Treatment Strategies in the Case of Advanced Attachment Loss.
Part I: The Conservation of Strategically Important Teeth in Order to Avoid Dental Restorations

Andreas Rühling

In adopting a treatment strategy with the objective of conserving strategically important teeth with advanced attachment loss in order to avoid possible complications in the case of prosthetic restoration, all clinically relevant therapeutic possibilities should be utilized. The main focus is on the treatment of teeth with horizontal bone loss down to the apical third of the root with deep, often only one-sided vertical bone defects , through-and-through furcations with considerable defect height, as well as combined periodontal and endodontic inflammations.
This article describes cases which show that it is possible to conserve critical teeth over many years without progressive bone loss, but that complications may endanger its long-term success due to endodontic factors, furcation caries, and root fractures. Hence, the implementation of this treatment strategy demands an active conservation therapy in order to control these complications. The successful periodontal treatment of an advanced, generalized, chronic periodontitis is illustrated, discussed, and documented over a period of 13 years by means of a specific patient case example.

Key words: treatment strategy, periodontitis, bone loss, critical teeth, dental restorations

TREATMENT STRATEGIES

Various studies show that good long-term clinical results have been achieved in the case of periodontal treatment both with open as well as closed debridement (Cobb 1996; Palcanis 1996) , given consistent conservation therapy (Axelsson 1978, 1981; Lindhe 1984). On the other hand, tooth loss patients with periodontal disease is a common phenomenon in everyday practice, and treatment planning must always take into account the following issues: first, is it worth conserving the teeth by means of periodontal therapy? Second, can we motivate the patient to effective daily cleaning of the interdental spaces? Third, are sufficient conditions fulfilled in order to achieve long-term clinical success? Fourth, is it possible to conserve already mobile teeth over a long period of time, or is it better to extract those and instead insert removable restorations and / or advise the patient to consider the option of implant therapy?

In a study performed at the clinic in Kiel, König et al. (2002 a) demonstrated that patients (n = 142) with advanced periodontitis had lost on average 0.07 teeth annually after basic periodontal treatment (curettage / flap operation). Taking into account earlier extractions prior to commencement of maintenance treatment, the number of tooth losses in this study increased to 1.9 teeth per patient in 10 years: initially 63% and after recall 37% of the teeth were extracted. Similar results were found in a study on 273 patients in Berne (Tonetti 2000) with an observation period of 5.6 years. Conversion of the data shows that during recall treatment, only 0.02 teeth, and considering the initial extractions, a total of 2.4 teeth had been extracted annually, where 54% of the extractions took place initially and 46% during maintenance treatment.
From the results of these studies it can be concluded that hopeless teeth should be extracted earlier (in the initial treatment phase), since periodontal

treatment is the more successful the more "critical" teeth are removed at an early stage. This strategy, however, results in the necessity of seating more prosthetic restorations, which, in view of the attachment loss of the remaining abutment teeth, cannot always be considered the best option.
In this article, therefore, the treatment of patients with advanced bone loss will be illustrated by means of various treatment strategies. Part 1 of this article deals with the conservation of critical teeth with the application of all therapeutic possibilities in order to avoid possible complications in the case of a prosthetic restoration. In part 2, the extraction of critical teeth and the insertion of dental restorations on abutments with advanced bone loss are discussed; in addition to the periodontal treatment of the prosthetic abutments, the main focus of treatment is on the avoidance of biomechanical and technical complications.

