Preface

Preparations for the 4th edition of *Clinical Periodontology and Implant Dentistry* started in 2001 when all senior authors of the various chapters of the current text were identified and invited to join the team of contributors. The authors were selected because of their reputations as leading researchers, clinicians or teachers in Periodontology, Prosthetic Dentistry, Implant Dentistry and associated domains. Their task was simple but demanding; within your field of expertise, find all relevant information, digest the knowledge and present to the reader a "state of the art" text that can be appreciated by (i) the student of dentistry and dental hygiene, (ii) the graduate student of Periodontology and related domains and (iii) the practicing dentist; the general practitioner and the specialist in Periodontology and/or Implant Dentistry.

I am proud to present the outcome of this collective effort as it appears in this 4th edition of *Clinical Periodontology and Implant Dentistry.*

As was the case in the 3rd edition, this textbook consists of three separate parts; *Basic Concepts, Clinical Concepts* and *Implant Concepts*; that together illustrate most, if not all, important aspects of contemporary Periodontology. Several chapters from the 3rd edition of this book have been thoroughly revised, some have required only modest amendment, while several chapters in each separate part are entirely new. The amendments and additions illustrate that Periodontology is continuously undergoing change and that the authors of the textbook are at the forefront of this conversion.

Chapter 26

The Effect of Therapy on the Microbiota in the Dentogingival Region

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Introduction

The information in Chapter 4 indicated that the biofilms that colonize tooth surfaces and oral soft tissues are complex and the resident bacteria have intriguing interactions with each other and with the surfaces that they colonize. The data indicated that organisms in biofilms are "worthy" adversaries for control and/or eradication. Of concern to the therapist in treating such dental infections is the fact that the pathogenic species exist in very large numbers, are widely distributed within the oral cavity and exist in community structures (biofilms) that provide protection against host defense mechanisms and antimicrobial agents. Further, the organisms can rapidly multiply and have a talent for attaching to new surfaces of the host or to other organisms that are already attached to the host; thus, spread and recolonization are a persistent threat. Given this formidable opponent, it is worth remembering that periodontal therapies, by and large, have a beneficial effect in terms of arresting progression of periodontal disease and maintaining the periodontium. The "by and large" is a phrase that certainly indicates that conventional, i.e mechanical therapies, are not always successful and that alternative or adjunctive methods are sometimes essential. The purpose of this chapter is to examine the microbiological changes that are brought about by therapies of different types, alone and in combination, and the effect that these changes have on clinical outcomes in both the short and longer-term.

The goals of periodontal infection control

The desired clinical outcomes of periodontal therapy have been clearly defined. These include reduction in (1) probing pocket depth, (2) the percentage of sites that exhibit bleeding on probing, (3) suppuration, (4) overt gingivitis, and (5) visible plaque accumulation. Even more critical is maintaining the stability of the periodontal attachment level as measured by probing attachment and alveolar bone level assessments. Given the complexity of the periodontal microbiota, microbial therapeutic endpoints are less well defined. Ideally, putative periodontal pathogens would be eliminated from the oral cavity. However, this is rarely achieved since many periodontal pathogens appear to be indigenous species and can frequently be found in periodontally healthy subjects albeit in lower numbers and proportions. Thus, the therapist is left with the problem of lowering the numbers of pathogenic species while maintaining or raising the level of host compatible species. Further, these changes in the microbiota must be maintained for the life of the patient if future disease episodes are to be prevented.

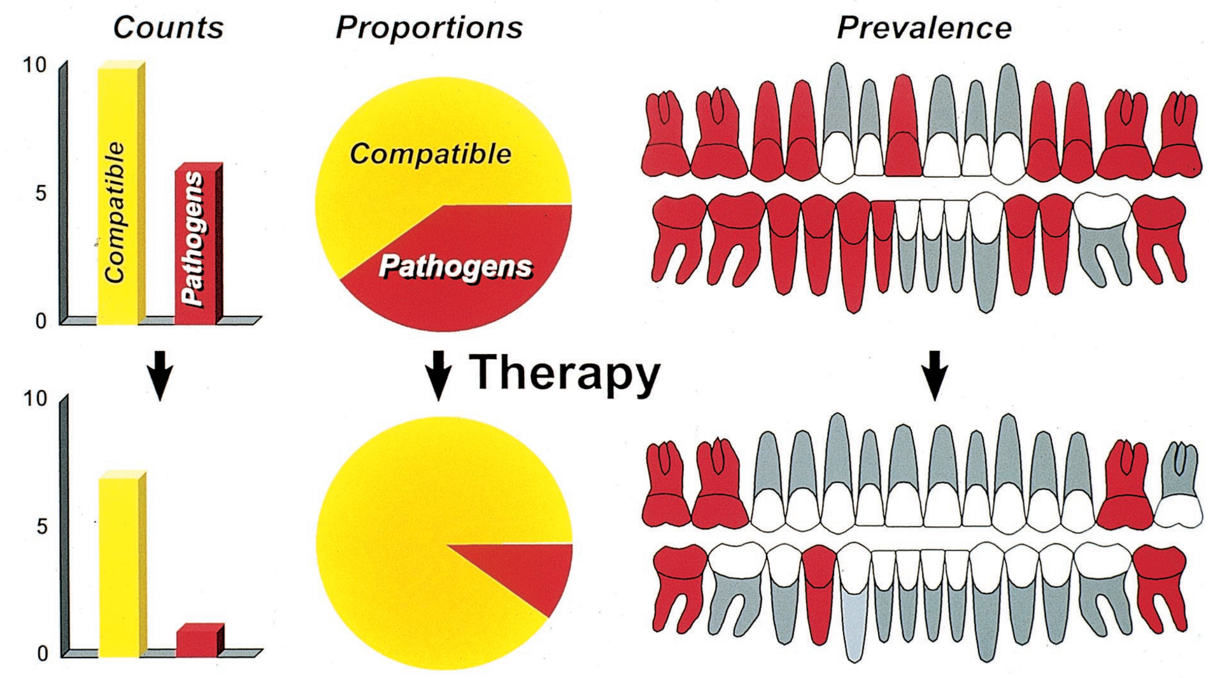

Fig. 26-1. Diagrammatic representation of methods of describing microbial changes in plaque samples. The left panel depicts changes in counts, the middle panel changes in proportions and the right panel changes in the percentage of sites colonized (in this instance percentage of teeth colonized).

Measurement of microbiological endpoints

Changing the composition of the subgingival microbiota in a directed fashion is not easy and if the microbiota is altered, how would the change be measured? Fig. 26-1 presents three microbiological parameters that have been used to describe changes in the composition of the subgingival microbiota after periodontal therapy. The first is a measure of the change in counts (numbers) of one or more pathogenic species. In this method, the plaque samples are taken at one or more sites before and after therapy, using, for instance, scalers or paper points. The test species in the sample(s) are enumerated by cultural, microscopic, DNA probe or immunologic techniques. In some studies, the counts at multiple sites in a subject are averaged prior to and after therapy and reductions identified. In the second example, the proportion of each species in the total sample is computed. From these data, changes in the proportions of each species resulting from therapy can then be determined. The third method requires sample taking from multiple sites within each subject. The percentage of sites colonized by each of the pathogens is computed and the difference in prevalence determined before and after therapy. Each of these measures provides different information. Counts indicate pathogen load at the sampled site(s) and usually are the most easily changed by therapy. The change in proportions at a site indicates the shifts in the composition of the sampled microbiota. If such shifts occur, one or more species would be reduced in proportion, while other species increase. The prevalence (percentage of sites colonized) is usually the most difficult parameter to change as a result of therapy. This parameter indicates the extent of the distribution of a species in the oral cavity and reduction in this parameter requires "elimination" of the species from one or more sites. It must be understood that "elimination" is dependent on the sensitivity of the microbiological method used. Thus, cultural or DNA probe techniques that indicate elimination of a species really mean reduction of the species to below detection limits of the method.

The first two techniques of microbial assessment, i.e. change in counts and change in proportions of test species, are commonly employed in therapeutic studies. The change in prevalence (percentage of sites colonized) is less frequently employed because multiple sites in the same subject must be individually sampled and analyzed.

Treatment of periodontal biofilms

At the present time, periodontal therapies designed to affect the composition of the subgingival microbiota can be grouped in three broad categories:

- Physically removing microorganisms, often called mechanical debridement
- Attempting to kill or affect the metabolism of the organism, such as antiseptics and antibiotics

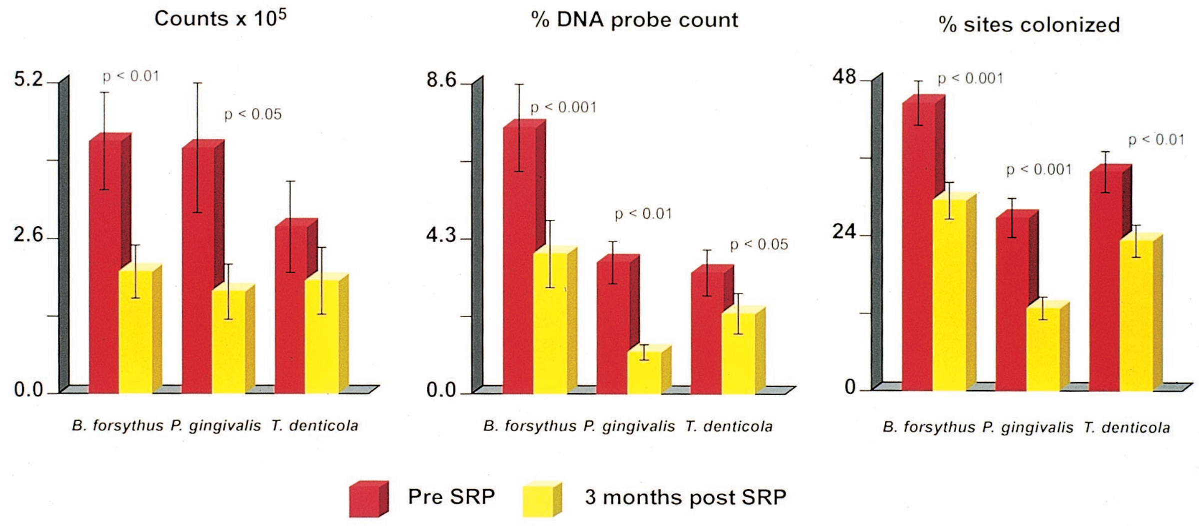

Fig. 26-2. Bar charts of the mean counts ($\times 10^5 \pm$ SEM) (left panel), mean proportions (± SEM) (middle panel) and mean percentage of sites colonized (± SEM) (right panel) pre and 3 months post SRP for red complex species in 71 subjects (N samples = 3546). The red bar of each pair summarizes pretherapy values and the yellow bar post-therapy values. The significance of differences in mean counts, prevalence and percentage of sites colonized between pre and post-therapy was determined using the Wilcoxon signed ranks test after adjusting for multiple comparisons (Socransky et al. 1991).

- Affecting the environment (habitat) of the organisms.

Other types of therapy are on the horizon, such as possible vaccines against oral pathogens or replacement therapy in which a species is introduced to the biofilm in order to control potentially pathogenic microorganisms. These two approaches will not be discussed further, although their addition to the therapist's armamentarium may eventually become real.

The physical removal of microorganisms – mechanical debridement

Given the remarkable resistance of organisms in biofilms to host defense mechanisms and antimicrobial agents, the logical first step in the control of these organisms would be their removal by physical means. Fortunately, biofilms in the oral cavity, unlike many other biofilms, are readily accessible, allowing their physical removal. Indeed, the most common form of periodontal therapy is the removal of supragingival and subgingival plaque by procedures such as self-performed oral hygiene, scaling and root planing (SRP), sometimes combined with periodontal surgery. Although many studies have documented the clinical effects of SRP, few have evaluated comprehensively the microbiological changes associated with SRP. Studies in the earlier years emphasized use of dark-field or phase contrast microscopy and indicated that the proportion of spirochetes and motile rods declined after SRP, while cocci and non-motile rods increased (Listgarten et al. 1978, Mousques et al. 1980, Lindhe et al. 1983a,b, Muller et al. 1986, Lavanchy et al. 1987). Other studies employed cultural techniques generally on small numbers of sites and subjects, largely because of the cost in terms of labor and time. Such studies indicated a decrease in groups of microorganisms such as "black pigmented *Bacteroides*" (Pedrazzoli et al. 1991) or specific species such as *Porphyromonas gingivalis* (Sbordone et al. 1990, Ali et al. 1992) and *Actinobacillus actinomycetemcomitans* (Ali et al. 1992). However, other studies found minimal long-term effects of SRP on the subgingival microbiota (Sbordone et al. 1990) particularly for species such as *A. actinomycetemcomitan* (Sato et al. 1993, Saxen & Asikainen 1993, Gunsolley et al. 1994, Mombelli et al. 1994, Nieminen et al. 1995). Other long-term studies reported a decrease in the levels and prevalence of certain species including *Bacteroides forsythus, Treponema gingivalis, Prevotella intermedia* and *T. denticola* (Simonson et al. 1992, Rawlinson et al. 1993, Shiloah & Patters 1994, Lowenguth et al. 1995, Takamatsu et al. 1999, Darby et al. 2001)

The use of DNA probe techniques has permitted larger scale studies of the effect of therapies on the composition of the subgingival microbiota. The following data demonstrate the effect of SRP on the composition of the subgingival plaque. In this study, an extension of the study described by Haffajee et al. (1997), 71 subjects with chronic periodontitis were monitored clinically at six sites per tooth. Subgingival plaque samples were taken from the mesiobuccal surface of each tooth and individually analyzed for their content of 40 bacterial species using a checkerboard DNA-DNA hybridization technique. Clinical measurements and microbial samples were taken at base-

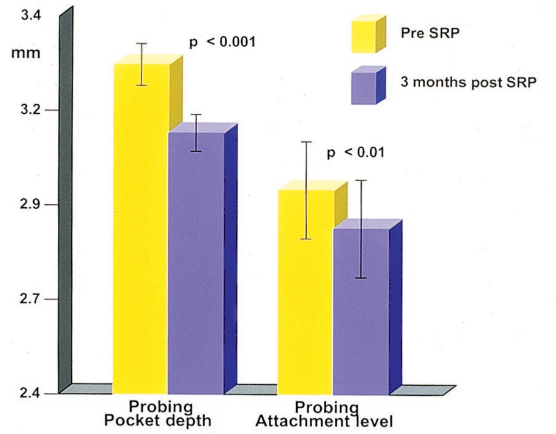

Fig. 26-3. Bar chart of the mean pocket depth and attachment level (± SEM) at baseline and 3 months post SRP (N subjects = 71). The significance of differences between pre and post-therapy visits was determined using the Wilcoxon signed ranks test. Note that the y-axis does not start at 0.

line and 3 months after treatment, which consisted of full mouth SRP accompanied by oral hygiene instruction. The data indicated that 37 out of 40 species monitored did not change significantly. However, three species of the "red" complex (see Chapter 4), *B. forsythus*, *P. gingivalis* and *T. denticola* were significantly decreased in counts, proportions and percentage of sites colonized 3 months post SRP (Fig. 26-2). These microbial changes were accompanied by improved clincial parameters such as a significant decrease in mean probing pocket depth and mean probing attachment level (Fig. 26-3).

The data of this and other investigations are of interest in the light of the discussion in Chapter 4 on biofilms. The mechanical procedures undoubtedly removed major proportions (90%) of the organisms that colonized the tooth surface. However, given the rapid multiplication rates of bacteria, it is not surprising that the majority of the species returned to almost baseline levels at 3 months. Data in the literature suggest that the return to baseline *total counts* of microorganisms may occur within 4-8 days after treatment (Sharawy et al. 1966, Furuichi et al. 1992). However, certain species were affected by SRP. These bacterial species might have been diminished by the mechanical procedures and returned more slowly, in part because of their fastidious nature, and in part because the environment presented by the healing tissues may have been changed.

Few studies have evaluated the effect of periodontal surgery on the composition of the subgingival microbiota. Rosenberg et al. (1984) used dark field microscopy to examine the composition of the subgingival microbiota after a procedure that included open flap curettage with some osseous recontouring and apical repositioning of the flaps. After surgery, the

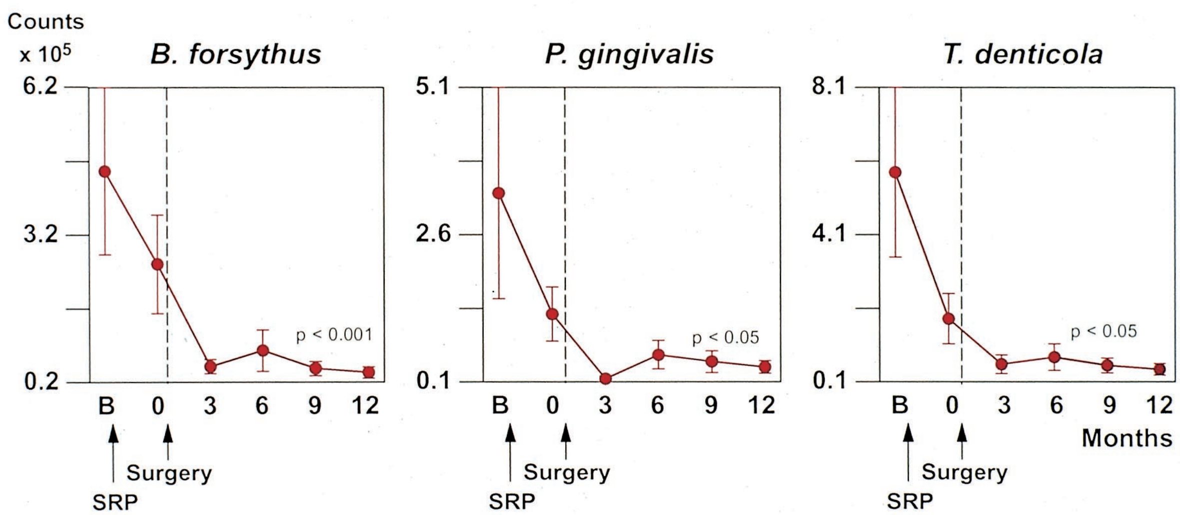

Fig. 26-4. Plots of the mean counts ($\times 10^5 \pm$ SEM) of red complex species, *B. forsythus, P. gingivalis* and *T. denticola* at baseline (B), 3 months post SRP (0 on the x-axis) and at 3, 6, 9 and 12 months post apically repositioned flap surgery. 18 patients with chronic periodontitis were monitored clinically and sampled microbiologically at baseline (B). They then received full mouth SRP and instruction in proper home care procedures. 3 months after SRP, the subjects were clinically and microbiologically monitored again (at time 0) to determine the effect of SRP on clinical and microbiological parameters and to determine which areas of the mouth required periodontal surgery. The time 0 monitoring also served as the starting values for the surgical phase of treatment. The subjects then received apically repositioned flap surgery at sites with PPD > 5 mm. Subjects were remonitored clinically and microbiologically at 3, 6, 9 and 12 months after the surgical treatment phase. The vertical dotted lines indicate the time of periodontal surgery. Significance of differences over time was tested using the Quade test and adjusted for multiple comparisons (Socransky et al. 1991).

