Immediate Function of Endosseous Implants: A Change in Paradigma

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Summary

The initial implant protocol recommends a healing period of three months in the mandible and six months in the maxilla. It has been developed on the basis of empirical data and neglects clinical, biomechanical and biological parameters. High success rates, progress in therapy and technical innovations have provided cause for a critical reflection on the decisive factors ensuring the success of implant-prosthetic restoration. Possibilities of accelerated implant protocols are discussed.

The aim of this bulletin is to evaluate the influence of implant macro-design, surface morphology, implant site preparation and insertion, as well as prosthetic solutions to ensure a simple, safe and fast implant treatment.

Current surgical and prosthetic implant protocols are summarized in a systematic manner. A standardized and consistent terminology is defined.

Introduction

In its early days [1, 2] implant dentistry was considered to be the treatment alternative for restoring the edentulous jaw. Today, on the contrary, it is the clinically and scientifically proven standard of care for replacing missing teeth. The pre-requisite for the long-term success of an implant-supported treatment concept is the development and re-evaluation of standard treatment protocols based on the patient's demands. New criteria for an "evidence-based implant dentistry" are assessed in order to influence and ensure predictable success.

Every treatment protocol can be regarded as the result of a continous learning process where rules are set up to avoid failures. The conventional implant protocol is based on empirical data that were introduced 25 years ago with the beginning of this ongoing learning curve. At that time, almost no clinically or scientifically based results were available, or if any, they were unsatisfying [3-8]. The initially recommended healing period of three months in the mandible and six months in the maxilla have proven to guarantee undisturbed osseointegration clinically. However, there is no evidence that safe osseointegration may not have been achieved after a reduced healing time.

The historical implant protocol according to Brånemark et al. [4] was developed on the basis of a series of preconditions that today are considered to be restrictive. At that time, the primary indication for placing dental implants was the restoration of the edentulous, atrophied mandible with anchoring elements for removable overdentures. The replacement of single teeth was not considered as a treatment option [7]. Data on a critical risk evaluation and clear indications were not available.

Biomechanical and biological parameters capable of accelerating hard and soft tissue integration were neglected. For this reason, a modification of the generally machined surface was not an issue. Over many years, the treatment protocol focused mainly on the standard implant site preparation from a surgical point of view, with guaranteed healing of implants. Since the osseointegration process is rather limited to a few weeks, the cellular reaction during the functional loading phase is now considered to be significantly more important for the long-term success [9].

Based on the patients' and clinicians' demands for shorter treatment times, clinical case presentations on early and immediate implant-supported prosthetic restorations are increasingly described in the literature [10-15]. The good success rates of these documentations with a small number of patients have provided reason to critically reflect on the need to determine the decisive parameters that ensure success in implant prosthodontics.

The aim of this scientific bulletin is to summarize state-of-the-art research on the success-determining factors for the immediate function of implants. The question whether the strict consideration of dogma for the healing period is indeed the absolute pre-requisite to ensure the long-term treatment success, or whether the development of revised implant-prosthetic protocols with shorter treatment periods are equally providing safety, will be critically discussed.

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Terminology

With regard to the description of new treatment concepts for early and immediate implant function, a series of terms have been defined to cover the various aspects of the time of implant placement, healing and prosthetic delivery.

To avoid confusion there is an urgent need to determine a standardized and consistent terminology.
Basically, the currently used terms are divided according to the description of the time of implant loss, the mode of implant healing and the type and time of prosthetic restoration. They represent partial aspects of the process of implant-supported prosthetic restoration and are interchangeable.

1. **Immediate implant placement**
   Implant placement immediately after tooth loss
2. **Delayed immediate implant placement**
   Implant placement before bone remodeling and final epithelial wound healing
3. **Late implant placement**
   Implant placement after bone remodeling of the alveolus

Classification according to the time of implant placement [16]

1. **Submerged healing**
   Healing under covered mucoperiosteal flap; second surgery required at uncovery of the implant
2. **Non-submerged healing**
   Transgingival healing with immediate exposition to the oral cavity. Primary soft tissue healing around the transgingival section of single stage implants or around premounted gingival formers of two stage implants

Classification of implant protocols according to the healing mode [17]

Anatomy

The clinical experience and scientific research over the past 25 years have provided new data on the biological and physiological processes related to implant integration and implant-supported prosthetic loading [20 - 24].

