

Prosthetic treatment planning on the basis of scientific evidence

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SUMMARY The objective of this report is to summarize the results on survival and complication rates of different designs of fixed dental prostheses (FDP) published in a series of systematic reviews. Moreover, the various parameters for survival and risk assessment are to be used in attempt to perform treatment planning on the basis of scientific evidence. Three electronic searches complemented by manual searching were conducted to identify prospective and retrospective cohort studies on FDP and implant-supported single crowns (SC) with a mean follow-up time of at least 5 years. Patients had to have been examined clinically at the follow-up visit. Failure and complication rates were analyzed using random-effects Poisson regression models to obtain summary estimates of 5- and 10-year survival proportions. Meta-analysis of the studies included indicated an estimated 5-year survival of conventional tooth-supported FDP of 93.8%, cantilever FDP of 91.4%, solely implant-supported FDP of 95.2%, combined tooth-implant-supported FDP of 95.5% and implant-supported SC of 94.5% as well as resin-

bonded bridges 87.7%. Moreover, after 10 years of function the estimated survival decreased to 89.2% for conventional FDP, to 80.3% for cantilever FDP, to 86.7% for implant-supported FDP, to 77.8% for combined tooth-implant-supported FDP, to 89.4% for implant-supported SC and to 65% for resin-bonded bridges. When planning prosthetic rehabilitations, conventional end-abutment tooth-supported FDP, solely implant-supported FDP or implant-supported SC should be the first treatment option. Only as a second option, because of reasons such as financial aspects patient-centered preferences or anatomical structures cantilever tooth-supported FDP, combined tooth-implant-supported FDP or resin-bonded bridges should be chosen.

KEYWORDS: treatment planning, fixed dental prostheses, dental implants, implant dentistry, resin bonded bridges, systematic review, survival, success, longitudinal, failures, complications, technical complications, biological complications

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Introduction

In the daily practice, dentists routinely face the challenge of making fast and difficult decisions. These are mostly influenced by paradigms dictated by basic dental education and many years of clinical practice. Scientific evidence provided by well-controlled studies is rarely available to influence and/or determine the treatment plan. When planning a fixed reconstruction, the options are tooth-supported or implant-supported fixed dental prostheses (FDP) or single crowns (SC). These treatment options have various documented longevities

and biological as well as technical risks that should be considered during treatment planning. As there are no randomized controlled clinical trials (RCT) in the dental prosthetic literature comparing tooth-supported FDPs with implant-supported FDPs, it is an open question whether or not the practice of evidence-based treatment planning is at all possible in prosthetic dentistry.

Ideally, treatment decisions should be based on well-performed systematic reviews of the available evidence and, if possible, on formal quantitative evidence synthesis and meta-analysis (1–3). If there are no studies on the highest level of evidence, the systematic review

has to be based on the highest level of evidence available (4, 5). The studies in the dental literature reporting on tooth-supported and implant-supported FDPs are mostly observational studies and single center case cohorts studies, both prospective and retrospective in nature.

Randomized controlled clinical trials (RCT), would best be conducted in a multicentre setting with long enough follow-up time and sample sizes that allow estimating relevant differences between the outcomes of the treatments. However, it must be kept in mind that to detect with an 80% power and at the significance level of 5% a clinically relevant difference of an annual rate of failures a two-arm study would need to randomize over 1000 patients and to follow them for at least 5 years. It is evident that such studies are difficult to perform, time-consuming and extremely costly. Therefore, it is understandable that the prosthetic literature is depleted of such studies of high quality and consequently, the professional must rely on studies of a lower ranking in evidence level. The analysis in a systematic review including meta-analysis may result in the necessary power of analysis provided the studies are homogeneous in nature.

Previously, a series of systematic reviews, based on consistent inclusion and exclusion criteria, summarized the available information on survival and success rates and the incidence of biological and technical complications of conventional FDP, cantilever FDP, combined tooth-implant-supported FDP and solely implant-supported FDP as well as implant-supported SC (6–10). These reviews have been updated and completed in a recent systematic review (11). For that endeavour, the relevant literature had been searched up to July 2006. The aim of the present report is to utilize available evidence on survival and risk assessment to perform evidenced-based treatment planning for fixed reconstructions.

