Dental implants: Introduction to dental implant

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1 Introduction to dental implants

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Implants have been used to support dental prostheses for many decades, but they have not always enjoyed a favourable reputation. This situation has changed dramatically with the development of endosseous osseointegrated dental implants. They are the nearest equivalent replacement to the natural tooth, and are therefore a useful addition in the management of patients who have missing teeth because of disease, trauma or developmental anomalies. There are a number of dental implant systems which offer predictable long-term results backed by good scientific research and clinical trials. In the first place it may be helpful to clarify some of the commonly used terms in implant dentistry (Table 1).

Success criteria

It is important to establish success criteria for implant systems, and for implants to be tested in well controlled clinical trials. The minimum success criteria proposed by Albrektsson *et al.* (*IJOMI* 1986; **1**: 11) is set out in Table 2.

The most obvious sign of implant failure is mobility. However, some of the criteria in Table 2 apply to the overall requirements of an implant system, but are not as useful when judging the success of individual implants. This is well illustrated by considering the radiographic criteria. Bone remodelling occurs in the first year of function in response to occlusal forces and establishment of the normal dimensions of the peri-implant soft tissues (See Part 2). The 'ideal' bone level is usually judged against a specific landmark on the implant (such as the implant/abutment junction) and it may differ therefore between implant systems (fig. 6). Subsequently the bone levels are usually more or less stable, and small changes such as 0.2 mm per annum are impossible to measure with conventional radiographs. These specified changes therefore do not apply to individual implants but to mean (average) changes measured across a large number of implants. For example, a detectable change of 1mm or more may occur at very few implants in contrast to the majority which remain unchanged or in a steady state. It is also difficult to stipulate what level of change in an individual implant over a given period of time would constitute failure. A rapid change in bone level may be followed by a long period of stability. On the other hand, progressive or continuous bone loss is a worrying sign of impending failure. An implant with marked loss of bone may therefore be judged as 'surviving' rather than 'successful'.

Implants placed in the mandible (particularly anterior to the mental foramina) enjoy a higher success rate than the maxilla (approximately 95% success for implants in the

This first part of a new series outlines the salient aspects of osseointegration, implant design and other factors which contribute to successful treatment.

In this part, we will discuss:
- Success criteria
- Basic guide to osseointegration:
  ➤ Biocompatibility and implant design
  ➤ Bone factors
  ➤ Loading conditions
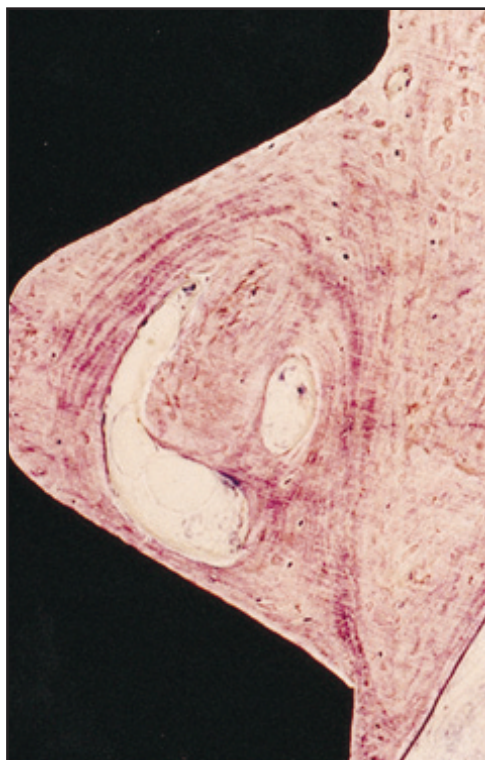 ➤ Prosthetic considerations

Table 1	Basic terminology in implant dentistry
Osseointegration	A direct structural and functional connection between ordered, living bone and the surface of a load-carrying implant (Albrektsson *et al.* Acta *Orthopaedica Scand* 1981; **52**:155 (fig. 1).
Endosseous dental implant	A device inserted into the jaw bone (endosseous) to support a dental prosthesis. It is the 'tooth root' analogue and is often referred to as a 'fixture' (fig. 2).
Implant abutment	The component which attaches to the dental implant and supports the prosthesis. A transmucosal abutment (TMA) is one which passes through the mucosa overlying the implant. A temporary or healing abutment may be used during the healing of the peri-implant soft tissue before the definitive abutment is chosen (fig. 3).
Abutment screw	A screw used to connect an abutment to the implant.
Single stage implant surgery	Surgical placement of a dental implant which is left exposed to the oral cavity following insertion. This is the protocol used in non-submerged implant systems (fig. 4).
Two stage implant surgery	Initial surgical placement of a dental implant which is buried beneath the mucosa and then subsequently exposed with a second surgical procedure some months later. This is used in submerged implant systems (fig. 5).

