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Implant Information for General Dental Practitioners

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1. Treatment Planning for Missing Teeth

1.1 Why do missing teeth need replacing?

Replacing missing teeth is a crucial component of dental rehabilitation, with the overall aim of improving quality of life and enhancing a patient's well-being through functional, aesthetic and psychological improvements.[1] Not all teeth need to be replaced when lost; however, where function or aesthetics are compromised, these factors are usually primary reasons for replacement. Other benefits can include improvements in speech clarity and phonetics (especially when replacing anterior teeth), minimising undesirable tooth movement and maintaining natural tooth position, or even restoring soft tissue profiles of the face (depending upon the number and position of teeth to be replaced).

1.2 What are the options?

Replacing a missing tooth or multiple teeth can be accomplished with either a fixed or removable prosthesis. This choice depends upon different clinical and patient-related factors that need to be considered as part of the treatment planning process. These include the patient's wishes, patient's finances, pre-existing medical comorbidities, smoking status, oral hygiene compliance and commitment to maintenance.[2] Then there are the clinical considerations, such as the characteristics of the edentulous saddle, prosthetic space availability, the position and prognosis of the remaining teeth, the quantity and quality of the remaining hard and soft tissue and the position of relevant local anatomy.[3]

Removable prostheses can be mucosal-supported, tooth-supported, or use a combination of both, depending on their design and the material of choice. They may also utilise strategically placed dental implants to gain retention or support, using different attachment systems such as locator abutments or bars. In both cases, removable prostheses provide an excellent option for replacing multiple missing teeth when fixed options are not suitable. Vacuum-formed or Hawley retainers with tooth-coloured acrylic pontic(s) can be used as a cost-effective, provisional solution to provide both aesthetics and function whilst a more definitive option is finalised, or to act as a diagnostic tool assisting tooth positioning.

Fixed tooth replacement options can replace single or multiple teeth and are typically retained on either natural teeth or dental implants. In comparison to bridgework on natural teeth, which is either adhesive or conventional, a fixed prosthesis on an implant fixture can be connected with either a screw or cemented onto the implant abutment.

Dental implants are often regarded as the gold standard for tooth replacement;[4] however, they are not without complications, which can be both mechanical[5] and biological.[6] They also require ongoing supportive and maintenance care to ensure their longevity.[7] Implants offer a great deal of flexibility and can be used as retainers for removable dentures (both partial and full), single units and fixed multiple units (short span, long span, or cantilevered). The majority of implants provided in the UK are within a private contract; however, under strict criteria, dental implants are available on the NHS for high-priority patient groups.[2]

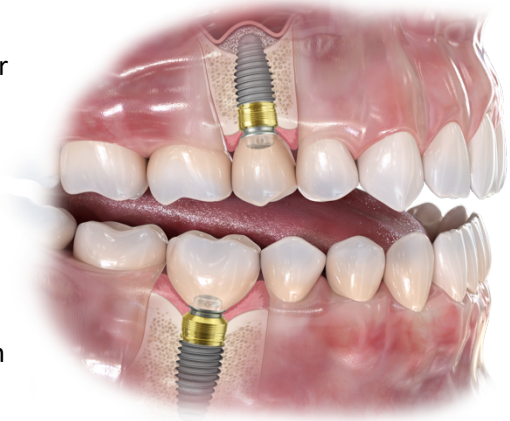

Fig. 1 Restored implants[a]

1.3 Considerations when planning the replacement of teeth with implants

Patient expectations
Patients must understand the differences between natural teeth and replacement teeth. Clear expectation management should form a pillar of the informed consent process, reducing the risk of dissatisfaction and ensuring patients are prepared for the maintenance journey. Discussion points should include both the short-term and long-term risks of treatment (including aesthetic, biological, and mechanical complications, as well as any patient-specific risks), alternative treatment options, treatment timelines, the longevity of treatment, costs of treatment and maintenance requirements.

Age
Implant placement should be postponed until craniofacial growth is complete, which is generally considered to be 18 years and above, but often occurs later in males.[8] If implants are placed before skeletal maturity, late facial growth may result in infra-occlusion of the implant prosthesis and a discrepancy in the occlusal plane.[9] There is no upper age limit for implant placement. However, consideration should be given to the patient's bone volume and quality, alongside their osteogenic propensity, by understanding their medical comorbidities, their ability to recover from surgery, and their ability to maintain complex dental work.

Aesthetics
It is essential to assess the aesthetic complexity of a case before commencing to ensure challenges are foreseen and patient expectations are managed. Aesthetic considerations include:

- The smile line, including the gingival show and the buccal corridors, determines what falls within the 'aesthetic zone'.
- Soft tissue factors include the periodontal phenotype and any pre-existing deficiencies that may be present.
- The shape, form and texture of the neighbouring teeth, as the aim of any aesthetic implant rehabilitation, will be to mimic the natural dentition.[3] Tooth shape and form will also influence the soft tissue and papilla architecture.
- Crucially, the patient's expectations must be evaluated to determine whether they can be met. A diagnostic wax-up is a valuable tool in implant planning, as it not only helps the clinician to prosthetically plan the implant positions but also helps to align patient expectations by showing a preview of the tooth position, shape, and overall aesthetic result.

Reason for tooth loss
Acquired tooth loss due to dental diseases, such as caries and periodontal disease, may indicate a lack of patient engagement or an inability to maintain an optimal oral environment conducive to long-term implant survival. Whilst stabilisation of active dental disease should be a prerequisite for dental implant treatment, careful consideration needs to be given to patients who have been unable to maintain their own dentition. The pattern of bone loss in patients who have lost teeth through periodontal disease or dental trauma may make replacement with dental implants more challenging and involve the need for additional soft or hard tissue augmentation procedures.

Medical History
As with any surgery, the patient's medical health must be taken into consideration when determining the suitability of implant therapy. Caution should be exercised with patient’s whose wound healing may be impaired. Poor diabetic control has been associated with delayed wound healing, a higher risk of infection and marginal bone loss around dental implants.[10] It has therefore

been recommended that glycaemic control should be established before implant therapy for diabetes.[6]

Implant placement is not recommended for patients who may have altered bony healing potential. These include patients who have received intravenous bisphosphonates (where a higher risk of complications is expected), long-term oral bisphosphonates or biologic agents due to the risk of post-surgical medication-related osteonecrosis of the jaw (MRONJ).[11, 12] Patients treated with head and neck radiotherapy are at risk of developing osteoradionecrosis (ORN).[13, 14] Consequently, patients with these risk factors require careful planning in conjunction with their medical team, often in a secondary care setting.

Social History

Smoking negatively impacts the immune response and wound healing, increasing the risk of implant failure and complications such as peri-implantitis.[15] Therefore, smoking cessation is highly recommended as part of 'primary prevention' to reduce the risk of complications.[6, 16] Although smoking is not an absolute contraindication, it must be conveyed as a risk factor and the NHS criteria for implant provision will not fund implants in those who smoke, even if they fall within the relevant high-priority category.

Prosthetically vs Anatomically Driven Implant Placement

Instead of placing implants based solely on available bone, a prosthetically driven approach begins with a prosthetic design and works backwards to guide surgical placement.[17] This planning step ensures the implant is placed in a position that supports a functionally and aesthetically optimal restoration, aids in the restoration's cleansability, and minimises the risk of complications.[6]

1.4 Periodontal, Endodontic and Prosthodontic Considerations

Periodontal

A patient's previous experience of periodontitis is a strong predictor of future dental and implant disease.[7, 18] Implants replacing teeth lost through periodontitis show lower survival rates and higher biological complications (peri-implantitis) compared to those lost for other reasons.[19] Therefore, caution is advised when planning implants for this patient cohort. Attachment loss resulting from periodontal disease may also necessitate the need for hard or soft tissue grafting.

It is essential to ensure periodontal stability before implant provision is considered. Poor oral hygiene significantly increases the risk of implant failure due to peri-implantitis.[20] Carrying out a risk assessment and controlling risk factors, in particular oral hygiene and compliance with treatment and supportive periodontal care, is key and has been highlighted in the EFP S3 level clinical practice guideline for peri-implant diseases.[6]

The gingival phenotype should be considered, as thick gingival tissue with a minimum band of 2mm keratinised tissue has been shown to contribute to improved peri-implant health.[7] A lack of keratinised gingival tissue with a thin phenotype may lead to difficulty maintaining plaque control in the area, peri-implant inflammation, peri-implant recession, shine-through or even exposure of the underlying implant components.

Endodontic

Chronic apical pathology is not a contraindication for implant placement, provided that the surgical site can be effectively degranulated and adequate primary stability of the implant can be achieved. If there is an inability to debride the site fully, primary stability cannot be achieved or if there is a fistula present, implant placement should be delayed.[21]

Teeth that have been lost as a result of endodontic pathology can present with bone loss that may complicate the provision of implants. Pathology associated with failed apicectomies, endodontic-periodontal lesions, or root fractures can exhibit specific patterns of bone loss, resulting in deficiencies in either apical or circumferential bone that are crucial for both short and long-term implant stability.

Retrograde peri-implantitis has been associated with chronic apical infection in adjacent site teeth. It is therefore essential to ensure that the primary disease has been treated and controlled prior to considering implant treatment.[22]

Prosthodontic

The planning of implant therapy should always be prosthodontically driven to optimise the outcome for aesthetics and cleansibility.[23] The first step in prosthodontic assessment is confirming the space available to replace the teeth, for which a diagnostic wax-up can be of great value. A wax-up will allow visualisation of ideal tooth positions in relation to residual ridge form, mesio-distal and facial-palatal aspects, and determining restorative space in occlusion.

Where teeth are malpositioned, realignment with orthodontic therapy or recontouring with composite bonding, veneers or crowns may be considered. Similarly, where there is suitable space but it is at risk of closure from drifting or overeruption, restorations or prostheses can be of value in maintaining this space.

Care should be taken with parafunctional patients as excessive loading may lead to an increase in mechanical failures, including screw loosening and fracture of implant components. This must also be considered in edentulous patients for planned implant management, whose parafunctional habits may not always be as obvious. In both cases, occlusal splint provision may be indicated.[24]

The clinician should look at the strategic value and prognosis of the remaining dentition. Strategic teeth (i.e., those that are key for function, maintenance of occlusal vertical dimension, or could serve as abutments for conventional tooth-borne prostheses) should be maintained where possible. However, teeth of an unfavourable prognosis should be considered as part of the overall management plan.

Planning for failure is a fundamental part of any comprehensive rehabilitation plan, whether it involves the failure of natural teeth in the area considered for implant placement or the potential failure of the implants or prosthesis themselves in the future.

