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Implant planning and surgical aspects to reduce the risk of peri-implantitis

Abstract: Peri-implant inflammation is still a frequent complication in dental implantology despite highly developed surgical techniques and implant components. The development of peri-implant inflammation may not only have post-implantological causes, but pre-implantological factors also play a role. In addition to the design of the prosthetic restoration, correct planning of the implant position and surgical preparation of the implant site are particularly important for the long-term success of dental implants. This paper deals with these pre-implantological factors with special emphasis on implant planning, hard and soft tissue management and navigated implant placement, taking into account current relevant literature.

Keywords: hard and soft tissue management; navigated implantation; peri-implantitis; pre-implant procedure

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Introduction

In Germany alone, more than 1,300,000 dental implants are placed annually [3]. The complication rate is still about 20 % over an observation period of 5 years, and peri-implant inflammation is one of the main causes of implant failure [2, 4]. Nevertheless, implantological treatment of the gap dentition or the edentulous jaw has become an indispensable part of the treatment spectrum in modern dentistry, especially because the range of indications for dental implants is constantly expanding due to further developments in manufacturing techniques and materials. Today, modern pre-implantological and implantological surgical techniques allow implant restorations in almost all areas. However, depending on various influencing factors, the long-term prognosis varies.

The focus of this article is on those aspects that influence the risk of complications occurring during the surgical procedure of implant restoration. General and general medical risk factors for implant complications, such as medications or pre-existing conditions, are not the focus of this article; rather, it is assumed that absolute and relative contraindications are recorded and taken into account on a patient-specific basis.

Figure 1 shows a flow chart for a standardized procedure that can reduce the occurrence of complications in the period leading up to implant placement. The main focus is on avoiding unfavorable hard and soft tissue conditions in the implantation region or improving unfavorable conditions prior to implant placement coupled with sensible backward planning and correct selection of the appropriate implant types.

In addition to the special requirements for the actual implantation, the planning of the desired implant position, taking into account the subsequent implant-prosthetic restoration, plays a particularly important role. Jepsen et al. demand that the selected implant position and the prosthetic restoration must be chosen or designed in such a way that they are accessible to regular oral hygiene at home as well as to professional prophylaxis [12]. According to Schwarz et al., however, there are still few data on this in the literature, so that the underlying evidence regarding the pre-implantological factors influencing the development of peri-implant inflammation is still limited [23]. Implant planning that not only takes into account in advance surgical aspects such as bone quality and quantity, but also considers the prosthetic restoration planned later in terms of the necessary implant diameter, subsequent soft tissue management and hygiene capability, helps to reduce the risk of peri-implant soft tissue inflammation and established peri-implantitis. For example, according to Romanos et al., larger diameter implants show greater degradation of the buccal bone lamella over time than thinner implants with a diameter ≤3.75 mm [21]. This shows that with regard to the selection of the correct implant position, the hard and soft tissue located in the desired area must be taken into account in addition to the planned restoration and its expected loading. Increased mucosal mobility, i.e., the absence of keratinized attached gingiva in the region of implants, may trigger peri-implant inflammation [23]. Pre-implant assessment of the surrounding soft tissue at the planned implant site is therefore particularly important. Often there is increased mucosal mobility in the region of the frenulum and labial frenulum, especially if atrophy of the alveolar ridge has occurred after tooth loss. Increased alveolar ridge atrophy also leads to a change in the positional relationship between the alveolar ridge and the enveloping folds, in the vicinity of which the proportion of keratinized attached gingiva is also reduced.

Today, drilling templates can be used to transfer the planned implant position(s) very precisely to the clinical situation in the patient's mouth [19]. Although the digitally supported modern planning and treatment options already offer good therapy safety, dental implants unfortunately exhibit the relatively high complication rate already mentioned above.

The aim of this review article is to first provide an overview of the so-called backward planning method, followed by a closer look at pre-implantological surgical strategies and guided implant placement. Finally, a brief review of the currently relevant literature will be given. By way of introduction, the following general question should be asked: Is there an ideal implant position and how can it be found?

