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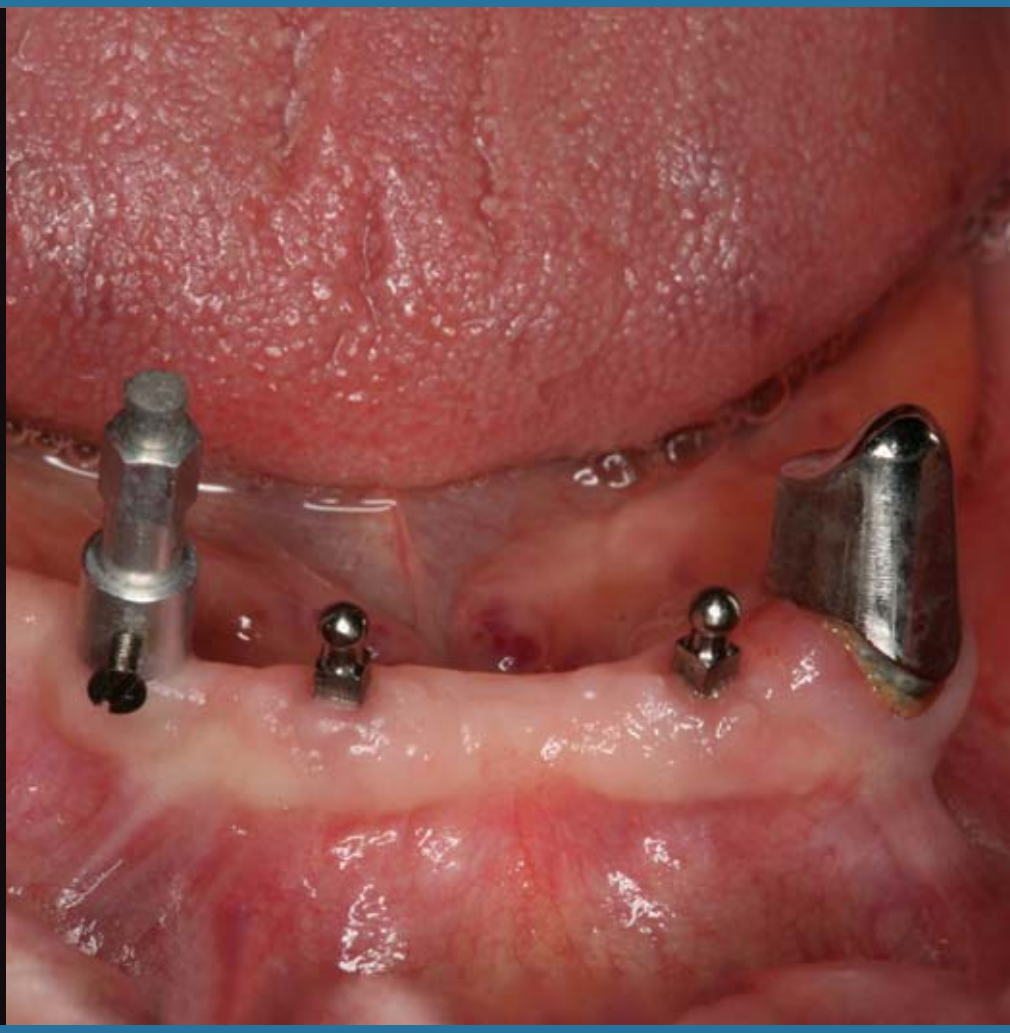

Which "band-aid" is appropriate for the dentin wound of permanent teeth?

Reconstruction and masticatory rehabilitation of a bilateral maxillary defect with a microvascular free fibula flap

Follow-up examination of patients with mini-implants for the stabilization of existing removable partial dentures

Relevance of mercaptans/ thioethers regulations in therapy decisions in endodontics

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Which "band-aid" is appropriate for the dentin wound of permanent teeth?

Caries is the most common non-contagious disease worldwide. It has a higher prevalence in people of lower socioeconomic status [17, 34]. Deep carious lesions are defined as defects that extend radiologically into the inner third or quarter of dentin. This is where the pulp is at risk of exposure [15]. When the remaining dentin thickness decreases towards the pulp, the risk of pathogenic changes in the pulp increases [21]. In daily practice, however, it is often difficult to assess the remaining dentin thickness close to the pulp and to decide when and with which preparation a „dentin wound treatment" should be performed [21, 32]. For this reason, it is useful to consider pulp symptoms when making a diagnosis [33] and to leave some infected dentin behind near to the pulp if there is a risk of pulp exposure [3]. The primary aim of treating deep carious lesions is always to avoid exposing the pulp and to keep it healthy and vital. Thus, the purpose of dentin wound care is manifold; it is to protect the pulp from further exogenous noxae (such as residual monomers or thermal damage caused by light polymerization when using the adhesive technique), from toxins of microorganisms (such as lipopolysaccharides) [8], to eradicate bacteria, as well as to stimulate the formation of reactive dentin [1]. Furthermore, the outflow of dentinal fluid from the dentin tubules should be avoided.

Which conditions must be present to keep the pulp vital?

To date, the decision for further therapy is linked to whether the pulpitis is reversible or irreversible. If the clinical diagnosis reveals that an irreversible pulpitis has already developed, root canal treatment is indicated. This is because it must be assumed that, despite therapy, healing of the pulp tissue is no longer possible. It is currently being debated whether or not pulpotomy represents a sufficient treatment [8]. If a reversible pulpitis is present, vitality-preservation measures such as dentin wound treatment together with subsequent filling therapy are indicated (Table 1) [8].

What is the goal of caries treatment?

The goal is to adequately remove caries and to treat the pulp and dentin areas in a manner that protects the pulp from further irritation and microorganisms. The desired material properties for adequate dentin wound care include: the eradication of any potentially remaining microorganisms, the ability to neutralize acidic tissue, which is a metabolic by-product of carious lesions, to promote remineralization, to protect against infection and to stimulate tertiary dentin formation, which in addition to the formation of reactive dentin, also involves the dentinal tubules undergoing sclerosis [11].

Calcium hydroxide

Calcium hydroxide has been used in dentistry since the 1920s [13]. It is the most frequently applied material in dental treatment for dentin wound care [10, 24]. Due to its positive properties, it can be used for both direct and indirect pulp capping. Moreover, calcium hydroxide's very alkaline pH value of up to approximately 12.5 has a bactericidal effect, neutralizes lipopolysaccharides and supports the regeneration of the pulp tissue.

Soft calcium hydroxide preparations

Paste preparations which remain soft such as UltraCal XS (Ultradent Products GmbH, Cologne, Germany) or Calcicur (Voco GmbH, Cuxhaven, Germany) adhere poorly to dentin. Furthermore, resorption leads to a mechanical instability of the material [2, 19]. Thus, these preparations do not offer long-term protection against leaks (microleakage, tunnel effect) [4].

Self-hardening two-paste preparations

The most frequent examples from this group are calcium salicylate ester

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cements such as Dycal (Dentsply De Trey GmbH, Constance. Germany) or KerrLife (KerrHawe SA, Bioggio, Switzerland). Such preparations result in a lower pH value than aqueous suspensions, [27] and hence, have an accordingly weaker antimicrobial effect. Moreover, they also show continuous disintegration and are characterized by a very low modulus of elasticity as well as low compressive and tensile strength [4]. After the application of self-hardening cements, inflammatory changes in the pulp occur more frequently than when using aqueous suspensions [22]. In addition, these preparations exhibit a higher toxicity, which is attributable to additives such as zinc stearate (accelerator), barium sulfate (contrast agent used to make the cement appear opaquer in X-ray images), or pigments and stabilizers [20].

Reversible Pulpitis	Irreversible Pulpitis
– Positive response to sensitivity test – Pain does not persist after the stimulus ends	– Strong response to sensitivity test – Pain clearly persists after stimulus ends or is permanently present – Pain radiates and can be triggered by warmth – *Also asymptomatic progression is possible*
Vitality-preservation measures	**Root canal treatment**

Table 1 The currently recommended diagnosis and therapy scheme for reversible and irreversible pulpitis

Alternatives to the classic calcium hydroxide preparations

Resin-modified calcium hydroxide preparations

These include:

1. liners and cements with added calcium hydroxide, e.g. Calcimol LC (Voco, Cuxhaven, Germany), Calcident LC (Willman und Pein GmbH, Barmstedt, Germany), Prisma VLC Dycal (Dentsply Sirona, York, USA), Kent Calciumhydroxide LC (Kent Dental, Instanbul, Turkey)
2. liners and cements with added calcium silicate, e.g. TheraCal LC (Bisco, Schaumburg, USA)

Only a few resin-modified preparations, e.g. Prisma VLC Dycal (Dentsply Sirona, York, USA) and TheraCal LC (Bisco, Schaumburg, USA) are approved for direct pulp capping in the treatment of profound caries. They possess several advantages due to their resin modification. Curing occurs very quickly by means of light polymerization. They also have better physical properties, are less soluble in water and show no signs of dissolution [4]. However, resin-modified pulp capping materials contain and release organic materials [18]. Thus, released residual monomers can damage the pulp, as they display a cytotoxic effect [12]. Also, the polymerization itself causes problems, as it is negatively influenced by the moist dentin surface [18]. The leakage of dentinal fluid and the resulting poorer adhesion may lead to the formation of micro/nanoleakage. Additionally, due to the depth of the cavity, thermal damage to the pulp as a result of light polymerization is possible. Soares et al. investigated the influence of light polymerization of light-curing pulp capping materials and adhesives in the area close to the pulp; they could show that a temperature increase of 3.8–6.4 °C can occur with a residual dentin thickness of 1 mm [26]. Since the remaining thickness of the dentin layer is often only approximately 0.2 mm in the treatment of profound caries, an even higher temperature increase in the area of the pulp is to be expected. If the temperature rises above 42 °C, tissue damage occurs. Moreover, a deformation in the area of the pulp chamber roof is produced [26]. Therefore, capping of the pulp with resin-modified calcium hydroxide preparations is not recommended [8].

