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The prosthetic superstructure as a risk factor for peri-implantitis

Abstract: Peri-implantitis is a plaque-associated pathological disease occurring in tissues surrounding dental implants. It is characterized by an inflamed peri-implant mucosa and resulting progressive loss of peri-implant supporting bone [8]. Prosthodontic etiologic factors such as hygiene-incompetent prosthetic designs or residual cement seem to favor the development of peri-implantitis [43]. During the course of the article, several characteristics of prosthetic superstructures are presented and their relevance in relation to peri-implant inflammation is discussed.

Keywords: implants; peri-implantitis; prosthetic; superstructure

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Figure 1 This case study shows the restoration of an interdental gap situation in region 34–36 using implant-supported single-tooth crowns. A dental hygiene design in the molar region was selected using an alternative crown design with a cleaning channel. The implant placement was partially guided by a drilling template.
a) Incorporated drilling template with visible sleeves region 34, 35, 36. Taking into account the minimum distances between implants and teeth, the prospective implant position 36 was planned to be further distally.

b) Clinical situation of inserted implants 34, 35 and 36 before impression taking. The more distally selected position of 36 is visible.

Introduction

The fifth German Oral Health Study indicates that the 35- to 44-year-old German population is already missing an average of 2.1 teeth [25]. The most common causes of tooth loss include caries and periodontitis. Only a small proportion of teeth are lost due to trauma. Dental implants make it possible to close gaps without drilling healthy teeth. Endosseous dental implants achieve survival rates of approximately 96 % after 10 years [22]. The long-term prognosis can be strongly compromised by the development of peri-implantitis. Systematic reviews show a wide prevalence range of peri-implantitis from 1–47 % [13]. Meta-analyses calculated mean peri-implantitis prevalences of 22 % [13] and mean implant- and subject-based peri-implantitis prevalences of 9–20 % [30]. To prevent peri-implant complications, the dental prosthesis must be designed in such a way that optimal cleaning of the scarred, defense-weak peri-implant tissue is possible. Implant planning is the basis for this. In contrast to the periodontal ligament, where the dentogingival and dentoalveolar collagen fiber bundles radiate from the root cementum in lateral, coronal and apical directions, the collagen fiber bundles on the implant are oriented from the periosteum parallel to the implant surface. In addition, the connective tissue in the supracrestal region contains more collagen fibers but fewer fibroblasts and vascular structures.

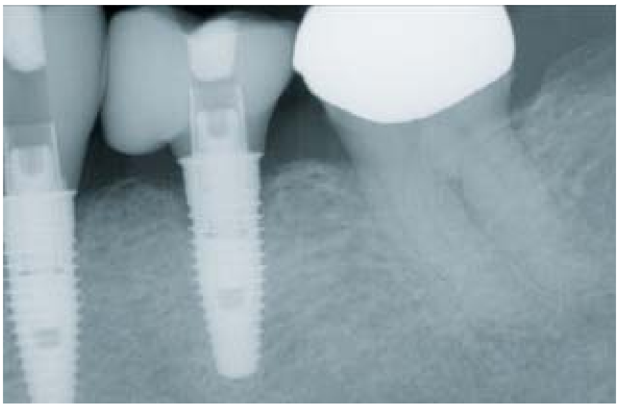
Implant planning

In terms of backward-oriented treatment planning, the starting point is a previously defined prosthetic goal. The ideal design of the prosthesis, simulated for example by an idealized wax-up/set-up, determines a favorable prospective implant position. The vertical height to the antagonist or the implant angulation can be used to assess in advance whether an implant-supported prosthesis will be anchored in a fixed position (screw-retained or cemented) or must be splinted, or whether a removable solution should be aimed for. Furthermore, it can be assessed to what extent it is possible to maintain the biological width with a distance of 2–3 mm from the rough implant surface, which is at bone level, and the superstructure and its effect on the esthetic appearance [42]. Additionally, it should be determined whether additional interventions are required to optimize the hard and soft tissue bearing in order to make the necessary compromise between ideal cleanability, esthetics and mechanical loading as beneficial as possible.