1.5 Indications and relative contraindications

Dental implants and their associated prostheses can offer long-term tooth replacement if planned carefully and executed in a way that minimises complications.[25] They can be used to replace single, multiple or full arches of missing dental units with either fixed or removable prostheses. The indications include:

- Improvement or restoration of aesthetic [1] and functional [26] oral health-related quality of life.
- Replacement of missing dental units where conventional treatment options (removable partial dentures or bridges) have been unsuccessful or contraindicated.
- Patients with:
    - Missing or malformed teeth due to inherited or congenital conditions e.g., hypodontia, cleft lip and palate, amelogenesis imperfecta.
    - Tooth loss due to dental trauma.
    - Tooth loss due to benign or malignant tumours of the head and neck.
    - A history of multiple conventional dentures that have been unsuccessful.[27]

These patients are considered high-priority groups for NHS implant funding and must fulfil the criteria for acceptance.[28]

Whilst dental implants can offer excellent solutions to replace missing teeth, they are not suitable for all patients. There are no absolute contraindications for dental implants; however, several relative contraindications and risk indicators may increase the likelihood of peri-implant disease, implant failure, or post-operative complications. [29] In these patients, caution should be exercised, and the risks vs benefits of dental implants should always be considered as part of the informed consent process.[6] The relative contraindications are:

- Unstable primary dental disease; including periodontal disease which leads to a higher risk of failure and biological complications.[19]
- Poor oral hygiene is associated with a higher risk of biological complications.[20]
- Habits such as parafunction can increase the risk of mechanical complications.[24]
- Active smokers who are at is a higher risk of peri-implantitis and implant failure [16]
- Uncontrolled diabetic patients who have poorer wound healing.[20]
- A history of head and neck radiotherapy due to osteoradionecrosis (ORN) risk.[16]
- A history of oral or intravenous anti-resorptive or anti-angiogenic medicines which pose a risk of medication-related osteonecrosis of the jaw (MRONJ).[25]
- Incomplete skeletal growth, which may result in infra-occlusion and occlusal plane discrepancies.[9]
- Unstable or uncontrolled medical conditions, e.g., epilepsy, drug or alcohol abuse, mental health issues, and blood disorders. The dentist should consult the patient's medical practitioners in the event of any concerns.
- Insufficient prosthetic or surgical space to facilitate dental implant placement.

2. Implants and their components

A dental implant is the replacement of the root portion of a missing tooth, to which a crown, bridge, or denture can be attached. Classically made of titanium, they integrate with the bone in which they are placed. These can be one-piece, where the implant includes a transmucosal portion, or two-piece, where an abutment is screwed on top of the implant.

The vast majority of implant fixtures are made of commercially pure titanium; however, alloys have been introduced that can offer increased tensile strength,[30] or ceramic implants, which provide metal-free options to patients.[31] Implant surface topography has also changed over the years starting from machined to acid etched and more recently to chemically active surfaces all with the view of promoting faster osseointegration.[32]

The design of the implant fixture is an important parameter to consider when planning a patient's treatment, ensuring the appropriate features are selected for the specific case. This includes the shape, diameter, length, thread design and prosthetic connection. The most commonly shaped implants used today are either tapered or parallel with each implant fixture being available in a range of lengths and diameters depending upon the implant system. Lengths may vary from 4 mm to 15 mm, and diameters range between 3 mm and 6 mm; however, options are available outside of this range.

The threads of the fixtures can vary in pitch, depth, and configuration depending on the clinical need. More aggressive thread designs are commonly used in Type IV (soft) bone or immediate cases where primary stability may be more challenging to achieve. The prosthetic connection, which is either external or internal, is a crucial feature as it imparts the anti-rotation and locking mechanism for the prosthesis into the implant fixture.

While implant companies vary in the type of product they market, the majority fall into the core features mentioned above, with minor variations within each type. The terminology regarding implants remains the same between available systems, as described below:

- **Fixture:** This is the part that is placed into the bone and is equivalent to the root of a tooth. The surface of the fixture will integrate with the bone and form a union through a process called osseointegration. It acts as the anchor onto which the prosthesis is connected.

- **Fixture head:** The most coronal portion of the fixture, which carries the anti-rotation connection and locking features. This connection can be:
    - Internal: the implant fixture has a recess within itself that allows for the abutment to 'fit into' the implant. The internal shape of these tends to have a form that prevents rotation of the connected abutment, such as hexagonal, octagonal, or triangular.
    - External: This is located outside the fixture head, and the abutment seats

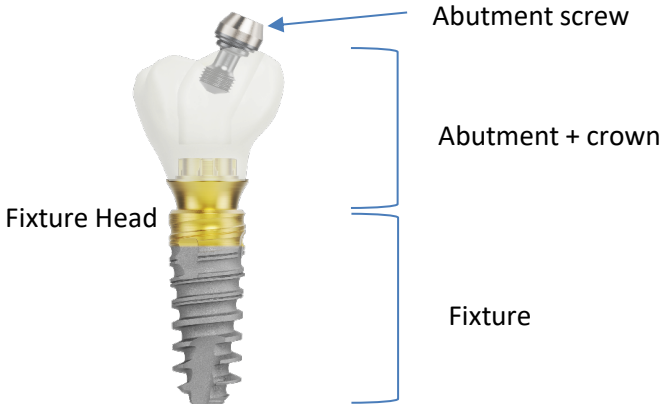

Fig. 2 Anatomy of the restored implant[a]

over it. The anti-rotational portion can be hexagonal or octagonal.

- **Abutment**: this is the transmucosal component which is screwed into the fixture head and connects the fixture to the prosthesis. There are a wide variety of abutments which are described below:

  - **Healing abutments** – connected to the fixture either at the time of implant placement or at second stage surgery when the fixture is uncovered, allowing the gingival tissues to heal around them. They can be either prefabricated or custom-created to develop an emergence profile that contours the gingival tissue during the early stages of healing.

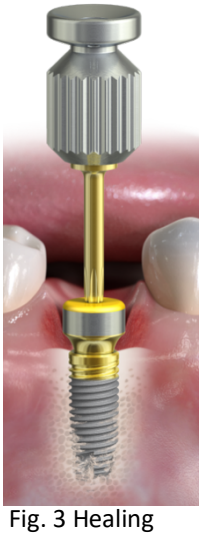

Fig. 3 Healing abutment placed immediately after surgery[a]

  - **Prefabricated/Stock Abutments** come in a variety of heights and diameters to suit differing clinical needs. Lower-profile abutments are generally used when there is limited inter-occlusal space, but they come with the risk of providing insufficient retention and resistance form to retain the prosthesis that is cemented to them. They can also be straight or angled, depending upon the requirement for angle correction of the implant positioning. (see Fig 2)

  - **Multi-unit abutments** are used when restoring multiple implant fixtures in a single, linked restoration or bridge – these can also come as straight or angled. They allow the restoration to be placed at 'abutment level' as opposed to 'fixture level' (directly onto the fixture') and can therefore account for differences in implant angulations.

Fig. 4 Multi Unit abutments (above un-restored and below restored)[a]

  - **Overdenture abutments** are stock abutments with retentive features that allow dentures to clip onto them. Most commonly, these are called locator abutments and have a 'press-stud' design, with more historic abutments being ball shaped.

  - **Customised Abutments** are designed and shaped to the required contour, often using CAD-CAM technology. They allow the clinician to create the emergence profile themselves, allowing for optimal tissue adaptation.

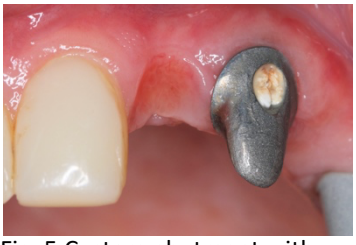

Fig. 5 Custom abutment with screw channel PTFE filled[b]

3. Osseointegration and healing

Osseointegration is a process whereby a biocompatible material is incorporated into bony tissue. It is primarily a histological term, first described by Branemark et al. 1969 as bone-to-implant contact at the light microscopic level.[33] This demonstrates an apparent direct attachment or connection of vital osseous tissue to the surface of an implant, without intervening connective tissue, and is maintained by the turnover of bone adjacent to the implant.

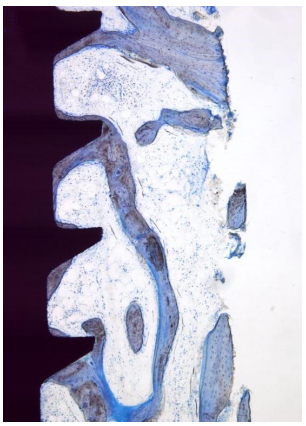

Fig.6 – Osseointegration on a microscopic level[a]

3.1 Stages of healing

The healing responses of dental implants have been described in experimental studies[34] and can be comparable to primary bone healing.[35] It is important to note that complete bony coverage of the implant surface does not occur. Instead, those areas not covered with bone will develop adipose cells. The bony coverage typically ranges from 56% to 85% with screw-type implants.[36]

Day 0: To achieve mechanical stability during the initial phase of wound healing, the implant threads should be in close contact with the surrounding bone, also referred to as primary stability. This stability largely depends on the quality of the bone and the implant design. In cases where soft bone is expected, an implant design or drilling protocol should be chosen to maximise primary stability. The clinician will be able to gain an appreciation of the primary stability through the insertion torque of the implant upon placement. Blood clots within the first 2 hours serve as a scaffold for reparative granulation tissue, promoting osseous healing.

Day 4: The blood clot is replaced with granulation tissue, characterised by the penetration of vascular structures and fibroblast-like mesenchymal cells. Osteoclasts, which are responsible for bony resorption, begin to become visible on the cut bone surface.

Week 1: Woven bony formation begins within some of the implant threads by extension of the newly cut bone. There are many vascular structures present, along with inflammatory cells, osteocytes and osteoblasts within the trabeculae.

Week 2: Profound new bone formation around the implant, which is rich in vascularity and has the presence of collagen fibrils adjacent to the implant. The primary bone contact begins to be lost due to remodelling, and new bone formation takes place to generate secondary bone contact. This is a crucial time during osseointegration, as the primary stability begins to decrease due to bone resorption around the implant threads, and the secondary stability through osseointegration has not yet fully commenced.

Week 4: Bony formation continues with more apparent signs of remodelling, with a large volume of the initial woven bone being replaced by lamellar bone.

Week 6, 8 and 12: By week 6, gradually more mineralised tissues form as lamellar bone continues to maintain a high degree of osseointegration. After 8 and 12 weeks, marked signs of remodelling are seen in the bone tissue, surrounded by bone marrow containing adipocytes, vessels, collagen fibres and some mononuclear leukocytes. As bone is dynamic, the interface will continually undergo remodelling, and even theoretically encapsulate the implant in bone as a 'foreign body'.[37]

3.2 Factors affecting osseointegration and healing

It has been shown that several factors can influence osseointegration and healing.[38] These include:

Primary Stability
The biomechanical stability of the implant during the healing phase is the most critical factor influencing osseointegration and is related to the bone quality and quantity, the implant design, and the surgical technique at placement.

Bone Quality and Quantity
This has been described by Lekholm and Zarb as Type I (dense compact bone) to Type IV (low density trabecular bone) with Type II and III in between.[39]. Whilst type I bone offers good primary stability due to its composition, it lacks vascularity which can affect longer term healing. On the other hand, type IV which is very soft and requires care during site preparation to maintain primary stability.

Implant Material, Design and Surface Topography
A biocompatible material with design features that encourage biomechanical stability of the implant will influence osseointegration. The macro-structure and microstructure will affect the rate at which osseointegration occurs. Early implants had machined titanium surfaces, but today, acid-etched, sandblasted, and chemically treated surfaces are the most common. This enables faster healing and potentially allows restorations to be placed either immediately or within a few weeks. However, a rough surface, if exposed to the oral environment through peri-implant disease, can act as a plaque retentive factor.

