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To save or to extract, that is the question. Natural teeth or dental implants in periodontitis-susceptible patients: clinical decision-making and treatment strategies exemplified with patient case presentations

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Dentitions damaged by severe periodontal disease often cause problems not only to the patient but also to the dentist, not least regarding the choice of therapy. Today's arsenal of therapeutics makes the choice of best treatment strategy for the individual patient very sophisticated.

Advanced periodontal breakdown will call for extensive cause-related treatment of the disease to achieve and maintain periodontal health. It may also require comprehensive prosthetic reconstruction to restore function and aesthetics to the patient (19, 20).

It is well documented that properly treated natural teeth with healthy but markedly reduced periodontal support are capable of carrying extensive fixed prostheses for a very long time with survival rates of about 90%, provided the periodontal disease is eradicated and prevented from re-occurring (16, 20, 29, 31). However, this knowledge seems to have penetrated only minor parts of the dental society.

During the last decades careful scientific documentation has provided a solid base for implant therapy as a reliable treatment modality to replace lost teeth (14, 17, 24, 25). Today we know that treatments including implant-supported single crowns or fixed partial dentures as part of a comprehensive therapy will generally have a good prognosis when performed on the correct indications and followed by proper oral hygiene measures and supportive care. The acquired knowledge related to implant-supported reconstructions has markedly penetrated dental society, gaining support from dentists and patients as well as from the dental implant industry. The treatment is often spectacular with rapid and clearly visible results both for the dentist and the patient. This, together with business-based promotion, may partly explain the widespread application of dental implant therapy.

There are opinions among clinicians that the prognosis of complex, often time-consuming, and trying periodontal therapy may not match the high levels of success of treatment with implants. As a consequence more and more teeth are extracted and replaced with implants in patients suffering from moderate to advanced periodontal breakdown. This approach is based on the assumptions that implants perform better than periodontally compromised teeth and that their longevity is independent of the individual's susceptibility to periodontitis. As a consequence, teeth that could be saved and used as supports for fixed partial dentures are extracted and replaced with implants, sometimes on doubtful indications.

However, other colleagues have started to realize that there sometimes is an over-confidence in implant therapy and that expensive treatments with uncertain prognosis are provided when other solutions, saving a greater number of natural teeth, would have been a comparable, or even a better, choice long-term. These colleagues emphasize the risk for loss of implants as a result of the use of implant sites with low bone density or insufficient bone volume or because of peri-implantitis. Certainly, there are extraordinary methods available to solve the problems of inadequate bone support, such as sinus floor elevation and other bone augmentation procedures, but these methods are clinically complex, time-consuming, and costly. In addition, follow-up studies showing long-term treatment results are scarce and deal primarily with implant survival (the implant is in function but its status is not accounted for) and not with implant success focusing on the marginal peri-implant bone level. It is therefore difficult to evaluate the annual peri-implant bone loss over a long time. Ekelund et al. (5) and Attard & Zarb (3) reported, in two 20-year follow-up studies on full-mouth mandibular implant bridges, that the annual bone loss was, on average, very small but showed great variability. However, no frequency distribution of data related to reasons for tooth extractions was given. Thus, there are no long-term data for implant success or failure in patients with a registered history of advanced or rapidly progressing periodontitis.

However, peri-implantitis lesions (with radiographic marginal bone loss of at least 2 mm) at one or more implants have been found to occur in 16–28% of implant patients after 5–10 years (4, 6, 27) and with higher prevalence among patients with multiple implants (6). These studies suggest that longitudinal bone loss around implants is correlated to previous experience of periodontal bone loss and that periodontitis-susceptible patients are at higher risk than nonsusceptible patients for also developing peri-implantitis (8, 14, 28). Such findings underscore the necessity of careful consideration regarding choice of therapy. Therefore, the patient's own natural teeth should be carefully taken into account when planning and performing complex treatment of periodontally compromised dentitions. The natural tooth should not be considered an obstacle but a possibility, whether or not the treatment is to include implant installations. If implant therapy is considered in periodontitis patients it should be preceded by elimination of the periodontal disease through cause-related treatment and supportive care for infection elimination. Continuous supportive infection control should of course also be provided to the implant patient to prevent development of peri-implantitis and peri-implant bone loss, whether there are natural teeth or dental implants that harbor the microorganisms, which threaten the longevity of their existence.

The purpose of this article is to discuss clinical decision-making and treatment strategies in the management of periodontally compromised patients. The presentation is exemplified by patient cases where one or several teeth are suffering from advanced periodontal breakdown and where treatment with dental implants is usually an alternative. All patient cases have been followed long-term. Both benefits and risks of treating periodontally compromised teeth / dentitions in combination or not with implant placement, are accounted for. Also the benefits and risks of using implants to cost-effectively improve the prognosis for the mobile natural tooth or tooth-supported fixed partial dentures are presented. The compilation will particularly discuss treatment alternatives, which are often discarded or not even considered, but which may offer certain advantages both regarding prognosis and invested efforts.

What is possible? What can be done? What should be done?

The therapeutic solutions of the patient cases shown in this compilation might, by some colleagues, be regarded as extreme, but it should then be remembered that the cases have been chosen to illustrate what is *possible* and what *can* be done, rather then what *should* be done. Knowing what can be done 'on the edge' gives greater freedom to act and a broader treatment arsenal to both the clinician and the patient.

Of course any serious dental treatment aims to achieve the best possible prognosis for the chosen therapy, i.e. reaching the goal with a minimum of complications over the longest possible time. The benefits and risks of the chosen therapy must, however, also be balanced against the patient's willingness to invest time and money and how broad or narrow the safety margin that both the dentist and the patient are prepared to build into the chosen therapy. These are issues that will vary considerably, not only between different dentists, but also from patient to patient. Adding the competence, experience, and 'dental attitude' of both the dentist and the patient and the variability of treatment strategies and performances will be considerable. Limited access to different specialists might constitute a decisive influence on the chosen therapy. Comprehensive

factors with great impact on all other factors are of course the attitudes and resources offered by the society in which the treatment takes place.

It is therefore not surprising that choice, planning, and performance of treatments will vary to a great extent between different dental teams. Accordingly we will face a variety of treatment modalities that, owing to the special circumstances, may all be more or less understandable. Some treatment strategies and performances may, however, be inadequate because of a lack of knowledge and/or because of inexcusable 'dental attitudes'.

Survival of teeth vs. implants

The prevalence of severely advanced periodontitis has been found to amount to 10–15% of the population in the industrial world [e.g. (9, 22, 23)]. However, in most patients the majority of teeth survive for a lifetime. For instance 97% of Swedish 70-year-olds are dentate and have on average 20 teeth (11). The major reasons for tooth loss are either related to periodontal disease or dental caries (significantly outnumbering losses as the result of trauma and aplasia). Another important cause of tooth loss, seldom openly discussed, is the action of the dentist's forceps, used on very variable and personal indications. Certainly there are several good and rationale reasons behind many tooth extractions, but there is also lack of knowledge about the criteria for 'hopeless teeth' (i.e. teeth that have to be extracted) that should be addressed.

The replacement of lost teeth with implants means that an artificial body is inserted in the oral cavity with seemingly excellent medium-term success, but with a long-term success of which we still know very little on both population and global levels.

A recent systematic review of the survival and complication rates of implant-supported fixed partial dentures found that biological complications in the form of peri-implantitis occurred in 8.6% of the cases after 10 years, while the survival rate of implant supported fixed partial dentures amounted to 87%. A corresponding review on tooth-supported fixed partial dentures showed a 10-year survival rate of 89% with 0.5% of the constructions lost as a result of periodontitis. (Loss of retention was the major cause to conventional bridge failure.) One could then ask: what is the cost (time and money) for treatment, maintenance, and follow-up for tooth-supported vs. implant-supported constructions on a long-term basis?

Recent reports indicate that implants may follow the same survival curve as natural teeth, i.e. have a skewed distribution on a population level. Thus, the risk for loss of bone support over time seems to be roughly the same for an implant as the loss of periodontal support for a natural tooth. This should be taken into consideration when planning for reconstruction of a partially edentulous dentition. In other words, a natural tooth in the patient affected by periodontitis may have a prognosis comparable to an implant and the risk for an implant to lose supporting bone seems on average to be as high as that for a tooth whether the patient is periodontally susceptible or not.

The root length of a tooth is, on average, about 20 mm while the most commonly used implant is 10 mm long. Longitudinal studies on random samples of Swedish populations have demonstrated that there is a gradual interproximal bone height reduction of about 0.1 mm per year around teeth (10, 12, 30). Corresponding annual bone loss around dental implants (after the first year with 1 mm of bone loss) has been reported to be between 0.1 and 0.2 mm (1). Thus, a tooth will have a prognosis that is at least as good as, if not even better than, an implant with 'normal' length if we simplify the assessments to a matter of distances. In the case of periodontitis or peri-implantitis, bone loss may progress more rapidly and be uncontrolled. It is well documented, however, that severe periodontitis can be successfully treated and further pathological bone destruction can be prevented (18). The long-term prognosis of peri-implantitis treatment is as yet poorly documented. If further periodontal destruction is arrested by successful periodontal treatment, there is no obvious reason to replace a tooth (with no or little caries experience) with an implant even in cases with significant bone loss.

Certainly there are several differences between a natural tooth with markedly reduced periodontal support and an implant with markedly reduced bone support. Teeth may (if unsplinted) become hypermobile, but they will, if reasonably well distributed, successfully function as support for extensive bridges. Of course there is a lower limit for how much periodontal support is needed but even as little as 25–30% remaining periodontal support seems to be sufficient, even in the long term (16, 21).

The capacity (prognosis) of implants with markedly reduced but healthy bone support to carry an extensive bridge is unknown. Therefore, the natural dentition ought to be considered as a functioning unit, including individual teeth as possible abut-

ments for fixed partial dentures, before implants are thought of. The case presentations in this compilation will hopefully illustrate this postulate.

Loss of one or several teeth, on the other hand, often calls for implant-supported replacements as an alternative to a tooth-supported bridge to avoid unnecessary grinding of intact teeth if there is sufficient bone volume and the patient is interested and can afford such treatment. Multiple tooth losses, especially with lack of end-support for a presumptive tooth-supported bridge, make the indication for implant placement particularly strong provided there is enough bone.

It has convincingly been shown that extreme full mouth reconstruction 'from ear to ear' often means overtreatment from a functional point of view. It might thus be sufficient, with a shortened dental arch, tooth supported or implant supported from second premolar to second premolar (i.e. patient case no. VI) if jaw relation is normal and the aesthetic and psychological demands from the patient perspective are fulfilled. It should in this context be remembered that the so-called 'classic Brånemark-bridge' (Nobel Biocare, Göteborg, Sweden) with bilateral two-unit, posterior cantilevers supported on implants from the right to left canine is an excellent illustration of stable fixed bridges with distal extensions only to the second premolar areas. These constructions provide good stability for the chewing apparatus with satisfactory function and aesthetics in most patients. The same stability and function will also, of course, be achievable with a tooth-supported bridge of the same design and extension (2, 13, 15, 16), provided the crown retentions are sufficient.

There are also situations where one or several implants might be used in combination with a natural tooth (teeth), to support so-called mixed bridges (7). This might be beneficial when the jaw anatomy restricts placement of multiple implants and where a natural tooth could be used preferably as a bridge abutment and provide adequate crown retention (patient case no VII).