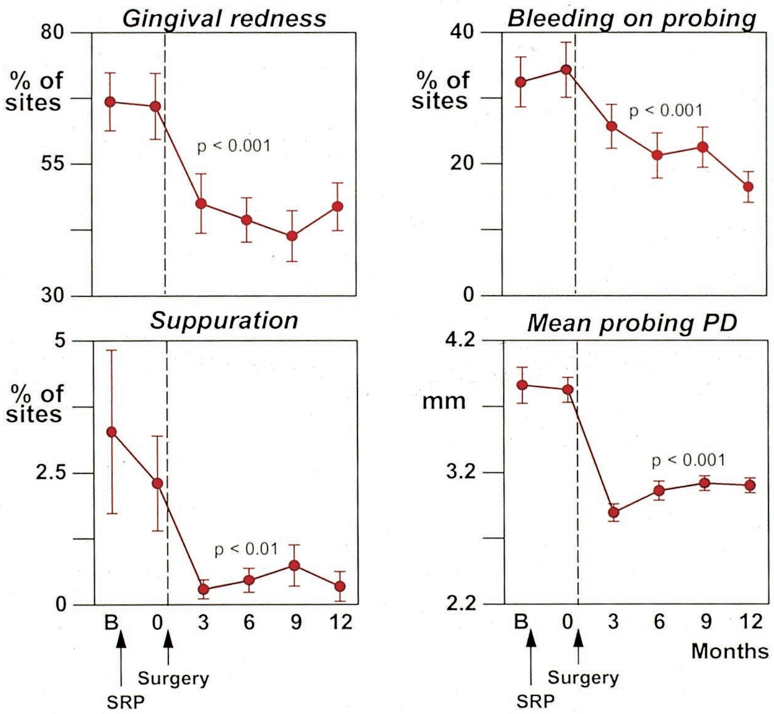

Fig. 26-5. Plots of the change in clinical parameters at surgically treated sites from baseline (B) to 3 months post SRP (0 on the x-axis) and 3, 6, 9 and 12 months post apically repositioned flap surgery. The experimental design was described in Fig. 26-4. The circles represent the mean values and the whiskers represent the standard error of the mean. Values for each parameter were measured at all surgically treated sites in each subject, averaged within a subject and then averaged across subjects for each time point. The vertical dotted lines indicate the time of periodontal surgery. Significance of differences over time was tested using the Quade test.

proportions of spirochetes and motile rods decreased while the proportions of cocci increased. Rawlinson and co-workers (1995) used cultural techniques to examine the effects of a modified Widman flap surgery or SRP on the microbiota in periodontal pockets. *P. intermedia* was reduced at 3 and 6 months, but began to increase at 1 year following therapy. Overall, Gram-negative species were not affected significantly by SRP, but became virtually eradicated in surgically treated subjects during the year of the study. Mombelli et al. (1995) performed a similar study using cultural techniques, in which they monitored the levels of subgingival species in plaque samples for 1 year post therapy. There was a decrease in total anaerobic viable bacteria along with a decrease in Gram-negative rod species. *P. gingivalis*, *Fusobacterium* sp. and *Campylobacter rectus* were lower, while *Capnocytophaga* sp. and *Actinomyces odontolyticus* were detected in higher numbers at the 1 year examination. More recently, a similar study was performed at the Forsyth Institute with essentially identical conclusions to the Rawlinson and Mombelli studies. Eighteen patients with chronic periodontitis received initial SRP, followed at 3 months by apically repositioned flap surgery at sites with PPD > 5 mm. Subjects were monitored clinically and microbiologically at baseline (B), 3 months post SRP (0) and at 3, 6 and 12 months post-surgery. Subgingival plaque samples were examined using checkerboard DNA-DNA hybridization. Treatment resulted in a decrease in the mean counts of, among others, *B. forsythus*, *P. gingivalis* and *T. denticola* (Fig. 26-4) as well as members of the orange complex (Socransky et al. 1998). The clinical changes at the surgically treated sites are presented in Fig. 26-5. There was a significant decrease in the percentage of sites exhibiting gingival redness, bleeding on probing and suppuration as well as a marked decrease in mean PPD. It seems likely that the decrease in PPD led to a decrease in the levels of pathogenic species and that the decrease in pathogenic species resulted in an improved clinical status as measured by changes in gingival inflammation and the continued decrease in PPD over time.

Antibiotics in the treatment of periodontal infections

Since periodontal diseases are infections, it is not surprising that antibiotics have been used and continue to be used in their treatment. Given the discussion on increased antibiotic resistance that occurs in organisms growing in biofilms, as well as the difficulty of some antibiotics in effectively penetrating a biofilm, one might of course question the use of such agents in the treatment of periodontal diseases.

Antibiotics have been successfully employed, however, as adjuncts in the treatment of periodontitis (Lindhe et al. 1983b, Joyston-Bechal et al. 1984a,b, Loesche et al. 1984, 1987, 1991, 1992, 1996, van Oosten et al. 1987, Asikainen 1989, Hull et al. 1989, Jenkins et al. 1989, Soder et al. 1990, Eisenberg et al. 1991, Paquette et al. 1992, Haffajee et al. 1995, van Winkelhoff et al. 1996, Noyan et al. 1997). The expectation that one might have of the results of treatment by a systemically administered antibiotic can vary widely. On the one hand, the expectation might be that the agent would kill all of the sensitive species and leave hopefully host-compatible species to emerge. On the other hand, from the discussion in Chapter 4, one might

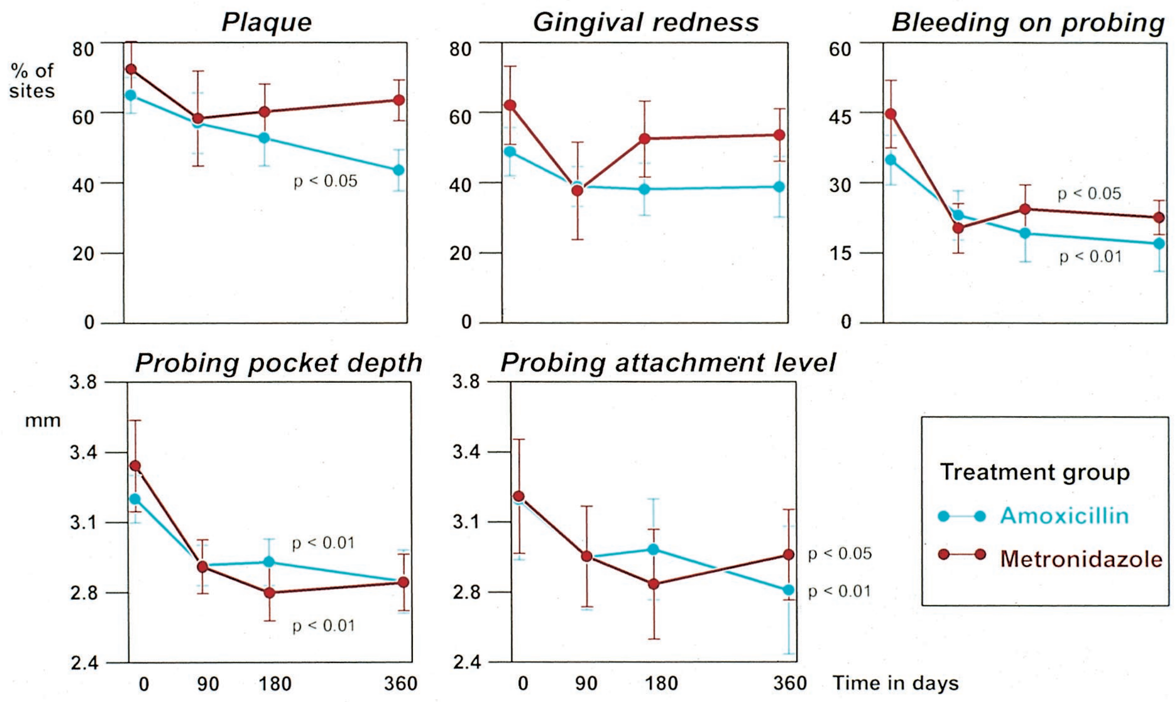

Fig. 26-6. Plots of the full mouth mean values (± SEM) for clinical parameters at baseline, 90, 180 and 360 days for subjects treated with SRP and metronidazole or SRP and amoxicillin. The circles represent the mean values and the whiskers represent the standard error of the mean. Values for each parameter were measured at up to 168 sites in each subject, averaged within a subject and then averaged across subjects in each treatment group for each time point. Significance of differences over time was tested using the Quade test.

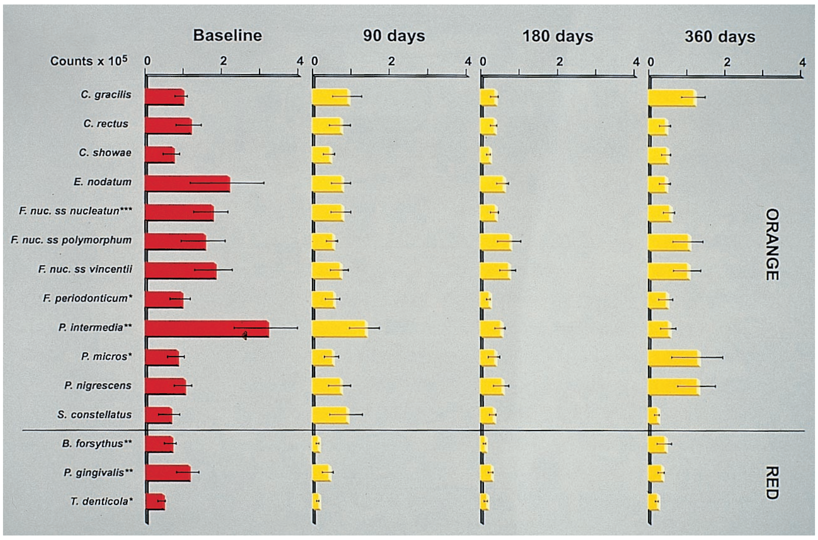

Fig. 26-7. Bar charts of the mean counts ($\times 10^5 \pm$ SEM) of red and orange complex species at baseline, 90, 180 and 360 days for the amoxicillin treated subjects. Mean levels of each species were computed for each subject and then averaged across subjects at each time point. Significance of differences over time was tested using the Quade test (*$p < 0.05$, **$p < 0.01$, ***$p < 0.001$). Seven of the 15 species were significantly reduced.

surmise that the antibiotic might have virtually no effect on organisms grown in biofilms. The "truth" lies somewhere in between. Systemically administered antibiotics do have certain effects on segments of the subgingival microbiota, but usually do not completely eliminate the bacterial species sensitive to the administered antibiotic.

The appropriate use of antibiotics in the treatment of periodontal diseases was discussed in more detail in Chapter 23. In the current chapter the effects of these agents on the composition of the subgingival microbiota will be described. The following study provides examples of two popularly employed systemic antibiotics, amoxicillin and metronidazole, used as adjuncts to SRP (Feres et al. 2001). After baseline clinical monitoring and microbial sampling, 17 chronic periodontitis subjects received full mouth SRP. Subjects were then randomly assigned to treatment groups receiving either systemically administered amoxicillin (500 mg tid) or systemically administered metronidazole (250 mg tid) for 14 days. Post-therapy, full mouth clinical monitoring and bacterial sampling was per-

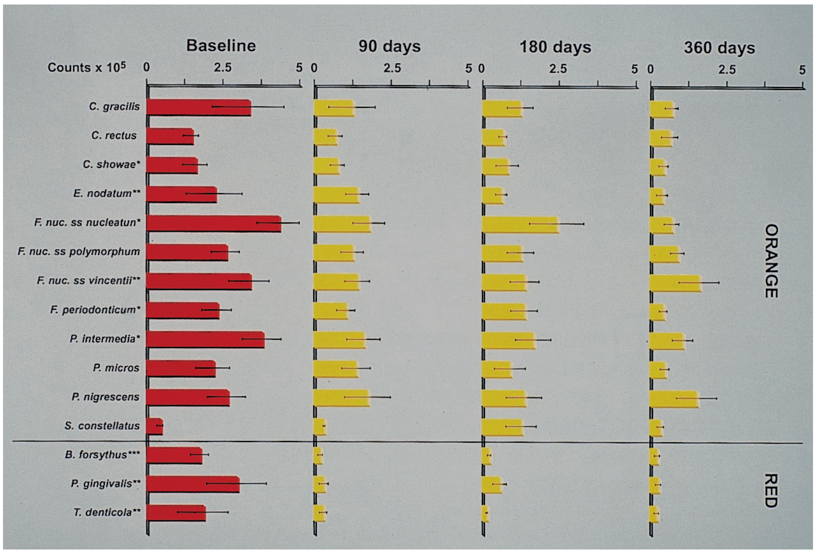

Fig. 26-8. Bar charts of the mean counts ($\times 10^5 \pm$ SEM) of red and orange complex species at baseline, 90, 180 and 360 days for the metronidazole treated subjects. The presentation of the data and significance testing was as described in Fig. 26-7. Nine of the 15 species were significantly reduced.

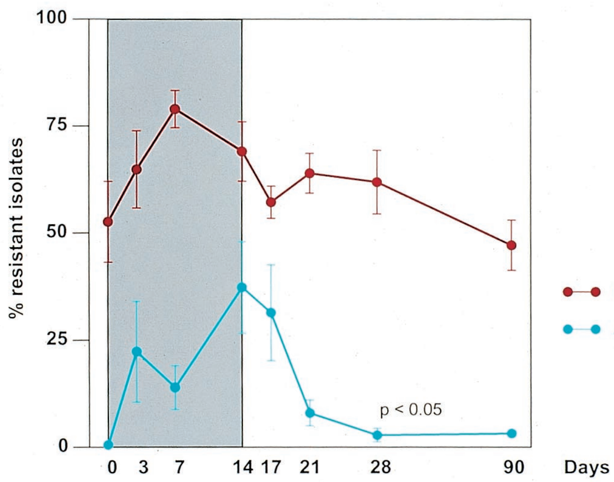

Fig. 26-9. Percentage of isolates resistant to amoxicillin or metronidazole in the plaque samples from subjects receiving those agents. Samples were plated on enriched blood agar plates with or without either 2 µg/ml metronidazole or 2 µg/ml amoxicillin. Colonies were counted at 7 days. Data were averaged within a subject at each time point and then across subjects separately in the two groups. The circles represent the mean and the whiskers the standard error of the mean. The shaded area represents the period of antibiotic administration in the test subjects. Significant differences in the percentage of resistant organisms over time were determined by the Quade test.

formed at 3, 6 and 12 months. Additional subgingival plaque samples were taken, from pairs of randomly selected posterior teeth, at 3, 7 and 14 days during antibiotic administration as well as at 3, 7 and 14 days after completion of the antibiotic therapy to determine antibiotic resistance of isolates. Both therapies produced a significant improvement in clinical parameters (Fig. 26-6). Figs. 26-7 and 26-8 present the counts of the red complex species at baseline, 3, 6 and 12 months in the two treatment groups. Both amoxicillin and metronidazole produced significant decreases in counts of many of the bacterial species, particularly those in the red and orange complexes. The decrease in counts of red complex species was particularly marked and the initial decreases were maintained to 12 months, most noticeably in the subjects treated with metronidazole.

The proportion of organisms that were resistant to the two agents before, during and after their administration are shown in Fig. 26-9. More than half of the cultivable organisms were resistant to metronidazole at baseline. This number increased to about 81% during metronidazole administration and decreased to baseline levels at 90 days. Only about 0.5% of the isolates were resistant to amoxicillin at baseline. The resistant proportion rose to about 41% at the end of amoxicillin administration and declined to close to baseline levels at 90 days. Thus, 19% of organisms in the biofilms were sensitive to metronidazole and 59% were sensitive to amoxicillin, even when the subjects had taken the prescribed agent for 14 days. These figures attest to the protection afforded to organisms in biofilms that was discussed in Chapter 4. The microbial count data and the antibiotic resistance data suggest the possibility that the systemically administered antibiotics may have affected, primarily, the organisms in the epithelial cell associated biofilms and the loosely adherent adjacent cells. These organisms might be more accessible to the administered agents, in part, because of their proximity to the host tissues and, in part, because of a less developed glycocalyx. Conceivably, organisms in this area were reduced to very low levels. However, the same species may also have been resident in the tooth associated biofilms but at much lower levels. The species in the tooth associated biofilms may have been more resistant to the antibiotics due to mechanisms described in Chapter 4 and thus, the potential for regrowth from this source was perpetuated.

The data from the study outlined above indicate that systemically administered antibiotics do affect microorganisms located within biofilms. Many of the test species were significantly reduced in numbers even up to 1 year after the initial therapy, although no species was eliminated. It was also clear that the two agents had different effects on the subgingival microbiota. While both agents reduced, at least initially, the red complex, metronidazole appeared to have a more pronounced and long-lasting effect. Further, amoxicillin produced a significant decrease in the proportion of *Actinomyces* species with a concomitant increase in the proportion of yellow complex species. This potentially undesirable effect was not seen in the subjects treated with metronidazole. It was also apparent, within the limitations of the study, that short-term use of these two agents did not affect the proportion of antibiotic resistant species long term.

The effect of an antibiotic can go beyond its direct effects on individual species. For example, the *counts* of *Actinomyces* species were found to be decreased 3 months after metronidazole administration. The *Actinomyces* are not sensitive to metronidazole, suggesting that this reduction was due to a decrease in other bacterial species that affected the inflammatory status of the habitat which in turn lowered levels of all colonizing species (Ramberg et al. 1994, 1995).

Therapies that affect the microbial environment – supragingival plaque removal

While it is widely recognized that bacteria can affect the tissues that they colonize, it is less appreciated that the environment of the bacteria has a major effect on their growth and activities. It is axiomatic in microbial ecology that colonizing species affect the environment in which they live (habitat) and the habitat affects the colonizing organisms. This is clearly the case in the oral environment where species have specific tissue tropisms with certain species flourishing on certain surfaces and others in other locations. The subgingival pocket is clearly an environment in which many species, including those of the red and orange complexes, flourish (Chapter 4). This habitat provides an environment conducive to their multiplication and perhaps to their ability to mediate tissue destruction. If the environment surrounding the subgingival microbiota was altered, then changes in numbers, proportions and prevalence of species would be likely to be affected. The two major environmental factors that impact on subgingival plaque are the tissues of the periodontal pocket and the supragingival plaque. Changes in either of these factors are likely to lead to changes in the composition of the subgingival microbiota. It has been recognized for a long time that meticulous removal of supragingival plaque leads to an improvement in the parameters associated with gingival inflammation. Indeed, clinicians have urged and continue to urge patients to carefully and regularly remove supragingival deposits. What is less appreciated is the effect of regular supragingival plaque removal on subgingival plaque composition. A few studies have suggested that supragingival plaque removal can decrease putative periodontal pathogens (Tabita et al. 1981, Smulow et al. 1983, Dahlen et al. 1992, Al-Yahfoufi et al. 1995, Hellstrom et al. 1996). These effects were examined further in a study of 18 chronic periodontitis subjects who were in a periodontal maintenance program (Ximenez-Fyvie et al. 2000). After baseline clinical and microbiological examination, the subjects received full mouth SRP followed by weekly professional removal of supragingival plaque for 3 months. The subjects performed their improved home care procedures for the 12 months of the study. The subjects were monitored at 3, 6 and 12 months, at which points they also received maintenance subgingival scaling. Fig. 26-10 presents the mean total counts of supra and subgingival plaque at baseline, 3, 6 and 12 months. Total counts of both supra and subgingival plaque decreased significantly at 3 months, immediately after completion of the professional supragingival plaque removal phase. It was of interest, however, that the counts continued to decrease at the 6 and 12 month visits, even though professional cleaning had not been employed for 3 and 9 months respectively. Similar findings were seen in both supra and subgingival samples for the 40 species examined. Fig. 26-11 presents the mean counts of the 40 test species at baseline, 3, 6 and 12 months; 34 species were significantly reduced over time. These included periodontal pathogens such as *B. forsythus*, *P. gingivalis* and *A. actinomycetemcomitans*. This suggests that meticulous removal of supragingival plaque after initial periodontal therapy, such as SRP, can lead to a microbiota that is remarkably similar to that observed in periodontal health.

The meticulous repeated removal of supragingival plaque not only lowers the counts of subgingival pathogens but has a clear beneficial clinical effect. This procedure is critical to a predictable, successful outcome after periodontal surgery (Lindhe & Nyman 1975, Nyman et al. 1975, Rosling et al. 1976b, Axelsson & Lindhe 1981, Lindhe et al. 1982, Westfelt et al. 1985) and for bone regeneration in infrabony pockets (Rosling et al. 1976a). Further, repeated professional tooth cleaning every 2 weeks reduced dental plaque, gingivitis and the caries increment in children (Axelsson & Lindhe 1974, Axelsson et al. 1976), while similar programs had comparable results in adults (Axelsson & Lindhe 1978, 1981).

