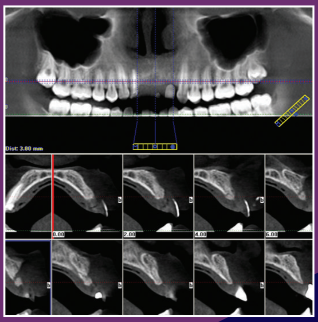
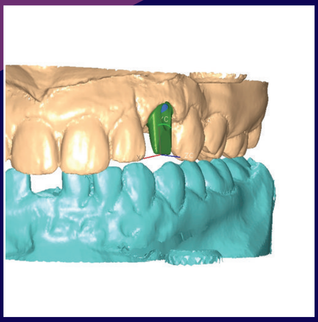
Implants in Clinical Dentistry

Second Edition





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Second Edition

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Preface to the Second Edition

Since the first edition of this book published in 2002, there has been a significant evolution of implant design where many of the major implant systems share common design features that facilitate treatment, improve success, and allow clinicians to more readily adapt to an alternative system. At the same time, there have been huge developments in CAD-CAM applications to implant dentistry and rapid treatment protocols. Despite these changes, the underlying basic principles of thorough diagnosis, meticulous treatment planning, and execution of treatment remain unchanged. This book is firmly based on promoting the acquisition and application of these basic principles in routine conventional treatment protocols before recommending that clinicians embark on more complex and sometimes higher risk treatments.

We are particularly grateful to two other clinicians in our implant dentistry team: Kalpesh Bavisha, who has revised the chapters on implant overdentures (chapters 6, 15, and 17), following the retirement of Brian Smith, and Mahmood Suleiman, who has revised the chapters on planning and surgery in fixed bridges (chapters 5 and 10). We also acknowledge the crucial importance of our highly skilled technicians as part of our team both within the institute and in private practice, in particular Geraldine Williams and her team at Guy's and St Thomas' Hospital; Mark Wade Dental Laboratory, Brentwood; and Brooker & Hamill, London W1.

The new text and format has been supplemented with a large number of new illustrations, and we sincerely hope that this book will continue to help many practitioners embarking upon this still exciting and innovative treatment modality.

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We would like to thank the following people and publishers:

Dr. David Radford for producing the scanning electron microscopy images in Figures 1.7 and 1.10.

Dr. Paul Robinson for help with the maxillofacial aspects of treatment in the case illustrated in Figure 12.17.

Our postgraduate students who have supported our implant dentistry program and have contributed some of the figures included.

Astra Tech, Nobel Biocare, and Straumann for providing illustrations of implant components in chapter 1.

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1

Overview of implant dentistry

INTRODUCTION

The development of endosseous osseointegrated dental implants has been very rapid over the last two decades. There are now many implant systems available that provide the clinician with

- a high degree of predictability in the attainment of osseointegration;
- versatile surgical and prosthodontic protocols;
- design features that facilitate ease of treatment and aesthetics;
- a low complication rate and ease of maintenance;
- published papers to support the manufacturer's claims;
- a reputable company with good customer support.

There is no perfect system and the choice may be bewildering. It is easy for a clinician to be seduced into believing that a new system is better or less expensive. All implant treatment depends on a high level of clinical training and experience. Much of the cost of treatment is not system dependent but relates to clinical time and laboratory expenses.

There are a number of published versions of what constitutes a successful implant or implant system. For example, Albrektsson et al. (IJOMI 1:11, 1986) proposed the following minimum success criteria:

1. An individual, unattached implant is immobile when tested clinically.
2. Radiographic examination does not reveal any peri-implant radiolucency.
3. After the first year in function, radiographic vertical bone loss is less than 0.2 mm per annum.
4. The individual implant performance is characterized by an absence of signs and symptoms such as pain, infections, neuropathies, paresthesia, or violation of the inferior dental canal.
5. As a minimum, the implant should fulfill the above criteria with a success rate of 85% at the end of a 5-year observation period and 80% at the end of a 10-year period.

The most definitive criterion is that the implant is not mobile (criterion 1). By definition, osseointegration produces a direct structural and functional union between the surrounding bone and the surface of the implant (Fig. 1.1). The implant is therefore held rigidly within bone without an intervening fibrous encapsulation (or periodontal ligament) and therefore should not exhibit any mobility or peri-implant radiolucency (criterion 2). However, to test the mobility of an implant supporting a fixed bridge reconstruction (fixed dental prosthesis), the bridge has to be removed. This fact has limited the use of this test in clinical practice and in many long-term studies, especially as many reconstructions are cement retained rather than screw retained. Radiographic bone levels are also difficult to assess as they depend on longitudinal measurements from a specified landmark (Fig. 1.2). The landmark may differ with various designs of implant and is more difficult to visualize in some than others. For example, the flat top of the implant in the Branemark system is easily defined on a well-aligned radiograph and is used as the landmark to measure bone changes. In many designs of implant, some bone remodeling is expected in the first year of function in response to occlusal forces and establishment of the normal dimensions of the peri-implant soft tissues. Subsequently, the bone levels are usually stable on the majority of implants over many years. A small proportion of implants may show some bone loss and account for the mean figures of bone loss, which are published in the literature. Progressive or continuous bone loss is a sign of potential implant failure. However, it is difficult or impossible to establish agreement between researchers/clinicians as to what level of bone destruction constitutes failure. Therefore, most implants described as failures are those that have been removed from the mouth. Implants that remain in function but do not match the success criteria are described as "surviving." Radiographic bone loss is also one of the criteria required within the definition of "peri-implantitis," in addition to the presence of soft tissue inflammation (see chap. 16). In most proposals this is defined as an absolute measurement of bone loss, for example, greater or equal to 1.8 mm, rather than a measure of progressive bone loss from a specific landmark. When reviewing the literature it is important to bear in mind that terms describing bone changes can be applied rather loosely, for example, "bone level" should describe the position of the bone in relationship to a fixed landmark at a point in time, whereas "bone loss" should indicate a deterioration in bone level over a period of time.

Implants placed in the mandible (particularly anterior to the mental foramina) have enjoyed a very high success rate, such that it would be difficult or impossible to show differences between rival systems. In contrast, the more demanding situation of the posterior maxilla where implants of shorter length placed in bone of softer quality may reveal differences between success rates. This remains to be substantiated in comparative clinical trials. Currently there is no comparative data to recommend one system over another, but certain design features may have theoretical advantages (see below).

PATIENT FACTORS

There are few contraindications to implant treatment. Following are the main potential problem areas to consider:

- Age
- Untreated dental disease
- Severe mucosal lesions
- Tobacco smoking, alcohol and drug abuse
- Poor bone quality
- Previous radiotherapy to the jaws
- Poorly controlled systemic disease such as diabetes
- Bleeding disorders

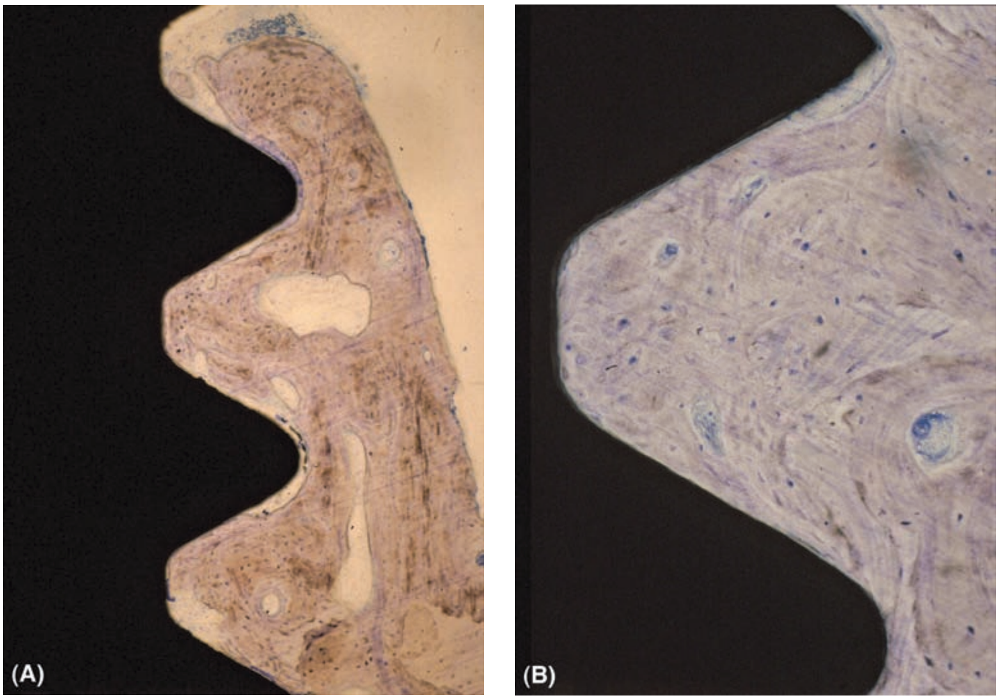

Figure 1.1 Histological sections of osseointegration. (**A**) The titanium implant surface has a threaded profile and bone is in contact over a large proportion of the area. Small marrow spaces are visible, some of which are in contact with the implant surface. (**B**) A higher power view of bone in intimate contact with the titanium surface.

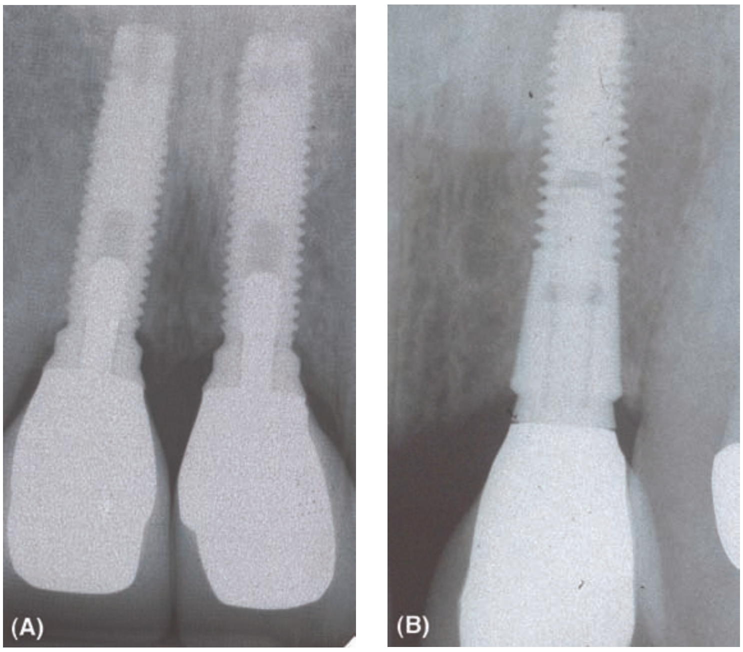

Figure 1.2 (**A**) Branemark implants used to replace upper central incisor teeth. The mesial and distal bone levels are level with the first thread of the implant body. The landmark usually chosen for measurement of bone levels is the head of the implant, which forms a flat plane at the junction with the titanium abutment. (**B**) An Astra Tech implant used to replace a central incisor tooth. The mesial and distal bone levels are level with the head of the implant. This is the normal landmark for measurement of bone changes with this implant system. The titanium abutment has a smaller diameter than the implant head, producing the appearance of a negative margin.

Age

The fact that the implant behaves as an ankylosed unit restricts its use to individuals who have completed their jaw growth. Placement of an osseointegrated implant in a child will result in relative submergence of the implant restoration with growth of the surrounding alveolar process during normal development. It is therefore advisable to delay implant placement until growth is complete. This is generally earlier in females than males but considerable variation exists. At present there is no reliable indication of when jaw growth is complete, and comparison with height measurement monitoring is not informative. It is usually acceptable to treat patients in the late teens. Although some jaw growth potential may remain in the early twenties, this is less likely to result in a significant aesthetic problem (Fig. 1.3).

There is no upper age limit to implant treatment, provided the patient is fit enough and willing to be treated. For example, elderly edentulous individuals can experience

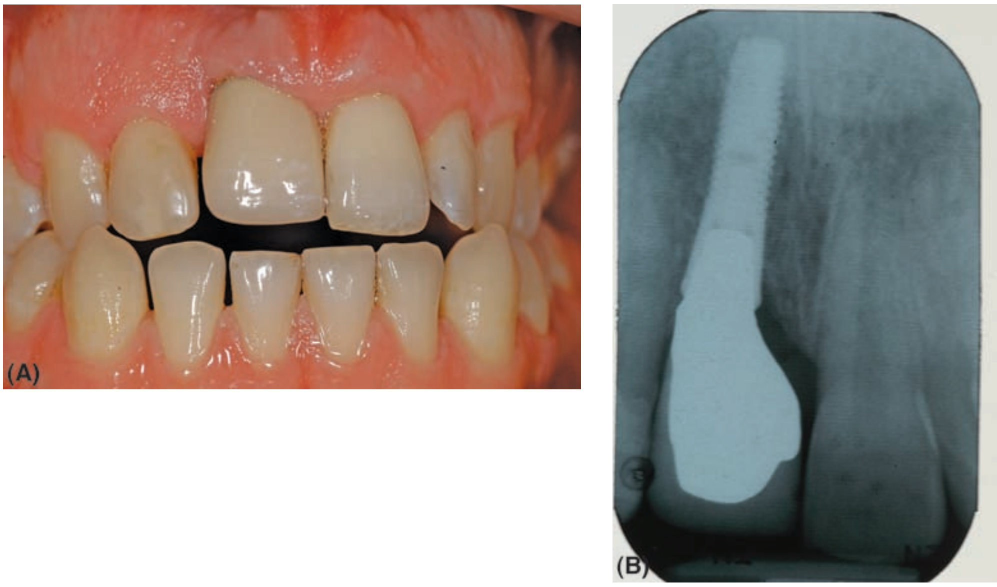

Figure 1.3 (**A**) A male patient in his mid-twenties who had the right central incisor replaced with a single tooth implant in his late teens. Further growth and eruption of the adjacent teeth has resulted in a relative infraocclusion of the right central incisor and a gingival margin, which is more apical. (**B**) The radiograph of the same case showing the relative apical positioning of the implant head, compared to the adjacent teeth.

considerable quality of life and health gain with implant treatment to stabilize complete dentures (see chap. 6).

Untreated Dental Disease

The clinician should ensure that all patients are comprehensively examined, diagnosed, and treated to adequately deal with concurrent dental disease. Poor oral hygiene will result in inflammation of the peri-implant soft tissues—peri-implant mucositis. Inflammation of the soft tissues may subsequently lead to bone loss (peri-implantitis). Placement of implants in subjects susceptible to periodontitis may lead to higher implant failure rates and more marginal bone loss. Implants placed close to peri-apical lesions or residual peri-apical granulomas may be lost as a result of resultant infection.

Severe Mucosal Lesions

Caution should be exercised before treating patients with severe mucosal/gingival lesions such as erosive lichen planus or mucous membrane pemphigoid. When these conditions affect the gingiva, they are often more problematical around the natural dentition and the discomfort compromises plaque control adding to the inflammation. Similar lesions can arise around implants penetrating the mucosa, giving rise to ulceration and discomfort.

Tobacco Smoking and Drug Abuse

It is well established that tobacco smoking is a very important risk factor in periodontitis and that it affects healing. This has been extensively demonstrated in the dental, medical, and surgical literature. A few studies have shown that the overall mean failure rate of dental implants in smokers is approximately twice that in nonsmokers. Smokers should be warned of this association and encouraged to quit the habit. Protocols have been proposed that recommend smokers to give up for at least two weeks prior to implant placement and for several weeks afterward. Such recommendations have not been adequately tested in clinical trials and nor has the compliance of the patients. The chance of the quitter relapsing is disappointingly high and some patients will try to hide the fact that they are still smoking. It should also be noted that reported mean implant failure rates are not evenly distributed throughout the patient population. Rather, implant failures are more likely to cluster in certain individuals. In our experience, this is more likely in heavy smokers who have a high intake of alcohol. In addition, failure is more likely in those who have poor bone quality and a possible association with tobacco smoking. It should also be noted that smokers followed in longitudinal studies have been shown to have more significant marginal bone loss around their implants than nonsmokers. Most of these findings have been reported from studies involving the Branemark system, probably because it is one of the best documented and widely used systems to date. More recent studies of modern implants with surface modifications have reported a reduced chance of early failure in both nonsmokers and smokers. However, differences may still be apparent especially if smoking is heavy.

Drug abuse may affect the general health of the individual and their compliance with treatment and may therefore be an important contraindication.

Poor Bone Quality

This is a term often used to denote regions of bone in which there is low mineralization or poor trabeculation. It is often associated with a thin or absent cortex and is referred to as type 4 bone. It is a normal variant of bone quality and is more likely to occur in the posterior maxilla. In the mandible, a thick cortex may disguise poor quality medullary bone in plain radiographs. Three-dimensional radiographs will give a much clearer idea of bone density and in medical CT this can be measured in Hounsfield units. Osteoporosis is a condition that results in a reduction of the mineral bone density and commonly affects postmenopausal females, having its greatest effect in the spine and pelvis. The commonly used DEXA scans for osteoporosis assessment do not generally provide useful clinical measures of the jaws. The effect of osteoporosis on the maxilla and mandible may be of little significance in the majority of patients. Many patients can have type 4 bone quality, particularly in the posterior maxilla, in the absence of any osteoporotic changes. Osteoporotic patients who have been treated with oral bisphosphonates for osteoporosis probably do not present a significant risk of osteonecrosis. This is in contrast to patients treated with IV bisphosphonates for tumors with bone metastases where the reported complication of osteonecrosis is significant.

