IN BRIEF

- A preventive strategy at the planning stage describing patient selection, surgical technique, prosthetic design and loading
- A preventive strategy for the maintenance period describing recall examination and diagnosis and therapy
- The level of evidence currently available to support these strategies

5

Prevention. Part 5: Preventive strategies for patients requiring osseointegrated oral implant treatment

VERIFIABLE CPD PAPER

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Prevention for patients requiring rehabilitation with oral implants is about preventing implant failure and biomechanical complications. This paper describes preventative strategies for the planning stage for implant treatment and the later maintenance period and indicates the level of scientific evidence supporting these strategies.

PREVENTION

1. Smoking cessation advice
2. Dietary advice
3. Prevention of tooth wear
4. Toothbrushing advice
5. **Patients requiring osseointegrated oral implant treatment**
6. Older dentate patient
7. Professionally applied topical fluorides for caries prevention
8. Pit and fissure sealants in preventing caries in the permanent dentition of children

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Missing teeth and supporting oral tissues have traditionally been replaced with dentures or bridges permitting the restoration of masticatory, phonetic function, and aesthetics. Dental implants now offer an alternative for tooth replacement. Inserted into the mandible or maxilla, these implants are retained because of the intimacy of bone growth onto their surface so that they can support a dental prosthesis. Osseointegration is the word used to describe the healing of bone around implants so that there is direct anchorage of the implant that is then maintained during functional loading without the growth of fibrous tissue at the bone-implant interface.[1]

Prevention for patients requiring rehabilitation with oral implants is about preventing implant failure. Biological failure occurs when osseointegration is not established or is not maintained. When not established in the first place, implant failure is described as 'early failure' and will be observed before or at abutment connection. When osseointegration does occur but then is lost, the implant failure is described as a 'late failure' as this is observed at any time after abutment connection. When an implant is not osseointegrated, a peri-implant radiolucency is observed radiographically and the implant is clinically mobile. It is obviously important to prevent implant failure through adequate planning to facilitate establishment of osseointegration and then to preserve the long-term maintenance of osseointegration. This paper describes preventive strategies for the planning stage (Table 1) for implant treatment and the later maintenance period (Table 2) and indicates the level of scientific evidence supporting these strategies.

Table 1 Factors in preventive strategy at planning stage

Patient selection
- General health
- Smoking
- Bone quality and other anatomical factors
- Oral hygiene
- History of radiotherapy

Surgical technique
- Surgical trauma
- Number of implants
- Type of implant
- Microbial contamination
- Antibiotic usage

Loading

Prosthetic design

Table 2 Factors in preventive strategy for the maintenance period

Recall examination and diagnosis
- Examination of the prosthesis
- Examination of the implants

Therapy
- Patient administered hygiene procedures
- Mechanical debridement by the professional
- Pharmacological therapy
- Surgical procedures

PREVENTIVE STRATEGY AT THE PLANNING STAGE

Patient Selection

General Health

It seems likely that systemic conditions that interfere with wound healing also interfere with implant osseointegration, although there are actually few studies looking specifically at particular medical conditions. Patients with systemic diseases such as diabetes mellitus, or those taking systemic steroid therapy or other immunosuppressive medication are known to have impaired wound healing and these patients are often thought to also have an increased rate of implant failure. Many of the published reports specifically investigating diabetes include too few patients to offer conclusive results.[2,3] A study analysing data from the Department of Veteran Affairs Dental Implant Registry in the USA observed an association between the medical history in general of a patient and implant failure.[4] This was then reported by a conference seeking consensus on variables predictive of implant failure (Perio Consensus Report 1996).[5] However, regarding diabetes, this publication reported no greater implant failure rate in patients with well-controlled diabetes mellitus than observed in the general population.