Calcium silicate cements

The best-known calcium silicate cement used in dentistry is MTA (mineral trioxide aggregate [di- and tricalcium silicate + water]). It has a higher strength and a lower solubility than conventional calcium hydroxide preparations [7]. Moreover, MTA has a high biocompatibility and it releases calcium hydroxide and silicon during the hardening phase [27, 29]. During the setting process, the pH value of MTA increases to a value of 12.5, which is comparable to the pH value of a calcium hydroxide preparation [14, 28]. The disadvantages of MTA in daily practice are the material's high cost and the long setting time [16]. In order to be able to perform an adhesive closure, a cover is necessary due to the long setting time of calcium silicate. Vural et al. conducted a clinical study over the course of 24 months, which compared MTA and calcium hydroxide in the treatment of profound caries [30]. Both preparations showed an equally good clinical success. No significant differences were found [30].

Summary

The treatment of dentin wounds should be considered in the context of the current consensus recommendation for caries excavation [25]. This recommendation states that complete caries excavation should be avoided in areas close to the pulp in order to avoid possible pulp exposure. In areas distant from the pulp, complete removal of the caries is mandatory for ensuring the stability of the subsequent restoration [25]. However, there is currently no precise guideline on how much carious dentin close to the pulp can be left [3]. Overall, based on studies, there is very little evidence to support the use or need of calcium hydroxide preparations in profound caries treatment [9, 10, 24, 31]. Even in the case of gradual or selective caries excavation, no influence on clinical success has been found [9].

However, a study from 2013 showed that a large proportion (about 70 %) of practicing dentists in northern Germany tries to completely excavate caries during treatment because they fear that the re-

maining caries could damage the pulp [23]. The age, gender and professional environment of the dentist were not significant variables in the clinical procedure [23]. If this procedure is chosen for the treatment of profound caries, the area near the pulp should to be covered. Based on its positive properties, MTA is the most suitable material. However, if handling, setting time and high costs are taken into account, calcium hydroxide would be the more reasonable alternative. In any case, an adhesive restoration is recommended so as to avoid recontamination with microorganisms [13]; adequate sealing plays a more important role for the success of the treatment than the material used for the capping [5, 6].

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(Photo: Hannover Medical School)

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Reconstruction and masticatory rehabilitation of a bilateral maxillary defect with a microvascular free fibula flap

Abstract: Microvascular free flaps are frequently applied in midfacial reconstruction to restore mastication and functional dentition in addition to aesthetic and contour rehabilitation. Especially bilateral maxillectomy defects are multidimensional and result in quality of life deterioration and long-term impairment if not reconstructed properly. Therefore, computer-aided three-dimensional surgical planning can help to achieve not only an adequate implant-fixed dentition but also proper soft tissue conditions in the palate and alveolar ridge. In this case presentation a 70-year-old lady after multiple cancer resections in the maxilla received a fibula free flap bilateral maxillary reconstruction including palatal coverage via a perforator perfused skin flap and implant-based dental rehabilitation. Additionally, vestibuloplasty was performed to restore proper lip contours and increase lip function. A one-stage, three-dimensional planned microvascular fibula free flap reconstruction after cancer resection in combination with postoperative implant placement and vestibuloplasty is a clinically valuable treatment concept even in older patients to restore function and facial contours.

Keywords: maxilla reconstruction; vestibulopasty; oscc; fibula grafting

Department of Oral and Maxillofacial Surgery, University of Erlangen: Dr. Mayte Buchbender DMD; Prof. Dr. Dr. Marco Kesting MD, DMD; Dr. Dr. Raimund H.M. Preidl MD, DMD

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Introduction

Midfacial reconstructions of bony and soft tissue defects are challenging in terms of achieving acceptable aesthetic and functional results [15]. Especially the replacement of larger, two-sided maxillary defects after cancer ablation or major trauma can be a sophisticated operative procedure when a separation of the nasal and oral cavity together with a restoration of the maxillary buttresses, functional dentition and mastication with aesthetic midfacial contours is required [8]. There are several options for maxillary defect reconstruction, like maxillary prostheses, pedicle flaps and free flaps. Compared to mandibula reconstruction, there are fewer reports and publications on maxillary free flap restorations and only a few of these papers report on free flaps applied for rehabilitation after subtotal or even total maxillectomy.

Considering the complexity of defects after subtotal maxillectomy, the sagittal, transversal and axial dimension of both the soft and hard tissue of free flaps is of major importance. During preoperative planning major attention should be turned to an optimal implant-fixed dental restoration in combination with adequate speech and swallowing as well as nasal cavity and maxillary sinus reconstruction. In this situation, 3D virtual planning for osteomyocutaneous free flaps is a very useful tool [9]. Additionally, individually prefabricated osteosynthesis materials enable fixation of the bone blocks of free flaps according to the preoperative planning. This aspect is of major importance to ensure proper mandibula-maxilla relations in order to achieve adequate dental and masticatory function.

Numerous free flaps have been used for maxilla reconstruction (e.g. scapula, radial, iliac crest and rib) [11]. However, focusing on larger, bilateral defects, free fibula flaps (FFF) are most frequently applied because of a relatively long flap pedicle, adequate bone dimensions for postoperative dental implant placement and the possibility to add one or two perforator perfused skin islands for palatal restoration if needed.

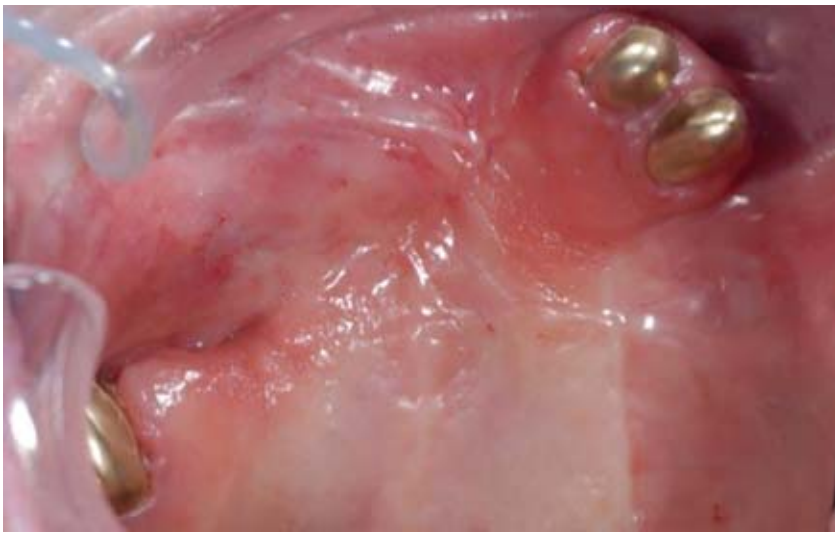


Figure 1 Partially edentulous maxilla with missing vestibule in region 15–22

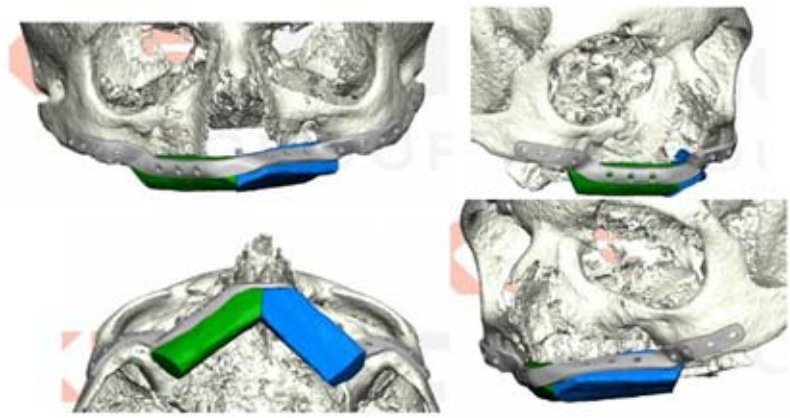


Figure 2 Virtual planning of CAD/CAM fibula bone transplant in the upper jaw.

In this article a case of a 72-year-old lady after multiple cancer resections in the maxilla with consecutive free flap reconstruction and dental restoration based on preoperative 3D planning and a patient-specific implant (PSI) is presented.

Case history

The patient has been undergoing treatment at the Oral and Maxillofacial Surgery Clinic in Erlangen since 2001. In this year (2001) an oral squamous cell carcinoma (OSCC) was diagnosed in the maxilla which was treated curatively with surgery and radio- and chemotherapy. In 2006 the patient was diagnosed with a recurrent cancer in the upper jaw which was again treated surgically and adjuvantly with radio- and chemotherapy.