Surgical Techniques
The surgical technique of implant site preparation has a significant influence on the mechanical stability achieved of the implant and subsequent wound healing. The site should be prepared under controlled conditions with adequate cooling using incremental site expansion following the recommended drilling protocol. This avoids overheating of the bone which otherwise can result in bone necrosis.

Implant Loading
The prosthetic design should ensure functional and aesthetic restoration, with appropriate occlusion and force distribution. Gradual, monitored loading is crucial to prevent excessive stress on the implant-bone interface, avoiding failure or crestal bone loss.

3.3 Timings of implant placement

Different timings for implant placement have been described in relation to the edentulous site,[21] and implants have been categorised as Type I, Type II, Type III and Type IV according to the time of placement following tooth extraction/loss:

- Type I implants: immediate implant placement (immediate placement at time of tooth extraction)
- Type II implants: early implant placement with soft tissue healing (4-8 weeks)
- Type III implants: early implant placement with partial bone healing (12-16 weeks)
- Type IV implants: late/delayed implant placement (typically 16 weeks or later)

It is important to note that there is not a 'one size fits all' approach to timing of implant placement and each protocol has its own pros and cons:

Fig. 7 – Type 1 placement with particulate graft material between buccal plate and implant, with primary stability gained through the apical portion of the implant[a]

- Type 1 implant placement (immediate placement) – this is the quickest route for the patient to have an implant placed. However, there can be challenges associated with implant positioning into an extraction socket and care should be taken. Particularly with implant angulation and in ensuring that the implant is placed subcrestally to account for bony remodelling that occurs after tooth extraction. The use of a surgical guide or stent with the ideal prosthetic tooth position can help overcome challenges related to implant angulation. Type 1 implants should generally be avoided in sites with active infection that cannot be degranulated, where there is a lack of primary stability, thin periodontal phenotype, lack of or very thin remaining buccal plate or extensive alveolar defects as these are complex to correct during immediate implant placement.

- Type 2 implants (placed at 4-8 weeks) have the advantages that there is early soft tissue healing in the site as epithelisation over the extraction socket has generally been completed, any infection has often been resolved and early bone remodelling has begun. However, there can be varying degrees of resorption of the alveolus following the extraction and bone augmentation is frequently still required.

- Type 3 placement protocols (placed at 12-16 weeks) mean that the soft tissues are mature. There is potential for significant bone infill into the extraction site (albeit still immature) and therefore primary stability is generally improved.

- Type 4 and late implant placements (placed >16 weeks) result in a long treatment pathway for the patient. However, this may be indicated in patients who cannot afford treatment at this present time or in those who are too young for treatment. The long time period between extraction and implant placement means there can often be extensive bone resorption that may require additional augmentation procedures.

All placement protocols demonstrate high implant survival rates of over 95% between 2 and 7 years, depending on the loading protocols.[21] It is for the clinician to decide in which clinical situations each protocol is suitable.

Implants can be placed in a one stage or a two-stage procedure, depending upon whether it is to be loaded immediately or delayed. In a one-stage procedure, the implant is not buried and is either loaded immediately (which will be discussed later), or a healing abutment connected to allow the soft tissues to heal around, but not over, the implant.

A two-stage procedure involves complete coverage and burying of the implant underneath the full thickness flap. It may require the provision of either a fixed or removable temporary prosthesis whilst the implant is integrating. The use of a prosthesis that does not load the mucosa is preferable, i.e., a clear retainer with a tooth, or a provisional resin-bonded bridge. The second stage of a two-stage procedure involves uncovering of the dental implant, with or without soft tissue augmentation if required.

4. Adjunctive procedures

When assessing a potential implant site (whether it is edentulous or has a tooth *in situ*), the quantity and quality of bone, as well as the quality of gingival tissue, must be evaluated to plan for any necessary augmentation. It should be noted that bone resorption following tooth extraction can be expected in the region of 3 mm width and 1.5 mm height.[40]

There are different techniques for hard and soft tissue augmentation that are outlined below, but each will use one or more of the following tissues to improve bone or soft tissue quantity and/or quality:

- Autogenous: tissue relocated from one site to another in the same patient. For bone, this can be in the form of particulate matter taken locally at the implant site or harvested locally from the ramus, anterior nasal spine, or zygoma. In cases where larger volumes are required, blocks can be taken from distant locations such as the iliac crest, fibula or lateral femoral condyle. Autogenous soft tissue can also be harvested from the palate or tuberosity.
- Xenograft: tissue that is taken from a different species and transplanted to another. This is typically from bovine or porcine sources, which undergoes strict processing to remove cellular and immunologic content.
- Allograft: tissue that is taken from the same species but transplanted to another individual. Commonly, this is from deceased donors.
- Alloplastic: this is a synthetic graft material that serves as a scaffold for new bone growth.

The choice of graft material will depend on patient preference, operator preference, availability, and cost implications.

Bone graft material properties should also be highlighted as being:

- Osteogenic: the graft material contains all of the cells required for bone formation e.g., autogenous grafts.
- Osteoinductive: the graft promotes differentiation and recruitment of bone-forming cells for osteogenesis.
- Osteoconductive: the graft provides a scaffold for new bone to grow on, e.g., xenograft and alloplastic.

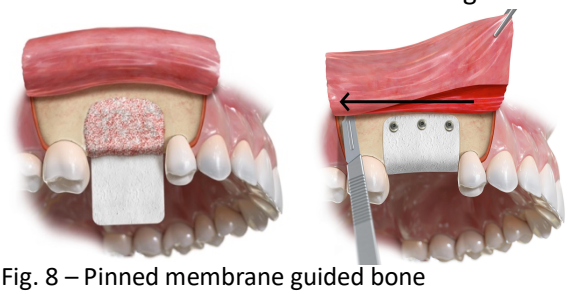

Fig. 8 – Pinned membrane guided bone regeneration into edentulous maxillary region[a]

4.1 Hard tissue

Guided Bone Regeneration

This involves the use of a membrane over a bone substitute to create space for osteogenic activity. The success of the surgery depends on the migration of pluripotent cells from the periosteum and adjacent bone, allowing for osteogenesis. The membrane prevents proliferating epithelial/connective tissue cells from rapidly entering the area, allowing time for slowly growing osteoprogenitor cells to colonise the defect and undergo osteogenesis.[41]

Guided bone regeneration can be undertaken either simultaneously with implant placement or before implant placement, depending on clinician preference and the amount of residual bone available for primary stability.

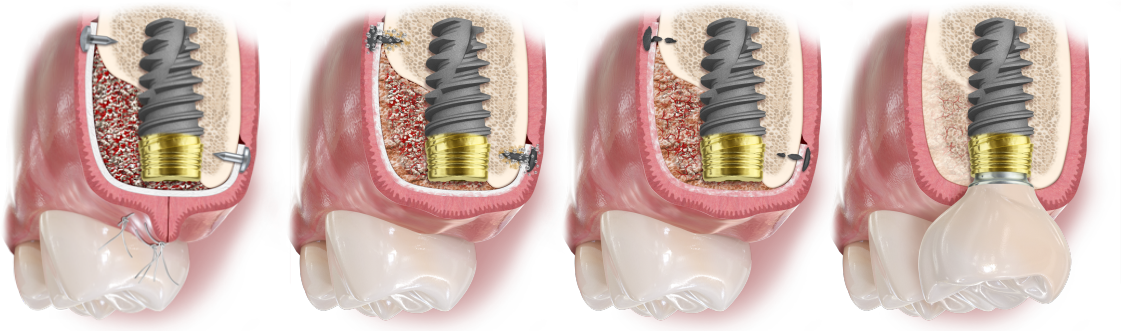

Fig. 9 – The process of osseointegration of crestal guided bone regeneration around an implant using a resorbable pinned membrane[a]

For guided bone regeneration to be successful, there are 4 key principles (known as the PASS principles)[42] that need to be considered:

- Primary closure – to prevent epithelial cell migration into the site and prevent contamination.
- Angiogenesis – this is key to allow perfusion of the graft with the host's blood, which will bring osteoprogenitor cells with it.
- Space – this needs to be created and maintained to allow a blood clot to form
- Stability – as with all healing, wound stability prevents early breakdown and maintains a scaffold for osteogenesis

There are multiple considerations when undertaking guided bone regeneration, including:

- Resorbable vs non-resorbable membranes
- Autogenous, allograft, alloplastic, and xenograft forms of bone graft
- Block vs particulate grafting
- The use of supporting metal meshes or pins to assist in providing space or stability to the surgical site

When this technique is used at the point of extraction, it is commonly called alveolar ridge preservation. It attempts to preserve bone volume during the remodelling phase, which can be prior to or in conjunction with immediate implant placement or soft tissue grafting. Evidence suggests that alveolar ridge preservation reduces both the height and width of bone resorption following an extraction.[43]

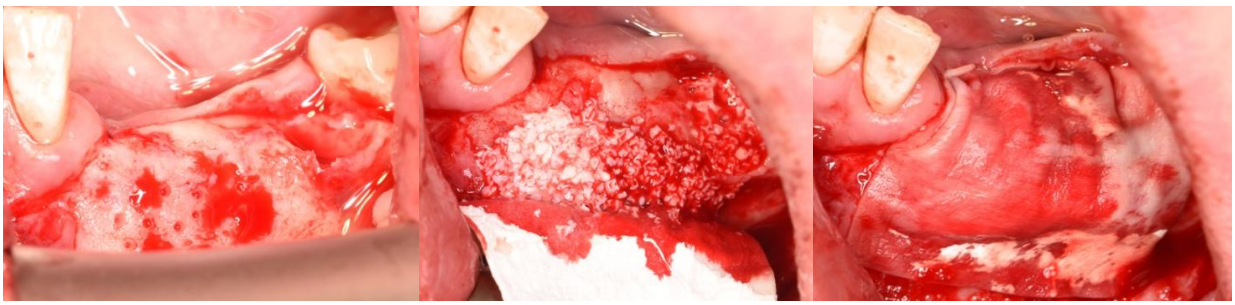

Fig. 10 – buccal guided bone regeneration showing decortication, xenograft material placement and coverage with a resorbable membrane[c]

Ridge Split

In cases of a thin residual ridge but with an adequate vertical dimension, a ridge split can be considered. Success is more likely where there is sufficient intra-cortical cancellous bone (a horizontal dimension of 4 mm or more) without a bony undercut, with an arch length suitable for cortical flex to house the fixtures.[44] Graft particulate is placed into the split site and around the implants, which are commonly placed under a membrane.

Sinus Lift

A sinus lift procedure can be undertaken where inadequate vertical height is present in the maxillary posterior regions. There are different approaches for sinus lifts, including trans-crestal (through the residual ridge) or lateral access (creating access directly into the sinus) with both providing vertical height for implant placement.[45] This space can be maintained with a particulate graft, which is placed between the sinus membrane and the bony walls/floor of the sinus. This can be performed prior to implant placement or in conjunction with implant placement where primary stability of the implant can be achieved (typically a residual height of 5 mm bone is considered satisfactory).[45]

Block Grafting

Block grafting can be employed where gross changes in bony volume are required, either in the horizontal or vertical dimension. Typically, autogenous block grafts are harvested from the ramus or the mental region, and fixated into the surgical site with screws. This technique can be enhanced by placing graft particulate in a method described by Khoury et al. (2019) and covering it with a membrane.[46] More recently, milled blocks of allograft material are available from human donors.

