Immediate Loading

The original protocol for osseointegrated implant therapy, developed by Professor Branemark some decades ago, provided for a 3-6 month healing period, during which implants were to be left submerged in order to avoid any trauma during healing.

In the following years some investigators observed that the osseointegration process could also occur in a transmucosal environment, with abutments being connected to implants directly upon placement (1-3), thus limiting surgery to one single stage.

A further development in the implant placement procedure was achieved in the early 1990’s, when some clinicians started to immediately load implants inserted into the mental symphysis, thus obtaining surprisingly good clinical results (4,5). Of course the mental symphysis is the most predictable area where to perform immediate loading, due to both the amount and the quality of bone available. In other jaw areas bone quantity and quality are less favourable, so early reports showed less satisfactory results there. In order to extend immediate loading also to areas with softer bone, clinicians had to fully understand the basic factors and requirements underlying the procedure. The main factor playing a role in immediate loading is implant stability in bone, which may be primary or secondary.

Primary Stability. This term refers to the mechanical stability of a dental implant immediately after placement. It depends on a number of factors, such as the surgical technique. The surgical site can be underprepared to obtain greater bone engagement upon insertion (6), implant geometry. A tapered implant design will considerably increase its stability, particularly in soft bone (7), sufficient quantity and quality of bone. A sufficient amount of bone is required both in the horizontal and vertical dimensions. The presence of cortical bone is associated with higher implant stability, with a corresponding increase in RFA ISQ values (8). In case of partial implant exposure, a GBR technique should be used to obtain bone coverage of the exposed implant threads.

Secondary Stability. The term refers to the dental implant biological stability that takes place in the weeks following implant placement. Thus, secondary stability and osseointegration tend to coincide. Secondary stability depends on the implant surface characteristics. Implants with a rough surface can speed up the process of osseointegration (4, 9, 10).

Primary (mechanical) stability may slowly decline starting from the day of surgery, whereas secondary (biological) stability shows a steady increase over time (Figure 1).

The following factors are of fundamental importance for immediate loading:

- achieving optimal primary stability to prevent implant micromotion in the earliest weeks of healing;
- attaining secondary stability early on, to induce quicker osseointegration.

As indicated above, implants with a slightly tapered geometry will induce bone compression and expansion during insertion, thus ensuring higher primary stability. In a multicentric prospective study Vanden Bogaerde et al. (11) placed 124 smooth-surfaced tapered implants in upper jaws and posterior mandibles; they loaded them early within 15 days from surgery and observed the results after 18 months. The overall implant survival rate was 96.8%. In the first weeks after implant surgery peri-implant bone remodelling was observed with possible stability changes.

Abrahamsson et al. (12) conducted a study in dogs where a histologic analysis was performed of the changes at the bone-to-implant interface during the first weeks of healing. The surgical wound compartment was initially occupied by a blood clot (red blood cells trapped in a mesh of fibrin) and granulation tissue, soon to be replaced by a provisional matrix. The bone formation process started as early as in the first week, with the formation of woven bone - a process that continued during the subsequent two weeks. Four weeks later, lamellar and medullary bone started to form. The study also showed
that the whole process was accelerated by rough implant surfaces. In addition, in the early healing period considerable bone remodelling could be observed in the presence of inflammatory processes, as well as bone resorption followed by new bone apposition. This sequence of events might be responsible for the decline in implant stability which can often be observed clinically (by means of Resonance Frequency Analysis) around week 3 or 4.

Rough-surfaced implants can therefore speed up the osseointegration process - a factor of paramount importance in immediate loading. Vanden Bogaerde et al. (13) conducted a multicentric study with a protocol similar to the one adopted in their previous study (2003). In this case, however, rough-oxidised-surface implants were used. 111 implants were placed in posterior edentulous areas of the upper and lower jaws. These were then early-loaded within 9 days from placement. The 18-month follow-up showed one single implant failure with a survival rate of 99.1%.

An analysis of the advantages afforded by immediate loading shows the following:

- the patient’s compromised aesthetic function can be restored in a very short time frame;
- the patient’s compromised masticatory function can be restored, at least in part;
- hard- and soft-tissue levels can be preserved;
- the time needed for prosthodontic restorations can be significantly reduced;
- treatment times and costs to the patient are reduced.

On the other hand, possible disadvantages of immediate loading include:

- a need for frequent monitoring in the first weeks after surgery;
- a need for consistent patient compliance (patient selection);
- a need for an extremely strict protocol (failure to comply with it - albeit partial - may lead to higher implant failure rates);
- a need for specific operator training.

There are two types of contraindications to immediate loading, i.e.

- Absolute contraindications; the treatment is not recommended in case of:
  - insufficient primary stability,
  - replacement of upper incisors and in deep bite patients,
  - acute inflammation,
  - untreated periodontitis;
- Relative contraindications; the treatment can be administered, provided that a strict control protocol is followed, in the following cases:
  - general illnesses;
  - bruxism,
  - treated periodontitis.

Why and how to measure implant stability

In modern implant dentistry we are increasingly striving to manage advanced cases with severely compromised tooth and bone conditions. Dental practitioners are increasingly required to treat such disorders with early and immediate loading protocols, to immediately treat fresh extraction sockets, to combine immediate loading with bone regeneration techniques, and to treat patients with severe bruxism or occlusal abnormalities. Hence, there is a need to quantify - and therefore to measure - implant stability not only at implant placement, but also in the following weeks.