TREATMENT DECISIONS

As a general rule, the individual needs of each individual patient must be taken into account for every treatment decision. The aim of evidence-based dentistry is to provide the best possible knowledge available for dental treatment. In recent times, this expression has been somewhat overused; it can, however, be understood only as a course of action and a decision-making aid, since treatment decisions must also respect the needs of the patient and the specific experience of the individual practitioner with regard to the various specialist subject areas (Tonetti, 2002).
The aim must always be to inform the patient by providing him or her with complete and objective facts regarding treatment. In a simplified description of the risks of dental restoration or implantation, mobile teeth are often generally considered as "bad" and fixed implants as "good". We know that evolution has provided teeth with an attachment mechanism which gives them a certain degree of physiological flexibility enabling them to perform special tasks, e.g., to direct occlusal forces through a complex network of receptors as well as to permit physiological remodelling procedures in terms of orthodontic tooth movement, but also to adaptive remodelling in the case of high functional loading and regenerative healing processes following the elimination of a bacterial inflammation.
Sometimes the patient desires a solution with implants, without, however, being aware that a risk of periimplant inflammation (for which, as opposed to periodontal treatment, no long-term results are available) exists, depending on the state of his or her individual immune system, a potential genetic predisposition, and acquired risk factors (such as smoking), or due to remaining bacterially infected pockets. In a considerable number of cases the patient decides against implants, because he / she simply cannot afford it, so that we are once again forced to return to the question: Can we treat all remaining teeth periodontally in order to avoid the necessity of a prosthetic restoration, or do we have to extract critical teeth – and if so, how can we give the patient prosthetic treatment with controlled and foreseeable risks?
For the successful implementation of this concept in practice, it means that an effective recall system must be established which is distinct – in terms of its objectives – from “wellness” prophylaxis. Highly motivated, well-trained professionals are required, since the aim of conservative periodontal therapy means the early recognition and treatment of pockets with unacceptable probing depths and requires locating any further or recurrent signs of inflammation and correcting these again. The periodontitis patient, as any patient with chronic health disorders, must be integrated into a feasible and effective treatment plan.

THE TREATMENT OF CRITICAL TEETH

In the case of a prosthetic treatment strategy with the simultaneous objective of conserving "critical" but strategically important teeth in order to avoid complications, all therapeutically feasible possibilities must be explored.
As regards treatment planning, teeth are usually categorized according to whether they are "secure", "questionable" or therapeutically "hopeless", although there is not always agreement about what, is meant. For instance, a "critical" tooth, which can be conserved by means of a complex and / or time-consuming treatment, but for which the patient's medical insurance company is not willing to pay and the patient cannot afford, can very quickly become a "hopeless" tooth. In the following patient cases, the question does not concern what is adequate, feasible or economical, but what is

Fig. 1a to c On a long-term basis, it is possible to conserve critical mandibular anterior teeth even in the case of severely advanced horizontal bone loss (a). The radiograph (b) shows no clinically relevant bone loss after 10 years. The patient cleans his teeth with interdental brushes that fill out the spaces (c). In this case the teeth were not splinted.

therapeutically possible in the case of "questionable" or "hopeless" teeth. The main focus is on the following problems:

- Advanced horizontal bone loss down to the apical root third,
- Through-and-through furcations on molars with great defect height,
- Deep, vertical bone defects with a poor defect morphology and
- The combination of periodontal and endodontic inflammations.

Whether the teeth treated also have a good long-term prognosis is not solely dependent on local factors. Lang and Tonetti have defined six risk parameters in a functional diagram with regard to the assessment of the individual risk following periodontal treatment. In this scheme, the condition of the inflammation, the frequency of remaining pockets, the tooth loss, the age-related attachment loss, genetic and systemic risk factors, and the patient's lifestyle (i.e. smoking) are assessed and viewed as a whole in order to asses the risk of a progredient advance of the disease, and to determine the frequency and complexity of the available treatments in the domain of conservative dentistry.

Advanced horizontal bone loss

Comprehensive root surface debridement and planing is the conditio sine qua non for basic periodontal treatment, regardless of which of the various therapeutic approaches are subsequently chosen. The effectiveness of scaling and root planing (SRP) decreases with increasing probing depth, and increases in the case of open root surface treatment (Cobb 1996). The training of the clinician in the use and handling of the relevant machine or manual instruments, as well as his/her ability to realistically assess the therapeutic efficacy of the therapy, have a significant influence on the outcome (König, 2002; Rühling 2003, 2002).
The case shown in figs. 1a to c demonstrates that with SRP it is also possible to conserve the mandibular anterior teeth on a long-term basis in the case of already severe bone loss without this developing into progressive attachment loss. The conditions are favorable, since the teeth are easily accessible in the oral cavity for both the patient and the dentist, and are easy to clean using interdental brushes. Furthermore, as these are single-root teeth with no complex root anatomy, the root surfaces can be effectively treated even where probing depths are high.