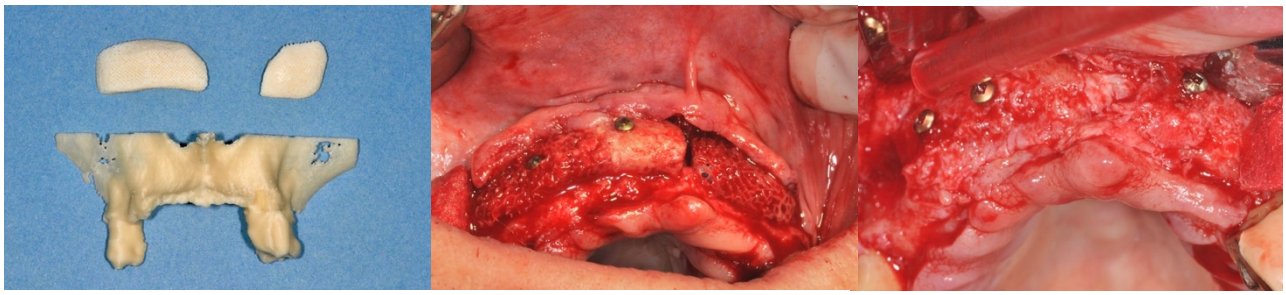

Fig. 11 – Printed maxilla and allograft with subsequent photos of initial placement and exposure post integration for screw removal and fixture placement[d]

It is generally accepted that vertical augmentation is more challenging than horizontal augmentation due to difficulties with creating space for the graft and blood clot, and then stabilising this. However, irrespective of bone augmentation technique, implant survival in augmented sites is high and comparable to implants placed at 'pristine' sites.[47]

The patient's own blood can also be an excellent source of growth factors and can be used to make platelet-rich plasma or platelet-rich fibrin through specific preparation techniques using centrifuges. This can then be mixed with bone substitutes to promote osteogenesis or used as a form of membrane to cover grafted sites.

4.2 Soft Tissue

The presence of adequate quality and quantity of soft tissues is equally important for improving predictability and outcomes. Implant stability and longevity are best when emergence is through stable, thick, keratinised tissue [6]; however, this is not always present and may require augmentation. Furthermore, soft tissue grafting around implants can be a valuable tool for providing solutions to recession or where tissue thickness is lacking, leading to compromised aesthetics.[6]

Free Gingival Grafts

Free gingival grafts aim to increase keratinised gingival tissue and are surgically taken from the patient's palate and placed onto the recipient site. This procedure is usually undertaken when there are high muscle attachments or a lack of keratinised tissue in the surgical site. This procedure can be completed at various stages during the patient's implant journey, but it may only be required later if extensive grafting has been necessary. These grafts can be undertaken before implant placement, afterwards at a second-stage surgery, or at some point in the future if peri-implant recession has resulted in a lack of keratinised tissue.

Connective Tissue Grafts

Connective tissue grafts can be used to enhance tissue volume or manage peri-implant recession. They are harvested from the patient's palate or tuberosity (without the overlying epithelium) and stabilised underneath a flap or tunnel around the dental implants. They provide an excellent solution for increasing soft tissue volume in the surgical site and can be used before, during or after implant placement. This procedure has advantages over the free gingival graft in its improved aesthetics with colour match and avoiding the "keloid" healing appearance.[48]

Soft Tissue Substitutes

One of the drawbacks of harvesting autogenous tissue from the patient's palate is the relatively high morbidity from post-operative pain. Recent efforts have been made to compare the effects of replacing this procedure with xenograft-stabilised collagen matrices or acellular dermal matrices that negate the need for harvesting the patient's own tissue. Whilst connective tissue grafts are still the gold standard,[49] consideration can be given to the use of xenograft materials to increase tissue thickness if there is poor quantity of donor site tissue or if the patient wishes to avoid a second surgical site.[50]

Soft Tissue Procedures at Second Stage Surgery

The peri-implant soft tissues can also be manipulated at the second-stage surgery (where the implant is buried and then uncovered). Free gingival grafts or connective tissue grafts can be used to augment or thicken the tissues during the second stage. Alternatively, with careful flap designs when uncovering the implants, the patient's native tissues can be moved and manipulated to provide increased thickness, eliminating the need for a free graft from the palate. Examples of these include:

- The pouch roll technique – where the tissue overlying the implant is de-epithelialised and folded underneath a small buccal pouch to thicken the tissue profile.
- Apically repositioned flaps – where a split thickness flap is created over the implant and sutured apical to where the gingival margin will be. This technique is beneficial when moving keratinised tissue from the palatal to the buccal.
- 'Split finger' or 'Palacci' flaps can be used to rotate the tissue that is overlying the implant into the interproximal areas in an attempt to bulk out or recreate papilla.[51]

5. Restoration of Dental Implants

5.1 Timing of restoration

The timing of implant restoration and loading was described by Morton et al 2023 and should be considered depending upon patient and clinical factors:[21]

- Immediate loading occurs within 1 week of implant placement
- Early loading occurs between 1 week and 2 months
- Delayed loading occurs >2 months

Differentiation needs to be made between loading and restoration. Immediate restoration of an implant does not necessarily result in immediate loading, as it depends on the occlusal scheme that has been designed. Conventional, delayed loading has historically been accepted as the gold standard due to the belief that loading should only be undertaken after osseointegration has completed. With advances in implant surface topography and osseointegration times, there is an increasing popularity (and evidence base [21]) to support immediate loading with single, multiple, and full-arch prostheses. Immediate loading offers the clear advantages of the patient leaving the surgery with an immediate tooth replacement. It can also allow for excellent soft tissue healing around the implant if the emergence profile is created appropriately. However, it may not be suitable in cases where extensive grafting has been undertaken, into which the implants have been placed, or where there is a lack of primary stability upon implant insertion.

Overall, immediate loading in the correctly selected cases can result in similar implant survival rates and marginal bone levels to conventional loading.[52]

Fig. 12 – Screw retained restoration[a]

5.2 Types of Implant Restoration

Dental implants can be restored with both fixed and removable prostheses. The end goal of rehabilitation should always be considered from the outset, ensuring a prosthetically driven treatment plan to optimise aesthetic and functional outcomes.

The decision for rehabilitation with either a fixed or removable prosthesis should be made at the planning stage when deciding upon the number, type and distribution of implants to be placed. In general, the following factors should be considered in the decision-making process:

- Number of dental units needing replacement - fewer dental units are more likely to be replaced with a fixed prosthesis.
- Surgical space availability – 4 or more implants are required in both the mandible and maxilla to be able to restore a full arch with a fixed prosthesis.[53] If it is only possible to place fewer implants in a full arch, due to anatomical limitations and where additional grafting is not being considered, a removable prosthesis would be indicated.
- Prosthetic space availability – more inter-occlusal space would be required to restore a patient with a bar retained removable prosthesis and less inter-occlusal space for a fixed screw retained prosthesis.
- Requirement for soft & hard tissue replacement – it is easier to replace hard and soft tissues (without additional augmentation), as well as support the soft tissues of the face, with a removable prosthesis.

- Patient factors – Patients with limited dexterity may find the oral hygiene maintenance burden of a fixed prosthesis more challenging than that of a removable prosthesis.
- Financial constraints

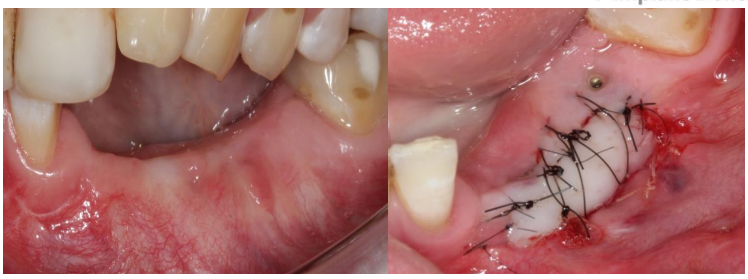

Fig. 13 – An edentulous site in a congential hypodontia case that had previous bony augmentation lacking in keratised tissue, where a palatal free gingival graft was placed to increase the width of keratinised tissue.[c] in the edentulous site[c]

5.3 Fixed restorations

Fixed restorations can either be cement or screw-retained, and restored at either fixture level (directly onto the head of the implant) or abutment level (allowing the use of an intermediary component to account for implant angulations).

Screw-retained restorations have the prosthesis directly screwed into the abutment or fixture, as opposed to a cement-retained restoration, where the abutment is screwed into the fixture. Then a crown is cemented onto the abutment.

Cement-retained restorations are generally used to overcome aesthetic challenges with implant angulations, avoiding screw access channels on the labial face. However, with the advance of angled screw access channels, this can generally resolve this issue. Diligence must be exercised to remove any excess cement, as it acts as a plaque-retentive factor and induces inflammation.
The advantage of screw retained restorations over cement retained is the ease of retrievability should complications be encountered.

Fig. 14 – Cement retained restoration[a]

Whether using a cement or screw retained restoration, a protective barrier must be placed on top of the internal screw (such as cotton wool or PTFE tape) to allow retrievability and avoid damage to the screw head.

Whilst evidence suggests similar survival and failure rates for screw *versus* cement retained implant restorations, both biological and mechanical complication rates are higher for cement retained.[54]

Material choices for fixed implant restorations may include metal-ceramic or zirconia. Both materials demonstrate similar survival rates for single units,[55] but metal-ceramic demonstrate superior survival for full arch restorations.[56]

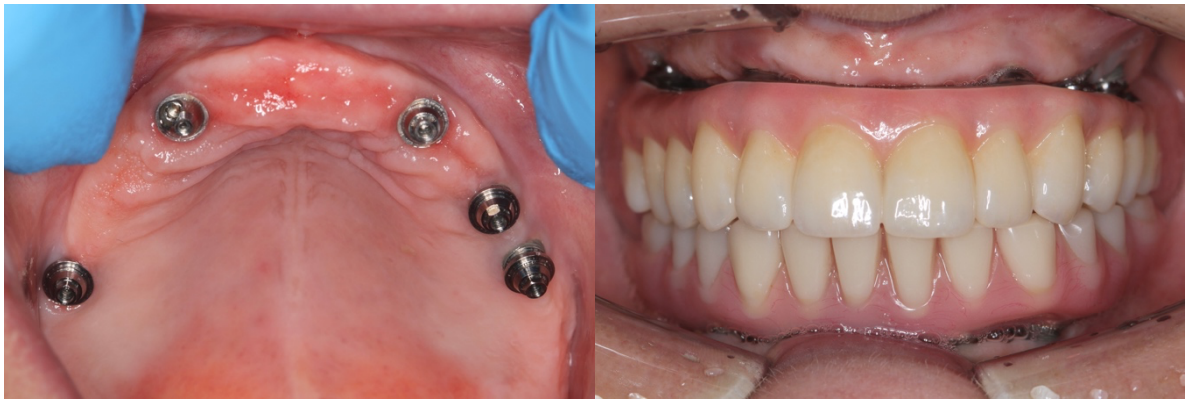

Fig. 15 – Upper full arch FP3, fixed appliance on straight and angled Multi Unit abutments[b]

General occlusal principles [57] for fixed implant restorations include:

- Light ICP contact with shimstock hold on heavier biting
- Clear of excursive movements, or at least shared with natural teeth
- For full arch restorations, a shallow excursive pattern, group function, and avoidance of heavy contacts on cantilevered segments are recommended.