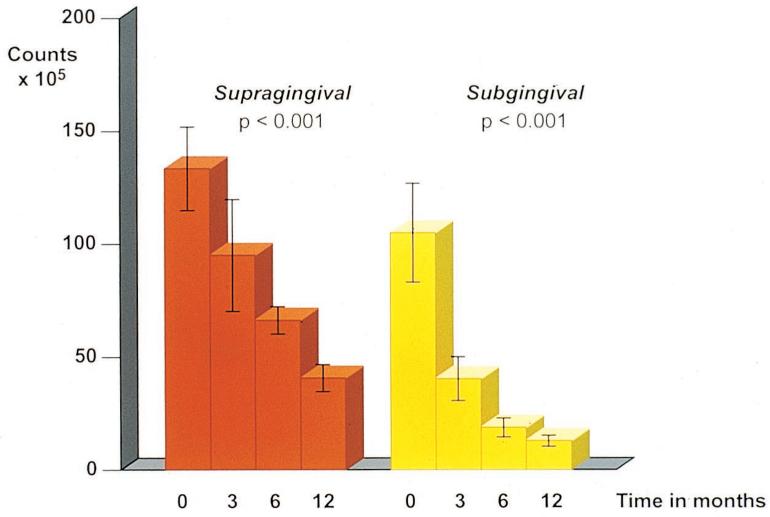

Fig. 26-10. Mean total DNA probe counts ($\times 10^5 \pm$ SEM) in supra and subgingival plaque samples taken at baseline, 3, 6 and 12 months. Professional supragingival plaque control was performed weekly between baseline and 3 months. Mean counts were computed for a subject for each visit and then values were averaged across the 18 subjects at each time point. The whiskers indicate the SEM. Significance of differences over time was sought using the Quade test.

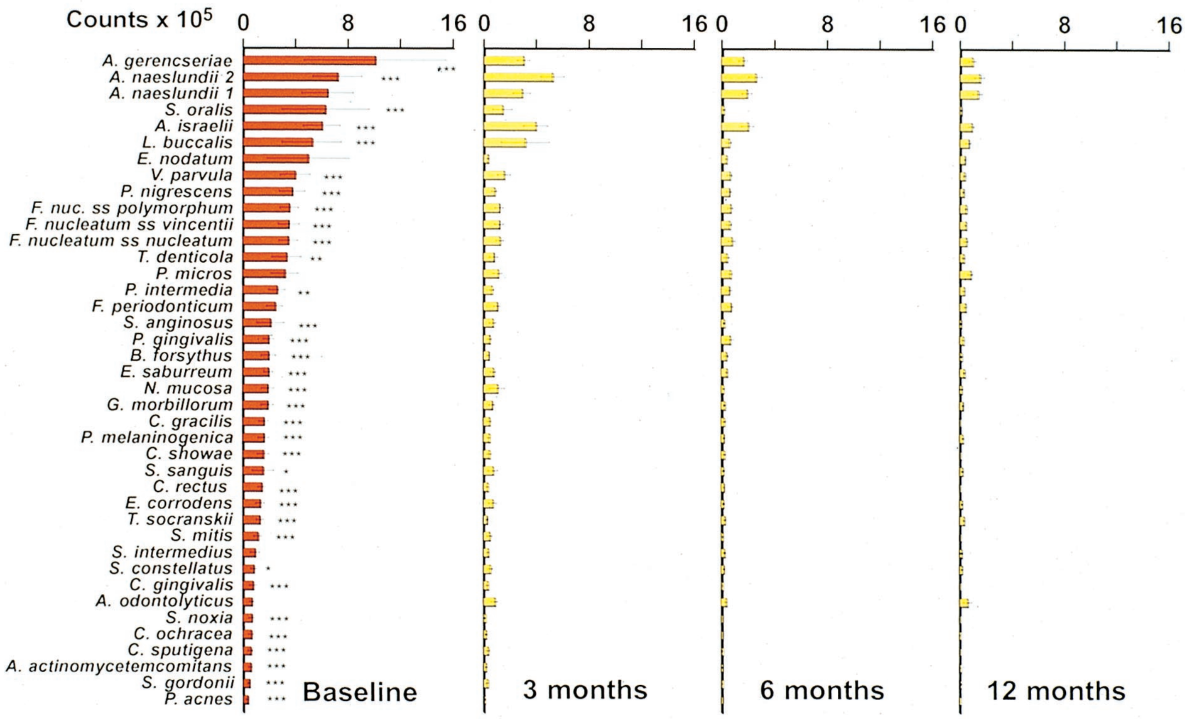

Fig. 26-11. Bar charts of the mean counts ($\times 10^5 \pm$ SEM) of the 40 test species in subgingival plaque samples taken at baseline, 3, 6 and 12 months. Professional supragingival plaque control was performed weekly between baseline and 3 months. Mean counts for each species were computed for a subject for each visit and then values were averaged across the 18 subjects at each time point. The whiskers indicate the SEM. Significance of differences over time was sought using the Quade test. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$ after adjusting for multiple comparisons.

The above studies demonstrated that repeated professional removal of supragingival plaque has major beneficial effects on altering the composition of the subgingival microbiota and the clinical status of the patient. However, repeated professional plaque removal may be somewhat impractical for most patients since it requires frequent visits to the dental office. Effective, self-performed plaque removal would be a more practical means of removing supragingival plaque providing the patient is proficient in the techniques employed.

The effects of self-performed plaque removal by either the use of manual or powered toothbrushes on clinical and microbiological parameters were examined in a study of 48 periodontal maintenance subjects (Haffajee et al. 2001a,b). After assignment to either the manual or powered toothbrushing group, subjects received instruction in the use of the assigned brush,

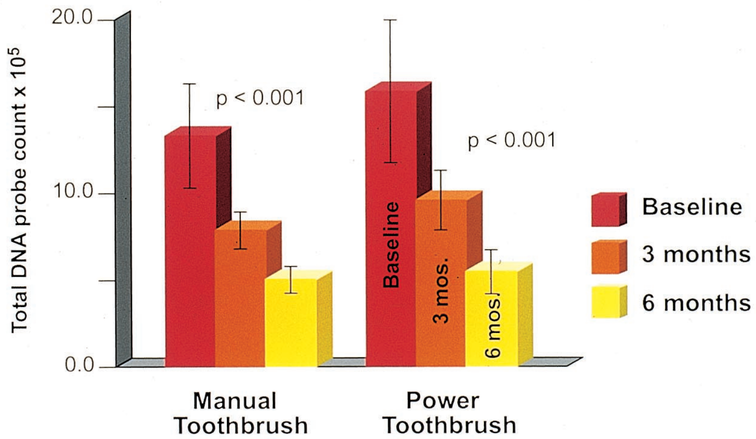

Fig. 26-12. Bar charts of the mean total DNA probe counts ($\times 10^5 \pm$ SEM) for subgingival plaque samples at baseline, 3 and 6 months in subjects using either the manual or power toothbrush. The bars indicate the means and the whiskers the SEM. The total counts were computed at each site, averaged within a subject for each time point. Significance of differences over time was sought using the Quade test.

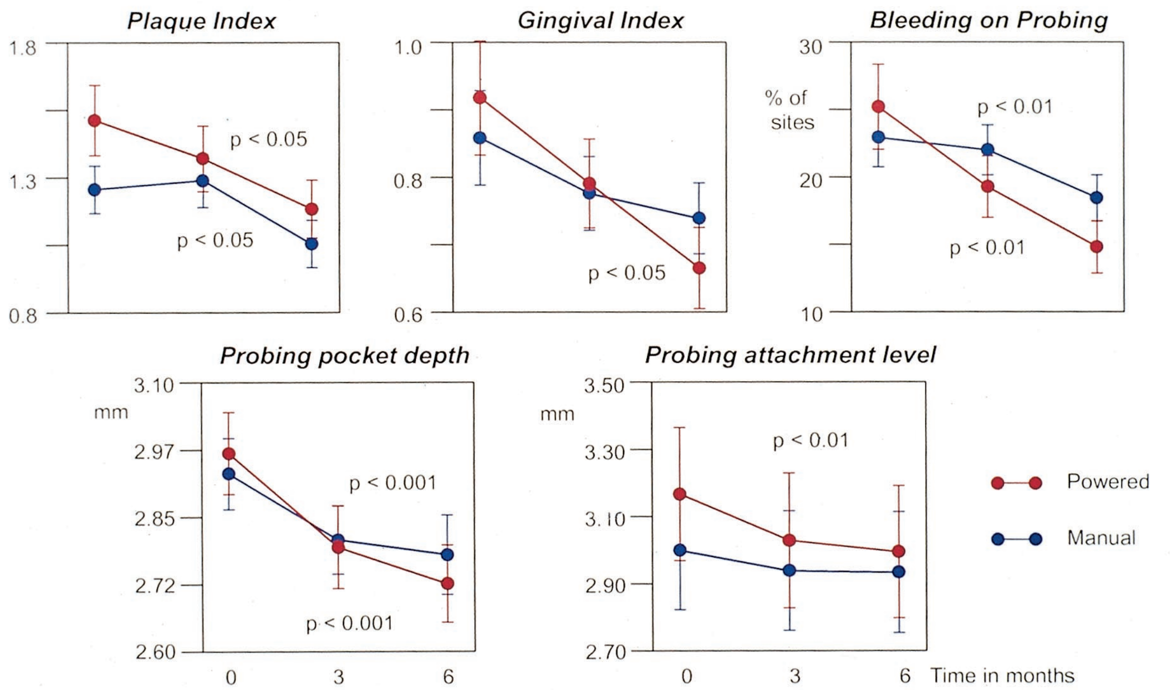

Fig. 26-13. Plots of the full mouth mean values (± SEM) for clinical parameters at baseline, 3 and 6 months for subjects in the manual and powered brushing groups. The circles represent the mean values and the whiskers represent the standard error of the mean. Values for each parameter were measured at up to 168 sites in each subject, averaged within a subject and then averaged across subjects in each brushing group for each time point. Significance of differences over time was tested using the Quade test.

which they used for 6 months. Clinical and microbiological parameters were measured at baseline and at 3 and 6 months. Mean total bacterial counts were significantly reduced for subgingival plaque samples in both groups (Fig 26-12). In addition, virtually all of 18 test species examined were reduced in mean counts and prevalence in subgingival plaque samples. The decrease in microorganisms was accompanied by improvements in clinical parameters. Both manual and powered toothbrushes significantly reduced PPD, plaque index and BOP, while the powered toothbrush also significantly reduced mean gingival index and probing attachment level (Fig. 26-13). Although the benefits of repeated professional supragingival plaque removal may be superior, these data suggest that careful self-performed plaque control is of benefit to the patient in terms of lowering subgingival species and improving clinical status.

In controlling infectious diseases, there are usually two types of procedures employed. The first is to control the level of the organism in the environment, usually by "sanitation" procedures. The second is to target the organism in an infected host who is exhibiting disease. On a population basis, the first might be the more important in that epidemic disease has been markedly reduced in first world countries by improvements in sewage systems, water supplies, food handling, etc. Supragingival plaque control may be thought of as a "sanitary" procedure that lowers the levels of potentially pathogenic species that colonize the individual and the community. As such, this reduction in the reservoir of potentially pathogenic organisms is of major importance in lowering the risk of new disease or recurrence of disease in infected individuals. However, supragingival plaque removal has an added benefit in that it appears to affect the numbers and composition of the subgingival microbiota. Clearly, the removal of the biofilm from the supragingival area affects the composition of the subgingival biofilm on the same surface. This may be due to a direct effect of the supragingival colonizers on subgingival organisms or an effect on the adjacent periodontal tissues which might lead to reduction in subgingival species. Most likely the effect is due to both phenomena. Supragingival organisms and also the adjacent periodontal tissues provide both nutrients and physical-chemical environments for proliferation of the subgingival species. Removal of the supragingival colonizers would diminish this source, while diminished inflammation and improved barrier function of the epithelium would decrease a second source of growth requirements (Ramberg et al. 1994, 1995). In essence, the subgingival biofilm numbers decrease because the essential requirements for growth have been cut off or decreased. Alteration of the habitat may be one of the most important mechanisms for the long-term control of subgingival pathogens. If our treatment or prevention efforts diminish nutrient availability and maintain epithelial barrier function, then the numbers of organisms in the subgingival environment will diminish and the proportions of organisms that appear to be pathogenic will be decreased. Further, decreasing reservoirs of pathogenic species by systematic removal from tooth surfaces, perhaps accompanied by suppression on soft tissue surfaces, should lead to long-term stability in the majority of periodontal patients. In a similar fashion, altering the habitat by pocket reduction, whether by SRP or by surgery, also affects the composition of the subgingival microbiota and thus the risk of periodontal disease progression.

Combined antimicrobial therapies

The use of combined therapies has been shown to be effective in treatment of several medically important infections. For example, the treatment of HIV infections currently employs two or three therapeutic agents providing better outcomes than the single therapies employed previously. Treatment of stomach ulcers caused by *Helicobacter pylori* is usually best accomplished by the combined use of two or more agents such as metronidazole with amoxicillin and protein pump blocking agents. The combination of systemically administered amoxicillin and metronidazole for the treatment of certain periodontal infections has been quite effective (van Winkelhoff et al. 1989, 1992, Pavicic et al. 1994, Berglundh et al. 1998, Winkel et al 1998, 2001, Rudiger et al. 1999). For example, this treatment in combination with SRP significantly reduced the detection of *A. actinomycetemcomitans* in subjects with *A. actinomycetemcomitans*-associated adult periodontitis (Pavicic et al. 1994), localized juvenile periodontitis, as well as rapidly progressive and refractory periodontitis (van Winkelhoff et al. 1989, 1992). Other studies have shown that the combination of these two agents was also effective in controlling the levels of other pathogens such as *P. gingivalis*, *B. forsythus* and *P. intermedia* (Pavicic et al. 1994, Winkel et al. 1997, 1998, 2001, Berglundh et al. 1998, Lopez & Gamonal 1998, Rudiger et al. 1999).

Long-term effects of antimicrobial therapy

The above sections focused on the effects of different periodontal therapies alone or in combination on clinical and microbiological parameters of periodontal diseases. The majority of the cited studies were relatively short term running from 3 months to 1-2 years. They leave unanswered the question, what are the effects of the various treatment procedures long term? Recently, a series of long-term studies have been reported from the University of Gothenburg in which the effect of different therapeutic procedures has been followed for large numbers of subjects for periods over 13 years. These studies suggested that different forms of periodontal therapy followed by careful maintenance care can maintain alveolar bone and periodontal attachment levels in patients with normal or high susceptibility to periodontal disease (Rosling et al. 2001). Periodontal surgery provided a better long-term reduction in mean probing pocket depth and percentage of subjects exhibiting deterioration of periodontal sites (Serino et al. 2001b). Adjunctive, systemically administered antibiotics such as tetracycline (Ramberg et al. 2001) or amoxicillin plus metronidazole (Serino et al. 2001a) may have provided a short-term clinical benefit which appeared to diminish over time. The nature of the microbial shifts that took place over time in these long-term treatment studies is not known. However, it may be speculated that a shift would have occurred in the subgingival microbiota toward that present before therapy, and this may have been delayed by rigorous removal of supragingival plaque accompanied by periodic subgingival instrumentation. Further studies of long-term microbial changes resulting from periodontal therapy are warranted.

Concluding remarks

Many different biofilms exist in nature, some of which are useful (to the human) while others are associated with potentially harmful effects. Dental plaque is a naturally occurring biofilm that has the potential to cause disease. Dental plaques have many properties

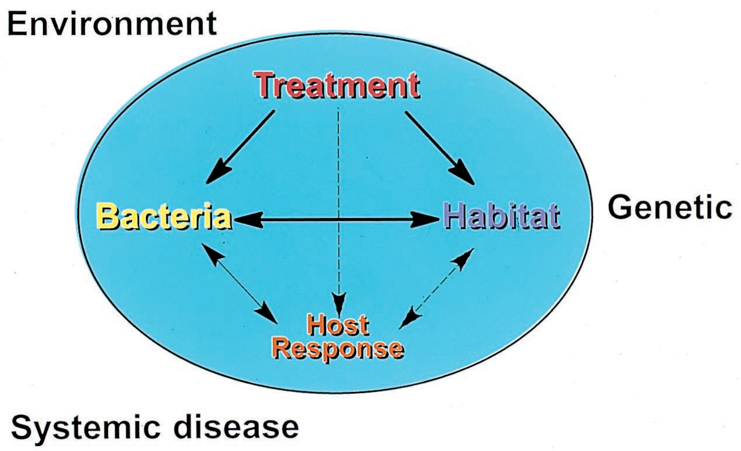

Fig. 26-14. Diagrammatic representation of the effect of therapy on colonizing bacteria, the host and the habitat. Treatment can affect the composition of the bacterial plaque directly, can affect the host response or can alter the habitat. Alterations of any of these factors can impact on the remaining factors in this triad. As indicated, treatment effects are influenced by the genetic background of the subject, environmental influences such as smoking and the systemic well-being of the patient.

in common with biofilms found in other locations. However, they have certain characteristics that are important in terms of control of disease. They are easily accessible and thus allow direct removal and application of antimicrobial agents. However, they are microbiologically very complex. This complexity helps the therapist in one way and presents problems in another. The complexity helps to assure the therapist that treatment will usually lead to the return of a relatively similar, diverse microbial plaque, hopefully with pathogenic species reduced or eliminated. If treatment virtually eliminated all or most species, the potential for colonization by even more harmful organisms would be very high. On the other hand, the complexity can present difficulties for the therapist. The first is knowing which of several potential pathogens in an individual is causing that individual's disease. The second is that the network provided by the community structure of the biofilm may help to "rescue" a suppressed species by providing the essential factors needed for rapid recolonization. Nonetheless, as indicated in this chapter and as described in greater detail in other chapters, dental biofilms can be altered by various therapies, providing a beneficial outcome to the patient. Treatment can affect bacteria directly by physical removal and/or chemotherapeutic agents (Fig. 26-14). Treatment can also affect the habitat, for example by eliminating or by meticulously removing supragingival plaque. As discussed earlier, the bacteria affect their habitat and the habitat affects the bacteria so that the elimination of pockets or the removal of supragingival plaque will provide a less favorable environment for the growth of subgingival species, particularly those associated with disease. Treatment can also affect host response, possibly by "vaccination" during mechanical debridement procedures or by using anti-inflammatory or host modifying local or systemic agents. Modification of host response affects the habitat and also affects the colonizing microbiota. Thus, the therapist can potentially affect periodontal infections at several levels, improving the possibility for long-term periodontal stability. For certain periodontal patients, combinations of therapy may be required in order to control the infection via different antimicrobial strategies.

By and large, the currently available treatment procedures do not eliminate periodontal pathogens. They often lower the numbers, perhaps proportions, or even prevalence of pathogenic species for various periods of time. The mechanical debridement procedures seem essential in any rational treatment protocol since they can directly remove the biofilms which provide the major survival mechanism for tooth associated bacterial species. Antimicrobial agents do affect pathogenic species in subgingival plaque and can be used judiciously to lower the number of such species when disease is extensive, rapidly progressive or refractory to conventional therapy. Ultimately, long-term control of pathogenic species resides primarily in habitat change. The control of subgingival pathogens can be markedly improved by minimizing supragingival plaque, decreasing gingival inflammation that provides nutrients to pathogenic species, decreasing periodontal pocket depth which also fosters pathogen reservoirs, and decreasing pernicious habits such as cigarette smoking. These procedures have been utilized for years in successfully controlling periodontal disease in the majority of patients. When these procedures prove inadequate, it seems likely that carefully selected combinations of therapeutic procedures will diminish pathogen loads to levels that are tolerated by the host.