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Figure 1. Histological section of an implant with bone growing in intimate contact with the surface. The dense bone which contains a small medullary space fills the area between two thread profiles which are 0.6 mm apart.

Implant design parameters
- Implant length
- Implant diameter
- Implant shape
- Surface characteristics

mandible compared with 85 to 90% for the maxilla with systems such as Branemark, 5 years after loading). An example of the lowest recorded success rates are for short implants (7 mm) used in the maxilla to support overdentures, especially when the implants are not joined together. A few studies have now shown that the overall mean failure rate in smokers is about twice that in non-smokers. Smokers should be warned of this association and encouraged to quit the habit. It should also be noted that reported mean failure rates are not evenly distributed throughout the patient population. Rather, implant failures are more likely to cluster in certain individuals.

### Basic guide to osseointegration

Figure 1 shows an histological section of a titanium screw threaded implant which has been in function in bone for 1 year. There is very close apposition of bone over most of the implant surface. It has been proposed that the biological process leading to and maintaining osseointegration, is dependent upon a number of factors which include:

Biocompatibility and implant design
Implants made of commercially pure titanium have 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

Prosthetic considerations
- The type of prosthetic reconstruction
- The occlusal scheme
- The number, distribution, orientation, and design of implants
- The design and properties of implant connectors
- Dimensions and location of cantilever extensions
- Patient parafunctional activities
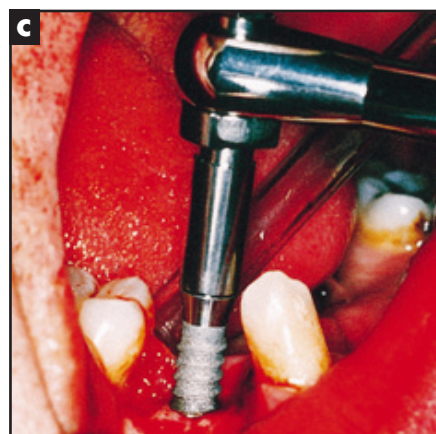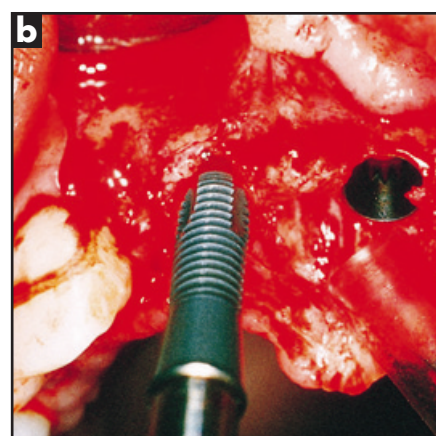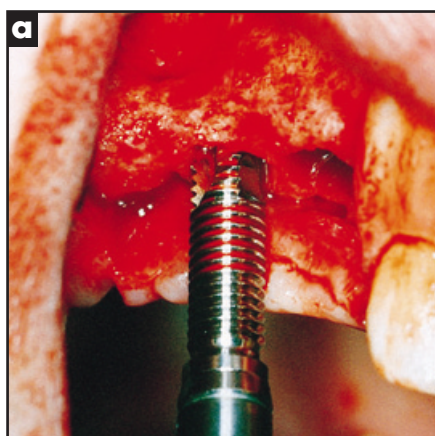
Figure 2. Three different designs of endosseous implants being inserted into prepared sites within the jaw bone. Scanning electron micrographs of the implants are shown in Figures 7 to 9. Figure 2a is a machined threaded implant of the Branemark design (Nobel Biocare). Figure 2b is an Astra ST implant which has a microthreaded coronal portion, a macro-threaded apical portion and the surface has been blasted with titanium oxide. Figure 2c is an ITI Straumann implant which has a smooth transmucosal collar, a macro-threaded body and a plasma sprayed surface.
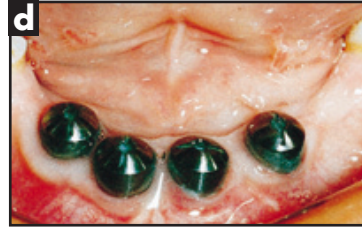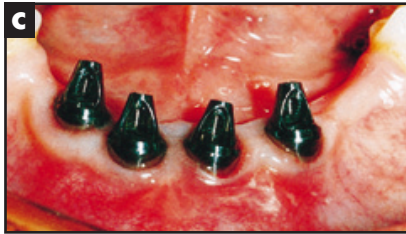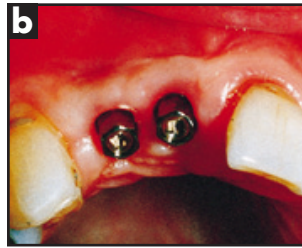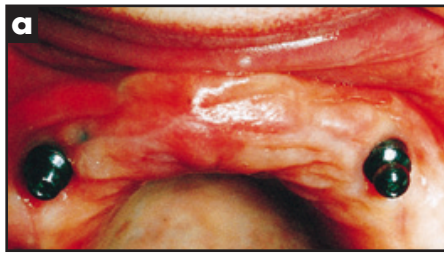
Figure 3. Various forms of implant abutment are illustrated. Figure 3a shows ball abutments which are used to support overdentures. Figure 3b shows abutments which are used to support individual crowns in 'single tooth restorations'. The crowns are cemented on the parallel sided hexagon. Figure 3c shows four conical shaped abutments which are used to support a bridge superstructure. In this the bridge would be screwed to the abutments rather than being cemented. Figure 3d shows some simple cylindrical healing abutments which are used during the healing phase of the mucosa before definitive abutments are selected.