In very special situations a strategically placed implant might also be used in combination with a natural tooth and supplied with a distal cantilever to extend a shortened dental arch (patient case no VIII). A single implant might also serve as a stabilizer for a hypermobile tooth (patient case no IX) or a bridge (patient case no X). This would save considerable treatment time and money and achieve a treatment result with good long-term prognosis. An unequivocal condition is, though, that the crown retentions to both teeth and implants are reliable.

Optimal timing for implant placement

As stated above, recent data indicate that the periodontitis-susceptible patient may be at risk for developing peri-implantitis, which may result in loss of the implant(s). This knowledge raises questions, not only on the indications for implant treatment but also on the optimal timing for implant placement in the individual patient.

If we assume that the periodontitis-susceptible patient is equally susceptible to peri-implantitis and that the expected development of peri-implantitis, as a worst case, will follow about the same progression curve as the patient's experienced periodontal breakdown, then the expected implant failure will be more postponed the later the implant is placed (Fig. 1).

On the other hand, periodontal disease progression can be prevented, or at least significantly retarded, by more or less efficient periodontal treatment (Fig. 2). Unfortunately, the periodontal (cause-related) therapy is often too inefficient, and/or is initiated too late, to prevent further progression of the disease, although the progression rate might be retarded (Fig. 2). However, repeated cause-related therapy will pay off even if the periodontal breakdown is only retarded. If the breakdown is so advanced that the tooth is scheduled for future extraction (whether involved as bridge-support or not) it is an advantage if the extraction, and thereby the implant installation, is postponed as long as possible.

In other words, the later in life the implant is installed, the further in the future, if at all, will a possible implant failure and implant loss occur. The younger the patient and the steeper the progression curve, the more important it is to interfere with the progress of the periodontal disease to delay implant installation and, once implant treatment has been performed, to follow the patient with peri-implantitis prevention measures.

Summary

To obtain the best possible long-term prognosis, clinical decision-making for optimal treatment strategies in periodontitis-susceptible patients should be based on evaluation of:

- periodontal disease severity and progression,
- functional and aesthetic demands,
- patient plaque control ability and patient compliance,

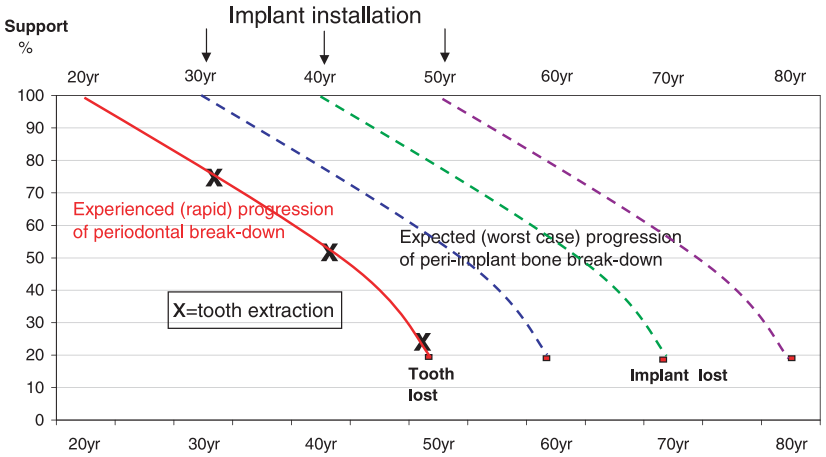


Fig. 1. Schematic presentation of fictive periodontal and peri-implant tissue breakdown in the lack of efficient treatment. Presuming that the expected peri-implant bone breakdown curves (broken lines) follow that of the experienced periodontal breakdown curve (unbroken line), it becomes obvious that the later in life the implant is installed the later in life will the implant be lost. For example, if a tooth with about 75% remaining periodontal support is extracted and replaced with an implant when the patient is 30-years old, the implant is likely to survive until the patient is 60 years old. If a tooth with about 50% periodontal support is extracted at the age of 40 years, the implant is likely to survive until the patient is 70-years old, while an implant that replaces a tooth with 30% periodontal support when the patient is 50-years old, is likely to survive until the patient is 80-years old.

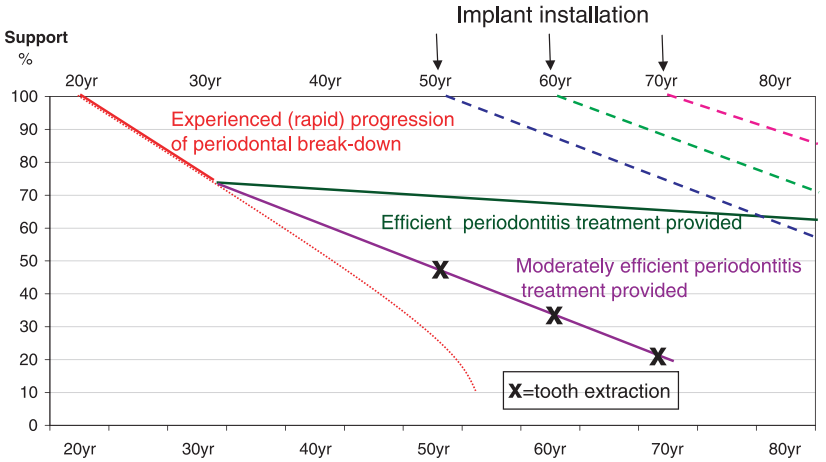


Fig. 2. Schematic presentation of fictive progressive periodontal tissue breakdown interrupted by treatment resulting in extended tooth survival and reduced need of implants. If the experienced progressive periodontal breakdown (unbroken line) is interrupted by efficient treatment there is probably no need for tooth replacement. Moderately efficient treatment may still postpone the need for tooth extraction and implant therapy until the patient is at least 50 years or older depending on how much periodontal tissue breakdown is accepted before tooth extraction is undertaken. If moderately efficient treatment is applied also to the peri-implant tissues the installed implants will probably survive the patient.

- risk factors for technical and biological failures, and
- treatment complexity and costs.

Patient case presentations

The following patient cases will exemplify the capacity of both natural teeth and dental implants to serve as functioning units in the long term. Furthermore, discussions elucidate what can be learnt from the treatment results of the presented cases.

Patient I – single-tooth periodontal breakdown in an unbroken tooth arch in the maxillary anterior area (aesthetic zone): 12-year follow-up

The patient was a 50-year-old, well-educated woman in good general health, who had been seeing her

Fig. 3. Clinical photograph (A) and radiographs (B) at the initial examination.

dentist at least once a year for a long time. No cause-related periodontal therapy had been given. She complained about bleeding gums, tooth mobility and flaring (proclined) front teeth in the maxilla, especially the diastema between tooth 22 and tooth 23.

The clinical and radiographic status at the initial examination are shown in Fig. 3A,B. Tooth 22 presented with a 9-mm pocket distally and an infrabony defect is seen on the radiograph.

Clinical decision-making

Tooth 22 was regarded as a 'key tooth' with doubtful prognosis. If extracted, replacement with a bridge would cause some other decision-making problems. How far should the bridge be extended? Would a single-tooth implant be a good alternative with regard to available bone volume and aesthetic demands?

With regard to both modern dentistry and patient attitude, fixed replacements are generally preferred over removable replacements. Thus, in this case, the alternatives would be a bridge or a single-tooth implant. Regarding the bridge alternative; what would be the design and extension, i.e. how many neighboring teeth should be involved and prepared, and what type of construction would be the most valuable and cost-effective for the patient (e.g. resin-bonded bridge, inlay bridge, full coverage bridge)? The other alternative is single-tooth implant therapy. Is there enough bone for an implant and will it be an aesthetically satisfactory solution? In this case, the answers to both questions are probably yes. However, this alternative would be both costly and time consuming.

Periodontal surgery at tooth 22 was therefore decided upon, to confirm the local anatomical diagnosis and guarantee an optimal debridement and healing of the periodontal defect.

Treatment

Cause-related periodontal therapy was initiated, including patient information, oral hygiene instructions, and supragingival and subgingival scaling and root planing of the entire dentition.

Buccal and lingual mucoperiosteal flaps were raised from teeth 21 to 23 (Fig. 4). The granulation tissue was removed and the root surface was carefully scaled and planed. The periodontal bone defect was classified as a one-wall defect at the entrance and a three-wall defect at the deeper part. No bone surgery was performed. The flaps were repositioned and sutured to completely cover the defect. The patient was ordered to rinse with a 0.2% chlorhexidine solution twice daily for 10 days.

Treatment evaluation

The patient responded very well to treatment and no bleeding pockets exceeding 4 mm could be detected at the follow-up examinations. Tooth 22 returned spontaneously to its original position, resulting in

Fig. 4. Clinical view during surgery. Note the deep infrabony defect distal to tooth 22.

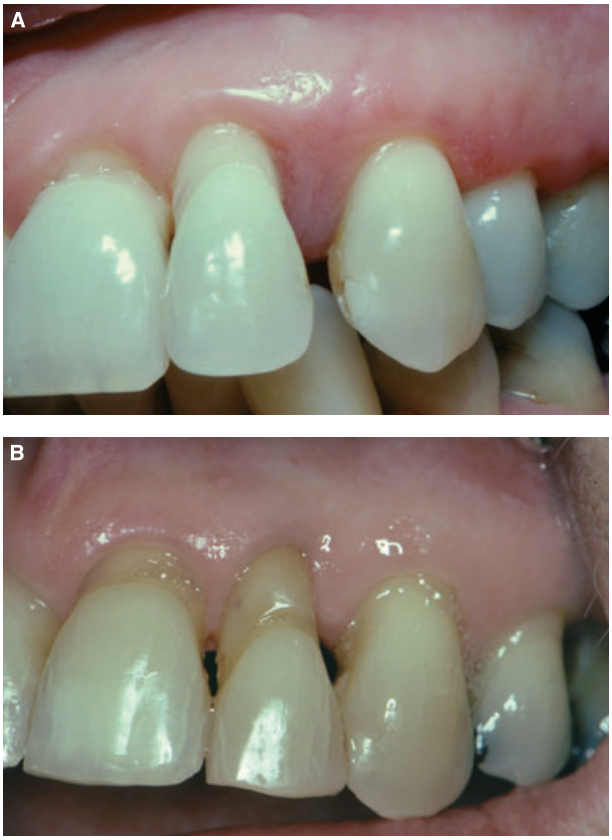


Fig. 5. Clinical photograph before treatment (A) and at 12 years after treatment (B).

satisfactory aesthetics. Fig. 5 shows clinical photos before (Fig. 5A) and 12 years after (Fig. 5B) treatment. Fig. 6 shows radiographs before (Fig. 6A) and after 12 years (Fig. 6B), exhibiting bone fill in the defect distal to tooth 22.

Discussion

The regular dental visits before the current treatment revealed that the patient had great interest in having a healthy dentition. Her observation that the front teeth in the maxilla had proclined and that a diastema had progressively developed between teeth 22 and 23 underscore her aesthetic consciousness. She was, however, not aware of the partially severe periodontal breakdown. As an unconditional prerequisite, a thorough cause-related treatment was undertaken. Many dentists might have suggested extraction of tooth 22 because of the deep intrabony defect, the evident tooth mobility, and the proclination.