Vertical bone defects with unfavorable defect morphology

With regard to the treatment of vertical bone pockets, favorable results can always be expected from the use of GTR (Guided Tissue Regeneration) in the case of three-sided bone pockets , while the outcome is less predictable if defect morphology is poor (Cortellini 2002). The membrane barrier enhances the stabilizing and adhesion of the blood coagulum to the root surface, which is a decisive factor for the success of the treatment in the early phase of wound healing (Wikesjö 2000). The case in figs. 2a to e shows a critical, but strategi-

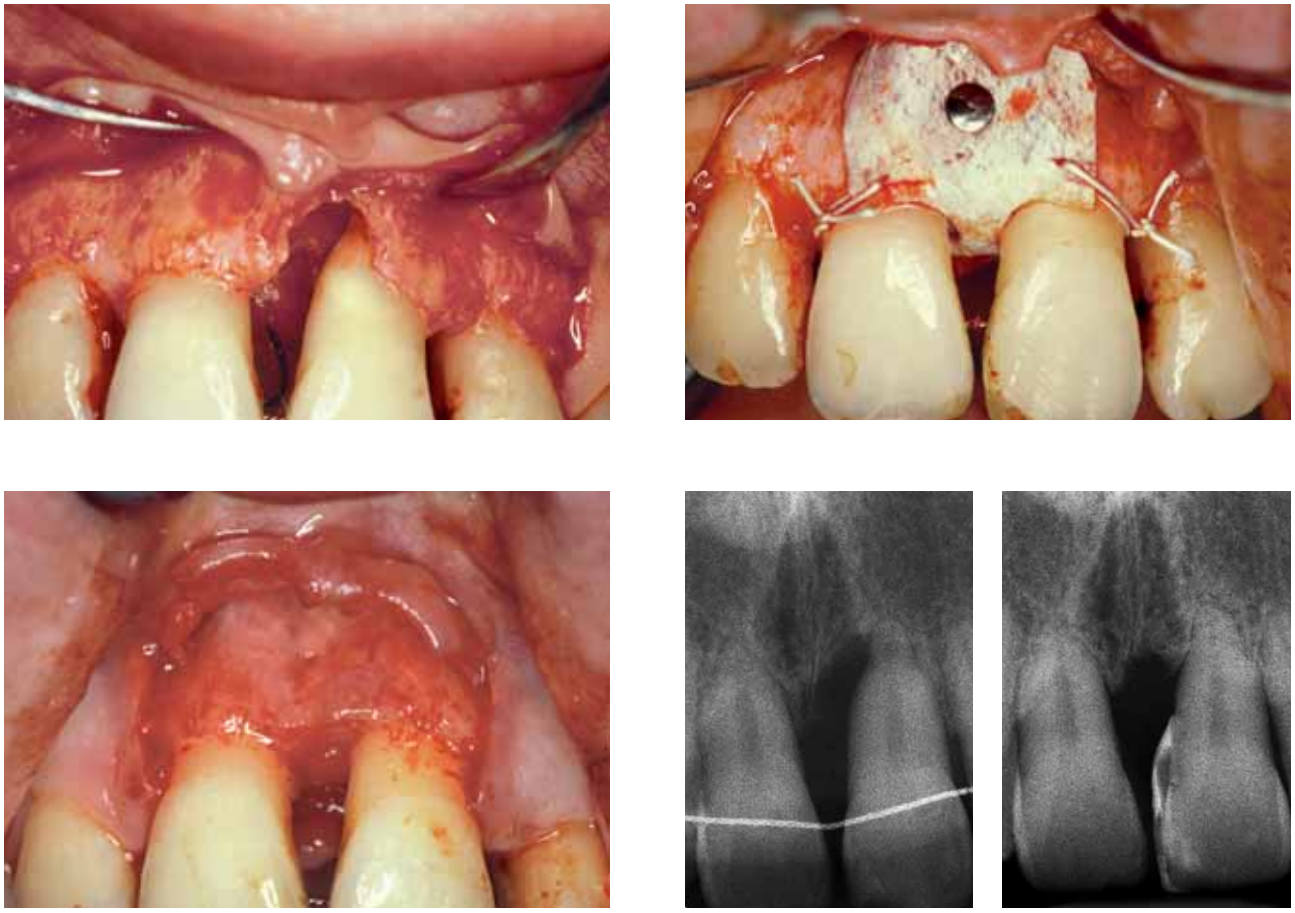


Fig. 2a to e Localized, aggressive periodontitis with a vertical bone defect on tooth 21 and critical defect morphology (a) and root shortening due to orthodontic tooth movement (d). The GTR membrane barrier was additionally anchored by means of a titanium spike (b). After 6 weeks, immature tissue which was firm on probing was observed (c). A radiopaque filling 10 years after treatment indicates that progression of the bone loss has not occurred (e).

cally important tooth (21) of a 22-year-old female patient with localized aggressive periodontitis. In the course of previous orthodontic treatment, resorption of the apex had resulted (fig. 2d). Clinically and radiologically, a vertical, one to two-sided bone crater extending into the apical area of the shortened root was observed (fig. 2a). The membrane barrier (PTFE, Gore, Flagstaff, AZ, USA) was additionally anchored by means of a titanium spike (fig. 2b) (Frios, Friadent, Mannheim, Germany). On removal of the material after 6 weeks, immature tissue, which is firm on probing, was present (fig. 2c). Ten years after treatment, a limited radiopaque filling can be seen, a clear indication that no progression of the aggressive periodontitis has occurred (figs. 2d and e).