Previous Radiotherapy to the Jaws

Radiation for malignant disease of the jaws results in endarteritis, which compromises bone healing and in extreme cases can lead to osteoradionecrosis following trauma/infection. These patients requiring implant treatment should be managed in specialist centers. It can be helpful to optimize timing of implant placement in relationship to the radiotherapy and to provide a course of hyperbaric oxygen treatment. The latter may improve implant success particularly in the maxilla. Success rates in the mandible may be acceptable even without hyperbaric oxygen treatment, although more clinical trials are required to establish the effectiveness of the recommended protocols. Unfortunately, more recent clinical trials have not managed to provide clear evidence of the benefits of hyperbaric oxygen.

Poorly Controlled Systemic Disease such as Diabetes

Diabetes has been a commonly quoted factor to consider in implant treatment. It does affect the vasculature, healing, and response to infection. Although there is limited evidence to suggest higher failure of implants in well-controlled diabetes, it would be unwise to ignore this factor in poorly controlled patients.

Bleeding Disorders

Bleeding disorders are obviously relevant to the surgical delivery of treatment, and require advice from the patient's physician.

OSSEOINTEGRATION

Osseointegration is basically a union between bone and the implant surface (Fig. 1.1). It is not an absolute phenomenon and can be measured as the proportion of the total implant surface that is in contact with bone. Greater levels of bone contact occur in cortical bone than in cancellous bone, where marrow spaces are often adjacent to the implant surface. Therefore, bone with well-formed cortices and dense trabeculation offer the greatest potential for high degrees of bone to implant contact. The degree of bone contact may increase with time. The precise nature of osseointegration at a molecular level is not fully understood. At the light microscopic level, there is a very close adaptation of the bone to the implant surface. At the higher magnifications possible with electron microscopy, there is a gap (approximately 100 nm in width) between the implant surface and bone. This is occupied by an intervening collagen-rich zone adjacent to the bone and a more amorphous zone adjacent to the implant surface. Bone proteoglycans may be important in the initial attachment of the tissues to the implant surface, which in the case of titanium implants consists of a titanium oxide layer, which is defined as a ceramic.

It has been proposed that the biological process leading to and maintaining osseointegration is dependent on the following factors, which will be considered in more detail in the subsequent sections.

- Biocompatibility
- Implant design
- Submerged or nonsubmerged protocols
- Bone factors
- Loading conditions
- Prosthetic considerations

BIOCOMPATIBILITY

Most current dental implants are made of commercially pure titanium. It has established a benchmark in osseointegration, against which few other materials compare. Related materials such as niobium are able to produce a high degree of osseointegration, and in addition, successful clinical results were reported with titanium aluminum vanadium alloys. There has been a renewed interest in titanium alloys, for example, titanium/zirconium alloy by Straumann, because they have the potential of enhancing physical/mechanical properties of the implants. This is of greater significance in narrow diameter implants.

Hydroxyapatite-coated implants have the potential to allow more rapid bone growth on their surfaces. They have been recommended for use in situations of poorer bone quality. The reported disadvantages are the delamination of the coating and corrosion with time. Resorbable coatings have been developed, which aim to improve the initial rate of bone healing against the implant surface, followed by resorption within a short time frame to allow establishment of a bone to metal contact. Hydroxyapatite-coated implants are not considered within this book as the authors have no experience of them.

All the implant systems used by the authors and illustrated in this book are made from titanium and therefore highly comparable in this respect. The main differences in the systems are in the design, which is considered in the next section.

IMPLANT DESIGN

Implant design usually refers to the design of the intraosseous "root form" component (the endosseous dental implant). However, the design of the implant-abutment junction and the abutments are extremely important in the prosthodontic management and maintenance and will be dealt with under a separate section.

The implant design has a great influence on initial stability and subsequent function in bone. Following are the main design parameters:

- Implant length
- Implant diameter
- Shape
- Surface characteristics

Implant Length

Implants are generally available in lengths from about 6 mm to as much as 20 mm (Fig. 1.4). The most common lengths employed are between 8 and 15 mm, which correspond quite closely to normal root lengths. There has been a tendency to use longer implants in systems such as Branemark, compared to, for example, Straumann. The Branemark protocol advocated maximizing implant length where possible to engage bone cortices apically as well as marginally to gain high initial stability. In contrast, the concept with Straumann was to increase surface area of shorter implants by design features (e.g., hollow cylinders) or surface treatments (see below).

Implant Diameter

Most implants are approximately 4 mm in diameter (Figs. 1.4B and 1.5). A diameter of at least 3.3 mm is normally recommended to ensure adequate implant strength. Implants of 3 mm diameter are now available and normally recommended for low load situations such as mandibular incisor teeth. Narrow implants may have to be designed as one piece (i.e., incorporating the abutment) as they are too narrow to allow connection

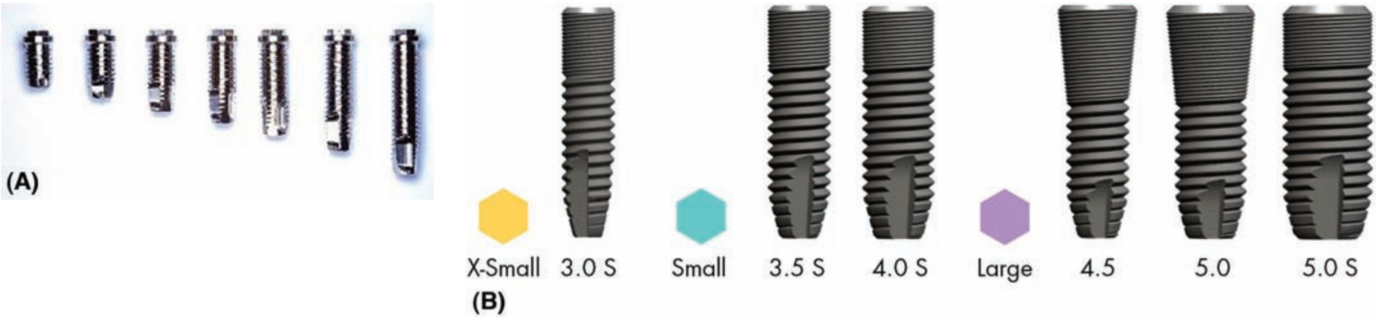

Figure 1.4 (**A**) Branemark implants in a range of lengths from 7 to 20 mm. The implant surface is machined or turned and the implant head has a flat top and external hexagon connection. (**B**) A range of Astra Tech implants from 3.0 to 5.0 mm diameter. The large diameter implants have a longer conical collar, which is microthreaded.

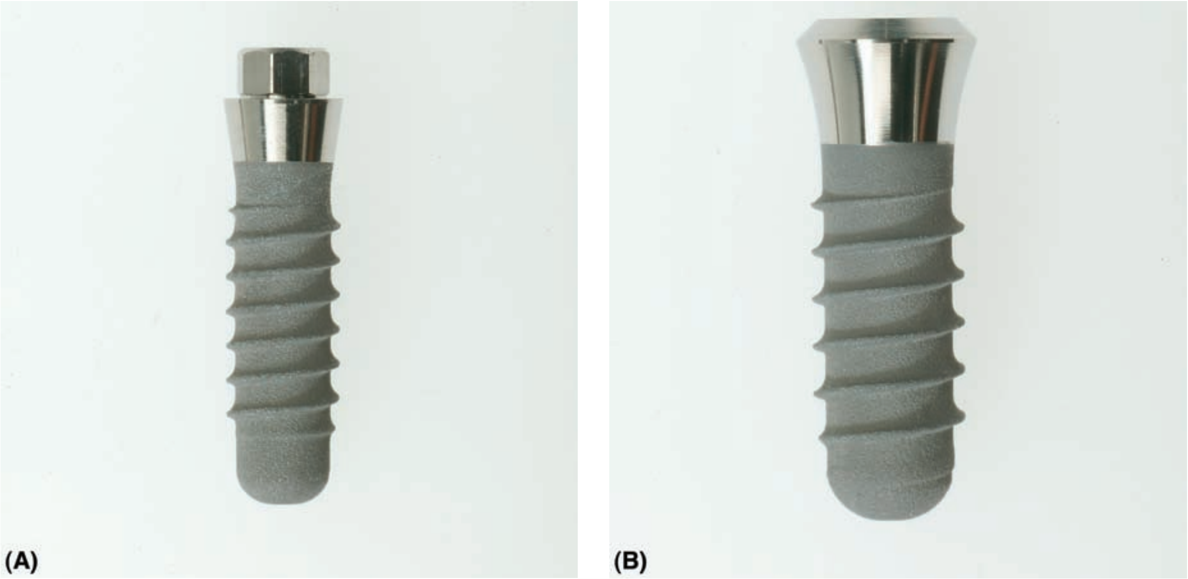

Figure 1.5 (**A**) A narrow diameter Straumann implant with a polished collar and external hexagonal abutment connection. (**B**) A standard diameter tissue level Straumann implant with a polished collar and internal abutment connection.

via an abutment screw of adequate diameter. Wider diameter implants (5 mm and over) are available, which are considerably stronger, have a much higher surface area, and are often indicated for molar replacement. They may also engage lateral bone cortices to enhance initial stability. However, they may not be so widely used because sufficient bone width is not commonly encountered in most patients' jaws.

Implant Shape

Implants come in a very wide variety of shapes with many of the design features shared between systems and others limited to systems, especially where patents exist. The shape and screw design of the implant together with the recommended site preparation does have an effect on the surgical performance and stability of the implant that may guide operator preference. Most implants are parallel cylindrical or tapered cylindrical threaded designs (Figs. 1.4–1.6). The tapered design will normally require more torque to insert as the wider part gradually engages the prepared site. The apical design may also be parallel or more commonly tapered to allow easier insertion, and may be smooth or have cutting faces to achieve self-tapping of the bone. The thread design and pitch vary considerably. A common thread pitch is 0.6 mm. The thread design may be more rounded or sharp and contribute to stability of the implant on insertion. The coronal end of the implant may be parallel sided or flared to provide a larger head or platform to connect to the abutment. The outer surface profile of the coronal end may have the same thread profile as the body of the implant, a finer microthread or a smooth profile (Figs. 1.4–1.6). The surface characteristics (see below) may be the same as the body of the implant or smoother. The abutment connection to the implant may be within the implant (internal connection) or sit on top of the implant (external connection).

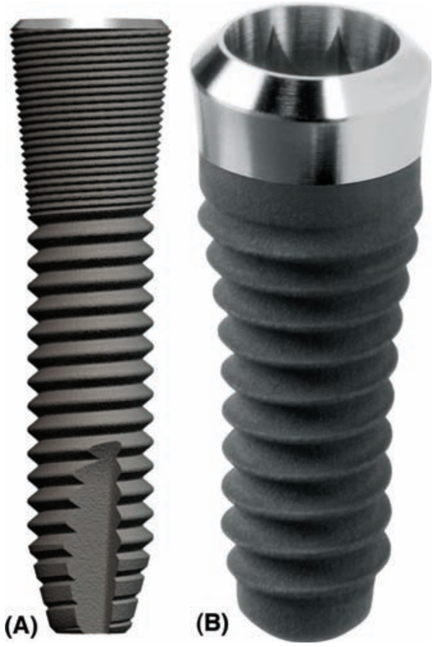

Figure 1.6 (**A**) An Astra Tech implant with a microthreaded conical top and a macrothreaded body. The entire surface has a dull appearance due to the surface treatment. (**B**) A Straumann implant with a conical design often used in immediate replacement protocols. There is a polished collar at the level where the soft tissue attaches.

Surface Characteristics

The degree of surface roughness varies greatly between different systems. Surfaces that are machined, grit-blasted, etched, plasma sprayed, coated, and combination treated are available (Table 1.1).

The original Branemark implants have a machined surface as a result of the cutting of the screw thread. This has small ridges when viewed at high magnification (Fig. 1.7). This degree of surface irregularity was claimed to be close to ideal because smoother surfaces fail to osseointegrate and rougher surfaces are more prone to ion release and corrosion. However, most modern implants have a slightly rough surface that favors more rapid and higher levels of osseointegration (Fig. 1.8). Comparative tests in experimental animals have demonstrated a higher degree of bone to implant contact and higher torque removal forces than machined surfaces.

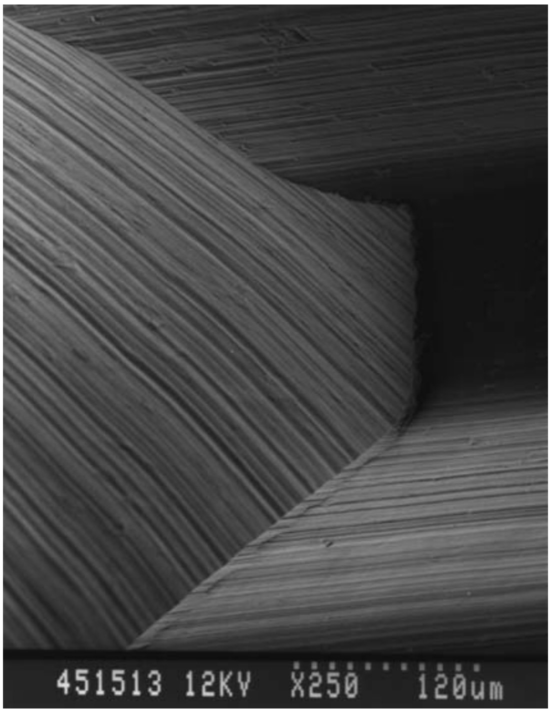

Figure 1.7 An electron micrograph of a machined implant surface. The ridges and grooves on this Branemark implant are produced during the machining process.

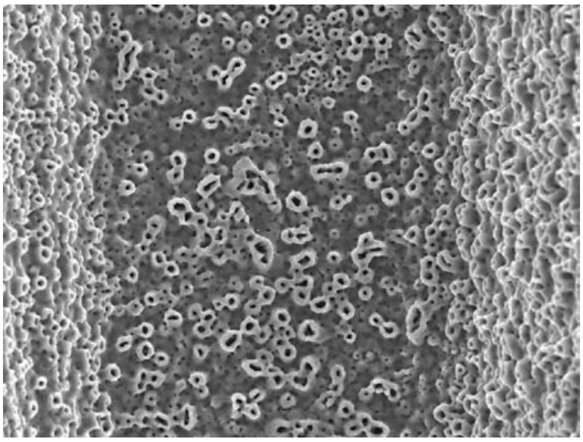

Figure 1.8 An electron micrograph of the Nobel Biocare Ti-unite surface.

These surfaces can be produced in a number of ways. The earlier Astra Tech implants had a roughened surface produced by "grit blasting," in this case with titanium oxide particles. The resulting surface has approximately 5-μm depressions over the entire intraosseous part of the implant. This surface treatment has more recently been modified to also incorporate fluoride ions (Fig. 1.9). The original Straumann surface was titanium plasma sprayed (TPS) (Fig. 1.10). Molten titanium is sprayed onto the surface of the implant to produce a very rough, almost porous surface. This type of surface is generally not used because of potential problems of peri-implantitis if it should become exposed to the oral environment. Straumann developed a newer surface called the SLA (sand blasted–large grit–acid etched) (Fig. 1.11). This technique produces a surface with large irregularities with smaller ones superimposed upon it. A newer version of SLA has been made more hydrophilic, which may further improve the speed of cell attachment and osseointegration.

Table 1.1 Implant Surface Sa Values

Smooth	<0.5 μm	Polished
Minimally rough	0.5–1.0 μm	Turned
Moderately rough	1.0–2.0 μm	Modern surfaces
Rough	>2.0 μm	TPS

Abbreviations: Sa, arithmetic mean of 3D roughness; TPS, titanium plasma sprayed.

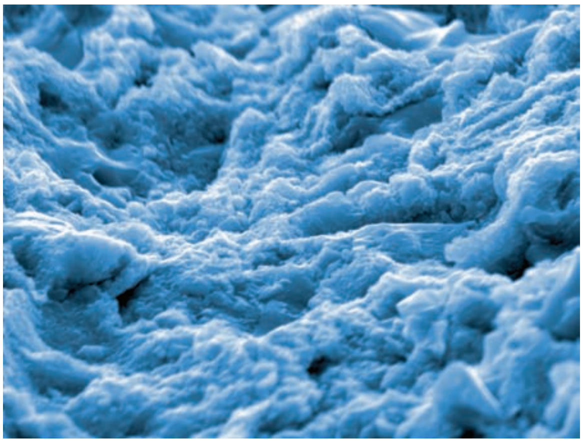

Figure 1.9 The Astra Tech osseospeed surface, which has fluoride irons incorporated.

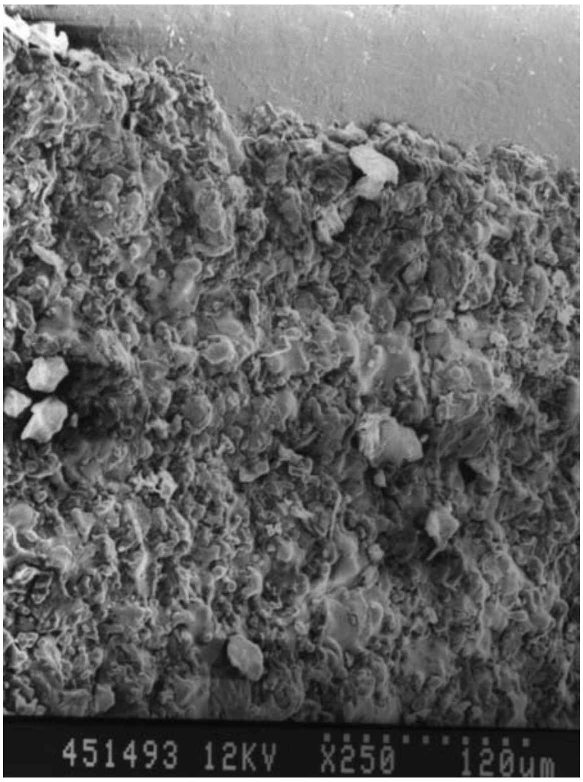

Figure 1.10 An electron micrograph of the original titanium plasma-sprayed (TPS) surface used by Straumann.