Good periodontal healing with bone fill and a good aesthetic result were obtained. One additional observation was that the diastema 22 / 23 was spontaneously closed following treatment as tooth 22 migrated palatally. The presented treatment was relatively inexpensive. However, how predictable is periodontal healing with this amount of bone fill? Many factors can interfere with the healing response: e.g. the defect morphology (a three-wall intrabony defect will heal with more bone fill than a two-wall or one-wall defect, to easily verify the obtained treatment result), tooth mobility, flap coverage of the defect, operator skill, and of course the level of patient compliance. An alternative therapy including conventional prosthodontic treatment or a single-tooth implant could hardly have given a more favorable aesthetic result.

What can we learn?

First, it is possible to successfully treat and keep periodontally diseased teeth with advanced peri-

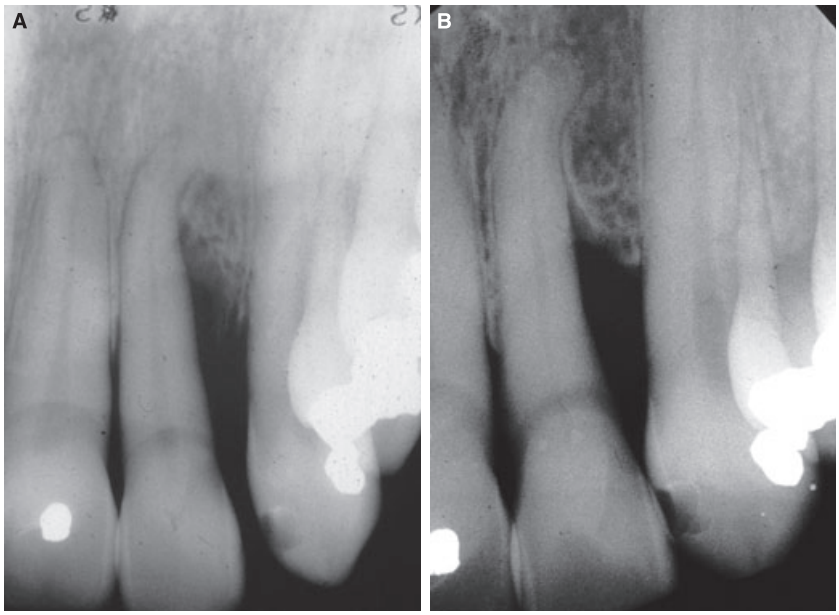


Fig. 6. Radiograph before treatment (A) and at 12 years after treatment (B).

odontal breakdown in a rational way. Second, it is possible to, at least partly, regain lost periodontium. Third, an important treatment might be successful with limited investment and last, the attitude and the capability of the patient are decisive for long-lasting results. In addition, treatment options other than implant therapy should always be seriously considered.

Patient II – single-tooth periodontal breakdown in an unbroken tooth arch in the mandibular anterior area: 7-year follow-up

A 68-year-old woman in good general health was referred to the specialist clinic for periodontal problems in the lower jaw, particularly at tooth 43. She had visited her dentist regularly. During the previous 6 months she had observed increasing mobility of the lower right canine.

The clinical situation at the initial examination is shown in Fig. 7A. Tooth 43 presented with probing depths of 6 mm mesially, 4 mm buccally, 9 mm lingually, and 12 mm distally.

There were no other periodontal problems except a mild papillary inflammation in the molar regions. The radiograph shows a deep infrabony defect at tooth 43 (Fig. 7B).

The tooth was not in traumatic occlusion and was sensitive to electric testing, therefore the lesion was diagnosed as being periodontal.

Clinical decision-making

Tooth 43 can be regarded as a 'key tooth'. If the tooth were to be extracted there would have been some problems in replacing it. Replacement with a conventional bridge would have implied that the existing bridge in the right side of the mandible had to be replaced or extensively rebuilt and supplied with a mesial cantilever extension. An anterior bridge with tooth 43 as a distal extension pontic might, for aesthetic and functional reasons, have to be extended to include even tooth 33. This would imply a rather expensive treatment so the 'single-tooth implant' alternative would be more attractive. The huge bone defect that would be left after extracting the tooth would, however, most likely require a bone grafting procedure to obtain an adequate bone volume for placing an implant in a proper position. This would require an extra healing period of at least 6 months. Immediate implant placement without bone grafting must be questioned at this site because the implant would be too apically located to allow for adequate oral hygiene.

Treatment

After initial information and oral hygiene instruction, periodontal surgery was performed. Fig. 8(A,B) shows clinical views during surgery. Note the deep intrabony defect at tooth 43.

Evaluation of treatment

The patient continued to visit her dental hygienist and/or dentist once a year for proper maintenance care. Fig. 9 depicts the clinical (Fig. 9A) and radiographic (Fig. 9B) result 7 years following therapy. The general periodontal status was good (low plaque and bleeding scores). No pockets with bleeding on probing could be observed around tooth 43. Radiographs taken 7 years after surgery show healing with bone fill of the defect compared to the baseline status.

Discussion

The presented treatment solution was quite simple and gave a good functional long-term result. As in patient case I, the healing after surgery resulted in significant bone fill but there was also a pronounced buccal gingival recession. The exposed root surface was, however, of no concern to the patient.

What can we learn?

As in patient case I, this patient exhibited a localized periodontal lesion at a 'key tooth'. This tooth

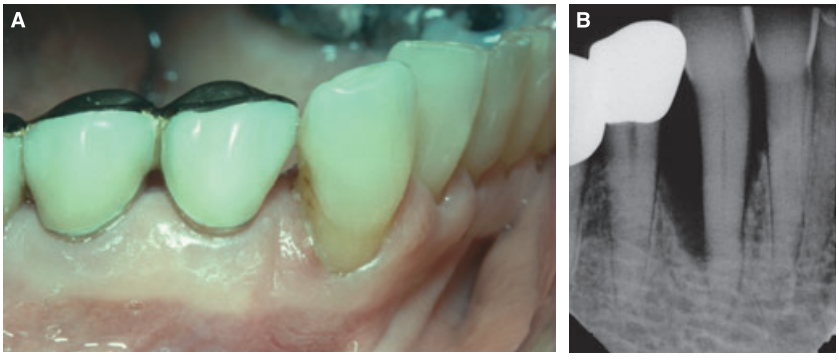
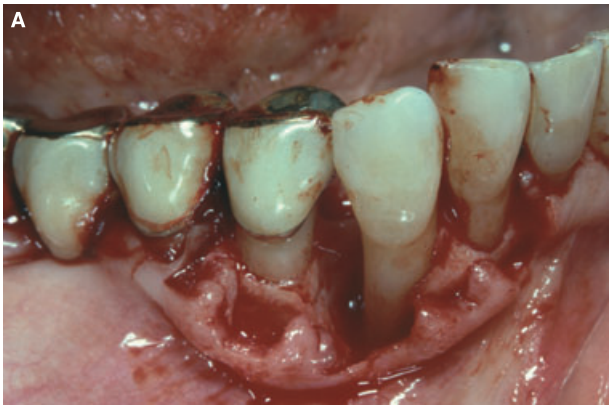


Fig. 7. Clinical photograph (A) and radiograph (B) at the initial examination. Note the deep infrabony defect at tooth 43.



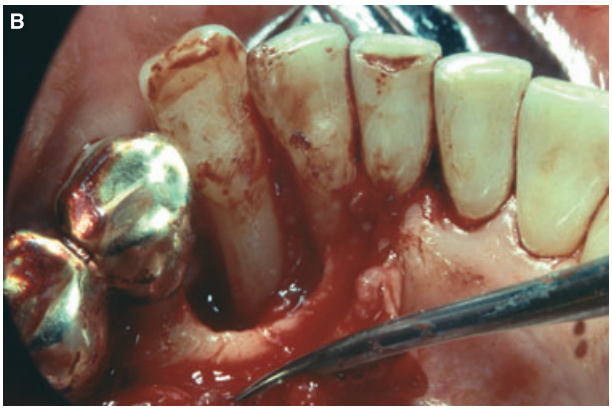


Fig. 8. Clinical views during surgery. Note the deep infrabony defect at tooth 43. Buccal aspect (A) and lingual aspect (B).

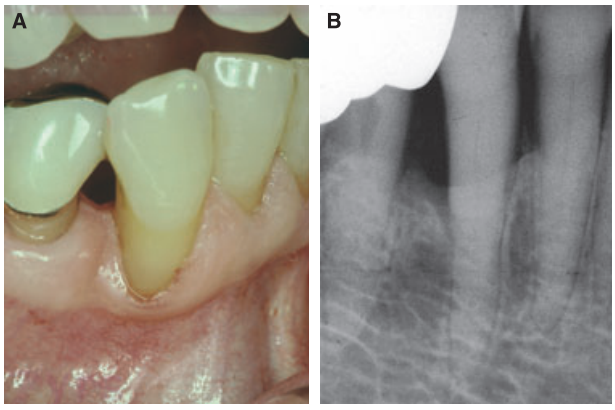


Fig. 9. Clinical photograph (A) and radiograph (B) 7 years after surgery.

could not have been replaced by an implant without extraordinary measures to achieve acceptable bone fill. Alternative treatment would have been a rather comprehensive remake of the existing bridge in the right lower jaw. Both of these alternatives would have been more time-consuming and costly than the periodontal therapy that was undertaken.

Patient III – advanced generalized chronic periodontitis with unbroken tooth arches: 20-year follow-up

This patient was a 52-year-old man in good general health. He had had a gingivectomy performed in both jaws 10 years before initial examination. Despite significant gingival recessions he presented with periodontal pockets in the 6- to 11-mm range around all teeth in the maxilla, and most teeth in the mandible, mainly interproximally (Fig. 10A,B) Bone-loss amounted to about 75% of most of the maxillary teeth, but was less pronounced in the mandible. The maxillary anterior teeth were slightly mobile, while teeth 14 and 27 with 11-mm pockets had mobility degree 2–3.

Clinical decision-making

A common (and reasonable) treatment suggestion would be multiple extractions in the maxillary jaw, followed by a provisional bridge and periodontal treatment of the entire dentition. After an interval, a permanent cross-arch bridge would have been performed on four to six suitable abutments. However, which teeth could be regarded as suitable or reasonably secure?

An alternative treatment would be a 10-unit bridge supported on four to six implants.

Despite the severe condition with considerable bone loss, a conservative treatment approach was determined. Teeth 14 and 27 were considered hopeless and irrational to treat.

Treatment

The treatment included providing the patient with information and motivating him to perform adequate oral hygiene, focusing on interdental cleaning, supragingival and subgingival scaling and root planing. Following re-evaluation after 6 months, residual pockets around tooth 46 were surgically corrected. Teeth 14 and 27 were extracted and tooth 14 was replaced with a four-unit inlay bridge extended from tooth 16 to tooth 13.