Smoking

Several observational studies have described a relationship between smoking and increased implant failure but the strength of this relationship varies between studies. One study has shown only a 0.6 mm mean difference in bone levels between smoking and non-smoking groups over a 10-year period, which is of little clinical significance.[6] More recently a study reported smokers to have a one and a half times the 6% failure rate observed in patients of the group who had never smoked.[7] Implants in the maxilla had almost two times the risk of failure in smokers than non-smokers. The authors of this study suggested that the increased failure rate was caused by the exposure of the peri-implant tissues to tobacco smoke. Other researchers have also implicated altered peri-implant tissue conditions.[8–10] Generally there is a consensus that smokers have about twice the number of failed implants compared with non-smokers, although well-designed trials are lacking.

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Bone quality and other anatomical factors

Implant success is related to the quality of the bone into which the implant is inserted and therefore this factor should be taken into account when planning the placement site of the implants. Site seems to be an important factor irrespective of whether the implants are loaded or not.[11–13] Higher failure rates have been reported for implants placed in maxillary bone compared with mandibular bone and also in the posterior segments of both jaws. Posterior sites may also restrict the bone volume available for placement of large implants because of vital structures such as the inferior alveolar nerve or maxillary sinus.[14] A reduced success rate has also been described when bone grafting is undertaken to facilitate implant placement at sites of inadequate volume.[16] Bone quality seems to relate primarily to bone density and the denser the bone, the fewer the failures, with the exception of extremely dense bone. The presence of dense bone may favour early implant stability, which is one of the prerequisites for predictable osseointegration. Interestingly, it has been shown in a laboratory model that the maximum stresses and strains are concentrated about the crestal cortical bone rather than the cancellous bone and that from a biomechanical point of view, implants may be almost completely supported by the cortical bone, when present.[15]

Oral hygiene

The patient should have demonstrated the ability to maintain proper hygiene before proceeding with implant treatment as a cause-effect relationship between bacterial plaque accumulation and the development of inflammatory changes in the soft tissues surrounding oral implants has been shown.[17] However, no relationship between previous periodontal disease and implant failure has been established yet.[18–20]

Several studies have indicated that remaining teeth might act as a reservoir for the colonization of the subgingival area around implants.[21,22] This suggested that there may be an association between susceptibility for periodontitis and susceptibility for peri-implantitis, especially in partially edentulous patients. However, a recent study has failed to find any relationship between ongoing periodontitis around teeth and bone loss around implants inserted in the same jaw. Patients were included in this study with either a history of stabilised or progressive periodontitis and patients had no more marginal bone loss than patients with a healthy periodontium when measured radiographically and clinically.[23]

Keratinised mucosa

It has been suggested that an adequate band of keratinised mucosa about an implant is necessary for its success[24,25] but it has not been possible to demonstrate this scientifically[26] and the consensus view now is that there is no correlation between the width of keratinised mucosa and implant failure.[5] However, it may be that the presence of keratinised tissue facilitates the patients' hygiene procedures but in many patients these may be adequate without keratinised tissue.[11] Similarly, an adequate sulcus is required for plaque control and to avoid tissue tension involving the peri-implant soft tissues.

Radiotherapy

Individual observational studies of implant failure rates in irradiated and non-irradiated patients have been compared. This has shown

that failure rates in the mandibles of irradiated patients are slightly higher than those of non-irradiated patients but that irradiated maxillas show a much higher failure rate than irradiated mandibles.[27] The failure rate was also shown to be dose dependent with an increased failure rate at higher radiation doses.

As fibrosis and loss of micro-vascularity begins about 6 months after irradiation and then progressively worsens,[28] implant treatment should probably be undertaken early. Whilst there is much support for the use of hyperbaric oxygen therapy for these patients from observational studies, there is a dearth of high-level evidence from randomised controlled trials (RCTs) evidence supporting or rejecting its benefits.[29]

Genetic factors
Differences in genetic makeup that reflect differences in healing or other factors may relate to implant success, but at present there is still no available information.