When filling vertical bone craters with bone replacement materials, high demands are still being placed on their regenerative potential. Histological studies of human biopsies, however, demonstrate that a periodontal or osseous regeneration had not occurred as a result of the use of various bone replacement materials, but merely a connective-tissue-like integration of the material and healing over a long junctional epithelium without any new formation of cement and inserting fibers to any clinically relevant degree (Carranza 1987; Ganeles 1986; Kenney 1986; Nevins 2000, Rühling 2001; Stahl 1987).

Radiologically, the filling of bone craters can mimic osseous regeneration. The patient case shown in figs. 3a to d reveals a critical bridge abutment 14 with a single-surface bone crater extending into the vicinity of the apex (figs. 3a and 3b), which was filled up with hydroxyl apatite (Algipore, Friadent). In the radiograph taken 29 months postoperatively, a periodontal gap and a filling with a dense, osseous character were recognizable (fig. 3c). Histo-




Figs. 3a to d A filling with bone substitute material can appear radiologically to be an osseous regeneration. The bone crater on the critical bridge abutment 14 was filled with hydroxyl apatite (a and b). The radiograph 29 months postoperatively shows dense bone healing (c). Histological examination, however, reveals only a connective-tissue-like integration of the material with healing via a marginal epithelium (d).

logical analysis, however, revealed a complete, connective-tissue-like integration of the material with healing via an junctional epithelium (fig. 3d) (Rühling 2001). Even if this could result in a certain reduction of tooth mobility, it would not lead to any significant improvement of the functional valency of a prosthetic abutment, since no new periodontal ligament has formed, by means of which the occlusal forces could be functionally directed into the bone.

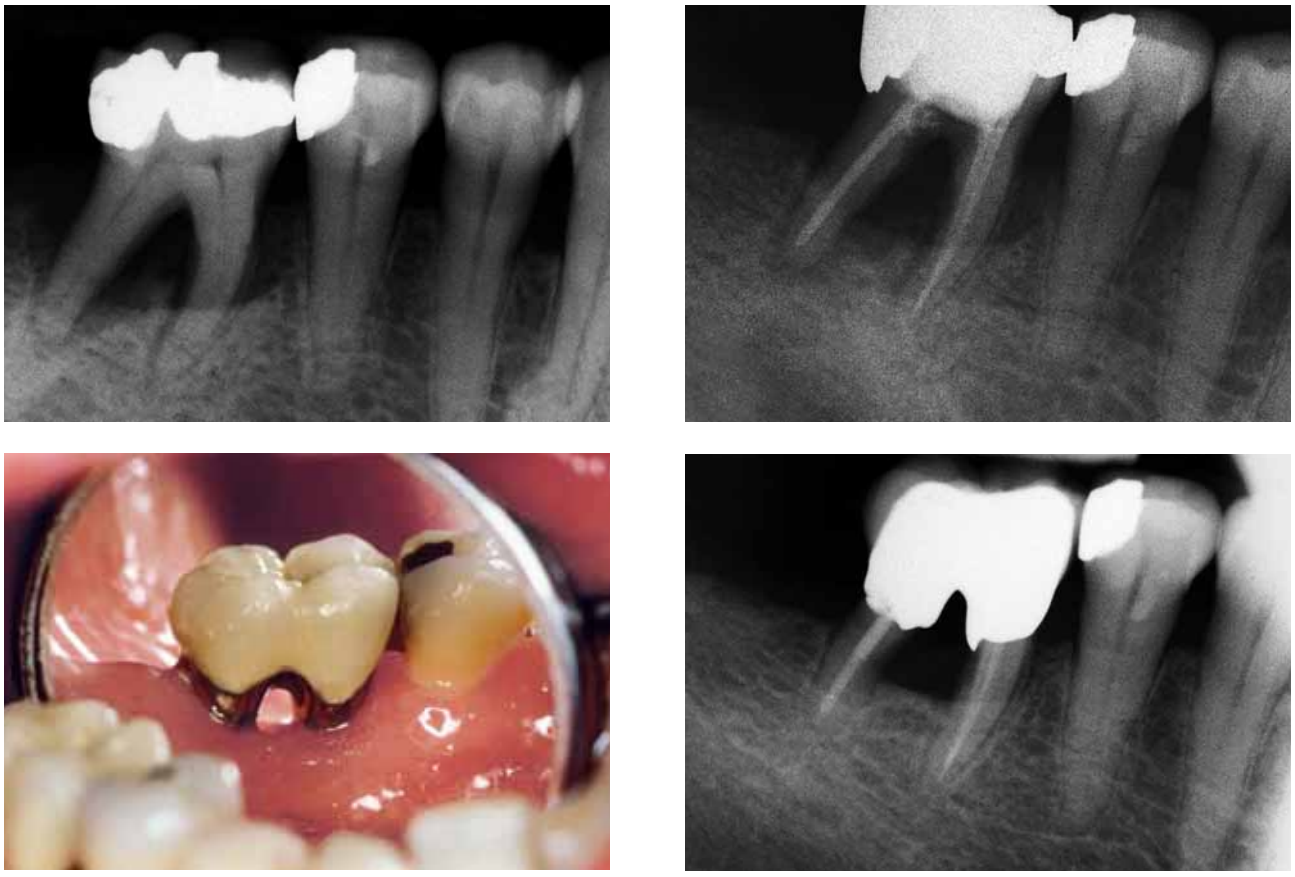
Molars with through-and-through furcations and a large defect height