After the removal of most of the remaining maxillary teeth (with progressive radiation damage) and iliac crest augmentation by the Oral and Maxillofacial Surgery Clinic, the patient was rehabilitated with dental implants by her general dentist in 2017. In April 2018 she presented herself for follow-up care and with a renewed desire for reconstruction, since the implants were gradually lost with insufficiently healed iliac crest and she currently had no dental prosthesis in the upper jaw (as seen in Figure 1).

After diagnostics using CT angiography of the neck and pelvis/legs, the decision was made together with the patient to perform a CAD/CAM fibula reconstruction from the right side as shown in Figure 2.

In May 2018 the operation was performed under intubation general

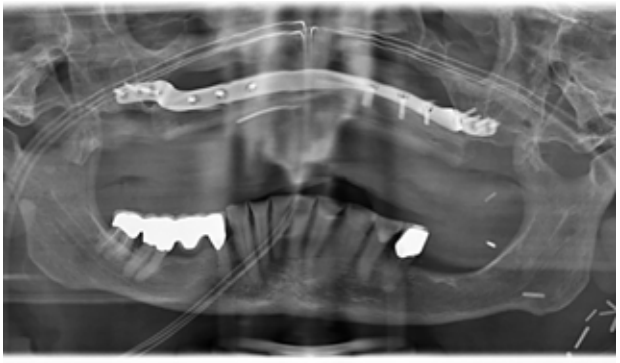


Figure 3 Postoperative panoramic X-Ray after fibula reconstruction.

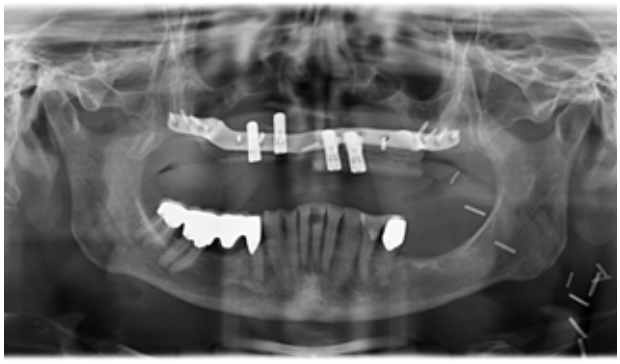


Figure 4 Postoperative panoramix x-ray after insertion of implants. The osteosynthesis material will be left.

anesthesia. In the course of the reconstruction, a biopsy was taken in region 13, which again revealed squamous cell carcinoma. Within the operative procedure the cancer, including major parts of the hard palate, were removed and reconstructed via a perforator perfused skin island taken together with the free fibula flap. The definitive histology was pT1, L0, V0, Pn0, G1, R0, so that the interdisciplinary tumor board decided on aftercare after total cancer removal. The patient could be discharged from hospital after 16 days and was placed in outpatient care. The postoperative bony situation is illustrated in Figure 3 in the form of a panoramic X-ray.

In November 2018, implants in region 22, 24, 12 and 14 (Straumann BL RC 4.1 mm × 12 mm) were inserted with primary stability in sufficient wound conditions and regularly healed bone graft (as seen in Figure 4). The patient received Amoxiclav 875/125 mg perioperatively twice daily per oral and metamizole 500 mg if required.

As the vestibule was missing after microvascular reconstruction, a vestibuloplasty using Mucograft (Geistlich Biomaterials GmbH, Baden-Baden, Germany) was performed during the exposure of implants in March 2019. The implants were regularly osseointegrated. In the case of severe scar tractions in the frequently pre-operated and irradiated area, a bandage plate was made using an intraoperative alginate impression to secure the vestibuloplasty. This was fixed using the 4 healings (Straumann BL RC, H: 6mm) with light-curing composite (Tetric flow A1, Ivoclar Vivadent, Schaan, Liechtenstein). The patient presented herself regularly to the outpatient clinic of the Oral and Maxillofacial Surgery Clinic for wound monitoring and cleaning of the plate (see Figure 5 and 6).

In June 2019, the patient was finally treated prosthetically with a removable bar-implant-supported denture in the Prosthetic Dental Clinic of the University of Erlangen-Nuremberg as illustrated in Figure 7. The last tumor follow-up in August 2019 showed no clinical or CT-graphical evidence of recurrence.

Discussion

For bilateral maxillary bony and soft tissue defect reconstruction the FFF in combination with a preoperative computer-aided planning and prefabricated osteosynthesis is a very useful tool. Although obturator prostheses are still a successful treatment strategy, there are recurrent problems with cleaning and leakage. The current literature reports of high patient satisfaction in terms of mastication, speech and swallowing as well as aesthetics after implant-based dental rehabilitation in combination with free flap reconstructions [16]. After previous cancer-related radiotherapy in the head and neck area, swallowing is impaired due to reduced tongue mobility and scar formation. Additionally, the enoral mucosa is intolerant for mechanical loading and the underlying jaw bone is prone to developing osteonecrosis in the event of local mucosal inflammation. Composite free flaps containing soft and hard tissue components enable implant-based dental rehabilitation and at the same time provide palatinal soft tissue coverage. In patients who

Figure 5a–c Interaoperative situation of the vestibuloplasty with mucograft **(a)** and fixation of the woundplate above the healing abutments **(b, c)**.

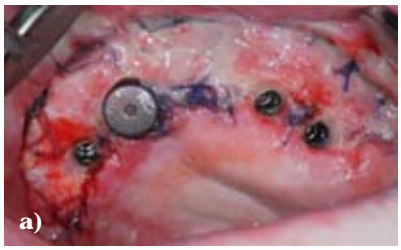
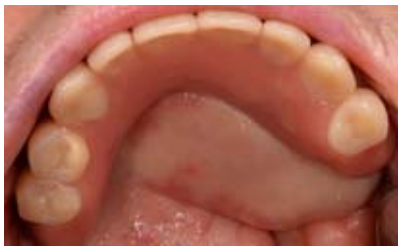


Figure 6 a and b (from left to right). Postoperative situation of vestibuloplasty, after 7 days **(a),** and after 17 days **(b).**



(Fig. 1–7: M. Buchbender)

Figure 7 Inserted prosthesis.

require total maxilla reconstruction after radiotherapy and/or previous free flap surgery, the pedicle length of the flap is of great importance, as closely located vessels like the facial artery and vein might not be present.

Some authors favor the deep circumflex iliac artery free flap (DCIA) for midfacial reconstruction because of relatively large bone dimensions and a flexible soft tissue component for oral cavity and maxillary sinus coverage. However, when planning bilateral defect reconstruction in combination with a reliable skin coverage the DCIA has to be chosen with caution [17]. Most authors prefer FFFs for a one-stage bony and soft tissue bilateral maxilla reconstruction, as presented in this analysis [5, 7, 8]. If immediate reconstruction of maxillary defects after cancer resection is planned, a special emphasis should be laid on resection margins according to preoperative imaging techniques. As the status of positive margins plays a crucial role in the treatment of oral squamous cell carcinoma (OSCC), precise and dedicated planning is necessary to successfully achieve a one-stage bilateral bony and soft tissue maxilla reconstruction suitable for dental and masticatory rehabilitation.

For smaller and unilateral defects, local flaps like the nasolabial flap from the cheek or temporal muscle flaps are also reliable options in terms of soft tissue reconstruction or closure of postoperative fistulas surrounded by scarred tissue [3, 4]. If needed, these flaps can be combined with non-vascularized bone grafts in order to achieve implant-based dental rehabilitation [6].

Zygomatic-anchored implants are another option for the fixation of functional dentition after resection of maxillary bone structures in some cases [14]. Operative implant placement into the zygomatic bone is a feasible and technically sophisticated procedure as the orbita and the maxillary sinus are situated nearby. Local infections, nerve injury or even vision impairment are significant problems which can be associated with this type of implant [2]. Additionally, the status of soft tissue coverage of the maxillary defects and the peri-implant keratinized mucosa is closely related to long-term stability and peri-implant health [1]. Especially in patients with strongly changed anatomical conditions, as in this case after bone and soft tissue reconstruction, a vestibule and thus also keratinized tissue is completely missing. In this case vestibuloplastic surgery is indicated, but is also a major operative challenge.

Especially the preparation and preservation of the neo-vestibulum can be difficult due to increased scar retractions in areas that have been frequently operated and in some cases even previously irradiated. To handle this problem, one possibility is the use of wound plates (in the sense of acrylic splints), which are designed to hold off the soft tissues without applying pressure to the grafts (regardless of whether autologous or not), but with slight pressure to the caudal or ventral side so that the graft can heal without recurrence by traction of soft tissue [12]. In the edentulous jaw, plate retention can be ensured by fixation with light-curing composite via the healing abutments. However, it must be ensured that the plate or wound is checked regularly, as excessive pressure on tissue via the plate itself or the composite can lead to undesired reactions, e.g. infections or severe pain [10].

After cancer ablation and previous or planned radiotherapy this reconstructive method should be critically investigated during the planning period if the patient's condition is suitable.

Especially after radiotherapy, peri-implantitis and finally implant loss is still an unsolved problem in some cases [13]. A sufficient amount of keratinized mucosa around dental implants inserted into the transferred bone seems to be very important here.

Conflicts of interest:

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

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(Photo: Markus Kohler)

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Follow-up examination of patients with mini-implants for the stabilization of existing removable partial dentures

Introduction: The aim of this study was to evaluate the clinical performance of mini-implants (MI), which were used for the stabilization of double crown retained removable partial dentures (RPDs), after a middle-term period of service in a dental practice. Additionally, implant stability and patient satisfaction with the dentures were evaluated.