Studies have shown that, contrary to the classic prosthetic options, functionally loaded implants preserve the alveolar process and the peri-implant soft tissue. Consequently, the earliest possible replacement of missing teeth by implant-supported reconstructions is absolutely necessary [21, 22]. The most important criterium for preservation of the bony structures of the alveolar process is the existence of a functionally loaded tooth root or an implant.

During the process of tissue regeneration it was observed that remodeling, as a dynamic equilibrium of tissue growth and resorption of the periimplant hard and soft tissue, starts at the same time with the implant-prosthetic load distribution. The decisive factors have proven to be: implant diameter, length, surface and position related to the natural root [24, 25].

1. **Immediate functional loading**
   Functional loading within 48 hours after implant placement with provisionals, in occlusion
2. **Non-functional loading**
   Prosthetic restoration within 48 hours after implant placement with provisionals, out of occlusion
3. **Early loading**
   Prosthetic restoration within 3 weeks after implant placement with final prosthetic restoration, in occlusion
4. **Advanced early loading**
   Prosthetic restoration within 8 to 10 weeks after implant placement with temporaries, in occlusion
5. **Progressive loading**
   Stepwise, increased loading through primary restoration with a temporary and final restoration after functional bone remodeling [19]

Classification of implant protocols according to type and time of prosthetic restoration [18,19]

The term "osseointegration" was defined with the development of the classic implant protocol [1, 2, 4]. It describes the bony anchorage of endosseous implants as an indicator for the resistance force at their functional loading. Illustrated by light-microscopical cross-sectional images of the implant-bone-interface, this was rather an empirical finding than the understanding of the process of peri-implant bone healing. In this respect, the bony integration process was compared to fracture healing. Consequently, due to insufficient knowledge of the specific processes related to the implant surface, no data could be provided with regard to the influence of surface modifications [7].

Basically, the integration at the implant-bone-interface results in a contact osteogenesis, i.e. direct bone growth on the implant surface. This process can be divided into three stages: During the first stage - the osseoconduction - the differentiating bone-inducing cells migrate to the implant surface, along a temporary fibrous matrix formed by blood coagulation. The anchorage of this matrix [26] depends on the implant surface morphology.

During the second stage – the de-novo bone synthesis - the osteoblasts deliver non-collageneous proteins into the extracellular matrix, acting as an interface between the new and the old bone. A bony layer is formed on the implant surface in this matrix due to formation of calcium phosphate nuclei and their crystal growth with simultaneous collagene production and subsequent mineralization.
After this layer has been formed, the third stage of bone remodeling begins. New bone substance is built between the old bone and the implant surface based on the principles of the de-novo bone synthesis.

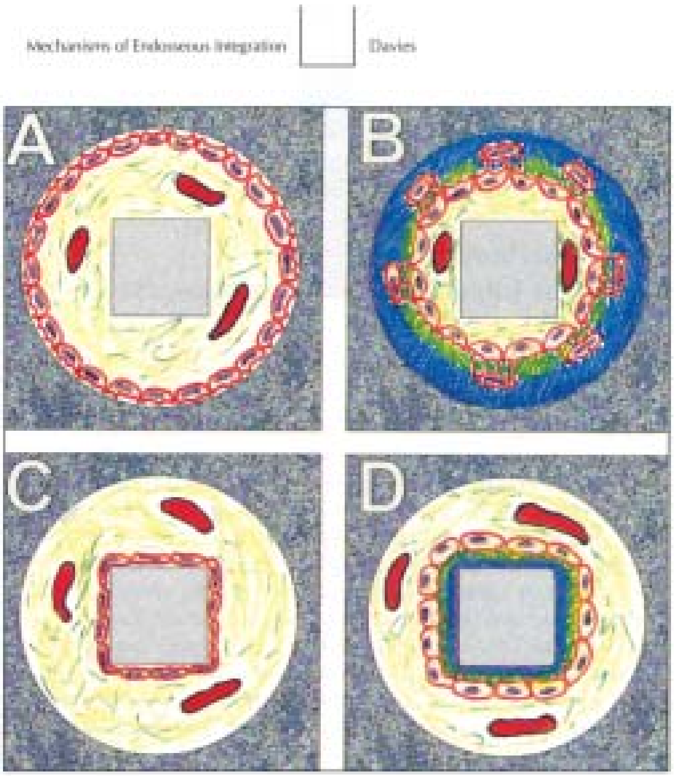

Fig.1: Distance osteogenesis: A. Osteogenic cells line the old bone surfaces (A results in B). B. Bone recruites the old bone surface. Contact osteogenesis: C. Osteogenic cells line the implant surface (C results in D). D. Bone recruites the implant surface. Source: Davies J.B. [26]