and in addition, successful clinical results are reported for some titanium alloys and hydroxyapatite coated implants. More recently resorbable coatings have been developed which aim to improve the initial rate of bone healing against the implant surface and then resorb within a short time frame to allow establishment of a bone to metal contact.

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

- *Implant length* – implants are generally available in lengths from about 6 mm to as much as 20 mm. The most common lengths employed are between 8 and 15 mm which correspond quite closely to normal root lengths.
- *Implant diameter* — most implants are approximately 4 mm in diameter. At least 3.25 mm in diameter is required to ensure adequate implant strength. Implant diameter may be more important than implant length in the distribution of loads to the surrounding bone. Implant diameters up to 6 mm are available, which are considerably stronger, but they are not so widely used because sufficient bone width is not so commonly encountered.
- *Implant shape* — hollow-cylinders, solid-cylinders, hollow screws or solid screws are commonly employed shapes which are designed to maximise the potential area for

Figure 4. An implant of the ITI Straumann type has been inserted and left protruding through the mucosa in a one stage surgical procedure. A wide screw has been placed on the top to protect the inner aspect of the implant until a definitive abutment is connected.

osseointegration and provide good initial stability (figs 7a–9a). Even minor alterations in the size and pitch of threads can enhance the latter property. Screw shaped implants also offer good load distribution characteristics in function.

- *Surface characteristics* — the degree of surface roughness varies greatly between different systems. Surfaces which are machined, grit-blasted, etched, plasma sprayed and coated are available. Figures 7b to 9b show the characteristics of these surfaces viewed with the scanning electron microscope, showing considerable increases in potential surface area. The optimum surface morphology has yet to be defined, and some may perform better in certain circumstances. By

Table 2	Suggested minimum success criteria for dental implants*

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 characterised by an absence of signs and symptoms such as pain, infections, neuropathies, paraesthesia, or violation of the inferior dental canal.
5. As a minimum, the implant should fulfil 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.

*after Albrektsson *et al. IJOMI* 1986; **1**:11

Figure 5. Exposure of two implants which have been buried beneath the mucosa for a period of 6 months. Bone has grown over the top of them and this needs to be removed before a healing abutment is connected.

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.

Bone factors

The stability of the implant at the time of placement is very important and is dependent upon bone quantity and quality as well as implant design. The edentulous ridge can be classified in terms of shape and bone quality (fig. 10). Following loss of a tooth the alveolar bone resorbs in width and height. In extreme cases bone resorption proceeds to a level which is beyond the normal extent of the alveolar process and well within the basal bone of the jaws. Radiographic determination of bone quantity and quality is considered in Part 5 and procedures which can be used to augment bone in Part 8. The most favourable quality of jaw bone for implant treatment is that which has a

well formed cortex and densely trabeculated medullary spaces with a good blood supply. Bone which is predominantly cortical may offer good initial stability at implant placement but is more easily damaged by overheating during the drilling process, especially with sites more than 10 mm in depth. At the other extreme, bone with a thin or absent cortical layer and sparse trabeculation offers very poor initial implant stability and fewer cells with a good osteogenic potential to promote osseointegration. Success is highly dependent upon a surgical technique which 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 (around 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 Part 6 (Basic Implant Surgery). Factors which compromise bone quality are infection, irradiation and heavy smoking. The effects of the latter two are a result of a diminution of the vascular supply to the bone which compromises the healing response, a feature which has been well described in the healing of fractures.