The optimum surface morphology has yet to be defined, and some may perform better in certain circumstances. By increasing surface roughness there is the potential to increase the surface contact with bone, but this may be at the expense of more ionic exchange and surface corrosion. Bacterial contamination of the implant surface will also be affected by the surface roughness if it becomes exposed within the mouth. The current trend is therefore toward moderately roughened surfaces (Table 1.1).

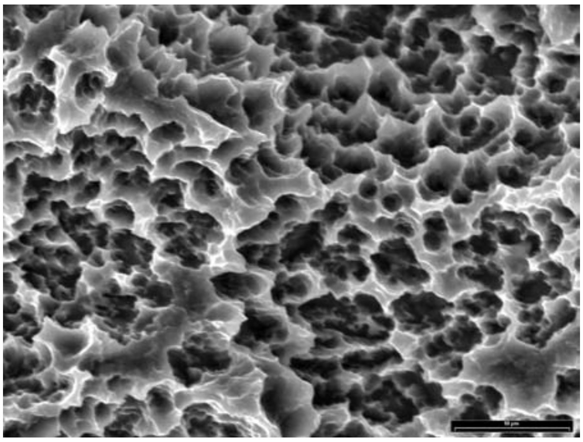

Figure 1.11 An electron micrograph of the Straumann SLA surface. *Abbreviation*: SLA, sand blasted–large grit–acid etched.

Implant-Abutment Design

Most implant systems have a wide range of abutments for various applications (e.g., single tooth, fixed dental prosthesis, overdenture) and techniques (e.g., standard manufactured abutments, prepable abutments, cast design abutments, and various materials from titanium and gold to zirconium; see chaps. 13 and 14). However, the design of the implant-abutment junction varies considerably. The original Branemark implant-abutment junction is described as a flat top external hexagon (Fig. 1.12). The hexagon was designed to allow rotation (i.e., screwing in) of the implant during placement. It is an essential design feature in single tooth replacement as an anti-rotational device. The design proved to be very useful in the development of direct recording of impressions of the implant head rather than the abutment, thus allowing evaluation and abutment selection in the laboratory (see chap. 13). The abutment is secured to the implant with an abutment screw. The joint between implant and abutment is precise but does not produce a seal, a feature that does not appear to result in any clinical disadvantage. The hexagon is only 0.6 mm in height and it may be difficult for the inexperienced clinician to determine whether the abutment is precisely located on the implant. The fit is therefore normally checked radiographically, which also requires a good paralleling technique to adequately visualize the joint. Similar designs of external hexagon implants have increased the height of the hexagon, making abutment connection easier. The original design concept was that the weakest component of the system was the small gold screw (prosthetic screw) that secured the prosthesis framework to the abutment, followed by the abutment screw and then the implant (Fig. 1.12B). Thus, overloads leading to component/mechanical failure should be more readily dealt with (see chap. 16).

The Astra Tech implant system was one of the first bone level implant designs to incorporate a conical abutment fitting into the conical head of the implant, described by the manufacturers as a "conical seal" (Fig. 1.13). The taper of the cone is 11°, which is greater than a Morse taper (6°). The abutments self-guide into position and are easily placed even in very difficult locations. It is not usually necessary to check the localization with radiographs. This design produces a very secure, strong union. The standard abutments are either a solid one-piece

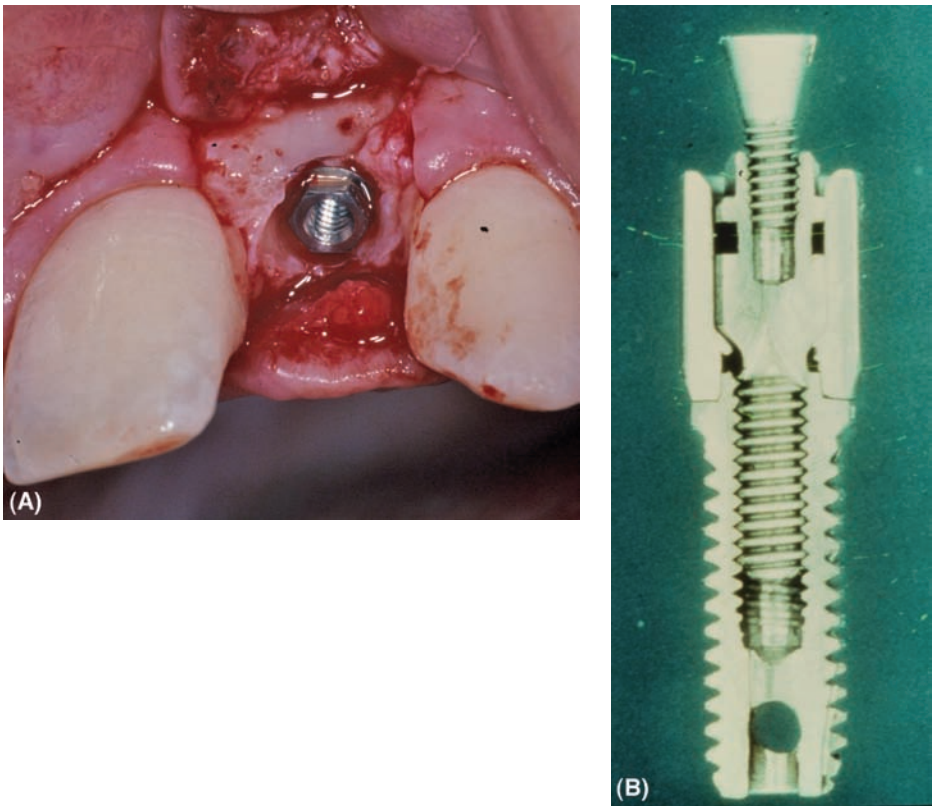

Figure 1.12 (**A**) A Branemark implant placed in the lateral incisor region, showing the external hexagonal head. (**B**) A cross-section through an original Branemark implant stack. At the top of the stack a gold bridge screw connects a gold cylinder to a titanium abutment screw and the titanium cylinder that is in turn connected to the titanium implant.

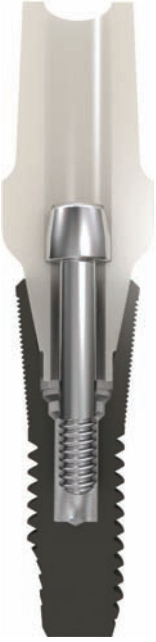

Figure 1.13 Section through a single tooth Astra Tech implant with a zirconium abutment, connected via an internal connection and titanium abutment screw.

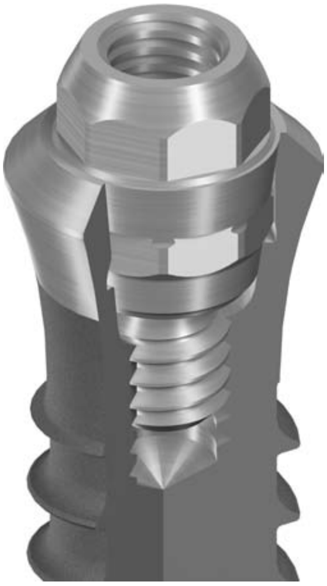

Figure 1.14 A cutaway section of a tissue level Straumann implant showing the internal abutment connection.

component or two-piece components with an abutment screw to utilize the internal hexagon anti-rotation design.

The tissue level Straumann implant has a smooth polished transmucosal collar to allow soft tissue adaptation, a feature that many of the other systems incorporate in the abutment design. The abutment-implant junction is therefore either supramucosal or just submucosal and therefore connection and checking of the fit of the components is easier than some systems. The implant-abutment junction also has an internal tapered conical design with an angle of 8° (Fig. 1.14).

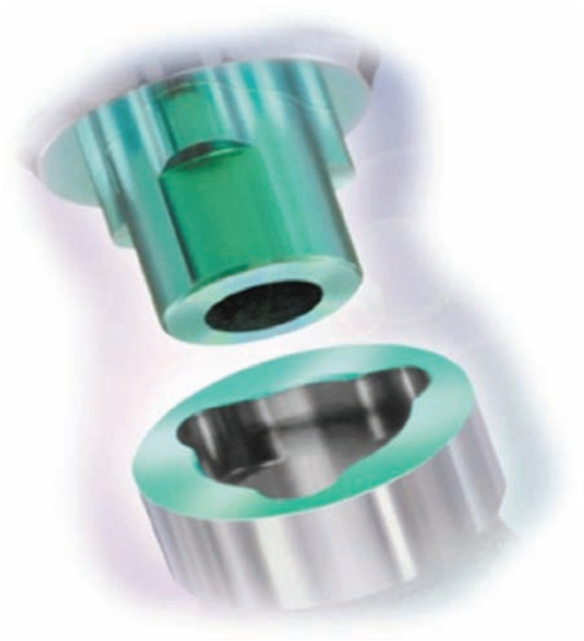

Figure 1.15 The Nobel Replace internal abutment connection.

Many of the currently available implant systems have some of the features described above. They tend to have an internal connection between abutment and implant that is either parallel sided with a small area of flat surface at the top or a conical design (Fig. 1.15). Most feature an internal hexagonal/octagonal anti-rotational system with an abutment screw but some rely on the frictional fit of a Morse taper cone. With internal connection designs there has also been a trend to make the abutment diameter smaller than the implant head resulting in a "negative" margin. This so-called platform switching allows a greater volume of soft tissue in this region and may contribute to maintenance of implant bone levels by increasing the available surface distance in establishing the soft tissue biological width. The improved seal of internal connections may also reduce or eliminate bacterial ingress and subsequent inflammation that could affect bone levels.

SUBMERGED AND NONSUBMERGED PROTOCOLS

The terms submerged and nonsubmerged implant protocols were at one time clearly applicable to different implant systems. The classic submerged system was the original protocol as described by Branemark. Implants are installed with the head of the implant and cover screw level with the crestal bone and the mucoperiosteal flaps closed over the implants and left to heal for several months (Fig. 1.16). This had several theoretical advantages:

1. Bone healing to the implant surface occurs in an environment free of potential bacterial colonization and inflammation.
2. Epithelialization of the implant-bone interface is prevented.
3. The implants are protected from loading and micromovement that could lead to failure of osseointegration and fibrous tissue encapsulation.

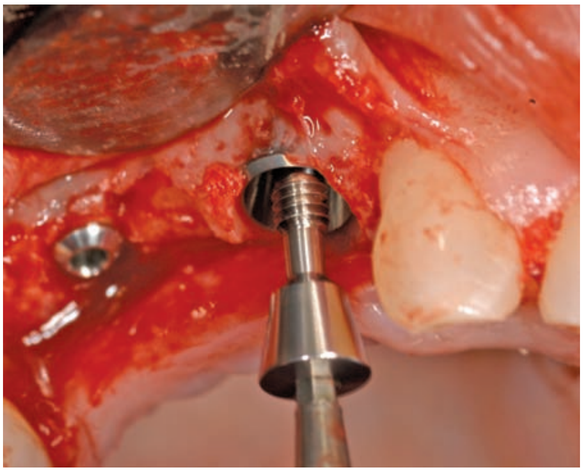

Figure 1.16 A cover screw being placed into an Astra Tech implant before suturing of the flaps to bury the implants in a submerged two-staged technique.

The submerged system requires a second surgical procedure after a period of bone healing to expose the implant and attach a transmucosal abutment. The initial soft tissue healing phase would then take a further period of approximately two to four weeks. Abutment selection would take into account the thickness of the mucosa and the type of restoration.

The best and first example of a nonsubmerged system is tissue level implant of Straumann. In this case, the implant is designed with an integral smooth collar that protrudes through the mucosa, and this allows the implant to remain exposed from the time of insertion (Fig. 1.17). The most obvious advantage is the avoidance of a second surgical procedure and more time for maturation of the soft tissue collar at the same time as the bone healing is occurring. Although this protocol does not comply with the three theoretical advantages enumerated above, the results are equally successful.

However, clinical development and commercial competition lead to many systems being used in either a submerged or a nonsubmerged fashion even though they were primarily designed for one or the other. The additional development of rapid treatment protocols involving immediate extraction/implant placement and early and immediate loading of prostheses has led to further development of single-stage nonsubmerged protocols (see chap. 11).

Another difference between systems designed for these protocols is the level of the implant-abutment junction in relationship to the bone. Many systems including Branemark/Nobel Biocare, Astra Tech, and Ankylos, and the newer Straumann bone level implant are designed such that the implant head is usually placed at the level of the bone or countersunk below the bone crest. At the time of abutment connection the interface with the implant is at the same level.

In the original Branemark system, it was observed that during the first year of loading the bone level receded to the level of the first thread and in following years most were relatively stable at this level (Fig. 1.2). The possible reasons for this initial bone change in the first year of loading have been proposed as

1. The threads of the implant provide a better distribution of forces to the surrounding bone than the parallel-sided head of the implant.

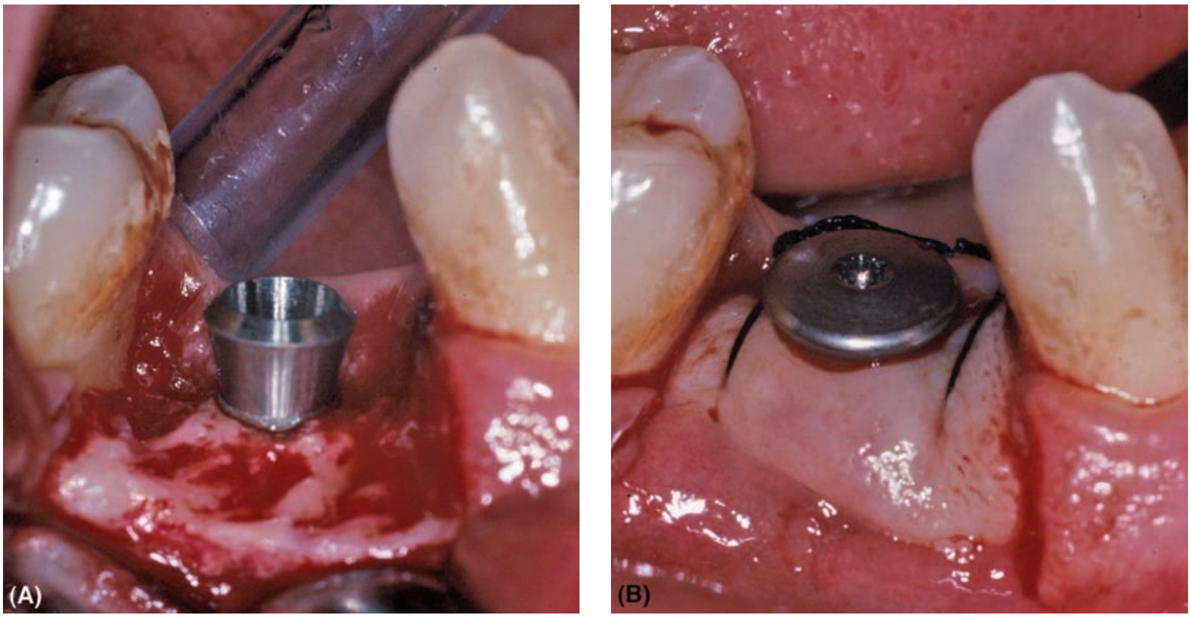

Figure 1.17 (**A**) A 4.1-mm-diameter tissue level Straumann implant has been placed so that the polished collar is above the crest of the bone. (**B**) A closure screw has been placed on top of the implant and the flaps are sutured around the collar to leave the head of the implant exposed in a nonsubmerged fashion.

2. The establishment of a biological width for the investing soft tissues. The junctional epithelium is relocated on the implant and not on the abutment.
3. The interface between the abutment and implant is the apposition of two flat surfaces (flat top implant) that are held together by an abutment screw. This arrangement does not form a perfect seal and may allow leakage of bacteria or bacterial products from within the abutment/restoration, thereby promoting a small inflammatory lesion that may affect the apical location of the epithelial attachment.

However, in modern implants with a moderately rough surface and a good abutment-implant seal the bone often remains at the level of the implant head (Fig. 1.2B). The biological implication of this is that the junctional epithelium must be superficial to this and, therefore, located on the abutment/restoration. The possible reasons for this arrangement in contrast to the explanations given above for the loss of marginal bone are as follows:

1. The surface of the implant maintains bone height more effectively in the collar region. This may be due to the moderately rough surface or other design features such as the presence of microthreading.
2. The implant-abutment junction is a conical junction—a cone fitting within a cone—which provides a tighter seal, thereby eliminating microbial contamination/leakage at the interface and also producing a more mechanically sound union with less chance of micromovement. The ensuing stability of the junction may facilitate positional stability of the junctional epithelium.

The original Straumann implant-abutment interface is conceptually different to those described above. The integral smooth transmucosal collar of the implant is either 2.8 mm (with the standard implant) or 1.8 mm long. The implant-abutment junction may be submucosal or supramucosal depending on the length of the transmucosal collar, the thickness of the mucosa, and the depth to which the implant has been placed. The end of the smooth collar coincides with the start of the roughened endosseous surface, which is designed to be located at the level of the bone at implant placement. There is, therefore, potential space for location of the junctional epithelium and connective tissue zone on the collar or neck of the implant at a level apical to the implant-abutment junction. Moreover, the implant-abutment junction is an effective conical seal. This would prevent any movement between the components and an interface that would prevent bacterial ingress.