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Chapter 40

Implant Placement in the Esthetic Zone

Urs Belser, Jean-Pierre Bernard and Daniel Buser

Basic concepts

The clinical replacement of lost natural teeth by osseointegrated implants has represented one of the most significant advances in restorative dentistry. Numerous studies on various clinical indications have documented high implant survival and success rates with respect to specific application criteria (Ekfeldt et al. 1994, Laney et al. 1994, Andersson et al. 1995, Brånemark et al. 1995, Lewis 1995, Jemt et al. 1996, Lindqvist et al. 1996, Buser et al. 1997, Ellegaard et al. 1997a,b, Levine et al. 1997, Andersson et al. 1998, Bryant & Zarb 1998, Eckert & Wollan 1998, Ellen 1998, Lindh et al. 1998, Mericske-Stern 1998, ten Bruggenkate et al. 1998, Wyatt & Zarb 1998, Gunne et al. 1999, Lekholm et al. 1999, Van Steenberghe et al. 1999, Wismeijer et al. 1999, Behneke et al. 2000, Hosny et al. 2000, Hultin et al. 2000, Weber et al. 2000, Boioli et al. 2001, Gomez-Roman et al. 2001, Kiener et al. 2001, Mengel et al. 2001, Oetterli et al. 2001, Zitzmann et al. 2001, Bernard & Belser 2002, Buser et al. 2002, Haas et al. 2002, Leonhardt et al. 2002, Romeo et al. 2002). Several recently published studies have focused on treatment outcome of implant therapy in partially edentulous patients in general, and related to maxillary anterior implant restorations in particular. Belser (1999) reviewed selected publications which appear to have impact when it comes to the discussion of esthetic aspects which will be addressed in this chapter. In a prospective longitudinal study involving a total of 94 implants (50 in the anterior maxilla) restored with fixed partial dentures (FPDs), Zarb and Schmitt (1993) published an average success rate of 91.5% for an observation period up to 8 years. The respective data concerning the maxillary implants demonstrated a success rate of 94% (100% for the prosthesis success). It was concluded that implant therapy in anterior partial edentulism can replicate the data established in the literature for fully edentulous patients. The same authors (Schmitt & Zarb 1993) published an 8-year implant survival rate of 97.9% for single-tooth replacement in partially edentulous patients. These results were confirmed by Avivi-Arber and Zarb in 1996.

Andersson et al. (1998) published similarly favorable prospective 5-year data on single-tooth restorations, performed either in a specialist clinic or in general practices, while Eckert and Wollan (1998) presented a retrospective evaluation up to 11 years on a total of 1170 implants inserted in partially edentulous patients, and found no differences in survival rates with respect to the anatomical location of the implants. A meta-analysis concerning implants placed for the treatment of partial edentulism was carried out by Lindh et al. (1998). The 6–7-year survival rate for single implant crowns corresponded to 97.5%, while the survival rate of implant-supported fixed partial

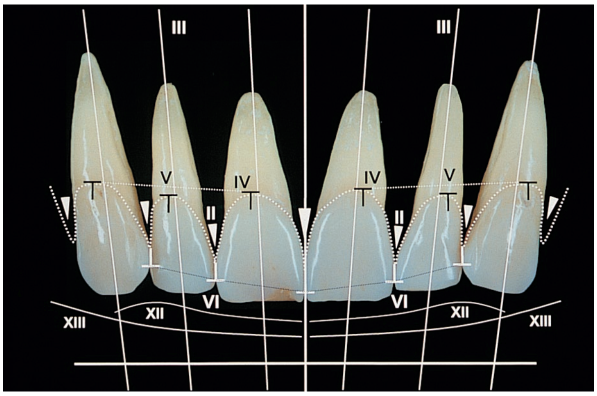

Fig. 40-1. The esthetic checklist, describing a number of respective fundamental objective criteria as they relate to the maxillary anterior segment (detailed description presented in Table 40.1). (Reprinted from Magne & Belser 2002, with permission.)

Table 40.1. Fundamental objective esthetic criteria (Magne & Belser 2002)

1.	Gingival health
2.	Interdental closure
3.	Tooth axis
4.	Zenith of the gingival contour
5.	Balance of the gingival levels
6.	Level of the interdental contact
7.	Relative tooth dimensions
8.	Basic features of tooth form
9.	Tooth characterization
10.	Surface texture
11.	Color
12.	Incisal edge configuration
13.	Lower lip line
14.	Smile symmetry
Subjective criteria (esthetic integration)	
Variations in tooth form	
Tooth arrangement and positioning	
Relative crown length	
Negative space	

dentures (FPDs) was 93.6%. The influence of implant design and surface texture was investigated by Norton (1998) by means of a radiographic follow-up of 33 implants loaded for up to 4 years. A most favorable maintenance of marginal bone around the conical collar was revealed, with a mean marginal bone loss of 0.32 mm mesially and 0.34 mm distally for the whole group.

Soft tissue stability around implant restorations and adjacent teeth is of paramount importance within the appearance zone (Bengazi et al. 1996, Chang et al. 1999, Ericsson et al. 2000, Grunder 2000, Choquet et al. 2001, Cooper et al. 2001, Mericske-Stern et al. 2001, Bernard & Belser 2002, Engquist et al. 2002, Haas et al. 2002, Krenmair et al. 2002). Scheller et al. (1998) specifically addressed this parameter in their 5-year prospective multicenter study on 99 implant-supported single-crown restorations. The authors reported overall cumulative success rates of 95.9% for implants and 91.1% for implant crowns. Soft tissue levels around implant restorations and adjacent teeth remained stable over the entire evaluation period. Wyatt and Zarb (1998) published a longitudinal study on 77 partially edentulous patients, involving a total of 230 implants and 97 fixed partial dentures, with an observation period of up to 12 years (mean 5.41 years) after loading. The average implant success rate was 94%, while the continuous stability of the prostheses (fixed partial dentures) corresponded to 97%. This study comprised 70 anterior and 31 posterior maxillary implants. No significant differences with respect to longevity could be detected either between anterior and posterior locations or between maxillary and mandibular implant restorations.

Along with osseointegration and restoration of function, the patient's subjective satisfaction is a key element of the success of implant therapy. Especially when the implant is located in the anterior part of the oral cavity, an essential part of the therapy aims at creating appropriate conditions, so that finally the implant prosthesis cannot be distinguished from the adjacent natural teeth. In this context, a variety of specific procedures have been developed, including novel bone augmentation protocols, connective tissue grafting and reconstruction of lost papillary tissue (Bahat et al. 1993, Salama & Salama 1993, Bahat & Daftary 1995, Salama et al. 1995, Price & Price 1999, Choquet et al. 2001).

Being part of a comprehensive textbook about clinical periodontology, this chapter will focus primarily on fixed implant restorations located in the esthetic zone.

General esthetic principles and related guidelines

The basic parameters related to dental and gingival esthetics in general and to the maxillary anterior segment in particular are well established in the dental literature (Goldstein 1976, Belser 1982, Schärer et al. 1982, Seibert & Lindhe 1989, Goodacre 1990, Rüfenacht 1990, Nathanson 1991, Magne et al. 1993a,b, Chiche & Pinault 1994, Magne et al. 1994, Kois 1996, Kokich 1996, Magne et al. 1996, Kokich & Spear 1997, Jensen et al. 1999) and have been recently summarized in the form of an updated integral check-list by Magne & Belser (2002). When it comes to the characteristics of the natural maxillary anterior dentition, a number of fundamental objective criteria, including gingival health and its normal morphology as well as dimension, form, specific structural composition, color, opalescence, translucency, transparency and surface texture of incisors and canines, have been identified (Ta-

Table 40.2. Patient expectations related to maxillary anterior edentulous segments

- Long-lasting esthetic and functional result with a high degree of predictability
- Minimal invasiveness (preservation of tooth structure)
- Maximum subjective comfort
- Minimum risk for complications associated with surgery and healing phase
- Avoidance of removable prostheses
- Optimum cost effectiveness

ble 40-1, Fig. 40-1). This list is completed by an addition of subjective criteria associated with esthetic integration, such as variations in the arrangement and positioning of front teeth, relative crown length and negative space.

Depending on the type of a given initial clinical situation requiring the replacement of one or several teeth, the patient's expectations may vary from the achievement of an almost perfect illusion, i.e. that the untrained eye cannot easily distinguish the restoration from the surrounding natural dentition, to the acceptance of various degrees of compromise from a purely esthetic point of view. The latter case is not infrequent after multiple anterior tooth loss in combination with significant hard and soft tissue deficiencies. In relation to maxillary anterior edentulous segments, patients expect in general a long-lasting functional and esthetic result with a high level of predictability (Table 40-2). To this primary objective are normally added a number of secondary goals which include parameters such as minimal invasiveness, low risk associated to eventual surgery, overall simplicity and cost effectiveness.

Prior to selecting an implant-based solution, one should comprehensively review all of the possible treatment modalities available (Table 40-3) which have the potential to solve a given clinical problem, and carefully ponder their respective advantages and eventual shortcomings, and only then take the decision together with the adequately informed patient. Currently, the restorative spectrum in the case of missing maxillary anterior teeth comprises conventional FPDs, resin-bonded bridges, removable partial dentures (RPDs), tooth-supported overdentures and implant-supported fixed or removable prostheses. Furthermore, one should not forget that occasionally orthodontic therapy, e.g. closure of limited edentulous spaces, can represent an effective and elegant alternative or adjunction to a prosthetic treatment. However, the availability of scientific evidence – when possible at its highest level – for the planned treatment modality, should be the key parameter for the final choice.

In this clinical decision-making process certain criteria, as for example the compromised structural, periodontal and/or endodontic status of potential natural abutments, or the extended dimension of the edentulous segment, are among the factors favoring an implant-borne restoration rather than a tooth-supported fixed prosthesis (Table 40-4).

Table 40.3. Therapeutic modalities for tooth replacement in the esthetic zone

- Conventional fixed partial dentures (FPDs), comprising cantilever units
- Resin-bonded ("adhesive") bridges
- Conventional removable partial dentures (RPDs)
- Tooth-supported overdentures
- Orthodontic therapy (closure of edentulous spaces)
- Implant-supported prostheses (fixed, retrievable or removable suprastructures)
- Combinations of the above

Table 40.4. Criteria favoring implant-borne restorations

- Normal wound healing capacity
- Intact neighboring teeth
- Unfavorable ("compromised") potential abutment teeth
- Extended edentulous segments
- Missing strategic abutment teeth
- Presence of diastemas

Esthetic considerations related to maxillary anterior implant restorations

In the context of the natural dentition, long clinical crowns, the irregular contour of the gingival margin, i.e. any abrupt change in vertical tissue height between neighboring teeth, and the loss of papillary tissue often have an adverse influence on dental-facial esthetics (Seibert & Lindhe 1989). Furthermore, the same authors have underlined that in the case of a *high scalloped gingival morphotype* (in contrast to a rather *low scalloped gingival morphotype*) there is mostly an unpredictable relationship between the underlying bone and the gingival contour, often leading to so called "black hole cases" and presenting a high risk for losing soft tissue (e.g. gingival or mucosal recession at the labial aspect of teeth or implants), particularly in relation to restorative procedures, as for example insertion of retraction cords and impression taking.

Another esthetically relevant concern lies in the fact that under normal conditions a maxillary front tooth extraction leads on average to approximately 2 mm loss in vertical tissue height. The mean length of the clinical crown of a maxillary central incisor is 10.2 mm, the one of a lateral incisor 8.2 mm and that of a canine

Table 40.5. Evaluation of anterior tooth-bound edentulous sites prior to implant therapy

- Mesio-distal dimension of the edentulous segment, including its comparison with existing contralateral control teeth
- Three-dimensional analysis of the edentulous segment regarding soft tissue configuration and underlying alveolar bone crest (ref. "bone-mapping")
- Neighboring teeth:
  - volume (relative tooth dimensions), basic features of tooth form and three-dimensional position and orientation of the clinical crowns
  - structural integrity and condition
  - surrounding gingival tissues (course/scalloping of the gingival line)
  - periodontal and endodontic status/conditions
  - crown-to-root ratio
  - length of roots and respective inclinations in the frontal plane
  - eventual presence of diastemata
- Interarch relationships:
  - vertical dimension of occlusion
  - anterior guidance
  - interocclusal space
- Esthetic parameters:
  - height of upper smile line ("high lip" versus "low lip")
  - lower lip line
  - course of the gingival-mucosa line
  - orientation of the occlusal plane
  - dental versus facial symmetry
  - lip support

Table 40.6. Optimal three-dimensional implant positioning ("restoration-driven implant placement") in anterior maxillary sites. *Implant = apical extension of the ideal future restoration*

- Correct vertical position of implant shoulder (sink depth) using the cemento-enamel junction of adjacent teeth as reference:
  - no visible metal
  - gradually developed, flat axial profile
- Correct oro-facial position of point of emergence for future suprastructure from the mucosa:
  - similar to adjacent teeth
  - flat emergence profile
- Implant axis compatible with available prosthetic treatment options (ideally: implant axis identical with "prosthetic axis")

10.4 mm. Consequently, any kind of maxillary anterior restoration should aim at staying within reasonable limits of these average morphological dimensions, if a harmonious and esthetically pleasing result is to be achieved. Ultimately, an anterior implant restoration should correspond closely to an ovate pontic of a conventional FPD with respect to the relevant soft tissue parameters (Kois 1996).

Numerous publications, mostly in the form of textbooks, book chapters, reviews, case reports and descriptions of clinical and laboratory procedures and techniques, have addressed various aspects specifically related to esthetics and osseointegration (Parel & Sullivan 1989, Gelb & Lazzara 1993, Jaggers et al. 1993, Vlassis et al. 1993, Bichacho & Landsberg 1994, Ghalili 1994, Landsberg & Bichacho 1994, Neale & Chee 1994, Studer et al. 1994, Carrick 1995, Corrente et al. 1995, De Lange 1995, Garber 1995, Garber & Belser 1995, Jansen & Weisgold 1995, Khayat et al. 1995, Touati 1995, Brugnolo et al. 1996, Davidoff 1996, Grunder et al. 1996, Hess et al. 1996, Marchack 1996, Mecall & Rosenfeld 1996, Bain & Weisgold 1997, Bichacho & Landsberg 1997, Chee et al. 1997, Garg et al. 1997, Spear et al. 1997, Salinas & Sadan 1998, Jemt 1999, Price & Price 1999, Belser et al. 2000, Tarnow et al. 2000).

In view of maxillary anterior implant restorations, the systematic and comprehensive evaluation of edentulous sites, including the surrounding natural dentition, is of paramount importance (Table 40-5). Key parameters comprise the mesio-distal dimension of the edentulous segment, the three-dimensional analysis of the underlying alveolar bone crest, the status of the neighboring teeth, and interarch relationships as well as specific esthetic parameters.

As one should consider the implant as the apical extension of the ideal future restoration and not the opposite, a respective optimal three-dimensional ("restoration-driven") implant position is mandatory (Table 40-6). Consequently, parameters addressing vertical (sink-depth) and oro-facial implant shoulder location, have been defined, as well as guidelines related to the long axis of the implant, as the latter has a significant impact on the subsequent technical procedures during suprastructure conception and fabrication.

Recently, the ITI Consensus Conference has approved the distinctly submucosal implant shoulder location in the maxillary anterior segment in order to respond to natural esthetic demands (Buser & von Arx 2000). As the current implant design – in contrast to the scalloped cemento-enamel junction – features a straight horizontal, "rotation-symmetrical" restorative interface, interproximal implant crown margins are often located several millimeters submucosally, and thus difficult to reach by the patient's routine oral hygiene efforts (Belser et al. 1998). Mainly for this reason a screw-retained implant suprastructure (Sutter et al. 1993, Hebel & Gajjar 1997, Keller et al. 1998) is preferred to a cemented one, as it benefits from the surface quality and marginal fidelity of prefabricated, machined components, and avoids potential problems associated with cement excess that may be difficult to reach and thoroughly eliminate.

Anterior single-tooth replacement

Favorable 5-year multicenter results for 71 single-tooth replacements in the anterior maxilla (implant success rate of 96.6%) were reported by Henry et al. (1996); however, this group mentioned an associated 10% esthetic failure rate. In a retrospective study on 236 patients treated with single-tooth implant restorations in the anterior maxilla (Walther et al. 1996), a Kaplan-Meier survival rate of 89% was found for an observation period of 10 years. The failure rate for lateral incisor replacement was lower than the one for central incisors. Furthermore, 5% of the related prosthetic suprastructures had to be replaced during the 10 years of observation. Kemppainen et al. (1997) prospectively documented 102 implants (ASTRA/ITI) for single-tooth replacement in the anterior maxilla of 82 patients and found survival rates of 97.8% and 100%, respectively, after 1 year. Still related to single-tooth maxillary anterior implants, a prospective study on 15 patients revealed a 100% implant survival rate after two years of function (Palmer et al. 1997). At crown insertion (6 months after implant placement) the mean bone level was located 0.47 mm apically to the top of the implants. No significant additional changes in crestal bone level occurred during the remainder of the study.

Today, it is generally accepted that the final implant shoulder sink depth for esthetic fixed single-tooth restorations can be determined primarily by the location of the cemento-enamel junction (CEJ) of the neighboring teeth and by the level of the free gingival margin at the vestibular aspect of these same teeth. This means that the implant shoulder is positioned 1-2 mm more apically to the labial CEJ of the adjacent teeth (Belser et al. 1998, 2000). However, the noticeable esthetic progress made in this kind of implant restoration is the result of recent developments in the absence of extensive long-term documentation. Because the exclusive use of clinical signs for establishing peri-implant health or disease may not be sufficient, the evaluation of additional objective parameters is needed. A number of diagnostic tests have been utilized by clinicians to supplement clinical signs with objective methods. These tests include microbiologic monitoring, proteolytic bacterial enzyme markers, markers of tissue destruction, and finally, markers of tissue repair and regeneration. In this context peri-implant crevicular fluid (PICF) analysis has become the focus of intense investigation. It has been observed that the volume of crevicular fluid did not differ between implant sites and natural teeth and that the features of inflammation seem to be the same around teeth and implants. In addition, the histologic arrangement of peri-implant soft tissues resembles basically that observed around natural teeth, although featuring also some aspects of scar tissue (Abrahamson et al. 1996, Berglundh & Lindhe 1996, Abrahamson et al. 1997, Lindhe & Berglundh 1998).

Table 40.7 Basic considerations related to anterior single-tooth replacement

Achievements	Predictable and reproducible results regarding both esthetic parameters and longevity in sites without significant vertical tissue deficienies Well defined and well established surgical protocols: • *restoration-driven* implant placement Adequate and versatile restorative protocols and prosthetic components: • occclusal/transverse screw-retention • angulated abutments • high-strength ceramic components
Sites with buccal bone deficiencies	Lateral bone augmentation using *autografts* and *barrier membranes*: • technique offers efficacy and predictability • *simultaneous* or *staged approach* depending on defect extension and defect morphology Lateral bone augmentation by means of *alveolar bone crest splitting* and/or various *osteotome techniques*: • limited clinical long-term documentation
Limitations	Combined vertical bone and soft tissue deficienies: • following removal of ankylosed teeth or failing implants • advanced loss of periodontal tissues, including gingival recession, on neighboring teeth • limited scientific documentation related to *vertical bone augmentation* and *distraction osteogenesis*

Giannopoulou et al. (2002) investigated the effect of intracrevicular restoration margins on peri-implant health of 61 maxillary anterior implants – mainly single-tooth replacements – in 45 patients up to 9 years. Results revealed that the only statistically significant differences between baseline and follow-up examination concerned pocket probing depth (PPD) and the distance between the implant shoulder and the mucosal margin (DIM measurements), which slightly increased over time. The remainder of the clinical measurements and almost all of the microbiologic and biochemical parameters analysed did not significantly change. Probably the most critical parameter from a purely esthetic point of view is the DIM value, particularly on the labial aspect of the maxillary anterior implants investigated in this study. A mean value of –1.5 ± 1.1 mm was found at baseline examination, and a slight increase (–1.7 ± 1.1 mm) at the follow-up. This indicates that the risk for exposure of the implant-to-crown interface or margin can be considered low. These findings corroborate recently pub-

Fig. 40-2. 10-year follow-up of a 28-year-old female patient. Both congenitally missing lateral incisors were replaced by implants, restored with screw-retained porcelain-fused-to-metal crowns.

Fig. 40-3. The frontal view in centric occlusal position documents the harmonious integration of the two implant restorations after 10 years of clinical service.