In other words, there is a need for greater diagnostic ability, with a view to:

- understanding when to load an implant, be it with an immediate, early, or delayed approach;
- understanding when to remove the load from an implant, being able to identify ‘early warnings’;
- being able to assess the implant conditions at any time;
- providing safer treatment for cases at risk, thus offering better guarantees to our patients;
- identifying an implant ‘finger print’, in order to achieve better communication with the patients and with our colleagues. There is a variety of methods for measuring implant stability. The following is a brief overview of them.

**Insertion Torque:**
- It provides a measure of the implant insertion force up to full bone adaptation (Seating Torque);
- it is a reliable method, even though it measures one single value at the time of implant placement. Thus it can only measure primary stability;
- the insertion torque measures torsional forces.

**Resonance Frequency Analysis (RFA):**
- This method was first developed by Dr Meredith in the 1990’s (14,15), to be further refined in the following decades. Today it is really reliable and repeatable. Hundreds of international publications confirm its validity;
- It is based on the diapason principle. A handpiece emits electromagnetic impulses toward a ‘SmartPeg’ screwed to the implant’s head. A numerical value is thus recorded. The measurement unit is the Implant Stability Quotient (ISQ). The measurement is performed with a wireless system (Figures 2-3);
- The measurement is extremely accurate and can be repeated at any time during treatment. Therefore it can measure both primary and secondary stability;
- It can provide two measurements for a single implant, along two orthogonal axes (in both mesio-distal and buccolingual
It measures the extent of the bone-to-implant contact, particularly in the coronal third of the implant; 
- It measures resistance to lateral excursions.

Clinical Indications for the Use of Resonance Frequency Analysis

Immediate Loading
RFA is useful in a variety of clinical settings, but it is essential for immediate loading. During the first six weeks following surgery, it is of paramount importance to carry out constant implant monitoring to promptly identify possible losses of stability, which might eventually lead to implant failure. Some Authors (16-18) have reported a physiological decline in stability after 3-4 weeks, which may be attributed to post-operative inflammation and bone remodelling (12).

In a prospective study Vanden Bogaerde et al. (19) used RFA in an 18-month follow-up of 69 Neoss implants. They reported a slight stability loss after 4 weeks, which was more marked in the upper jaw. The mean ISQ value at baseline was 68, climbing back to 72 after six months. The study also provided for immediate implant placement in post-extraction sockets. In cases of residual bone defects of a ‘closed’ type, the mean baseline stability value was anyway fairly high, with an ISQ of 65.8.

In ‘open-type’ defects, however, stability values were rather low, approaching the feasibility threshold, with an ISQ value of 51.

Immediate Loading in Fresh Extraction Sockets
The possibility of placing implants in fresh extraction sockets and of loading them immediately was analysed in a prospective clinical trial (30) where 50 implants were placed in fresh extraction sockets. The results of the 18-month follow-up showed a surprising success rate of 100%. RFA was carried out at baseline, at 1, 3, 4, and 6 weeks, and 3 and 6 months later. When plotted on a graph, the results gave rise to three types of curves. A first group of implants had maintained their stability over time. A second group showed a progressive stability increase, while a third, smaller group exhibited an initial decline followed by stability maintenance during the observation period.

Immediate Loading Combined with GBR
In well-selected and controlled cases, immediate loading can also be used on implants treated with GBR to correct localised bone deficiencies. The evolution of the regenerative process can be followed by means of RFA. After a minimum of six months, bone regeneration will have occurred despite initial implant exposure and ISQ values will have increased proportionally to bone regeneration. In a cadaver study (21), all natural teeth were extracted and replaced with implants inserted into the post-extraction sockets. The insertion torque, resonance frequency and bone defect depth were measured. The study showed that resonance frequency values were directly proportional to peri-implant vertical defects.

Immediate Loading in the Maxillary Incisors
Immediate loading in the upper incisors is one of the procedures with the highest failure rates. In severe deep bite cases, treatment is contraindicated. However, immediate loading can be used in more favourable occlusal conditions, provided that constant monitoring is carried out during the first weeks of healing. It is however essential to eliminate all possible occlusal contacts from provisional restorations. Patients should be instructed to avoid any bad dental habit which may cause trauma for the implant concerned.

Possibility to Early Intercept Implant Failures
RFA offers an unprecedented option, never afforded before by any other instrument. It offers the possibility to early intercept an implant failure. In fact, continuous implant monitoring by means of RFA allows practitioners to plot an ‘implant stability curve’. By analysing the values plotted on the curve, they will be able to intervene before implant stability starts to progressively or continuously decrease.
decline, thus approaching or reaching a specific ‘threshold value’, beyond which implant failure would be irreversible. If the stability loss is intercepted before critical values are reached, the provisional restoration can be removed. After a suitable healing period, the implant can be loaded again. This is a ‘rescue procedure’ which allows practitioners to salvage an implant otherwise doomed to failure (Figures 4a-4f, Table 1).

**Implant Control Protocol for Immediate Loading by Means of RFA**

The implant stability threshold value, as measured with the Implant Stability Quotient (ISQ), is said to represent the minimum value below which immediate loading should not be performed. To date, however, there is no general consensus on the exact determination of such value.

In a prospective study Vanden Bogaerde et al. (19) arbitrarily determined a baseline threshold value of 50 ISQ. Based on clinical observations, they showed that values below 50 ISQ were associated with visible implant mobility. Other authors, however, have identified and used different values. An adequate threshold value for immediate loading might probably be equal to 55 ISQ, provided that the following protocol is used, as described in the table below.