Evaluation of treatment

The patient responded well to treatment and his compliance was excellent. At the final examination at 6 months after completion of active treatment, there were no residual pockets. The patient was offered regular supportive care with re-enforced oral hygiene instructions when needed, supragingival scaling and debridement of sites with pockets 5 mm or deeper that bled on probing. Tooth 11

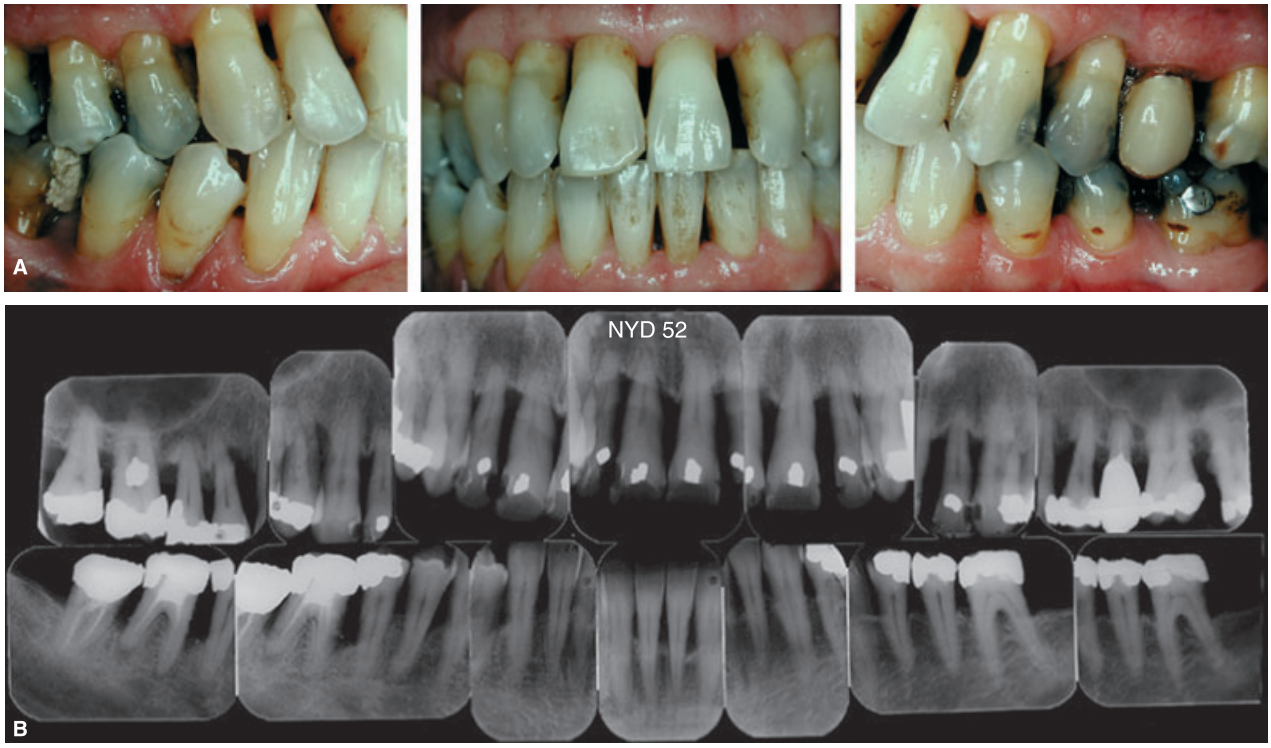


Fig. 10. Clinical photographs (A) and radiographs (B) at the initial examination.

presented with pulpal necrosis after 6 years and was endodontically treated. The patient has been seeing the dental hygienist every 6 months and the dentist/periodontist once a year and has been followed for 20 years without further periodontal breakdown (Fig. 11A,B) During the 20 years of follow-up, treatment input has therefore been simple and inexpensive.

This is a patient with advanced periodontal breakdown and about 25% remaining bone support around most teeth in the maxilla at the start of the treatment. It would have been reasonable to suggest

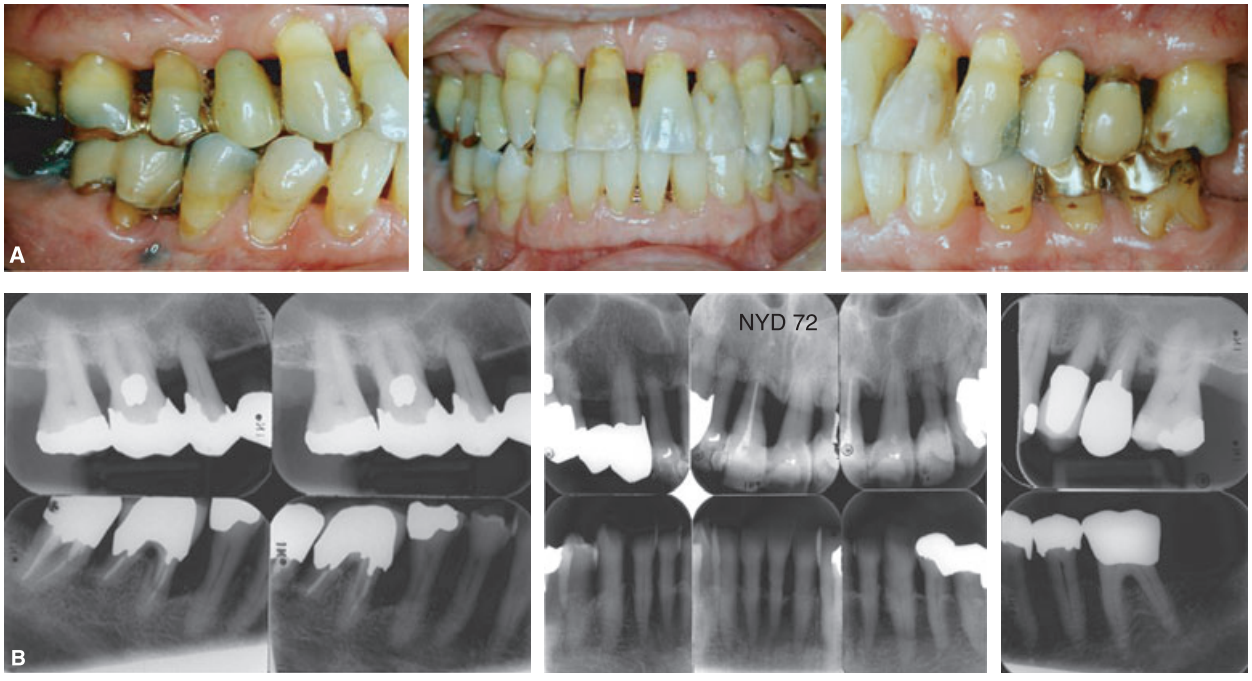


Fig. 11. Clinical photographs (A) and radiographs (B) at the 20-year examination.

that several teeth in the maxilla had to be extracted and replaced with implants. This would have been a very expensive treatment and as the patient evidently was periodontitis-susceptible, the prognosis would not have been secure. The mobility of the teeth was only slightly increased, indicating that there was a good balance between functional load and the capacity of the remaining periodontium to withstand that load. In addition, the patient was anxious to keep all or at least most teeth and he was highly motivated to comply with both home care and maintenance visits. Together these factors constituted a good basis for a conservative treatment plan.

What can we learn?

This patient case illustrates that dentitions with advanced periodontal breakdown can also be successfully treated and further breakdown can be prevented. Furthermore, as in this case, nonsurgical periodontal therapy can often be very efficient, limiting the need for surgical interventions. However, with so little periodontal support there is a risk that even a mild trauma / blow to the mouth could result in one or several of the anterior teeth in the maxilla becoming luxated, which actually happened after 6 years for teeth 11 and 21. An acrylic splint (obvious in Fig. 11) was therefore made, which has been *in situ* ever since.

It should also be observed that the suggested treatment alternative, including multiple extractions and implant placements, has so far been postponed by 20 years. Such treatment could be carried out in the future without essentially negative consequences because there will probably still be a sufficient amount of bone to harbor implants.

Patient IV – advanced periodontal breakdown of almost all teeth, most of which have been engaged as bridge support for long time: 30-year follow-up

This 52-year-old man presented with severely advanced generalized chronic periodontitis and multiple tooth losses at the initial examination. Existing crowns and bridges, and a removable partial denture in the lower jaw supported on a few teeth with advanced periodontal destructions, are shown in the radiographs (Fig. 12). A comparison with radiographs taken 8 years before treatment shows not only the ongoing progression of the periodontal disease with the concurrent lack of adequate plaque control but also how treatment had been performed without an overall treatment plan (Fig. 13A,B).

Clinical decision-making

It is interesting to consider the different treatment alternatives that were available at the time when the present treatment was initiated (30 years ago). Removal of all teeth in both jaws and fabrication of complete dentures would have been a highly realistic alternative or, if possible, a removable partial denture in the lower jaw after periodontal treatment of the remaining teeth. Observe the periodontal status of tooth 44 and also the endodontic–periodontal status of tooth 33. Implant therapy was essentially not available at that time and the use of teeth with

Fig. 12. Radiographs at the initial examination. Note the advanced periodontal destruction.

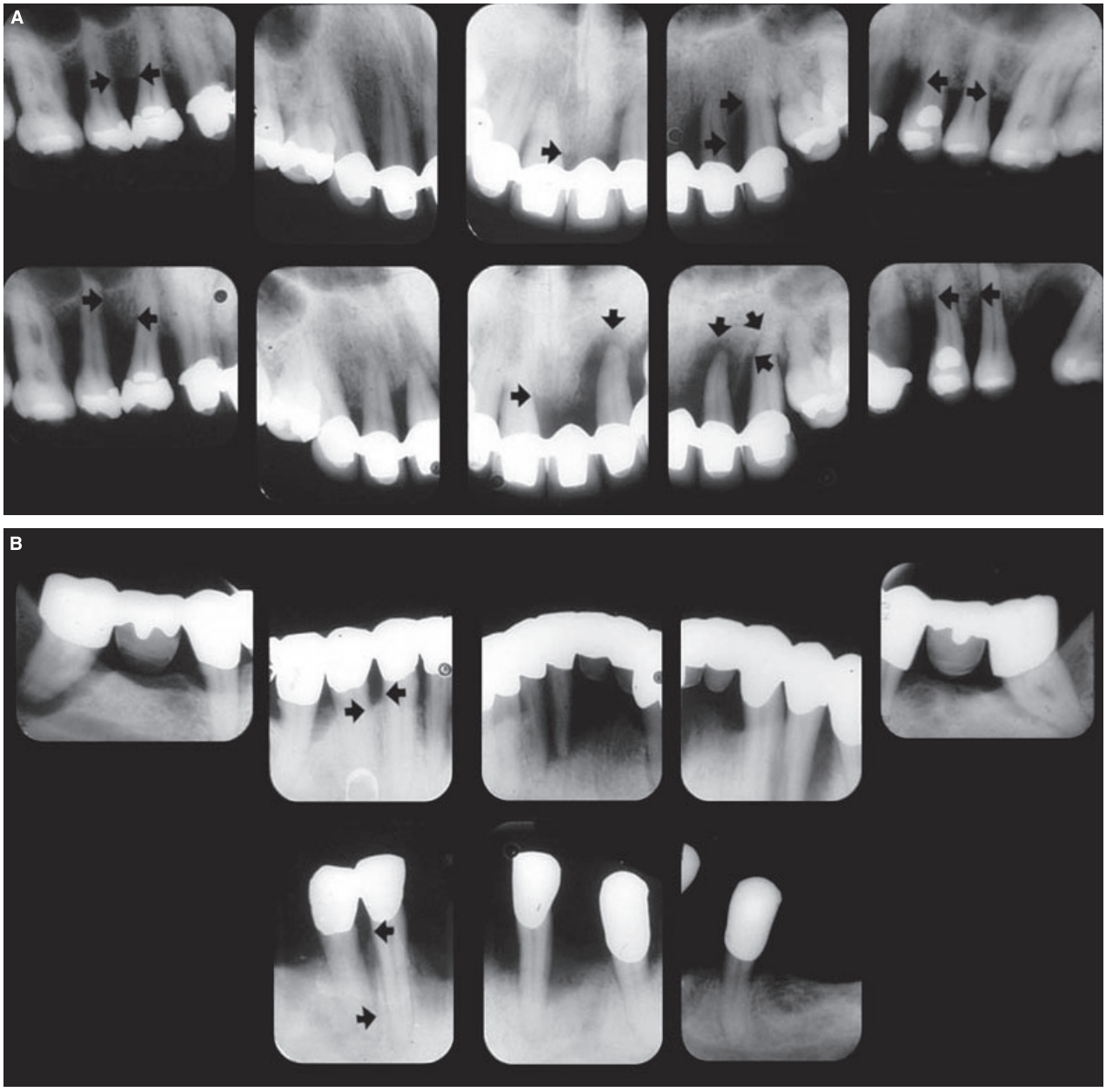


Fig. 13. Radiographs of maxilla (A) and mandible (B) at 8 years before (top) and at baseline examination (bottom). Arrows indicate sites with severe periodontal destruction and progression.

advanced periodontal breakdown as bridge support was generally considered extremely hazardous. The patient was extremely anxious to keep, if possible, at least some teeth to support a fixed reconstruction so it was decided to give the dentition (and the patient) a chance.

