implant disease and found that 10% to 25% of implants are infected with peri-implantitis during a decade [10]. Misguided dental hygiene, smoking, frequent periodontal disease, and uncontrolled systemic illness including diabetes are risk factors for peri-implantitis [6, 8]. Prevention procedures - such as routine cleaning and maintenance, early diagnosis, and treatment of peri-implantitis in those with mucositis when the disease is initiated, rapid detection, may help to prevent the progression of peri-implantitis. Moreover, the implant design, particularly through the platform swapping technique, has been shown to reduce the likelihood that marginal bone loss occurs and prevent peri-implantitis [6]. To have long-term success of dental implants, the soft tissues surrounding them need to be well. They are, in part, a barrier against infection.

Problems with machines

While mechanical problems are less common than biological problems, they are essential for the long-term success of dental implants. Some of the challenges that can result in this type of implant failing (from screws coming loose to prosthetic fractures, from implant fractures, etc) are costly and invasive procedures performed. The loosening of the screw is one of the most frequent mechanical problems and can occur in single crown and multi-unit restorations alike [12]. There are implant fractures, rare but could come from high occlusal pressures, inferior bone quality and manufacturing imperfections. This type of a mechanical fracture occurs more frequently in implants with substantial chewing power, primarily in full-arch or multiple-unit restorations [1]. Prosthetic problems are another major risk [11] and can manifest particularly in fractures of the implant abutments or crowns if an excessively or asymmetrically occluded implants

exist. Adequate combination of abutment screws and proper occlusal adjustment is required to minimize mechanical failure. The mechanical construction, along with the implant and abutment joint interface, is also very critical to minimize mechanical failures. However, most notably in the initial stages of implant recovery, is an accepted risk factor for complications [2].

Comparison Between Patients by Demographic and Implant Type

We need to understand the differences between patient populations and implant types to obtain optimal outcomes from implant therapy! Several studies show time and again, that the presence of either age, sex or other general health factors have pronounced effects on implant success rates. So younger patients have increased success rates due to better quality of bone, and their ability to heal, which are all reflected in their success rates [7]. Conversely, older patients with increased risk, and especially with osteoporosis and other systemic diseases, may face other challenges like higher bone loss of density with prolonged healing time [8]. The type of implant is also extremely important for long-term success. Titanium implants remain the most common type of implant, being extremely biocompatible and well established. But as they become increasingly popular, zirconia implants look better – especially to the front of the mouth. Short-term results show acceptable performance of zirconia implants, but for their long-term durability versus titanium are questioned [17]. Others are more likely to fail, particularly smokers or those with poorly controlled systemic infections. Smokers suffer a high risk of both implant failure and peri-implantitis [6], and patients suffering from diabetes, with an inadequately managed diabetes, may experience osseointegration complications [9].

Long term Marginal bone loss

Marginal bone loss occurs as a typical consequence of dental implant placement. In fact, this is arguably one of the most important variables to consider when evaluating the success of an implant. The first year after implantation is typically the time when most bone is lost. At this stage, the average amount of bone loss is between 0.5 and 1.5 mm [3]. Nevertheless, after this initial phase, the bone loss reaches a relatively steady state, typically at less than 0.2 mm per annum after that [11]. Too much bone loss can be a symptom of conditions like peri-implantitis, in which both soft tissue and bone become inflamed over time and break down. Marginal bone loss may occur because of mechanical stress; improper implant positioning, or improper prosthetic design [10]. Implants located in posterior maxillary sites, which are generally associated with inferior bone quality, tend to have increased marginal bone loss, most notably in the first year [2].

Outcomes Reported by Patients:

Patient-reported outcomes (PROs) are a key part of evaluating the long-term usefulness of dental implants; they can provide a great deal of information about the patient's perception with respect to function, aesthetics, satisfaction, etc. PROs can be subjective metrics including comfort, masticatory function, speaking performance, aesthetics, with psychological dimensions such as self-esteem and lifestyle being discussed alongside the medical aspects [11]. Although quantitative measures such as implant lifespan and bone stability are pivotal, these subjective outcomes can dramatically influence overall implant effectiveness at the patient level. Research has been conducted and shown, that people with dental implants are more efficient at chewing food, have clearer speech, and higher overall quality of oral health [1]. Those with these forms of denture or bridge are often happier compared to normal people. Immediate loading methods have also been correlated with higher satisfaction, since they accelerate therapy [12] and make the result seem natural. But others, especially those at the front of the mouth, might be unhappy with how their implants appear as well as face imperfections, as implant failure or issues may create gaps or problems with the prosthesis [17]. Psychological problems, such as anxiety at the implant or fears about body image, have

been linked to patients' satisfaction with therapy, but also patients' perceptions of therapy's efficacy.

Limitations of Current Evidence:

Because there are many studies showing that dental implants actually work; however, there are still some pitfalls with the current data that come into play, particularly long term results. One major issue is that the studies used different designs; they used different criteria for who could participate, how long they followed up after completion, and what outcomes they measured [12]. This heterogeneity is a major pain point in comparing data across a significant amount of research, particularly with regards to long-term implant survival and success rates. Some studies, for example, use small quantities of bone loss to measure success, while others examine conditions such as peri-implant disease or prosthetic issues. The other issue is that implant research has no clear standards for success or failure. Standard criteria (absence of pain, implant mobility, marginal bone loss) seem to be widely accepted, but differences in measurement and reporting of these factors can introduce biases into results [3]. The use of subjective measures, such as patient satisfaction, inter-study comparisons is hindered by multiple psychological and social determinants of outcome [17]. In addition, little long-term data exists on new implant material developments, such as zirconia implants and bioactive coatings, which have demonstrated promising outcomes in shorter to medium-term studies but are lacking long-term follow-up [17]. Similarly, in case of quick loading the increased use of rapid loading technologies, longer-term studies to fully understand their true impact especially in high-risk patients has been called for [11].

4. Conclusion

Long term treatment with dental implants increases survival by over 90–95% over 10 years. But its success depends on many factors: patient age, health, smoking status, the implant's design and surface features, plus prosthetic factors. Smoking and undiagnosed systemic conditions remain major risk factors. Advances in micro and macro-design of implant such as platform switching and surface adaptation, has enhanced marginal bone stability by far. Titanium implants continue to achieve predictable results, whereas zirconia implants have promising short to medium-term results with a need for more long-term testing. The posterior maxilla remains a higher risk area, too, because the quality of the bone is not adequate.

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