The preceding considerations of the different implant systems reveal a number of basic differences:

1. The designed level of the implant-abutment interface.
2. The design characteristics at the implant-abutment interface in terms of mechanical stability and seal.
3. The macroscopic features of the implant and its surface characteristics.
4. The level of the transition of the surface characteristics on the implant surface.

This multitude of features has an impact on the level of the bone crest and the position of the junctional epithelium/connective tissue zone. Despite what appears to be a large and fundamental difference, the bone level comparison between the systems is clinically and radiographically very small (less than 1 mm at baseline values) and the maintenance of bone levels thereafter is very similar with all systems reporting highly effective long-term maintenance of bone levels. The differences reported in longitudinal trials are not sufficient to recommend one system over another.

BONE FACTORS

When an implant is first placed in the bone, there should be a close fit to ensure primary stability. The space between implant and bone is initially filled with blood clot and serum/bone proteins. Although great care is taken to avoid damaging the bone, the initial response to the surgical trauma is resorption, which is then followed by bone deposition. There is a critical period in the healing process at approximately two to three weeks post implant insertion when bone resorption will result in a lower degree of implant stability than that achieved initially. Subsequent bone formation will result in an increase in the level of bone contact and secondary stability. The stability of the implant at the time of placement is very important and is dependent on bone quantity and quality as well as implant design features considered above. The edentulous ridge can be classified in terms of shape (bone quantity) and bone quality. Following loss of a tooth, the alveolar bone resorbs in width and height (Fig. 1.18). In extreme cases, bone resorption proceeds to a level that is beyond the normal extent of the alveolar process and well within the basal bone of the jaws. Determination of bone quantity is considered in the clinical and radiographic sections of the treatment planning chapters. Assessing bone quality is rather more difficult. Plain radiographs can be misleading and sectional tomograms provide a better indication of medullary bone density (see chap. 2). In many cases the bone quality can only be confirmed at surgical preparation of the site. Bone quality can be assessed by measuring the cutting torque during preparation of the implant site. The primary stability (and subsequent secondary stability) of the implant can be quantified using resonance frequency analysis, which has proved to be useful in experimental trials and rapid treatment protocols.

The simplest categorization of bone quality is that described by Lekholm as types 1 to 4. Type 1 bone is predominantly cortical and may offer good primary stability at implant placement but is more easily damaged by overheating during the drilling process, especially with sites over 10 mm in depth. Types 2 and 3 are the most favorable quality of jaw bone for implant treatment. These types have a well-formed cortex and densely trabeculated medullary spaces with a good blood supply (type 2 has more cortex/dense trabeculation than type 3). Type 4 bone has a thin or absent cortical layer and sparse trabeculation. It offers poor primary implant stability and fewer cells with a good osteogenic potential to promote osseointegration, and has therefore been associated with higher rates of implant failure.

Healing resulting in osseointegration is highly dependent on a surgical technique that avoids heating the bone. Slow drilling speeds, the use of successive incrementally larger sharp drills, and copious saline irrigation aim to keep the temperature below that at which bone tissue damage occurs (approximately 47°C for 1 minute). Further refinements include cooling the irrigant and using internally irrigated drills. Methods by which these factors are controlled are considered in more detail in the surgical sections (see chaps. 7–11). Factors that compromise bone quality are infection, irradiation, and heavy smoking, which were dealt with earlier in this chapter.

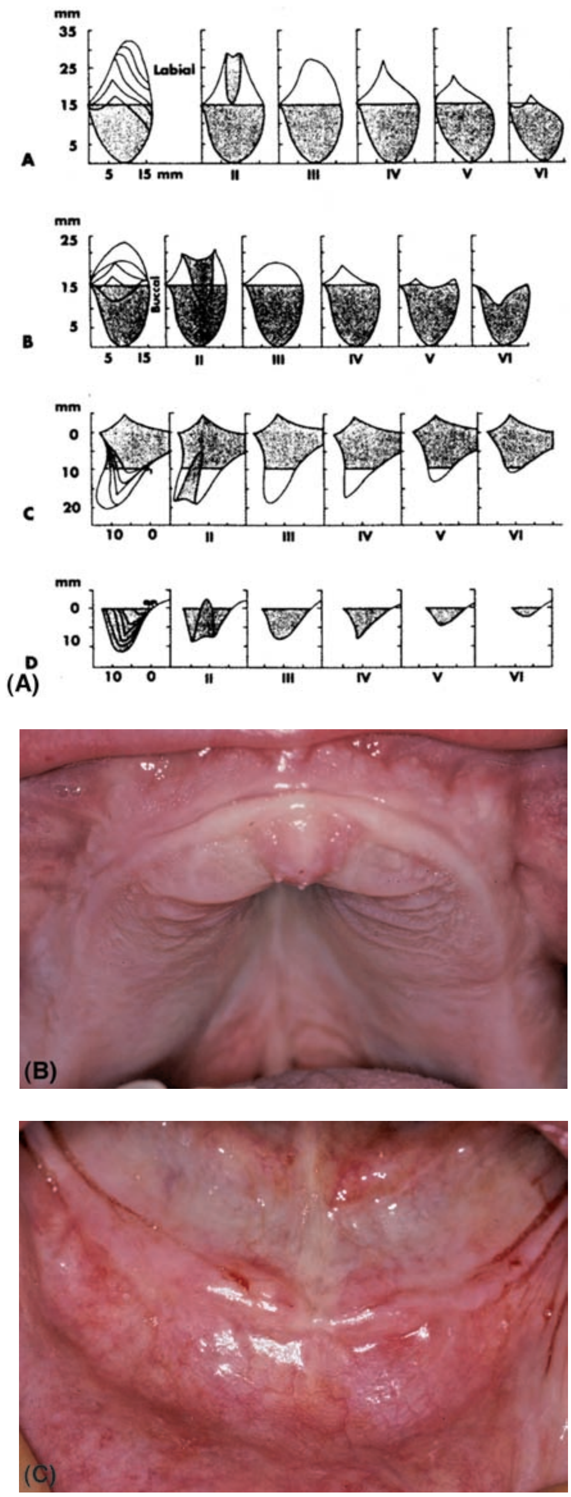

Figure 1.18 (**A**) Classification of jaw resorption as described by Cawood and Howell (1991) showing cross-sectional profiles through different regions, 1 = anterior mandible, 2 = posterior mandible, 3 = anterior maxilla, 4 = posterior maxilla. (**B**) An example of an edentulous maxilla that would be clinically classified as class 3 in both the anterior and posterior regions. Although the ridges appear broad, there may be little bone in the posterior regions, due to the extension of the maxillary air sinuses. (**C**) An example of a severely resorbed edentulous mandible would be classified as class 5 or 6. Confirmation would require radiographic examination.

LOADING CONDITIONS

Osseointegrated implants lack the viscoelastic damping system and proprioceptive mechanisms of the periodontal ligament, which effectively dissipate and control forces. However, proprioceptive mechanisms may operate within bone and associated oral structures. Forces distributed directly to the bone are usually concentrated in certain areas, particularly around the neck of the implant. Excessive forces applied to the implant may result in remodeling of the marginal bone, that is, apical movement of the bone margin with loss of osseointegration. The exact mechanism of how this occurs is not entirely clear, but it has been suggested that microfractures may propagate within the adjacent bone. Bone loss caused by excessive loading may be slowly progressive. In rare cases it may reach a point where there is catastrophic failure of the remaining osseointegration or fracture of the implant. Excessive forces may be detected prior to this stage through radiographic marginal bone loss or mechanical failure of the prosthodontic superstructure and/or abutments (see chap. 16).

It has been shown that normal/well-controlled forces may result in increases in the degree of bone to implant contact. Adaptation is limited, and osseointegration does not permit movement of the implant in the way that a tooth may be orthodontically repositioned. Therefore, the osseointegrated implant has proved itself to be a very effective anchorage system for difficult orthodontic cases.

Loading Protocols

Loading protocols, that is the duration of time between implant insertion and functional loading, have been largely empirical. The time allowed for adequate bone healing should be based on clinical trials that test the effects of factors such as bone quality, loading factors, implant type, etc. However, there is very limited data on the effects of these complex variables and currently there is no accurate measure that precisely determines the optimum period of healing before loading can commence. This has not limited the variety of protocols advocated, including the following:

- Delayed loading (for 3–6 months)
- Early loading (e.g., at 6 weeks)
- Immediate loading

Delayed Loading

This has been the traditional approach and has much to commend it as it is tried, tested, and predictable. Following installation of an implant, all loading is avoided during the early healing phase. Movement of the implant within the bone at this stage may result in fibrous tissue encapsulation rather than osseointegration. In partially dentate subjects, it may be desirable to provide temporary/provisional prostheses that are tooth supported. However, in patients who wear mucosally supported dentures, it has been recommended that they should not be worn over the implant area for one to two weeks. In the edentulous maxilla, we would normally advise that a denture is not worn for one week and in the mandible for two weeks because of the poorer stability of the soft tissue wound and smaller denture-bearing surface. Patients can normally wear removable partial prostheses directly after surgery, provided they are adequately relieved. The original Branemark protocol then advised leaving implants unloaded and buried beneath the mucosa for approximately six months in the maxilla and three months in the mandible, due mainly to differences in bone quality. Nowadays the majority of delayed loading protocols recommend a maximum three-month healing period for both jaws.

Early Loading

Many modern systems with moderately rough implant surfaces now advocate a healing period of just six weeks before loading. Some caution is recommended in that the implants should be placed in good quality bone in situations that are not subjected to high loads.

Immediate Loading

It has also been demonstrated that immediate loading is compatible with subsequent successful osseointegration, provided the bone quality is good and the functional forces can be adequately controlled. In studies on single tooth restorations, the crowns are usually kept out of contact in intercuspal and lateral excursions, thereby almost eliminating functional loading until a definitive crown is provided. In contrast, fixed bridgework allows connection of multiple implants providing good splinting and stabilization and therefore has been tested in immediate loading protocols with good success. However, the clinician should have a good reason to adopt the early/immediate loading protocols particularly as they are likely to be less predictable.

The early and immediate loading protocols are dealt with in more detail in chapter 11. The long-term functional loading of the implant-supported prosthesis is a further important consideration that is dealt with in the following section.

PROSTHETIC LOADING CONSIDERATIONS

Carefully planned functional occlusal loading will result in maintenance of osseointegration. In contrast, excessive loading may lead to bone loss and/or component failure. Clinical loading conditions are largely dependent on the following factors.

The Type of Prosthetic Reconstruction

This can vary from a single tooth replacement in the partially dentate case to a full arch reconstruction in the edentulous individual. Implants that support overdentures may present particular problems with control of loading as they may be largely mucosal supported, entirely implant supported, or a combination of the two.

The Occlusal Scheme

The lack of mobility in implant-supported fixed prostheses requires provision of shallow cuspal inclines and careful distribution of loads in lateral excursions. With single tooth implant restorations, it is important to develop initial tooth contacts on the natural dentition and to avoid guidance in lateral excursions on the implant restoration. Loading will also depend on the opposing dentition, which could be natural teeth, another implant-supported prosthesis, or a conventional removable prosthesis. Surprisingly high forces can be generated through removable prostheses.

The Number, Distribution, Orientation, and Design of Implants

The distribution of load to the supporting bone can be spread by increasing the number and dimensions (diameter, surface topography, length) of the implants. The spacing and three-dimensional arrangement of the individual implants will also be very important, and is dealt with in detail in chapter 5.

The Design and Properties of Implant Connectors

Multiple implants are usually joined by a rigid framework. This provides good splinting and distribution of loads between implants. It is equally important that the framework has a passive fit on the implant abutments so that loads are not set up within the prosthetic construction. However, some clinicians advocate restoring multiple implants as single unsplinted units—this requires sufficient space for an implant per tooth unit and consequently a higher number of implants.

Dimensions and Location of Cantilever Extensions

Some implant reconstructions are designed with cantilever extensions to provide function (and appearance) in areas where provision of additional implants is difficult. This may be due to practical or financial considerations. Cantilever extensions have the potential to create high loads, particularly on the implant adjacent to the cantilever. The extent of the leverage of any cantilever should be considered in relation to the anteroposterior distance between implants at the extreme ends of the reconstruction. This topic is dealt with in more detail in chapters 5 and 14.

Patient Parafunctional Activities

Great caution should be exercised in treating patients with known parafunctional activities.

CHOICE OF AN IMPLANT SYSTEM

In routine cases it may not matter which system is chosen, this is particularly the case with treatment in the anterior mandible. However, in our experience, choice of a system in any particular case depends on the following:

- The aesthetic requirements
- The available bone height, width, and quality (including whether the site has been grafted)
- Perceived restorative difficulties
- Desired surgical protocol

Therefore, we would suggest the following:

- In the aesthetic zone, choose an implant where the crown contour can achieve good emergence from the soft tissue with a readily maintainable healthy submucosal margin.
- Choose an implant of the appropriate length and width for the existing crestal morphology. Ensure that choice of a reduced width implant does not compromise strength in the particular situation.
- If the site will only accommodate a short implant or if the bone quality is poor or grafted, then splinting of implant units is more important.
- If there are likely to be difficulties with prosthodontic construction due to difficult angulation of the implants, choose a system that is versatile enough to cope with these difficulties, that is, has a good range solutions/components.
- If you wish to use a rapid treatment protocol, then choose a system that has a proven published record with that particular protocol.

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2

Treatment planning for implant restorations: general considerations

INTRODUCTION

This chapter provides an overall view of treatment planning. The reader should consult the chapters on planning for single tooth restorations, fixed bridges, and overdentures for more detailed considerations. The treatment plan should begin with a clear idea of the desired end result of treatment, which should fulfill the functional and aesthetic requirements of the patient. It is important that these treatment goals are realistic, predictable, and readily maintainable. Realistic means that the end result can be readily achieved and is not unduly optimistic. Predictable means that there is a very high chance of success of achieving the end result and that the prosthesis will function satisfactorily in the long term. The prosthesis should withstand normal wear and tear and not be subject to undue mechanical and technical complications (see chap. 16). Readily maintainable means that the prosthesis does not compromise the patient's oral hygiene and increases the patient's susceptibility to inflammation of the peri-implant tissues (see chap. 16 on peri-implant mucositis and peri-implantitis) and that the "servicing" implications for the patient and the dentist are acceptable.

In this chapter, it will be assumed that treatment options other than implant-retained restorations have been considered and there are no relevant contraindications (see chap. 1). Evaluation begins with a patient consultation and assessment of the aesthetic and functional requirements, and proceeds to more detailed planning with intraoral examination, diagnostic setups, and appropriate radiographic examination. At all stages in this process it is important to establish and maintain good communication (verbal and written) with the patient to ensure that they understand the proposed treatment plan and the alternatives.

Aesthetic considerations assume great importance in most patients with missing anterior teeth. This is an increasing challenge for the clinician and is related to

1. the degree of coverage of the anterior teeth (and gingivae) by the lips during normal function and smiling (Figs. 2.1A–C and 2.2A–C);
2. the degree of ridge resorption, both vertically and horizontally (Fig. 2.3A–C);
3. provision of adequate lip support (Fig. 2.4A,B).

The appearance of the planned restoration can be judged by producing a diagnostic setup on study casts or providing a provisional diagnostic prosthesis (Fig. 2.5A–C). The latter usually proves to be more informative for the patients as they can judge the appearance in their own mouth and even wear it for extended periods to adequately assess it. Both diagnostic casts and provisional prostheses can serve as a model for the fabrication of

1. a radiographic stent to assess tooth position in relation to the underlying ridge profile (Fig. 2.5D);
2. a surgical stent (or guide) to assist the surgeon in the optimal placement of the implants (Fig. 2.5E–H);
3. a transitional restoration during the treatment program (Fig. 2.5C).

Ideally, patients should be examined with and without their current or diagnostic prosthesis to assess

- facial contours;
- lip support;
- tooth position;
- how much of the prosthesis is revealed during function;
- occlusal relationships.

The diagnostic setup should then be adjusted if necessary to fulfill the requirements of the desired end result before proceeding with treatment.

Reduced or insufficient function is a common complaint for patients who have removable dentures or who have lost many molar teeth. Functional inadequacy is often a perceived problem of the patient and is assessed by interview rather than any specific clinical measure. The variation between individuals in how they perceive this problem is large. In patients who are accustomed to an intact arch of teeth from second molar to second molar, the loss of a single molar can be completely unacceptable, and replacement with a conventional fixed prosthesis or implant restoration becomes necessary. In contrast, a shortened dental arch extending to the first molar or second premolar may provide adequate function and appearance for some patients. However, missing maxillary premolars (and occasionally first molars) often present an aesthetic problem.

Provisional dentures can be used to clarify these needs, for example how many posterior units are required to satisfy both appearance and function.

INITIAL CLINICAL EXAMINATION

A thorough extraoral and intraoral clinical examination should be carried out on all patients to ensure diagnosis of all existing dental and oral disease. The diagnosis and management of caries, periodontal disease, and endodontic problems is not the remit of this book and the reader is referred to other more relevant texts. However, it is very important to remember that susceptibility to periodontitis is associated with more implant loss and peri-implantitis, and implants placed close to apical endodontic lesions may fail. Factors of more specific relevance to implant treatment are dealt with here and in the related more detailed sections on single teeth, fixed bridges, and overdentures.