Implant system

The number of available implant systems on the market has become confusing. Studies have shown that there is a relevant correlation between the risk of developing peri-implantitis and the used system [12, 19]. Design features could play a role. For example, the height of the implant shoulder, i.e., its position at bone or soft tissue level, is discussed. The configuration of the interface is also being considered. Despite the great precision of dental implantology, bacterial colonization occurs inside dental implants [36]. The penetration path of bacterial colonization occurs via microgaps between the implant and the superstructure as well as screw channels. This implant-internal microflora is inaccessible to oral hygiene products. It has been shown that implants with tapered internal connections can reduce the micro-

c) Fabricated denture on model with occlusal screw accesses.



d) Radiographic view of implant restoration 36 after insertion. The slender emergence profile in combination with a mesially cantilevered pontic can be seen. The creation of a cleaning channel by the concave mesial emergence profile in combination with the cantilever pontic enables targeted cleaning.

gaps at the transition from implant to superstructure and reduce bacterial penetration [5, 7, 14, 28, 45]. However, to date, there is no evidence for the clinical significance of this aspect. The recommendation can be made to prefer systems with a good clinical study situation, regardless of the implant design.

Hygiene maintenance

Prosthetic rehabilitation concepts should allow complete plaque control and 360° cleanability of the peri-implant area. To achieve this, the design of the prosthesis must ensure accessibility for oral hygiene items. In addition to the toothbrush, interdental space brushes and Superfloss can be considered. Inaccessible areas should be avoided and guide functions for cleaning instruments such as interdental brushes should be designed. For all types of implant-supported restorations it is important to ensure that the patient can perform the cleaning independently. Home care and professional follow-up are crucial for the long-term success of dental implants [41]. It is advisable to define follow-up intervals on a patient-specific basis according to individual risk assessment. The risk assessment should consider indicators such as poor oral hygiene, for example as a result of limited manual skills, cigarette consumption, previous periodontal diseases, genetic predispositions or systemic diseases such as diabetes mellitus [21].

Design of the superstructure

The endosteal part of an osseointegrated implant is ideally surrounded by bone and therefore not exposed to biofilm formation. This is in contrast to the transmucosal part, which is colonized by microorganisms [17]. In addition to factors such as the composition of the oral microbiome, prosthetic aspects also influence the local biofilm formation. These aspects can be the surface texture, the design of the prosthesis itself and its accessibility for oral hygiene [35, 51].

The typical central implant position in single tooth gaps in the molar region often causes restorations with much larger dimensions than the diameters of the implant shoulders. Due to the size difference, niches can develop at the transition between the implant shoulder and the restoration. This leads to difficult accessibility for oral hygiene products, which may favor the development of peri-implant diseases [35, 41].

Accessibility for cleaning can be improved by reducing the vestibulo-oral extent of the dental crown. However, esthetic limitations due to the deviating tooth morphology have to be accepted. In an in vitro study on the removability of simulated biofilms on implant-supported molar crowns, an alternative modified crown design was presented [47]. Here, the implant is placed further mesial or distal of the replaced tooth, taking into account the minimum distance between the implant shoulder and the adjacent tooth or adjacent implant. This allows a restoration consisting of a premolar crown in combination with a cantilever pontic [50]. The decisive factor is the placement of a cleaning channel in the area of the connector that is easily accessible for the patient. With this approach areas inaccessible to cleaning can be avoided with this approach, and the cleaning channel can facilitate accessibility for oral hygiene products.

Cleaning channels on implant-supported restorations guide oral hygiene products such as interdental space brushes to the peri-implant soft tissue closure and thus enable targeted cleaning. If the design of cleaning channels on the restauration itself is not possible, for example in the case of removable dentures with functional margins, customized cleaning guides can be fabricated.

For fixed prostheses, an orally and vestibularly open design is indicated, as is a convex bridge pontic design. The emergence profile should be concave and an emergence angle of ≥30 degrees should be avoided [51]. This avoids inaccessible niches and improves the rinsing function of saliva. In addition, avoiding extensive splinting can optimize access for oral hygiene aids. In edentulous jaws,

Figure 2 In this case study, a free-end situation in the third quadrant was restored with three implants (region 35, 36, 37) and a three-unit implant-supported bridge construction. Due to the crown-to-implant length ratio, the implant crowns were splinted. The central implant in region 36 had to be removed due to peri-implant complications.
a) The radiological situation shows an unfavorable dental hygienic design of the implant bridge region 36, with inaccessible niches mesially and distally and an emergence angle >30 degrees. Mesial 36 shows a bowl-shaped bony defect.

b) Implant 36 after explantation.

c) Clinical situation after explantation 36. The bridge construction was separated distally 35 and mesially 37. The bone defect was covered plastically with bone graft substitute and a free connective tissue graft, and a vestibuloplasty to enhance the attached gingiva. The implant crowns Regio 35 and 36 remained in situ and the separation points were polished.

implant-supported, removable constructions facilitate care.