When applying this protocol, it is essential to be able to remove the provisional restorations at regular intervals. Hence, screw-retained implant prostheses should be preferred over cement-retained restorations.

When the stability curve continuously declines over time from the baseline to a threshold value of 55 ISQ, the load should be removed from the implant. After a few months, once stability has been regained, the load can be reinstated.

**Guided Bone Regeneration**

The most important requirement for successful implant osseointegration is the availability of sufficient bone quality and quantity to ensure implant stabilization and optimal bone-to-implant contact (22-23). A low implant success rate has been recorded in sites with insufficient bone volume (24).

Over the years, Guided Bone Regeneration (GBR) (25-28) has been the most successful technique for bone support augmentation. The concept behind GBR is based on the Guided Tissue Regeneration (GTR)(29-31) procedure, also used for regeneration of the periodontium destroyed by periodontal disease.

### Table 1

<table>
<thead>
<tr>
<th>Baseline ISQ values (Threshold Value of 55 ISQ)</th>
<th>Treatment</th>
<th>Load</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lower than 55 ISQ</td>
<td>Immediate Loading Not Recommended</td>
<td>-</td>
</tr>
<tr>
<td>Ranging between 55 and 65 ISQ</td>
<td>Weekly Monitoring</td>
<td>No Load</td>
</tr>
<tr>
<td>Higher than 65 ISQ</td>
<td>Monitoring Every Two Weeks</td>
<td>Highly Limited</td>
</tr>
</tbody>
</table>

This method envisages the use of a membrane which acts as a mechanical barrier, blocking out non-competent epithelial and connective tissue cells from the surgical repair area. At the same time, it also enhances the proliferation of periodontal ligament cells. These are the only cells able to reconstruct the deep periodontium.

Based on the biological principles underlying GTR, in GBR barrier membranes are used to prohibit the penetration of non-bone cells into the healing area, thus favouring the migration of osteocompetent cells that are able to regenerate peri-implant tissues.
GBR has proved to be a highly successful treatment modality for the correction of peri-implant defects (32-35), and for bone regeneration followed by implant placement in localized ridge deficiencies (36-38)(Figure 5).

Peri-implant bone regeneration may be feasible depending on a number of factors, such as:
- defect morphology;
- type of membrane used (resorbable or non-resorbable);
- type of filling material used (autogenous or heterologous bone, materials of animal origin);
- surgical technique used.

The membranes used for tissue regeneration procedures should meet a set of fundamental requirements for the regenerative process to be safe and predictable. These requirements include:
- biocompatibility. The material must be biocompatible;
- cell occlusivity. The membranes must have a barrier function and insulate the regeneration zone from other areas that are not competent for this process;
- tissue integration. Connective tissue should be allowed to grow inside the membrane to allow for its stabilization and to delay epithelial cell migration.
- space-making function. The membrane should be rigid enough to allow sufficient room for tissue regeneration to occur, particularly during early healing stages. Membrane collapse within the defect is a frequent cause of GBR failure;
- the membrane should be easy to handle in different clinical situations. The material should come in different...
shapes and sizes to fit different defect types. It should also be sufficiently malleable to facilitate adaptation to the morphology of the area to be treated. However, do implants placed into regenerated bone exhibit the same success rates as those inserted in native bone? In a recently published 5-year follow-up study (39) implants with simultaneous GBR were compared to implants placed in native bone. The latter were used as controls. The implant survival rate was equal to 100% for the group with GBR and 94% for the control group. The difference was not statistically significant. The marginal bone resorption levels were also similar for the two groups at 5 years.

**Peri-implant GBR**

In periodontology, periodontal defects are classified based on the degree of periodontal tissue damage and the number of bony walls surrounding the defect. There are one-, two-, three-wall and circumferential bone defects. The regenerative potential and the difficulty of the surgical technique will directly depend on the number of bony walls present around the defect. A three-wall defect will respond much better to therapy because it can maintain clot stability during the first healing stages, and due to its intrinsic spacemaking ability. On the other hand, in a one-wall defect the clot is much less protected and regenerative therapy is more complex. A “regeneration chamber” needs to be created to allow competent tissue migration and maturation. A rigid membrane needs to be applied and be suitably fixed to the surrounding areas, often in combination with a filling material. Based on the biological principles of periodontology, a peri-implant defect classification (40) has been proposed, as follows:

- closed bony defects, with preserved bone walls (Figure 6);
- open defects, with one or more missing walls (Figure 7);
- dehiscences. Bone is missing on one side of the implant, usually on the buccal side;
- defects within the envelope. These defects are contained within the alveolar crest (Figure 8);
- defects outside the envelope. These defects extend beyond the contours of the alveolar crest (Figure 9).

**Closed Defects**

With their preserved bone walls, closed defects offer favourable conditions for the regenerative process. They are shaped like a cup or a small crater.
They maintain the stability of the clot and of any bone graft throughout the healing period. The preserved bony walls protect the healing environment from the movements of the overlying tissues, thus allowing the undisturbed invasion of osseoregenerative cells. In addition, the defect margins offer support, thereby preventing membrane collapse into the defect.

**Therapy.** These defects - particularly those with gaps not exceeding 2 mm - might be left to heal spontaneously, without resorting to GBR. However, an experimental study (41) has shown that the wider the defect, the worse it will heal in terms of Bone-to-Implant Contact (BIC). Hence, it is only extremely narrow defects (1-2 mm) that should be left untreated. For wider defects, it is advisable to use a filling material, preferably autogenous bone harvested from adjacent areas. Given the containing ability of the defect, in most cases there is no need for a membrane to be applied (Figures 10-11).