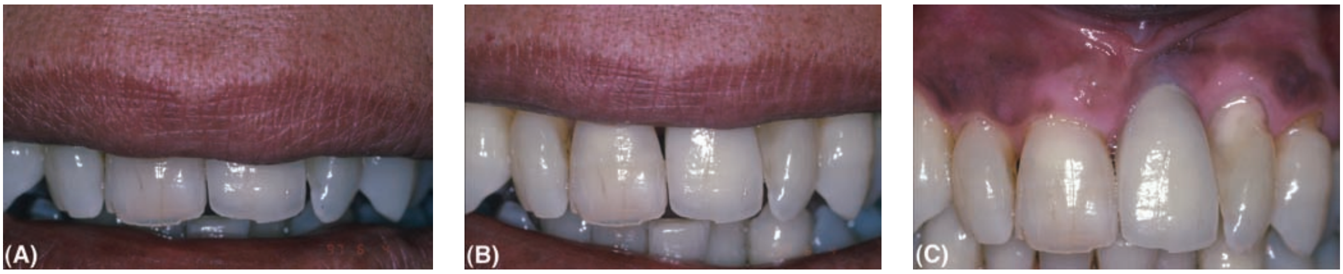

Figure 2.1 (**A**) In normal function this patient reveals the incisal half of the anterior teeth. (**B**) The same patient smiling reveals most of the crowns of the teeth, but not the gingival margins. (**C**) The patient with the lips retracted showing a gross discrepancy of the gingival margins that is not visible in normal function and smiling.

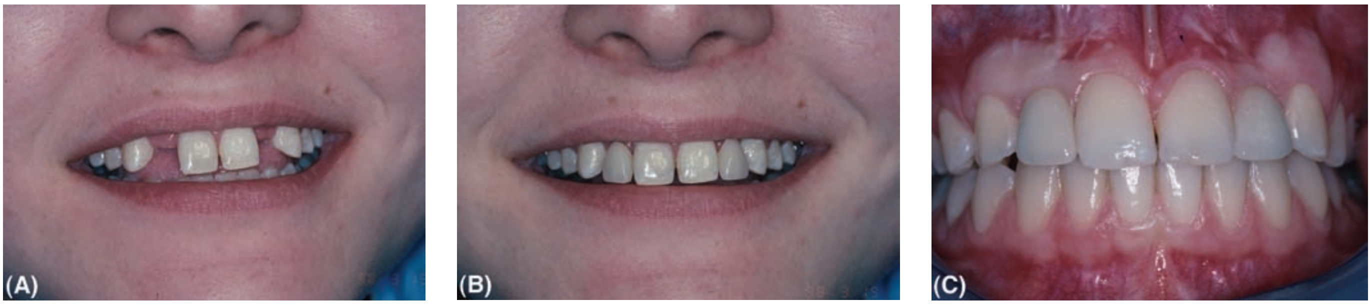

Figure 2.2 (**A**) A young patient with missing maxillary lateral incisors. (**B**) The same patient wearing an existing partial denture allows assessment of the aesthetics and tooth position. (**C**) The completed result with two single tooth implants replacing the lateral incisors.

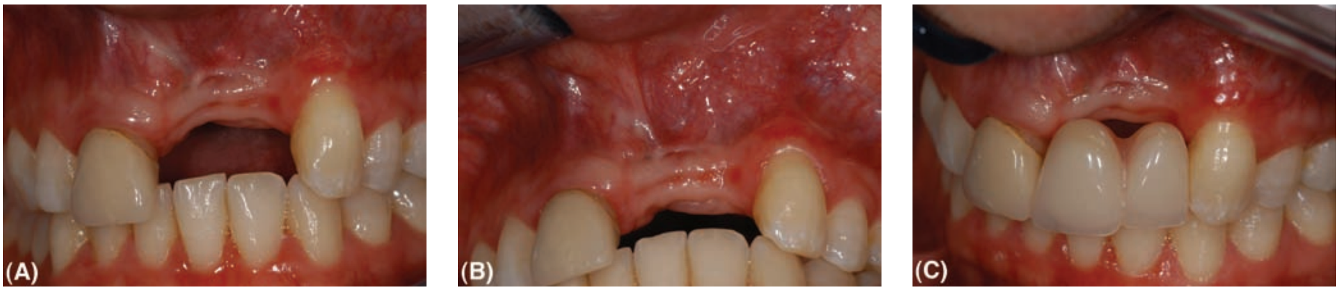

Figure 2.3 (**A**) A patient with missing maxillary central and lateral incisor, showing loss of vertical ridge height. (**B**) The occlusal view shows some loss of ridge width. (**C**) The patient wearing a removable prosthesis showing the discrepancy between the tooth height and the underlying ridge form.

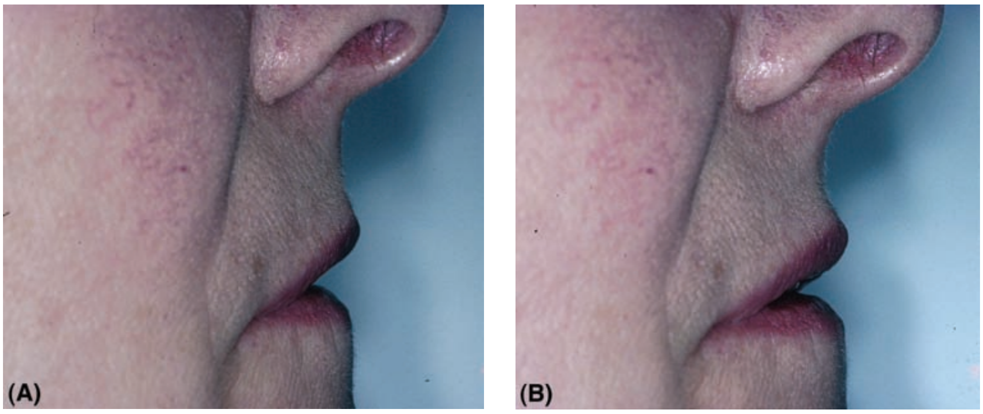

Figure 2.4 (**A**) Profile of a patient wearing a removable denture with a labial flange to provide lip support. (**B**) Profile of the same patient showing poorer lip support, following removal of the labial flange.

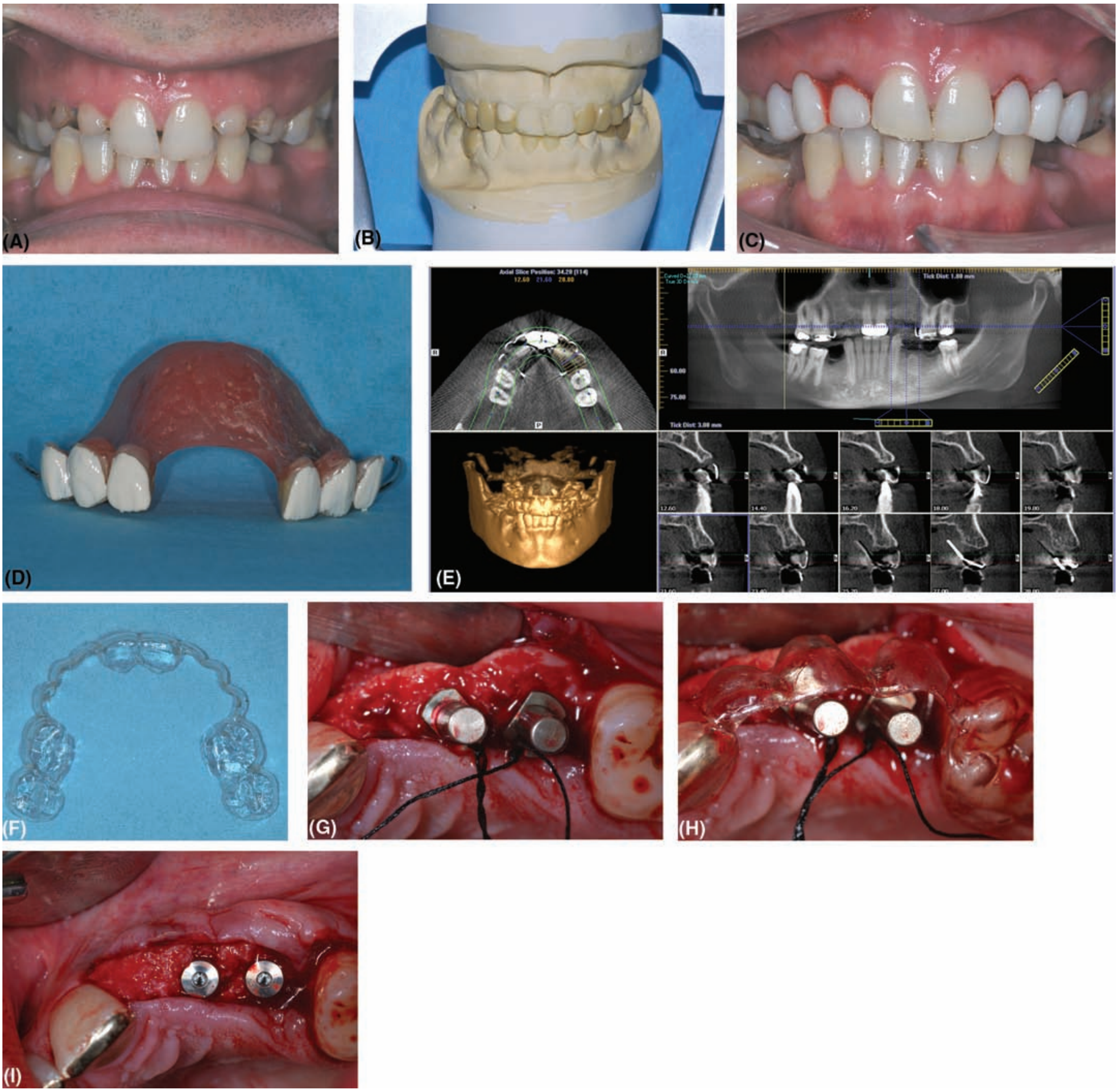

Figure 2.5 (**A**) A patient with severe hypodontia and retained deciduous teeth in the maxillary lateral incisor, canine, and premolar areas. (**B**) Articulated study casts with a diagnostic wax-up. (**C**) The patient has been fitted with an immediate replacement partial denture based on information from the diagnostic wax-up. (**D**) The partial denture has been coated on the labial surfaces with a radiopaque medium (TempBond). (**E**) A cone-beam CT of the same patient wearing the denture with radiopaque medium. The outline of the teeth can be seen in relationship to the underlying ridge form. (**F**) A blowdown plastic surgical stent constructed based on the diagnostic denture. (**G**) Direction indicator placed in the implant site preparations at surgery. (**H**) The surgical stent in place showing a good relationship between the indicator post and the planned tooth position. (**I**) The implants inserted and cover screws placed.

Evaluation of the Edentulous Space or Ridge

The height, width, and contour of the edentulous ridge can be visually assessed and carefully palpated (Fig. 2.6A–F). The presence of concavities/depressions (especially on the labial aspects) is usually readily detected. However, accurate assessment of the underlying bone width is difficult especially where the overlying tissue is thick and fibrous. This occurs particularly on the palate where the tissue may be very thick/dense and can result in a very false impression of the bone profile. The thickness of the soft tissue can be measured by puncturing the soft tissue with a calibrated probe after administering local anesthetic or carrying out a more detailed ridge mapping.

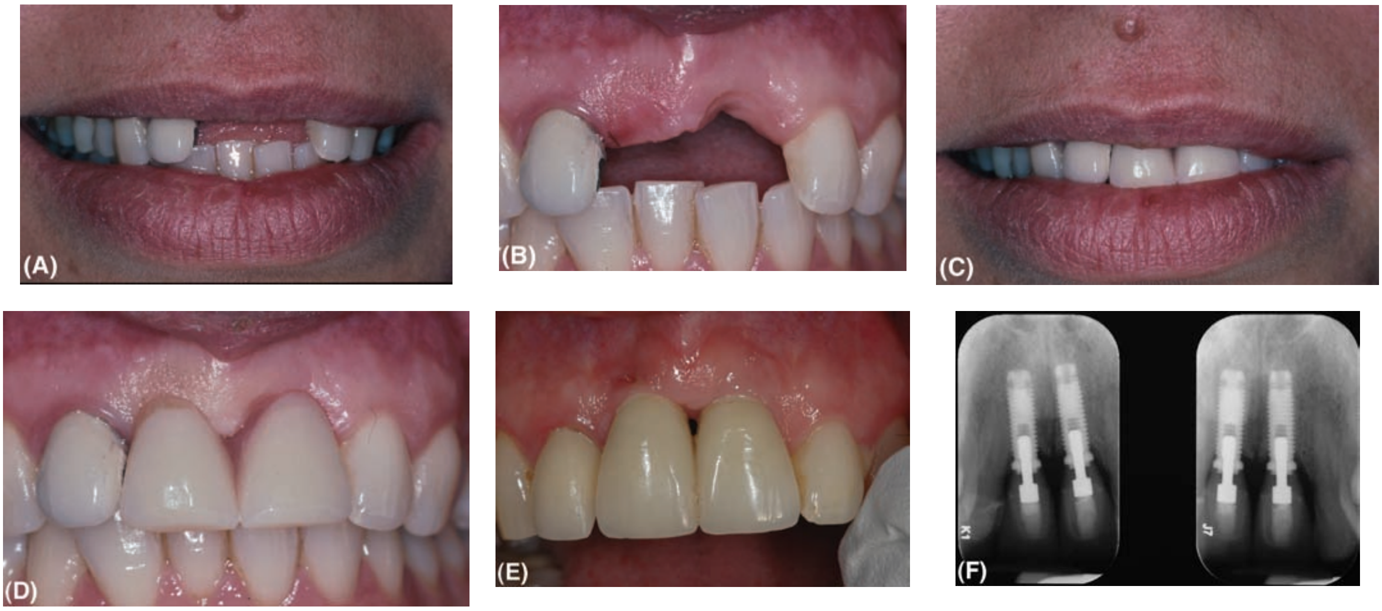

Figure 2.6 (**A**) A patient with missing maxillary central incisors following loss of a fixed prosthesis. (**B**) The intraoral view showing good ridge height at tooth 11 but loss of vertical height at tooth 21. (**C**) The patient with a diagnostic denture in place with lips at rest. (**D**) The intraoral appearance of the diagnostic denture. There is no labial flange and the discrepancy in ridge height between teeth 11 and 21 is less obvious. This patient was treated without the ridge augmentation. (**E**) The same patient treated with single tooth implants after a period of eight years. The clinical crown heights of the central incisors are symmetrical but longer than the adjacent natural teeth. (**F**) The radiographs eight years following treatment showing ideal bone levels at the first thread of the Branemark implants. The abutments and crowns are ceramic.

However, 3D tomography to examine the bone profile is more commonly used (Fig. 2.5E).

The profile/angulation of the ridge and its relationship to the opposing dentition is also important. The distance between the edentulous ridge and the opposing dentition should be measured to ensure that there is adequate room for the prosthodontic components (Fig. 2.7). This will vary with the implant system being used and whether the prosthesis is to be cemented or screw retained. Retention of a cemented prosthesis is dependent on the abutment height and parallelism (which is more readily achieved with CAD-CAM technology), whereas a screw-retained prosthesis has to have sufficient height to accommodate the abutment/abutment screw and prosthesis-retaining screw (ideally with sufficient place to place a protective restoration over it). These factors are dealt with in more detail in chapters 13 and 14. Proclined ridge forms will tend to lead to proclined placement of the implants that could affect loading and aesthetics, especially if a screw-retained prosthesis requires angulated abutments. Increased vertical space between opposing jaws (Fig. 2.8) will result in a prosthesis with an increased vertical height that will be subject to higher leverage forces. Large horizontal discrepancies between the jaws, for example, the pseudo class 3 jaw relationship following extensive maxillary resorption must be recognized, and management appropriately planned. This may be solved by prescription of an overdenture treatment (see chaps. 6 and 15) or extensive grafting/orthognathic surgery (see chap. 12).

The clinical examination of the ridge also allows assessment of the soft tissue thickness, which is important for the attainment of good aesthetics. Keratinized tissue, which is attached to the edentulous ridge, will also generally provide

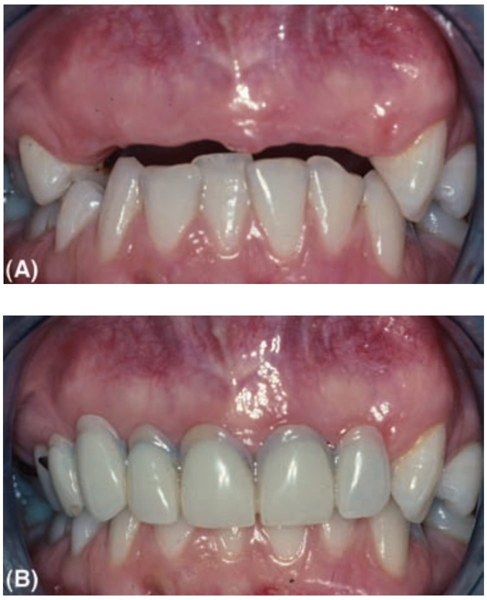

Figure 2.7 (**A**) A patient with missing maxillary anterior teeth in whom the lower incisors nearly touch the soft tissue ridge in centric occlusion. The space available for implant components will depend on the level of placement of the implant heads in the underlying bone. (**B**) The same patient with the existing partial denture. The prosthetic teeth have been ridge-lapped and no labial flange has been provided. The denture teeth produce a considerable overlap of the existing ridge. Implants would have to be placed in a submerged position to allow an emergence of the implant crowns at the cervical level of these teeth.