Regardless of the type of fixed restoration, it is of paramount importance to ensure it has been designed in such a way that provides sufficient access for effective patient-performed oral hygiene and professional monitoring to ensure longevity.[6]

5.4 Removable Restorations

Removable prostheses can be considered as implant retained (in which the implants retain the denture, but the underlying tissues still support it) or implant supported (in which a bar will both retain and support the denture).

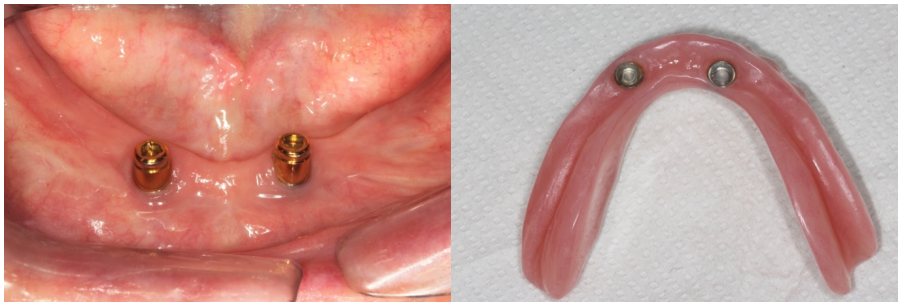

Fig. 16 – Lower full arch RP5, removable mucosa and implant-supported, implant-retained denture[b]

The York/Magill Consensus Statements suggest that two implants should be the gold standard for retaining a mandibular complete denture, which can lead to a significant improvement in patients' quality of life.[27, 58]

For a fully implant supported overdenture, a greater number of implants are required, generally splinted together with a bar. It would seem prudent to follow the principles on implant number and distribution from fixed restorations, in that 4 well-distributed implants would be required to support a complete denture. If only a shorter occlusal table is being used, three implants could be considered, but they require splinting to improve survival.[58, 59]

Along with implant number, prosthetic space availability is a key consideration when planning for removable prostheses. Free standing attachments, such as locators or ball attachments require only 7 mm of space availability in a vertical orientation, whereas a splinted bar requires up to 14 mm of vertical space. Housings within the prosthesis are then required which hold the retentive components. Regardless of whether implants are being utilised, a removable prosthesis should be constructed to ideal extensions and prosthodontic principles.

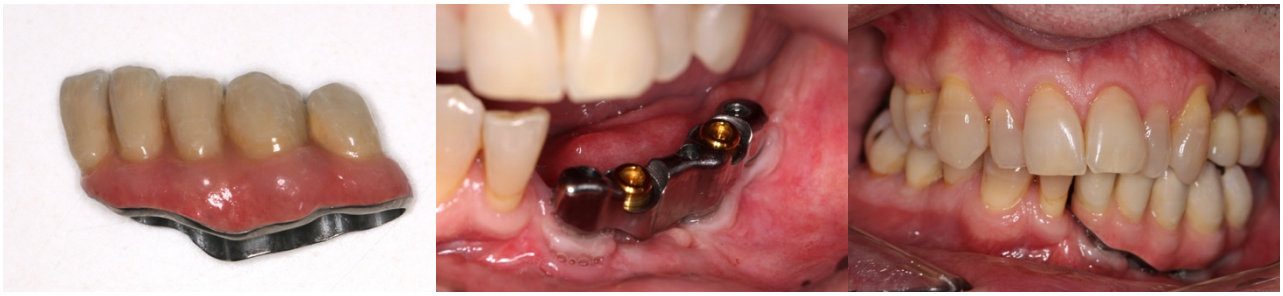

Fig. 17 – Lower partial RP4 prosthesis with a titanium milled superstructure, on an implant-retained bar with locators for prosthesis retention[b]

6. Complications

Complications with dental implants may occur at an early or late stage and can be categorised as aesthetic, biological or mechanical. Planning, visualising, and understanding of the final restoration are crucial in prosthetically driven implant placement and can help reduce the risk of the aforementioned complications.

6.1 Aesthetic Complications

These are often multifactorial arising from issues with the soft tissues or the implant prosthesis itself, influencing patient satisfaction.

Soft tissue factors [60] that may influence the aesthetics of implant restorations:

- Gingival margin position - this can sometimes be influenced and modified through a period of provisionalisation with the restoration.
- Deficiencies - this is most notable with the loss of the interdental papilla, and can be especially challenging to recreate with multiple unit restorations and where there was a lack of soft tissue volume pre-operatively.
- Phenotype - a thin phenotype may result in shine-through of the transmucosal abutment (especially where titanium is used) and predispose to recession around the implant restoration.

If implants are placed in an incorrect three-dimensional orientation with no consideration of the final restoration, the aesthetics can be severely compromised. For example, implants placed too buccally can result in a thin residual buccal plate at an increased risk of resorption, leading to peri-implant soft tissue deficiencies,[6] highlighting the importance of prosthetically driven placement.

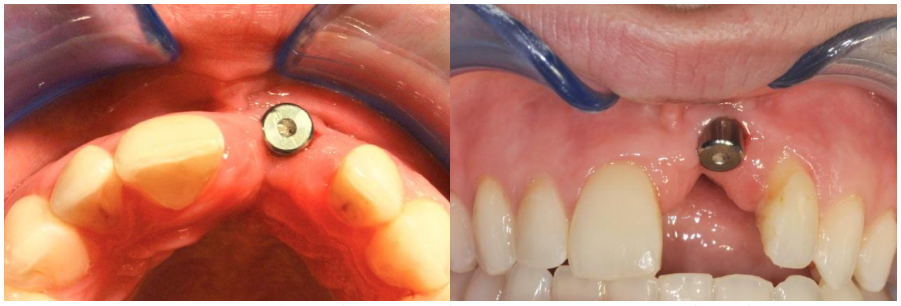

Fig. 18 – Post trauma implant placement leaving a compromised implant positioning currently restored with healing abutment[c]

The importance of the soft tissue around dental implants should not be overlooked and should be thought of as equally as important as hard tissues and considered as part of the pre-operative assessment. The management of soft tissue aesthetic complications typically involves a surgical approach but may also require prosthesis modification and/or remaking. The surgical management, if pre-empted, can be undertaken prior to fixture placement, at fixture placement, at a second-stage procedure, or at the restorative phase, depending on the type of procedure required.

Prosthetic factors that may influence the aesthetics of implant restorations include:

- Tooth form and shape
- Shade - including value, chroma and hue
- Surface texture in comparison to the adjacent teeth
- Translucency and additional characterisation

To optimise the 'white' aesthetics, excellent communication with the laboratory is paramount. Sharing of records to assist with planning may include detailed diagrams and photographs (colour, black & white, and cross-polarised).

6.2 Biological complications

It is of paramount importance to reduce the risk of biological complications, to ensure patients have modifiable risk factors controlled before embarking on their implant journey. A thorough evaluation and stabilisation of their risk factors are required, including inflammation in the form of gingivitis and periodontitis, glycaemic control, and smoking cessation.[7]

Biological complications are multifactorial and arise from the soft and hard tissues surrounding an implant. To understand what peri-implant disease is, it is essential to first define peri-implant health. Peri-implant health [61], much like periodontal health, is a clinical term used to describe the absence of visual inflammation (including swelling and suppuration) and the absence of bleeding on probing. Regarding the bone surrounding the implants, there should be no crestal bone remodelling beyond 2 mm within the first year of function.

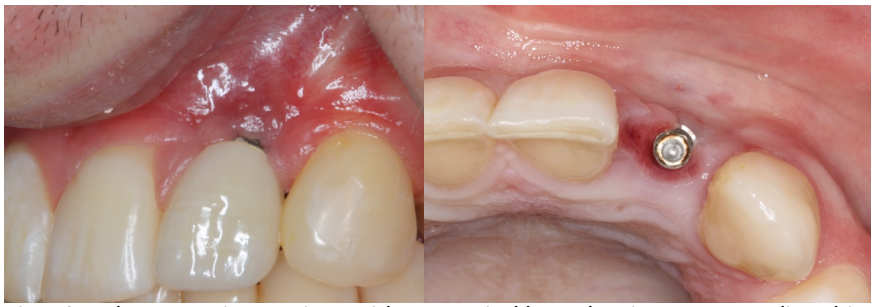

Fig. 19 – Placement in a patient with congenital hypodontia, corresponding thin alveolar ridge and minimal keratinised tissue; leading to a requirement for further post-placement treatment considerations[b]

Peri-implant mucositis can be considered similar to gingivitis, characterised by visual inflammation and swelling, but without associated peri-implant bone loss. Defining features include inflammation of the peri-implant tissues with bleeding on probing, but crucially no radiographic evidence of progressive crestal bone loss.[6, 29] Generally, risk factors for peri-implant mucositis include biofilm, smoking and plaque-retentive factors such as excess cement. There is debate as to whether a lack of keratinised tissue (<2 mm) is a true risk factor, but what is accepted is that an absence of tissue causes discomfort during cleaning, resulting in biofilm accumulation and inflammation.[7, 62]

The recommended treatment for peri-implant mucositis has been thoroughly summarised in the European Federation of Periodontology S3 guidelines, "Prevention and treatment of peri-implant diseases"[6] and should be considered the first line of defence in preventing peri-implantitis. Treatment should involve optimisation of biofilm control, ensuring prosthesis cleansibility to facilitate self-performed cleaning and professional mechanical plaque removal (PMPR). There is still debate and a lack of evidence,[63] as to the most effective material for hand and powered PMPR, with plastic-coated tips and titanium instruments being popular choices. The S3 level guidelines do not recommend the following in the management of peri-implant mucositis alongside conventional PMPR: air polishing, diode lasers, or locally or systemically administered antibiotics.

Re-evaluation should occur at 3 months with ideal treatment outcomes being ≤ 1 point bleeding on probing with the absence of suppuration. Re-instrumentation should occur if these end-points have not been met.

Peri-implantitis, similar to periodontitis, is a biofilm-associated condition characterised by inflammation of the peri-implant tissues accompanied by progressive crestal bone loss. Diagnostic criteria include peri-implant inflammation with bone loss above that expected after initial

remodelling (>2 mm).[61] If there are no baseline records to compare to, crestal bone loss >3 mm from the fixture head constitutes peri-implantitis.

Probing depth thresholds for the diagnosis of peri-implant health, peri-implant mucositis and peri-implantitis should be used with caution. There is a large degree of variability of probing depths of the peri-implant tissues which a multitude of factors other than the presence or absence of disease can influence. Surgical factors such as depth of implant placement, anatomical factors such as soft tissue thickness and prosthetic factors such as emergence profile of the restoration can all affect the accuracy of peri-implant probing depths. Therefore, specific thresholds for diagnosing disease or health are unreliable and should not be relied upon solely.