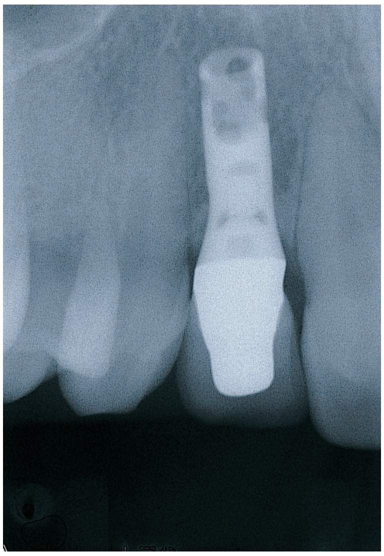

Fig. 40-4. 10-year postoperative radiograph of the maxillary right lateral single-tooth implant restoration.

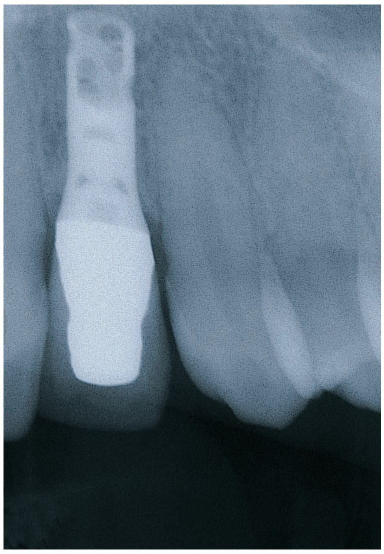

Fig. 40-5. 10-year postoperative radiograph of the maxillary left lateral single-tooth implant restoration.

Fig. 40-6. During unforced smiling an adequate balance between implant-crowns and natural dentition can be noticed.

lished data addressing similar parameters (Grunder 2000). The consistently negative Periotest scores confirmed the stability and osseointegrated status of the implants examined. Furthermore, no associations were observed between the above results and the number of years that the implants had been in function. Based on these clinical, microbiologic and biochemical data, and on an observation period of 4-9

Fig. 40-7. Schematic representation of an intact maxillary right anterior segment. The alveolar bone follows the scalloped course of the cemento-enamel junction for a distance of approximately 2 mm (white dotted line), whereas, accordingly, the gingival tissue occupies completely the interdental area.

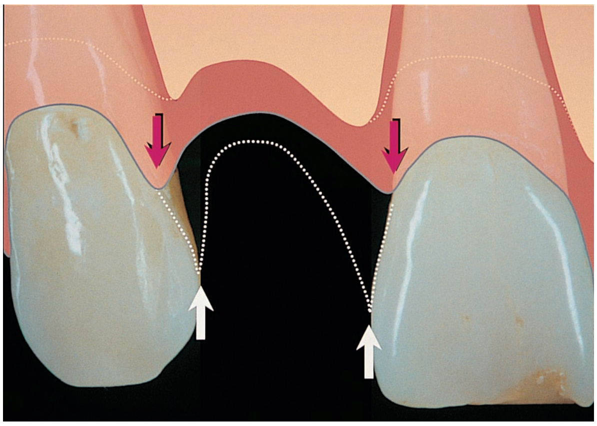

Fig. 40-8. Schematic representation of the same segment after loss of the lateral incisor. While the interproximal bone height has basically been maintained, the corresponding gingival tissue is flattened due to a lack of support originally provided by the now missing tooth.

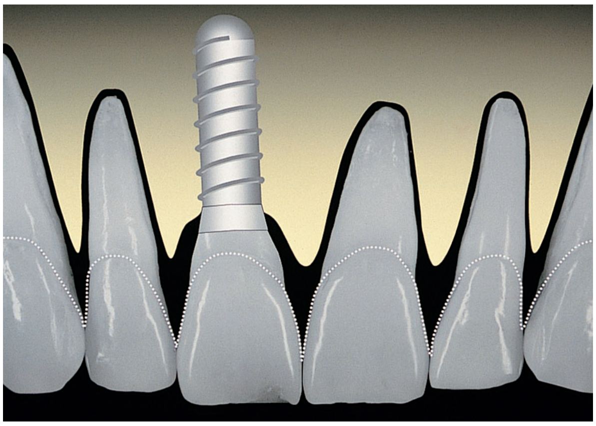

Fig. 40-9. The treatment objective in the case of an anterior single-tooth replacement is an implant restoration with a gradually developed, flat emergence profile from the implant shoulder to the peri-implant mucosal surface. Ideally, the clinical crown of the implant restoration should aim at replicating the clinical crown of the corresponding contralateral tooth.

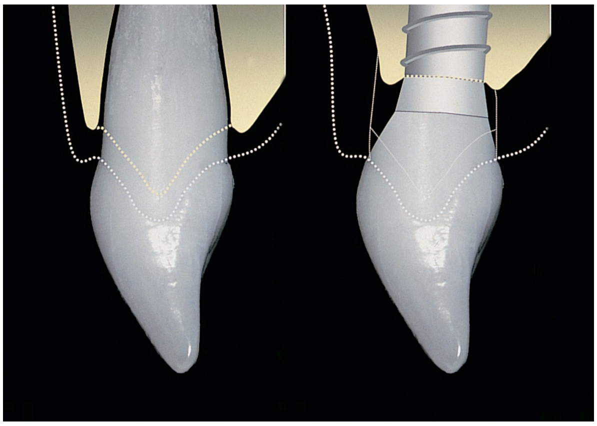

Fig. 40-10. Schematic comparison in the sagital plane between a natural maxillary incisor and a respective implant borne single-tooth restoration. The decrease of alveolar bone height on the labial and palatal aspect following tooth loss leads to a more palatal implant position when compared to the original root position, which in turn influences the axial profile of the restoration.

years (mean: 6.8 years), it was concluded that in patients with appropriate oral hygiene, implant-supported maxillary anterior crowns with distinctly intracrevicular margins did not predispose to unfavorable peri-implant host and microbial responses. In particular, overall healthy and stable peri-implant tissue conditions – a paramount criterion when it comes to esthetic implant crowns – were consistently encountered and maintained longitudinally. One of the patients participating in this study and who recently passed the 10-year clinical and radiographic follow-up control, is presented in Figs. 40-2 to 40-6. An adequate esthetic integration of the two single-tooth restorations, replacing the congenitally missing lateral incisors, could be achieved and maintained over time.

In a simplistic way, the morphologic and esthetic consequences in the frontal plane of the loss of a single maxillary incisor, when compared to the original intact situation, can be summarized as follows: maintenance of the tooth-sided interproximal bone height at the neighboring teeth, and vertical loss (“flattening”) of the corresponding gingival tissue due to a lack of support originally provided by the now missing tooth (Figs. 40-7 and 40-8). In case of an anterior single-tooth replacement, the related implant restoration should aim at replicating the clinical crown of the contralateral control tooth from the line of soft tissue emergence to the incisal border. Additionally, a gradually developed, flat emergence profile from the implant shoulder to the peri-implant mucosal margin is mandatory (Figs. 40-9 and 40-10).

The basic considerations related to maxillary ante-

Fig. 40-11. Preoperative close-up view of the upper right anterior region of a 22-year-old female patient with a missing right central incisor. The scalloped course of the gingiva is maintained, featuring interproximal soft tissue at the level of the cemento-enamel junction.

Fig. 40-13. The oblique close-up view confirms optimal conditions for the insertion of an implant, namely interproximal soft tissue height and no significant loss of the buccal bone plate.

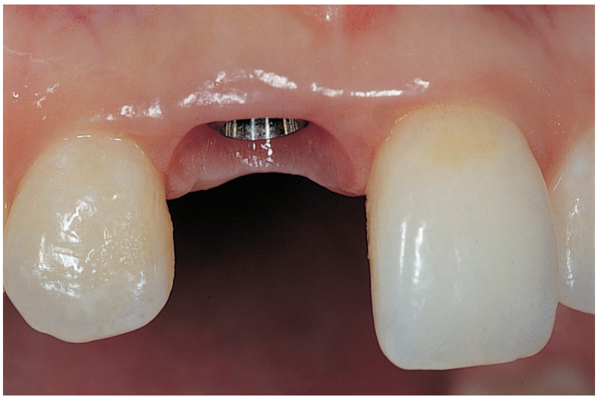

Fig. 40-14. Clinical view of the maxillary anterior implant site 8 weeks after insertion of a solid screw implant according to a one-stage transmucosal surgical protocol. A harmonious peri-implant soft tissue profile has been established by means of a titanium healing cap featuring a respective emergence profile and thus offering adequate interproximal soft tissue support.

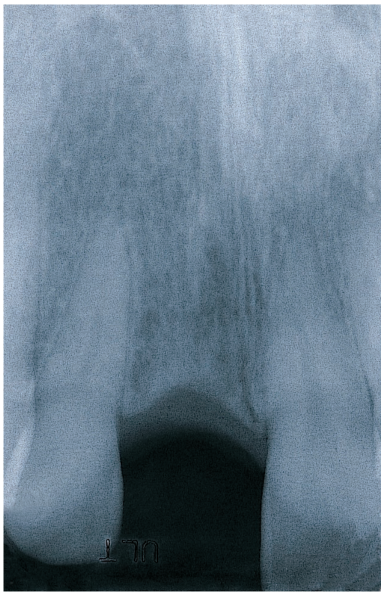

Fig. 40-12. The corresponding radiograph displays favorable bony conditions in view of implant therapy. Note in particular the interproximal bone height, following the cemento-enamel junction for a distance of less than 2 mm.

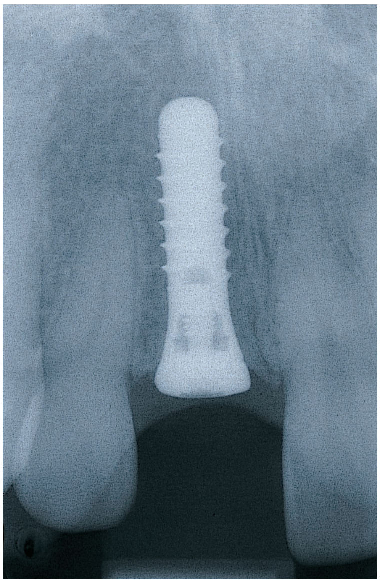

Fig. 40-15. The corresponding radiograph displays a continuous close contact between bone and implant and confirms that the vertical interproximal bone level has been maintained.

rior single-tooth replacement, including the respective general achievements and limitations, and addressing edentulous segments with different types of labial bone deficiencies, are presented in Table 40-7.

Sites without significant tissue deficiencies

An increasing body of evidence indicates that the most determinant parameter for achieving an esthetic single-tooth restoration is the interproximal bone height at the level of the teeth confining the edentulous gap. The related bone should be within a physiologic dis-

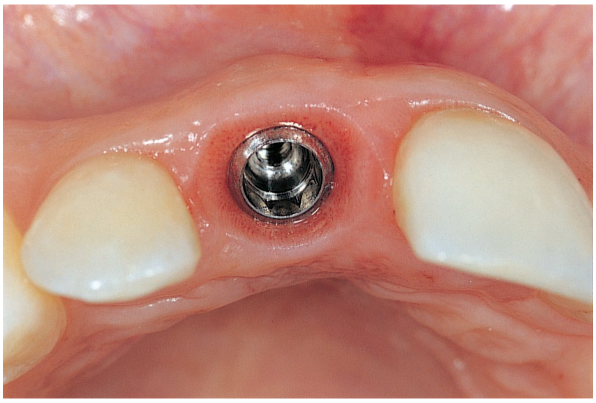

Fig. 40-16. The occlusal view reveals an implant position in the orofacial plane that is in accordance with the adjacent natural roots and thus permits development of a flat emergence profile.

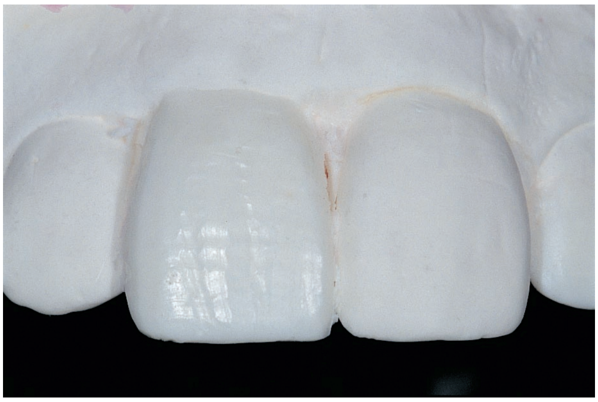

Fig. 40-17. On a stone model derived from the clinical situation, the laboratory technician defines the treatment objective in wax. At this stage priority is given to esthetic principles and maintenance of symmetry rather than to the actual position of the underlying implant.

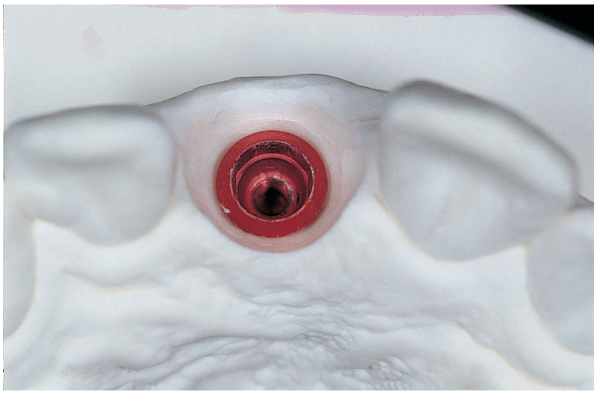

Fig. 40-18. The configuration of the peri-implant soft tissue is subsequently adapted on the stone model according to the diagnostic wax-up. Ultimately, it will be the restoration itself that completes the last phase of soft tissue conditioning by subtle respective physical displacement.

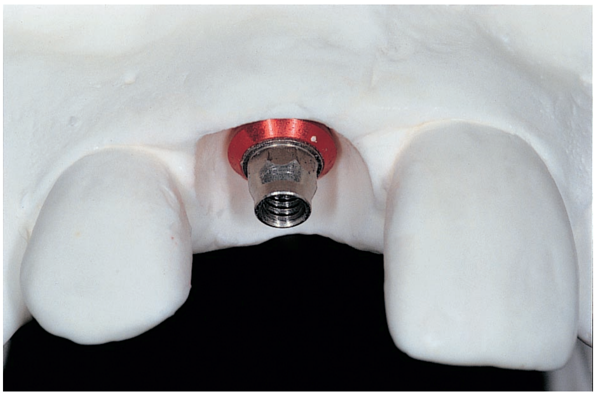

Fig. 40-19. An appropriate secondary titanium component (abutment) is selected as support for the planned screw-retained implant restoration.

tance, i.e. approximately 2 mm, of the cemento-enamel junction (CEJ) and thus be providing the essential support for the overlaying soft tissue compartments. Consequently, preoperative diagnosis will include interproximal radiographic bone height assessment and periodontal probing of the soft tissue attachment level.

If the comprehensive presurgical analysis of a given maxillary anterior single-tooth gap has confirmed on the one hand a favorable vertical level of both soft tissue and underlying alveolar bone at the interproximal aspect of the two adjacent teeth (Figs. 40-11, 40-12, 40-13), and no major vestibular bone deficiencies on the other hand, the site can be considered compatible with a straightforward implant surgical protocol. In order to ensure the best probability of a successful and long-lasting esthetic treatment outcome, the actual implant placement has to be carried out meticulously according to the surgical guidelines defined in Table 40-6. These guidelines include key-parameters such as low-trauma surgical principles in general and precise three-dimensional ("restoration-driven") implant positioning in particular. In the case of standard single-tooth sites, most surgeons do not advocate the use of a surgical guide or stent, as the adjacent teeth and associated anatomical structures normally offer sufficient morphologic landmarks to safely reach the therapeutic objective. As far as the detailed surgical protocol is concerned, readers are referred to Chapter 37, "The surgical site". Buser and von Arx (2000) have published the surgical step-by-step procedure related to maxillary anterior single-tooth implants, and insisted on a slightly palatal incision technique to preserve a maximum of keratinized mucosa on the labial aspect of the future implant restoration. Another crucial parameter is the maintenance of at least 1 mm of bone plate on the vestibular aspect of the implant in order to minimize the risk for peri-implant soft tissue recessions, a factor parameter when it comes to esthetics. Under such conditions one may consistently

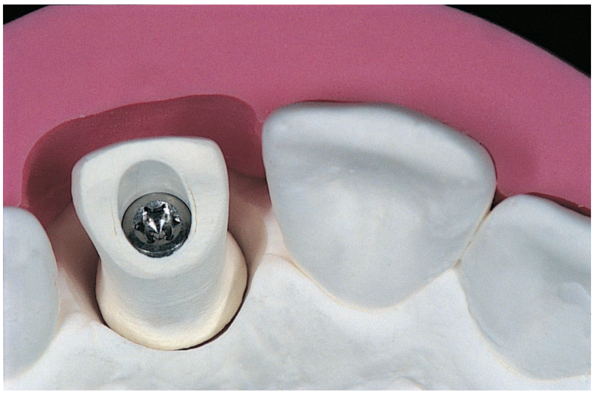

Fig. 40-20. Using a silicon template as guide, a prefabricated ceramic blank is inserted and subsequently reduced to provide adequate space for the external layers of cosmetic porcelain.

Fig. 40-21. Labial view of the completed ceramo-ceramic restoration on the master cast.

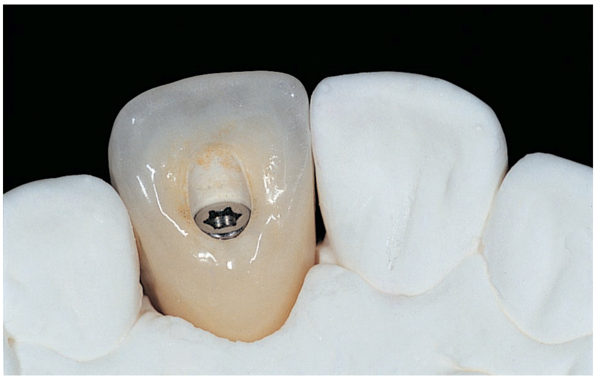

Fig. 40-22. In particular, the completed screw-retained all-ceramic restoration displays a high degree of translucency on its incisal third.

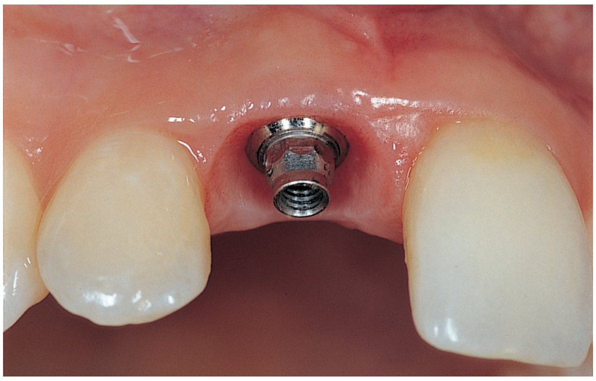

Fig. 40-23. A titanium abutment will serve as infrastructure for the transocclusally screw-retained high-strength all-ceramic restoration.

achieve postsurgical treatment outcomes featuring unaltered vertical soft tissue and underlying bone levels at the interproximal aspect of the adjacent natural teeth (Figs. 40-14, 40-15, 40-16).

Once osseointegration is confirmed radiologically and clinically, the clinical situation is transferred to the master model by means of an impression, normally assisted by auxiliary components in the form of prefabricated impression copings. On the master model, which in turn contains a replica (analogue) of the implant, the laboratory technician defines the final configuration of the single-tooth implant restoration by means of a diagnostic wax-up (Fig. 40-17). Under normal circumstances, i.e. when the natural contralateral control tooth corresponds mostly to the esthetic and functional requirements of an appropriate "target model", the technician basically copies the clinical crown of this control tooth in wax, regardless of the actual underlying implant position. At this stage a close-to-ideal restoration is planned, while its connection to the underlying implant will be addressed later. This approach comprises the minute shaping of the peri-implant soft tissue configuration (on the master model in the form of stone), in view of an identical emergence from the labial and interproximal soft tissue margin, like the one observed on the natural tooth site (Fig. 40-18). Only after having completed this preparatory step, will the ceramist select the most adequate secondary component (i.e. abutment), depending on the three following cardinal criteria (Fig. 40-19):

1. implant shoulder depth in relation to the labial mucosal margin
2. oro-facial implant shoulder position with respect to the future line of emergence of the suprastructure
3. long axis of the implant.