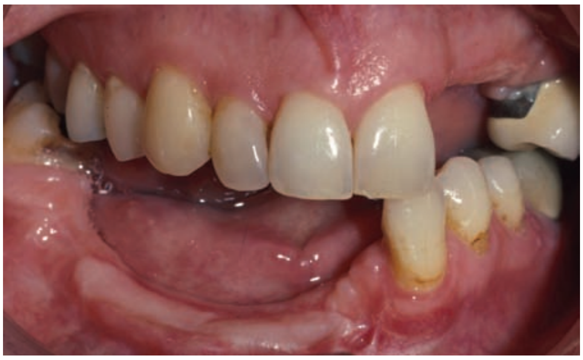

Figure 2.8 This patient has suffered extensive loss of mandibular bone following a road traffic accident that resulted in a fractured mandible and osteomyelitis. There is now a marked vertical and horizontal discrepancy between the jaws.

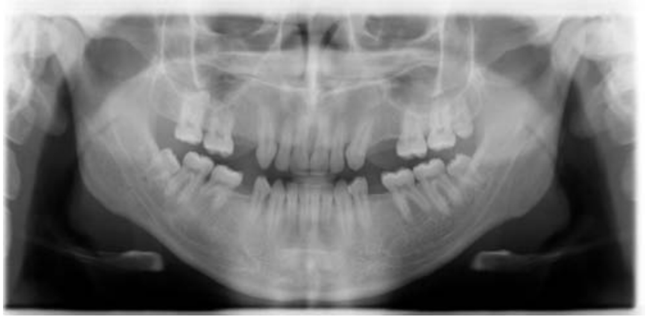

Figure 2.9 A dental panoramic tomogram provides a very good radiograph to show the major anatomical features of the jaws in relation to the existing teeth. This patient has good bone height in the premolar regions of the upper and lower jaw. The maxillary sinuses do not encroach upon the maxillary premolar sites and the mental nerve and inferior dental nerve are located well apically.

a better peri-implant soft tissue than nonkeratinized mobile mucosa. The mesiodistal length of the edentulous ridge can be measured to give an indication of the possible number of implants that could be accommodated (see chap. 1). This is best done with calipers and a millimeter rule. The space should be measured between the tips of the crowns, the maximum contour of the crowns, and at the level of the edentulous ridge. However, this also requires reference to

1. radiographs to allow a correlation with available bone volume;
2. the diagnostic setup for the proposed tooth location;
3. the edentulous ridges bound by teeth; the available space will also be affected by angulation of adjacent tooth roots, which may be palpated and assessed radiographically.

INITIAL RADIOGRAPHIC SCREENING

A screening radiograph should give the clinician an indication of

1. overall anatomy of the maxilla and mandible and potential vertical height of available bone;
2. anatomical anomalies or pathological lesions;
3. sites where it may be possible to place implants without grafting and sites that would require grafting;
4. restorative and periodontal status of remaining teeth;
5. length, shape, angulation, and proximity of adjacent tooth roots.

In many instances the dental panoramic tomograph (DPT) is the radiograph of choice (Fig. 2.9). It provides an image within a predefined focal trough of both upper and lower jaws that gives a reasonable approximation of bone height, the position of the inferior dental neurovascular bundle, the size and position of the maxillary antra, and any pathological conditions that may be present. It is therefore an ideal view for initial treatment planning and for providing patient information as it presents the image in a way that many patients are able to understand. Some areas may not be imaged particularly well, but this can be minimized by ensuring that the patient is positioned correctly in the machine and that the appropriate program is selected. It provides more information about associated anatomical structures than periapical radiographs but with less fine detail of the teeth. It should be remembered that all DPTs are magnified images (at approximately ×1.3). Distortion also occurs in the anteroposterior dimension reducing their usefulness when planning implant spacing/numbers. The initial screening radiograph allows selection of the most appropriate radiographic examination for definitive planning (see sections on single teeth, fixed bridgework, and overdentures) and together with the clinical examination indicates whether 3D scanning is needed.

STUDY CASTS AND DIAGNOSTIC SETUPS

Articulated study casts allow measurements of many of the factors considered in the previous section. The proposed replacement teeth can be positioned on the casts using either denture teeth or teeth carved in wax (Fig. 2.5B, C). The former have the advantage that they can be converted into a temporary restoration that can be evaluated in the mouth by clinician and patient. The diagnostic setup therefore determines the number and position of the teeth to be replaced and their occlusal relationship with the opposing dentition.

Once the diagnostic setup has been agreed by the patient and clinician, it can be used to construct a stent (or guide) for radiographic imaging and surgical placement of the implants (Fig. 2.5D–F). The stent/guide can be positioned on the original cast, and with reference to the radiographs the clinician can decide upon the optimum location, number, and type of implants (see chap. 5).

BASIC TREATMENT ORDER

Deciding on the treatment order may be very straightforward in some circumstances and in others extremely difficult, particularly for those cases involving transitional restorations.

A traditional plan may include the following:

1. Examination—clinical and initial radiographic
2. Diagnostic setup, provisional restoration, and specialized radiographs if required
3. Discussion of treatment options with the patient and decision on final restoration
4. Completion of any necessary dental treatment including
   - Extraction of hopeless teeth
   - Periodontal treatment

- Restorative treatment, new restorations and/or endodontics as required

5. Construction of provisional or transitional restorations if required
6. Construction of surgical guide or stent
7. Surgical placement of implants
8. Allow adequate time for healing/osseointegration according to protocol, bone quality, and functional demands
9. Prosthodontic phase

CONCLUSION

It is imperative to consider all treatment options with the patient, and during detailed planning it may become apparent that an alternative solution is preferred. In all cases the implant treatment should be part of an overall plan to ensure health of any remaining teeth and soft tissues. Once the goal or end point has been agreed it should be possible to work back to formulate the treatment sequence. The cost of the proposed treatment plan is also of great relevance. The greater the number of implants placed, the higher will be the cost, and this may therefore place limits on treatment options. In difficult cases it is better to place additional implants to the minimum number required to take account of possible failure and improved predictability and biomechanics.

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3

Single tooth planning in the anterior region

INTRODUCTION

Single tooth restorations are often thought to be the most demanding implant restorations, particularly from the aesthetic viewpoint. Achievement of an ideal result is dependent on

1. the status of the adjacent teeth;
2. the ridge and soft tissue profile;
3. planning and precise implant placement;
4. sympathetic surgical handling of the soft tissue;
5. a high standard of prosthetic restoration.

The assessment and planning are dealt with in this chapter and surgical and prosthodontic factors in subsequent chapters.

CLINICAL EXAMINATION

Examination should start with an extraoral assessment of the lips and the amount of tooth or gingiva that is exposed when the patient smiles (Fig. 3.1). A high smile line exposing a lot of gingiva is the most demanding aesthetically with both conventional and implant prosthodontics. The appearance of the soft tissue and particularly the height and quality of the gingival papillae on the proximal surfaces of the teeth adjacent to the missing tooth are important in these cases (Fig. 3.2). If there has been gingival recession, this should be noted. Exposure of root surface on the adjacent teeth labial surfaces may be correctable with periodontal mucogingival plastic surgery procedures, but recession on proximal surfaces is not usually correctable. The patient needs to be made aware of the limitations (which are the same as those that apply to tooth supported fixed bridgework). It is always easier to judge the aesthetic problems if the patient has an existing replacement, preferably one without prosthetic replacement of soft tissue. A simple "gum-fitted" removable partial denture, which has a satisfactory appearance, is very helpful (Fig. 3.3). The height of the edentulous ridge and its width and profile should be assessed by careful palpation. Large ridge concavities are usually readily detected. Ridge mapping is advocated by some clinicians. In this technique, the area under investigation is given local anesthesia and the thickness of the soft tissue measured by puncturing it to the bone using either a graduated periodontal probe or specially designed calipers. The information is transferred to a cast of the jaw, which is sectioned through the ridge. This method gives a better indication of bone profile than simple palpation but is still prone to error. Whenever the clinician is in doubt about the bone width and contour, it is advisable to request a radiographic examination that will achieve this (see section on sectional tomography).

One of the most important assessments is measurement of the tooth space at the level of the crown, at the soft tissue margin (narrowest point between natural teeth at gingival level), and between the roots (Fig. 3.4). The first is important for the aesthetics and is best judged by measuring the width of the crown in comparison to the contralateral natural tooth if present. The available width at the root level determines whether an implant and abutment can be accommodated without compromising the adjacent tooth roots and soft tissue. A commonly quoted minimal dimension is 6 mm, both in the mesiodistal and buccolingual plane. This allows for an average implant of 4 mm diameter to have a margin of 1 mm of bone surrounding it. It is of equal importance to have sufficient space around the abutment and implant crown for a healthy soft tissue cuff and soft tissue attachment to the adjacent natural teeth. The mesiodistal dimension is commonly compromised in the maxillary lateral incisor region and the lower incisor region where the natural teeth are small (Figs. 3.2 and 3.5). In the case of young patients with developmentally missing maxillary incisors, it is advisable to liaise with the treating orthodontists to agree space requirements and to check that adequate space has been achieved before removal of the orthodontic appliance. The adjacent root alignment can sometimes be palpated, but usually requires verification radiographically. Spaces that are 5 mm wide mesiodistally may be amenable to treatment with a narrow diameter implant/abutment (e.g., 3.3 mm rather than 4 mm diameter), provided the forces it is subjected to are not too high (Fig. 3.5). For example, utilization of narrow implants would be contraindicated in a patient with a parafunctional activity such as bruxism.

However, patients with a spaced dentition have excess mesiodistal space. Provided the ridge has an adequate buccolingual width, the clinician could plan to place a wider diameter implant that more closely matches the root of the tooth that is being replaced (Figs. 3.6 and 3.7). The selection of the most appropriate diameter implant has a bearing on the aesthetics and surgery. This is dealt with in more detail in the surgical section (see chap. 9), which also compares some of the implant systems available.

Examination of the Occlusion

This can be usually be accomplished by simple clinical examination. The adjacent tooth contacts (and that of the preexisting prosthetic replacement if available) should be examined in centric occlusion, retruded contact, and protrusive and lateral excursions. Occlusal contacts on the single tooth implant restoration should be designed such that contacts occur first on adjacent teeth. This takes account of the normal physiologic mobility of the teeth compared to the rigid osseointegrated implant. Difficulties can arise when replacing canines in a canine-guided occlusion. Under these circumstances, attempts should be made to achieve group function and light contacts on the implant restoration. Similar precautions are required with central and lateral incisor replacements in class 2 division 2 incisor relationships with deep overbites (Fig. 3.8).

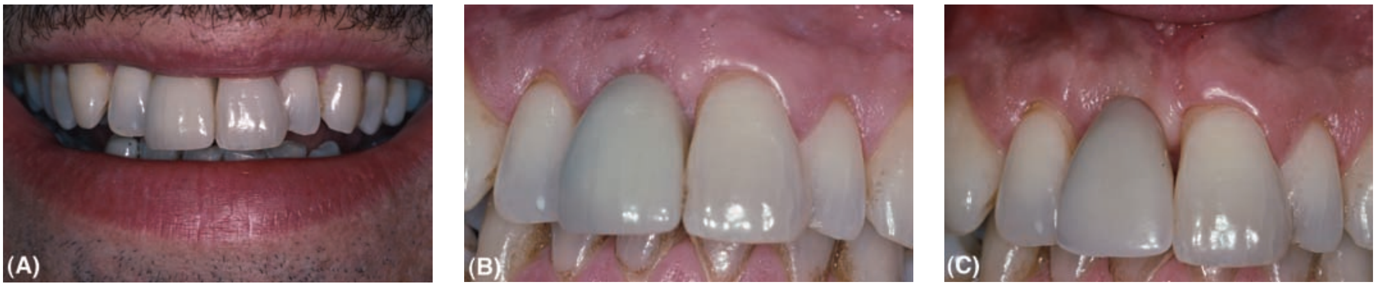

Figure 3.1 (**A**) This patient who has tooth 11 replaced with a single tooth implant does not expose any gingival tissue when he smiles. (**B**) An intraoral view of the single tooth implant at position 11. Note that the adjacent incisors have small amounts of gingival recession on the labial and proximal surfaces, which was present before treatment. This loss of attachment on the proximal surfaces affects papillary height and is very difficult or impossible to regain. (**C**) The same patient before implant treatment, confirming the position of the gingival margins on the natural teeth. The prosthesis is a simple gum-fitted spoon denture, which provides acceptable aesthetics but poor function. It is a useful diagnostic aid.

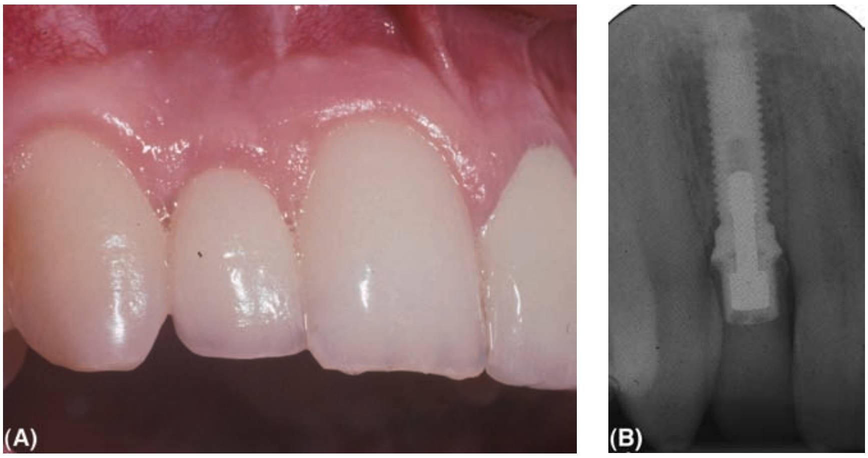

Figure 3.2 (**A**) Replacement of a small upper lateral incisor with a single tooth implant showing good soft tissue form and aesthetics. (**B**) Radiograph of the single tooth implant, which in this case is a narrow diameter (3.3 mm) Nobel Biocare implant. Narrow implants are normally only suitable for low load situations.

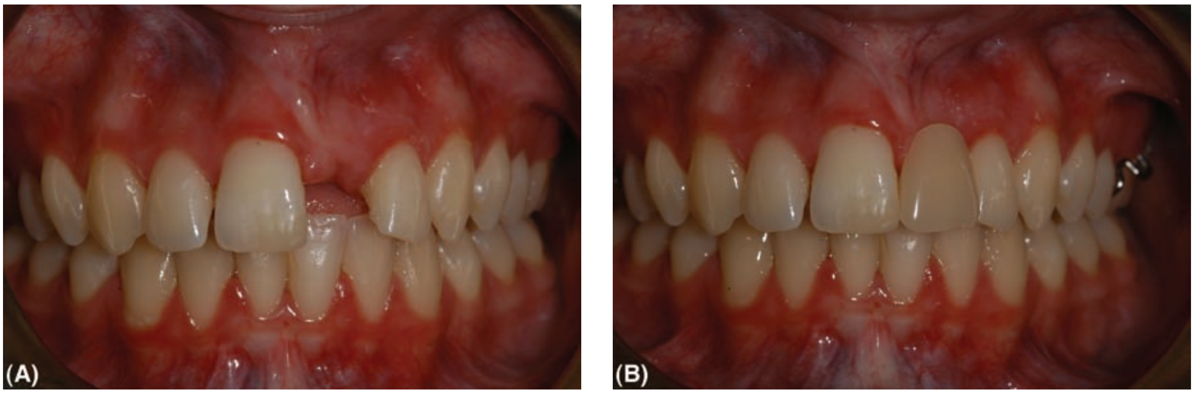

Figure 3.3 (**A**) A patient with a missing maxillary central incisor tooth. (**B**) The same patient with a simple removable diagnostic denture showing the relationship between the cervical margin and the underlying ridge.

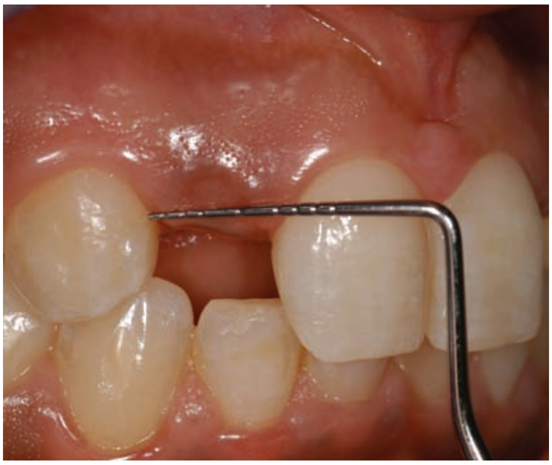

Figure 3.4 Measurement of the edentulous space can readily be performed with a calibrated periodontal probe or caliper. It is important to measure the narrowest point between the crowns of the adjacent teeth at the level of the soft tissue. This clinical assessment will be supplemented with radiographic measures.