There have been many factors associated with a risk of developing peri-implantitis(6). These include:

- A history of periodontitis, poor oral hygiene, a lack of supportive care/compliance, active smoking and uncontrolled diabetes. These are all strongly associated with an increased risk of developing peri-implantitis for patients.
- Genetic factors, cardiovascular disease and rheumatoid arthritis have less conclusive evidence regarding their association with peri-implantitis.
- Local risk factors that may predispose patients to peri-implant disease include excessive cement, a lack of keratinised tissue and unencapsulated prostheses.

Implant positioning may also predispose to peri-implant disease, whether this is due directly to alveolar bone resorption in sites where there is insufficient native bone, or indirectly due to uncleansible restorations:

- Implants placed too buccal risk resorption of the alveolar plate and subsequent recession.
- Implants placed too palatal result in the need for ridge-lap restorations which are difficult for patients to keep clean.
- Implants placed too apical or coronal result in uncleansible and unaesthetic prostheses.
- Implants placed too close together as well as multiple implants placed too close to each other risk inter-implant bone resorption and difficulty with self-performed plaque control.

The management of peri-implantitis has been well summarised in the evidence-based S3 level guidelines from the EFP.[6] These include:

- Non-surgical management of peri-implantitis should be the first line of treatment, involving oral hygiene education, risk factor control, prosthesis modification, and subgingival PMPR with curettes or ultrasonic instruments. There is little evidence to support the use of lasers, subgingival air polishing, local antimicrobials or routine use of systemic antimicrobials.

- A review should be undertaken at 6-12 weeks, with ideal endpoints being PPD ≤5 mm, no BoP at >1 point, no suppuration, and absence of progressive crestal bone loss. If these endpoints have not been met, it is for the clinician to decide whether to proceed with further non-surgical treatment or make a plan for surgical management of the peri-implantitis, with or without referral, depending upon the clinician's experience.

- Surgical management of peri-implantitis can be considered as either [64]:
  - Reparative - which aims to raise a flap around the implant, remove granulation tissue and clean the surface under direct vision, maintaining the soft tissues without any removal. This can be considered akin to access flap surgery or open flap debridement, and ultimately, this will result in some level of recession as the inflammation resolves.

- Resective - this treatment aims to remove some of the inflamed peri-implant tissue and apically reposition the flap to reduce the probing depths. This can be combined with implantoplasty to smooth the roughened surface of the implant that will now be exposed to the oral environment. This option results in greater recession and should be limited to areas of low aesthetic demand. Implantoplasty should be undertaken carefully due to the risks of titanium particle debris being left within the surgical site, as well as the theoretical risks of weakening the implant if excessive surface removal is undertaken.
- Regenerative - This treatment option aims to regenerate some of the lost peri-implant bone. It should be limited to sites with contained vertical defects (>3 mm), which provide the space and support required for the stability of the grafting material (as in any regenerative procedure).

With all surgical techniques, there is a lack of robust evidence on the most effective way to decontaminate the implant surface, and therefore recommendations are limited. All of the above surgical options result in a reduction in probing depths and bleeding on probing[64-66]. However, whilst the recurrence of peri-implantitis can be high [67], so can implant retention in successfully treated cases of peri-implantitis.[68] Supportive care for patients with implants and treated peri-implantitis will be discussed in a later section.

Fig. 20 – implant requiring removal with the use of a trephine and reverse torque tool. Notice how the apical threads of the implant were still integrated[c]

If all treatment is unsuccessful in the management of peri-implantitis, an open and honest conversation needs to be had with the patient as to the risks and benefits of retaining vs removing the implant. If removing implants, care should be taken to avoid any excessive supporting bone removal and a decision made as to whether additional grafting is required at the time of implant removal, or whether any further implant therapy would be considered in the site. Both peri-implant health and peri-implant mucositis can be apparent in sites of previously treated, but stable, peri-implantitis around implants with reduced bone levels (much similar to periodontal disease). Diagnostic criteria for peri-implant health and disease are as below:[6]

Peri-implant Health	• Absence of visual signs of inflammation • Absence of bleeding or suppuration on probing • Absence of crestal bone remodelling beyond 2 mm within the first year of function (baseline radiographs will be required to quantify this)
Peri-implant Mucositis	• Visual signs of inflammation and swelling • Bleeding upon probing • Absence of progressive crestal bone loss upon radiographic examination
Peri-Implantitis	• Peri-implant inflammation with bone loss above that expected after initial remodelling (>2 mm) • If there are no baseline records to compare to, crestal bone loss >3 mm from the fixture head constitutes peri-implantitis N.B. whilst probing depths are often increased in diseased peri-implant sites, specific thresholds for defining disease are not considered a reliable measure.

Table 1 - Diagnostic criteria for peri-implant health and disease.

6.3 Mechanical Complications

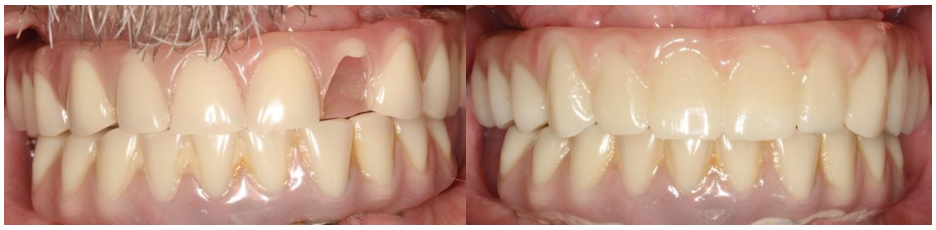

Fig. 21 – Fractured prosthetic tooth on a full arch restoration. This prosthesis required a remake to provide more prosthetic space for material thickness and alterations to the occlusion to reduce the risk of the complication occurring again[c]

These often arise when the forces exerted on an implant and its component parts exceed that of the weakest component failing. They may arise from incorrect planning of implant design (type, number, diameter, position), inappropriate prosthetic design (occlusal considerations, cantilever lengths), laboratory production errors or in some instances, patient-generated (habits, bruxism or trauma). Patients with bruxism have been shown in a recent systematic review to be at twice the risk of implant failure than non-bruxists.[24]

Complications can range from minor and straightforward to fix, to catastrophic, necessitating implant removal. Overall complications range between 16-53%,[5] depending upon the nature of the complication:

- Loss of screw hole access restoration in screw-retained prostheses - this is straightforward to resolve and requires irrigation of the access channel, protection of the underlying screw with PTFE/cotton wool and replacement of the restoration.

- Screw loosening - 3-11% 5-year complication rate.[5] This will present as looseness of the prosthesis in a single-unit restoration, where the screw can be re-torqued according to the manufacturer's guidance. If it occurs in a cement-retained prosthesis, it is often more challenging to resolve, as the cemented crown first needs to be removed (often rendering it unusable in the process) to gain access to the abutment screw underneath. A rarer screw complication is fracture of the screw (5-year complication rate: 0-6%). These will present similarly to loosening but can be more challenging to resolve and will require either patience and counterclockwise use of an instrument or a specific screw retrieval kit.

- Veneering material fracture - 3-25% 5-year complication rate.[5] These were generally more common in historic acrylic wraparound of titanium bars due to differential flexibilities of the materials, but is still seen in both metal-ceramic and zirconia restorations (with it being more common in full arch zirconia restorations). The management and intricacy of these complications depend on both the extent of the fracture and the underlying substructure. More catastrophic fractures will necessitate a remake of the prosthesis with careful consideration of why the complication arose in the first place.

- Implant or framework fracture - these are relatively uncommon, with 5-year complication rates of 0.08% to 0.2%.[5] They most likely arise from the inappropriate design of the prosthesis or implant type, resulting in unfavourable

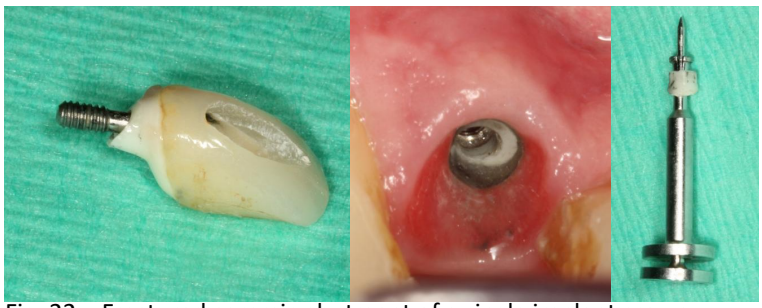

Fig. 22 – Fractured ceramic abutment of a single implant crown. Removed using a specific abutment retrieval tool[c]

forces being transmitted through them.

- Crown decementation – 5-year complication rate 3%.[5] In these cases, as long as the abutment screw is protected, they can be straightforward to re-cement, often with a temporary cement given the minimal taper of the abutments. Again, analysis of the reason for decementation should be undertaken as well as vigilant removal of all excess cement.

A common theme to note with mechanical complications is the accurate diagnosis of why they occurred in the first place, to prevent them from happening again.

Mechanical complications can also occur with removable prostheses, most often resulting in a loss of retention or fracture of the denture in the area where the retentive housing is located. To address these, the clinician should know the type of retention system used (magnet, ball, locator, clip, or bar) to determine the degree of complexity in rectifying the problem.

The type of complication will influence whether it can be managed chairside (for example, replacing a worn locator housing insert or cold-curing a new housing into a denture with acrylic) or whether laboratory input is required (as may be the case for fractured prostheses or complications arising with bars). Whilst locator-retained removable prostheses do carry a risk of frequent complications, they remain a popular choice due to their lower cost and ease of chairside complication management compared to bar systems.