GTR therapy on molars with advanced horizontal bone loss, Class III furcations, and a large defect height is of no clinical benefit to the patient. The only choices remaining are often a single root surface debridement and maintenance of the vitality of the tooth (if necessary with tunnelation), or a radectomy with devitalization (Carnevale 1991, 1995; Karring 1999).

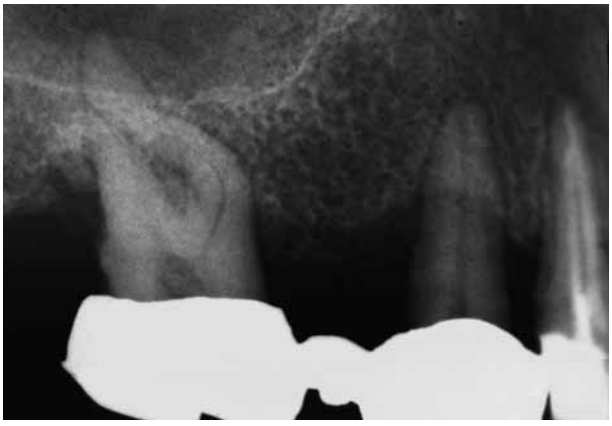
The advantage of conservative treatment retaining the vitality of these molars is that the success of the conservation of the teeth is not also dependent on the success of the endodontic treatment, and the desmodontal anchorage is not further reduced by a radectomy. The SONICflex-Airscaler® with diamond coated tips (KaVo, Biberach, Germany) which, on account of their convex shape, enables effective instrumentation of the existing concavities within the furcation, is particularly suitable for treating furcations (Kocher 1999).

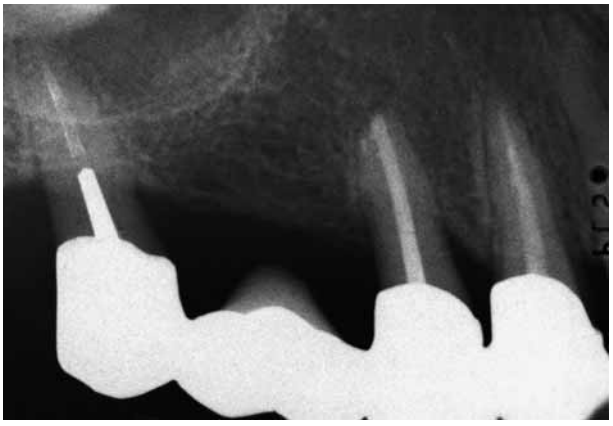
The case shown in figs. 4a to c demonstrates that molars with through-and-through furcations (fig. 4a) can be maintained for a long period of time solely by means of root surface debridement. Given sufficient distance between the roots and a short root trunk, the patient will be able to clean the