Material and Methods: Patients who had received 10 to 13 mm long MI with diameters of 1.8, 2.1, and 2.4 mm and ball attachments for supplementary support of their existing double crown retained RPDs at least 3 years ago were included in this study. After patient chart and medical history analysis as well as the completion of an 8-item questionnaire on satisfaction with the RPD (Likert scale 1 to 5) by the participants, an experienced dentist independently examined the periodontal/peri-implant conditions; this involved measurement of implant stability by using the Periotest and the Osstell device. In addition to descriptive statistics, survival analyses based on the Kaplan-Meier and Cox regression analyses were used to estimate possible risk factors for implant loss.

Results: Out of 70 reachable patients, 66 study jaws in 57 patients were examined. The duration between the time of implant placement and the follow-up examination ranged between 3 and 9 years for the examined 77 MI in 25 upper jaws and 113 MI in 41 lower jaws. The MI in 20 jaws with good bone quality (insertion torque ≥ 35 Ncm) were loaded immediately using matrices (housing with O-rings), while the other RPDs were initially soft-relined for 3–4 months. The 5-year-survival rates of the MI in the maxilla and mandible were 97.4 % (3 failures) and 86.9 % (13 failures, one fracture), while the tooth survival rates were 88 % and 88.9 %, respectively. The Cox regression analyses revealed no statistically significant effect of possible risk factors on implant failure (tooth status, smoking habits, diabetes mellitus, loading modus). In 18 of the study participants, a total of 40 MI were placed subsequent to implant or tooth loss. The aftercare of the RPDs comprised of 8 O-ring replacements and 26 denture base relinings. The complications included denture base ($n = 17$), secondary crown veneering ($n = 11$) and artificial denture teeth ($n = 2$) fractures. The mean Periotest values were 5.5 and 6.7 ($P = 0.078$), while the mean Osstell values were 38 and 33 ($P < 0.0001$), in the maxilla and mandible, respectively. The majority of participants were very satisfied with their RPD (80 % in the maxilla, 70 % in the mandible) and nobody was dissatisfied.

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Discussion: The lower MI survival rate in the mandible compared with the maxilla comes as a surprise and is contrary to previous studies performed on edentulous jaws. The complications were manageable, despite implant losses and denture fractures. The stability values of MI were lower than those of standard-diameter implants.

Conclusion: Strategic MI under double crown retained RPDs are a recommendable therapeutic option in the dental practice. Prospective randomized clinical studies are required to investigate this therapeutic alternative.

Keywords: mini-implant; strategic; removable partial denture; double crown; survival; satisfaction; stability

Introduction

Dental implants for the stabilization of removable partial dentures (RPD) have become an accepted therapy alternative [2–4, 13, 15, 16, 30, 31]. In addition to providing distal support for free-end dentures [4] and increasing the number of primary abutments prior to new prosthetic restoration [2, 3, 13, 15], implant placement under an existing RPD is an interesting alternative [30]. Abutment extractions and/or their unfavorable distribution can lead to problems with denture retention. In a prospective study, in a total of 11 patients with unfavorable distribution and a low number of abutment teeth in one jaw, the subsequent incorporation of retaining elements on implants led to an improvement in the oral health-related quality of life [30] and chewing efficiency [31]. After 6.5 years, all implants and RPDs were still functional although some abutment teeth had to be extracted (89 % tooth survival rate) [16].

Despite the fact that this is less expensive than making a new superstructure, the associated costs are still relatively high. Moreover, the use of implants with standard diameters (> 3.5 mm) is limited due to bone atrophy after tooth extraction and the resulting narrowing of the alveolar process. Implants with reduced diameters (3–3.5 mm) are not always indicated for single attachment. Finally, augmentative procedures to improve the bone volume are not only associated with risks for patients with systemic diseases, but they are also frequently rejected, particularly by older patients because of the longer treatment duration as well as the greater effort required [29].

Mini-implants (MI) with an even smaller diameter (< 3 mm) are usually one-piece, and therefore, a no-load osseointegration is hardly possible. They are mainly used to stabilize complete dentures by means of ball attachments. For this, 6 MI in the upper jaw and 4 MI in the lower jaw are recommended [14]. The most recent systematic reviews have reported high survival rates (> 95 %) after an average period of 3 years and low bone resorption rates (< 1.2 mm) in the edentulous mandible [12, 14, 23]. Contrary to this, after immediate loading in the edentulous maxilla, the MI rate of failure was unacceptably high at 32 % [14]. If the bone quality is poor, or more specifically, the insertion torque < 35 Ncm, the dentures should first be hollowed out in the area of the ball attachments and lined with soft material. This apparently leads to fewer failures [9, 20].

In addition to the insertion torque as a measure of primary strength, implant stability can also be determined longitudinally with Periotest measurements or resonance frequency analyses [22]. For immediate loading and for follow-up checks, reference values as for two-piece standard diameter implants are desirable. However, previous Periotest measurements on MI have shown different mean values of < -3 [7] and > 5 [25]. For resonance frequency analysis of one-piece MI with ball-shaped heads, only data from an animal experiment (rabbit lower leg bone) with a specially designed attachment have been published so far. In direct comparison with two-piece standard implants, the differences between the values were not significant [5].

Meanwhile, there are now 2 studies with an observation period of 12 and 6 months, respectively, on the successful application of MI for better support of RPDs in the presence of remaining anterior teeth (Kennedy Class I) [6, 28]. To date, there have only been case reports on the use of MI as strategic abutments to improve load distribution and retention under existing RPDs in the conditions of few or unfavorably distributed residual teeth [19, 27]. The results from a prospective, randomized 3-year study on the same topic, where the design has been published so far, are still pending [18].

Therefore, a retrospective examination was initiated on patients from a dental practice who had received MI for the stabilization of double crown-retained RPDs for a longer time. Following implant placement for a minimum period of 3 years, clinical performance, implant stability and patient satisfaction with the dentures were evaluated.

Material and treatment methods

Study participants

The study initiated by the Greifswald University Hospital was financially supported by the company 3M Deutschland GmbH (Germany) and received the vote (BB 025/13) from the responsible ethics committee. Patients were invited to a dental practice in North Rhine-Westphalia,

where they had received mini-implants (Mini Dental Implant, MDI, 3M ESPE, Seefeld, Germany) as supplementary abutments under existing RPDs at least 3 years ago (Figure 1). Meanwhile, MDIs are distributed by another company (Condent, Hannover, Germany). Patients who could not be expected to take part in the study due to general medical conditions and who did not give written consent to participate in the study were excluded. The neutral losses to follow-up (deceased, seriously ill and those who had moved out of the catchment area of the practice) were subtracted from the gross sample size so that the difference, being the net sample size, could be used to determine the response. Drop-out was a (multiple) failure to attend the examination dates or a refusal to participate in the study. The study participants were examined by a trained and experienced dentist who was not involved in the treatment of the patients.

Therapy

In cases where the denture retention was insufficient such as after abutment tooth extraction, or primarily due to an insufficient number or distribution of remaining teeth, patients received subsequent MI for additional stabilization of their RPDs. The number and position of the implants was determined based on the distribution of the remaining teeth and the existing vertical bone height, which is limited distally by the maxillary sinus and the inferior alveolar nerve. Insertion was largely performed transgingivally or, as in a few cases, subsequent to the mobilization of a small mucoperiosteal flap and preparation of the implant site with a 1.1 mm thin pilot drill at different depths (one to two thirds of the implant length); the drilling depth was of course dependent on bone quality. In practice, only MI with lengths of 10 and 13 mm and diameters of 1.8, 2.1 and 2.4 mm were used. In the patient example in Figures 2 and 3, the use of standard implants would only have been possible by employing procedures to widen the bone bed such as splitting or augmentation, or with a reduction of the narrow part of the alveolar ridge. Immediate loading was made on MI having a sufficient insertion torque (approx. 35 Ncm). For this purpose, the dentures were hollowed out above the ball attachments and the matrices (metal housings with O-Rings) were incorporated using self-curing acrylic resin either direct intraorally or indirectly using an impression and a model. If the insertion torque was insufficient, the dentures were first soft relined and the housings were directly or indirectly incorporated after approximately 3 months.

Investigation parameters

The medical findings prior to implantation were based on the documentation in the patient's chart and the postoperative panoramic X-ray. All treatments, technical and biological complications on teeth, implants, the superstructure as well as any post-implantations between the primary implant placement and the follow-up examination were also recorded.

The study jaws were classified according to the residual dentition which was present at the time of primary implant placement [18]: one quadrant is edentulous (class 0), in one or both quadrants there are either only incisors (1), or the canine is missing and only one posterior tooth (2), the canine is missing and two posterior teeth (3), only the canine and no posterior tooth (4) or the canine and one posterior tooth (5).

During the follow-up examination, a medical anamnesis was first performed; diseases, medication and smoking habits were recorded. The patients were divided into smokers, former smokers (quitting smoking 5 years before the follow-up examination), and never smokers. With the help of a validated questionnaire, the satisfaction with the prosthetic restoration in the study jaw was determined based on the grading system used in German schools; 8 questions regarding general satisfaction, retention, position stability, resilience, speaking, eating, appearance and ease of cleaning of the denture were asked. The answers were marked according to a Likert scale of very good (1), good (2), neither good nor bad (3), bad (4) to very bad (5) [1].