Treatment

After a hygienic test phase the periodontal treatment was carried out with very good results. Teeth 14, 22, 24, and 44 were extracted. In retrospect, extraction of tooth 44 was probably a more radical treatment than was necessary. The patient was supplied with provisional, diagnostic acrylic bridges during the periodontal treatment phase, which included hygienic measures and periodontal surgery. The provisional bridges were carried for 1 year, after which permanent gold–acrylic bridges were inserted (Fig. 14). Fig. 15 shows radiographs of the patient after 30 years of follow-up, and Fig. 16 shows a montage of clinical photos and radiographs of the patient after 30 years of follow-up. Observe the status of teeth 17, 25, and 33 before and after treatment (Figs 12, 15, and 16).

Fig. 14. Radiographs illustrating the status after the insertion of the permanent prosthetic construction.

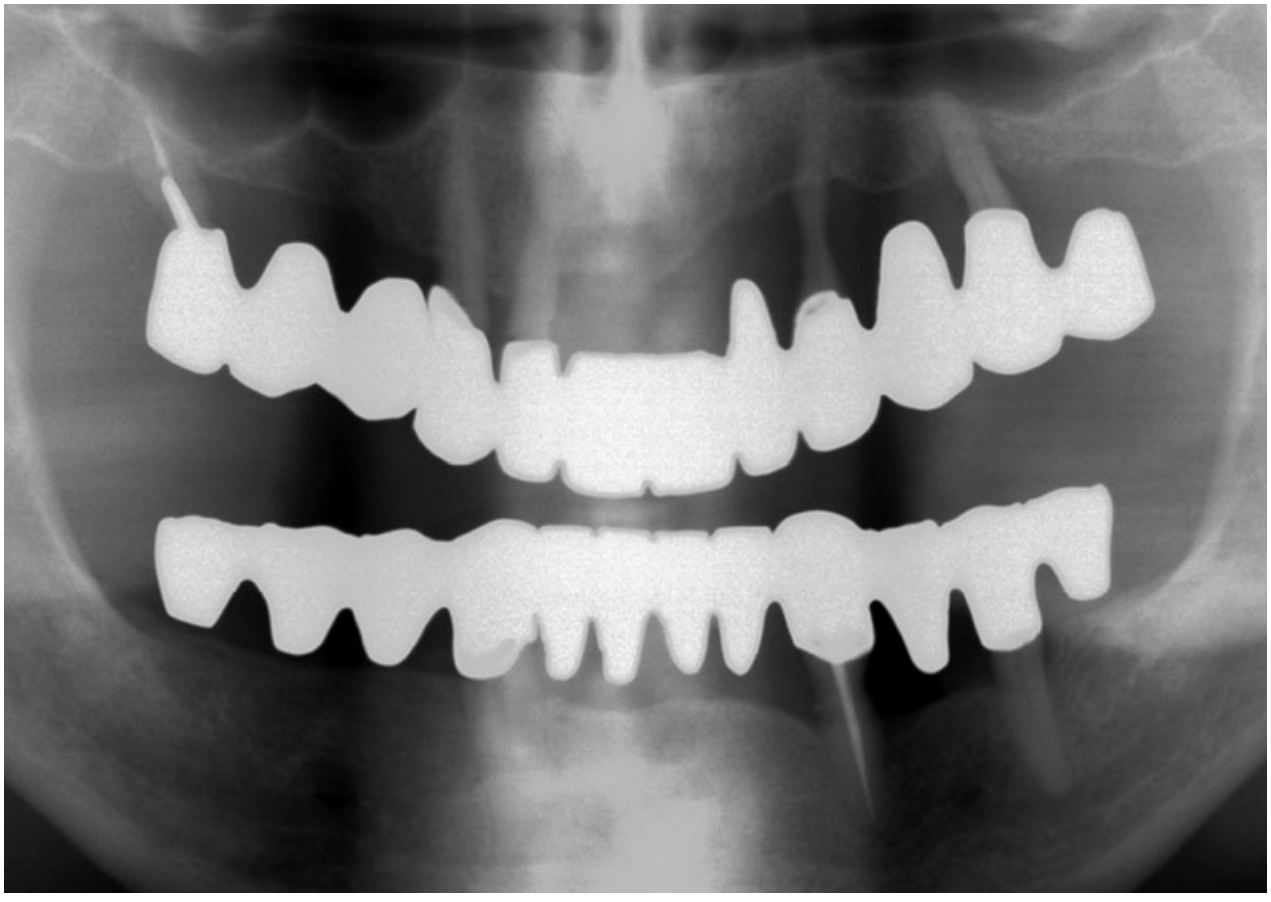


Fig. 15. Radiograph representing the status 30 years following the prosthetic rehabilitation.

Evaluation of treatment

Overall, the treatment result must be judged as excellent with largely status quo after 30 years of follow-up. The treatment time devoted to the case was not longer than if implant-supported bridges had been fabricated, but was almost certainly significantly less expensive. The follow-up schedule,

Fig. 16. Montage of clinical photographs and radiographs showing details from the 30-year follow-up.

with recalls twice a year for the first 5 years and once a year after that, illustrates the limited follow-up costs. A risk factor in extensive fixed prosthodontics is loss of retention of abutment crowns that would jeopardize the treatment outcome, especially when there are posterior cantilever extensions (25, 26). However, long clinical crowns as the result of periodontal breakdown allowed for long parallel abutment preparations to secure retention (16, 20).

What can we learn?

The main message from this case is that in patients with very advanced periodontal destructions, tooth-supported fixed bridges can be highly cost-effective alternatives to implant-supported bridges. This statement presupposes, however, that the periodontal disease has been eliminated and that disease recurrence is prevented through supportive maintenance care designed on patient needs. Preconditions for such a success after 30 years in service are of course the excellent patient compliance, the fact that there was a low risk for caries and that no extreme bruxism existed. It should also be observed that the possibilities of placing implants to support fixed prostheses are not worse than they were 30 years ago.

Patient V – aggressive periodontitis with extremely advanced periodontal breakdown around almost all teeth with unbroken maxillary tooth arch: 26-year follow-up

The patient was a woman, 44-years old at the initial examination, with extremely advanced periodontal destruction around almost all teeth (Fig. 17). She had been advised to have all her teeth extracted and replaced with full dentures. She was prepared to comply at any extent if her teeth, or at least some of them, could be kept and used as support for fixed bridges.

Fig. 17. Radiographs at the initial examination.

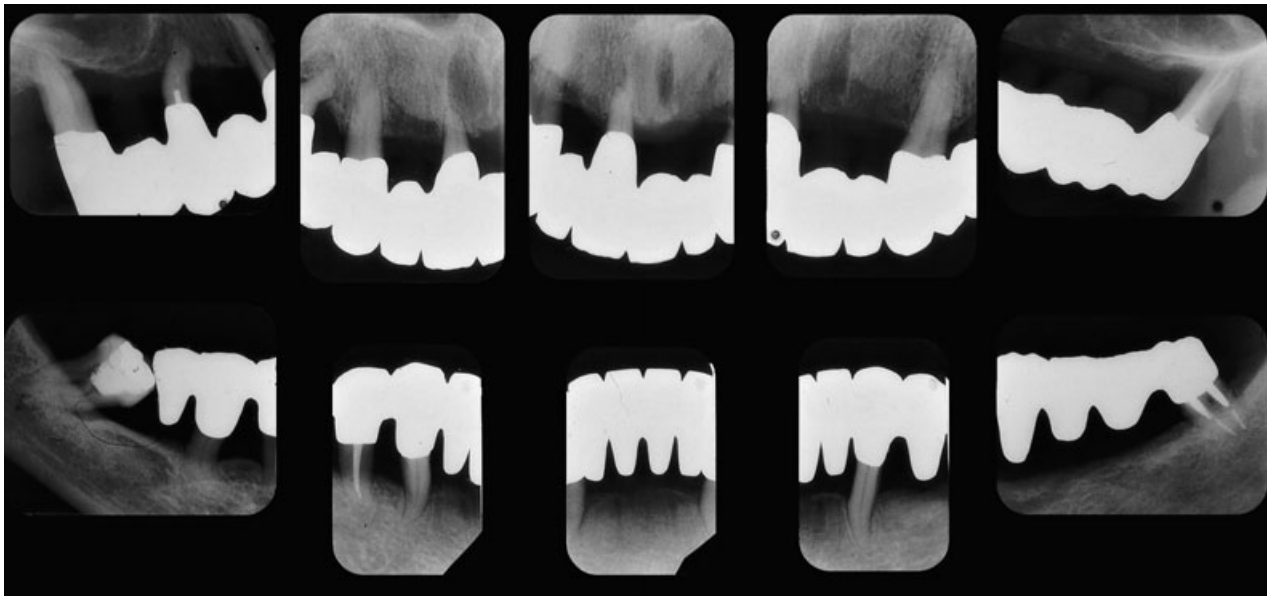


Fig. 18. Radiographs representing the status 26 years following completion of periodontal and prosthetic treatment.

Clinical decision-making

The most common treatment suggestion would be extraction of all teeth and replacement with full dentures or placement of implants to support cross-arch bridges. Implant therapy was not well established at the time of examination. Our clinical decision was to perform provisional 'diagnostic' cross-arch fixed bridges on teeth that were judged as treatable.

Treatment

The periodontal and prosthodontic treatment followed well-known principles. Multiple extractions were performed but a sufficient number of reasonably well-distributed teeth, although with advanced breakdown, were kept to serve as support for provisional acrylic bridges after careful periodontal treatment. After a diagnostic period of about 1 year, permanent bridges were delivered. Fig. 18 shows the situation after 26 years of follow-up.

What can we learn?