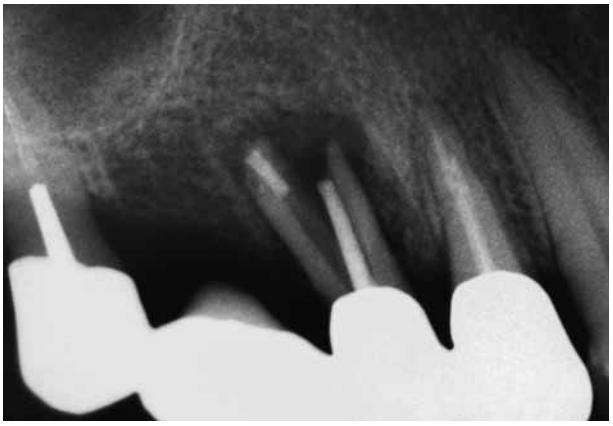
Figs 4a to c Molars with through-and-through furcations (a) can be conserved on a long-term basis by root surface treatment alone. In the case of sufficient distance between the roots and a short root base, it is possible to clean the tooth through the natural furcation tunnel. The radiograph (b) shows no clinically relevant bone loss after 9 years; however, furcation caries occurred after 13 years (c).



Figs 5a to d The conservative treatment of a critical molar with through-and-through furcation and severely advanced bone loss which reaches the apex of the distal root (a). 2 years after commencement of treatment, furcation caries was observed. The tooth was treated endodontically (b), the furcation caries removed by hemisection – thereby conserving both roots – and a twin crown restoration was seated (c). The radiograph shows no further progressive bone loss, but a dense bone refilling at the distal root 11 years after commencement of treatment (d)







Figs. 6a to c On a strategically important bridge abutment 17, (a) the severely buccally curved roots were removed by radectomy and the palatal root used as a bridge abutment. The radiograph shows no clinically relevant bone loss 11 years after treatment. After 18 years, a root fracture on tooth 15 occurred (c).

tooth through the natural furcation tunnel using an interdental brush. The radiograph shows no clinically relevant bone loss after 9 years (fig. 4b); after 13 years, however, furcation caries occured (fig. 4c). Reports on the frequency of furcation caries by Hamp et al. (1975) and Hellden et al. (1989) are available.

Compared with the large number of patients with open furcations in the patient group of König et al. undergoing conservation therapy, the frequency of furcation caries is not sufficient to justify the immediate radectomy of every molar with furcation involvement. The success rate of this conservative treatment varies between 88% (Ross, 1978) and 43% (McFall, 1982), depending on the clinician. If furcation caries in its initial stages is recognized in time, there is always the option of radectomy or premolarization (as in the patient case shown in figs. 5a to d). The root caries on tooth 46 (fig. 5b) following conservative dental treatment was removed in this case by means of a hemisection, thereby conserving both tooth roots and providing a restoration in the form of a twin crown (fig. 5c). The radiograph shows no further clinically relevant bone loss 11 years after commencement of treatment (fig. 5d).

A radectomy can be performed to facilitate the cleaning of the furcation area by removing individual roots. Whether the remaining roots can then be utilized for prosthetic purposes depends on the length, cross-section (diameter) and size of the remaining desmodontal surface, as well as on the success of the endodontic treatment. Figures 6a to c show a case in which the extremely curved buccal roots of a maxillary molar with a Class III furcation (fig. 6a) were amputated and only the palatal root conserved and used as a bridge abutment. Eleven years after treatment (fig. 6b) the radiograph shows no clinically relevant bone loss on the radectomied bridge abutment 16, but after 18 years, a root fracture on tooth 15 can be observed (fig. 6c).

Carnevale et al. (2000) conclude that in the case of a Class II furcation, regenerative therapy can be attempted, and in the case of abutments with Class III furcations, a radectomy should be performed if

Figs. 7a to d Combined periodontic / endodontic inflammation. Vertical defect on caries-free tooth 33 (figs. 7a and b). A radiograph 6 months after GTR treatment shows a radiopaque filling of the defect, but also apical radiolucency (Fig. 7c). Healing of the apical periodontitis after endodontic treatment (Fig. 7d).

the tooth is to be used as a prosthetic abutment. The failure rates quoted in the literature for radectomy likewise vary depending on the clinician. Failure rates are low in Carnevale's group (Carnevale 1991): only 4% of 488 molars treated by radectomy, hemisection, or trisection which were integrated in prosthetic restorations were extracted. Langer et al. (1981) and Buhler (1988) observed higher failure rates of 38% of 100 molars and 32% of 28 molars, respectively. The most frequent causes of tooth loss were reported to be root fracture and endodontic failure.