Contrary to the initial consideration of the classic implant protocol that the undisturbed bony healing of an implant provides a close bony contact at the implant interface on the long-term, it was determined that the quality and quantity of the peri-implant bone at the time of functional loading significantly differ from the unloaded situation.

According to Brunski et al. [27, 28] implants can be loaded early or immediately if micro-movements of implants of more than 150 µm can be avoided during the osseointegration phase. Stronger movements would lead to soft tissue resorption at the interface rather than to the desired osseointegration. Cameron et al. [29] reported that osseointegration can be achieved even with micro-movements, but not with so-called macro-movements. Although there are no reliable and proven data on the definition of micro- and macro-movements, clinical studies have shown that osseointegration may occur as long as movements do not exceed approximately 150 µm during the healing phase.

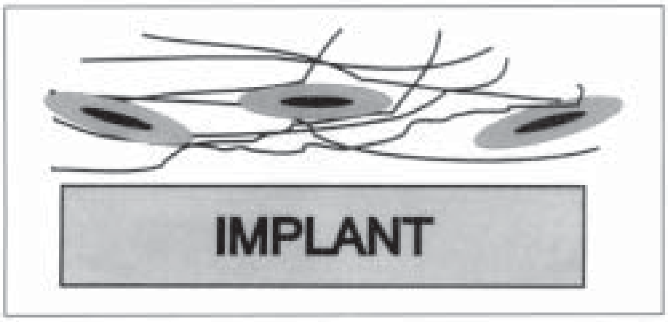

Fig. 2a: Fibrin retraction and loss of contact to implant surface

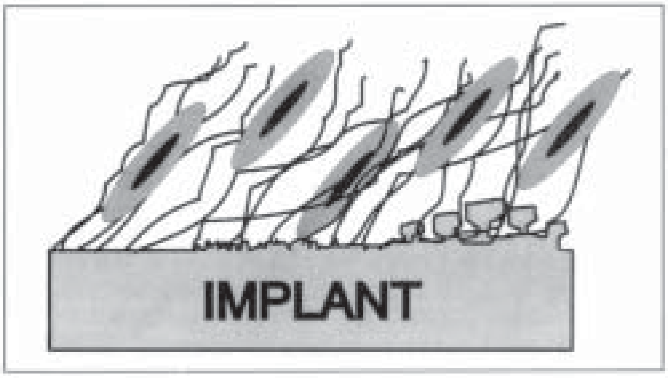

Fig.2b : Interconnecting three-dimensional topography. Fibrin remains attached to modified implant surface. Source: Davies J.B. [26]

Consequently, the dogma of an undisturbed healing phase as a guarantee for long-term success is questionable and, with regard to a dynamic equilibrium, requires for setting up realistic, success-relevant criteria.

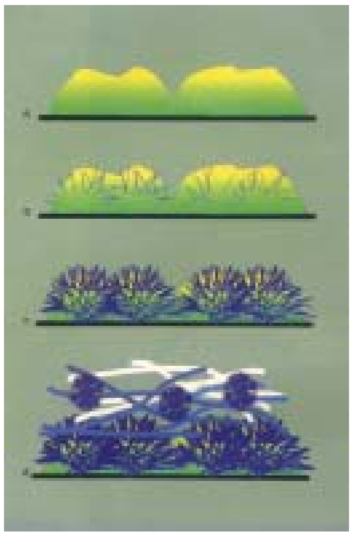

Fig 3 : a. Secretion of noncollagenous proteins. b. Calcium phosphate nucleation. c. Crystal growth phase. d. Collagen production and mineralization. Source: Davies J.B. [26]

The following parameters will be evaluated based on immediate implant restoration and loading: implant macro- and micro-design, instruments according to bone quality, surgical implant site preparation, prosthetic treatment protocol and system components.