**Open Defects**

The anatomy of open defects is less favourable than that of closed defects in terms of regenerative process. In fact, the absence of one or more bone walls will expose the healing environment to external trauma. In open defects the blood clot is less protected, particulate bone grafts are more exposed to movement, and a membrane positioned to cover the defect can easily collapse due to insufficient support from surrounding bone walls (Figure 12). Of course some open defects are more favourable than others. The least favourable are those above the crest.

In these cases, due to the complete absence of all bone walls, regenerative therapy faces some key challenges and the prognosis is uncertain.

**Therapy.** Given the morphology of open defects, in this case regenerative therapy will be more complex than for closed defects. It is always advisable to fill the defect with particulate graft material, preferably with autogenous bone rather than bone substitutes. The graft must be contained and protected with a non-resorbable or resorbable membrane. Many years ago Gelb (42) had already emphasized the importance of defect anatomy for the regenerative process. Different regenerative therapies were used to treat both three-walled and one-walled defects. The Author observed that three-walled defects healed irrespective of the type of therapy used.
whereas for one-walled defects the most effective approach was a combination of a membrane and a filling material.

Dehiscences

A dehiscence is a defect in which bone is missing only on one side of the implant, usually on the buccal aspect, where the bone plate is thinnest. This defect leads to implant thread exposure up to the implant head. Dehiscence-type defects can be classified as follows:

- Dehiscences within the envelope. These defects are contained within the alveolar ridge contours, so the exposed part of the implant is surrounded by bone walls which are able to maintain a graft and provide bone-promoting cells (space-making defect). The defect anatomy allows for the positioning of an autogenous bone graft. This will often be so stable that no containing membrane will be needed (Figures 13-14);
- Dehiscences outside the envelope. These defects extend beyond the bone contours, so the exposed implant threads are not surrounded by containing bone walls (Figure 15). In fact the bone is quite far from the threads and the distance that bone-promoting cells need to cover is quite large. These are non-space-making defects, which do not provide sufficient protected space for regeneration to occur. The therapy consists in using a ‘space-maker’, i.e. some filling material to cover the threads and maintain space within the compartment. The defect must then be covered with a membrane to be firmly fixed with tacks to the surrounding bone. Membrane stability is of paramount importance, since by its own nature the defect is not anatomically protected. Hence, it is exposed to movements in the oral cavity and therefore to dislocation.

Figure 14. In dehiscences within the envelope, the particulate autogenous bone graft is maintained within the defect by the presence of the lateral walls. The use of membranes is generally not required.

Figure 15. In dehiscences outside the envelope, the implant protrudes through the bone contour, so the bone regeneration technique requires the use of space-making devices, membranes, and fixation tacks.

Figure 16. Example of a bone fenestration.

Fenestrations

These defects are similar to dehiscences, but they do not involve the most coronal part of the implant (Figure 16). In other words, they refer to cases of limited exposure of threads confined within the implant body. No instances of implant failures due to fenestrations have been described. Thus, in the least extensive cases, the defect is left untreated. Larger fenestrations can be treated with the same procedures as used for dehiscences.

Filling Materials for Periimplant Defects

Particulate autogenous bone is regarded as the gold standard for filling peri-implant bone defects, since it combines osteoconductive and osteoinductive properties. Bone substitutes, on the other hand, only have osteoconductive properties. Bone substitutes, on the other hand, only have osteoconductive properties. They act as scaffolds. If they come in contact with connective tissue, they are immediately invaded by fibrous tissue, thereby thwarting any

| Table 2 |
|---|---|---|
| Filling Materials | Advantages | Disadvantages |
| Autogenous bone | Osteoconductive properties | Higher morbidity |
| | Osteoinductive properties | Easier resorption |
| | Excellent prognosis | |
| Bone substitutes | No graft harvesting | Osteoconductive properties only |
| | | Higher costs |
| | | High risk of connective tissue cell invasion |
regeneration attempt.

Table 2 shows the advantages and disadvantages of autogenous bone and its substitutes. Small amounts of particulate autogenous bone can be harvested by means of minimally invasive techniques. For larger quantities, like solid bone blocks, burs and trephines can be used. Piezoelectric instrumentation can be employed for less traumatic procedures. Table 3 shows a list of some of these techniques. A morphogenic study was conducted on the repair of critical size defects, i.e. defects that will not heal spontaneously. The Authors used both deproteinized bovine bone (DBB) and autogenous bone in rat calvaria (43). In that study DBB was not able to regenerate the missing bone and the defects appeared to be predominantly filled with fibrous connective tissue and only by 16% with newly formed bone. On the other hand, the defects treated with autogenous bone exhibited complete defect closure with newly formed bone. Bone grafts must often be covered and protected with membranes. There are non-resorbable membranes (e-PTFE), which must be removed a few months later, and resorbable membranes (in PLA or collagen) which need not be removed. Table 4 lists the advantages and disadvantages of the two types of membranes.