In most instances, preference will be given to a screw-retained implant suprastructure, unless a combination of mesiostructure and cemented restoration is chosen. Screw-retention is primarily preferred due to a marked submucosally located implant shoulder, in particular at the interproximal aspect, which may render the removal of excess cement difficult, and which is mostly not within reach of the patient's routine oral hygiene measures. In addition, screw-retained suprastructures benefit from the close-to-perfect surface quality characteristics and the marginal precision of machined, prefabricated components. Nowadays several of the leading implant systems also offer high-strength ceramic tertiary components which may

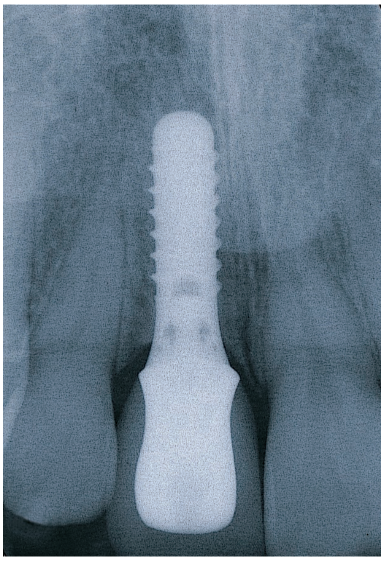

Fig. 40-24. The one-year postoperative radiograph confirms favorable conditions at the bone-to-implant interface. Note a high degree of radio-opacity of the all-ceramic substrate, permitting the evaluation of the fidelity of the marginal adaptation.

Fig. 40-25. An acceptable overall integration of the metal-free implant-borne restoration on site 11 can be noted.

positively contribute to the esthetic treatment outcome, particularly in the case of a rather thin labial peri-implant mucosa (Fig. 40-20). Another parameter which is of primary importance when it comes to esthetic considerations relates to maxillary anterior implant restorations and is associated with the suprastructure design itself at the interproximal aspect. In order to provide optimal conditions for the related soft tissue, a long interdental contact line is established, located slightly more towards the palatal aspect of the restoration (Figs. 40-21, 40-22). This design offers optimal support for the interproximal soft tissue and thereby reduces the potential hazard of a so-called "black triangle" (Figs. 40-23, 40-24, 40-25). In this context some studies have indicated that there exists a predictable relationship between the location of the interdental contact point and the associated alveolar bone crest when it comes to presence or absence of interdental papillae fully occupying the interdental space of maxillary anterior teeth (Tarnow et al. 1992, Tarnow & Eskow 1995).

Sites with localized horizontal deficiencies

In a case of a localized (minor) horizontal deficiency, i.e. a confined vestibular alveolar bone crest defect at the vestibular aspect of a maxillary anterior single-tooth gap, one prefers to place the implant and simultaneously undertake a lateral bone augmentation procedure, on condition that several well-defined prerequisites are fulfilled. These include an implant placement in accordance with the guidelines presented in Table 40-6 ("restoration-driven" implant placement), the achievement of an adequate primary stability and a resulting cervical dehiscence-type bony defect which is compatible with a predictable bone augmentation procedure. More specifically, the dehiscence should have the form of a two-wall bony defect, whereas the labial aspect of the inserted implant should not exceed the surrounding bone contours. Under such conditions, the treatment of choice consists of the application of autogenous bone chips, harvested at the site of the implant surgical intervention. The bone chips which can be combined with one of the numerous available bone substitutes (e.g. BioOss®) if necessary, will provide adequate support for a subsequently adapted barrier membrane. The described grafting material is finally complemented with "bone slurry", constantly collected during the entire procedure. Subsequently, a bioabsorbable membrane is applied prior to repositioning and tension-free suturing of the mucoperiosteal flap. This implicates a rather extended flap design, comprising vertical releasing incisions.

In conclusion, a simultaneous lateral augmentation procedure is recommended if the three following conditions are present:

1. ideal three-dimensional ("restoration-driven") implant position
2. adequate primary implant stability
3. localized two-wall bony defect, exceeding the labial contour of the implant and hereby assuring an appropriate bone regeneration potential and providing the necessary stability to the applied bone graft.

Under these specific conditions, the implant can be functionally loaded after 2-4 months, depending on size and configuration of the respective bone defect.

It is not infrequent in the anterior maxilla, due to its specific alveolar bone crest morphology, that "restoration-driven" rather than "bone-driven" implant positioning leads to a fenestration-type defect in the apical area of the implant. If adequate primary implant stability can be obtained, a similar simultaneous lateral bone augmentation procedure, as described for localized dehiscence-type defects, appears feasible. Under

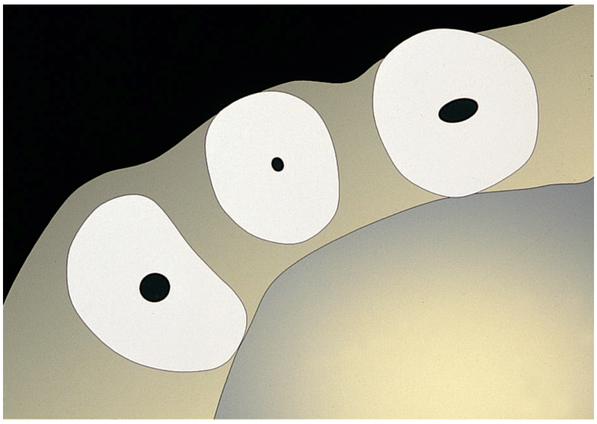

Fig. 40-26. Schematic representation of a horizontal section at the cemento-enamel junction level of the maxillary right anterior segment.

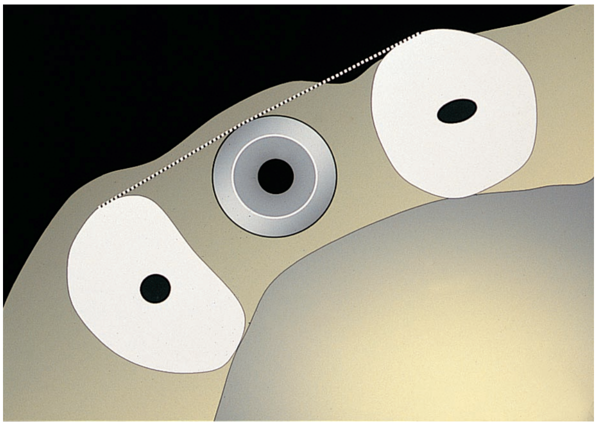

Fig. 40-27. "Restoration-driven" implant placement in the horizontal plane at the site of the maxillary right lateral incisor. In order to maintain at least 1 mm of alveolar bone also on the labial aspect, the implant has to be inserted approximately 1-2 mm more to the palate when compared to the adjacent roots.

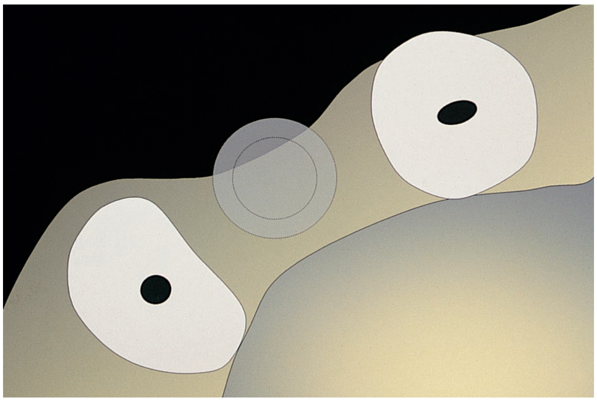

Fig. 40-28. In case of an extended lateral bone deficiency, where an adequately placed implant would largely exceed the vestibular border of the alveolar bone crest, a lateral bone augmentation procedure (staged approach) is indicated

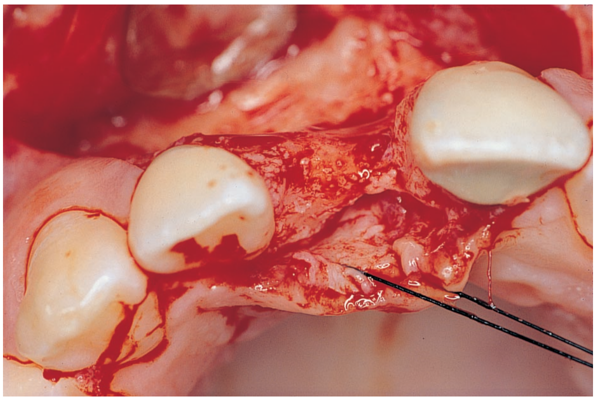

Fig. 40-29. After elevation of a mucoperiosteal flap a severe extended resorption – namely on the vestibular aspect – of the edentulous alveolar ridge becomes apparent. Such a morphology is hardly compatible with "restoration-driven" implant placement.

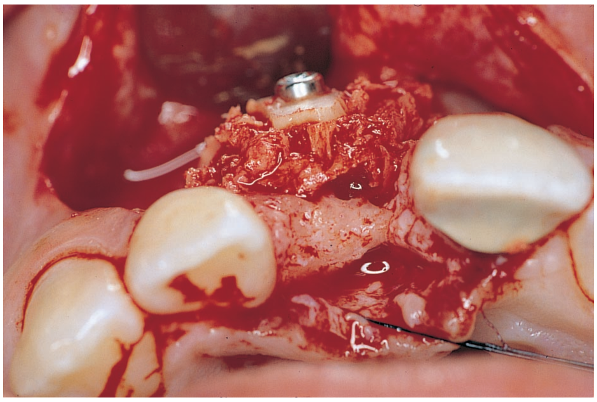

Fig. 40-30. An autogenous bone graft, harvested from the patient's chin region, has been secured with a fixation screw and its periphery filled in with additional bone chips prior to membrane placement.

Fig. 40-31. Six months after the lateral ridge augmentation procedure the clinical occlusal view documents that uneventful healing has occurred and that the orofacial ridge profile has been improved.

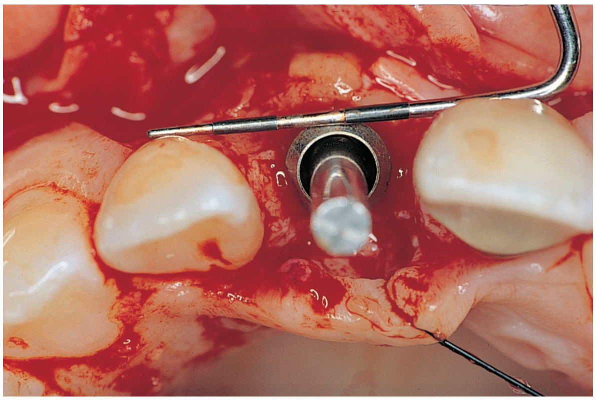

Fig. 40-32. During implant surgery one can note that all key parameters characterizing an optimal implant position (shoulder sink depth, orofacial point of emergence, implant axis) could be satisfied.

Fig. 40-33. After three months of healing the labial view documents a slight excess of keratinised peri-implant mucosa in a coronal direction, which is a prerequisite for the development of the final esthetic soft tissue contours. The first step of the subsequent procedure will consist of the insertion of a longer titanium healing cap, following a minor mucosaplasty.

Fig. 40-34. Two weeks after mucosaplasty and exchange of healing caps the initiation of a harmoniously scalloped labial soft tissue course is apparent. Furthermore, the access from the surface to the underlying implant shoulder has been established.

Fig. 40-35. The two ceramo-metal crown restorations – one tooth borne (site 21) and one implant borne (site 11) – display little difference in appearance since symmetry has been respected from the line of mucosal emergence to the incisal edge.

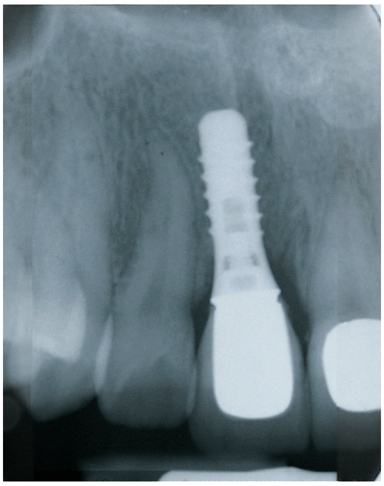

Fig. 40-36. The 1-year follow-up radiograph confirms the stability of the osseointegrated 10-mm titanium screw implant.

Fig. 40-37. An esthetically pleasing overall integration of the two maxillary anterior restorations is underlined by a close-up view of the patient’s unforced smile.

such circumstances the healing time prior to functional implant loading remains the same as advocated for standard implant protocols (i.e. two months for SLA-coated screw-type titanium implants).

Sites with extended horizontal deficiencies

In a case of more extended horizontal alveolar bone crest deficiencies, a simultaneous implant placement and lateral bone augmentation procedure becomes technically more difficult and less predictable, as the ultimate goal remains an optimal "restoration-driven" implant positioning (Figs. 40-26, 40-27). The described extended horizontal bone deficiency may often, on the one hand, not permit an acceptable primary implant stability to be achieved, and on the other hand may lead to a vestibular bone dehiscence that does not have a distinct two-wall morphology. Furthermore, the labial implant contour would be more prominent than the respective surrounding bone (Fig. 40-28). Under these specific circumstances the principal prerequisites for a simultaneous approach are clearly not present, thus leading to the recommendation to proceed according to a staged surgical protocol, which will address the lateral bone augmentation first and the actual implant placement in a second stage.

This may represent a major problem for some patients, as two surgical interventions, normally separated by approximately six months, are necessary, leading to a total treatment time of eight months or more. It is therefore indispensable to thoroughly inform the patient about both the reasons for the staged approach associated to implant therapy, and the possible conventional prosthodontic alternatives (e.g. a traditional tooth-borne FPD, eventually in combination with a connective tissue grafting procedure to optimize the deficient edentulous ridge in view of an optimal and esthetic pontic). The patient will then be in a position to give his or her informed consent to either of the two therapeutic modalities, according to individual preference.

In a case of implant therapy, the first step consists of the elevation of a rather extended mucoperiosteal flap featuring vertical releasing incisions, as the added site volume (due to the block graft and barrier membrane) will require subsequent splitting of the periosteum prior to flap repositioning and suturing (Fig. 40-29). Numerous studies reporting results of various bone augmentation techniques and related materials have been published (Hürzeler et al. 1994, Buser et al. 1996, Ellegaard et al. 1997b, Chiapasco et al. 1999, 2001, von Arx et al. 2001a,b, Zitzmann et al. 2001). To date, autogenous bone block grafts, mostly harvested from the chin or the retromolar area, in combination with e-PTFE barrier membranes, still have the best clinical long-term documentation (Buser et al. 2002). These authors presented prospectively documented 5-year data of 40 consecutively treated patients, according to a staged protocol. On all laterally augmented sites implants could be subsequently inserted. It was concluded that the clinical results of implants placed in regenerated bone were comparable to those reported for implants in non-regenerated bone. A clinical example of the described approach is presented in Figs. 40-29 to 40-37.

Sites with major vertical tissue loss

When it comes to maxillary anterior single-tooth gaps with significant vertical tissue loss, the predictable achievement of an esthetically pleasing treatment outcome, ideally providing a so-called perfect illusion with respect to its integration in the surrounding natural dentition, gets difficult. As pointed out earlier in this chapter, there exists a close relationship between the interproximal bone height and the associated soft tissue level (Figs. 40-7, 40-8). If the coronal border of the alveolar bone is no longer within the physiological distance of approximately 2 mm from the interproximal CEJ of the teeth confining the edentulous space, there is an increased risk for an altered respective soft tissue course (due to a lack of underlying bony support) and its adverse impact on the appearance. Such situations can be encountered following the removal of ankylosed teeth or failing implants, or in case of advanced periodontal tissue loss – including gingival recession – on neighboring teeth. Under these specific circumstances, the final decision whether or not to use implants will ultimately depend on the one hand on the careful and comprehensive evaluation of all of the therapeutic modalities available for anterior tooth replacement (Table 40-3), and on the other hand the patient's individual smile line and expectations. This process includes an objective analysis of the advantages and eventual shortcomings associated with each modality.

To illustrate these clinically relevant aspects, the initial situation and the subsequent implant treatment of a 35-year-old female patient consulting with an ankylosed maxillary deciduous left canine, are presented in Figs. 40-38 to 40-46. The preoperative analysis had led to the conclusion that the fabrication of a conventional tooth-borne three-unit FPD, using the intact lateral incisor and first premolar as abutments and featuring a canine pontic, was not opportune from several points of view. Among these should be particularly mentioned aspects related to the questionable mechanical resistance of the resulting conventional prosthesis, specific occlusal considerations (e.g. canine guidance in a pontic area), lack of esthetic superiority when compared to a virtual implant-borne fixed restoration, and last but not least the conflict with the general principle of minimal invasiveness (maximum preservation of intact tooth structure).

Once the decision was made, both the implant surgical and the restorative strategies focused on improving or at least optimally exploiting the pre-existing

Fig. 40-38. Preoperative view of a 35-year-old female patient consulting with a persisting primary tooth in the position of the maxillary left canine. Note the irregular course of the adjacent gingiva in general and the loss in vertical tissue height in particular.

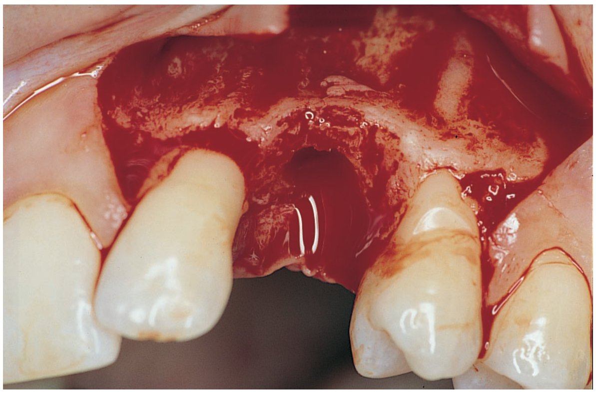

Fig. 40-39. One month after removal of the deciduous canine, the root of which was severely resorbed, a mucoperiosteal flap with vertical releasing incisions is elevated and the preparation of a calibrated implant bed performed. One can note an increased distance between the cemento-enamel junction and the coronal border of the alveolar bone and the left lateral incisor.

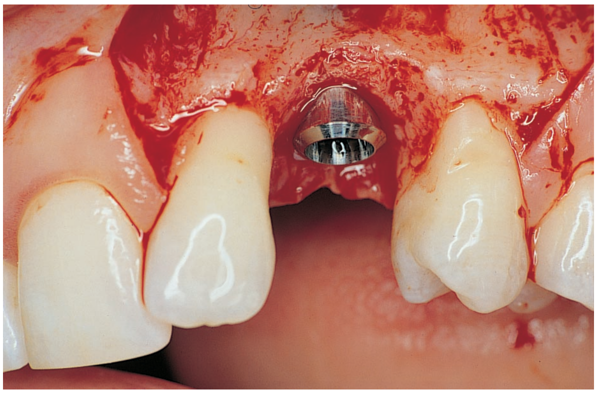

Fig. 40-40. Buccal view after insertion of the implant.

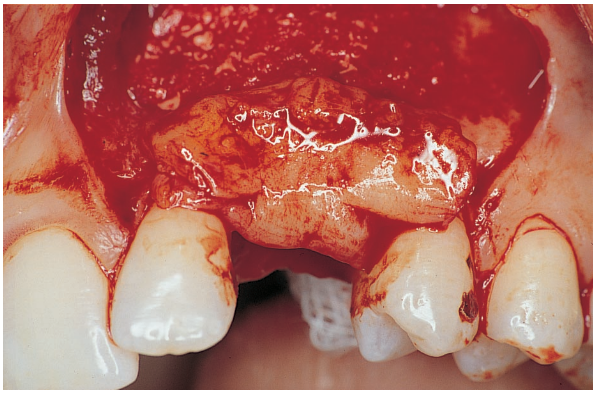

Fig. 40-41. In a case of rather thin mucosa, the utilization of a connective tissue graft, harvested from the palate, may be indicated to create a sufficient thickness of soft tissue at the implant site.

