Are mini-implants an alternative to standard-diameter implants?

What must I be aware of when using mini-implants?

Dental implants are an indispensable part of the dental treatment spectrum and represent an integral component of contemporary prosthodontic treatment concepts. The use of implants for both removable and fixed prosthodontics offers clinically relevant advantages, which have been recorded for patients in the form of an improvement in the oral health-related quality of life and masticatory function, as well as, better long-term restorative treatment prognosis [9].

Implant-prosthetic concepts

The prognosis for fixed restorations on implants is very good (5-year prognosis 96.4 %, 10-year prognosis 93.9 %) and corresponds to the prognosis for short-span restorations on teeth [29]. Thus, through the use of implants, the grinding of the natural teeth and long-span bridges can be avoided, while free-end edentulous spaces can also be treated. Moreover, it is possible to restore the edentulous jaw with a complete denture using 4–8 implants [25, 26].

In the case of removable dentures, the use of implants in the edentulous jaw (1–6 implants in the mandible and 4–8 implants in the maxilla) can significantly improve the masticatory function and satisfaction with dental restorations. Patients prefer good fixation and low rotation of dentures [9]: special consideration is needed to provide an utmost quadrangular support, while the axes of rotation and selection of the attachment system concept must be thoroughly thought out. In order to achieve the best possible retention and support for a denture in a partially edentulous dentition, so-called strategic implants, which are placed in strategically important positions, can be used. In cases of complete edentulism, one or two implants may be used to reduce the the denture's rotation. A rigidly supported, removable denture, or more specifically, a denture that wobbles less, not only leads to better patient satisfaction, but also to less wear and tear of the attachment systems, and thus to a better long-term prognosis. The prognosis of strategic implants is very good and comparable to that of single-tooth implants [22].

The use of implants is thus recommended in many cases requiring prosthetic rehabilitation. This has been documented for almost 20 years in the McGill Consensus Statement, which describes the rehabilitation of an edentulous patient with a complete denture as being an inadequate restoration and therefore demands the use of at least 2 implants in the mandible [16]. According to current data, the minimum number of implants in the edentulous mandible can be defined as a single implant placed near the mandibular symphysis [23].

Narrow-Diameter-Implants (NDIs)

The described implant-prosthetic concepts for standard diameter implants (> 3.5 mm) have been investigated and are evidence-based. The results, however, cannot be generalized 1:1 with regard to reduced diameter implants.

Reduced diameter implants are also called Narrow-Diameter-Implants (NDIs). They have diameters that range between 1.8–3.5 mm and can be divided into 3 categories based on their diameter [20]:

Category 1 is comprised of mini-implants (MDI, 1.8–2.5 mm) which are basically one-piece. Category 2 (diameter 2.5–3.25 mm) and category 3 (diameter 3.3–3.5 mm) consist of two-piece implants.

Category 3 NDIs that are made of pure titanium (titanium grade IV) have only one fifth of the mechanical load capacity (200 N vs. 1000 N) in comparison to standard-diameter implants (4.1 mm) [5]. This reduction of implant diameter consequently leads to an increased risk of fracture, at least in theory. Therefore, the susceptibility to fracture of the two-piece category 2 and 3 implants can be reduced by making modifications to the implant-abutment connection, which allows for thicker implant wall thickness, or by employing titanium-zirconium alloys with a higher fracture resistance. Category 1 implants cannot be made of pure titanium due to the high fracture potential; instead, they are produced from a titanium alloy (Titanium Grade V, Ti6Al-4V ELI) and are a single piece, as a two-piece design would reduce the wall thickness.

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It is also known from materials science and finite element studies that a change in implant geometry leads to a changed force distribution into the peri-implant cortical bone [19]. In this regard, a change in implant diameter has a greater effect than a change in implant length [8]: an increase in diameter from 2.5 mm to 3.3 mm reduces the stress on the cortical bone by 30.7 %, whereas an increase in implant length from 8.5 mm to 15 mm reduces it by only 1.7 %.

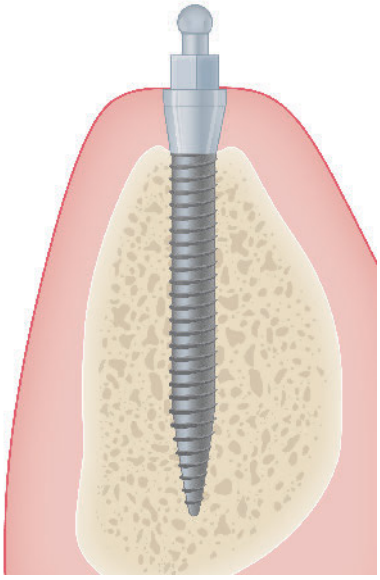
This raises the question of the survival prognosis of reduced diameter implants, especially in cases of compromised bone supply. It should be noted that in spite of the fact that very good implant survival and success rates have been documented for standard-diameter implants [24], these were not achieved in cases of poor bone quality and quantity [7, 15].