Bacterial adhesion to surfaces is strongly influenced by surface roughness [10]. Thus, bacterial colonization is higher on rough surfaces than on smooth surfaces. Therefore, scratched or damaged transmucosal abutments should be replaced if possible, and surface roughness should be repolished and smoothed. However, a average roughness value (Ra) of surface roughness <0.2 µm, such as achievable by mirror polishing, does not seem to have any further effect on quantitative and qualitative bacterial colonization and can therefore be considered as a threshold value [9]. In addition to surface roughness, material-specific differences are also apparent, but their clinical influence on plaque colonization has not been clarified. For example, several studies show that titanium abutments have a stronger bacterial colonization compared to zirconia abutments. [15, 20, 40]. In addition, the composition of the salivary membrane appears to vary on different surfaces. An in vitro study showed a different protein composition of the salivary membrane on titanium surfaces compared to enamel surfaces [16]. However, an influence on the bacterial composition of the biofilm could not be detected in the different salivary membranes [31].

Occlusal overloading

Premature, excessive occlusal and/or off-axis loading can have a detrimental effect on the osseointegration of implants and, in the worst case, lead to loss [38]. The role of occlusal overloading in osseointegrated dental implants is controversially discussed. The literature describes cases in which increased biological and technical failures have occurred due to implant overloading, while other studies have not found any significant influence [23, 24, 29, 32]. The problem is that there are no values to assess overloading.

For the immediate temporary restoration of small fixed restorations static and dynamic contacts should be removed. In contrast, they cannot be dispensed with for extensive constructions. Sufficient primary stability of all implants and their splinting are then strongly recommended.

Loosened screws or crestal bone loss are the first clinically recognizable signs of implant overload. This can have many causes, such as an unfavorable relationship between implant diameter or length and the absorbed forces. The number and position of implants, the length of extensions or excessive parafunctional forces also have an influence [44].

In order to decide whether superstructures can be splinted or not, older studies recommended splinting if the ratio of crown length to osseointegrated implant length was ≥0.8 [27]. However, more recent studies do not show an increased incidence of biological or technical complications with non-blocked single-tooth implants with a mean crown-to-implant ratio between 0.86 and 2.14 [34]. Implants with splinted or non-splinted superstructures showed no difference in the extent of crestal bone loss or peri-implant parameters [3, 4]. Again, splinting may have a negative effect on cleanability [2]. In a recent cross-sectional study, implants with superstructures blocked on both sides, especially in combination with an emergence angle of ≥30 degrees and a convex emergence profile, showed an increased risk of peri-implantitis [51]. There is no evidence that a splinted or non-splinted design affects implant survival. Complications can occur with either design, although splinted restorations generally have fewer technical problems [37]. Knowing which patients are more likely to experience certain complications is of strategic importance [37].

Screwing versus cementing

In the following, the advantages and disadvantages of the respective types of fixation will be discussed and trends in peri-implant complications will be listed. Cemented reconstructions are suitable for compensating different implant axes or fabrication-related fitting inaccuracies, as well as for esthetically demanding crown designs, since there is no need for occlusal or incisal screw access. Another advantage is the passive fit of the reconstruction. In one study, cemented bridges achieved lower strain values compared to screw-retained bridges [26]. A disadvantage of cemented reconstructions is the risk of subgingival cement residues. Several clinical studies of cemented reconstructions have reported soft tissue complications due to excess cement [1, 11]. The retained cement causes increased retention of biofilm, which may cause peri-implantitis [48]. In the review by Sailer et al., cemented multiunit reconstructions showed a general trend toward more bone loss compared with screw-retained reconstructions [39]. To exclude biological complications due to excess cement residues, its proper removal is essential. In this regard, the crown margin should not be deeper than 1.5–2 mm subgingivally, as there seems to be a correlation between the amount of residual cement and the depth of the crown margin [18, 33]. The least amount of residual cement is observed when the crown margin is in an epi- or supragingival position [33]. By choosing individual abutments, the prospective location of the crown margin can be determined and deep subgingival placement can be circumvented. To avoid serious biological complications, the mentioned correlations should be taken into account when cementing the reconstruction.

Screw-retained reconstructions are suitable if there is a need for removal, for example, for dental hygiene reasons or for temporary restorations. Temporary or semipermanent cementations are also discussed in the literature. Similar to screw-retained restorations, they guarantee subsequent non-destructive removal of the restoration. However, their clinical relevance in relation to peri-implant complications is unclear.