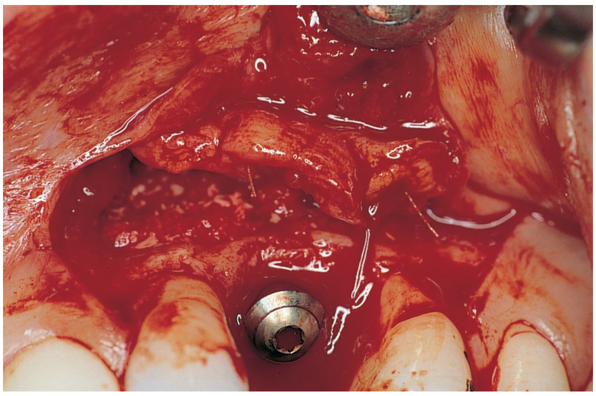

Fig. 40-42. Prior to flap closure, the connective tissue graft is secured to the flap with bioabsorbable sutures.

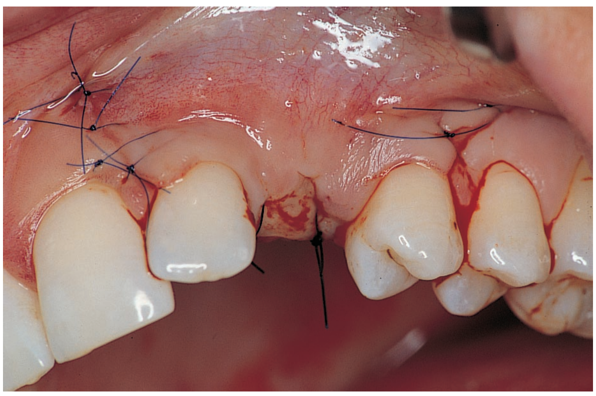

Fig. 40-43. Coverage of most of the healing cap during suturing is recommended, leading to a submerged or at least to a "semi-submerged" healing mode.

limited esthetic potential of the site. From the surgical side, this comprised a deeper than normal implant shoulder sink depth (Fig. 40-40), the use of a connective tissue graft on the vestibular aspect (Fig. 40-41), a localized lateral bone augmentation (simultaneous approach) procedure (Fig. 40-42) and a coronally repositioned flap (Fig. 40-43). The metal-ceramic implant restoration featured a transverse screw-reten-

Fig. 40-44. The clinical aspect after insertion of the ceramometal implant crown reveals stable and esthetic peri-implant soft tissue contours.

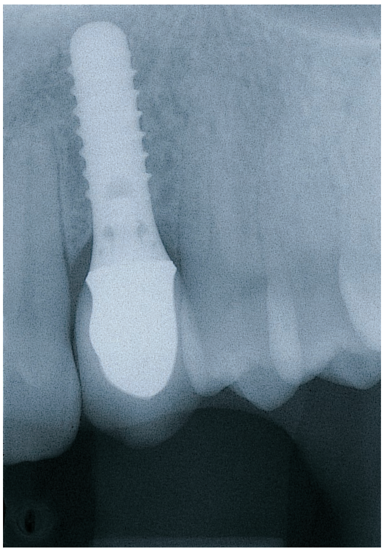

Fig. 40-45. The 2-year follow-up radiograph confirms the stability of the osseointegrated 10 mm solid screw titanium implant.

Fig. 40-46. On a left-lateral view, during the patient's forced smiling, one can note that the lack of vertical soft tissue in the interproximal area has been compensated for with an apically extended interdental contact line.

tion to provide maximum space for esthetic porcelain stratification and a long contact line on the mesial aspect to compensate for the missing interdental soft tissue height (Figs. 40-44 to 40-46).

A more severe preoperative situation of vertical tissue deficiency, combined with a marked horizontal bone defect, is presented in Figs. 40-47 and 40-49. This 19-year-old female patient lost her maxillary right lateral incisor due to a localized periodontal problem. Again, the comprehensive site analysis concluded that a single-tooth implant restoration was the best compromise in view of major disadvantages associated with all of the conventional prosthodontic options. From a purely esthetic point of view, none of the therapeutic modalities had the potential to predictably lead to a perfect re-establishment of a symmetrical, harmoniously scalloped soft tissue course at its original physiological level. However, a rather low lip-line during the patient's normal communication and unforced smiling permitted the least invasive approach to be chosen. Following a lateral connective tissue and bone augmentation procedure (Fig. 40-50), an implant could be inserted in an acceptable position and subsequently restored with a screw-retained crown. The final frontal view, allowing a direct comparison between the intact (Fig. 40-51) and the restored side, clearly demonstrates the current esthetic limitations associated with implant therapy in sites with a marked vertical tissue deficiency (Fig. 40-52).

Multiple-unit anterior fixed implant restorations

The normal consequence following loss of two or more adjacent upper anterior teeth comprises a flattening of the edentulous segment. In particular one can observe the disappearance, in an apical direction, of the crestal bone originally located between the incisor teeth. This phenomenon is not, or only minimally, present at the interproximal aspect of the remaining anterior teeth and thus explains the fundamental difference between a maxillary anterior single-tooth gap and a multi-unit edentulous segment.

If two standard screw-type titanium implants are inserted to replace two missing maxillary central incisors (Figs. 40-53, 40-54), an additional peri-implant bone remodeling process will take place. In the frontal plane, two different characteristic processes, one between the natural tooth and the implant and the other between the two implants, can be distinguished. At the site between tooth and implant, the tooth-sided interproximal bone height should theoretically remain at its original location, i.e. within 2 mm from the CEJ, from where the implant-sided interproximal bone height drops in an oblique manner towards the first implant-to-bone contact, normally located approximately 2 mm apically of the junction ("microgap") between the implant shoulder and the abutment or suprastructure. This phenomenon has been referred to in the literature as "saucerization" or establ-

Fig. 40-47. Labial close-up view of the maxillary right anterior region of a 19-year-old female patient. The interdental soft tissue height distal to the central incisor and the corresponding underlying alveolar bone height are markedly reduced, leading to exposure of the cemento-enamel junction.

Fig. 40-48. The contralateral side of the dental arch shows perfectly intact and harmonious conditions with respect to the course of the gingiva.

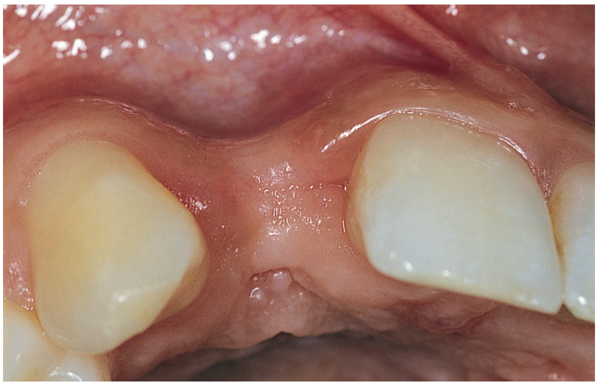

Fig. 40-49. On the occlusal view of the edentulous site a significant lateral crest deficiency becomes apparent, which calls for both a bone and soft tissue augmentation procedure, particularly if an implant solution is planned.

Fig. 40-50. Six months after combined lateral bone and soft tissue augmentation, the site appears to be compatible with "restoration-driven" implant placement.

Fig. 40-51. The buccal view in centric occlusion position before therapy summarizes the problems associated with localized vertical tissue deficiencies: lack of a harmoniously scalloped soft tissue course in general and missing interdental papillae in particular.

Fig. 40-52. The corresponding view after lateral bone and soft tissue augmentation on the one hand and insertion of an implant borne single-tooth restoration on the site of the right lateral incisor on the other hand, underlines the resulting shortcomings with respect to esthetic parameters. Vertical tissue deficiencies – which at present cannot be predictably compensated for – clearly compromise the overall integration of an otherwise successful treatment.

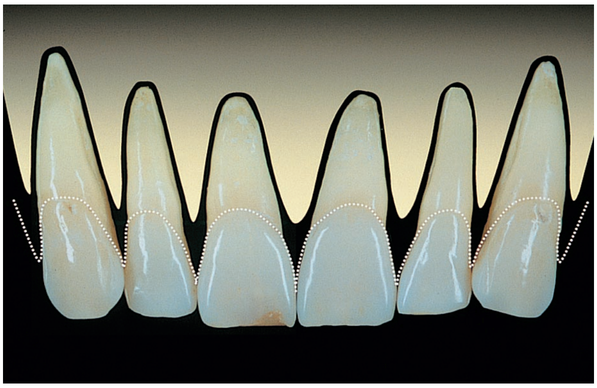

Fig. 40-53. Schematic representation of the six maxillary anterior teeth, including their bony support and the course of the marginal soft tissue, corresponding ideally approximately to the cemento-enamel junction (dotted line).

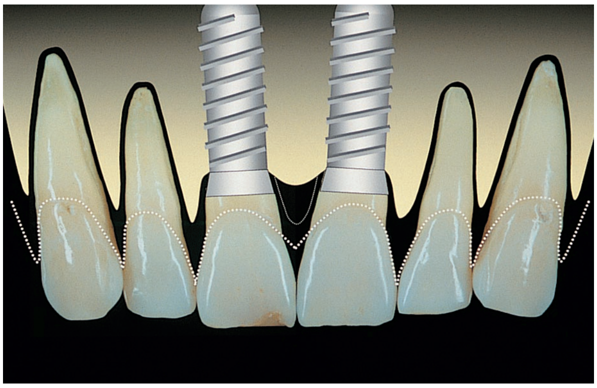

Fig. 40-54. Loss of the two central incisors and their subsequent replacement by implant restorations normally leads to well-defined bone loss ("micro-gap", establishment of a "biologic width") around the implant sites. The main consequence from an esthetic point of view consists of vertical soft tissue deficiencies, namely between adjacent implants (dotted lines).

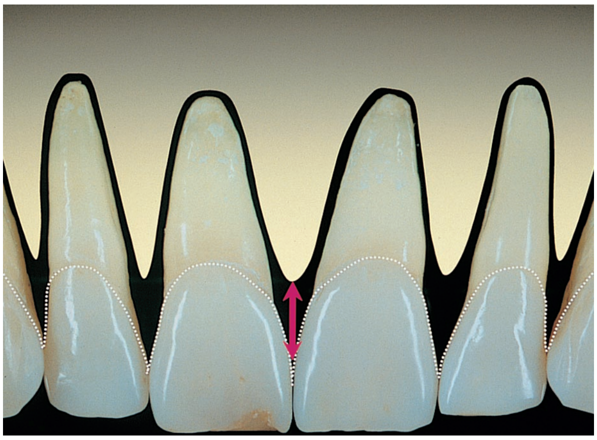

Fig. 40-55. Schematic close-up view of the relationship between cemento-enamel junction, alveolar bone and course of the gingiva in the maxillary incisor area.

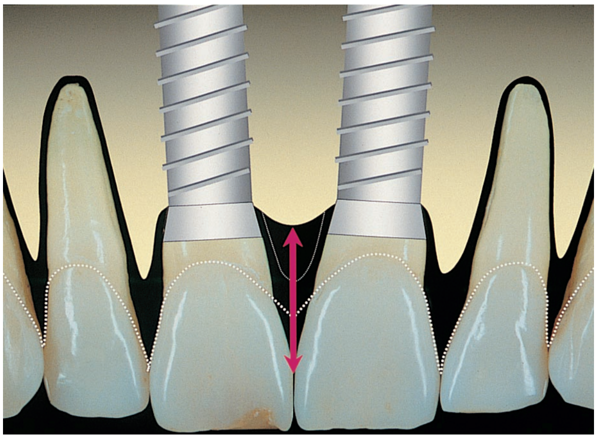

Fig. 40-56. Same area after implant therapy. The red arrow represents the distance between the interimplant bone crest and the interdental contact point. The lack of bony support for the interdental soft tissue often causes the appearance of black triangles, compromising the esthetic treatment outcome.

Table 40.8. Basic considerations related to anterior fixed multiple-unit implant restorations in sites with horizontal and/or vertical soft and hard tissue deficiencies

Achievements	Predictable and reproducible results regarding lateral bone augmentation using barrier membranes supported by autografts: • allows implant placement in patients with a low lip line
Limitations	Vertical bone augmentation is difficult to achieve and related surgical techniques lack prospective clinical long-term documentation Interimplant papillae cannot predictably be re-established as of yet

ishment of a "biologic width" (Hermann et al. 1997, 2000, 2001a,b). In contrast, the interimplant bone height normally decreases further in an apical direction, once the respective abutments or suprastructures are connected to the implant shoulder. This process is mostly accompanied by a loss of interimplant soft tissue height and hence may lead to unsightly, so-called "black interdental triangles". The schematic close-up views comparing the original dentate situation with the status after integration of two adjacent implant restorations, clearly demonstrate the negative consequences on the course of the marginal soft tissue line in a case of multiple adjacent maxillary anterior implants (Figs. 40-55 and 40-56).

The basic considerations related to the current state of achievements and limitations of maxillary anterior fixed multiple-unit implant restorations in sites with and without horizontal and/or vertical soft and hard tissue deficiencies are summarized in Table 40-8.

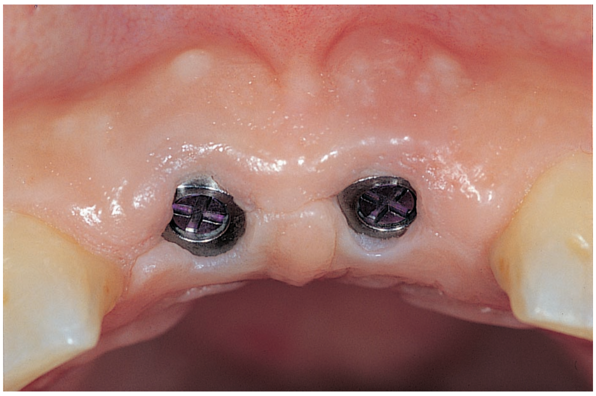

Fig. 40-57. Clinical close-up view of the maxillary anterior segment of a 32-year-old female patient following placement of two 12 mm solid screw implants according to a one-stage transmucosal surgical protocol.

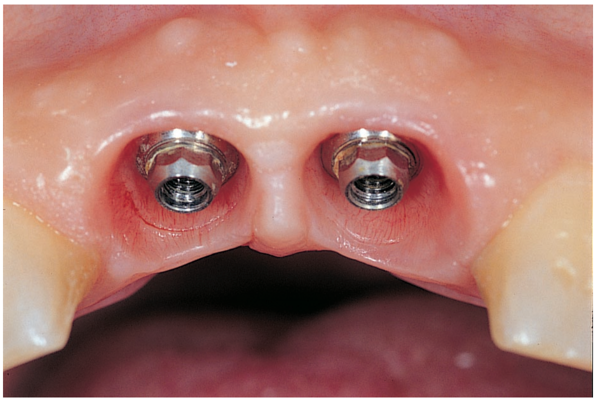

Fig. 40-58. The conditioning of the peri-implant mucosa in view of the future restorations has been performed by means of auxiliary plastic components featuring the possibility of individualizing the emergence profile.

Fig. 40-59. The corresponding clinical close-up view, taken shortly after insertion of the two screw-retained ceramometal restorations, documents the effect of a long interdental contact line, the presence of pronounced mesial ridges and a slight increase of color saturation in the cervico-interdental area. Such technical measures contribute to the compensation of a flat and more apically located labial mucosa line.

Fig. 40-60. Clinically, a slight fill-in of interimplant mucosa and an overall stable soft tissue situation can be noted after 6 years of clinical service.

Fig. 40-61. In order to compensate for the reduced height of the interimplant soft tissue, the ceramist has used an apically prolonged interdental contact line in the form of so-called “mini-wings”. These interdental ceramic extensions are made of a more saturated root-like porcelain and are slightly displaced to the palatal aspects of the crowns. This approach results in restorations that integrate successfully, although being physically larger than the original anatomical crowns.

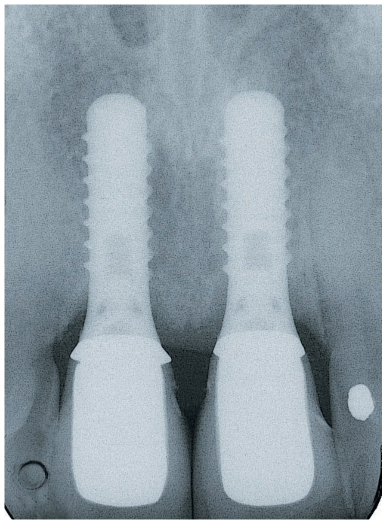

Fig. 40-62. Six years after placement of the 12 mm solid screw titanium implants, the respective radiographs reveal stable conditions at the osseointegrated interface and adequate marginal adaptation.

Sites without significant tissue deficiencies

Due to the previously described shortcomings inherent in multiple adjacent implant restorations, the clinical decision-making process will thus address both the height of the patient's smile-line (low, medium, high) and the individual gingival phenotype ("thick and low scalloped or thin and high scalloped"). In the presence of a favorable gingival morphotype, some restorative "tricks", including peri-implant soft tissue conditioning and particular interproximal crown design, need to be implemented to predictably achieve an acceptable esthetic compromise (Figs. 40-57 to 40-62). Peri-implant soft tissue conditioning is primarily achieved by using either healing caps featuring an appropriatelyshaped, continuously increasing (in a coronal direction) axial emergence profile, or by means of plastic components permitting the customization of the best suited axial contour in the region from the implant shoulder or abutment to the mucosal margin (Fig. 40-58). The particular suprastructure design concerns the interimplant aspect, where instead of an interdental contact point a long and slightly palatal contact line is developed in the form of two adjacent "wings", which are more color-saturated in order to create a discrete shade transition ("blending-in") at the mucosal margin. If the mesial oblique triangular ridges of the two adjacent implant restorations are located at their normal location, the ceramic crowns will not – despite their increased vestibular diameter – optically appear larger (Fig. 40-61). This design reduced the interimplant cervical triangle to a minimum at the moment of the crown insertion (Fig. 40-59), and favoured a coronal soft tissue increase, clearly visible at the 6-year clinical follow-up (Fig. 40-60).

Sites with extended horizontal deficiencies

If the absence of multiple adjacent teeth in the anterior maxilla is accompanied by a marked, but primarily horizontal, resorption of the edentulous alveolar bone crest towards the palate, one can adopt two different strategies. One consists of a so-called "bone-driven" implant placement which will lead to a distinct palatal implant position. In most instances this strategy calls for an implant assisted overdenture-type prosthesis which can more easily compensate for the discrepancy between the required position of the teeth to be replaced and the actual implant location, when compared to a fixed implant prosthesis. Furthermore, the denture flange can solve quite efficiently shortcomings related to esthetics, phonetics and/or insufficient labial and facial tissue support. Normally, denture stability and subjective comfort are excellent and – owing to its removable nature – access for oral hygiene is easy (Mericske-Stern 1998, Kiener et al. 2001). One should be aware, however, that this approach also has its inherent limits and has to take into account crucial parameters such as phonetics and minimal room required for the tongue. As this chapter focuses primarily on fixed maxillary anterior implant restorations, we refer to the relevant respective literature.

Another approach consists of one of the various lateral bone augmentation procedures reported in the literature (Buser et al. 1996, 1999, Chiapasco et al. 1999, von Arx et al. 2001a,b, Zitzmann et al. 2001, Buser et al. 2002), which ultimately should lead to a more "restoration-driven" implant placement, ideally compatible with a straightforward fixed implant prosthesis featuring a continuous, flat axial emergence profile. To date a scalloped course of the peri-implant mucosa cannot be predictably achieved around multiple adjacent maxillary anterior fixed implant restorations, and as an increased clinical crown length is normally inherent in this approach as well, the preoperative assessment of the patient's lip line or smile line (Jensen et al. 1999) is of primary importance during the related decision-making process.

Sites with major vertical tissue loss

The replacement of multiple missing adjacent maxillary anterior teeth with a fixed implant prosthesis still represents a major therapeutic challenge in the presence of combined major horizontal and vertical alveolar ridge deficiencies. Vertical bone augmentation techniques, as for example the distraction osteogenesis procedure (Chiapasco et al. 2001), hold promise for the future but at present are lacking clinical long-term documentation.

As a consequence, the treatment of choice consists in most instances of an implant assisted (e.g. spherical attachments, bar devices) removable overdenture.