Pre-implantological backward planning

An ideal implant position depends on various aspects. Surgically, good primary stability and subsequently good osseointegration are of decisive importance. A good initial bony situation, complication-free implant placement and postoperative bacteria-proof mucosal closure are important for achieving these goals. In

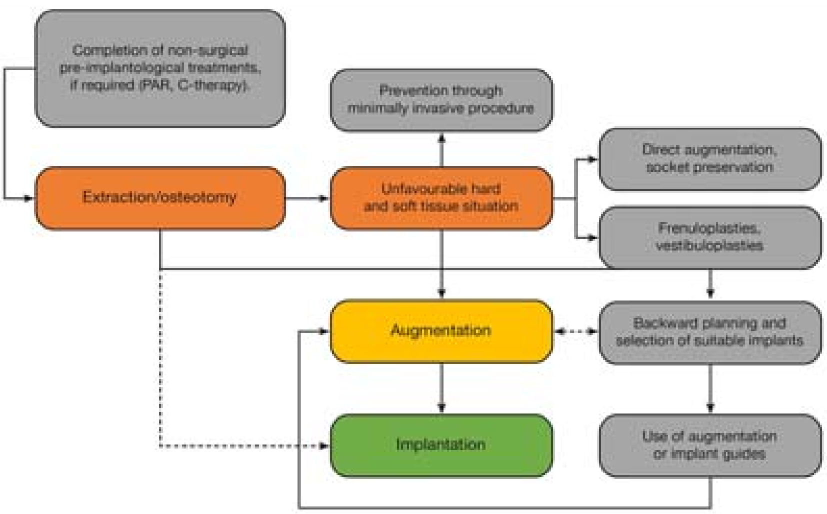

Figure 1 Basic strategies to reduce the peri-implant risk before and during implant placement.

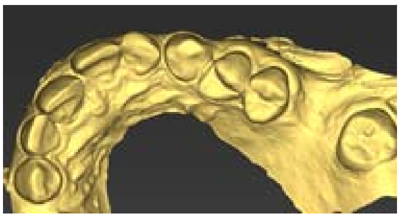

Figure 2a 3D data set of a switching gap in region 26 after direct intraoral scan.

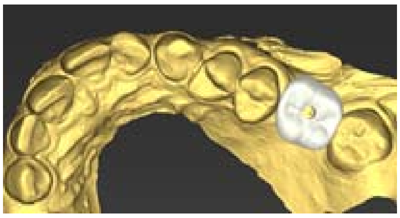

Figure 2b Virtual set-up of a prefabricated planning tooth 26 in the present 3D data set.

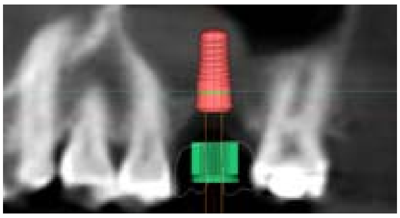

Figure 2c Sectional view from planning DVT (before pre-implantological measures) with virtually positioned implant 26, superimposed virtually positioned tooth and virtual drill sleeve. Here it is clear that a sinus lift is required before implant placement.

terms of implant prosthetics, the ideal implant position depends on the expected load from the denture and the available space. In particular, the expected load plays a prominent role in connection with the desired ideal long-term stability, as the ideal force distribution via the denture and the implant into the bone can only take place if the acting force has a direct effect in the implant axis and the implant has been correctly selected in terms of shape and diameter. In addition, it is essential to consider aspects of subsequent hygiene capability.

Due to the individual anatomical conditions of each patient, ideal conditions can only be found in extremely rare cases, so that in almost all cases the "ideal" implant position means the best implant position for the individual patient. Kalra et al. point out in their paper that optimal positioning taking into account biomechanical, masticatory, esthetic and phonetic aspects is a prerequisite for an optimal implant restoration [16]. The design of the subsequent prosthesis must therefore be determined before the actual implant placement. The following applies: the more precisely the planning corresponds to the subsequent restoration, the more information can be included in the implant planning. It is important to remember that not only the position and angulation of the implant play a role. According to Yi et al., the selected implant diameters with the resulting emergence angles and emergence profiles also have a significant influence on the development of peri-implant inflammation and thus on the long-term success of the restoration [28].