Loading conditions

Following installation of an implant it is important that it is not loaded during the early healing phase. Movement of the implant within the bone at this stage results in fibrous tissue encapsulation rather than osseointegration. This has been compared to the healing of a fracture where stabilisation of the bone fragments is very important to prevent non-union. In partially dentate subjects it is desirable to provide temporary/provisional prostheses which are tooth supported to avoid early implant loading. However, in patients who wear mucosally supported dentures it is generally recommended that they should not be worn over the implant area for 1 to 2 weeks. This also helps to prevent breakdown of the soft tissue wound. Systems such as Branemark have advised leaving implants unloaded beneath the mucosa for around 6 months in the maxilla and 3 months in the mandible, mainly because of differences in bone quality. However, these are largely empirical guidelines, and bone quality and implant stability will vary greatly between individuals, jaws and sites within jaws. Currently there is no accurate measure which precisely determines the optimum period of healing before loading can commence. Bone quality can be assessed by measuring the cutting torque during preparation of the implant site. The stability of an implant and increasing bone-to-implant contact has been quantified using resonance fre-

Figure 6. A periapical radiograph of a single tooth implant. The bone contacts the implant up to the most coronal thread. An abutment screw which is more radio-opaque can be seen connecting the abutment to the implant. The crown is all porcelain and is cemented to the abutment. In this system (Branemark) the landmark for measuring the bone level from is the junction between implant and abutment.
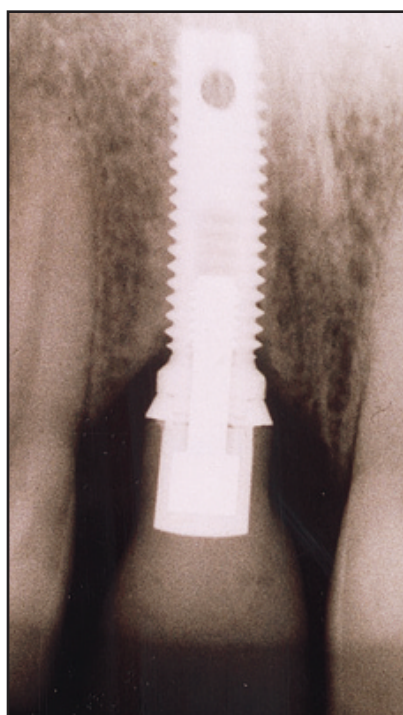
quency analysis. This newly developed non-invasive research tool measures the stiffness of the implant at the bone interface. In some circumstances it has been shown that immediate loading is compatible with subsequent successful osseointegration, providing the bone quality is good and the functional forces can be adequately controlled. The latter may involve placing an adequate number of implants and connecting them together as soon as possible with a rigid framework. However, these latter protocols should be considered experimental at the present time, and there is much data to support the more cautious approach advocated by Branemark in ensuring a high level of predictable implant success. Some systems employ a single stage approach in which the implant is installed so that it protrudes through the overlying mucosa (ie non-submerged), although avoidance of early loading is equally critical. Following the recommended healing period (around 3 months) abutments are connected to the implant to allow construction of the prosthesis. This protocol therefore avoids further surgery to uncover the implants. The loading of the implant supported prosthesis is a further important consideration which will be dealt with in the following section.

Prosthetic considerations
Carefully planned functional occlusal loading will result in maintenance of osseointegration and possibly increased bone to implant contact. In contrast, excessive loading may lead to bone loss and/or component failure. Clinical loading conditions are largely dependent upon:

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 which 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 upon the opposing dentition which could be natural teeth, another implant supported prosthesis or a conventional removeable prosthesis. Surprisingly high forces can be generated through removable prostheses.
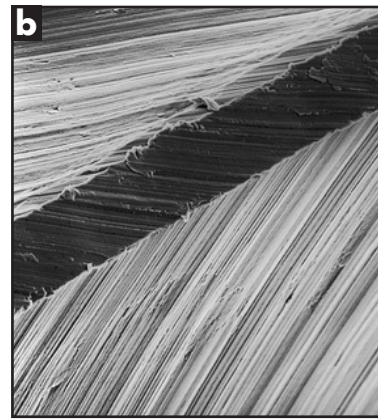