### Pre-Implant GBR

**Ridge Reconstruction (RR)**

Quite often the jaws exhibit extensive bone loss due to infection, cysts, tooth extraction, root fracture and implant failure. These areas may be of strategic importance for mastication or aesthetics and the placement of implants is required to restore the patient’s lost function. The term ‘Ridge Reconstruction’ (RR) refers to a set of surgical procedures aiming to restore the integrity of the alveolar ridge by means of filling materials and membranes, with a view to subsequent implant treatment. Large alveolar ridge defects have a varying ability to contain and protect blood clots or grafts, based on the presence of any preserved bone wall. **Therapy.** Given the size of the defect, it is essential to use a filling material that allows osteogenic cell proliferation. In fact, the distance between the bone walls does not allow for natural ‘cell jumping’, so the bone graft represents an essential scaffold for the regenerative process to occur. In addition, the filler should be combined with a non-space-making membrane (a collagen membrane) in defects with preserved bone walls, or with a space-making membrane (PLA resorbable membrane or e-PTFE non-resorbable membrane). These should be fixed with titanium pins. The procedure almost invariably requires a fair amount of scaffold material. There are various possibilities, as follows:

- harvesting autogenous bone from the ascending ramus of the mandible, then reducing the bone particles to final particulate size;
- harvesting autogenous bone with a scraper after raising a flap or by using a tunnel technique;
- mixing autogenous bone chips with DBB in a proportion of 40:60. The use of bovine bone alone is not recommended, due to the risk of extensive connective tissue colonization and insufficient bone formation;
- using a layer technique (Layer Technique, Vanden Bogaerde, 2011). The procedure consists in filling the apical half or two thirds of the defect with DBB and the remaining coronal part with autogenous bone chips. The basic principle of this technique consists in completely surrounding the bovine bone graft with autogenous bone, in order to prevent connective tissue cell invasion of the xenograft particles. A PLA resorbable membrane is then positioned and fixed above the graft. The biggest advantage offered by resorbability is that in case of exposure the

### Table 3

<table>
<thead>
<tr>
<th>Filling Materials</th>
<th>Bone Harvesting Systems</th>
<th>Characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Autogenous bone</td>
<td>Scraper</td>
<td>Bone shavings of fairly good density and volume, with low morbidity</td>
</tr>
<tr>
<td>Particulate Bone</td>
<td>Implant burs</td>
<td>Small amounts, of rather low density, no morbidity</td>
</tr>
<tr>
<td>Disposable chisels</td>
<td>Rongeurs</td>
<td>Fairly large amounts of dense bone, low morbidity</td>
</tr>
<tr>
<td>Small trephines</td>
<td></td>
<td>Small amounts of dense bone, low morbidity if used at implant site</td>
</tr>
<tr>
<td>Bone Blocks</td>
<td>Burs or Piezo</td>
<td>Large reconstructions possible, high morbidity preventable with piezo</td>
</tr>
<tr>
<td></td>
<td>Large trephines</td>
<td>Large reconstructions possible, high morbidity</td>
</tr>
</tbody>
</table>

### Table 4

<table>
<thead>
<tr>
<th>Membranes</th>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Resorbable</td>
<td>No need to be removed in case of exposure</td>
<td>In non-space-making defects they require the use of supporting fillers</td>
</tr>
<tr>
<td></td>
<td>No re-entry needed</td>
<td></td>
</tr>
<tr>
<td>Non-resorbable</td>
<td>Higher space-making ability</td>
<td>They need to be removed in case of exposure. Re-entry required for removal</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Large trephines</td>
<td>Large reconstructions possible, high morbidity</td>
<td></td>
</tr>
</tbody>
</table>
membrane does not need to be removed (Figure 17a - 17g).

**Horizontal Ridge Augmentation (HRA)**
Following tooth extraction, the alveolar ridge undergoes severe bone resorption, with both vertical and horizontal bone loss. However, horizontal bone resorption is usually more marked. A knife-edge ridge is thus formed, with inadequate width for implant placement. For this reason, a series of techniques need to be applied to augment bone in the horizontal dimension before implant placement. There are multiple procedures available and their selection will often depend on the operator’s experience or familiarity with one specific method.

- autogenous bone graft + resorbable membrane fixed with tacks;
- autogenous bone graft + non-resorbable membrane fixed with tacks;
- autogenous block bone graft fixed with osteosynthesis screws;
- a split-crest procedure.

**Vertical Ridge Augmentation (VRA)**
Vertical Ridge Augmentation is a technique used for augmentation of the vertical height of bone on deficient alveolar ridges. It is probably the most challenging GBR technique and should be reserved only for the most skilled and experienced operators. It is also one of the least predictable techniques in our armamentarium, in that the defect to be treated is completely devoid of bone walls and the source of bone-promoting cells comes only from the defect base. In addition, serious difficulties may be encountered in obtaining appropriate graft coverage with soft tissues.

It can be carried out in one of two ways, as follows:
- with a two-stage procedure. Use an autogenous bone graft or a mixture of autogenous bone and bovine bone to be positioned on the ridge + a reinforced non-resorbable membrane fixed with titanium tacks. Waiting a minimum of 9 months before inserting the implants is usually recommended.
- with a single-stage procedure. The implants are positioned a few millimeters above the crest. The
regenerative technique is performed simultaneously, as described above. This procedure is riskier than the previous one because in case of membrane exposure, regeneration will not occur and a part of the implant threads will remain exposed.