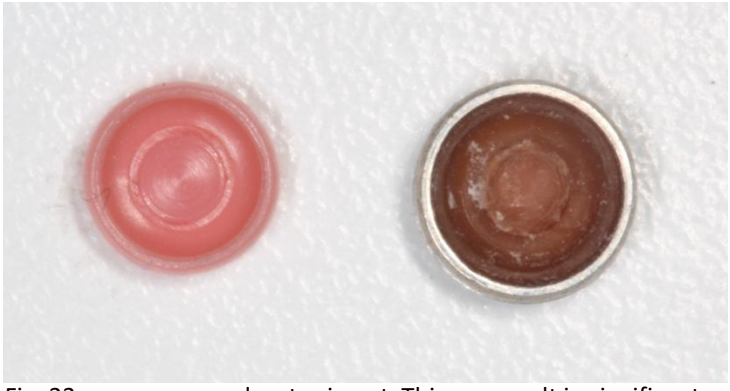

Fig. 23 – new vs worn locator insert. This can result in significant loss of retention of removable prostheses[c]

7. Maintenance of dental implants

It has been consistently shown that patients who are not enrolled in a regular supportive peri-implant care maintenance programme are at greater risk of peri-implant disease, exhibit greater probing depths and marginal bone loss, and are at greater risk of implant failure.[7] This is also the case for patients who have successfully treated peri-implant disease who are at greater risk of recurrence without regular maintenance.[69]

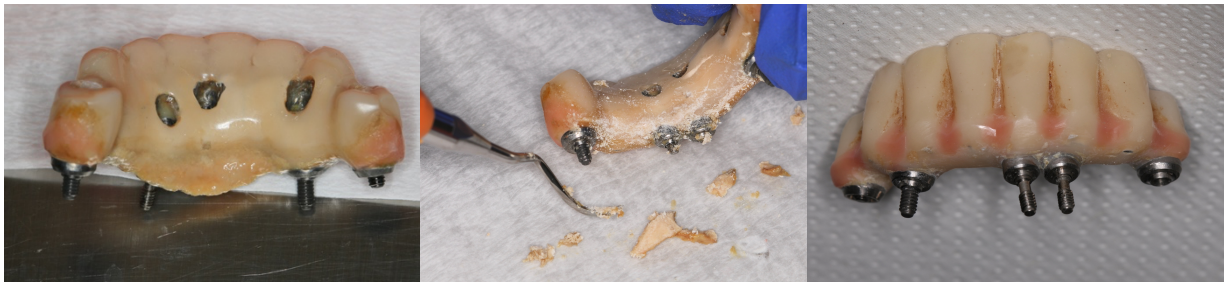

Fig. 24 – Biofilm accumulation associated with poor plaque debridement. Acrylic was debrided and polished prior to prosthesis replacement[b]

Whilst it is accepted that self-performed plaque control is an effective measure for prevention of peri-implant disease, the specific methods for this remain unclear.[70] Chemical plaque control has limited additional benefits to mechanical plaque control.[70] The oral hygiene regime should be tailored to the individual patient and prosthesis design. There is no difference in effectiveness between manual and powered brushes for maintaining peri-implant health,[71] and interproximal biofilm control should be based upon prosthesis design but may include a combination of interdental brushes, superfloss or single tufted brushes.

If patients are finding biofilm control challenging, it is worth noting the design of the prosthesis and whether this facilitates optimal cleaning, or requires adjustment e.g., avoiding ridge lap prosthesis that are difficult to clean.[6] Technicians should design fixed prostheses with cleansibility in mind. Also, as part of the laboratory prescription you can request any specific requirements that you may want for that prosthesis in that particular patient. For example, ensuring that specific interdental brushes can pass beneath fixed bridge work, or avoiding concave designs in pontic sites.

It is also worth reminding patients who have a removable prosthesis that the implants used to retain/support these still need to be cleaned, just as they would their natural teeth. The patient's compliance and dexterity are important in the success of the rehabilitation.

It is imperative that clinical information be obtained prior to implant restorations.[6] It is recommended that the following are included:

- Baseline radiograph at fit of the prosthesis to assess fitting of the components and to act as a baseline for crestal bone levels.
- 12-month radiograph to assess for crestal bone levels after the first year in function (this should not exceed 2mm).
- Further radiographs should be taken at the clinician's discretion, based on patient problems or complications noted by the clinician.
- Baseline probing depths should be taken within 3 months of the prosthesis fit and rechecked at each subsequent recall visit, recommended at 6 sites around the implant.

Alongside probing depths and a record of bleeding on probing, a visual assessment should be undertaken at each recall visit looking for inflammation as well as an evaluation of the self-

performed plaque control. These can both give early indicators as to risks of developing peri-implant disease. Visual inspection for any excess cement for cement-retained restorations should be noted, and subsequently removed if identified.

Supportive peri-implant care should be offered 3 monthly during the first year following successful treatment of peri-implantitis, and based upon individual risk factors thereafter.[6] There are many courses, certificates, diplomas, masters and specialist training opportunities available across the UK depending on what level the practitioner wants to train at. Indemnity must always reflect the practices undertaken and the practitioner must be trained and competent to undertake these, for best patient care and to fulfil our regulatory obligations.

References

(1) Pavel, K.; Seydlova, M.; Dostalova, T.; Zdenek, V.; Chleborad, K.; Jana, Z.; Feberova, J.; Radek, H. Dental implants and improvement of oral health-related quality of life. *Community dentistry and oral epidemiology* **2012**, *40*, 65-70.
(2) Darbar, U.; Shahdad, S.; Ashley, M. Guidance on the standards of care for NHS-funded dental implant treatment. *London: Royal College of Surgeons of England* **2019**.
(3) Morton, D.; Gallucci, G.; Lin, W. S.; Pjetursson, B.; Polido, W.; Roehling, S.; Sailer, I.; Aghaloo, T.; Albera, H.; Bohner, L. Group 2 ITI consensus report: prosthodontics and implant dentistry. *Clinical oral implants research* **2018**, *29*, 215-223.
(4) Ali, Z.; Baker, S. R.; Shahrbaf, S.; Martin, N.; Vettore, M. V. Oral health-related quality of life after prosthodontic treatment for patients with partial edentulism: A systematic review and meta-analysis. *The Journal of prosthetic dentistry* **2019**, *121* (1), 59-68. e53.
(5) Pjetursson, B.; Asgeirsson, A.; Zwahlen, M.; Sailer, I. Improvements in implant dentistry over the last decade: comparison of survival and complication rates in older and newer publications. *International journal of oral & maxillofacial implants* **2014**, *29* (Suppl.), 308-324.
(6) Herrera, D.; Berglundh, T.; Schwarz, F.; Chapple, I.; Jepsen, S.; Sculean, A.; Kebschull, M.; Papapanou, P. N.; Tonetti, M. S.; Sanz, M. Prevention and treatment of peri-implant diseases—The EFP S3 level clinical practice guideline. *Journal of Clinical Periodontology* **2023**, *50*, 4-76.
(7) Carra, M. C.; Blanc-Sylvestre, N.; Courtet, A.; Bouchard, P. Primordial and primary prevention of peri-implant diseases: A systematic review and meta-analysis. *Journal of Clinical Periodontology* **2023**, *50*, 77-112.
(8) KOCH, G. Consensus conference on oral implants in young patients. Foflagshuset Gothia. *Stockholm* **1996**.
(9) Mankani, N.; Chowdhary, R.; Patil, B. A.; Nagaraj, E.; Madalli, P. Osseointegrated dental implants in growing children: a literature review. *Journal of Oral Implantology* **2014**, *40* (5), 627-631.
(10) Annibali, S.; Pranno, N.; Cristalli, M. P.; La Monaca, G.; Polimeni, A. Survival analysis of implant in patients with diabetes mellitus: a systematic review. *Implant dentistry* **2016**, *25* (5), 663-674.
(11) Chrcanovic, B. R.; Kisch, J.; Albrektsson, T.; Wennerberg, A. Factors influencing the fracture of dental implants. *Clinical implant dentistry and related research* **2018**, *20* (1), 58-67.
(12) Sulaiman, N.; Fadhul, F.; Chrcanovic, B. R. Bisphosphonates and dental implants: a systematic review and meta-analysis. *Materials* **2023**, *16* (18), 6078.
(13) Butterworth, C.; McCaul, L.; Barclay, C. Restorative dentistry and oral rehabilitation: United Kingdom national multidisciplinary guidelines. *The Journal of Laryngology & Otology* **2016**, *130* (S2), S41-S44.
(14) Toneatti, D. J.; Graf, R. R.; Burkhard, J.-P.; Schaller, B. Survival of dental implants and occurrence of osteoradionecrosis in irradiated head and neck cancer patients: a systematic review and meta-analysis. *Clinical oral investigations* **2021**, *25* (10), 5579-5593.
(15) Costa, F. O.; Lages, E. J. P.; Cortelli, S. C.; Cortelli, J. R.; Mattos-Pereira, G. H.; Lima, R. P. E.; Cota, L. O. M. Association between cumulative smoking exposure, span since smoking cessation, and peri-implantitis: a cross-sectional study. *Clinical Oral Investigations* **2022**, *26* (7), 4835-4846.
(16) Chrcanovic, B. R.; Albrektsson, T.; Wennerberg, A. Smoking and dental implants: a systematic review and meta-analysis. *Journal of dentistry* **2015**, *43* (5), 487-498.
(17) Garber, D.; Belser, U. Restoration-driven implant placement with restoration-generated site development. *Compendium of continuing education in dentistry (Jamesburg, NJ: 1995)* **1995**, *16* (8), 796, 798-802, 804.
(18) Romandini, M.; Lima, C.; Pedrinaci, I.; Araoz, A.; Soldini, M. C.; Sanz, M. Prevalence and risk/protective indicators of peri-implant diseases: A university-representative cross-sectional study. *Clinical Oral Implants Research* **2021**, *32* (1), 112-122.
(19) Karoussis, I. K.; Salvi, G. E.; Heitz-Mayfield, L. J.; Brägger, U.; Hämmerle, C. H.; Lang, N. P. Long-term implant prognosis in patients with and without a history of chronic periodontitis: a 10-year

prospective cohort study of the ITI® Dental Implant System. *Clinical oral implants research* **2003**, *14* (3), 329-339.
(20) Ferreira, S.; Silva, G. M.; Cortelli, J. R.; Costa, J.; Costa, F. Prevalence and risk variables for peri-implant disease in Brazilian subjects. *Journal of clinical periodontology* **2006**, *33* (12), 929-935.
(21) Morton, D.; Wismeijer, D.; Chen, S.; Hamilton, A.; Wittneben, J.; Casentini, P.; Gonzaga, L.; Lazarin, R.; Martin, W.; Molinero-Mourelle, P. Group 5 ITI Consensus Report: Implant placement and loading protocols. *Clinical oral implants research* **2023**, *34*, 349-356.
(22) Ramanauskaite, A.; Juodzbalys, G. Diagnostic principles of peri-implantitis: a systematic review and guidelines for peri-implantitis diagnosis proposal. *Journal of oral & maxillofacial research* **2016**, *7* (3), e8.
(23) Goodacre, C. J.; Bernal, G.; Rungcharassaeng, K.; Kan, J. Y. Clinical complications with implants and implant prostheses. *The Journal of prosthetic dentistry* **2003**, *90* (2), 121-132.
(24) Häggman-Henrikson, B.; Ali, D.; Aljamal, M.; Chrcanovic, B. R. Bruxism and dental implants: A systematic review and meta-analysis. *Journal of oral rehabilitation* **2024**, *51* (1), 202-217.
(25) E. Jung, R.; Zembic, A.; Pjetursson, B. E.; Zwahlen, M.; S. Thoma, D. Systematic review of the survival rate and the incidence of biological, technical, and aesthetic complications of single crowns on implants reported in longitudinal studies with a mean follow-up of 5 years. *Clinical oral implants research* **2012**, *23*, 2-21.
(26) Melas, F.; Marcenes, W.; Wright, P. S. Oral health impact on daily performance in patients with implant-stabilized overdentures and patients with conventional complete dentures. *International Journal of Oral & Maxillofacial Implants* **2001**, *16* (5).
(27) Thomason, J. M.; Feine, J.; Exley, C.; Moynihan, P.; Müller, F.; Naert, I.; Ellis, J. S.; Barclay, C.; Butterworth, C.; Scott, B. Mandibular two implant-supported overdentures as the first choice standard of care for edentulous patients-the York Consensus Statement. *British dental journal* **2009**, *207* (4), 185-186.
(28) NHS England, N. I. *Commissioning Standard for Restorative Dentistry*. 2019. (accessed).
(29) Renvert, S.; Polyzois, I. Risk indicators for peri-implant mucositis: a systematic literature review. *Journal of clinical periodontology* **2015**, *42*, S172-S186.
(30) W. Nicholson, J. Titanium alloys for dental implants: A review. *Prosthesis* **2020**, *2* (2), 11.
(31) Pieralli, S.; Kohal, R.; Jung, R.; Vach, K.; Spies, B. Clinical outcomes of zirconia dental implants: a systematic review. *Journal of dental research* **2017**, *96* (1), 38-46.
(32) Wennerberg, A.; Albrektsson, T.; Chrcanovic, B. Long-term clinical outcome of implants with different surface modifications. *Eur J Oral Implantol* **2018**, *11* (Suppl 1), S123-S136.
(33) Albrektsson, T.; Brånemark, P.-I.; Hansson, H.-A.; Lindström, J. Osseointegrated titanium implants: requirements for ensuring a long-lasting, direct bone-to-implant anchorage in man. *Acta Orthopaedica Scandinavica* **1981**, *52* (2), 155-170.
(34) Abrahamsson, I.; Berglundh, T.; Linder, E.; Lang, N. P.; Lindhe, J. Early bone formation adjacent to rough and turned endosseous implant surfaces: an experimental study in the dog. *Clinical oral implants research* **2004**, *15* (4), 381-392.
(35) Jayesh, R. S.; Dhinakarsamy, V. Osseointegration. *Journal of Pharmacy and Bioallied Sciences* **2015**, *7* (Suppl 1), S226-S229.
(36) Sennerby, L.; Ericson, L.; Thomsen, P.; Lekholm, U.; Åstrand, P. Structure of the bone-titanium interface in retrieved clinical oral implants. *Clinical Oral Implants Research* **1991**, *2* (3), 103-111.
(37) Albrektsson, T.; Tengvall, P.; Amengual, L.; Coli, P.; Kotsakis, G.; Cochran, D. Osteoimmune regulation underlies oral implant osseointegration and its perturbation. *Frontiers in immunology* **2023**, *13*, 1056914.
(38) Sykaras, N.; Iacopino, A. M.; Marker, V. A.; Triplett, R. G.; Woody, R. D. Implant materials, designs, and surface topographies: their effect on osseointegration. A literature review. *International Journal of Oral & Maxillofacial Implants* **2000**, *15* (5).