Combined periodontal / endodontic inflammations

As the periodontium and the pulp are in close anatomic relation, the spread of inflammatory alterations from one structure to the other is conceivable (Harrington 2002). If horizontal bone loss or a vertical bone defect has occurred, an infection of the pulp can spread laterally via the dentinal tubules and lateral pulp canals; vice versa, bacteria from a primarily infected pulp can spread towards the periodontium and lead to a periodontal pocket detectable by probing (König 1994; Rubach 1965; Seltzer 1963).

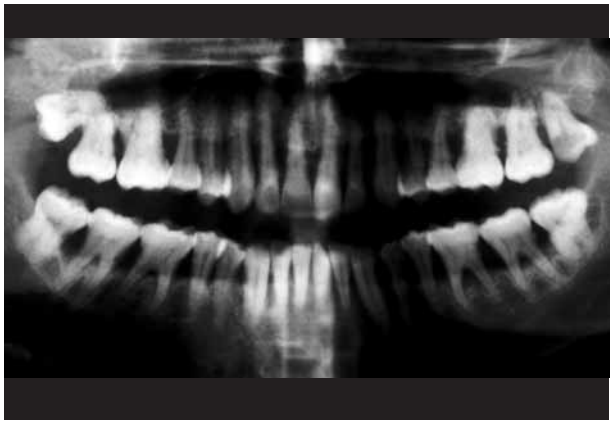
The case shown in figs. 7a to d demonstrates the close periodontic-endodontic relationship. An isolated vertical defect of initially indefinite origin had occurred on 33, a caries-free tooth (figs. 7a and b). The tooth showed a sensitive reaction to cold. Radiological examination 6 months after GTR treatment showed that the defect was filled to a good degree; apical radiolucency, however, was also observed (Fig. 7c), which meant that endodontic treatment had to be carried out prematurely (Fig. 7d).

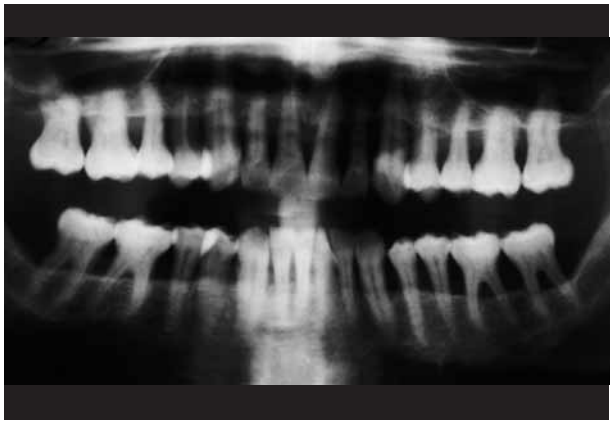
Figs. 8a to d
Combined periodontal / endodontic inflammation. After closed root planing of tooth 43 (a), no satisfactory periodontal healing had occurred (b). On re-evaluation it became evident that this was a two-root canine. Only after completion of endodontic treatment was a radiopaque, dense bone filling of the defect to be observed (c), so that tooth 43 could now be used as an abutment for a prosthetic restoration (d).

In the case of combined periodontal and endodontic disease, the principal cause cannot always be ascertained, since a positive reaction to a vitality test is apparently still possible even in the case of an already infected pulp and in the early stages of apical radiolucency (Langeland 1987, 1993; Lin 1984).In the event of such combined lesions it is recommended to first perform the endodontic treatment in order to achieve maximum regeneration in the area of the perhaps only slightly infected root surface of the apical lesion, and subsequently to complete the treatment of what is left of the remaining pocket (König 1994).
The case study depicted in figs. 8a to d shows a critical tooth (43) with severe inflammatory symptoms (Fig. 8a). There were no signs of periodontal healing after closed root debridement and seating of a metal-reinforced bridge (Fig. 8b). The tooth showed a positive reaction to a vitality test. In the course of re-evaluation it became evident that this was a two-root canine with a pulp canal which may still react sensitively. Furthermore, a possibly already infected root canal had communicated bacteriologically with the periodontal gap, and could have been the cause of the persistent periodontal inflammation. Only after completion of the endodontic treatment a clinically and radiologically visible healing of the periodontal bone pocket occured (Fig. 8c), which enabled the tooth to be integrated 2 years later as a bridge abutment in the final prosthetic restoration (Fig. 7d).

PRESENTATION OF THE CASE

The implementation of the treatment strategy is illustrated and documented over a period of 13 years by the following case (figs. 9a to e).