The result demonstrates that even aggressive, extremely advanced periodontitis can be successfully treated with a good long-term prognosis, provided the patient is motivated, willing, and capable of maintaining a high standard of plaque control. It should, however, be remembered that there is a risk for periodontal overload or loss of crown retention,

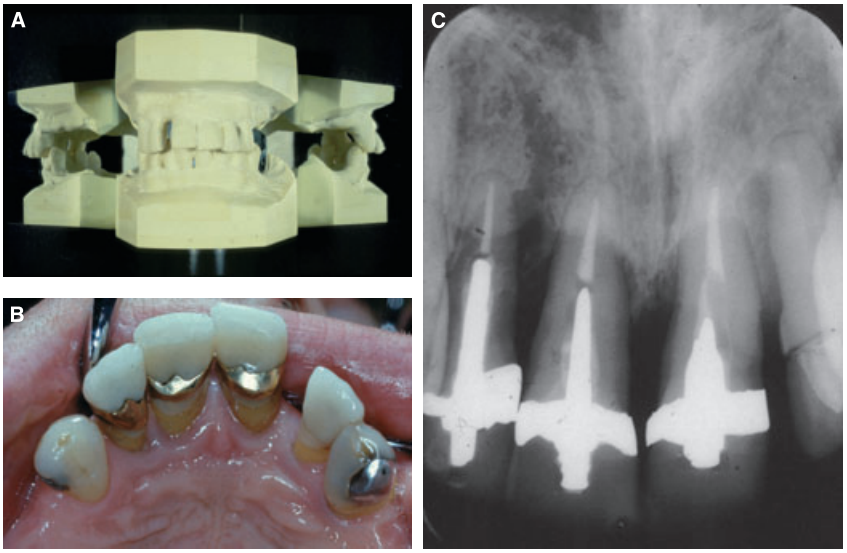


Fig. 19. Study model (A), clinical photograph (B), and radiograph (C) at the initial examination.

particularly in the maxilla, even if the occlusion is optimized.

It should also be stressed that this type of treatment really is 'on the edge' and should be reserved for highly motivated patients. Another important issue is that both the patient and the dentist should be prepared for an alternative therapy if the treatment should fail.

Patient VI – remaining maxillary anterior teeth from canine to canine with advanced periodontal breakdown of all four incisors, moderate periodontal breakdown of remaining mandibular teeth from right to left first premolar: 16-year follow-up

The patient was a man aged 55 years at the initial examination. He presented with reduced dentition in the upper jaw from right to left canine and in the lower jaw from right to left first premolar, as demonstrated with the study models in Fig. 19A. The jaw relation was normal. The periodontal breakdown was slight to moderate in the mandible and at the upper canines and advanced at the upper incisors, which were flared and proclined because of the loss of occlusal stability. Fig. 19 shows the clinical (Fig. 19B) and radiographic (Fig. 19C) status at the start of the treatment.

Clinical decision-making

The advanced periodontal destruction and the few remaining teeth called for both cause-related treatment of the disease and prosthetic reconstruction. One treatment alternative would of course be removal of all teeth in the upper jaw and fabrication of a complete denture, another would be to keep the canines as retention for a removable partial denture. A third alternative would be to install implants to support a cross-arch bridge with or without including the canines as support. Since the patient very much wanted a fixed bridge it was important to try to meet his desire. When planning for prosthetic reconstructions, decisions have to be made about the reliability of the presumptive abutments and how extensive the occlusal table should / must be in the posterior direction. Bilateral stability is a key issue for patient comfort and good prognosis, but this does not mean that molar support is mandatory, if the smile allows for a tooth-arch reduced to including the premolar areas only.

Treatment

The treatment was carried out at a time when implant therapy was not fully established so there were no considerations of whether implant therapy would have been a preferable alternative. The initial periodontal treatment included the extraction of teeth 12 and 22 and surgery on teeth 11 and 21, aiming at regaining lost periodontal tissue, which according to radiographic documentation and periodontal re-examination, was obtained. Finally, the patient was provided with a 10-unit bridge from the right to the left second premolars supported on the canines and the central incisors, i.e. with posterior, bilateral two-unit cantilevers.

An interesting question is how this case would have been treated today. Would the central incisors have been extracted? Would the canines have been kept or would all teeth in the maxilla have been extracted and replaced with implants? Would there have been implants installed in the first premolar and the central

Fig. 20. Clinical photograph showing the smile-line.

incisor areas and a mixed bridge made with connection to the canines? There is no doubt that the treatment alternatives that include implants would have been more expensive than the alternatives without implants. It should be observed that the patient had a very favorable smile line in relation to his 'second premolar to second premolar bridge' (Fig. 20). The patient was extremely satisfied with the extension of the bridge, which matched the extension of the shortened dental arch in the mandible. The stability of the dentition implied that there was no unconditional need for molar support. It should also be kept in mind that a 'classic Brånemark bridge', i.e. a bridge supported on four to six implants, would have had the same extension in the posterior direction as the tooth-supported bridge that the patient received.

Fig. 21 shows the treatment result clinically (Fig. 21A) and radiographically (Fig. 21B) 16 years after treatment.

What can we learn?

Although a stable occlusion is important, there is not always a need for occlusion from molar to molar. Occlusion from second premolar to second premolar is sufficient if the smile line permits and the patient feels comfortable with a reduced dental arch. It is not necessary or even desirable to install implants as support for the type of bridge that is presented, as long as the jaw relation is normal, natural teeth can be used and sufficient crown retention can be established. It should also be remembered that implant therapy may very well be applied in the future if the bridge should fail because there will certainly be sufficient bone left to allow for implants.

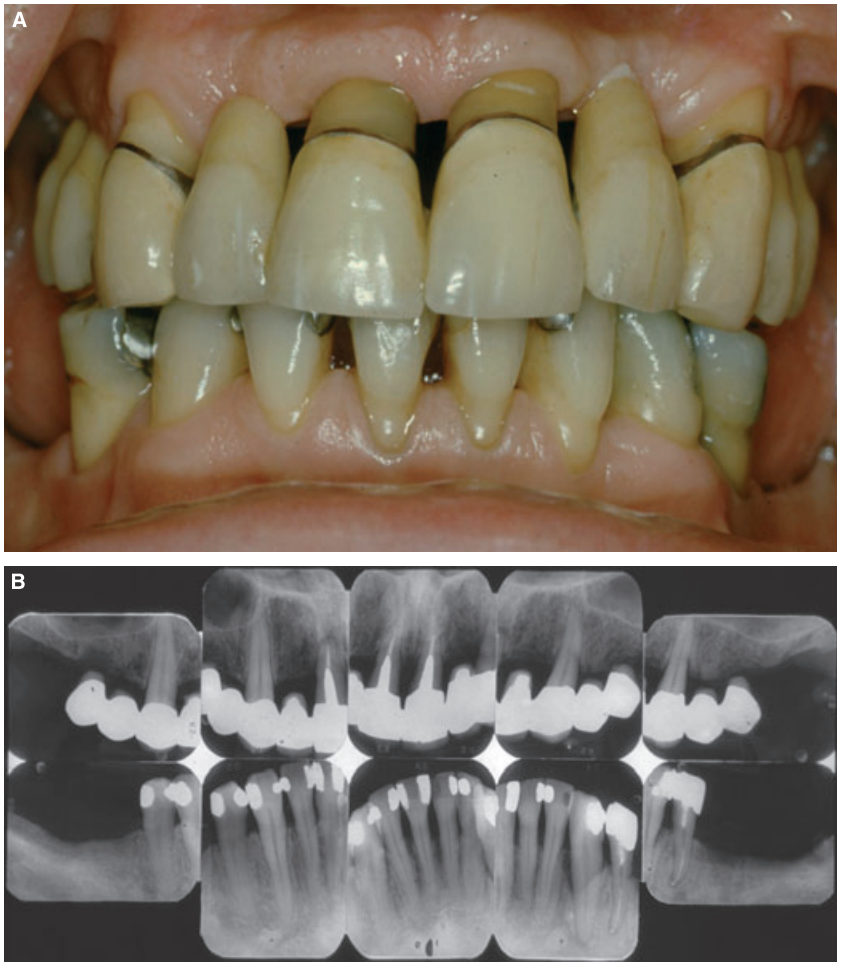


Fig. 21. Clinical photograph (A) and radiographs (B) at 16 years following the completion of treatment.

Patient VII – a mixed bridge with 18-year follow-up

The patient, a 55-year-old woman, presented with an intact tooth 17, edentulousness from teeth 16 to 13 and largely intact teeth from 12 to 27 at the initial examination (Fig. 22). She expressed a strong desire to have some type of fixed construction to replace the lost teeth.

Clinical decision-making

A tooth-supported bridge in the right upper jaw would require the inclusion of at least three of the intact incisors (12, 11 and 21) as abutments. To avoid grinding of intact teeth it was decided to place two implants in the area of 13 and 14 to support a so-called mixed bridge, with tooth 17 used as the end support. Placing two implants in the canine and first premolar areas of the right maxilla would be easy, while the extension of the sinus cavity prevented placement of a third and a fourth implant without extraordinary measures.

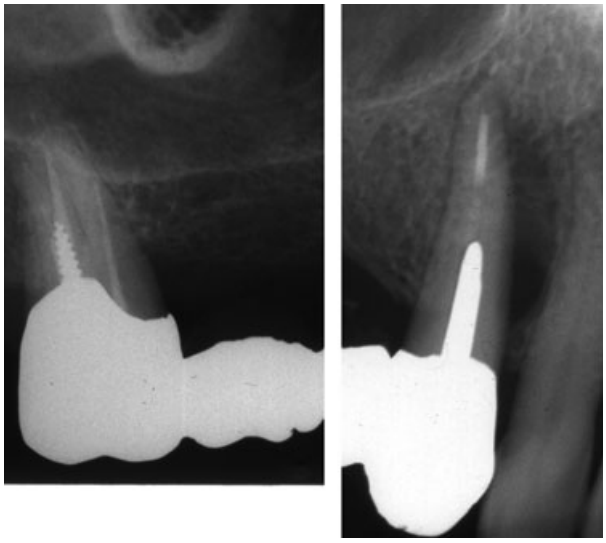


Fig. 22. Radiographs at the initial examination. Note the advanced periodontal destruction at tooth 13.

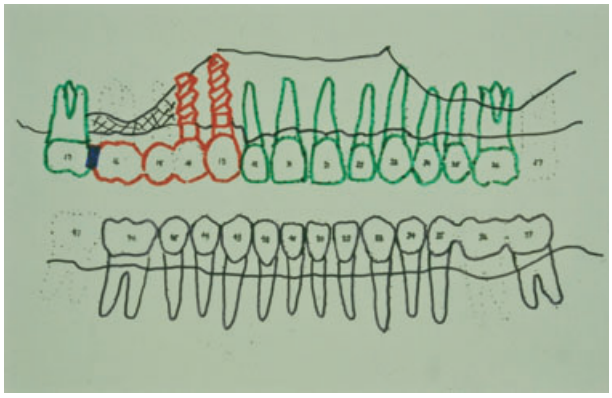


Fig. 23. Schematic illustration of the planned mixed bridge.

Treatment

It was therefore decided to utilize the right second molar as a posterior end support for a combined tooth- and implant-supported bridge, i.e. a so-called mixed bridge, to be cemented to the tooth and screw-retained to the implants (schematic illustration, Fig. 23A). The installation of the implants was uneventful, as was the healing and the provision of the mixed bridge (Fig. 23B).