**Sinus Floor Augmentation (SFA)**

Very often the presence of the maxillary sinus cavities may prevent proper implant positioning in the posterior portion of the upper jaw. The surgical technique called ‘sinus floor elevation’ aims to provide adequate bone volume for implant placement. Today it can be regarded as a well-tested and codified procedure. It was first proposed in 1980 by Boyne et al. Today it is used on a routine basis and the scientific literature confirms its potential long-term success (44, 45). Deproteinized Bovine Bone (DBB) has the property of maintaining bone volume unchanged over time. A morphologic and morphometric analysis (46) was carried out on biopsies performed at an 11-year follow-up using deproteinized bovine bone mixed with autogenous bone in a proportion of 80/20%. After 11 years, the Authors identified the presence of DBB particles which were well integrated in the lamellar bone with no signs of resorption.

The procedure is generally carried out in two stages, with a minimum interval of 6 months. Sometimes, however, if the residual crestal bone height exceeds 6 mm, the implants can be inserted simultaneously with the sinus elevation procedure.

The surgical technique can be summarized as follows:

- a full-thickness flap is raised, usually with a mesial or distal releasing incision;
- the sinus external bone wall is thinned out with a scraper, until the characteristic bluish colour of the membrane becomes apparent. The scraper can also be used to harvest bone fragments that can be used at the end of the surgery to close the bone window. Bone can also be thinned out with piezoelectric instruments;
- a piezoelectric instrument or a ball bur can be used to outline the window contour and reach the membrane;
- the membrane is carefully lifted away, first with the piezo instrument and then with dedicated elevators;
- the sinus is filled with bovine bone or with a mixture of bovine and autogenous bone. The presence of a blood clot is favourable.

Autogenous bone can of course be used for the graft. However, the need for a fairly large amount of such a material entails higher patient morbidity;

- the bone window is closed with a layer of autogenous bone harvested with the scraper. The area is then covered with a collagen membrane;
- interrupted sutures are applied.

Possible small tears in the membrane can be treated with a collagen membrane,
by replacing bovine bone particulate with bovine bone/collagen. This presents lower risks of graft material dispersion within the maxillary sinus. On the other hand, large lacerations represent a real contraindication to this procedure. Implants inserted in an augmented maxillary sinus should always be monitored over time by means of RFA. The repeated measurements will help identify when the implants have achieved sufficient stability to withstand occlusal loads.

**The Treatment of Post-Extraction Sockets**

In our daily clinical practice we increasingly have to choose between maintaining a natural tooth or extracting it with subsequent immediate or delayed implant placement. Excluding of course those cases where root fractures or tooth decay extending to the roots make extraction imperative, there is a gray area where the choice will depend on a number of factors, as follows:

- the integrity and the length of the natural tooth root;
- the presence of periapical lesions;
- the need to perform clinical crown lengthening on the adjacent teeth, with consequent bone loss also for the latter;
- the presence of diffuse periodontitis, which entails an uncertain prognosis for the medium-term maintenance of the natural tooth;
- the cost-benefit ratio of a complex therapy aiming to maintain the natural tooth.

If the operator decides to extract the natural tooth, he/she needs to know the dynamics of the bone remodelling that will occur in the weeks and months after surgery.

In a clinical study Schropp et al. (47) analysed post-extraction socket changes with the use of standardized x-ray. The results showed that the biggest socket modifications occurred within the first 12 months after tooth extraction, with a 50% alveolar ridge thickness reduction, amounting to 5-7 mm. In addition, two thirds of this reduction occurred within the first three months after extraction. Araújo and Lindhe (48) studied the changes in post-extraction sockets with a conventional flap technique and a flapless approach. The experiment showed that following tooth extraction the alveolar ridge underwent a marked reduction during healing, particularly in the most coronal part and on the buccal aspect rather than the lingual one. A 35% bone volume reduction was recorded after 6 months of healing. However, the most important observation was that the amount of hard tissue loss during healing was comparable with both conventional flap surgery and the flapless approach. Bone resorption appears to be predominantly localised on the buccal side of the socket because of the anatomical characteristics of that area. In fact, the buccal bone plate is often exclusively composed of ‘bundle bone’, i.e. the bone lamina that Sharpey’s fibers - the fibers of the periodontal ligament - insert into, coming from the root cementum. After tooth extraction, the bundle bone seems to lose its function and is therefore resorbed. As it is composed of both bundle and lamellar bone(49), the lingual bone plate undergoes less resorption. When the buccal bone plate is resorbed, soft tissue penetrates into the space previously occupied by bundle bone, with a consequent lack of sufficient room for bone regeneration to occur. Therefore the ridge will undergo both horizontal and vertical collapse.

Covani et al. (50) showed that removing a single intercalary tooth caused a marked change in the buccal bone wall. As a consequence, the alveolar ridge was reduced and moved lingually. Vertical bone resorption was more marked (10.6 mm) at the centre of the ridge than at its mesial (5.4 mm) and distal (6.6 mm) ends.

In summary, when a decision is made to extract a tooth, there are three options available:

- waiting until the socket has healed;
- reconstructing the socket;
- placing an implant at the time of tooth extraction.

As mentioned above, tooth extraction often leads to alveolar socket collapse. Can this problem be prevented today by using techniques that promote alveolar bone reconstruction?

**Socket Reconstruction**

Fickl et al. (49) evaluated possible interventions to maintain post-extraction socket dimensions based on the following research protocol:

- filling the socket with bovine bone/collagen;
- using bovine bone/collagen and a free gingival graft;
- using coagulum only as a control.

The xenograft seemed to be able to replace the bundle bone, partially preventing socket collapse. It also appeared to act as a scaffold for bone regeneration, even though in the most coronal part the grafted particles were surrounded with connective tissue. In addition, the use of a free gingival graft to seal the orifice of the socket seemed to offer advantages over the control group that received no grafts. However, there is no final agreement on the possibility to prevent socket collapse with the use of biomaterials.