Surgical technique

Surgical trauma
Prevention of failure should also take into account the surgery. This should be undertaken as atraumatically as possible and implants should be placed using drills at appropriate speed and with adequate irrigation to prevent bone heating. If the temperature is permitted to rise to over 47°C for 1 minute, then this may cause a zone of necrotic bone surrounding the inserted implant and it is thought that this may be clinically significant.[30,31]

Number of implants
An adequate number of correctly positioned implants should be planned as part of the loading consideration. Excess loading may lead to biological failure, that is, loss of osseointegration, but also to mechanical failure of the implants or retained prosthesis. There is some evidence from a few studies to show that the number of implants supporting a fixed prosthesis may be important for treatment success.[6,32] Three or more implants seems to be more successful than two implants for the rehabilitation of partially dentate patients.

Implant type
Implant surface characteristics such as roughness and type of coating may influence the failure pattern and numerous surface modifications have been developed to enhance clinical performance. A recent systematic review found that there were very few studies comparing different implant types and no evidence that any of the implant systems evaluated was superior to the another.[33] Those studies included investigated Astra, Branemark, IMZ, ITI, Steri-Oss and Southern implant systems. However, these findings were based on a few RCTs all having short follow-up periods and few study patients.

Microbial contamination
A high standard of cross-infection control should be adopted for implant surgery as a correlation has been observed between increasing numbers of implants placed in a patient and increased failure rate.[34] The authors of this study suggested that this could have been due to the longer operating time and consequent larger wound contamination. A larger failure rate has also been reported in patients with high plaque scores likely as a result of bacterial contamination at the time of implant placement.[35] It is also known that biomaterial infections are extremely resistant to host defence mechanisms and antibiotic therapy.[36] Microorganisms preferentially adhere to implant surfaces and form a biofilm to protect themselves from the host.[37] The shape of the implant therefore may also have a bearing on infection rate. Hollow implants used in orthopaedic surgery (intramedullary nails) have been found to have an infection rate almost two times that of solid nails but this was from an animal study rather than a clinical trial.[38] Similarly, implants with a porous surface have been reported to have more early infections than dense implant.[39]

Antibiotic usage
It is common practice to use prophylactic antibiotics or a course of antibiotics after implant placement to increase the success although this practice remains controversial. There is some evidence from observational studies that preoperative antibiotics reduce the early failure rate [40] although no randomised controlled trial has been carried out yet. Chlorhexidine mouthrinse used pre-operatively is also associated with a reduced complication rate.[41]

Loading
Excessive loading in relation to bone quality is another cause of implant failure.[11,23] It has been suggested that implants should not be loaded during a healing phase of 3–4 months in the mandible and 6–8 months in the maxilla if osseointegration is to occur.[1] Some studies comparing immediately loaded and conventionally loaded Branemark mandibular implants showed an overall seven times higher early failure rate for those immediately loaded.[42,43] Experimental evidence has indicated that early loading causes micromovement of the implant and differentiation of cells into fibroblasts resulting in fibrous encapsulation rather than osseointegration.[44] Alternatively, other laboratory experiments have shown that daily low frequency micromotion may stimulate bone growth.[45] The precise level of micromotion that can be tolerated clinically without significantly inhibiting bone formation is unknown.

Recently, immediate and early loaded implants are being used particularly in the mandible.[46] It is likely that the bone quality is of major importance for success in this situation. Some authors are also advocating implant surface modifications as a means of facilitating the

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earlier loading of implants.[47] There are an inadequate number of good quality randomised controlled trials comparing immediate versus conventionally loaded implants[48] and also the related question of whether to close over soft tissues during healing (two-stage surgery) or to leave exposed (one stage surgery) to provide clear evidence for practice.[33]

Whilst there is little clinical evidence that bruxism or clenching parafunctions are associated with increased implant failure, there seems to be general consensus that excessive loading may induce bone loss. It is actually difficult to obtain good evidence as it is difficult to clinically quantify the magnitude and direction of bite forces applied by a patient in relation to the bone quality and control groups.[49]

Prosthetic design

The planned type of prosthesis, crown, fixed bridge or overdenture, has implications for maintenance by the patient. The implant plan should aim to achieve an emergence profile that enables easy cleaning. The suprastructure should be designed so that the patient can maintain proper oral hygiene. If the reconstruction is overcontoured, especially interproximally, this will prevent the achievement of optimal oral hygiene.[50]