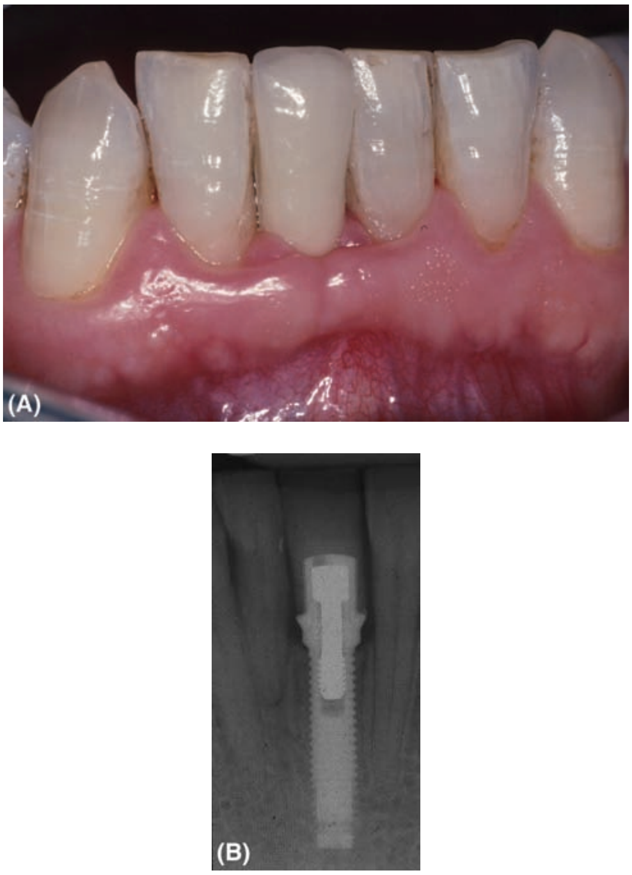

Figure 3.5 (**A**) Replacement of the lower right central incisor with a single tooth implant is particularly challenging because of the limited space available. (**B**) Radiograph of a narrow diameter (3.3 mm) Nobel Biocare implant. The standard abutment is relatively wide and may compromise the soft tissue morphology. A resin-bonded bridge is often a more suitable method of replacement of single mandibular incisor teeth.

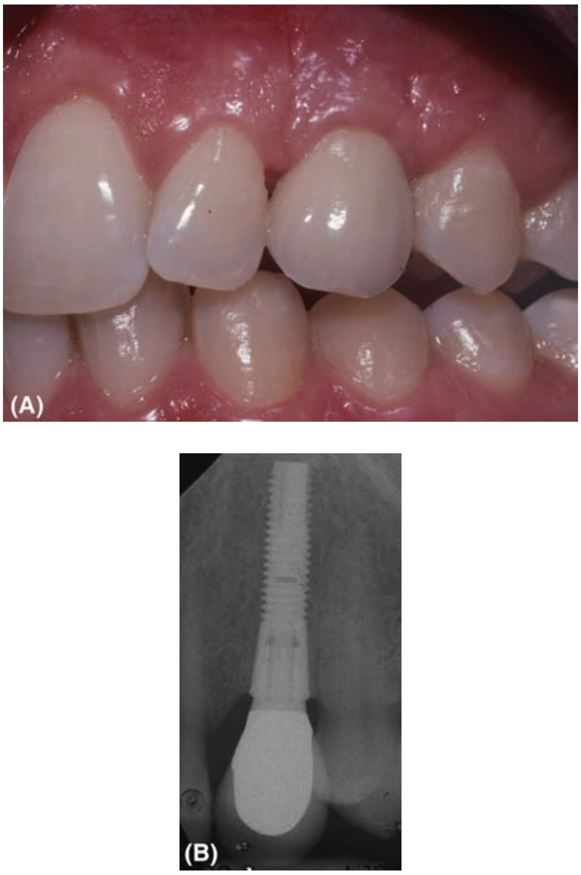

Figure 3.6 (**A**) The maxillary canine has been replaced with an Astra Tech implant of suitable diameter to withstand the high forces in this application. (**B**) Radiograph of the implant showing ideal bone levels at the top of the implant, a titanium abutment and a metal ceramic crown. The design of the implant abutment junction and the material selected are important in reducing future mechanical complications.

RADIOGRAPHIC EXAMINATION

Radiography for single tooth replacement in individuals with little bone loss can normally be accomplished by intraoral radiographs taken with a long cone paralleling technique (Fig. 3.9). However, it must be remembered that an overall evaluation of the mouth should be made for a full assessment of treatment needs. Image quality is of the utmost importance and the clinician should ensure that all relevant anatomical structures are shown on the image being used and that any allowances for distortion of the image are made. It can be surprisingly difficult to obtain accurate radiographic mesiodistal measurements of spaces at sites in the arch such as the maxillary lateral incisors/canines and the mandibular canines (Fig. 3.9). This is due to the curvature of the arch and the difficulty of achieving parallel film alignment with the space. The clinical measures can be checked against the radiographic ones to obtain a more accurate estimate.

Sectional Tomography

Although some clinicians routinely use CT scans for single tooth planning, we would consider this to be in excess of what is normally required. CT scans, however, may be very important aids with some areas such as the maxillary central incisors

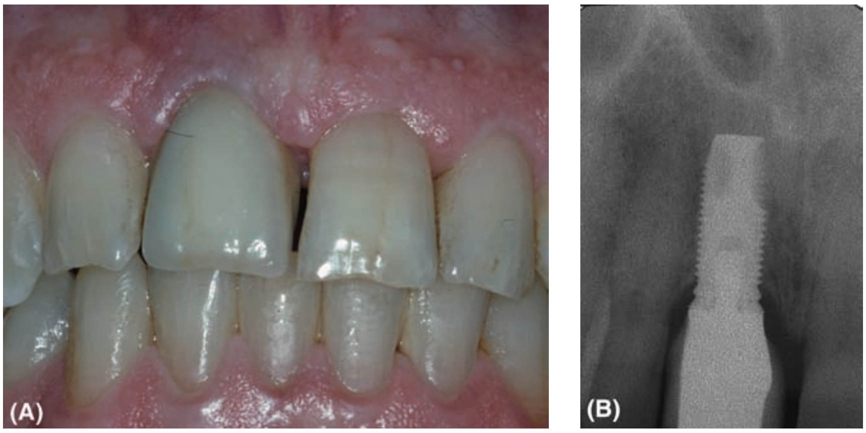

Figure 3.7 (**A**) The upper right central incisor has been replaced with a 5-mm-diameter Nobel Biocare implant. (**B**) Radiograph of the wide diameter implant showing bone at the first thread. Standard diameter implants of approximately 4 mm in diameter are more commonly used in the incisor region, whereas wider diameter implants are indicated in the molar regions where forces are higher.

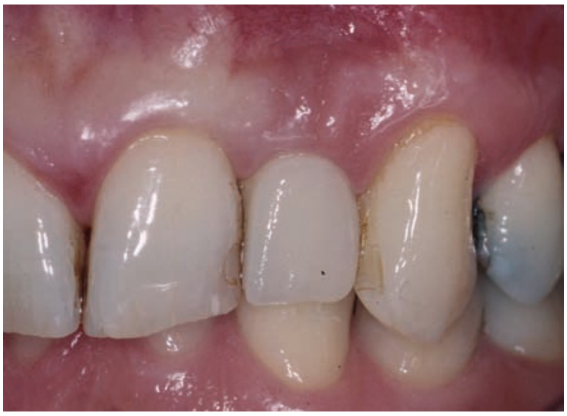

Figure 3.8 The upper lateral incisor has been replaced using an Astra Tech implant six years ago. There has been complete stability and no complications despite the difficult class 2 division 2 incisor relationship.

where the presence of the incisive canal may compromise implant placement (Figs. 3.10 and 3.11). CT scans are more commonly used in complex cases and they are also dealt with in the chapter on fixed bridge planning (see chap. 5). Many modern dental panoramic tomogram (DPT) machines now offer sectional tomography for implant planning (see below).

To optimize the information provided by 3D radiographic techniques, it is helpful to provide information about the planned final restoration. A suitable existing partial denture or a customized stent that mimics the desired tooth setup is constructed and radiographic markers incorporated. The radiopaque marker can be placed in the cingulum area of the tooth if a screw-retained crown is planned to indicate the access hole for the screw. Alternatively, the labial surface of the stent can be painted with a radiopaque medium such as TempBond to show the labial profile and cervical margin of the planned crown in relation to the underlying bone ridge (Fig. 3.12). Simpler types of stent involve placing radiopaque markers, for example, ball bearings of various diameters, into a baseplate, designed to help determine mesiodistal distortion and location.

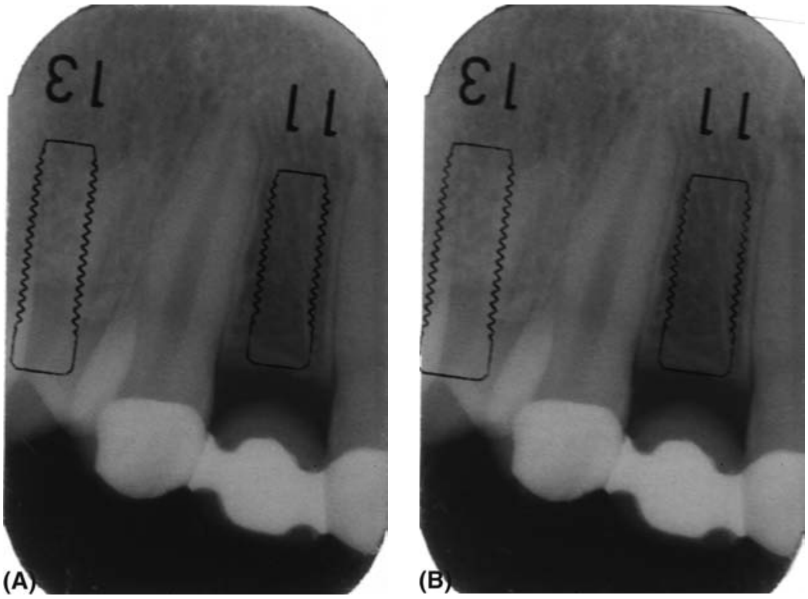

Figure 3.9 (**A**) An intraoral radiograph of a maxillary lateral incisor space with an overlay showing an 11-mm-long × 3.5-mm-diameter implant allowing an assessment of distance between the implant surface and adjacent tooth root. (**B**) The same radiograph with the outline of a 4-mm-diameter implant suggesting that there would be no more than 1 mm of bone available between the implant surface and adjacent tooth root. This would require very precise implant placement to avoid damage to the adjacent teeth.

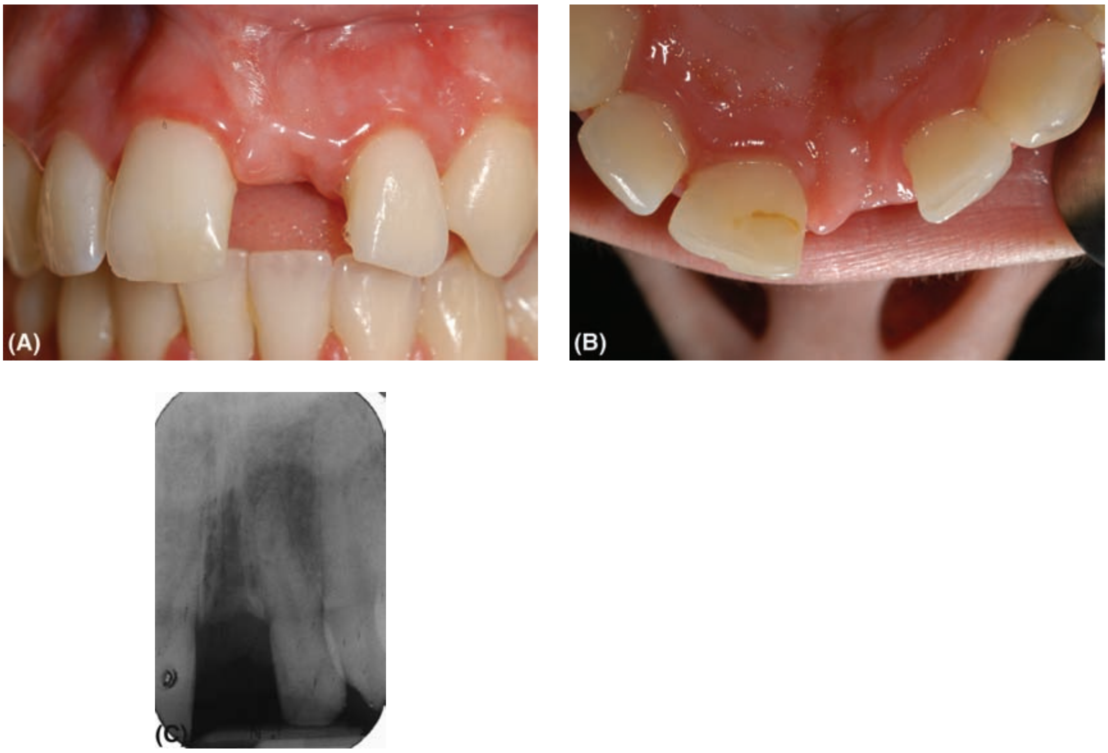

Figure 3.10 (**A**) The labial view of the missing maxillary central incisor suggests good ridge height and morphology. (**B**) The occlusal view of the same case shows a prominent incisive papilla and relatively narrow space. (**C**) A radiograph of the case shows that the incisive canal occupies most of the edentulous space and there is slight convergence of the adjacent tooth roots. If an implant were planned, this may require both orthodontic tooth movement and bone grafting of the incisive canal.

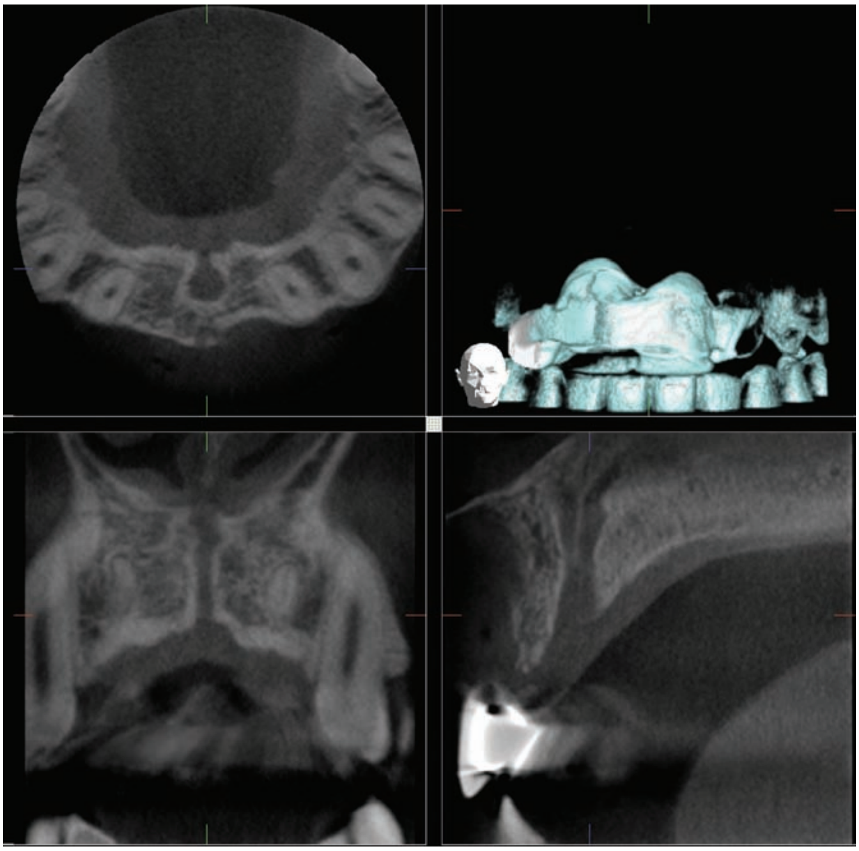

Figure 3.11 A series of cone-beam CT sections of the incisive canal. The upper left shows the canal in the axial plane, the lower left in the coronal plane, and the lower right in the sagittal plane. The top right is a 3D reconstruction showing the radiographic stent. The incisive canal occupies a larger proportion of the bone volume between the adjacent incisor roots.