Treatment evaluation

Fig. 24 shows the clinical photograph (Fig. 24A) and the radiographs (Fig. 24B) 18 years later. The patient was very satisfied with the aesthetic result (Fig. 25). The patient has been checked twice a year during the follow-up period, particularly with regard to the crown retention to tooth 17.

What can we learn?

Mixed bridges might be a smart and cost-effective solution in certain dentitions with remaining natural teeth. It is, however, important to include a strict control of the retention of the bridge both to the

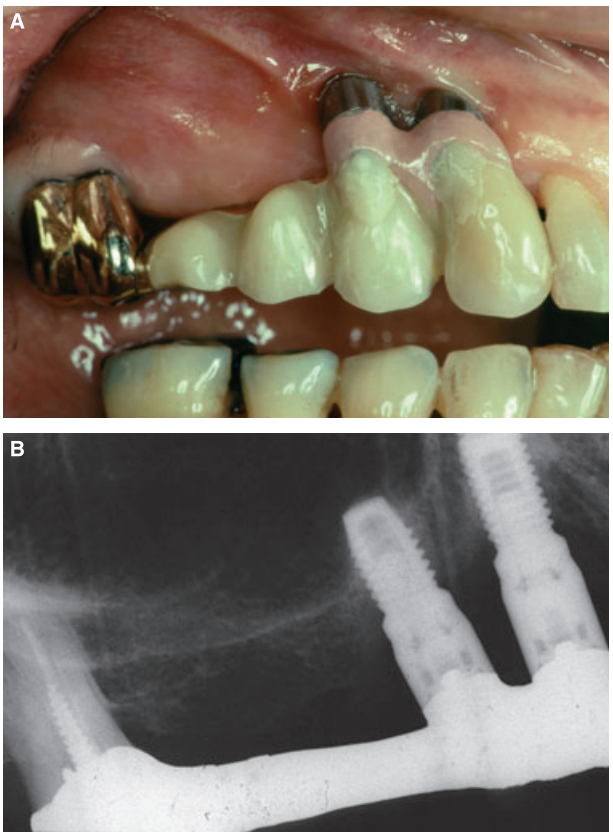


Fig. 24. Clinical photograph (A) and radiographs (B) at 18 years following therapy.

Fig. 25. Clinical photograph showing the smile-line.

natural tooth and to the implants in conjunction with the follow-up controls to ensure a good long-term prognosis.

It has been convincingly shown that this type of therapy can be successful (7). However, in a systematic review Lang et al. (14) demonstrated that the risk for failures seems somewhat higher than for free-standing bridges. This should, however, be related to the benefits in each individual case. The knowledge, clinical experience, and engagement of the dentist performing the treatment are decisive for a successful outcome because there are delicate considerations to make concerning the retention requirements, the occlusion, and the biting habits.

Patient VIII – mixed cantilevered bridge for unilateral extension of the tooth arch: 12-year follow-up

The patient, a man aged 37 years at the initial examination, had a reduced maxillary dental arch, with teeth from the right canine to the left second premolar. In the lower jaw the tooth-arch extended from right to left second premolar. He had a strong desire to 'have fixed teeth' in the right maxilla extending at least to the second premolar area.

Clinical decision-making

To provide the patient with fixed teeth in the right maxilla there were a few treatment alternatives. One was to make a tooth-supported bridge with two cantilevers distal to the right canine. This would, however, demand that most of the intact front teeth be ground to secure abutment crown retention. Another alternative would be placement of two implants distal to the canine. This would then call for sinus lift surgery for the posterior implant. Yet another alternative would be extraction of the canine and placement of two implants to support a three-unit bridge. A fourth alternative was the one chosen; namely, installation of an implant immediately distal to the canine but mesial to the sinus cavity to carry a three-unit bridge together with the canine.

Treatment

A regular platform implant, 13 mm in length, was installed in the right first premolar area immediately mesial to the sinus cavity. The canine was prepared for a full-crown and a three-unit fixed bridge was made, supported on the implant and the canine and supplied with a distal cantilever extension to include the second premolar area. The bridge was cemented to the canine and screw-retained to the implant (Fig. 26A,B). The cantilever pontic in the second premolar area was placed in a slightly infra-occluded position while the occlusion of the canine crown and the first premolar crown (supported by the implant) was such that the occlusal load was evenly distributed both in central occlusion and during lateral excursions.

Evaluation of treatment

This specially designed, so-called 'mixed' bridge will have a good prognosis provided that the crown retention to the canine is secured and the occlusion was designed as described in the treatment section. Careful daily control by the patient himself and

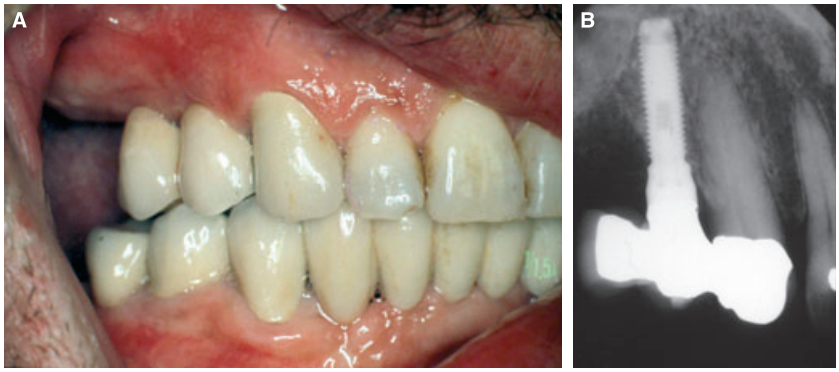


Fig. 26. Clinical photograph (A) and radiograph (B) of the inserted three-unit bridge in upper right jaw.

checking at least twice a year by the dentist are recommended.

What can we learn?

There was space available for only one implant distal to the right canine because of anatomical limitations (sinus recesses). A maxillary tooth arch from right to left second premolar should satisfy the patient. To avoid extensive bone augmentation procedures for placement of more than one implant distal to the right canine, the present solution, with one implant connected to the natural canine and supplied with a distal cantilever, was chosen. A close follow-up schedule is necessary to check the cement locking of the canine crown to the prepared tooth.

Patient IX – mixed bridge to immobilize a hypermobile tooth and extend the dental arch: 16-year follow-up

This woman, 58-years old at the initial examination, had a reduced dentition with teeth from right canine to left second premolar in the maxilla and from right to left second premolar in the mandible. Tooth 13 had a distal pontic extension left behind from a previous bridge from 16 to 13. Tooth 13 had become extremely hypermobile (degree 2–3), as illustrated on the radiograph by the pronounced widening of the periodontal ligament (Fig. 27).

Clinical decision-making

One alternative was extraction of tooth 13 followed by installation of one implant in the extraction socket and another implant in the first premolar area to carry a two-unit, or even a three-unit, bridge with a posterior cantilever unit. Another alternative was placement of an implant in the first premolar area to be connected to the hypermobile canine.

Treatment

An implant was installed in the first premolar area. Fig. 28 shows radiographs of the implant and the canine about 2 months after connection of the two units with a three-unit bridge extended to the second premolar area. A remarkable narrowing of the periodontal ligament is seen as a result of remodeling as the mobility of the tooth decreased to normal. The cantilever pontic in the second premolar area was placed in a slightly infra-occluded position while the occlusion of the canine crown and the first premolar crown (supported by the implant) was such that the occlusal load was evenly distributed both in central occlusion and during lateral excursions.

Figure 29 shows radiographs of the area 16 years later.

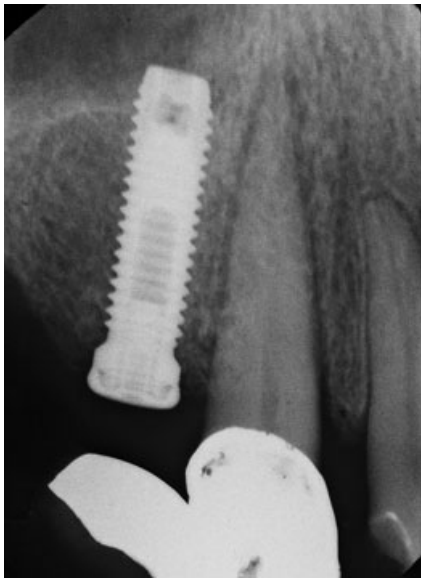


Fig. 27. Radiographic illustration of tooth 13 and the implant. Note the widened periodontal ligament.

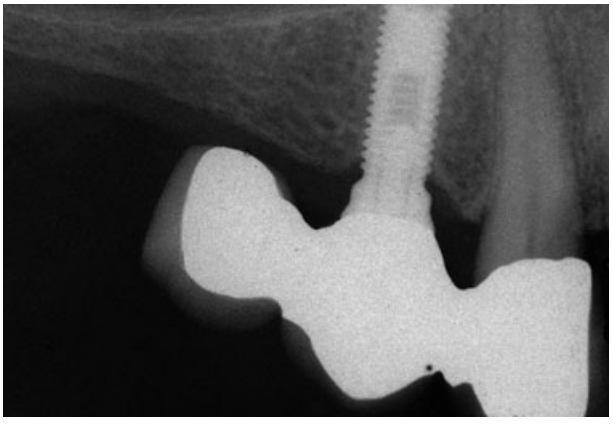


Fig. 28. Radiograph showing the implant and the canine 2 months after implant installation and insertion of a three-unit bridge. Note the narrowing of the periodontal ligament.

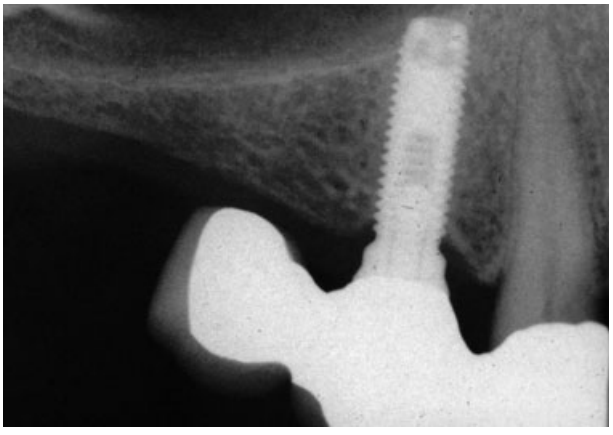


Fig. 29. Radiograph at 16-year-follow-up.

Evaluation of treatment

The bridge has been controlled twice a year and no signs of loss of crown retention or of supporting bone have been observed throughout the years. The bridge is stable and the occlusion is intact.

What can we learn?

Not only can an implant be connected to a natural tooth (teeth) to extend a tooth-arch for improved function and aesthetics, but an implant can also be used to stabilize a hypermobile tooth, reducing the mobility to normal and so decisively contributing to the rebuilding of the overloaded periodontium. It should be observed that the 'weak link' in this type of 'mixed bridge' is the crown retention to the canine.

Patient X – use of an implant to stabilize a hypermobile bridge: 18-year follow-up

The patient, a 45-year-old man at the initial examination, had been previously treated, 2 years earlier, for advanced generalized chronic periodontitis and the mandible had been restored with a 10-unit bridge on four abutments. The bridge had become hypermobile as illustrated on the schematic drawing of the right and left canines (Fig. 30A) and on the radiographs (Fig. 30B,C) showing the widened periodontal ligament, probably caused by overload through excessive bruxism. The mobility of the bridge was of degree 2–3 with vertical amplitude of almost 1 mm in the anterior area. There were, however, no periodontal pockets exceeding 4 mm and no other signs of periodontal disease recurrence.