In addition to the dental and prosthetic status, the following clinical parameters were assessed on teeth and implants:

1. Modified plaque index according to Mombelli [17] ranging from grade 0 (no plaque) to grade 3 (massive plaque)
2. Probing depth: 4 measuring points (mesial, vestibular distal, oral) were carefully probed (< 0.2 N) with the periodontal probe PCP-12 (Hu-Friedy)
3. Bleeding on probing: yes/no
4. Periotest value (Periotest device, Medizintechnik Gulden, Germany): The measurements were made at right angles to implants (center of ball-shaped head). The lower the Periotest values were, the more fixed the implants were.
5. Resonance frequency analysis (Osstell, Gothenburg, Sweden): A smartpeg prototype developed by the former manufacturer of MDI was placed on the spherical head and fixed below the spherical equator with a lateral screw (Figure 4). The hand-operated probe stimulated the Smartpeg. The resonance was recorded by the Osstell measuring device. The implant stability quotient (ISQ) indicated the resonance frequency (kHz) on a clinically applicable scale of 1–100 ISQ. The higher the ISQ was, the more fixed the implant was. The Smartpeg attachment is being tested for the first time in a clinical study. Reference values are therefore not yet available.

Statistical analysis

In some study participants, both jaws were treated, but at different time points. Thus, the upper and lower jaws were evaluated separately. In addition to descriptive statistics, the survival probabilities of implants and teeth were calculated using Kaplan-Meier analyses and subgroups were compared using log-rank tests. Possible predetermined factors for implant failure (age, gender, type of incomplete dentition, smoking, diabetes mellitus, loading mode) were evaluated with Cox regression anal-

yses. The software used was Stata/MP software, release 14.2 (Stata Corporation, College Station, TX, USA). The significance level for the statistical tests was set at 0.05.

Results

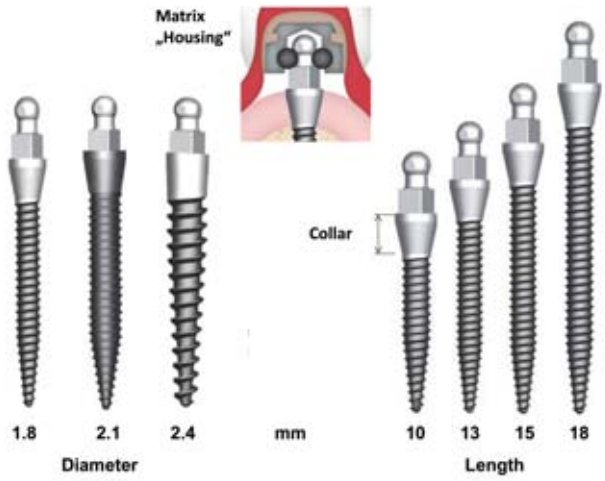
Patient characteristics

From the original 98 patients (35 men, 63 women) with strategic MI, 28 were no longer reachable; 9 were deceased, 11 were seriously ill and 8 moved to another and/or unknown location. Of the remaining 70 patients, 13 refused to participate in the study (18.6 % drop-out). In the end, 57 study participants (35 women, 22 men) with 25 upper jaws and 41 lower jaws were included. The general characteristics are shown in Table 1.

All study jaws were treated with double crown-retained RPDs and 9 of the participants received strategic MI in both jaws. In the antagonist jaws, double crown-retained RPDs (n = 12), clasp-retained RPDs (n = 4), complete dentures (n = 14, exclusively upper jaw), precision attachment-retained RPDs (n = 2) or fixed restorations on teeth (n = 15) or implants (n = 1) were found. In 42 study jaws, no tooth (class 0, n = 18), exclusively anterior teeth (class 1, n = 16), at most one posterior tooth (class 2, n = 7) or 2 posterior teeth (class 3, n = 1) were present in at least one quadrant before implantation. In 24 study jaws, the dentures were supported on both sides at least on canines (classes 4 and 5).

At the time of implant insertion in the upper and lower jaws, the average age of the participants was 64 ± 9.7 years and 66.4 ± 9.1 years, respectively, without any relevant gender differences. The average time between initial implant insertion and examination was 5.5 ± 1.8 years in the maxilla and 5.3 ± 1.9 years in the mandible with a minimum duration of 3.1 and a maximum duration of 9.7 years for both jaws. In the upper and lower jaws, 77 MI and 113 MI were inserted, respectively. Most frequently, 2 implants were placed in both jaws (Table 2).

MI with lengths of 10 mm (n = 5) and 13 mm (n = 185) were placed in the tooth areas between 15 and 25 as well as 36 and 46 (a total of 10 molar implants) in the upper and lower jaws, respectively. Most frequently, implants were placed in the first premolar and central incisor areas. In the maxilla, 61 MI with a diameter of 2.4 mm, 10 of 2.1 mm and 6 of 1.8 mm were used. In the mandible, 88 MI with a diameter of 1.8 mm, 20 MI of 2.1 mm and the remaining 5 MI of 2.4 mm were used. In 9 upper jaws (36 %) and 11 lower jaws (26.8 %), the MI were immediately loaded with the housings.



(Fig. 1: 3M ESPE, now Condent Hannover)

Figure 1 Configuration of implants and matrices (Housings with O-rings) of the MDI system. Mini-implants without a collar are used in the case of a thin mucosa.

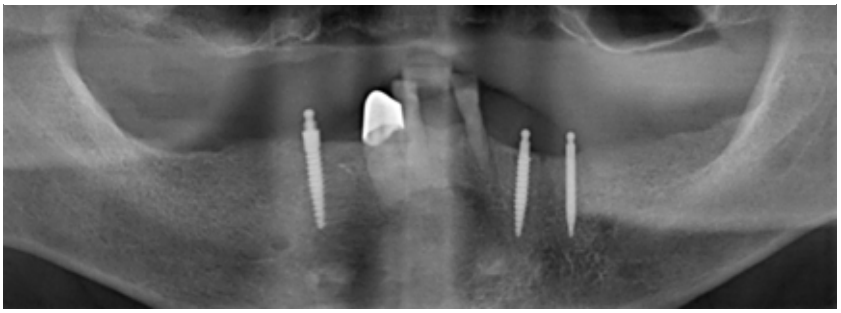


Figure 2 Post-surgery panoramic X-ray of a patient after placement of additional mini-implants in the mandible

Implant and tooth survival/ post-operative care

According to the Kaplan-Meier analysis, the 5-year survival rate of MI was 97.4 % in the maxilla (3 losses due to missing/lost osseointegration) and 86.9 % in the mandible (13 losses due to missing/lost osseointegration, one fracture). The log-rank test, without regard to the person level, showed a statistically significant difference between the jaws (P = 0.0481). As can be seen in Figure 5, the vast majority of losses were recorded in the first year (n = 12). The statistical evaluation did not take into account 14 and 26 replaced implants subsequent to tooth and/or implant loss in the maxilla and mandible, respectively.

A Cox regression analysis on possible factors influencing implant failure was only meaningful for the mandible due to the number of events and patients; it did not reveal any significant effects of age, gender, gap dentition classification, smoking, diabetes mellitus, loading mode on implant failure (Table 3). Also, diabetics did not lose implants.

During the entire period of study, 19 out of 106 upper teeth and 18 out

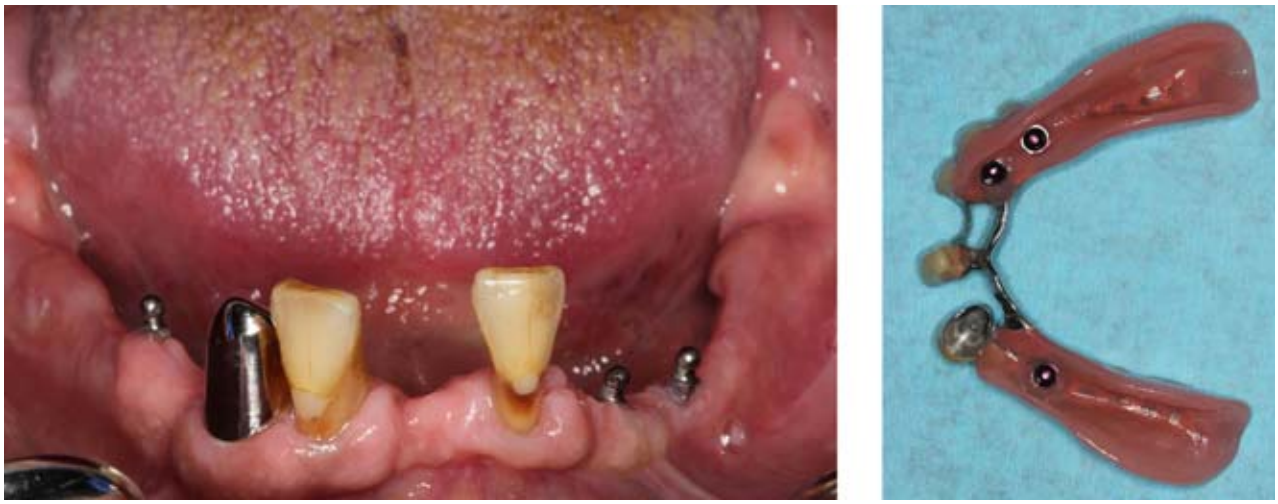


Figure 3 Clinical picture of the patient in figure 2 and the modified denture with housings

Characteristic	Men (n = 22)		Total (n = 57)		Total (n = 57)	
	n	(%)	n	(%)	n	(%)
Smoking habits						
Never smoker	9	(40.9)	21	(60.0)	30	(52.6)
Former smoker	10	(45.4)	6	(17.1)	16	(28.1)
Smoker	3	(13.6)	8	(22.8)	11	(19.3)
Cardiovascular diseases	12	(54.5)	18	(51.4)	30	(52.6)
Diabetes mellitus	3	(13.6)	2	(5.7)	5	(8.8)
Anticoagulant medication	7	(31.8)	7	(20.0)	14	(24.6)
Rheumatoid arthritis	0	(0)	5	(14.3)	5	(8.8)
Cancer	1	(4.5)	3	(8.6)	4	(7.0)
Number of medications per day						
0	9	(40.9)	8	(22.8)	17	(29.8)
1	5	(22.7)	8	(22.8)	13	(22.8)
2	3	(13.6)	6	(17.1)	9	(15.8)
3	2	(9.1)	3	(8.6)	5	(8.8)
>3	3	(13.6)	10	(28.6)	13	(22.8)

Table 1 Characteristics of study participants

of 170 lower teeth were lost. The 5-year survival rate of teeth was 88.0 % in the maxilla and 88.9 % in the mandible based on Kaplan-Meier estimates.

