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Dental implants – are they better than natural teeth?

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Nowadays, patients find much information on dental treatment from the Internet. There is a vast amount of information on dental implants, in contrast to the limited information available on natural teeth. This review addresses research on survival of natural teeth and dental implants, and discusses factors affecting the survival rate of implants, as well as certain dogmas in implant dentistry. To simplify treatment planning, the article presents a classification system in which teeth are classified as secure, doubtful, or irrational to treat. Secure teeth should last for a long period of time without need for complex treatment. Doubtful teeth are teeth that might need complicated treatment and additional maintenance in order to be maintained. Teeth irrational to treat are teeth that cannot be saved and for which extraction is the only treatment option. Multiple risk factors might decrease the survival probability of teeth. The survival and success rates of dental implants will never succeed the survival rates of healthy, clean teeth. Dental implants and implant-supported restorations are an excellent treatment modality, but it must always be kept in mind that it is associated with a risk of biological and technical complications. Implants are supposed to replace missing teeth – they are not supposed to replace teeth.

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In daily practice, dental professionals routinely face the challenge of making difficult decisions in a relatively short period of time. When making a treatment plan for patients with compromised dentitions, the choice is often one of either building on the existing teeth or extracting teeth followed by restoration with implant-supported reconstructions (1). Such decisions are mostly influenced by paradigms dictated by basic dental education and many years of clinical practice.

During undergraduate education, students learn that there can be several problems with teeth. They can develop caries (2–4), and this can go so far that the decay enters the pulp of the tooth causing it to lose vitality (2–5). The tooth can fracture, and the tooth can lose attachment as a result of periodontal disease (2, 6, 7). If a tooth is restored with a filling or a crown, problems may also arise with the reconstructions (2). However, when it comes to dental implants, the dental profession has so far been focusing mainly on survival rates and, until recently, technical and biological complications have not been a topic of frequent discussion. This may indicate that problems arise with teeth but implants are reliable devices because of the high survival rates reported (8–12).

Tooth survival

A few years ago, Schätzle *et al.* (13) evaluated gingival inflammation as a risk factor for tooth mortality. This research group analyzed a database established by Löe, Ånerud, and Boysen that followed Norwegian middle-class men for 26 yr in an exceptional longitudinal study. The participants were repeatedly examined at intervals of 3–7 yr over the entire study period. The gingival inflammation severity levels were classified, based on the gingival index (GI) of Löe & Silness (14), into the following longitudinal severity groups (13):

- *Severity group 1*. Teeth for which all sites always scored a maximum GI value of 1 over all sites of the tooth at every examination conducted during the entire study period, representing a healthy gingival tissue that never bled on probing.
- *Severity group 2*. Teeth for which all sites always scored a minimum GI of 1 and a maximum GI of 2 at every examination, representing teeth that had healthy gingival tissues at some examination time points and at other examination time points showed gingival inflammation.
- *Severity group 3*. Teeth for which, at every examination over the 26-yr follow-up period of the study, a minimum GI of 2 was recorded, representing bleeding on probing at all sites, indicating consistent gingival inflammation.

The authors calculated the survival rate of teeth based on an approximation of the time of tooth eruption into the oral cavity. The 10-yr survival of teeth in severity groups 1 and 2 were 100%. Moreover, the 10-yr survival

of teeth in severity group 3 (i.e. teeth that always had gingival inflammation) was 99%. Furthermore, the authors also calculated the 50-yr survival of the evaluated teeth and the survival rate for severity group 1 (i.e. healthy teeth without gingival inflammation) to be 99.5%. The 50-yr survival rate for teeth in severity group 2 was also quite high, at 93.8%. On the other hand, the 50-yr survival rate for teeth in severity group 3 (i.e. teeth always presenting gingival inflammation) was significantly lower, at 63.4% (13). Hence, it can be concluded that healthy teeth without gingival inflammation show extremely high survival rates over decades.