Materials and methods

Originally, three MEDLINE (PubMed) searches were performed for articles published in the Dental Literature. The first search, covered the time period from 1966 to April 2004 (6–9), and the second one the period of May 2004 to July 2006 (11). In a supplementary search of the dental literature up to August 2007 using the same search strategy no additional studies were identified to influence the outcome of the systematic

review (11). In addition, results from 5-year studies of resin-bonded bridges (RBB) (12) were added to the data bank of the review mentioned (11). All searches were complemented by manual searches of the bibliographies of all full text articles and related reviews, selected from the electronic search.

Inclusion criteria

In the absence of RCT, this report is based on prospective or retrospective cohort studies. The additional inclusion criteria for study selection were that: (i) the studies had a mean follow-up time of 5 years or more, (ii) the included patients had been examined clinically at the follow-up visit, i.e. publications based on patient records only, on questionnaires or interviews were excluded; and (iii) the studies reported details on the characteristics of the suprastructures.

Data extraction

Survival was defined as the reconstruction remaining *in situ* at the follow-up examination visit irrespective of its condition. *Success* was defined as the reconstruction that remained unchanged and did not require any intervention during the entire observation period.

Biological complications for tooth-supported reconstructions covered dental caries, loss of pulp vitality and periodontal disease progression. Biological complications for implant and combined tooth-implant-supported reconstructions were characterized by a biological process affecting the supporting tissues.

Technical complications for tooth-supported reconstructions encompassed loss of retention, abutment tooth fractures and fractures, or deformations of the framework or veneers. Technical complications for implant and combined tooth-implant-supported reconstructions denoted mechanical damage of implants, implant components and/or the suprastructures. Among these, fractures of the implants, fracture of screws or abutments, loss of retention, fractures or deformations of the framework or veneers, loss of the screw access hole restoration and screw or abutment loosening were included.

Survival estimates and complication rates were used for decision-making. The following clinical situations will be addressed:

- 1 Single tooth gaps in the anterior maxilla.
- 2 Single tooth gaps in the anterior mandible.

Table 1. Summary of annual failure rates, relative failure rates and 5-year survival estimates

Type of reconstructions	Total number of reconstructions	Total exposure time	Mean follow-up time	Estimated annual failure rate	5-year survival summary estimate, % (95% CI)
Conventional FDP	2088	11998	5.7	1.28 [†] (0.64–2.59)	93.8 [†] (87.9–96.9)
Cantilever FDP	432	2112	5.2	1.80* (1.15–2.82)	91.4* (86.9–94.4)
Implant supported FDP	1384	6880	5	0.99 (0.64–1.52)	95.2 (92.7–96.8)
Tooth-implant supported FDP	199	976	5	0.92* (0.50–1.70)	95.5* (91.9–97.5)
Implant supported SC	465	2280	5	1.14* (0.76–1.70)	94.5* (91.8–96.3)
Resin bonded bridges	1374	8241	6	2.61* (1.68–4.06)	87.7* (81.6–91.9)

*Based on standard *Poisson* regression.[†]Based on random-effects *Poisson* regression.**Table 2.** Summary of annual failure rates, relative failure rates and 10-year survival estimates

Type of reconstructions	Total number of reconstructions	Total exposure time	Mean follow-up time	Estimated annual failure rate	10-year survival summary estimate, % (95% CI)
Conventional FDP	1218	10446	11.9	1.14 [†] (0.48–2.73)	89.2 [†] (76.1–95.3)
Cantilever FDP	239	2229	10.9	2.20* (1.70–2.84)	80.3* (75.2–84.4)
Implant supported FDP	219	1889	10	1.43* (1.08–1.89)	86.7* (82.8–89.8)
Tooth-implant supported FDP	72	517	10	2.51* (1.54–4.10)	77.8* (66.4–85.7)
Implant supported SC	69	623	10	1.12 (0.45–2.32)	89.4 (79.3–95.6)
Resin bonded bridges	51	464	9.1	4.31* (2.63–6.66)	65.0* (51.4–76.9)

*Based on standard *Poisson* regression.[†]Based on random-effects *Poisson* regression.**3** Single tooth gaps in the posterior region.**4** Multiple gaps in the anterior maxilla.**5** Multiple gaps in the anterior mandible.**6** Multiple gaps in the posterior region.**7** Free-end situation with missing molars.**8** Free-end situation with missing premolars and molars.