CONCLUSIONS AND PERSPECTIVES

When it comes to implants to be inserted within the esthetic zone in view of a fixed restoration, a deep placement – close to or at the alveolar bone crest level – of the shoulder of implants often specifically designed for this indication, permits the suprastructure margin below the mucosa to be hidden, and the development of a gradual harmonious emergence profile from the implant shoulder to the surface, so that the resulting clinical crown replicates the profile of the natural control tooth despite a slightly more palatal implant position. This in turn leads to a secondary peri-implant bone loss or bone remodeling – particularly in a case of multiple adjacent implants – due to the reorganization of a biologic width (Hermann et al. 1997, 2000, 2001a,b). Under these particular circumstances, screw-retained restorations, based on prefabricated, machined components, will assure a maximum marginal adaptation, favoring the maintenance

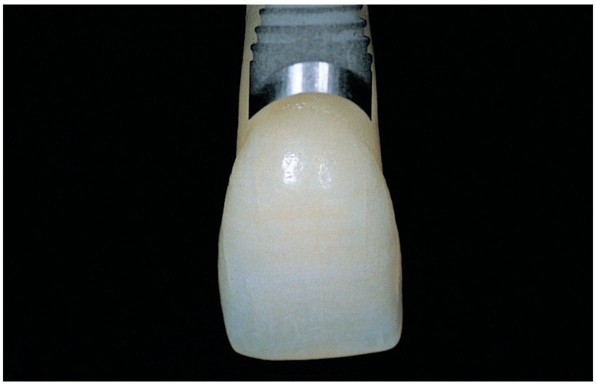

Fig. 40-63. Instead of the traditional implant design, featuring a flat rotation symmetrical coronal aspect, a scalloped connection, inspired by the natural cemento-enamel junction, may lead to a more superficial implant insertion and by this to the preservation of more bone in the interproximal area.

Fig. 40-64. Comparison in the sagital plane of a natural maxillary central incisor and a titanium implant featuring a scalloped design at its coronal end. The radius corresponds to the amount of bone which might theoretically be preserved.

Fig. 40-65. Vestibular view in centric occlusion position of a 24-year-old male patient. The two maxillary central incisors have been lost due to a traumatic injury.

Fig. 40-66. After one year of clinical service, the presence of a harmoniously scalloped marginal soft tissue course, including the most critical interimplant area, can be noted.

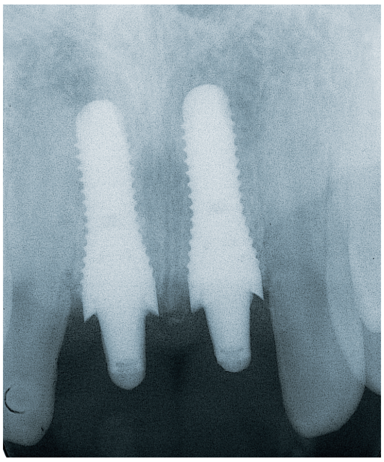

Fig. 40-67. The 1-year follow-up radiograph shows prototype of titanium implants featuring a scalloped design at their coronal end. This design permits a more superficial implant insertion, aiming at a better preservation of interimplant alveolar bone.

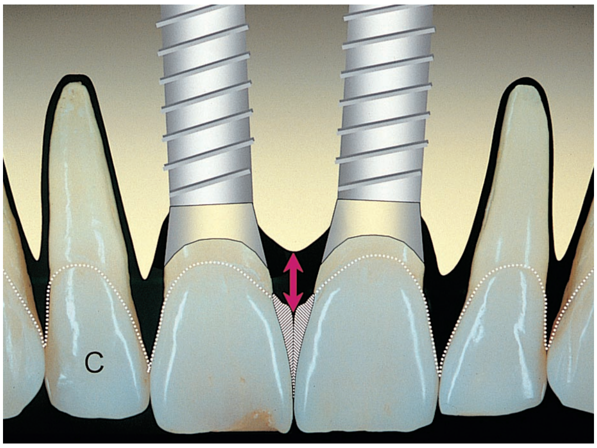

Fig. 40-68. Schematic representation of the theoretical advantages of a scalloped implant design: more superficial implant placement, increased bone and soft tissue preservation particularly in the interimplant area, and improved esthetics (in combination with interdental "mini-wings").

of the long-term stability of the esthetic result (Belser 1999, Belser et al. 1998, 2000). The currently flat, "rotation-symmetrical" design of standard screw-type titanium implants, leading to a marked submucosal implant shoulder position at the interproximal aspect, may not represent, however, the optimal design, in particular in the context of multiple adjacent implants.

Scalloped implant design

As pointed out earlier in this chapter, the traditional implant design may lead to esthetic shortcomings in a case of multiple adjacent maxillary anterior fixed implant restorations. One could hypothesize in this context whether a modified design at the coronal end of the implant, in the sense of a scalloped, more "CEJ-like" configuration, might lead to an improved preservation of peri-implant bone at the interproximal aspect in general, and between adjacent implants in particular. One of the possible design solutions and its anticipated theoretical impact on bone and esthetic parameters are presented in Figs. 40-63, 40-64 and 40-68. More specifically, this approach ultimately aims at creating an interimplant bone height and resulting soft tissue level situation compatible with generally accepted esthetic criteria. Among these one should primarily mention the establishment and/or maintenance of a harmoniously scalloped course of the marginal peri-implant mucosa. At present, the combination of the following three elements appears important:

1. screw-type titanium implant body, featuring optimal surface characteristics
2. tooth-colored transmucosal portion with adequate axial emergence profile and scalloped coronal end
3. mechanically sound suprastructure-connection, permitting both screw-retention and cementation.

The clinical potential of such a novel, scalloped implant design is anecdotally documented in Figs. 40-65 to 40-67, presenting a 24-year-old male patient who had lost his two maxillary central incisors in the course of an accident. The 1-year clinical and radiographic follow-up appears to support – at least short-term – the hypothesis that such an approach may preserve to a certain extent interimplant crestal bone and overlaying soft tissue.

Segmented fixed implant restorations in the edentulous maxilla

Another particular challenge from both a surgical and a prosthodontic point of view represents the implant-supported fixed prosthetic rehabilitation of the edentulous maxilla. Undoubtedly esthetic considerations and certain aspects associated with the patient's subjective comfort – both during the actual treatment phase and once the prosthesis is completed – also play a major role in this context. We will limit our reflections to (1) specific aspects of pre-implant diagnosis, (2) the importance of implant number, alignment and spatial distribution, and (3) conception of the suprastructure.

These elements are addressed in the form of a respective clinical case presentation, involving a 67-year-old female patient, edentulous in the maxilla (Figs. 40-69 to 40-89). Besides the traditional clinical and radiologic investigation, an in-mouth try-in of the envisioned treatment objective in the form of a set-up of teeth without vestibular denture-type flange is of primary importance (Fig. 40-73). Among other aspects, this approach will allow the visualization of the length of the clinical crowns of the future fixed implant prosthesis, and the evaluation of whether a fixed prosthesis will provide sufficient lip and facial support (Fig. 40-74). A surgical guide, derived from the described tooth set-up, will guarantee that the future implant positions are in accordance with the determined tooth positions. Whenever possible, parallelism of implants is recommended, as it permits an eventual early or immediate loading approach (Szmukler-Moncler et al. 2000, Cooper et al. 2001, Andersen et al. 2002, Cochran et al. 2002), and facilitates the subsequent clinical and laboratory procedures. Although little scientific evidence exists to indicate how many implants of which dimension and in what position are required for a predictable and long-lasting fixed implant rehabilitation of an edentulous maxilla, some clinical trends – mostly derived from traditional prosthodontic experience – do exist. If one plans to extend the prosthesis to the first molar area, and if the anatomical conditions allow the use of standard-size (length and diameter) implants, between six and eight implants seems reasonable. However, in order to increase the overall prosthetic versatility and to be able to apply the principle of segmenting, which includes the ease of eventual reinterventions in a case of localized complications (Priest 1996, Goodacre et al. 1999, Lang et al. 2000, Johnson & Persson 2001), eight implants may be considered adequate. The recommended respective positions are on both sides of the jaw – the sites of the central incisors, the canines, the first premolars and the first molars (Fig. 40-76). This approach will ultimately allow the fabrication of four independent three-unit FPDs, with all the related technical and clinical advantages (Figs. 40-78 to 40-89). Some of the scientific data available to date and supporting the concept of smaller segments rather than full-arch splinting will be presented and discussed in Chapter 41.

In conclusion, the concepts and therapeutic modalities do exist nowadays to solve – by means of implants – elegantly as well as predictably a majority of clinical situations requiring the replacement of missing teeth in the esthetic zone, and the most promising novel approaches and perspectives can already be identified on a not too distant horizon.

Fig. 40-69. Vestibular view of a 67-year-old female patient, edentulous in the maxilla since 18 months. Date when the pre-existing fixed prosthetic rehabilitation had to be removed due to periodontal disease and was replaced by an immediate complete upper denture to which she never adapted. In the mandible a natural dentition until the premolar area is present.

Fig. 40-70. The corresponding panoramic radiograph reveals – at least as far as the vertical bone volume is concerned – favourable conditions in view of implant therapy in both the upper and the lower posterior jaw.

Fig. 40-71. The oblique view confirms the presence of an appropriate intermaxillary relationship which is essential for a fixed implant supported prosthesis.

Fig. 40-72. On the occlusal view of the edentulous maxilla, one can note on the one hand overall favorable conditions for implant therapy and on the other hand the clinical signs of the recently performed tooth extractions.

Fig. 40-73. During an unforced smile, the height of the smile line and the eventual need for additional lip support, are evaluated. Both parameters are decisive for the selection between a fixed implant prosthesis or an implant overdenture.

Fig. 40-74. In order to evaluate the feasibility of a fixed implant prosthesis, the clinical try-in of a diagnostic tooth set-up is of paramount importance. One should perform this tooth set-up without vestibular denture flange, so that the patient can realize how long the clinical crowns will be.

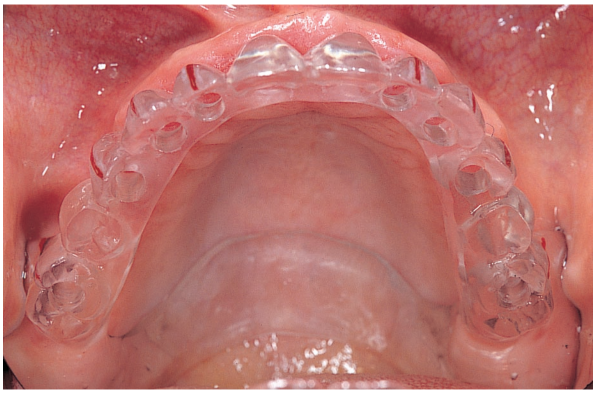

Fig. 40-75. A duplicate of the diagnostic tooth set-up in transparent acrylic will serve as a surgical guide. For optimal stability during surgery, the guide is extended to the posterior palate, an area which will not be concerned by the flap elevation.

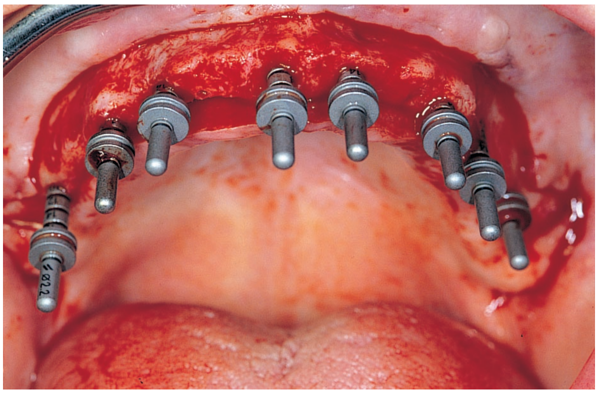

Fig. 40-76. Intrasurgical view of the edentulous maxilla, prepared for the insertion of eight implants to support a fixed prosthesis. Particular attention has been paid to achieving optimal parallelism of the implants by means of a respective surgical guide.

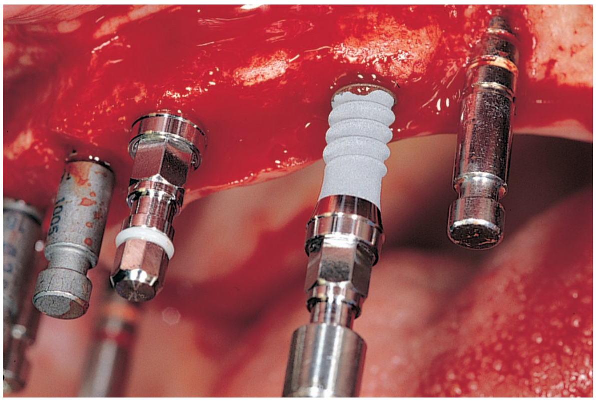

Fig. 40-77. Insertion of a titanium solid screw implant, featuring an SLA surface, in the area of the maxillary left canine.

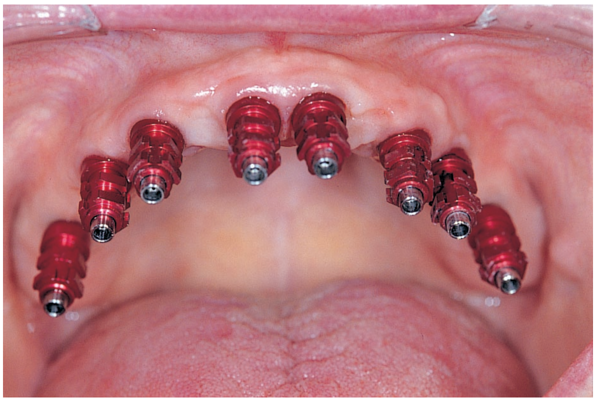

Fig. 40-78. Eight weeks after implant surgery osseointegration is confirmed radiologically and clinically. Screw-retained impression copings are inserted to perform an implant-level impression.

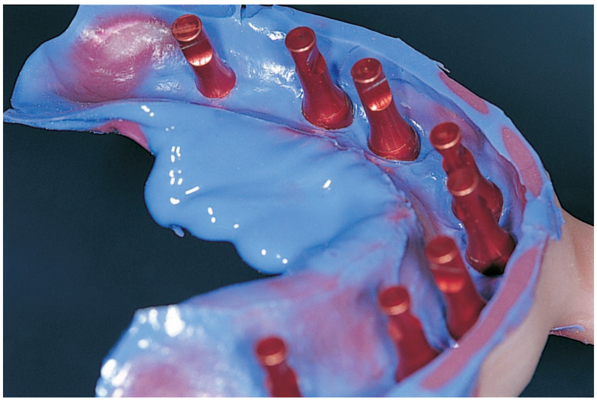

Fig. 40-79. Prior to the master cast fabrication, color-coded implant replicas (analogues) are secured to the respective impression copings.

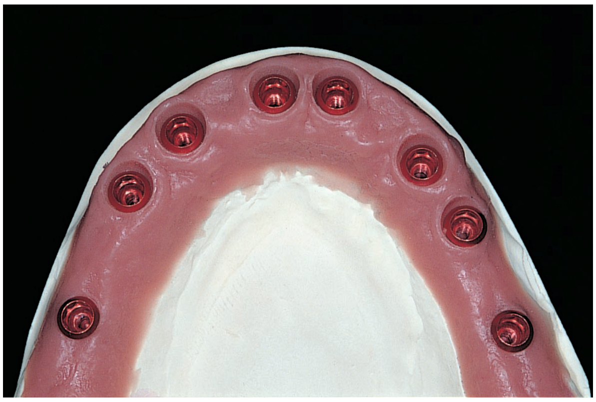

Fig. 40-80. The maxillary master cast features a removable silicon representation of the peri-implant soft tissues.

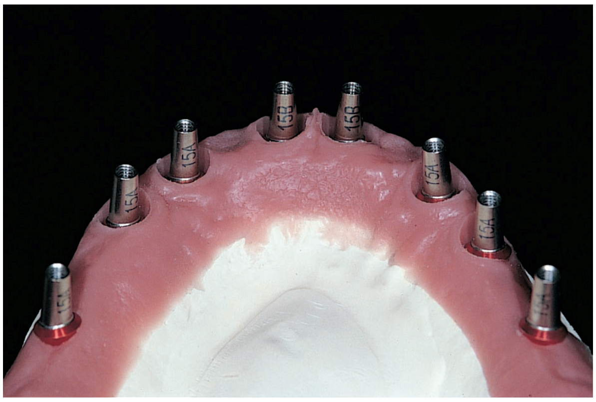

Fig. 40-81. After mounting the master cast in a second-generation, semi-adjustable articulator, the most suitable secondary components (abutments) in view of a cementable fixed implant prosthesis are selected.

Fig. 40-82. Using a silicon key, derived from the diagnostic wax-up, as a guide, the laboratory technician has fabricated the cast metal framework in the form of four independent three-unit segments. Each segment will be supported by two implants.

Fig. 40-83. The completed ceramometal implant prosthesis on the master cast, ready to be inserted in the patient's mouth.

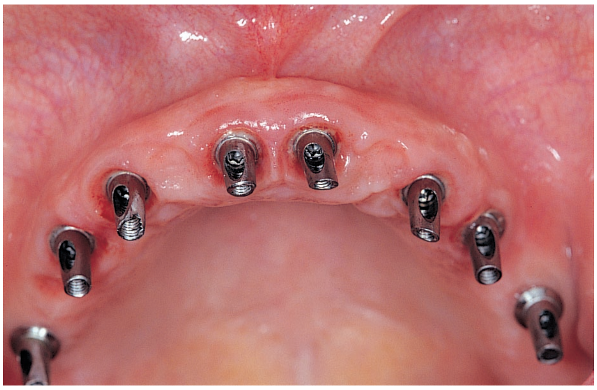

Fig. 40-84. Prior to cementation of the described ceramometal suprastructure, the secondary implant components (abutments) are tightened to 35 Ncm with a calibrated torque wrench.

Fig. 40-85. The corresponding clinical view documents that a design similar to that applied in the natural dentition has been used.

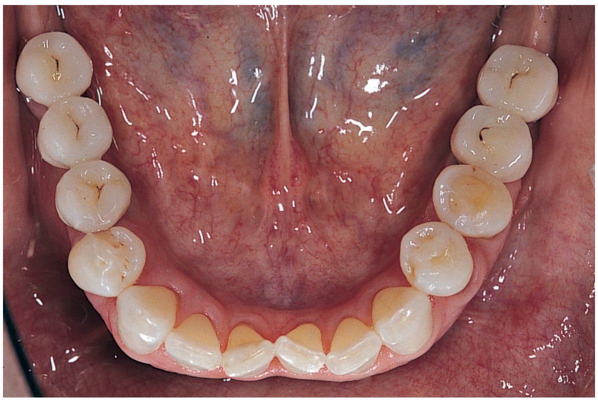

Fig. 40-86. In the mandible the bilaterally shortened arch has been prolonged to the first molar area by means of two fixed cemented ceramometal implant prostheses.

Fig. 40-87. The oblique clinical close-up view of the final implant restoration reveals an acceptable integration both from a functional and an esthetic point of view.

Fig. 40-88. Finally, an esthetically pleasing result could be achieved by means of a fixed implant-supported prosthesis.

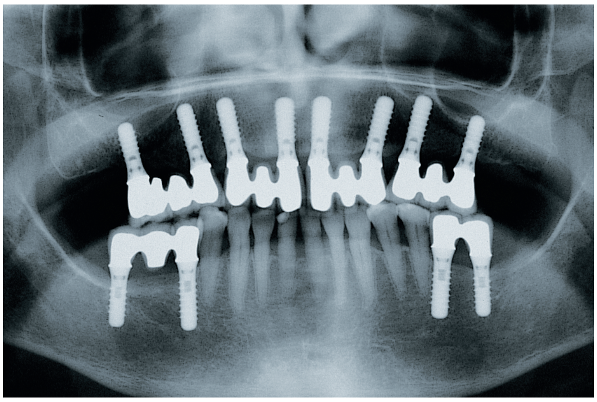

Fig. 40-89. The 1-year postoperative panoramic radiograph confirms osseointegration and documents that the maxillary prosthesis has been completed in four independent segments.

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