Implant survival

One of the first systematic review and meta-analysis evaluating the incidence of biological and technical complications in implant dentistry was published by Berglundh *et al*. (15). The authors included prospective longitudinal studies with a follow-up time of at least 5 yr, reporting on the survival rate of dental implants. They concluded that the 5-yr survival rates of implants supporting overdentures was 92% and the 5-yr survival rate of implants supporting fixed reconstructions was 95% (15). Both 92% and 95% can be considered as high rates on the percentage scale. It basically means that if the survival rate of implants is 92%, 8% of implants are lost over the study period, corresponding to one out of 12 implants. If the 5-yr survival rate increases to 95%, then 5% (or one out of 20) of the implants are lost. Hence, it makes a huge difference for dental professionals, working with dental implants, whether they achieve survival or success rates of around 90% or whether the survival/success rates are around 99%, representing one out of 10 or one out 100 implants, respectively, that are placed being lost over an observation period.

Recent series of systematic reviews (1–5), evaluating the survival rates of implants, reported that approximately 2–3% of inserted implants are lost during the healing phase. Moreover, the annual failure rate after loading was estimated to be between 0.3% and 1.3%, representing 10-yr survival rates of 95.2% for implant-supported single crowns (12), 93.1% for implants supporting fixed dental prostheses (11), and 82.1% for implants supporting combined tooth–implant-supported prostheses (9).

Comparison of survival rates of teeth and implants demonstrates that healthy teeth without gingival inflammation have survival rates that exceed the survival rates of dental implants. To date, there is also limited evidence on survival rates for dental implants measured over decades.

Factors influencing survival rate

When discussing implant survival rates, several factors should be taken into account. The patient cohorts that are included in implant follow-up studies do not always represent the general public as authors frequently apply strict exclusion criteria. For example, patients with diabetes, heavy smokers, smokers who are interleukin-1 positive, patients with history of periodontal disease, patients with reduced compliance or poor oral hygiene, patients with limited bone volume, or patients with parafunctions are often excluded from studies addressing implant survival and success. Nonetheless, patients with such conditions are frequently in need for implant-supported fixed reconstructions because of loss of teeth. Another issue that has to be considered is that more than 1,000 different implant systems have been introduced to the implant market in the past decades. Most of these have been designed without any previous research or scientific background. The question is whether utilizing grade IV titanium as the implant material, creating implant geometry with fine or coarse threads to increase primary stability, or making the surface rough with some kind of sandblasting or acid-etch technique provides a guarantee for high survival and success rates (16). Karoussis *et al*. (17) looked at the effect of implant design on survival and success rates in a 10-yr prospective cohort study. They included 89 patients who received implants with different geometry. A total of 112 hollow-screw implants and 49 hollow-cylinder implants were studied. Both implant types were made from the same titanium material, had the same implant diameter, had a machined neck, and had a rough titanium plasma-sprayed surface (Fig. 1). Furthermore, both implant types were hollow, allowing the bone to grow into the implant body. The only difference between those two implant types was that the hollow-screw implants had additional external threads for increased primary stability. During the 10-yr follow-up period, a few implants were lost during the healing phase and, after 5 yr of follow-up, there was no statistically significant difference between hollow-screw and hollow-cylinder implants in terms of their survival. However, after 10 yr, significantly more (14.3% vs. 4.6%) hollow-cylinder implants were lost (17). To put this into a clinical perspective, this means that one implant out of seven was lost in the hollow cylinder-group compared with one out of 22 in the hollow-screw group. It can be concluded that a minor difference exists (i.e. the external threads have a significant influence on the long-term survival of the implant) but this difference does not appear during the first 5 yr after loading the implant. In this study, the clinician had to wait 7–9 yr to experience this significant difference. This could be of utmost importance because the majority of studies addressing implant survival rates usually do not have follow-up times exceeding 5 yr. Furthermore, it has to be kept in mind that survival rates of implants simply represent the implant still being in situ, and this may be with or without complications.

Implant success

A systematic review (8) evaluating the survival and complication rates of implant-supported fixed dental prostheses over a 5-yr observation period defined

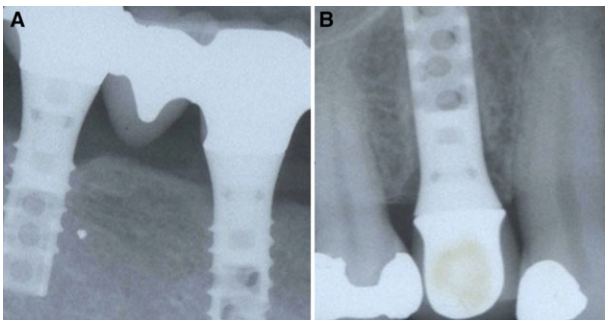

Fig. 1. Radiograph showing hollow-screw implants (A) and a hollow-cylinder implant (B).

success in terms of the patients being free from all complications over the entire observation period. Even though the meta-analysis reported impressively high survival rates, only 61.3% of the patients were completely free of all technical and biological compliations over a 5-yr period. For the authors, this was an eye-opener as they had been accustomed to look at, and report, the high survival rates. For example, a study performed at the University of Bern in which the outcome of implant-supported reconstructions was evaluated (18), reported a failure rate of 2.5% but an additional 16.8% of the reconstructions had some kind of biological and/or technical problems.