Implant design and surgical concept

The implant design and the surgical armamentarium for immediate loading and immediate restoration have to address various requirements.

According to Brunski et al. [27, 28] macro-movements should be avoided in the initial period of implant integration. Consequently, on the one hand, a high primary stability has to be achieved after implant placement, and, on the other hand, a fast and safe osseointegration must be reached during the functional loading period.

In order to achieve primary stability of implants, the local amount of bone should be taken into consideration. According to Misch et al.[19] , Lekholm and Zarb [70] , bone density can be classified.
The type D1 to D4 bone classes basically describe the ratio of dense versus spongy bone substance. While class D1 bone almost exclusively represents the type of cortical, dense bone, class D4 bone covers soft spongy bone with a thin cortical layer.

For all bone qualities, a safe and gentle insertion of implants must be ensured. Therefore, the threads of screw implants should cut bone atraumatically. In dense, cortical bone the risk of trauma, whereas in spongy bone the risk of lack of primary stability can be observed.
A narrow thread profile and an increased profile depth are the pre-requisites for a good cutting performance and highest possible bone contact in spongy bone.

However, a reduced resistance to cutting is required in cortical bone. The cutting depth of the thread determines the friction of the implant in the bone. In dense bone, a high insertion torque results from such friction that could damage the bone due to compression or heat necrosis (Fig 4). In spongy bone, narrow thread profiles may lead to poor primary stability because of a limited cutting depth (Fig 5). The stability achieved by applying a pre-cut thread in this type of bone quality is insufficient.

In order to meet the various requirements of all bone classes, it is of advantage to provide a synchronized thread geometry for the spongy and cortical sections of the implant site. This guarantees for an atraumatic pre-cutting performance of the threads in the cortical section.

Due to a reduced friction in class D3 and D4 bone density, the bone density of the implant site has to be improved for

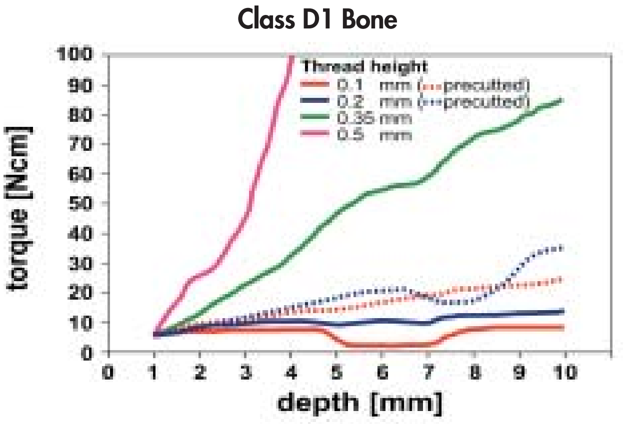

Fig 4 : Insertion torque related to thread depth in D1 bone quality

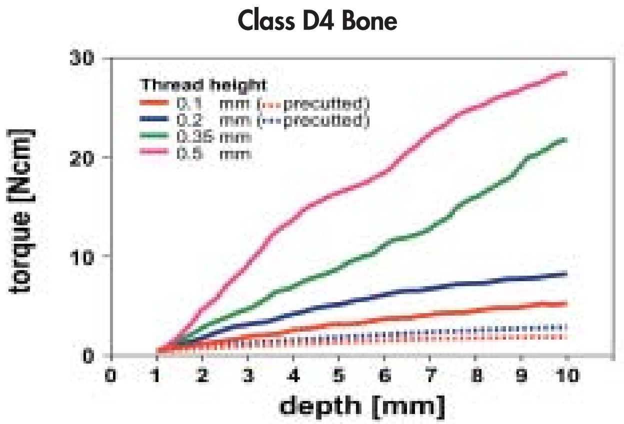

Fig 5 : Insertion torque related to thread depth in D4 bone quality

implant placement by internal condensation (Fig. 7-9)[68,69].
An implant site preparation according to bone density can only be achieved by an adequate surgical armamentarium. The different bone elasticities of cortical and spongy bone have to be considered. To ensure the insertion depth of the implant, a preparation of the cortical bone layer (Fig. 6) is recommended as well as a crestal support of the implant macro-design.