Figure 7. This shows a scanning electron micrograph of a Branemark/Nobel Biocare implant. Figure 7a shows the basic thread design and figure 7b a higher power view of the machined surface.
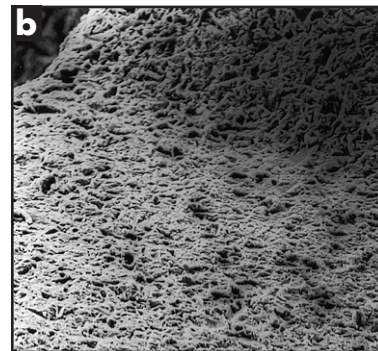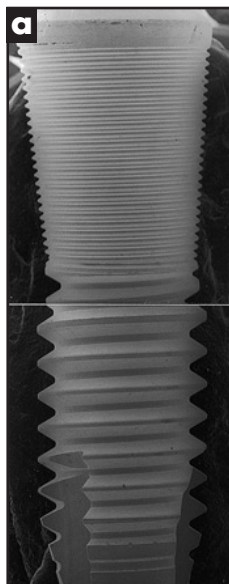
Figure 8 shows a scanning electron micrograph of an Astra ST implant. The conical neck has a microthread and the apical part a coarser self tapping thread (fig. 8a). Figure 8b shows a higher power view of the blasted (Tio-blast) surface at the same magnification as figure 7b.
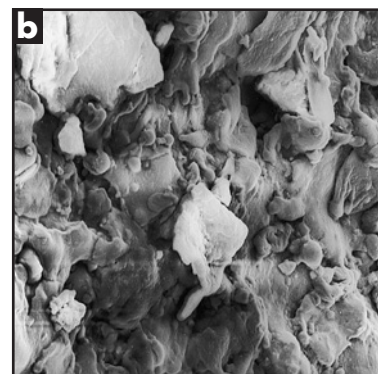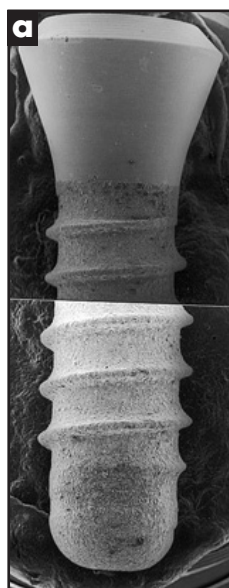
Figure 9 shows a scanning electron micrograph of an ITI Straumann solid screw implant. The polished transmucosal neck is clearly demarcated from the plasma sprayed body (fig. 9a). The thread has a coarser pitch than the implants shown in figures 7 and 8. Figure 9b shows the plasma sprayed surface at the same magnification as figure 7b and 8b. The increase in surface area is considerable.
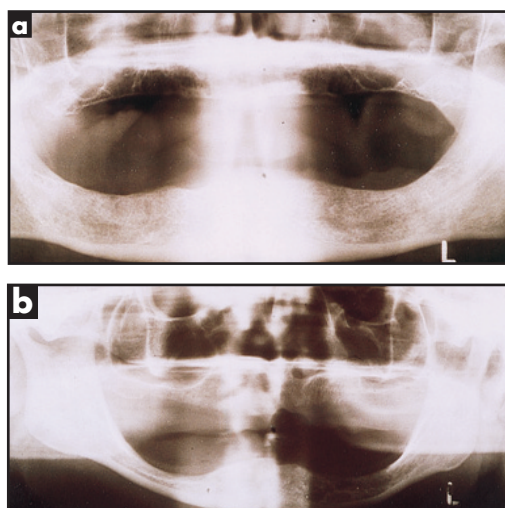
Figure 10 shows examples of dental panoramic tomograms of edentulous jaws. Both show extensive resorption of the maxillary ridge. There is far less resorption of the mandible in figure 10a than figure 10b. In the latter case there is reasonable bone volume in the anterior mandible but resorption close to the level of the inferior dental canal in the posterior part.

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 3-dimensional arrangement of the individual implants will also be very important. The so-called 'tripod' arrangement of three implants is recommended in situations of high load, such as replacement of molar teeth in the partially dentate individual.

The design and properties of implant connectors
Multiple implants are joined by a cast or milled framework. A rigid connector provides good splinting and distribution of loads between implants. It is equally important that the connector has a passive fit on the implant abutments so that loads are not set up within the prosthetic construction.

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 caused by 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 supporting the reconstruction. The cantilever extension should not exceed this length and the cross sectional design should be adequate to prevent flexing.

Patient parafunctional activities
Great caution should be exercised in treating patients with known parafunctional activities. Excessive loads may lead to loss of marginal bone or component fracture.

These factors will be considered in more detail in Parts 4 and 7.

Conclusion
There are a great many factors to take into account to ensure predictable successful implant treatment. There is no substitute for meticulous attention to detail in all of these areas. Failure to do so will result in higher failure rates and unnecessary complications.

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