(39) Al-Ekrish, A. a. A.; Widmann, G.; Alfadda, S. A.; Al-Ekrish, A. a. A. Revised, Computed Tomography-Based Lekholm and Zarb Jawbone Quality Classification. *International Journal of Prosthodontics* **2018**, *31* (4).
(40) MacBeth, N.; Trullenque-Eriksson, A.; Donos, N.; Mardas, N. Hard and soft tissue changes following alveolar ridge preservation: a systematic review. *Clinical oral implants research* **2017**, *28* (8), 982-1004.
(41) Buser, D.; Urban, I.; Monje, A.; Kunrath, M. F.; Dahlin, C. Guided bone regeneration in implant dentistry: Basic principle, progress over 35 years, and recent research activities. *Periodontology 2000* **2023**, *93* (1), 9-25.
(42) Wang, H.-L.; Boyapati, L. "PASS" principles for predictable bone regeneration. *Implant dentistry* **2006**, *15* (1), 8-17.
(43) Atieh, M. A.; Alsabeeha, N. H.; Payne, A. G.; Ali, S.; Faggion, C. M. J.; Esposito, M. Interventions for replacing missing teeth: alveolar ridge preservation techniques for dental implant site development. *Cochrane Database of Systematic Reviews* **2021**, (4).
(44) Waechter, J.; Leite, F.; Nascimento, G.; Carmo Filho, L.; Faot, F. The split crest technique and dental implants: a systematic review and meta-analysis. *International journal of oral and maxillofacial surgery* **2017**, *46* (1), 116-128.
(45) Lundgren, S.; Cricchio, G.; Hallman, M.; Jungner, M.; Rasmusson, L.; Sennerby, L. Sinus floor elevation procedures to enable implant placement and integration: techniques, biological aspects and clinical outcomes. *Periodontology 2000* **2017**, *73* (1), 103-120.
(46) Khoury, F.; Hoppe, A. Soft tissue management in oral implantology: a review of surgical techniques for shaping an esthetic and functional peri-implant soft tissue structure. *Quintessence international* **2000**, *31* (7).
(47) Donos, N.; Mardas, N.; Chadha, V. Clinical outcomes of implants following lateral bone augmentation: systematic assessment of available options (barrier membranes, bone grafts, split osteotomy). *Journal of clinical periodontology* **2008**, *35*, 173-202.
(48) Langer, B.; Calagna, L. The subepithelial connective tissue graft. *The Journal of prosthetic dentistry* **1980**, *44* (4), 363-367.
(49) Stefanini, M.; Barootchi, S.; Sangiorgi, M.; Pispero, A.; Grusovin, M. G.; Mancini, L.; Zucchelli, G.; Tavelli, L. Do soft tissue augmentation techniques provide stable and favorable peri-implant conditions in the medium and long term? A systematic review. *Clinical oral implants research* **2023**, *34*, 28-42.
(50) Gargallo-Albiol, J.; Barootchi, S.; Tavelli, L. Efficacy of Xenogeneic Collagen Matrix to Augment Peri-implant Soft Tissue Thickness Compared with Autogenous Connective Tissue Graft: A Systematic Review and Meta-Analysis. *International Journal of Oral & Maxillofacial Implants* **2019**, *34* (5).
(51) Palacci, P. Papillae reconstruction: clinical considerations. *Faculty Dental Journal* **2012**, *3* (1), 8-19.
(52) Chen, J.; Cai, M.; Yang, J.; Aldhohrah, T.; Wang, Y. Immediate versus early or conventional loading dental implants with fixed prostheses: A systematic review and meta-analysis of randomized controlled clinical trials. *The Journal of prosthetic dentistry* **2019**, *122* (6), 516-536.
(53) Daudt Polido, W.; Aghaloo, T.; Emmett, T. W.; Taylor, T. D.; Morton, D. Number of implants placed for complete-arch fixed prostheses: A systematic review and meta-analysis. *Clinical oral implants research* **2018**, *29*, 154-183.
(54) Wittneben, J.-G.; Millen, C.; Brägger, U. Clinical Performance of Screw-Versus Cement-Retained Fixed Implant-Supported Reconstructions-A Systematic Review. *International journal of oral & maxillofacial implants* **2014**, *29*.
(55) Pjetursson, B. E.; Valente, N. A.; Strasding, M.; Zwahlen, M.; Liu, S.; Sailer, I. A systematic review of the survival and complication rates of zirconia-ceramic and metal-ceramic single crowns. *Clinical oral implants research* **2018**, *29*, 199-214.

(56) Sailer, I.; Strasding, M.; Valente, N. A.; Zwahlen, M.; Liu, S.; Pjetursson, B. E. A systematic review of the survival and complication rates of zirconia-ceramic and metal-ceramic multiple-unit fixed dental prostheses. *Clinical oral implants research* **2018**, *29*, 184-198.
(57) Kim, Y.; Oh, T. J.; Misch, C. E.; Wang, H. L. Occlusal considerations in implant therapy: clinical guidelines with biomechanical rationale. *Clinical oral implants research* **2005**, *16* (1), 26-35.
(58) Sadowsky, S. J.; Zitzmann, N. U. Protocols for the Maxillary Implant Overdenture: A Systematic Review. *International Journal of Oral & Maxillofacial Implants* **2016**, *31*.
(59) Raghoebar, G. M.; Meijer, H.; Slot, W.; Slater, J.; Vissink, A. A systematic review of implant-supported overdentures in the edentulous maxilla, compared to the mandible: how many implants. *Eur J Oral Implantol* **2014**, *7* (Suppl 2), S191-S201.
(60) Zucchelli, G.; Tavelli, L.; Stefanini, M.; Barootchi, S.; Mazzotti, C.; Gori, G.; Wang, H. L. Classification of facial peri-implant soft tissue dehiscence/deficiencies at single implant sites in the esthetic zone. *Journal of periodontology* **2019**, *90* (10), 1116-1124.
(61) Renvert, S.; Persson, G. R.; Pirih, F. Q.; Camargo, P. M. Peri-implant health, peri-implant mucositis, and peri-implantitis: Case definitions and diagnostic considerations. *Journal of clinical periodontology* **2018**, *45*, S278-S285.
(62) Souza, A. B.; Tormena, M.; Matarazzo, F.; Araújo, M. G. The influence of peri-implant keratinized mucosa on brushing discomfort and peri-implant tissue health. *Clinical oral implants research* **2016**, *27* (6), 650-655.
(63) Verket, A.; Koldsland, O. C.; Bunaes, D.; Lie, S. A.; Romandini, M. Non-surgical therapy of peri-implant mucositis—Mechanical/physical approaches: A systematic review. *Journal of Clinical Periodontology* **2023**, *50*, 135-145.
(64) Schwarz, F.; Jepsen, S.; Obreja, K.; Galarraga-Vinueza, M. E.; Ramanauskaite, A. Surgical therapy of peri-implantitis. *Periodontology 2000* **2022**, *88* (1), 145-181.
(65) Karlsson, K.; Trullenque-Eriksson, A.; Tomasi, C.; Derks, J. Efficacy of access flap and pocket elimination procedures in the management of peri-implantitis: A systematic review and meta-analysis. *Journal of Clinical Periodontology* **2023**, *50*, 244-284.
(66) Donos, N.; Calciolari, E.; Ghuman, M.; Baccini, M.; Sousa, V.; Nibali, L. The efficacy of bone reconstructive therapies in the management of peri-implantitis. A systematic review and meta-analysis. *Journal of Clinical Periodontology* **2023**, *50*, 285-316.
(67) Esposito, M.; Grusovin, M. G.; Worthington, H. V. Treatment of peri-implantitis: what interventions are effective? A Cochrane systematic review. *Eur J Oral Implantol* **2012**, *5* (Suppl), S21-S41.
(68) Roccuzzo, M.; Layton, D. M.; Roccuzzo, A.; Heitz-Mayfield, L. J. Clinical outcomes of peri-implantitis treatment and supportive care: A systematic review. *Clinical oral implants research* **2018**, *29*, 331-350.
(69) Stiesch, M.; Grischke, J.; Schaefer, P.; Heitz-Mayfield, L. J. Supportive care for the prevention of disease recurrence/progression following peri-implantitis treatment: A systematic review. *Journal of Clinical Periodontology* **2023**, *50*, 113-134.
(70) Jepsen, S.; Berglundh, T.; Genco, R.; Aass, A. M.; Demirel, K.; Derks, J.; Figuero, E.; Giovannoli, J. L.; Goldstein, M.; Lambert, F. Primary prevention of peri-implantitis: Managing peri-implant mucositis. *Journal of clinical periodontology* **2015**, *42*, S152-S157.
(71) Grusovin, M. G.; Coulthard, P.; Worthington, H. V.; George, P.; Esposito, M. Interventions for replacing missing teeth: maintaining and recovering soft tissue health around dental implants. *Cochrane Database of Systematic Reviews* **2010**, (8).