At implant placement, a torque of 30 Ncm should be ensured for sufficient primary stability. This value can be achieved and controlled by strong surgical units, like the FRIOS® Unit E (DENTSPLYFriadent, Mannheim, Germany).

Long-term success is not only influenced by bone density of the implant site and the implant macro-design, but also by the implant surface. The morphology, roughness and topography of the implant surface at the interface play an important role for primary stability and safe osseointegration (Fig. 7)[49-51, 54, 73, 74].

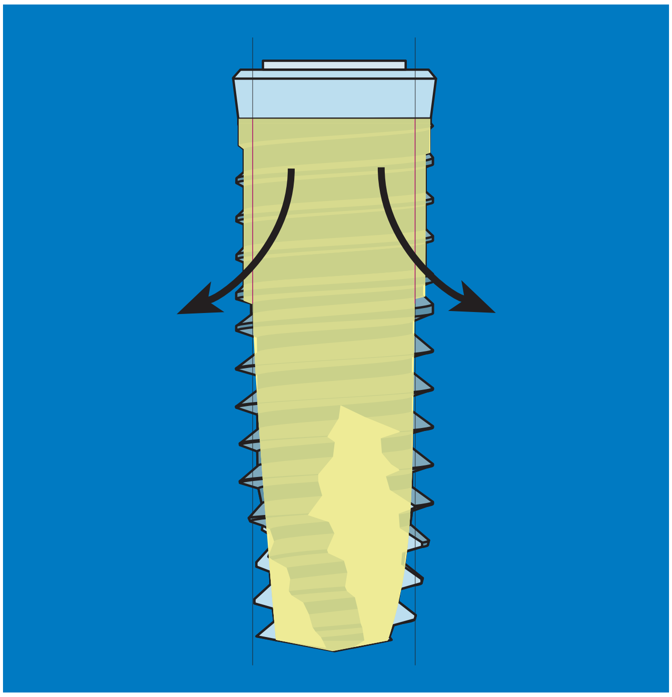

Fig 6 : Preparation of the cortical implant site according to bone density

Fig 8 : Fluorescence-microscopic image (Oxytetracycline) 20x. Implant-bone-interface 2 weeks after conventional implant site preparation and placement. Source: Nkenke E. et al.[72]

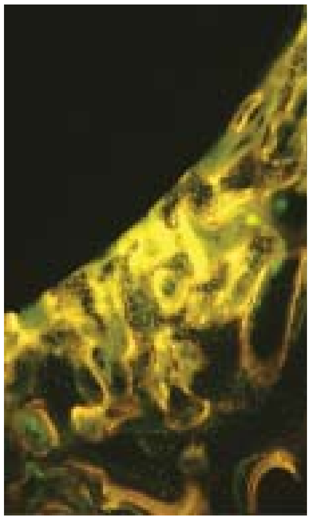

Fig 9 : Fluorescence-microscopic image (Oxytetracycline) 20x. Implant-bone-interface 2 weeks after internal bone condensing and implant placement. Source: Nkenke E. et al.[72]

Rough surfaces influence and stimulate the cell activity of surrounding bone structures. Cell proliferation and differentiation, matrix synthesis and production of the tissue growth factor (TGF) are enhanced and lead to a tight bone-to-implant-contact. A cervically textured surface is

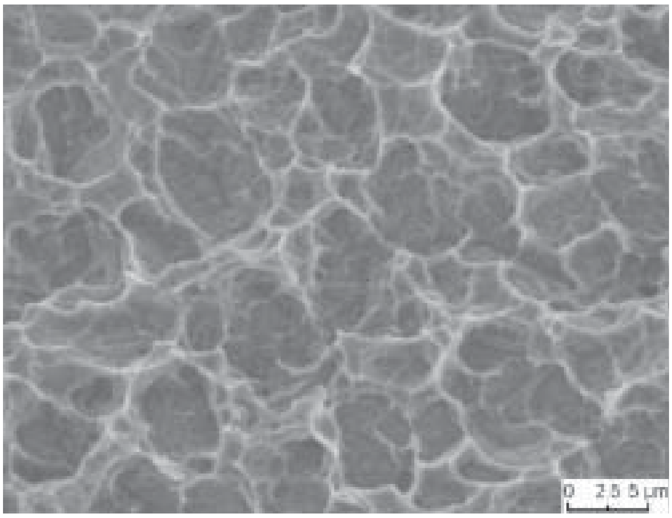

Fig 7 : SEM picture 3000x. Bimodular grit-blasted and acid-etched FRIADENT surface

advantageous for a hybrid implant design. The structure-polished implant collar favors the cellular orientation for adhesion control. In the region of the gingival margin, it represents a diffusion barrier for bacteria between the oral cavity and the implant site[76].