It has been suggested that cantilever length influences stress distribution, particularly on distal implants,[51] but only a few studies have investigated this. One study reported that cantilevers longer than 15 mm had to be remade more often than shorter cantilevers.[52]

PREVENTIVE STRATEGY FOR THE MAINTENANCE PERIOD

The aim after completion of implant and restoration is to prevent implant failure by offering the patient a programme designed for his or her individual needs

Examination and diagnosis

It is generally recommended that patients should be reviewed regularly. The recall interval may be 6 months but will vary according to the patient's individual needs. There are no cost benefit analyses studies relating to this view. The examination should focus on the prosthesis, the implants and the peri-implant tissues.

Examination of the prosthesis

This should include noting the retention and stability, any abutment or screw loosening or loss of cement. The occlusion should be examined.

Examination of the implants:

• *Mobility*

Pain or sensitivity when eating or when the abutment screw is tightened may be an early indication of osseointegration failure. However, it is important to bear in mind that failed implants can be completely asymptomatic. Any indication of mobility indicates a failed implant as a result of loss of osseointegration and is occasionally present when radiographic bone changes are not distinct. For research purposes, the prosthesis may need to be removed but this would be unreasonable in normal clinical practice at review appointments and mobility testing cannot be carried out if implants are supporting a cemented prosthesis. Radiographic examination, whilst not as accurate a test for implant failure as mobility, provides a good indication and avoids having to remove a fixed prosthesis.

The Periotest electronic device provides an objective measure of mobility although it does not provide an indication of implant failure any earlier than indicated by radiographic changes.[53] Several factors have an influence on Periotest values including, the length of the implant and abutment, whether the implant is in mandibular or maxillary bone, and bone density.

It has been proposed that at abutment connection, a 10 N cm reverse torque could be applied to the implant to check for mobility but this may risk damaging a weak immature bone/implant interface and is therefore not recommended.[54] Other non-invasive evaluation methods are now available but the correlation between their measures and osseointegration are not clear.[55,56] Simply to know whether an implant is mobile or not may be more clinically relevant.

• *Radiographs*

Periapical radiographs should be taken to show the bone level about implants. These should be taken in a standardised way so that they are reproducible and avoid distortion. Dental panoramic radiographs are of less use than periapical radiographs, particularly for research, in monitoring bone stability about implants because of the inferior image resolution and the inability to modify the angulation of the x-ray beam.[57] A periapical radiograph should be first taken soon after abutment connection to provide a baseline measure of bone level for comparing subsequent follow-up radiographs taken to monitor any progressive marginal bone loss or 'saucerization'.[58] This bone loss may result from peri-implantitis or overloading of the implant. Regular radiographs at determined follow-up periods may not be necessary but rather should be taken to clarify some question prompted by the clinical examination.

The implant would not initially be mobile with this type of bone loss as there remains a large area of bone/implant interface osseointegration. Alternatively, a thin radiolucent peri-implant margin may be observed surrounding the entire implant, suggesting absence of osseointegration and a loss of stability.[59] When excessive marginal bone loss or a radiolucent peri-implant margin is observed then the implant mobility should be checked and this may require removal of a bridge.

Less than 1.5 mm of marginal bone loss during the first year of loading, and thereafter less

Radiographs

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than 0.02 mm each year, has been defined as success[60] although some authors have doubted whether a firm limit for an acceptable annual bone loss can be established.[61] It is not technically possible to observe radiographic changes of 0.1 mm but threaded implants permit reference by way of the threads for serial radiographs. Another shortcoming is that only interproximal aspects of an implant can be observed.