Complications are usually divided into:

- biological complications, such as early failures, soft-tissue complications, and peri-implantitis;
- technical complications, such as implant fractures, loss of retention, screw or abutment loosening or fracture, fracture of the framework, fracture of the veneering materials (such as ceramic fractures), and chipping; and
- esthetic complications.

However, this classification is not always clear because many complications trace their roots back to a combination of biological, esthetic, and/or technical complications. Pjetursson *et al.* (19) addressed the question of whether there has been significant improvement in implant dentistry in the last decade by comparing the survival and complication rates in older (published in 2000 and earlier) and newer (published after 2000) publications. The authors reported that there has been a significant decrease in many of the biological and technical complications (Table 1) but concluded that the incidence of esthetic, biological, and technical complications was still high. Hence, it is important to identify these complications and their etiology to make implant treatment more predictable in the future (19). Finally, there might be a tendency for publication bias in implant dentistry. There is frequently a strong financial interest behind the research, but this is one of the critical issues that is difficult to evaluate. However, with increased quality in dental research and preregistration of prospective clinical studies, this is being significantly improved.

Dogmas in implant dentistry

Nowadays, patients find much information about dental treatment and treatment options from the Internet. Relative to the amount of information available on the Web, there is limited information available addressing the predictability of the survival of teeth and tooth-supported reconstructions. On the other hand, there is a huge amount of dubious information and advertisements addressing the glory of dental implants and implant treatment. As a result, many patients and clinicians may be more focused on implant solutions than on tooth-supported reconstructions, and some clinicians seem to have lost faith in treating compromised natural teeth. In conferences, in publications, and in textbooks, treatments are presented in which teeth that could easily have been maintained with traditional restorative methods have been extracted and the post-extraction site restored with an implant-supported reconstruction. This has created dogmas such as 'periodontal overtreatment', to indicate that by trying to save teeth using traditional periodontal treatment the dentist might compromise the possibility of subsequent implant placement by 'allowing' the gradual loss of supporting bone over the years. Clinicians who adhere to this kind of thinking tend to extract periodontally compromised teeth despite only limited attachment loss. Hence, teeth that could easily be maintained for a long period of time will be extracted (20).

Another dogma that has been serving patients with compromised dentitions less well, is the total extraction of all remaining teeth. By doing so, the risk of reinfection and peri-implantitis is supposed to be reduced. Fransson *et al.* (21) evaluated the prevalence of subjects with progressive bone loss at implants. They included 423 patients representing 3414 implants with a follow-up time of at least 5 yr. Twenty-eight per cent of the included patients had one or more implants with

Table 1

The 5-yr esthetic, biological, and technical complication rates in implant-supported fixed dental prostheses (FDPs) and implant-supported single crowns (SCs) reported in studies published after 2000

Type of complication	Complication rate for SCs (%)	Complication rate for FDPs (%)
Esthetic complication	5.4	n.r.
Biological complication	6.4	9.4
Marginal bone loss ≥ 2 mm	6.3	2.5
Screw or abutment loosening	5.6	4.0
Loss of retention	3.1	n.r.
Implant fracture	0.1	0.5
Screw or abutment fracture	0.3	0.8
Fracture of the framework	n.r.	0.2
Fracture of the veneering material	3.2	7.7

n.r., Not reported.

progressive bone loss, defined as bone loss down to the third thread of the traditional Brånemark implant. A total of 12.4% of the implants were affected. The authors defined two groups of patients:

- *Group A* (having one or more implant *with progressive bone loss*); and
- *Group B* (having *no implants with progressive bone loss* involving more than three threads).