None of the 66 dentures had to be renewed until the follow-up examination. Prosthetic aftercare measures included replacement of O-rings a total of 8 times, 26 denture relinings in connection with tooth extractions, MI losses or replacement of MIs, 9 times replacement of denture teeth, as well as, 17 and 11 repairs following the fracture of the denture base and double crown veneering, respectively.

Clinical examination

In the maxilla, 57 % of the MI were plaque-free (plaque index degree 0), while the other MI showed a thin plaque film (degree 1). In the mandible, 39 % of MI were plaque-free (grade 0), 51 % had a thin plaque film (grade 1), 9 % showed visible plaque (grade 2) and 1 % had massive plaque deposits (grade 3). From the remaining teeth, 20 % in the maxilla and 25 % in the mandible were plaque-free. However, 19 % of the teeth in both jaws displayed visible plaque (grade 2), but no massive plaque deposits.

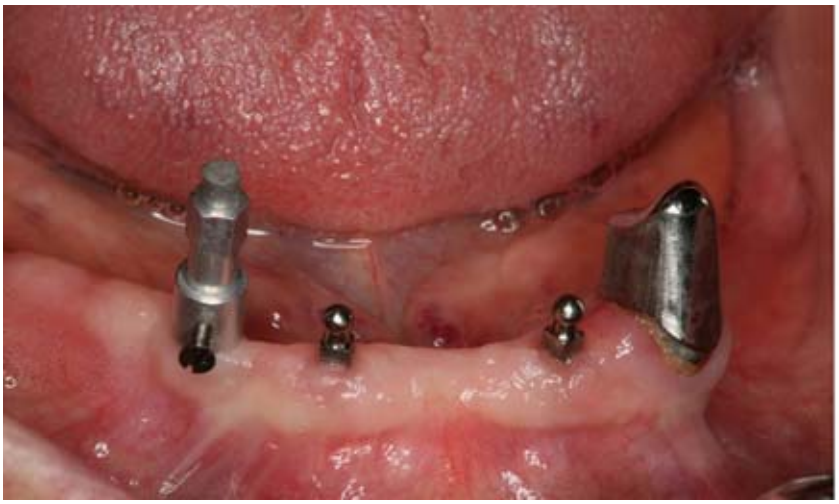


Figure 4 Smartpeg screwed onto the mini-implant ready for Osstell measurement

Number	Upper Jaw		Unterkiefer		Total	
Implants	Number	(%)	Number	(%)	Number	(%)
1	1	(4)	2	(5)	3	(5)
2	9	(36)	19	(46)	28	(42)
3	6	(24)	9	(22)	15	(23)
4	7	(28)	9	(22)	16	(24)
5	0	(0)	2	(5)	2	(3)
6	2	(8)	0	(0)	2	(3)
Total	**25**		**41**		**66**	

Table 2 Number of implants per jaw at the time of first implant placement

The maximum probing depth around implants and teeth was on average 2.5 mm and 3.2 mm, respectively. Slightly higher values were recorded in the maxilla (Table 4 and Table 5).

After careful probing, 58 % of implants and 34 % of teeth in the maxilla and 40.5 % of implants and 37 % of teeth in the mandible showed sulcus bleeding.

On average, the Periotest measurements yielded slightly lower values of 5.3 ± 5.6 in the upper jaw compared to 6.7 ± 6.4 in the lower jaw (Figure 6). However, the difference was not statistically significant after a Box-Cox transformation of the values for a symmetrical distribution ($P = 0.078$). The box-cox plots revealed a large upward dispersion with values smaller than 0 being rare. The mean ISQ values (Osstell) in the upper jaw (38 ± 9.4) were higher than those in the lower jaw (33 ± 10.9) ($P = 0.001$) (Figure 7).

When the Periotest and Osstell values are correlated, the Pearson correlation is -0.87 and the Spearman correlation is -0.82; this indicates a high correlation (Figure 8). Further analyses show an interaction between jaw and diameter ($P = 0.0092$) after the Box-Cox transformation of the Periotest values. The highest values were found in the mandible with 1.8 mm thick implants ($P = 0.0006$). In the maxilla, the differences in Periotest values between implant diameters were not significant ($P = 0.5828$). Here, however, only 6 MI with a diameter of 1.8 mm were included. There was also an interaction between jaw and diameter ($P = 0.0095$) for the Osstell values. The 1.8 mm MI in the mandible showed statistically significant lower values than the thicker MI ($P < 0.0001$). In the maxilla, the differences were again random ($P = 0.5886$). Repeated problems occurred when using the Smartpeg attachment. When the peri-implant mucosa reached very close to the sphere, fixation of the attachment with the lateral screw was not always easy to control.

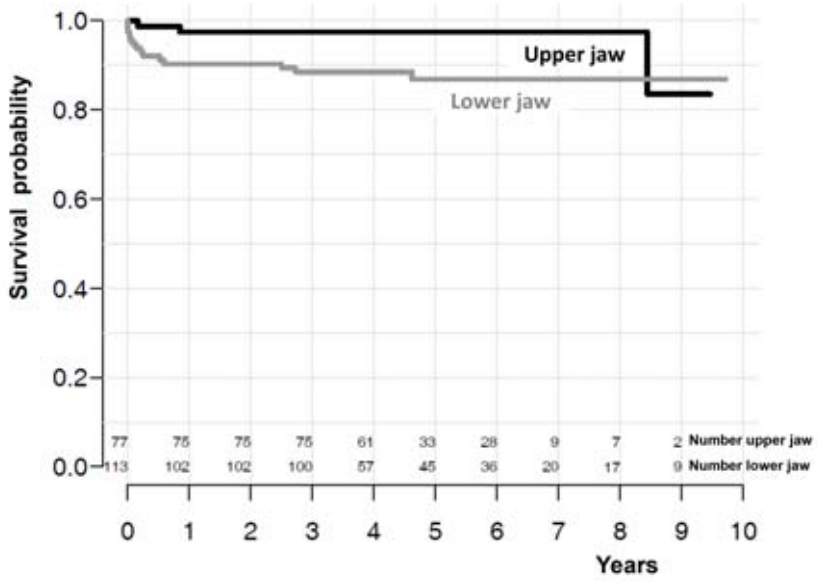


Figure 5 Survival probabilities of implants by jaw

Satisfaction with the prosthetic treatment

The evaluation of one mandibular denture is missing. The overwhelming majority of the participants answered the individual questions on satisfaction with the prosthetic treatment of the study jaw with very good or good. Only a few were not quite so satisfied and no study participant was dissatisfied (Table 6). These ratings are reflected in the cumulative scores. From the sample of study participants, almost half with maxillary dentures and about one third with mandibular dentures answered all questions with „very good" (cumulative score = 8, Table 7).

Discussion

The use of MI as supplementary abutments under existing RPDs is a successful medium-term therapy option. The lower survival rate of MI in the mandible compared to the maxilla was surprising. Apart from repairs following the fracture of denture bases, the aftercare of the dentures required relatively low effort because no RPD had to be renewed during the period of observation. The presence of plaque (80 % of the teeth in the upper jaw and 75 % in the lower jaw) together with probing depths around teeth (more than half ≥ 3 mm) are indicative of a periodontally involved dentition with partly active inflammation (bleeding on probing in about one third of the teeth and about half of MI). In order to measure implant stability, the Osstell device with corresponding Smartpegs can be used in addition to the Periotest device. However, the values for MI are higher with the Periotest and lower with the Osstell compared to standard diameter implants; moreover, the values are also influenced by MI diameter, at least in the mandible. The questionnaire revealed that the vast majority of patients were very satisfied or satisfied with the prosthetic treatments.