• *Peri-implant tissues*

The attachment between an implant and the surrounding tissues is quite different from that between a tooth and the surrounding tissues, primarily because there is no periodontal ligament. Nevertheless, if an implant is biocompatible, one may expect the usual wound healing principles to establish healthy peri-implant tissues. One of the key factors for the long-term success of oral implants is the maintenance of healthy tissues around them.[62]

A cause-effect relationship between bacterial plaque accumulation and the development of inflammatory changes in the soft tissues surrounding oral implants has been shown.[17] Peri-implant mucositis is the term used to describe the reversible inflammatory changes in the tissues around an implant.[65] If this condition is left untreated, it may lead to the progressive destruction of the tissues supporting an implant (peri-implantitis) and ultimately to its failure.[63] The majority of the evidence for this association comes from microbiological observations based on observational studies. These demonstrate the presence of suspected periodontal pathogens in peri-implantitis situations or the presence of the usual microorganisms associated with health in the clinically healthy situation.[65,66] For maintaining healthy tissues around oral implants it is important to institute an effective preventive regimen and, when a pathological condition of the tissues around implants has been diagnosed, then a therapeutic intervention should be initiated as soon as possible.[67] Peri-implant inflammation is successfully treated by effective oral hygiene and plaque control as with inflammation around natural teeth. Different maintenance regimens and treatment strategies for peri-implantitis (failing implants) have been suggested, however it is unclear which are the most effective.[62,67–69]

It is not clear how reliable the various periodontal parameters are for identifying peri-implant pathology.

Bleeding on probing (BOP) is the periodontal parameter used to evaluate the presence of an inflammatory process at the base of a periodontal pocket. The presence of bleeding is noted on probing in the pocket until a slight resistance is met using gentle force. Standardised probes which produce forces of 0.25 N are available. The absence of BOP is a reliable indicator for periodontal stability[70] but the use of this measure for peri-implant tissues is not necessarily as helpful and insufficient data are currently available.

The sulcus bleeding index (SBI), is the bleeding tendency of the alveolar mucosa surrounding the implant abutment observed by running a periodontal probe along the abutment circumference 1 mm into the mucosal pocket and parallel to the margin of the soft tissues. This parameter distinguishes between healthy and inflamed tissues but may not be able to identify failing implants.[11]

Pocket probing depth (PPD), is the linear distance from the free mucosal margin to the base of the pocket. The base of the pocket is defined as the apical termination of the junctional epithelium when used for teeth but for implants there is no periodontal attachment to stop the tip of the probe. A deep pocket is a protective habitat for putative pathogens which may lead to peri-implant pathology.[71] A recent report suggested that probing measurements around osseointegrated oral implants and teeth were different. Even mild marginal inflammation was associated with deeper probe penetration around implants in comparison to teeth.[72] Pocket probing depth may not provide as accurate an indication of disease as bone level measurements on intraoral radiographs,[11] but it could still be useful in practice.

Other signs of infection such as hyperplastic tissues, suppuration, swelling, or colour change may also provide an indication that therapy is indicated. Mucosal recession exposing threads or a rough implant surface might reduce the ability of the patient to maintain the implant clean from plaque in addition to causing an aesthetic problem.

Therapy

Patient administered hygiene procedures

The patient should be instructed in brushing using soft brushes and interproximal brushes and flossing with appropriate designs of floss such as superfloss for mechanical plaque removal.[73] Adjunctive twice-daily antimicrobial mouthrinsing with an agent such as chlorhexidine has been recommended for patients with physical impairment.[73–75] Powered toothbrushes have also been recommended.[76,77] Recently a Cochrane Systematic review examined the effectivness of different maintenance therapies for patients with oral implants.[62] This review indicated that there was little available evidence for the effectiveness of interventions for maintaining healthy tissues around dental implants. However, Listerine mouthwash, 20 ml used twice a day for 30 seconds, as adjunct to routine oral hygiene was found to be effective in reducing plaque formation and improving health around implants. There was no evidence that the use of powered or sonic toothbrushes was superior to manual tooth brushing.

Mechanical debridement by the professional

Given the association between plaque and the development of pathology of the tissues about implants, it would be reasonable to arrange the following regimen, although no cost benefit

Therapy

When a pathological condition of the tissues around implants has been diagnosed, then a therapeutic intervention should be initiated as soon as possible

analyses have been carried out. An appropriately trained professional should provide intensive motivational hygiene instruction for the patient about 1 week after abutment surgery.