Figs. 9a to e Long-term results of periodontal treatment over a period of 13 years. The treatment objective was to conserve critical teeth and avoid dental restorations. The panoramic view at the start of treatment (1990) shows generalized, severely advanced horizontal bone loss of approx. 50 to 70% with visible furcation involvement of all molars (a). Flap surgery with tunnelation on teeth 36 and 37 was performed. Check-ups revealed inflammation-free conditions and an esthetically acceptable result (b to d). After 13 years (in 2003), radiological examination (e) revealed no further clinically relevant bone loss compared with 1990 (a).

Case history

The patient was 47 years of age (1990) and complained of pain in the region around 28. He was at that time a smoker (< 20 cigarettes a day) and reported no systemic diseases. Visits to the dentist had been seldom, since his dentition was not very susceptible to caries.

Diagnosis

The patient's dentition was free from restaurations. Severe plaque accumulation and smokers' stains as well as caries on tooth 28 were observed. The gingiva was reddened and inflamed. Bleeding on probing occurred at generalized probing depths of 6 to 8 mm with palpable massive concretions. Degree II-furcations were observed at teeth 17,

27, 46 and 47 and through-and-through furcations at 16, 26 and 36. Furthermore, increased tooth mobility was determined.

Radiological analysis

Generalized, severely advanced horizontal bone loss of approx. 50% to 70% of the root length in the maxilla and approx. 50% in the mandible with visible furcation involvement of all molars was observed (Fig. 9a).

Diagnosis

Advanced adult periodontitis (generalized chronic periodontitis) was diagnosed.

Treatment strategy

The treatment objective was to carry out periodontic treatment of critical teeth with advanced bone loss in order to avoid extractions / prothetic restorations, to treat the furcations, thereby retaining the vitality of the molars, and to halt the process of bone loss.

Therapy

The treatment was completed after in four sessions taking place in 1990, with subsequent flap operations and tunnelation on teeth 36 and 37 as well as the extraction of teeth 18, 28, 38 and 48.

Maintenance treatment 1992 – 2003

The patient received conservative treatment beginning in 1992. The recall visits showed inflammation-free conditions and an esthetically acceptable outcome (figs. 9a to d). The plaque indexes were between 10% and 20%. Bleeding was observed on probing only at very few locations (<5%), with localized probing depths of 4 mm. The patient has been a non-smoker since the 8th year of maintenance treatment. After 13 years (in 2003), no further clinically relevant bone loss was observed compared with 1990 (Fig. 9a).

DISCUSSION

As a result of the poor oral hygiene of the 47-year-old patient, progressive, generalized chronic periodontitis with advanced horizontal bone loss and furcation involvement of the molars occurred. Conservative treatment consisting of flap surgery and tunnelation on the molars 36 and 37 was carried out. Additional regenerative procedures were omitted owing to lack of suitable vertical bone pockets and the advanced furcation on teeth 36 and 37. Since 1990, the patient has been cleaning his teeth once daily with interdental brushes. The patient is now (2003) 62 years of age. It was possible to conserve all teeth for 13 years without any clinical signs of progressive attachment loss. The proportion of bleeding on probing was < 5%, there were no remaining pockets (≥ 5mm), no further extractions were necessary and the age-related bone loss factor decreased to 1.4. No systemic diseases are known, and the patient has now been a non-smoker for 5 years. With regard to the further prognosis according to Lang and Tonetti[20], this results in a low to medium risk of progressive attachment loss, since five risk parameters are situated in the low risk and only one remaining parameter (the bone loss factor) in the high risk region.

CONCLUSIONS

By means of a treatment strategy with the objective of conserving strategically important teeth in order to avoid possible complications in the case of prosthetic restoration, critical teeth with severely advanced attachment loss can be conserved over many years without the occurrence of progressive bone loss. Complications may occur due to endodontic problems, furcation caries, and root fractures. Should critical teeth be extracted in the event of severe bone loss, it is not possible to avoid having to seat a prosthetic restoration on periodontally predamaged abutments. The successful implementation as well as the risks and technical complications are discussed in the second part of this article.

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Reprint requests:
Dr. med. dent. Andreas Rühling, Senior Dentist
Department of Periodontology
Clinic for Operative Dentistry and Periodontology
Universitätsklinikum Schleswig-Holstein, Campus Kiel
Arnold-Heller-Straße 16, D-24105 Kiel, Germany
E-mail: ruehling@konspar.uni-kiel.de