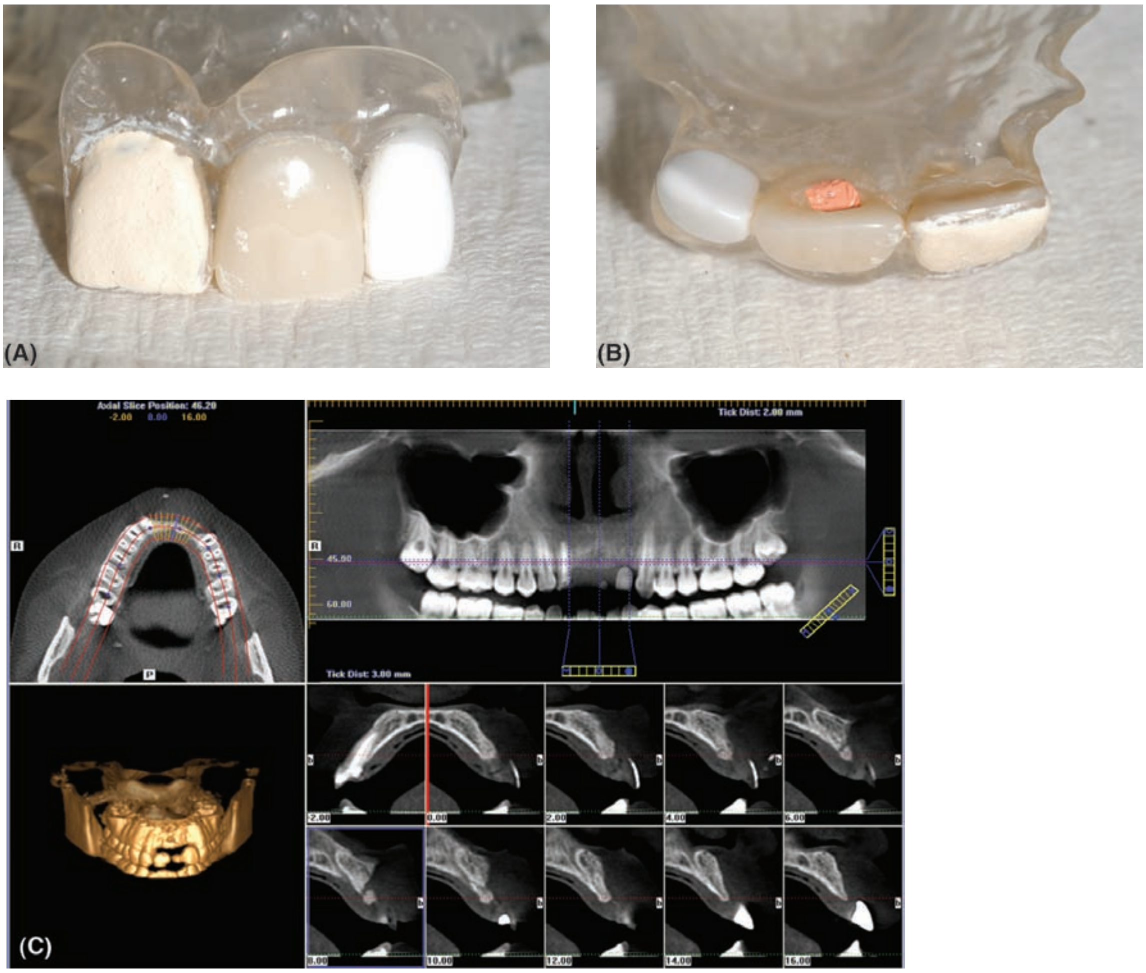

Figure 3.12 (**A**) A radiographic stent shown from the labial aspect. The upper right central incisor has a radiopaque medium on the labial surface and the upper left lateral incisor is a manufactured radiopaque tooth. (**B**) An occlusal view of the radiographic stent showing the upper left central incisor with a gutta percha restoration placed in the cingulum denoting the point of ideal screw access. (**C**) A cone-beam radiograph of the same case with the radiographic stent in situ showing the relationship of the various radiopaque markers to the underlying ridge form.

The early Scanora (Soredex, Finland) was an example of a tomographic machine with facilities to generate high-quality sectional images, although these have largely been superseded by cone-beam CT. In contrast to CT scanning where the sectional images are software generated, the Scanora produced a tomographic image directly onto film. It used complex broad beam spiral tomography and was able to scan in multiple planes. The scans were computer controlled with automatic execution. They relied on good patient positioning and experience in using the machine. The patient's head was carefully aligned within the device and this position recorded with skin markers and light beams. A conventional DPT image was produced from which the sites which require sectional tomographs were determined (Fig. 3.13). The patient was repositioned in exactly the same alignment and the appropriate tomographic programme selected for the chosen region of the jaw.

The Scanora magnification was ×1.3 or ×1.7 for routine DPTs but ×1.7 for all sectional images. Tomographic sections were normally 2 mm or 4 mm in thickness. As with all tomograms the image produced includes adjacent structures which are not within the focal trough which therefore appear blurred and out of focus.

To facilitate planning using images at different magnifications, transparent overlays depicting implants of various lengths and diameters at the corresponding magnifications can be superimposed directly on the radiograph (Figs. 3.9A, B, and 3.13B). These provide a simple method of assessing implant sites and implant placement at different angulations.

DIAGNOSTIC SETUPS

Patients with aesthetically acceptable provisional restorations may not require diagnostic wax-ups. There are considerable advantages in using the preexisting prosthesis or a new provisional restoration that can be worn by the patient to provide a realistic potential end-result. This can be agreed upon between patient and clinician and recorded. Wax-ups are difficult for the patient to judge, and computer-manipulated images may not be entirely realistic or achievable. We routinely use simple acrylic removable prostheses for this purpose (Fig. 3.3, and see below). The setup should establish the emergence profile of the crown and estimate the level of emergence from the soft tissue at the planned cervical/gingival margin.

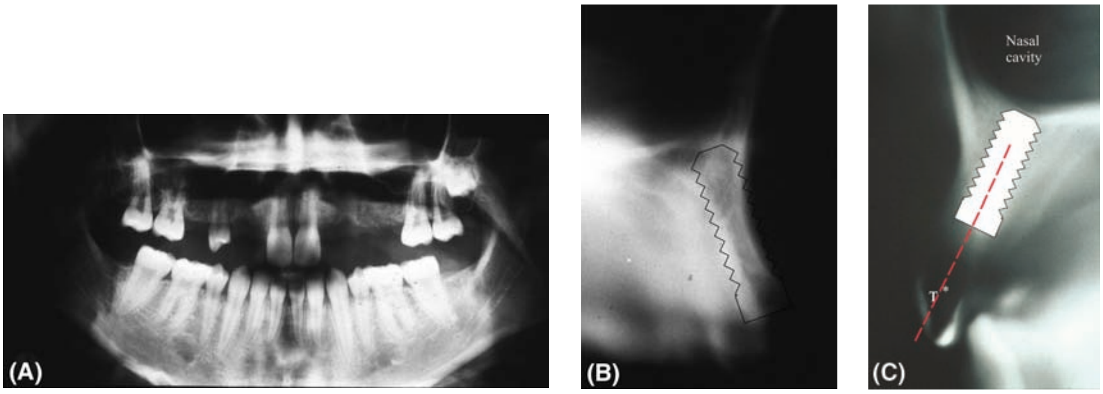

Figure 3.13 (**A**) A dental panoramic tomogram taken on a Scanora at ×1.7 magnification. The young patient has a large number of developmentally missing teeth, including maxillary lateral incisors and canines. (**B**) A sectional tomogram of the anterior ridge, which is angled labially and is thinner than the outline of the superimposed 4-mm-diameter implant. (**C**) The sectional profile of the tooth (T*) to be replaced can be visualized by coating the radiographic stent with a radiographic medium. The Scanora section of this wider ridge profile has been assessed using a transparent overlay of the appropriate implant design, which can be accommodated within the available bone volume. The red dashed line shows that the angle at the implant would pass through the labial face just apical to the incisal tip. A cemented restoration would be satisfactory.

CEMENTED OR SCREW-RETAINED CROWNS

The preceding information should provide the clinician with sufficient information to indicate whether it is possible and or desirable to provide a cemented or screw-retained crown (Fig. 3.14). This is dealt with in some detail in chapter 9, but needs to be considered here. Nowadays most anterior single tooth crowns are cemented. This produces very good aesthetics without a visible screw hole on the palatal surface, even though this can be carefully restored with tooth-colored restorative material. Optimum labial contour and emergence profile is achieved with an implant that is angled with its long axis passing through the incisal tip or slightly labial to it (Fig. 3.15). This restoration cannot be screw retained. However, in cases where there has been fairly extensive ridge resorption that has not been corrected by bone grafting, the position and angle of the implant may be more palatal (Fig. 3.15D). Screw retention through the palatal surface permits full retrievability of the crown and would make it possible to retighten a loose abutment should it occur (Fig. 3.16). The disadvantage is that it is usually associated with a ridge lap labial margin (Fig. 3.15C). The above mainly applies to the upper incisors and canines. In the premolar zone, the implant is normally in the long axis of the crown allowing either cementation or screw, according to the clinician's preference.

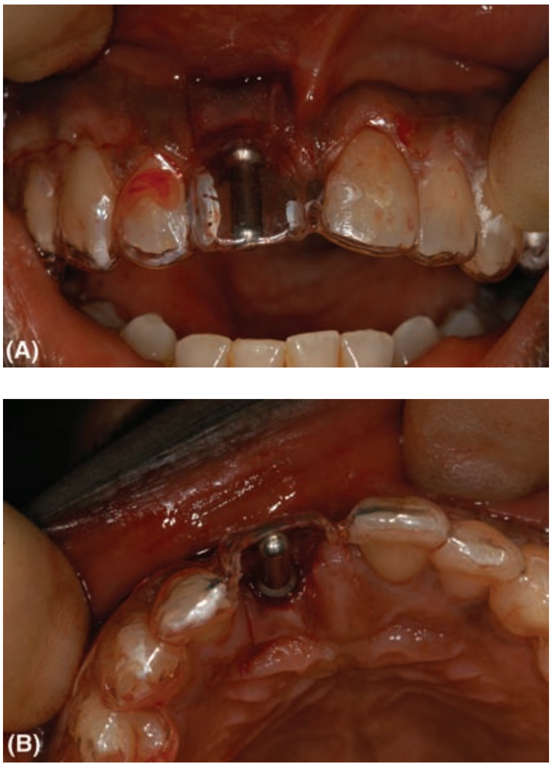

Figure 3.14 (**A**) A surgical stent viewed from the labial surface with an indicator pin inserted in the initially prepared implant site. The indicator pin is in good alignment in the mesiodistal plane. (**B**) The same case reviewed from the occlusal aspect showing the indicator pin is aligned with the incisal tip and consistent with the planned cemented restoration.

PROVISIONAL RESTORATIONS

In the majority of treatment plans, the provisional restoration is an essential component. It helps establish the design of the final reconstruction and is used by the patient throughout the treatment stages. The following provisional restorations are most commonly used for single tooth restorations.

Removable Partial Dentures

Although it has been suggested that dentures should not be worn for one or two weeks following implant surgery, this does not usually apply to the single tooth cases. Single tooth or short span dentures can usually be worn immediately after surgery. The denture can be adjusted so that little or no pressure is transmitted at the site of the implant. Acrylic dentures are simple and inexpensive to construct and allow easy adjustment to

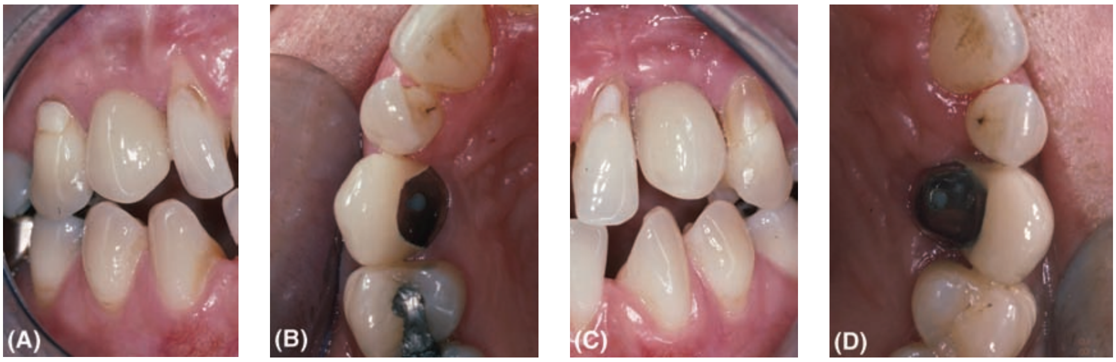

Figure 3.15 (**A**) The upper right canine has been replaced by a single tooth implant in an ideal position, giving a very good buccal emergence profile. (**B**) The palatal view of the crown of the upper right canine shows that it is a cemented crown with a good contour. The angle of the implant was close to the long axis of the tooth, passing through the cusp tip. (**C**) In contrast, the single tooth implant replacing the upper left canine has a more ridged lapped buccal profile. (**D**) The palatal view of the upper left canine shows the cemented crown with a much more bulbous palatal contour because the implant is palatally placed and the angle of the implant goes through the cingulum area. In this case it would have been possible to have provided a screw-retained restoration.

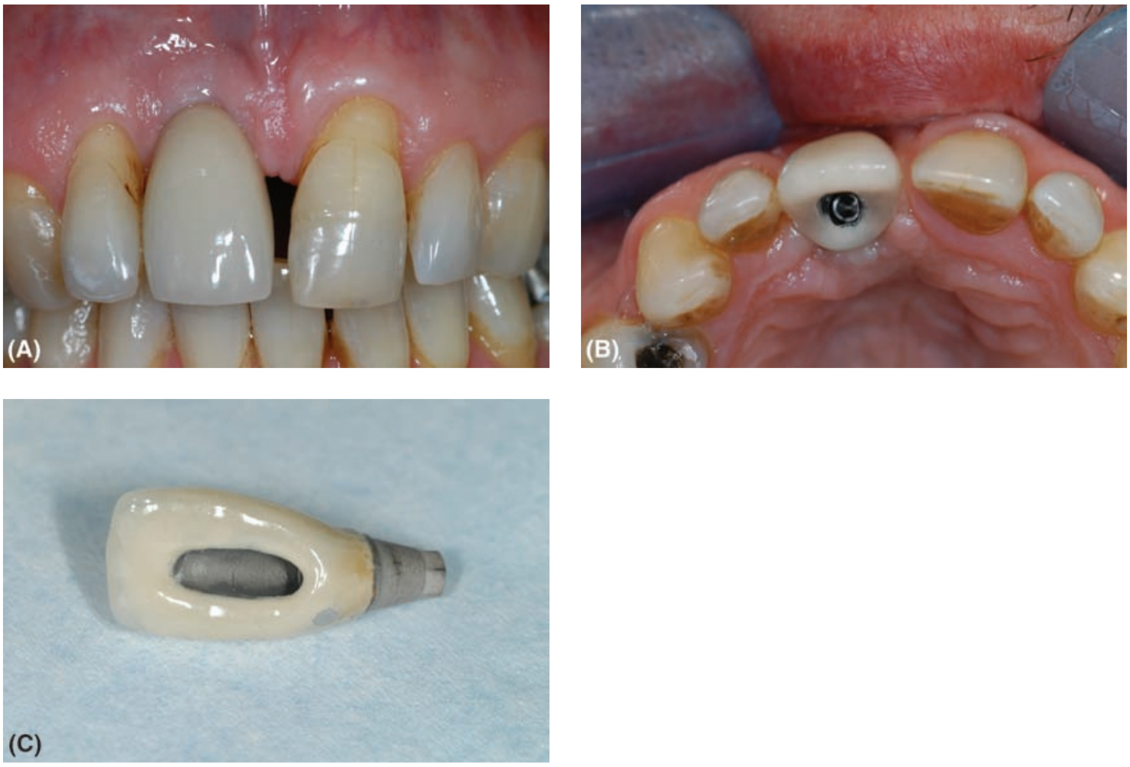

Figure 3.16 (**A**) The upper right central incisor single tooth implant has a long clinical crown, consistent with the adjacent teeth, which have considerable gingival recession. (**B**) The palatal view showing the abutment screw through a cingulum access hole. (**C**) The single piece crown and abutment and large access hole for the abutment screw.

accommodate any changes in tissue profile following implant placement and the transmucosal abutments when they are fitted. When used as an immediate replacement following tooth extraction, the shape of the gum-fitted pontic can be adjusted to develop a good emergence profile and soft tissue contour.

Adhesive Bridgework

Many patients prefer the idea of a fixed provisional restoration. Adhesive bridgework is normally retained by a single adjacent retainer that should permit removal by the clinician. Therefore, the Rochette design is recommended as drilling out the composite lugs within the framework holes should allow removal. However, this occasionally proves to be more difficult than one might expect and removal and replacement of adhesive bridges considerably adds to the treatment time particularly in the restorative phase. It is worthwhile making the prosthetic tooth from acrylic or composite to allow more rapid adjustment when the bridge is recemented over a protruding abutment. The fixed restoration has considerable advantages in case where it is important to avoid any loading of the ridge/mucosa, for instance where grafting or regenerative techniques have been used (see chap. 12).

TREATMENT SCHEDULES

The treatment schedule for single tooth replacement in most cases should be relatively simple.

1. Initial consultation, clinical evaluation, and radiographic examination
2. Agreement of aesthetic/functional demands using existing prosthesis or diagnostic setup/new provisional prosthesis
3. Treatment of related dental problems, which could compromise implant treatment
4. Surgical placement of the implant and provision of temporary prosthesis
5. Healing phase to allow osseointegration according to established protocol
6. Abutment connection
7. Prosthodontic treatment

However, there are a number of situations that will need modification:

1. Immediate replacement following extraction (see chap. 11).
2. Soft tissue or bone augmentation prior to implant placement (see chap. 12).
3. Early loading or immediate loading protocols. Provided bone quality is good and implant stability is good, immediate or early loading (e.g., 4–6 weeks following implant placement) should not compromise success. However, failure rates can be higher particularly where loading is difficult to control (see chap. 11).

CONCLUSION

This chapter has dealt with most of the basic planning issues of anterior single tooth replacement. However, many of the more detailed issues are best considered in the surgical chapter (chap. 9) and the prosthodontic chapter (chap. 13).

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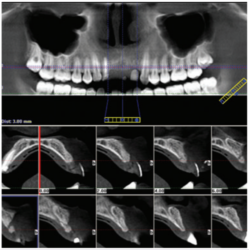

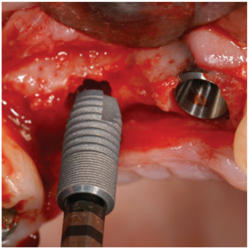

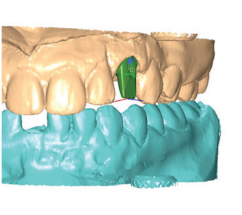

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Dental implants that integrate with bone are a very popular option for tooth replacement; they are, however, very demanding for the practitioner to plan and implement properly, and although there has been technical consolidation between different systems there are still important considerations remaining between them. This new edition of the best-selling guide to current implant systems considers the practical features that a clinician needs to know for successful treatment planning, surgical placement, prosthodontics and long-term maintenance.

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