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**Table 5**

<table>
<thead>
<tr>
<th>Options</th>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Waiting for healing to be completed</td>
<td>The treatment is simple and cheap</td>
<td>Severe bone resorption, very long clinical crowns</td>
</tr>
<tr>
<td>Socket Reconstruction</td>
<td>Bone levels can be partially preserved Implanted in stabilised bone</td>
<td>Highly demanding therapy, long treatment times, high costs</td>
</tr>
<tr>
<td>Implant Placement</td>
<td>Bone levels can be partially preserved Very short treatment time</td>
<td>Unpredictable soft tissue recessions; Residual inflammatory tissue in the socket</td>
</tr>
</tbody>
</table>

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Table modified: Removed line breaks and formatted correctly.
Araujo et al. (51) conducted a study in dogs. They treated post-extraction sockets with bovine bone/collagen and used the untreated contralateral side as a control. Histology showed that the presence of multinucleated cells in the tissue surrounding the xenograft delayed socket healing. A significant presence of newly formed bone was observed only in the most apical part of the socket, where the graft material was absent. In the remaining part of the grafted socket, the granules of biomaterial were surrounded by an inflamed provisional matrix. They were frequently covered with multinucleated cells that could be identified as osteoclasts derived from the macrophage lineage. The presence of multinucleated cells in the provisional matrix showed that the xenograft particles had been recognized as foreign.

In the ungrafted control sites large amounts of woven bone were distributed in most of the socket compartments. Santos et al. (52) conducted an investigation on dogs to evaluate hard and soft tissue reactions after the insertion into fresh extraction sockets of two different types (natural and synthetic) of hydroxylapatite (HA) and of bioactive glass. The results for the control group showed the formation of lamellar bone after 4 weeks and of compact bone after 28 weeks. At 28 weeks, hydroxylapatites and bioglass exhibited similar results, with the formation of both connective tissue and new bone around the particles. None of the materials appeared to have been completely resorbed. In the final analysis, all the grafted materials appeared to have delayed socket healing.

Our favourite technique for socket preservation is the so-called ‘Layer Technique’ (Vanden Bogaerde, 2011). This technique consists in filling the socket with a layered approach. Bovine bone is placed on the bottom of the socket, up to two thirds of the socket height. The coronal third of the socket is then filled with autogenous bone harvested with a scraper. Lastly, a free gingival graft is used to seal the socket orifice. In our opinion the main advantage offered by this technique consists in completely insulating the biomaterial graft, which is completely surrounded with native and grafted bone. The biomaterial does not get in direct contact with the connective tissue or the epithelium. Therefore it is only colonized with bone-promoting cells (Figures 18a-18d).

Simultaneous Implant Placement
An analysis of the afore-mentioned
studies shows that attempts to preserve the socket with the use of biomaterials are often unable to meet expectations. At this point the question is whether immediate implant placement into fresh extraction sockets can help to maintain the bone level. But what does the literature tell us on the predictability and success rate of implants placed in post-extraction sockets? Botticelli et al. (53) conducted a prospective 5-year follow-up study obtaining a 100% implant survival rate. Hence, if an appropriate surgical protocol is followed, implants placed in post-extraction sockets seem to have success rates and a prognosis comparable to implants placed in native bone.

However, can implants prevent marginal bone resorption?
In a clinical and histological study in man, Paolantonio et al. stated that immediate implant placement in fresh extraction sockets can prevent buccal plate resorption. These findings were subsequently refuted by other investigators (55,56). Sanz et al. (57) have recently confirmed that immediate implant placement in post-extraction sockets leads to a marked reduction in both vertical and horizontal bone levels, with more pronounced resorption on the buccal than on the lingual/palatal aspects of the ridge.

According to Araujo et al., who conducted a 3-month study in dogs, vertical bone resorption on the buccal side amounted to 2.6 mm. Botticelli et al., again in a 4-month study in dogs, reported a value of 2.8 mm.

Spontaneous Healing of the Peri-Implant Gap
There is a need to clarify what happens in the peri-implant gap during the healing process.

A histological study conducted more than a decade ago (41) examined the bone healing process in the peri-implant gap when this was left to heal spontaneously.

The Authors evaluated the effects of peri-implant gaps of varying widths which had been left to heal untreated in simulated post-extraction sockets. Experimental defects were prepared with increasing widths of 0.5, 1.0 and 1.4 mm. Control sites had no gaps. The defects were left to heal without using guided bone regeneration. Even though clinically all the defects had healed, the histological examinations performed 12 weeks later showed that the larger the initial defect width, the smaller the bone-to-implant contact (BIC).

This article shows that a defect can be left to heal spontaneously provided that its width is small. The bone-to-implant connection may otherwise be weakened.

Peri-implant Defect Morphology
Defect healing also depends on defect morphology. A defect space-making ability may vary, i.e. defects may be more or less able to maintain sufficient space during the healing period.

A bone defect classification has been proposed based on defect morphology and on the number of bone walls present (40).

Bone defects adjacent to implants have been divided into two major groups. They include closed defects, i.e. those with fully preserved bone walls, similar to three-walled periodontal defects; and open defects, i.e. those with one or more missing walls. Clearly, due to its anatomic conformation, the first type of defect shows to have a space-making ability, with excellent coagulum stability during early healing stages. Hence the regenerative process is more predictable. In open defects, on the other hand, one or more bone walls are missing. Thus, ensuring blood clot or graft stability is more difficult.