The influence of the final design of the prosthetic restoration on the risk of peri-implant inflammation is also an important aspect. This topic is the subject of another article in this issue and will therefore not be considered in depth below.

The basic procedure of backward planning is briefly described below using 2 examples: In the first example, a switching gap in the maxilla at position 26 is to be restored with an implant-supported single crown (Fig. 2a–e). A DVT image is taken to evaluate the bony structures and the maxillary sinus. The subsequent crown is clearly predetermined by the extent of the gap and the position of the antagonists. In this case, therefore, a virtual tooth set-up on the computer in suitable software is sufficient if required, which is then used for the initial virtual positioning of the implant. A three-dimensional data set of the clinical situation is required for the fabrication of the drilling template. This can either be obtained by scanning a situation model, or intra-oral scanning systems can be used for direct data acquisition. By merging the planning data and the model data set, all relevant information is available for the fabrication of the surgical guide, e.g. in 3D printing.

In the second example, a patient with a cleft jaw in the maxilla is to be restored with an implant-supported complete denture. No old denture is available. In this case, the subsequent position of the teeth and the volumes of the denture bases must first be determined by means of jaw relation determinations and wax-up, analogously to the procedure in conventional complete denture prosthetics. After the try-in on the patient, the wax-up and models can also be digitized.

If necessary, for example if the jaw relationship is unclear, the wax-ups can also be converted into radiopaque templates for a DVT scan using barium sulfate. Alternatively, in some cases it is also possible to use the palatal soft tissue situation in the maxilla to match the digitized model data sets with and without a wax-up as a reference in the implant planning software (Fig. 3).

In this example, too, all the relevant data for manufacturing the drilling templates are now available.

Today, digitally pre-planned implant positions and corresponding drilling templates can already achieve a particularly high predictability of the subsequent real implant position. Van de Wiehle et al. studied the transfer accuracy of template-guided implant placement and found deviations of the implant shoulder from the digitally planned position in both the vertical (0.5 ± 0.5 mm) and horizontal (0.9 ± 0.5 mm) directions [26]. Similar data have been found in other research groups, although maximum deviations in all spatial directions of up to 2 mm have also been observed [15, 27]. According to Ruppin et al., the accuracy of navigated implant placement depends on the quality and image resolution of the underlying 3D radiographic data set and the available bone [22]. Therefore, even with theoretically very good initial situations, slight deviations from the ideal implant position may ultimately occur during implant placement, e.g. in the maxilla due to the

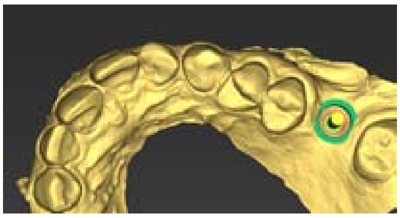

Figure 2d Projection of the virtually positioned implant onto the 3D dataset with additionally superimposed drill sleeve.

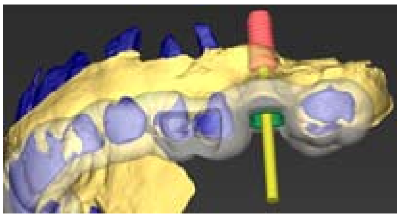

Figure 2e Teeth from DVT superimposed in the 3D dataset for correct matching of datasets with virtual implant, drill sleeve, implant axis and virtual drill guide.

lower density of cancellous bone (Fig. 4).

Pre-implant surgery and soft tissue management

The term pre-implant surgery covers all surgical procedures that serve to provide a biologically adequate hard-tissue implant site and adjacent soft-tissue site. This term must be distinguished from that of pre-prosthetic surgery. The latter includes surgical procedures that serve to improve the prosthetic bearing, especially in the era before the breakthrough of implant-supported dentures [11]. Typical procedures include lowering of the mouth floor, vestibuloplasty, and removal of slack ridges and ostoses [11].