Like any retrospective study, the present evaluation also has limitations that must be taken into account when interpreting the results. For instance, the initial periodontal situation was not known. Also, there were no regular X-ray controls. The distribution of the remaining teeth in the study jaws varied considerably and the number of additionally inserted MI was also variable, partly due to the limited vertical bone in dorsal jaw regions [8, 23, 24]. The study population was broadly diversified and it included patients with

		Hazard Ratio (95%-Confidence Interval)		
		Lower Jaw (14 Results; adjusted for 41 clusters from patients)		
Risk factor	**Reference-Category**	**Not adjusted**	**Adjusted for age**	**Adjusted for age and gender**
Age (≥ 70 years)	< 70 years	0.73 (0.21–2.47)	---	0.76 (0.23–2.52)
Female Gender	Male	1.28 (0.39–4.23)	1.19 (0.37–3.77)	---
Dentition classification	Continuous	0.80 (0.58–1.12)	0.81 (0.58–1.11)	0.81 (0.58–1.13)
Smoking	Never/Ex-Smoker	2.17 (0.64–7.30)	2.49 (0.60–10.4)	2.46 (0.61–10.0)
Diabetes mellitus	No	(0)	(0)	(0)
Delayedloading	Immediate-loading	4.49 (0.57–35.5)	4.46 (0.56–35.7)	4.51 (0.53–38.3)

Table 3 Cox regression analyses of possible factors for implant failure

Jaw	Number	Mean	Standard deviation	Min	1st Quartile	Median	3rd Quartile	Max
Upper jaw	76	2.7	1.0	1.0	2.0	3.0	3.0	8,0
Lower jaw	105	2.3	1.2	1.0	2.0	2.0	3.0	10,0
Total	181	2.5	1.1	1.0	2.0	2.0	3.0	10,0

Table 4 Maximum probing depths around implants

Jaw	Number	Mean	Standard deviation	Min	1st Quartile	Median	3rd Quartile	Max
Upper jaw	93	3.5	1.1	1.0	3.0	3.0	4.0	8.0
Lower jaw	151	3.0	1.1	1.0	2.0	3.0	4.0	10.0
Total	244	3.2	1.1	1.0	2.5	3.0	4.0	10.0

Table 5 Maximum probing depths around teeth

underlying diseases, smokers, or subjects displaying bruxism. Lastly, the retrospective patient's chart analysis showed that the attitude with respect to coming for dental check-ups varied considerably among the participants.

The latter aspects can also be considered a strength of the study because the results reflect the performance of MI, and their prosthetic treatment, under normal practice conditions without prior selection. The data were collected by a dentist with more than 20 years of professional experience, who had no experience with MI before his training prior to the beginning of the study. Further strengths of the study are the minimal (3 years) and mean (5.5 years) observation period, as studies of at least 5 years duration on MI are still rare [9, 23, 26, 27]. Despite the fundamental retrospective design, all implants were clinically examined and the current subjective satisfaction with the prosthetic restoration was determined using a validated measuring instrument [1].

The MI 5-year survival rate of 86.9 % in the mandible is lower than in previous studies on MI-supported overdentures for edentulism, where 2 to 5-year survival rates were 93–100 % [9, 12, 23, 24]. Possible reasons for this are: First, periodontal inflammation of the remaining teeth has been shown to negatively affect osseointegration and lead to implant loss or peri-implantitis [10]. Secondly, in the MI studies on edentulous mandibles, all patients had complete dentures in the maxilla; this is in contrast to the present study, which included 14 complete dentures, 20 RPDs and 6 fixed restorations in the maxilla. This could contribute to an overload of the MI during the healing phase. The high failure rate in the first 6 months after insertion in the lower jaw supports this assumption.

In contrast to prospective studies with MI rates of failure of up to over 30 % after 2–3 years in the edentulous maxilla [8, 14, 24], the survival probability in the present study was 97.4 % after 5 years with a total of 3 losses. In the prospective studies mentioned above, all MI were immediately loaded with the housings, regardless of bone quality or insertion torque. In the present study, 64 % of the maxillary RPDs were milled out above the ball attachments and relined with a soft material. The MIs with the housings were loaded only after 3 to 4 months; this mirrors another retrospective study where the MI survival rate in the edentulous maxilla was 94.3 % [20]. The Cox regression analysis to determine potential risks for implant failure in the mandible had too small of a sample size in the subgroups. The confidence intervals of the hazard ratios indicate the possible negative influence of smoking and initial soft relining or poor bone quality on implant survival.

The 5-year tooth loss rates of 12 % in the maxilla and 11 % in the mandible confirm the results of a similar study where the 6.5-year rate of loss of abutment teeth was 11 % with standard diameter implants and ball attachments as supplementary anchors for 6 telescopic dentures in the maxilla and 5 in the mandible [16]. However, none of the delayed loaded implants were lost in this study. Similar results are shown in 2 recent systematic reviews of combined tooth and implant-supported RPDs. The 1 to 10-year survival rates of implants were 92–100 % and those of teeth bearing clasps, ball anchors or double crowns as retaining elements were 79–100 % [2]. The calculated 95 % confidence intervals were 97–100 % for implants and 85–98 % for teeth where exclusively double crowns on teeth and implants were used [15].

Among the prosthetic aftercare measures, 26 relinings from a total of 66 dentures with an average observation period of 5.5 years is comparable with the study mentioned above, in

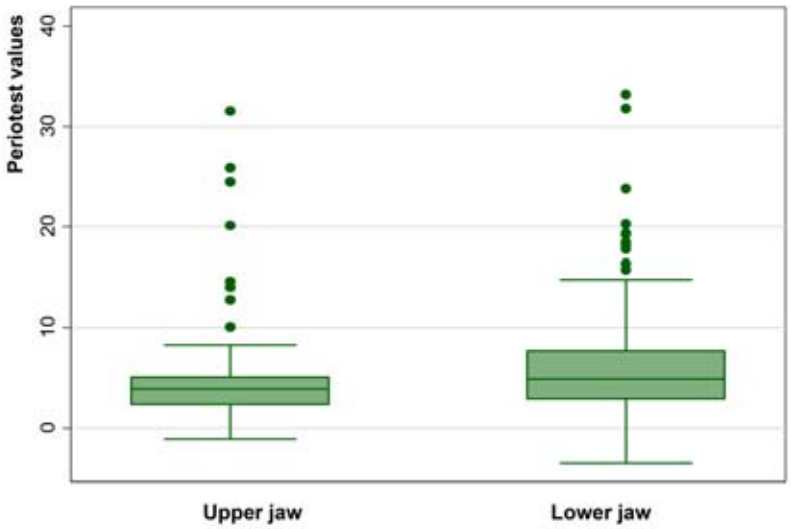


Figure 6 Box plots of periotest values by jaw

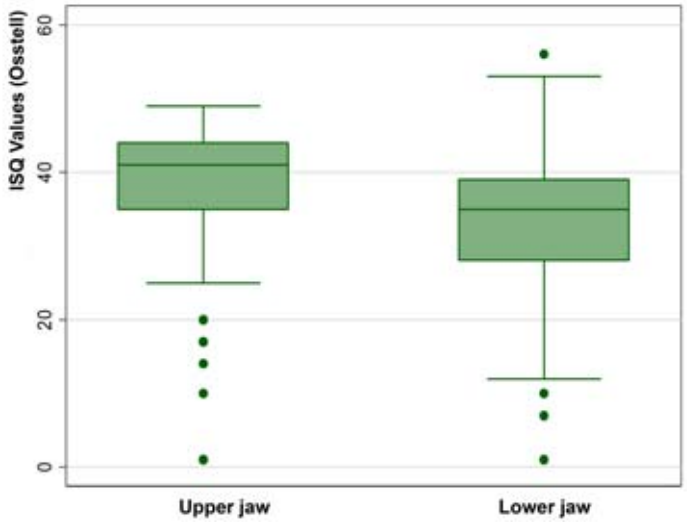
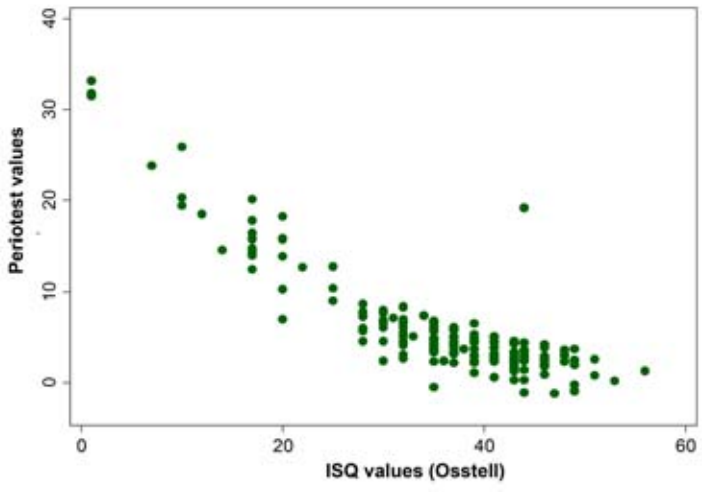


Figure 7 Boxplots of implants stability quotients (ISQ-Osstell) values by jaw



(Fig. 2–8, Tab. 1–7: T. Mundt)

Figure 8 Plot showing the association between Periotest values and implant stability quotients (ISQ) values

which conventional implants were delayed loaded following strategic placement under double crown dentures [16]. In this study, 6 of 11 dentures were relined. However, in contrast to the present study with only 8 O-silicone ring changes for retention improvement, all matrix inserts of the standard implants were adjusted multiple times, or in some cases, even replaced several times in the course of the 6.5 years. This can be explained by the different retention and wear mechanism of the 2 types of matrices. Conversely, the number of denture base, veneering and denture tooth repairs were comparable between the 2 studies and affected approximately half of the dentures. It can be assumed that the subsequent incorporation of the matrices into an existing denture can lead to denture base and framework weakening.