The scientific data published to date on NDIs shows very good results with regard to implant survival and success which is comparable to that of standard implants (90–100 %) [6, 35, 36]. Nonetheless, a recent review indicates that there are significant differences between the 3 categories of NDIs in terms of failure rates: category 2 and 3 show very good prognoses, which are comparable to standard-diameter implants. In contrast, category 1 implants which are mini-implants with a diameter of 2.5 mm or less, show a significantly higher risk of implant loss with an odds ratio of 4.54 (CI: 1.51–13.65) [33]. Therefore, if possible, a category 2 and 3 NDI or a category 1 implant which is thicker should preferably be chosen.

Modern category 3 NDIs show very good results and, with regard to the prosthetic concepts described above, can probably be employed similarly to standard implants in many cases. The use of category 2 and 3 NDIs is unproblematic for the indication of lower incisor and upper lateral incisor single-tooth implants, but their use in the molar region, where high masticatory loads exist, is not recommended [19, 33]. If these principles are followed, a very good implant survival rate (90–100 %) has been documented for fixed restorations on reduced diameter implants [36].

Mini-implants

The extremely resorbed alveolar bone can be so thin, however, that only category 1 implants are possible without bone augmentation. There are thus clinically relevant indications for this implant group: in a recent review of category 1 implants, very good survival rates (98 %) and success rates (93 %) were reported for the indication stabilization of a complete mandibular denture [27]. For the same indication, in a recently published prospective 5-year study performed at the University of Bern, a survival and success rate of 100 % for immediately loaded 1.8 mm diameter implants [12, 13] was documented. However, the use of category 1 NDIs for the indication of fixed restorations does not seem advisable. Although mini-implants can function well as described above, they should not be taken lightly. The success of therapy with mini-implants depends on patient selection and the experience of the dental practitioner [31]. In a study conducted in 5 centers and on 1029 examined implants, it was shown that the average implant survival rate was 91 %. When the data was assessed for each particular center, however, the situation was as follows: Four centers achieved success rates of over 90 % while the fifth achieved a success rate of only 69 %, as 13 from 42 implants were lost [10]. An intensive analysis of the surgical procedure therefore seems advisable: the surgical procedure is in principle very straightforward, but the drilling



(Fig. 1 and 2: Ines Badertscher, University Bern)

Figure 1 The mini-implant (1.8 mm diameter)