Consideration will be given to the vitality of the teeth, the remaining tooth structure, the presence or absence of reconstructions on adjacent teeth and the morphology of the alveolar bone in edentulous areas.

Statistical analysis

Failure and complication rates were calculated by dividing the number of events (failures or complications) in the numerator by the total exposure time of the reconstruction in the denominator.

The event rates for reconstructions were calculated by dividing the total number of events by the total reconstruction exposure time in years. For further analysis, the total number of events was considered to be *Poisson* distributed for a given sum of reconstruction

exposure years and *Poisson* regression with a logarithmic link-function and total exposure time per study as an offset variable were used (13, 14). All analyses were performed using Stata®, version 8.2*.

Results

Meta-analysis of the included studies indicated an estimated 5-year survival of conventional tooth-supported FDP of 93.8%, cantilever FDP of 91.4%, solely implant-supported FDP of 95.2%, combined tooth-implant-supported FDP of 95.5% and implant-supported SC of 94.5% as well as resin-bonded bridges 87.7% (Table 1). Moreover, after 10 years of function the estimated survival decreased to 89.2% for conventional FDP, to 80.3% for cantilever FDP, to 86.7% for implant-supported FDP, to 77.8% for combined tooth-implant-supported FDP, to 89.4% for implant-supported SC and to 65% for resin-bonded bridges (Table 2).

*Stata Corp. College Station, Texas, USA.

Despite the high survival rates, 38.7% the patients with implant-supported FDP had some complications during the 5-year observation period, when compared with 15.7% for conventional FDP and 20.6% for cantilever FDP respectively.

For conventional tooth-supported FDP, the most frequent complications were biological complications such as caries and loss of pulp vitality. Compared with tooth-supported FDP, the incidence of technical complications was significantly higher for the implant-supported reconstructions. The most frequent technical complications were fractures of the veneer material (ceramic fractures or chipping), abutment or screw loosening and loss of retention. For resin-bonded bridges, the most frequent complication was debonding.

Discussion

For the present discussion, it was assumed that the dentition presents with endodontically and periodontally healthy teeth. Implant treatment in periodontitis-susceptible patients has been described in another review article (15). Teeth that were considered irrational to treat for whatever reason were extracted prior to decision making for the prosthetic reconstruction of the dentition. Hence, the clinical situations will be evaluated prior to replacing teeth that are already missing.

Single tooth gaps in the anterior maxilla

In areas of aesthetic priority, single tooth replacement is faced with the challenges to achieve an illusion close to nature. In this respect it is important to identify aesthetic parameters such as heights and extension of smile lines, tissue biotype, tooth characteristics, etc. These factors may determine the choice of treatment modality with higher priority than the longevity of the reconstruction *per se*.

However, based on the evidence of the systematic reviews the missing tooth is replaced preferably by an implant-supported SC (Annual failure rate: 1.12%) (11) provided the adjacent teeth are intact and in perfect condition (Fig. 1). This represents the most conservative and most 'biological' treatment option. However, if the adjacent teeth are severed, or in need of being crowned, the conventional FDP is to be preferred (Annual failure rate: 1.14%) (11). Both from a longevity and economic point of view, the two options are



Fig. 1. A young patient who lost her upper right central incisor (tooth 11) in a bicycle accident. The edentulous space was restored with a screw-retained implant-supported single crown.

similar with a 10 year survival rate of 89.4% and 89.2% for implant-supported SC and conventional FDP respectively (11). An RBB should be considered only as a second option because of a higher annual failure rate (2.61%) based on results of a 5-year follow-up period and even higher annual failure rate (4.31%) in the 10 year perspective (12).