Fig 10 : Histology/Tri-Chrome-Mason-Goldner : Initial situation after bone condensing using FRIALIT®-2 BoneCondensers. Internal elevation of the sinus floor (magnification 2.5x). Source: Nkenke E. et al.[72]

Prosthetics

An initial period without any removable prosthesis or wearing provisional restorations as well as the inconvenient prospect of a long treatment period may preclude some patients from seeking implant treatment.
The standard of care in implant dentistry focusses on elaborating clinical protocols for fast and simple delivery of provisional or final implant-supported restorations.

Today, the treatment concept of immediate bar-supported prosthetic loading, proven and documented by P.D. Ledermann [30], is considered to be the "golden standard" for an accelerated implant-supported treatment. It serves as the basis for alternative protocols that provide a shortening of treatment time.

The method of immediately loading four rigidly bar-splinted implants in the edentulous mandible resulted in the development of the New Ledermann Screw (NLS) in 1987 in cooperation with FRIADENT GmbH (formerly FRIATEC AG, Mannheim/Germany) [31].

However, there was a concern that TPS particles may shear off during insertion and subsequently migrate into the surrounding tissues[47]. Consequently, the implant surface morphology of the NLS was changed in 1987 from titanium plasma sprayed to the grit-blasted and acid-etched FRIADENT deep profile surface. With the FRIALOC® threaded implant introduced in 1999, DENTSPLY Friadent is providing a further development of an implant concept for immediate function in the edentulous mandible that has been clinically and scientifically proven for over 20 years.

In a multicenter study by Chiapasco et al.[45] it was demonstrated that the success rate of immediately loaded bar-supported implants is similar to that of delayed loaded implants. The study demonstrates an almost 100% success rate for implants with completed osseointegration. The restoration of the edentulous mandible with four bar-splinted implants can therefore be considered as a recognized and proven standard protocol for immediate loading.
Consequently, the following pre-conditions for early or immediate function of implants can be derived from this technique:

- Sufficient number of implants for primary splinting
- Appropriate implant length of minimum 10 mm
- Absolute primary stability of implants at insertion
- Rigid, primary splinting of the implants with the superstructure to avoid uncontrolled macro movements
- Anterior-posterior implant distribution to avoid rotation

Pre-requisites for early or immediate function of implants

Current prosthetic and laboratory protocols have shown good success rates for immediate function of implants beyond the indication of the edentulous mandible.

- Functional immediate loading and splinting of final implants (evenly distributed in the edentulous maxilla or mandible) with a rigid provisional restoration[10-14]
- Functional immediate loading and splinting of provisional implants (evenly distributed in the edentulous maxilla or mandible) with a rigid provisional restoration[11,15]
- Functional immediate loading and bar-splinting of implants in the symphysis region with a final restoration[30-45]

Prosthetic restoration of edentulous jaw

- Non-functional immediate loading (occlusal support through residual teeth) and splinting of minimum two implants with a rigid provisional restoration in the maxilla or mandible
- Functional immediate loading and splinting of minimum two implants with a rigid provisional restoration in the maxilla or mandible
- Functional immediate loading and splinting of minimum two implants with a final superstructure in the maxilla or mandible

Prosthetic restoration of partially edentulous jaw

- Non-functional immediate loading of a single tooth implant (occlusal support through residual teeth) with a provisional restoration in the maxilla or mandible
- Functional immediate loading of a single tooth implant with a rigid provisional restoration in the maxilla or mandible

Prosthetic restoration of a single-tooth implant

Numerous clinical studies underline the importance of primary splinting multiple unit implants for an undisturbed osseointegration. Studies [10-15, 30-45] have shown that immediate function is successful in the edentulous and partially edentulous jaw if the implant protocol is strictly adhered to. However, studies on immediately loaded single implants are still missing. In addition, a differentiation has to be made between functional [18] (single crown in full occlusion) and non-functional implant loading (provisional single crown/ single crown out of occlusion) [58]. Clinical case presentations on non-functional immediate loading of implants with a reduced number of patients [58] have been described in the literature, but need to be confirmed in standard long-term studies.