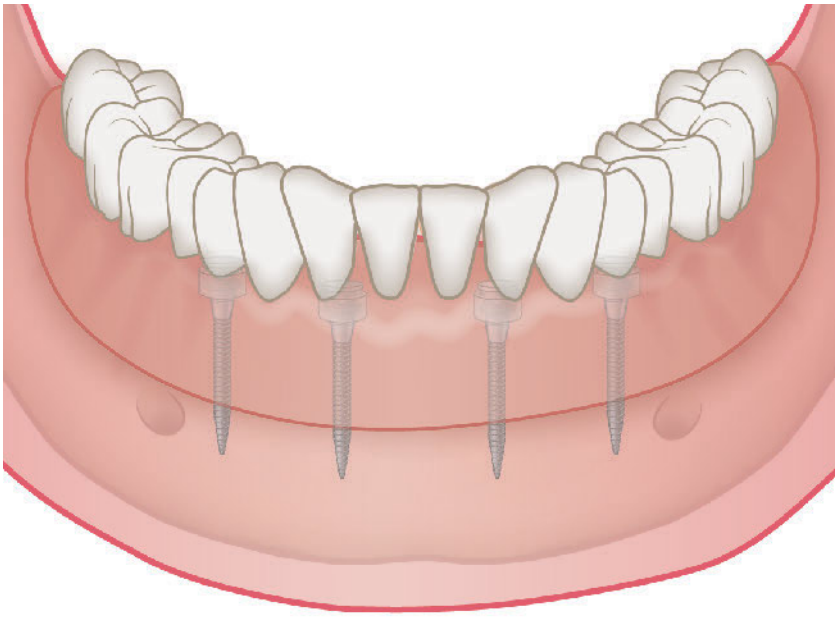


Figure 2 Four interforaminal mini-implants with corresponding overdenture

protocol must be adapted to each individual patient [35]. Conventional drilling is not performed, but rather a perforation of the cortical bone, as the implant always has a self-drilling and self-cutting feature. For 1.8 mm diameter implants, a torque of 45 Ncm should by no means be exceeded because the risk of fracture increases considerably: based on the scientific data published to date, it is evident that thin implants are somewhat susceptible to fracture during insertion. In a prospective study performed at the University of Belgrade, implant surgery was accompanied by a 2.5 % implant fracture rate (3 of 120) [32], and in a retrospective evaluation from the USA, a 0.8 % fracture rate was documented during implant insertion [35]. An increased implant fracture rate after loading with the removable denture could not be demonstrated thus far: the implant fracture rate of 1 % in the mandible, which was determined in a recent multicenter study from Germany (4 of 402 MDI implants) [28] corresponds to the reported data on standard-diameter implants [18]. This positive data on the clinical fracture stability of MDIs in removable prosthetics is probably due to the way the denture is connected to the implant: MDIs are one-piece implants with 1.8 mm ball attachments that are connected to the denture by means of polymerized matrices (metal housings with an inserted rubber O-ring). The only contact which is permitted, however, is between the ball and the rubber O-ring; no contact between the metal matrix housing and the ball-shaped patrix is allowed. This design feature means that the denture is only retained and not supported on the mini-implants. As with conventional complete dentures, mucosal support on the alveolar process mucosa occurs. In this manner, the matrices serve to increase retention and reduce denture rotation. Wear is also limited to the rubber O-ring of the matrix in every matrix and patrix system in the oral cavity [1]. This is an advantageous feature because the wear of the patrix cannot be compensated, as it is fixed to the implant body and cannot be replaced. On the other hand, the rubber ring is easily replaceable. The rubber O-rings display a retention force of 5–9 N; this is comparable to blue and pink locator inserts (Zest-Anchors, Escondido, USA) [2]. Normally, 20 % of the rubber O-rings must be replaced after one year [28]. The precision of the O-rings is very good which means that the original retention force after replacement can be restored predictably [2].

The use of mini-implants has been shown to considerably improve the masticatory function and biting power in both older and younger patients [14], although elderly patients needed more time to attain the improvements in masticatory function [12]. In spite of these benefits, the retention of the implant overdentures using the O-rings of the MDI matrices is less rigid than the anchorage provided by a milled parallel-walled bar. This represents a certain loss of comfort which must be taken into account during individual therapy planning. Nevertheless, in a prospective 5-year study, it was shown that the oral health-related quality of life improved significantly through the use of 4 interforaminal implants [30]. The mobility can also bring about a clinically relevant benefit: the spherical ball-shaped patrices of the mini-implants display hardly any tartar build-up and the peri-implant mucosa is usually healthy, which can be attributable to the self-cleaning effect of the rubber O-rings [37]. It should be emphasized that the absence of peri-implant keratinized mucosa did not lead to increased bone resorption rates [13]. For prophylactic reasons, however, a peri-implant keratinized mucosa is still recommended for easier implant hygiene.

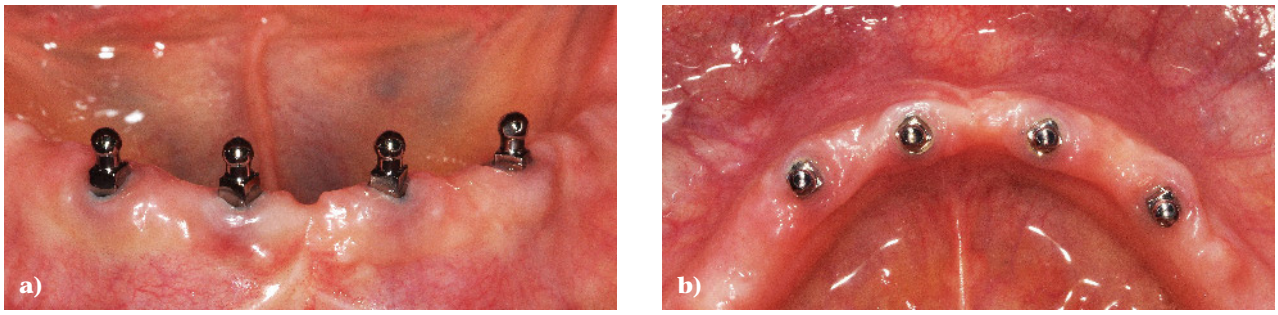
In the edentulous mandible, mini-implants have been proven to be a safe therapy option for better retention of removable dentures. [10, 13, 35]. In addition to their indication in edentulous patients, partially edentulous patients can also benefit from the use of mini-implants.