Single tooth gaps in the anterior mandible

In the anterior mandible, the aesthetic aspect usually has a lower priority when compared with the maxilla. On the other hand, the anterior mandible represents an important issue from the functional aspects, especially for speech. While choosing the treatment option for optimal functional outcomes, both an implant-supported SC (Fig. 2) and a conventional FDP may be chosen. However, it has to be kept in mind that the preparation of mandibular incisors presents a serious risk for the pulp vitality. Hence, whenever the bone



Fig. 2. A patient with a congenitally missing lower central incisor. After orthodontic treatment, the edentulous space was restored with a screw-retained implant-supported single crown.

morphology and volume allow the placement of an implant, the implant-supported SC should be preferred. Furthermore, similar thoughts as specified for the anterior maxilla may apply. In addition, the resin-bonded bridge is an often chosen option, when economic and space issues play a role. However, such RBB need to be placed on teeth with favourable jaw relations, adequate periodontal support and intact enamel.

Single tooth gaps in the posterior region

In the posterior region, the functional aspects dominate the decision making process. Moreover, the condition of the gap-adjacent teeth is of crucial relevance. If these are intact or only repaired with minimally invasive restorations, they should preferably not be prepared as abutments. Again, implant-supported SC is the first choice and represents the most tissue-preserving treatment. The conventional FDP should only be chosen if the adjacent teeth require reconstructions (Fig 3). RBB yield an annual rate of debonding of 5.17% in the posterior region (12) and can, therefore, not be recommended.

Multiple missing adjacent teeth in the anterior maxilla

In addition to the thoughts expressed for the single gaps in the anterior maxilla, functional as well as aesthetic aspects have to be considered. In situations with, e.g. four missing incisors, the volume of soft tissues and bone has to be analysed. The placement of two non-adjacent implants may be the first choice of treatment provided that both soft tissue and bone volumes are



Fig. 3. A patient with a missing upper first premolar. As both adjacent teeth required reconstructions the edentulous space was restored with a three-unit conventional tooth-supported FDP. The soft tissue in the edentulous space was conditioned by a provisional bridge to provide optimal aesthetic as visualized by the incomplete seating of the FDP prior to cementation.



Fig. 4. A female patient who lost all her upper incisors because of periodontal disease. Two implants were placed in the positions of 12 and 22 and the edentulous space was restored with a four-unit implant-supported FDP.

adequate (Fig. 4). However, the decision may be influenced by the morbidity encountered with advanced augmentation procedures. In preferring, the conventional FDP over the implant-supported FDP, the extension and the retention aspects of the FDP have to be analysed. The use of more than one abutment adjacent to a large edentulous space may increase the risk for complications. The implant-supported FDP results in a smaller reconstruction. From a longevity point of view, the implant-supported FDP exhibit an annual failure rate of 1.43% (6, 11) compared with that of the conventional FDP of 1.14% (11). The 10-year survival is also slightly lower (86.7%) (6, 11) for the implant-supported FDP when compared with conventional FDP (89.2%) (11).

Multiple missing adjacent teeth in the anterior mandible

Similar aspects govern the decision-making process in the anterior mandible as those for the anterior maxilla,



Fig. 5. A smoker who lost all lower incisors because of periodontal disease. Implant placement would only have been possible with lateral bone augmentation (two-stages). As the canines had good periodontal support the edentulous space was restored with a six-unit tooth-supported FDP extending from 43 to 33.

although the risks for complications with the incorporation of conventional FDP (Fig. 5) appear to be lower than in the maxilla. Tissue volume and morphology of the alveolar bone may, however, dictate the necessity of augmentation procedures that are difficult to perform and often result in unpredictable outcomes. Therefore, unfavourable morphologic conditions may preclude the possibility of an otherwise preferred implant-supported reconstruction. Evidence for the incorporation of multi-unit RBB in the anterior mandible is lacking (12).

Multiple missing adjacent teeth in the posterior region

As opposed to the opinion expressed during previous decades in which implant-supported reconstructions were not yet considered a predictable treatment, large edentulous gaps may, today, be reconstructed preferably with implant-supported FDP (Fig. 6). The shorter extension of these usually reduces the biomechanical risks encountered with long-span conventional FDP.