A variety of different procedures exist to create a hard tissue implant site for subsequent implant placement. Frequently, reconstructive or augmentative procedures are divided into autologous, allogenic and xenogenic procedures according to the origin of the biomaterial used. While autologous bone, either microsurgically anastomosed or avascular, is considered the gold standard for reconstruction of continuity defects, allogeneic and xenogeneic materials can be used in addition to autologous procedures for circumscribed, local augmentation. In addition to their use in pure form, biomaterials can also be used in combination. For this purpose, the admixture of xenogeneic or allogeneic materials to autologous bone has proven successful. Intraoral donor sites for autologous bone, either as a block or in particulate form, include the retromolar region, the chin region, and for reconstruction in the esthetic region, the crista zygomatico-alveolaris [9]. For the sake of completeness, alveolar ridge distraction and sandwich osteoplasty should also be mentioned here, although both are indicated much less frequently in daily practice [1, 10].

In principle, bone grafts must be fixed in a positionally and rotationally stable manner to allow access by ingrowing vessels. Covering with a collagen membrane can improve the result and allows secondary wound healing without complications if dehiscence occurs.

Especially in the esthetically relevant anterior region or if large extraction sockets are expected, the possibility of socket preservation must be considered. In their review from 2019, Juodzbalys et al. have elaborated that esthetic, functional and risk-associated aspects should be used for decision-making in this context and presented a corresponding decision tree [14].

The use and success of allogeneic and xenogeneic materials in pre-implantological surgery have already been demonstrated scientifically in large numbers. For this reason, many of these bone substitutes or biomaterials are established as standard augmentative procedures for many indications. While the interaction between the implant surface and the hard tissue bearing is crucial for the initial osseointegration of dental implants, the maintenance or generation of an adequate soft tissue situation around the implant is seen as a key factor for long-term success and for the prevention of peri-implant diseases. In their systematic review, Pranskunas et al. found that the absence of keratinized attached gingiva in the implant site is necessary to improve hygiene and reduce the risk of peri-implantitis [18]. For this reason, soft tissue interventions, often in the form of various free connective or mucosal grafts, are an integral part of current dental implantology [24]. Soft tissue grafting can be performed temporally before, during, and after placement of a dental implant [25]. The goal of all procedures is basically to create a hem of 2 mm of keratinized mucosa circularly around the implant [20].

Navigated, template-guided implantation

The targeted use of digital image analysis enables precise prediction for pre-implant bone augmentation and the creation of computer-assisted drill guides with pinpoint implementation of both bone augmentation and implant placement [8, 9].

In this context, too, the terms navigation and template-guided implantation should be handled carefully, as they are often erroneously used synonymously. The basic prerequisite for both procedures is a 3D data set (DVT/CT) with a slice thickness <1 mm. Navigation is a real-time scanning procedure. For this purpose, (drilling) instruments can be provided with reference markers, registered and used for real-time scanning – so-called real-time navigation. In dental implantology, the implant drill can thus be registered ("tracked"), and the three-dimensional movement of the instrument can be followed in real time on the screen [29, 30, 31]. Three-dimensional control of the drill instrument is freely in the hands of the surgeon. The vector and length of the drill bit can be planned virtually, but are not fixed in a template. In contrast, in template-guided implantation ("guided surgery") – depending on the nature of the template – implant position, length and vector are encoded. It usually does not include a real-time component, as the implant hole is coded in all dimensions in the template. Theoretically, both methods could be combined, but this would not result in any additional gain in information and safety. It has been