Therefore these defects have a less predictable prognosis than the closed ones and require more complex and costly regenerative treatment, with the use of bone grafts and membranes.

Treatment of the Peri-Implant Gap
An important aspect is the type of graft material to be used to fill bone defects. Autogenous bone is generally accepted as the gold standard among bone graft materials, due to both its osteoconductive and osteoinductive properties.

In spite of the increasingly widespread use of bone substitutes, autogenous bone can still be considered the material of choice for this kind of lesions. Peri-implant defects can generally be treated with relatively small amounts of bone, thus micrografts can be harvested from the oral cavity. Bone harvesting can be performed by means of a bone scraper, an instrument that can be used to remove small amounts of graft material from the bone surface.

Interestingly, quite often these small grafts contain viable bone cells. This shows that the procedure is largely atraumatic. Today there are also miniscrapers available to harvest bone with minimally invasive techniques. One such procedure is the ‘tunnel technique’. A vertical incision is performed on the outer side of the mandible at the level of the first molar. The periosteum is elevated and tubular miniscrapers are inserted to scrape the cortical bone surface and harvest small bone shavings with a special basket.

Very few sutures are necessary to close the access wound.

In our opinion, the use of bone substitutes in the treatment of peri-implant gaps exposes the defect to the ingrowth of undesirable connective tissue, with consequent encapsulation of biomaterial particles and a lack of new bone formation. This is likely to lead to improper defect healing. In addition, connective tissue proliferation might promote infection and inflammation.

Implant Position within the Socket
The implant location within the post-extraction socket has been the subject of a specific study conducted by Caneva et al. (60) in experimental animals (dogs). Implants were installed immediately into fresh extraction sockets. In the control sites they were placed in the centre of the alveolus, while in the test sites they were positionned 0.8 mm deeper and more lingually.

Four months later they were evaluated histomorphometrically. All implants were osseointegrated, with the presence of lamellar bone. Marginal resorption was observed in both groups. However, bone loss was less pronounced in the test group (with deeper and more lingual implants) than in the control group.

In conclusion, implants should always be inserted in a lingual position in relation to the centre of the alveolus for the following reasons:

- the lingual bone plate is thicker and
subject to less resorption;

- the lingual bone wall is generally made up of cortical bone. Therefore it ensures greater implant primary stability;

- by positioning the implant more lingually, we leave more free space for bone grafting on the buccal side. With regard to insertion depth, different positions within the jaws need to be evaluated as follows:

- in the aesthetic area implants should be positioned flush with the crest or deeper. The choice will depend on both the alveolar bone thickness and on the thickness and volume of the soft tissues. It should be remembered that an implant placed flush with the crest or subcrestally is often accompanied – during the healing process – by ridge resorption, due to the need for biological width to be established;

- on the other hand, in the posterior areas it can be helpful to place implants 1-2 mm above the crest in order to minimize the vertical bone loss related to the biologic width. This also helps to reduce the interocclusal distance and therefore the lever arm.

Flapless Technique

Araujo and Lindhe (48) conducted a study in dogs to evaluate bone healing after tooth extractions performed with either a flap or a flapless technique. There was no statistically significant difference in terms of marginal bone resorption between the flap and the flapless procedures. Bianco et al. (61) conducted a study in dogs to assess alveolar ridge changes after tooth extraction, in both the horizontal and vertical planes. Measurements performed 3 months later showed a vertical resorption of 1.48 mm and 1.22 mm for the flap and flapless groups respectively, and a horizontal bone loss of 4.41 mm and 4.5 mm again for the flap and flapless groups respectively. However, the results were not statistically significant. Therefore bone resorption was not influenced by the type of technique used, be it flap or flapless. There are divergent opinions on this point, though. In fact, Fickl et al. conducted an animal study with the aim of assessing the consequences on bone of flap or flapless tooth extraction techniques. The Authors observed a bone loss of 2.1 mm in the flapless group, and 2.5 mm in the flap group. The difference was considered statistically significant. Therefore they concluded that leaving the periosteum in situ slowed down bone resorption in post-extraction sockets. It should be emphasized that the differences between the results obtained in the aforementioned studies might be attributed to the different locations of the teeth involved, with variations in anatomy and bone thickness.

Precautions To Be Adopted In Immediate Implant Placement Into Post-Extraction Sockets

Before proceeding to immediate implant placement into fresh extraction sockets, it is essential to adopt a set of precautions in order to evaluate the following factors:

- the presence of periodontitis. The presence of active periodontal disease is a contraindication to immediate implant placement into fresh extraction sockets. An appropriate therapy should first be administered to treat periodontitis. Bacterial plaque should be kept under control through a strict oral hygiene plan and implant conditions should be monitored over time with x-rays and RFA. It has been shown that in cases of Generalized Aggressive Periodontitis (GAP), patients have a higher incidence of periodontal disorders, more marked marginal bone resorption and lower implant survival rates (63, 64).

- implants in infected sites. Apparently, it is possible to place implants also into infected sites, after careful socket curettage. However, it should always be remembered that residual inflammatory tissue fragments may remain trapped after implant insertion, giving rise to infections that may become severe, with consequent implant loss or with the onset of apical periimplantitis (granulomas).

- Periodontitis and concomitant smoking can represent a real and serious contraindication to implant therapy (63).
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