Corresponding concepts for mini-supportive implants have been published: 1–4 implants could be used in the lower jaw and 1–6 implants in the upper jaw depending on the number and distribution of the remaining teeth [3]. However, the characteristics of the above described ball attachments must be taken into account for the mini-strategic implants: The attachments on the teeth are always more rigid than those on the 1.8 mm balls. The effect of the mini-strategic implants is that the denture is better retained, but not better supported. This implies that the restoration in the area of the mini-strategic implants is still supported by the mucosa and the natural attachment teeth can then act as a fulcrum. Thus, the denture exhibits a certain degree of mobility and this should be taken into account during planning and patient education.

Clinical tips for mini-implant use

The simple surgical and prosthetic procedure, which requires minimal material and time, coupled with less follow-up care, is highly valued by dental practitioners [34]. For prosthetic planning, it is important to note that mini-implants should be well distributed and respect a minimum distance of 4 mm from each other. If the distance is less than 4 mm, difficulties arise in positioning the matrices side by side due to the matrix housing size. In patients with strong masticatory forces and thin mandibular dentures, where the plastic coating of the matrix is less than 2 mm thick, there is an increased denture fracture risk in the area of the matrix housing [11]. In a study by Mundt et al., a fracture rate of 20 % was determined for MDI-implant-overdentures which had no model cast reinforcement [28]. The incorporation of a lingual 1 mm thick reinforcement band made of cast alloy is recommended in such cases [13]. In a recent prospective study with 5-year results, a 35 % fracture rate was determined for mandibular dentures without model cast reinforcement. After the model cast reinforcement was adopted, no further fractures occurred [13]. A lingual reinforcement, or more specifically, a lingual thickening of a mandibular prosthesis by about 2–4 mm is well tolerated by many patients and is not perceived as disturbing [4].

The recommendation of a model cast prosthesis after a fracture has oc-



(Fig. 3a and 3b: N. Enkling, University Bern)

Figure 3a and. 3b Example case from the mini-implant study performed at the University of Bern, 5 years after implant placement: 4 immediately loaded interforaminal implants 1.8 mm x 1.3 mm/overdenture; **a)** frontal view; **b)** top view

curred can lead to disagreements with the patient: therefore, it is advisable to offer a model cast reinforcement as a matter of principle, which can even be integrated at a later point in mandibular dentures. In the maxilla, a model cast reinforcement should be planned from the outset, as the thickness of the denture is consistently reduced.

According to the clinical protocol for mini-implant systems, 4 implants in the mandible and 6 implants in the maxilla are needed for implant overdenture retention. If a minimum insertion torque of 35 Ncm is achieved, mandibular MDIs may be loaded immediately. In the case of lower primary stability values, immediate loading in the mandible is not advisable and a soft relining is recommended instead; just after a 3-month healing period, the matrix housings can be polymerized and the delayed loading of the implants performed. In the maxilla, a 6-month healing period is generally recommended before loading. However, data from the University of Montreal in Canada show that in the mandible, a torque of 15 Ncm would be sufficient for immediate loading [21].

Despite the good implant survival outcomes in the mandible, the same results should not readily be assumed for the maxilla, as the rates of implant loss are higher in the edentulous maxilla. Shatkin et al. report a survival rate of 95.1 % for mandibular and 83.2 % for maxillary overdentures [35]. The working group for implantology and biomaterials research at the University of Bonn reported similar results with respect to the differences between the upper and lower jaws, although these are momentarily still being scientifically evaluated. With regard to the increased rates of implant loss in the maxilla, there appears to be a cluster effect, meaning that more implants are lost in single patients. Increased caution is therefore required in the edentulous maxilla. This assessment is consistent with the recommendations of the International Team for Implantology (ITI) and its SAC system: the edentulous mandible is classified surgically as being straightforward and the edentulous maxilla as being complex.

Conclusion

The simplicity of treatment and low material costs result in the fact that social indications can also be treated with mini-implants. Using MDIs, it is possible to come close to the goal, as formulated in various scientific statements, of restoring the edentulous mandible in patients using implant-supported overdentures [16]. Treatment with 4–6 mini-implants also opens up new possibilities for a minimally invasive approach. Future scientific studies are necessary in order to explore the limits for mini-implant indication. Mini-implants already represent an established and well documented treatment option for treating the edentulous mandible. On the other hand, they are not suitable for the indication of fixed restorations in masticatory load bearing areas. Their mechanical inferiority compared to standard-diameter implants has been proven and it must be taken into account when determining their indication [5, 17, 19].

Conflicts of interest

In the past, Prof. Dr. Norbert Enkling has given paid lectures at scientific conferences and lectures with workshops for implant companies such as Nobel Biocare, SIC Invent, Dentaurum Implants, 3M Espe and Condent.

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(Photo: Norbert Enkling)

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