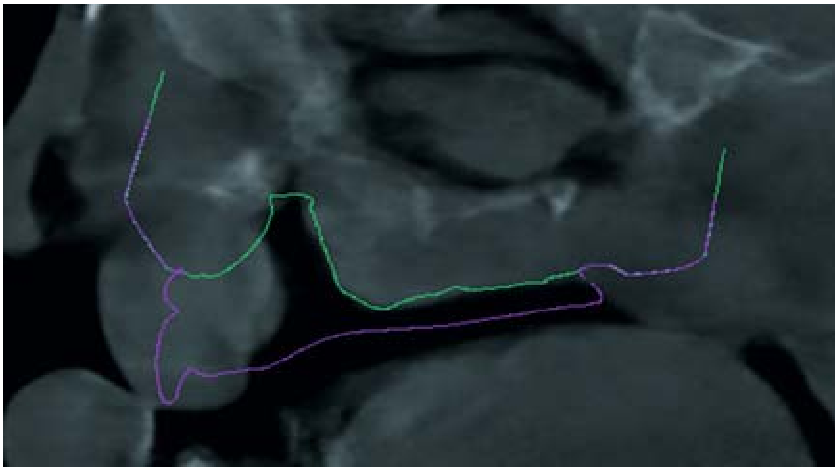

Figure 3 Data sets from DVT and model scan (green line) and wax-up (violet line) superimposed on the basis of the mucosa reference. It is particularly clear which soft tissue support can be expected from the anterior set-up.

Fig. 1–4: P.-C. Pott

Figure 4 Implant in region 15. The screwed-in impression post shows a slight mesial angulation of the implant.

demonstrated in numerous scientific publications that guided and navigated implant placement is superior to freehand implant placement for achieving the preoperatively virtually planned implant position [13]. In addition, both procedures provide additional safety to protect important adjacent anatomical structures. It seems conceivable that precise implant positioning in accordance with the preliminary planning can also reduce the probability of occurrence of peri-implant diseases, but this has not yet been proven beyond doubt.

Brief overview of current relevant literature

Overall, the literature on surgical prevention in particular is still very limited. Although there are many articles on surgical therapy of peri-implant diseases, there are only few on direct prevention of peri-implantitis. This brief review intentionally includes only articles from the past 5 years, as the authors believe that current literature is relevant for new patient care.

A PubMed search of current literature from the past 5 years on the topic of surgical prevention of peri-implant inflammation with the search term "surgical prevention of peri-implantitis" resulted in a total of 98 hits. After independent review of the hit list, 95 articles were excluded based on the titles that dealt with the therapy of peri-implant inflammation and not with its prevention.

After reviewing the abstracts, a total of 3 articles remained, plus one additional article from the relevant secondary literature, which have been included in the following brief overview.

Romanos et al. describe that, in addition to implant-prosthetic components, trauma during surgically invasive treatment, the choice of the correct implant diameter and the misplacement of implants have an influence on the formation of biofilm and on the processes of bone remodeling. Biological aspects, such as sufficient bone volume and an adequate attached mucosa in the surgical site, also play prominent roles [21].

Plonka et al. have dealt with vertical ridge augmentation and described a decision tree for augmentation heights of less than 4 mm, between 4 and 6 mm, and of more than 6 mm. Plonka's group also emphasizes that anatomical, clinical, and patient-specific factors influence treatment success [17]. Fu and Wang already dealt with horizontal bone augmentations in 2011 and found that the thickness of the soft tissue, position and shape of the alveolar ridge and the availability of autogenous bone in the augmentation area have an influence on the augmentation success [5]. In their paper published in 2020, Geisinger et al. also emphasize the particular importance of patient-centered and evidence-based implant planning for long-term treatment success. Above all, patient-specific risk factors must be taken into account in the therapy finding process. In particular, Geisinger et al. cite underlying systemic diseases, systemic medications, smoking, existing periodontal disease, effectiveness of plaque control, quality and quantity of relevant soft tissue, and individual anatomical conditions as influencing factors [6]. All the groups of authors cited here agree that long-term successful implant treatment requires targeted planning of the implant placement, taking into account patient-specific anatomical as well as anamnestic conditions.

Conclusion

Finally, the question posed at the beginning "Is there an ideal implant position and how can it be found?" will be answered.

Taking into account the patient-specific risk factors, the individual hard and soft tissue situation, the requirements for high esthetics, long-term functionality and the associated good hygiene, it can be summarized that the "ideal implant position" must be understood as a patient-specific optimum. This optimum can be achieved today with a high degree of planning reliability by means of a complete clinical assessment taking into account the aspects listed in this article with regard to pre-implantological surgical measures and adequate backward planning. Nevertheless, the risk of peri-implant infections cannot be completely eliminated in the course of treatment, but can only be reduced.

Conflict of interest

The authors declare that there is no conflict of interest as defined by the guidelines of the International Committee of Medical Journal Editors.

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