Fig. 6. A patient with three missing teeth in the fourth quadrant. Instead of inserting a long-span tooth-supported FDP from 43 to 47, the edentulous space was restored by a three-unit FDP supported by two implants.

On the other hand, it has to be considered that the incidence of technical complications such as ceramic fractures or chipping is generally higher for implant-supported (annual complication rate of 1.84%) than for tooth-supported reconstructions (annual complication rate of 0.59%) (11).

Free-end situation with missing molars

The treatment options available to replace missing molars with fixed reconstructions are the implant-supported SC or the tooth-supported cantilever FDP. The former presented with a very favourable annual failure rate (1.12%) (11), while the latter yields a higher annual failure rate of 2.20% (11). It is evident



Fig. 7. A female patient who had lost tooth 16 because of a vertical root fracture. She was not satisfied with a shortened dental arch. Hence, an implant was placed in position 16 and after a healing period of 8 weeks, it was restored with a cemented crown. This improved the subjective chewing capacity of the patient.

that the implant-supported SC (Fig. 7) is preferred over the tooth-supported cantilever FDPs provided the bone morphology favours implant installation. If the adjacent teeth of the free-end saddle are to be restored, the tooth-supported cantilever FDP may be chosen. However, it has to be realized that non-vital endodontically treated terminal-abutments present with an increased risk for tooth fractures when compared with vital end-abutments (16, 17).

Prior to choosing a treatment option for missing molars an evaluation of the subjective chewing capacity and the functional needs of the patient regarding molar replacement has to be made. Shortened dental arches with bilateral premolar occlusion provide a reasonable and individually optimal, restricted treatment goal in many patients (18–20), presenting an option where no prosthetic reconstruction is needed.

Free-end situation with missing premolars and molars

In these situations, increasing subjective chewing comfort is a desire in most patients. In addition to the options discussed above for the free-end situation with missing molars, tooth-implant-supported FDP, solely implant-supported FDP and multiple implant supported SC may be considered. From a longevity point of view, the first category of preferred options include solely implant-supported FDP (Fig. 8) and multiple implant-supported SC. These presented with an annual failure rate of 1.43% (6, 11) and 1.12% (11), respectively, based on the 10-year data. As a second option, the tooth supported cantilever FDP and the combined



Fig. 8. Several years ago, the patient lost all his premolars and molars in the maxilla. He had difficulties adjusting to a removable dental prosthesis. Bilateral sinus floor elevations were performed, and five implants were placed to support one three-unit and one four-unit FDP.

tooth-implant-supported FDP may be performed. These yielded an annual failure rate of 2.20% (11) and 2.51% (7, 11) respectively. It is evident that aspects other than those of longevity and complication rates may dominate the decision-making process. For example, anatomical situations may dictate choosing the second option treatments.

Conclusions

When planning prosthetic rehabilitations, conventional end-abutment tooth-supported FDP, solely implant-supported FDP or implant-supported SC should be the first treatment option. Cantilever tooth-supported FDP, combined tooth-implant-supported FDP or resin-bonded bridges should only be chosen as a second option.

For conventional tooth-supported FDP, the most frequent complications were biological complications such as caries and loss of pulp vitality. For cantilever FDP, the incidence of biological complications was similar to that of conventional FDP. Technical complications such as loss of retention and material fractures were, however, more frequent.

For implant-supported reconstructions, the incidence of biological complications, such as mucositis and peri-implantitis was similar for solely implant-supported, combined implant-tooth-supported FDP and implant-supported SC. Fractures of the veneer material (ceramic fractures), abutment or screw loosening and loss of retention were the most frequently encountered technical complications. Fractures of the veneer material was more frequent in studies reporting on gold-acrylic than metal-ceramic reconstructions.

The incidence of complications is substantially higher in implant-supported than in tooth-supported reconstructions. This, however, does not necessarily imply that the possibilities for corrective measures are more cumbersome. Although a variety of subjective and objective aspects heavily influence the choice of treatment modalities, the knowledge of survival and complication rates of various reconstructions based on the long-term studies certainly help in optimizing the decision process.

Conflicts of interest

Both authors declare no conflicts of interest.

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