If the total extraction philosophy leads to a reduced prevalence of peri-implantitis, a higher proportion of patients with fixed complete dentures (FCDs) should be found in the 'healthy' Group B. However, the authors reported that significantly more of the patients restored with FCDs were found in Group A (i.e. they had one or more implants with progressive bone loss). Hence, this study indicates that extraction of all remaining teeth does not reduce the risk of progressive bone loss and peri-implantitis (21).

If the majority of dental professionals and educationers were of the conviction that dental implants are more reliable than teeth, the future of dentistry could entail a risk that the present know-how in different fields, such as periodontology, endodontology, and restorative dentistry, might be lost, as most compromised teeth would simply be extracted and replaced with dental implants.

Unfortunately, the treatment option of using dental implants has turned some clinicians into being more aggressive in extracting compromised teeth. On the other hand, some clinicians see the implant treatment modality as a possibility to be more conservative by saving compromised teeth and trying to maintain them as single units, bearing in mind that if the long-term treatment plan does not work out, the possibility of extracting a single tooth and replacing it with a dental implant is still open.

Treatment planning

It is of utmost importance to follow a systematic approach when it comes to tooth evaluation and treatment planning of complex cases. After discussing a patient's chief complaint, dental history, and general medical risk assessment, and collecting the necessary data for treatment planning, the next step in the treatment plan is to establish the pretherapeutic single-tooth prognosis. Before making the treatment plan, every single tooth should be evaluated from a dental aspect (tooth substance), from an endodontic aspect, and by periodontal criteria. After careful evaluation of each tooth, it should be classifed as secure, doubtful or irrational to treat (Table 2).

- *Secure teeth* are teeth that should last for a long period of time without the need for significant or complex treatment. Secure teeth are, from dental and periodontal perspectives, all teeth that are not classified as doubtful or irrational to treat and, from an endodontic point of view, all teeth with intact root canal anatomy in need of primary endodontic treatment whether or not symptoms are present.
- *Doubtful teeth* are teeth that might need complicated treatment and additional maintenance to be maintained. It is not always clear how these teeth will respond to treatment and therefore it can be of an additional risk to use them as bridge abutments, which is why it may be more reasonable to keep them as single units. In many instances, doubtful teeth can be turned into secure teeth with treatment. From a tooth substance point of view, doubtful teeth are teeth that have lost so much substance that it is difficult to achieve an acceptable ferule restoring them, teeth in which dental decay extends far down the root, and teeth with large posts that are weakened because of loss of tooth substance. From a periodontal point of view, doubtful teeth are teeth with furcation Class (I), II, or III (22), teeth with vertical bone defects, and teeth with bone loss evaluated on a periapical X-ray which is assessed in percentages to be at least the same as the age of the patient in years (Fig. 2). From an endodontic perspective, doubtful teeth are teeth, with or without symptoms, with large periapical lesions on X-rays; teeth with altered root canal anatomy that need endodontic retreatment; and teeth that need periapical surgery.
- *Teeth irrational to treat* are teeth than cannot be saved with extraction being the only treatment option. The timing of extraction can depend on situation of the tooth, pain or infection, or the treatment plan. From a dental point of view, teeth irrational to treat are teeth in which the dental decay extends into the root canal or into the tooth furcation. From a periodontal point of view, teeth irrational to treat are teeth with repeated periodontal abscesses, attachment loss down to the apical part of the tooth, or extensive perio-endo lesions. From an endodontic point of view, teeth irrational to treat are teeth with vertical root fractures, teeth with horizontal root fractures in the mid-third of the root, and teeth that have been endodontically retreated conventionally or surgically without success (Table 2).

As part of the treatment plan, the decision of whether the edentulous gaps should be restored with tooth-supported fixed dental prostheses (FDPs) or a single or multiple unit implant-supported reconstruction must be made. If a decision is made to use tooth-supported reconstructions, the neighboring teeth of the edentulous area will always be involved as abutment teeth. Hence, the situation of the neighboring teeth is one of the critical factors in deciding whether to opt for a tooth-supported or an implant-supported reconstruction. If the neighboring teeth are intact, a large proportion of intact tooth substance has to be sacrificed when preparing the tooth for a conventional tooth-supported FDP (23, 24). If the neighboring tooth is compromised as a result of dental, periodontal, or endodontic issues, it might be more reasonable to leave it as a single standing unit instead of including it into a multi-unit tooth-supported reconstruction. The situation of the neighboring teeth frequently leads to the