The rehabilitation of the stomatognathic system with implant-supported restorations can be considered as the standard of care in cases of missing teeth. The clinical requirements for simple and safe treatment and the patient's wish for a quick restoration are today, more than ever, the main focus in the development of implant dentistry. Implant components meeting the demands of these requirements are therefore of decisive importance for achieving the functionality of such a concept.

Implant design

An implant system for immediate function should include a variable range of diameters between 3.0 mm and 5.5 mm to provide a functional restoration of edentulous spans and single tooth gaps.

A high primary stability should be achieved in all bone qualities by high versatility of the implant system with regard to diameter and length.

Implant-abutment connection

Besides an optimized distribution of forces and bacteria-proof sealing at the implant-abutment interface, the mechanical strength and anti-rotational stability of the abutment play a decisive role for the immediate function of implants [77]. Recent studies have shown that the stability between implant-abutment and implant-superstructure can vary significantly according to the depth and design of the connection (internal/external hexagon).

From a biomechanical and clinical point of view, a deep internal hex with parallel walls is clearly more favorable for immediate function.

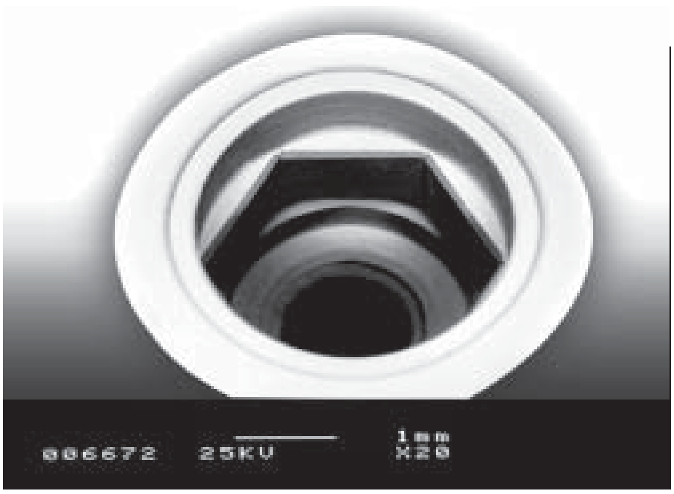

Fig 11 : SEM picture 20x. View: Internal hexagon with parallel guiding walls

Temporary components

Macro-movements during the initial osseointegration period can not be tolerated since they lead to implant failure. The goal of immediate restoration of implants should therefor be to reduce such macro-movements by a primary splinting of the superstructure.

In order to meet the requirements of an accelerated implant treatment, dentists and technicians need simple, safe and fast system components for implant placement, indexing/impression, temporary restoration and prosthetic seating.

The pre-mounted classic placement head that, so far, served only for placement of the implant, should be modified that it can be additionally used as transfer and provisional coping for the fabrication of temporary restorations.
A deep rotation stop inside the implant can ensure a stable and accurate fit of such a "multifunctional coping".
The implant position could be registered immediately after placement with a system cap via an index impression and then transfered to the master cast. The same "multifunctional coping" can be used chairside for fabrication of the provisional restoration.
For the final restoration, the castable system cap can be used as a prefabricated waxing aid for cemented and horizontally screw-retained superstrucutures.

Fig 12 : Abutment secures implant insertion and serves also as crown support

Fig 13 : System cap simplifies the implant indexing procedure and accelerates the fabrication of provisional restorations

Conclusion

After more than 25 years of continuous learning and development, the initial implant protocol is now experiencing a change in paradigma.
In the future, the pre-requisites and risks have to be identified and minimized to ensure a long-term success of accelerated implant treatment.
Current available implant systems were initially developed for the "conventional" implant protocol and therefore have to be adapted to meet the new demands.

Translated by Lolita Keller

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