Clinical decision-making

The most obvious treatment would probably be extraction of the bridge abutments and insertion of a full denture in the lower jaw, a therapy of which the patient disapproved. An alternative would be placement of four to six implants to support a mandibular cross-arch bridge. The final solution was, however, to place one implant underneath the anterior pontic of the existing bridge without removing it, with the intention of stabilizing the extremely hypermobile bridge and, hopefully, reducing its mobility. After healing the bridge was to be connected to the implant.

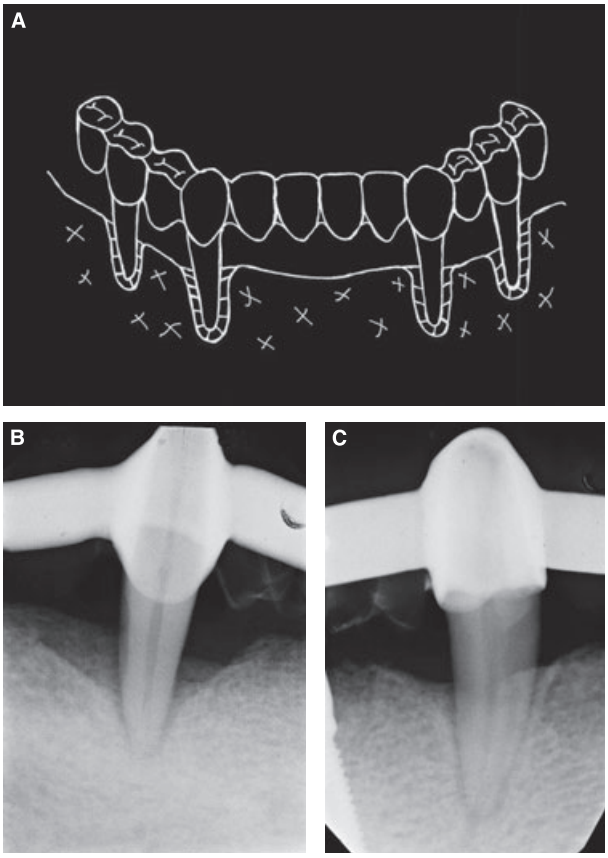


Fig. 30. Schematic drawing (A) and radiographs of the mandibular canines (B,C) illustrating the situation at initial examination.

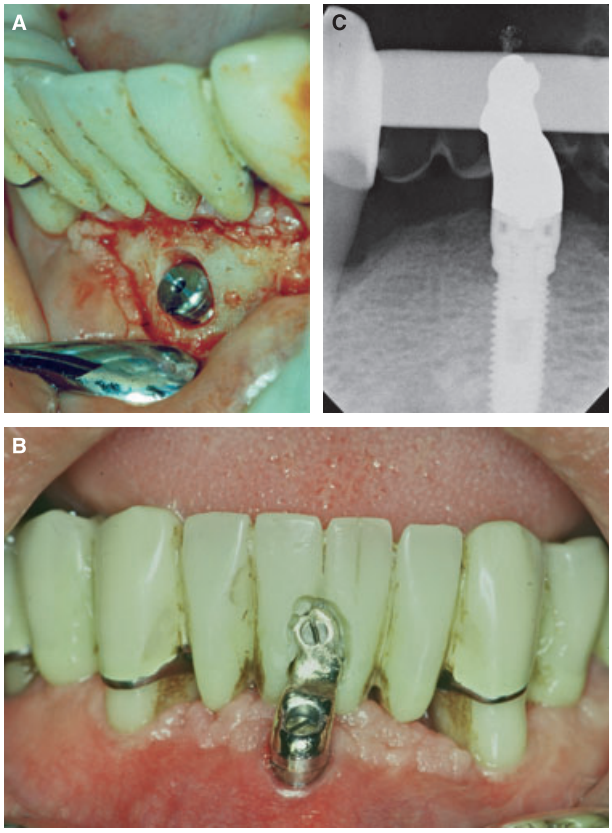


Fig. 31. Clinical photograph at the time of surgery after the installation of the implant (A), and clinical photograph (B) and radiograph (C) at 3 months after surgery.

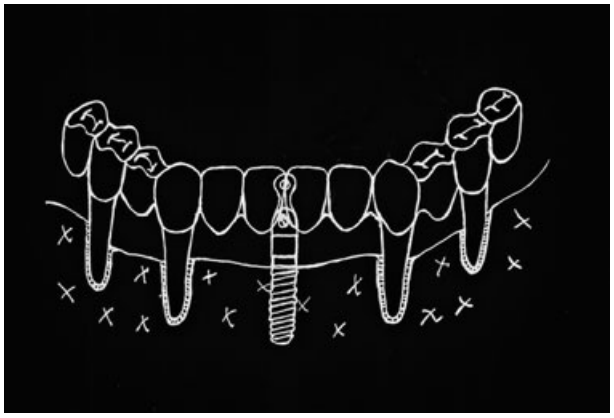


Fig. 32. Schematic drawing illustrating narrowing of the periodontal ligament.

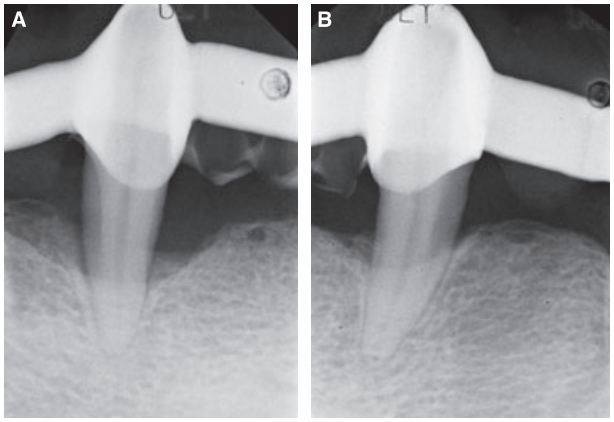


Fig. 33. Radiographs of the right (A) and left (B) canine 3 months after connection, showing narrowing of the periodontal ligament.

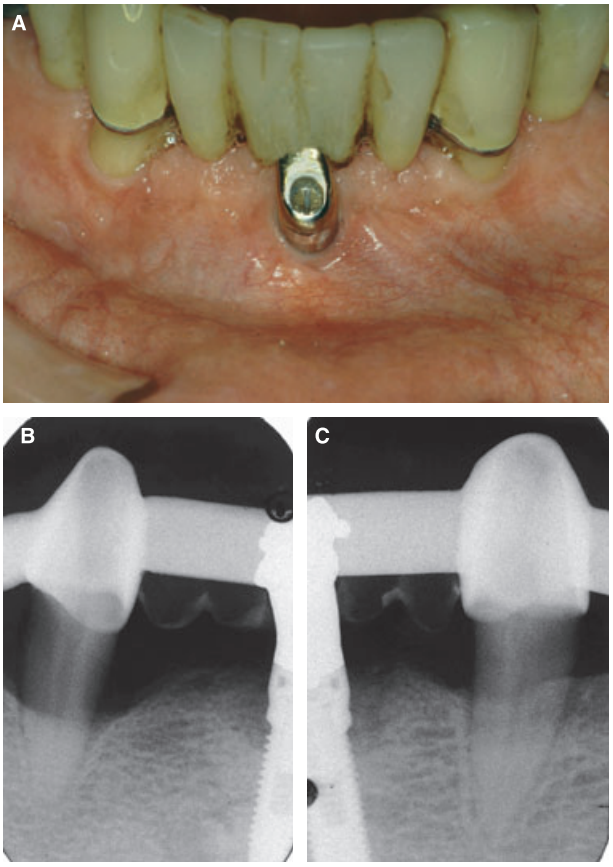


Fig. 34. Clinical photograph (A) and radiographs showing the right (B) and the left (C) canines at 18 years after installation of the implant.

Treatment

Fig. 31 depicts the case during surgery after installation of the implant (Fig. 31A) and 3 months after connection of the implant to the bridge (Fig. 31B,C).

Fig. 32 is a schematic illustration of the case 3 months after connection of the implant to the bridge. Radiographs taken 3 months after connection show the remodeling of the periodontium at both the right and left canines (Fig. 33A,B). Fig. 34 shows a clinical photograph (Fig. 34A) and radiographs (Fig. 34B,C) after 18 years of follow-up. Observe the recovery of the periodontal support at both canines compared to the initial status (Fig. 30B,C).

What can we learn?

This patient case shows that it is possible to save an extremely hypermobile, extensive bridge by placing a single implant under the anterior pontic to stabilize the bridge without removing it. This allowed for remodeling of the periodontium of the two canines, which, together with the right and left second premolars, supported the bridge. It should be stressed that the increased tooth mobility of the canines was not a consequence of periodontal disease recurrence but was the result of overload. The alternative treatment would probably have been extraction of the bridge followed by fabrication of a new bridge supported on four to six implants. The treatment provided is an example of a cost-effective therapy where the natural teeth are saved and decisive support is provided by installation of only one implant. The treatment undertaken does not preclude or impair a future alternative therapy with a conventional implant-supported bridge.

Conclusion

Extraction of teeth and their replacement with implants are becoming increasingly frequent in the management of periodontally compromised patients. This approach is based on the assumptions that

implants perform better than periodontally compromised teeth and that their longevity is independent of the individual's susceptibility to periodontitis. However, recent studies suggest that periodontitis-susceptible patients are at risk for also developing peri-implantitis.

The purpose of this article was to discuss and evaluate the prognosis of natural teeth vs. dental implants in decision-making and treatment strategies for the management of periodontally compromised patients. The presentation is exemplified with patient cases where one or several teeth suffered from advanced periodontal breakdown and where treatment including tooth extraction and dental implants might have been an alternative. All patient cases have been followed long-term. The compilation of patients particularly presents treatment alternatives that are often discarded or not even considered but that may offer certain advantages both regarding prognosis and invested efforts.

The presented cases show that 'many roads lead to Rome' and that the dental team has a delicate palette of treatment options to consider, not least regarding the use of natural teeth vs. implants in various prosthetic treatments. The natural tooth should not be considered an obstacle but a possibility, whether or not the treatment is to include implant installation.

Important questions are: do implants perform better than natural teeth in patients with no history of periodontitis and do implants perform better than periodontally compromised teeth in periodontitis-susceptible patients? The answers to those questions are probably that, on average, single teeth and implants, as well as tooth- and implant-supported bridges, perform equally well. A decisive component for a good long-term prognosis in the management of periodontitis-affected patients is plaque control efficient enough to maintain healthy periodontal tissues. Likewise, a central part of implant therapy ought to be adequate infection control around implants to maintain healthy peri-implant tissues. It is then relevant and important to reflect on how many dental teams are prepared to take the responsibility of carefully monitoring the treated patients and carrying out measures to prevent and treat periodontal or peri-implant lesions that may occur / re-occur. It is also relevant to ask how many patients are prepared to comply with the necessary measures to ensure a good long-term prognosis for the treatment provided.

An important issue also brought up is the need to consider a strategically postponed implant installation in the periodontitis-susceptible patient to fully utilize and extend the capacity of the natural tooth, before an implant is taken into account, to optimize the longevity of the dentition.

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