Table 2

Overview of aspects to consider when evaluating the pretherapeutic single-tooth prognosis

Group	Definition	Dental aspects	Periodontal aspects	Endodontic aspects
Group I Secure teeth	Teeth that should last for a long period of time without the need for significant or complex treatment	All teeth not classified as doubtful or irrational to treat	All teeth not classified as doubtful or irrational to treat	All teeth not classified as doubtful or irrational to treat and all teeth with an intact root canal anatomy, with or without symptoms, that need primary endodontic treatment
Group II Doubtful teeth	All teeth that might need complicated treatment and additional maintenance to last. It is not always clear how these teeth will respond to treatment and therefore it can be of an additional risk to use them as bridge abutments and more reasonable to keep them as single units. In many instances, doubtful teeth can be made secure by treatment	Teeth that have lost so much substance that it is difficult to restore them with an acceptable ferule Teeth with caries lesions that extend far down the root Teeth with weakened root structure caused by a wide metal or fiber-reinforced post	Teeth with attachment loss in percentage values, as evaluated by assessment of radiographs, that are equal to or exceed the age of the patient (i.e. ≥50% attachment loss in a 50-yr-old patient) Molars with furcation involvements of Class (I), II, or III Teeth with vertical bone defects	Teeth with large periapical lesions evaluated on radiographs, whether symptomatic or not Teeth with altered root-canal anatomy in need of endodontic retreatment Teeth that need periapical surgery
Group III Teeth irrational to treat	Hopeless teeth for which extraction is the only option. The timing of extraction can depend on the situation of the tooth, pain, infection, or the treatment plan	Teeth with caries lesions that extend into the root canal Teeth with caries lesion extending into the furcation	Attachment loss extending down to the apical part of the root Teeth with recurrent periapical abscesses Teeth with extensive perio-endo lesions	Teeth with vertical root fractures Horizontal root fractures in the mid-third of the root Teeth that have been endodontically retreated conventionally or surgically without success

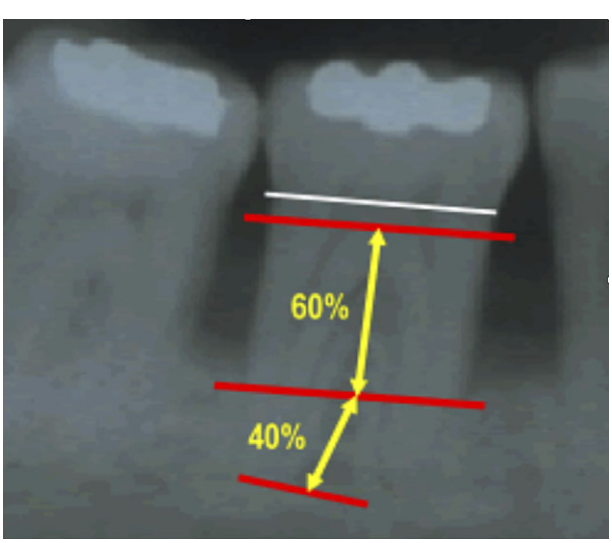

Fig. 2. A molar with approximately 60% attachment loss, evaluated on a radiograph. This tooth would be considered to be doubtful if presented in an individual younger than 60 yr of age.

decision of using implant-supported reconstructions instead of tooth-supported reconstructions. In treatment planning there are basically four options for compromised teeth. Sometimes, the most reasonable treatment option is to extract. In other instances, the most reasonable option is an inexpensive restoration with a conventional filling. The third option would be a crown and, finally, the teeth can be used as bridge abutments. Compromised teeth are, however, more often kept as single units and are seldom used to support multiple unit reconstructions.