After restoration this should be repeated. Remotivation and patient instruction in oral hygiene should be carried out every 6 months or at an appropriate time period for the individual patient.

Professional removal of plaque and calculus from the implant-abutment surface should be undertaken when needed. Scaling with hard plastic or titanium instruments is recommended to avoid scratching and roughening the titanium implant abutment surface that may increase the chance of bacterial colonization,[78] although all of the evidence for colonisation is derived from *in vitro* studies and no clinical trials have validated this hypothesis. Plastic scalers are also recommended to avoid galvanic corrosion and contamination of metallic implants although there is no evidence to support this.[79,80] Plastic tips for ultrasonic devices are also recommended. A rubber cup and fine abrasive polishing paste (fluor of pumice, Nupro Fine, tin oxide) might be helpful.[81]

Scaling

Scaling with hard plastic or titanium instruments is recommended to avoid scratching and roughening the titanium implant abutment surface

Pharmacological therapy

Systemic antibiotics are frequently used in clinical practice as an adjunct to surgical intervention for the treatment of peri-implantitis although the evidence for their efficacy has not been clearly demonstrated.[82] Subgingival irrigation with antimicrobial agents has also been advocated for the prevention of peri-implantitis.[82] Phosphoric acid gel application has also been recommended,[81] although a recent Cochrane review on maintenance for implant patients did not find any evidence that phosphoric etching gel (monthly 35% for one minute) offered any clinical advantage over mechanical debridement.[62]

Surgical procedures

Surgical procedures have been recommended for the management of peri-implantitis.[67] In particular, open flap debridement to facilitate smoothing of the implant surface and removing unsupported implant threads that protect bacterial plaque. The implant surface may also be 'decontaminated' using various chemical agents[83] or laser energy,[84] but there is no evidence that either is necessary or effective. Once the surface has been rendered 'bacterial free', further surgery to alter the local anatomy may be necessary to enable easy plaque removal.[85]

DISCUSSION AND CONCLUSIONS

Early implant failure is most commonly attributed to excessive surgical trauma together with inadequate healing because of host compromise, premature loading and infection. The most important causes of late failure are likely to be peri-implantitis and overload together with host factors.[11,27] The common observation that failures tend to be concentrated in particular individual patients suggests that certain factors are important in determining implant success. Even though several factors have been highlighted as associated with a higher failure rate this may not preclude the patient from proceeding with implant treatment. This particularly applies to the patient selection factors. The most appropriate clinical option for tooth replacement for a patient who smokes or who has undergone radiotherapy may be implant treatment but the clinician should advise the patient as to the likely reduced success rate.

It is important to know which therapy is most effective to manage a patient and consequently the importance of evidence-based dentistry is becoming increasingly recognised. There is a general consensus that randomised controlled clinical trials (RCTs) are preferred to answer questions of therapy effectiveness, and systematic reviews can evaluate the quality of RCTs and combine their results to reach more reliable conclusions.[86] A randomised controlled trial is not however always feasible. Patients cannot be randomised to smoking, diabetes, or radiotherapy groups, for example, and so the evidence must sometimes be based on good observational studies. Systematic reviews have a clearly formulated hypothesis employing systematic methods to identify, select and critically appraise relevant research. Data from original trials are collected, analysed and if possible summarised to provide a more precise estimate of the intervention effects than available from individual trials. Unfortunately there are few RCTs as yet available investigating any management alternatives for oral implant rehabilitation.[87] Recently a Cochrane Systematic review examined the effectiveness of different maintenance therapies for patients with oral implants.[62] This review indicated that there was little available evidence for the effectiveness of interventions for maintaining healthy tissues around dental implants and the relatively few findings that were presented were based on short follow-up periods (the longest was 5 months) and there is no reliable evidence for long-term maintenance. Therefore many of the standard maintenance therapies used are not based on reliable scientific evidence. These therapies may be effective, but their efficacy needs to be demonstrated in trials and their relative cost should also be investigated.

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