The main advantages of screw-retained implant restorations include their reparability and the avoidance of cement residues [48]. In addition, if the screw-retained reconstruction fits well, severe biological failures appear to be less frequent compared to cemented alternatives [39]. However, in a systematic review, screw-retained reconstructions showed more soft tissue complications, mostly rooted in loose abutment screws; inflammation healed after their reattachment [6, 39]. The required screw access may affect esthetics and occlusion, and possibly the strength of the restoration. Thus, higher fracture rates of veneering ceramics are observed in screw-retained reconstructions, which are mostly associated with the open screw access [46, 52]. The most common technical complication in screw-retained reconstructions seems to be the loosening of the abutment screw [49]. Screw-retained reconstructions tend to have more technical problems and higher loss rates, but fewer serious biological complications [39].

Overall, soft tissue inflammation is seen with both luting options. They are associated with excess cement [1, 11] or with loose abutment screws [6]. The predominantly technical complications of screw-retained reconstructions are treatable with little effort compared with the biological complications associated with cementation. To avoid possible serious biological complications, it is recommended that implant-supported reconstructions be screw-retained when the clinical situation is appropriate. However, there is no general consensus on the superiority of one procedure over the other. The choice of fixation should be made after weighing the patient-specific advantages and disadvantages as well as the clinical situation.

In literature, a direct comparison of the estimated 5-year survival rate between screw-retained and cemented implant crowns showed no significant difference [39]. In combined fixed-removable dental restorations, there is a trend towards more complications with cemented reconstructions [39]. For fixed full-arch restorations, the risk of complications was significantly higher for cemented reconstructions than for screw-retained ones. No significant differences were seen in the survival and success rates of cemented and

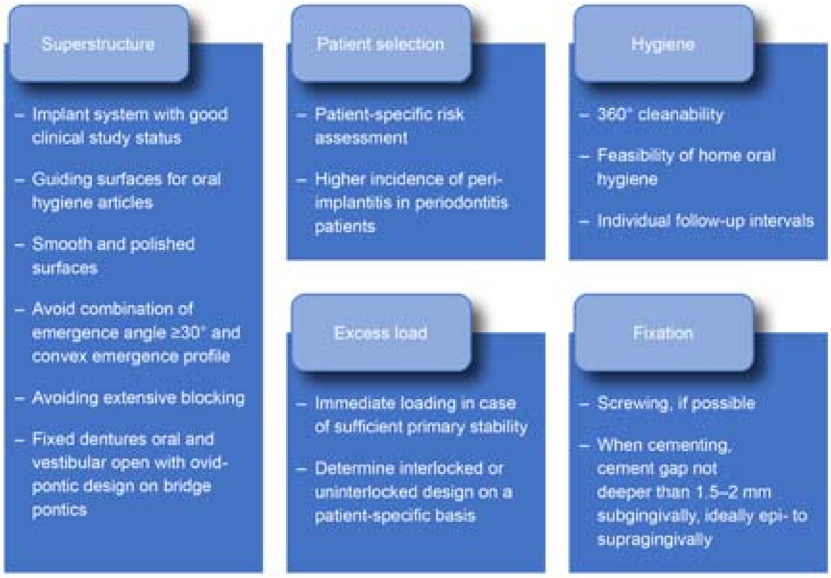


Fig. 1–3: Ufuk Adali

Figure 3 Summary of discussed aspects that should be considered in the design of prosthetic superstructures related to peri-implantitis.

screw-retained multi-unit reconstructions.

Conclusion for the practice

Peri-implantitis is a plaque-associated pathological disease and can be promoted by prosthetic factors in addition to patient-specific factors such as general diseases. In the sense of the rehabilitation concept, patient-specific risks should be known at the beginning of implant planning. With backward treatment planning, design aspects of the superstructure can be determined before implant placement. When designing the superstructure, 360° cleanability must be ensured. Extensive blocking should be avoided and guide surfaces for oral hygiene products should be created. The guide surfaces should allow targeted cleaning at the peri-implant soft tissue end. Cleaning splints can be helpful. Materials with a lower bacterial colonization can be used and rough surfaces can be reduced by polishing. The combination of an emergence angle of ≥30 degrees, a convex emergence profile and a central position within a bridge should be avoided. For immediate temporary restorations, ensure adequate primary stability. Whether a restoration is designed to be fixed or removable, splinted or non-splinted, screw-retained or cement-retained should be decided on a patient-specific basis. Due to serious biological complications caused by subgingival cement residues, screw-retained fixation should be preferred or an epi- to supragingival position of the cement joint should be aimed for. Adequate performance of oral hygiene at home and patient-specific follow-up intervals are decisive for long-term success.

Conflict of interest

The authors declare that there is no conflict of interest according to the guidelines of the International Committee of Medical Journal Editors.

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