Multiple risk factors

Another issue that should always be taken into account is that the value of a compromised tooth decreases dramatically with combined or multiple risk factors. If a tooth has a 100% chance of surviving for the next 10 yr, it is assigned a survival probability of 1.0. However, if a tooth has only an 80% chance of surviving for the same period of time, it will be assigned a survival probability of 0.8. Moreover, if a tooth has more than one risk factor, the survival probability will

decrease. For example, if the risk of losing a tooth because of periodontal problems is 20% and the risk of losing the same tooth because of endodontical problems is 20%, the combined survival probability for that tooth is calculated by multiplying $0.8 \times 0.8 = 0.64$. That means that the tooth has a 64% chance of surviving for the next 10 yr, which is equivalent to a risk of losing that tooth, as a result of endodontic or periodontal problems, of 36%. It would be very helpful for treatment planning if methods were available to evaluate different risk factors for each tooth. If the risk of losing a tooth as a result of caries, periodontal disease, or endodontic problems could be evaluated, and the risk of failure of the posts and cores, crowns, and FDPs could be estimated, an exact risk estimation for each tooth would be possible. This would definitely be of enormous benefit in making an evidence-based treatment plan (Fig. 3 & Table 3).

Implants and periodontally compromised patients

Worldwide, large proportions of teeth that are lost, are lost from periodontal disease (25). Hence, large proportions of patients in need for dental implants are periodontally compromised. Pjetursson *et al*. (26) evaluated the outcome of dental implants inserted in 70 periodontally compromised patients. The included patients received comprehensive periodontal treatment and, as part of the initial treatment, they received 165 dental implants. Later on, 12 additional implants were inserted because of further tooth loss or per patient request. Supportive periodontal treatment was offered to all patients on a regular basis. The patients were re-examined after an average follow-up time of 8 yr. The included patients were divided into two groups;

- No implants showed signs of peri-implantitis. That is, only healthy implants or implants not diagnosed as having peri-implantitis.
- One or more implants were diagnosed having peri-implantitis.

When evaluating the outcome of the initial periodontal treatment, the group of patients with only healthy implants had statistically significantly fewer residual pockets (mean = 1.9) than the group of patients experiencing peri-implantitis (mean = 4.1). Hence, the success of the initial periodontal treatment significantly influences the outcome of dental implant treatment. Patients with semi-optimal outcomes (i.e. with a larger number of residual pockets) tend to have significantly more problems with their implants. Furthermore, patients who had healthy implants had, on average, 1.9 residual pockets at the end of active periodontal treatment and (on average) an identical number of residual pockets (i.e. 1.9) after 8 yr of maintenance. This represents a patient group with a relatively stable periodontal situation. On the other hand, for the patient group in which peri-implantitis was found on one or more implants, the number of residual pockets had increased from 4.1 to 6.4 over the period of 8 yr. This indicates recurrent periodontitis with a less stable periodontal situation compared with the group of patients with healthy implants (26).

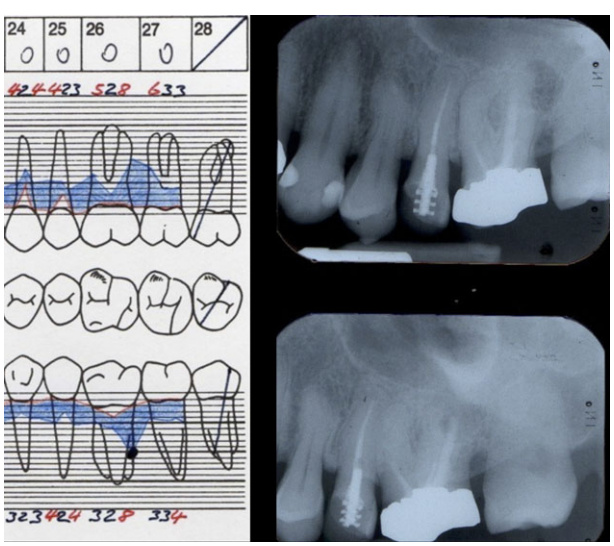

Fig. 3. Example of a compromised tooth (+6) with external root resorption on the palatal root, attachment loss, a class II furcation distally, and a caries lesion on the mesial aspect.

Table 3

Example of a multiple risk analysis of the tooth presented in Fig. 3: the tooth would need to be built up and the crown to be restored properly

Risk factor	Per cent
Loss from caries	3
Loss from periodontitis	15
Endodontic complications	29
Failure of post and core build-up	10
Failure of reconstruction	5
Chances of 10-yr tooth survival	53

Conclusion

The survival and success rates of dental implants will never succeed the survival rates of healthy, clean teeth. Dental implants and implant-supported restorations are an excellent treatment modality but it must always be kept in mind that it is associated with a risk of biological and technical complications. Implants are supposed to replace missing teeth – they are not supposed to replace teeth.

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