In the present study, subsequent to 37 tooth extractions and 17 MI losses, a total of 40 implants were placed in a number of 18 study participants; in many cases, the implants were placed at the same or another site with the aim of keeping strategically important positions for denture retention. On the one hand, this was again a surgical procedure. On the other hand, the patients were familiar with this minimally invasive surgery with low postoperative morbidity [12, 14, 26] and for which the costs also remained manageable.

The clinical data indicate a patient population with prior periodontal disease of the remaining teeth and numerous active inflammations (bleeding on probing on more than one third of the teeth). Less than a quarter of the teeth were plaque-free and more than half showed maximum probing depths ≥ 3 mm. The fact that about half of the MI showed bleeding on probing should be interpreted with caution; this is because an injury to the mucosa can still be caused even by careful probing in healthy peri-implant mucosa [11].

The stability measurements of the MI yielded higher Periotest values (interquartile range 2–7) and lower ISQ values (30–43) through resonance frequency analysis than osseointegrated standard diameter implants (Periotest: < 1, ISQ: > 60) [22]. According to the

Item	Upper jaw: Number of answers n (%)						Lower jaw: Number of answers n (%)					
	Very good		Good		Neither good nor bad		Very good		Good		Neither good nor bad	
General Satisfaction	20	(80)	5	(20)	0	(0)	28	(70)	11	(27)	1	(3)
Retention	20	(80)	5	(20)	0	(0)	31	(77)	9	(22)	0	(0)
Stability	17	(68)	7	(28)	1	(4)	30	(75)	10	(25)	0	(0)
Support	20	(80)	3	(12)	2	(8)	29	(73)	11	(27)	0	(0)
Speaking	21	(84)	4	(16)	0	(0)	35	(87)	5	(13)	0	(0)
Eating	18	(72)	6	(24)	1	(4)	29	(73)	11	(27)	0	(0)
Appearance	14	(56)	11	(44)	0	(0)	25	(62)	15	(38)	0	(0)
Cleanability	15	(60)	9	(36)	1	(4)	20	(50)	20	(50)	0	(0)

Table 6 Answers to questions relating to study participant satisfaction with dentures by jaw

manufacturer, these values would indicate insufficient osseointegration. The Periotest values are within the range given by Stepanovic et al. [25] as a mean value = 6 ± 6 for osseointegrated 1.8 mm thick MI in the edentulous mandible. In another study using 1.8 mm MI, however, a Periotest mean value of -3.7 was found [7]. In this latter study, it may be that the plunger of the Periotest device was not directed towards the center of the ball, but rather towards the square base, thus leading to reverse oscillations with a smaller amplitude.

The smaller Osstell values are comparable with the measurements of orthodontic MI (2 x 9 mm), which use a special axially screwed Smartpeg [21]. However, the values are about 30–40 % below the values obtained with identical MI and a similar Smartpeg prototype after insertion into the lower leg bones of rabbits [5]. The connection of this smartpeg to the implant appears to be more stable. Its attachment fits the insertion square of the MI perfectly and thus bridges the thin neck that carries the ball. This could explain the relatively high Osstell values of about 60, which were in the range of standard implants. The high scattering of values with a wide interquartile range of the Osstell measurements in the present study is due, among other things, to the occasional uncertain fixation of the Smartpegs by the lateral screw in deep inserted MI. Further studies are needed to validate the Osstell measurements with an optimized Smartpeg for MI with ball attachments.

Sum score	Upper jaw		Lower jaw	
	n	(%)	n	(%)
8	11	(44)	14	(35)
9	2	(8)	9	(22,5)
10	5	(20)	3	(7,5)
11	0	(0)	1	(2,5)
12	1	(4)	5	(12,5)
13	0	(0)	0	(0)
14	2	(8)	3	(7,5)
15	2	(8)	2	(5)
16	1	(4)	3	(7,5)
17	1	(4)	0	(0)
Total	**25**	**(100)**	**40**	**(100)**

Table 7 Sum scores relating to study participant satisfaction with dentures by jaw

The lower stability values of MI compared to conventional implants

are probably due to the dimensional differences. This assumption is supported by the trend towards a higher stability of maxillary MI compared to mandibular ones, as the 2.4 mm MI were mainly used in the maxilla. In addition, the 1.8 mm MI showed higher Periotest and lower ISQ values in the mandible than the 2.1 and 2.4 mm MI. In the upper jaw, only a total of 6 MI with a diameter of 1.8 mm were used.

Patient satisfaction with the prosthetic treatment was chosen as a subjective parameter. The predominantly very good to good values according to the grading system used in German schools in this study are consistent with those of longitudinal studies, where patient satisfaction according to similar criteria (general satisfaction, comfort, stability, hygiene, esthetics, chewing ability) increased noticeably after supporting free-end dentures with posterior implants [4]. In another study on jaws with few residual teeth, after strategic placement of standard diameter implants, not only the subjective chewing ability but also the objectively measured chewing efficiency was improved based on a test diet [31].

Conclusion

In light of the limitations of a retrospective investigation, the use of MI for subsequent stabilization of double crown-retained RPDs is a viable medium-term therapy option in a general dental practice setting. Apart from a few fracture repairs, the aftercare effort was low and no denture had to be renewed. In the event of tooth or implant loss, subsequent MI were frequently used. The stability values based on the Periotest and resonance frequency analysis were lower for MI than for standard diameter implants. The vast majority of patients were very satisfied with the prosthetic treatments. Prospective randomized studies with MI used in this indication are required.

Conflicts of interest:

The first author uses the implant system in dentistry and receives fees for lectures and further training on mini-implants, including from the implant manufacturer. There are no conflicts of interest for the co-authors.

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(Photo: T. Mundt)

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Relevance of mercaptans/ thioethers regulations in therapy decisions in endodontics

Scientific Notification of the German Society of Endodontology and Dental Traumatology

Background

Recently in holistic dentistry, more statements are spread that non-vital teeth and root canal treated teeth release mercaptans and thioethers. These products are expected to cause a postulated direct toxic effect as well as pathological immune reactions. In reference to a study by Jacobi-Gresser et al. [2], it is stated that the laboratory results can be impacted significantly by retreatment of a root canal treatment or a tooth extraction. It is therefore suggested that at allegedly increased laboratory values an extraction of a tooth with a non-vital pulp or that has already been root canal treated is indicated.

Mercaptans are aromatic or aliphatic thioalcohols, give off a very unpleasant odor and result from degradation and the decomposition process of organic material. They naturally act as flavoring substances in milk, cheese, onion, garlic, coffee aroma and nuts. Methanthiole (methyl mercaptan) forms during bacterial protein degradation, amongst others also in human saliva. It is the main cause of halitosis, however, it also exists physiologically in the blood, brain and other human organs. Mercaptans are produced daily during the anaerobic metabolization of intestinal proteins. Increased methyl mercaptan-values in air were found in decompensated liver cirrhosis [6], and in patients with periodontal diseases [5] or gastric ulcers and tumors [4].

Thioethers are sulfur analogues of ethers, mostly insoluble in water and have an extremely unpleasant odor. The dimethyl sulfide results from the decomposition of sulfurous proteins, but is also responsible for the odor and taste of different types of truffles.

Data situation

There is no data on how many mercaptans and thioethers have been released from teeth with a non-vital pulp or that have been root canal treated [1].

Therefore, no statement can be made on if and to what extent teeth with a non-vital pulp contribute to a relevant increase of the physiological concentration of these substances in blood, saliva, air or different organs. It seems highly unlikely that the quantity of theoretically formed substances in a non-vital tooth compared to the physiologically produced quantity have any relevance on daily digestion.

According to a current review on this topic [1] only 2 publications from the dental field are available in PubMed [2, 3]. Therefore methyl mercaptans and thioethers present metabolic products of some bacteria found in root canals during the metabolization of peptides rich in cysteine, glutathione and L-methionine [2]. Methyl mercaptans and thioethers are then expected to stimulate inflammatory cytokines (IL-1; IL-6) from within the tooth. In this retrospective investigation [2] two groups were formed: the experimental group (n = 53 patients) with clinic and/or radiological references to an insufficient root canal treatment as well as (n = 20 patients) with clinical symptoms and/or „radiological findings“ as well as the control group (n = 31 patients) with one tooth that had been successfully treated endodontically at least 5 years prior. The authors came to the following results:

- The patients in the experimental group showed significantly higher stimulated gamma-interferon (IFN-γ) and interleukin-10 (IL-10) values compared to patients of the control group.
- The tumor necrosis factor-alpha (TNF-α) levels were significantly higher in patients of the experimental group compared to the patients in the control group.
- After endodontic retreatment or extraction, IFN-γ- and IL-10 values have decreased significantly and were not significantly increased any further compared to the control group.

Assessment

This described investigation [2] is constantly referenced by advocates of mercaptans/thioethers regulations as scientific justification is supposed to verify the test's specificity. A critical evaluation of the relevant publication allows the following conclusions:

- A root canal treatment performed successfully obviously does not go along with increased mercaptans/ thioethers values. This was definitely confirmed by the control group, which only included patients that had at least one root canal-treated tooth which showed no clinical and radiological findings, and where the root canal

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treatment was performed 5–24 years prior. Therefore, the statement of the current overview of Hülsmann [1] that „Correctly performed root canal treatments are safe and provide no danger for general health" is strongly confirmed by the results of the work.

- Endodontic retreatment reduces – to the same extent as a tooth extraction – the IFN-γ- and IL-10-values to the magnitude how it is found in the control group. An indication for extraction can under no circumstances be derived from the present data.
- The examination can only be used as a limited reference as proof for the tests' specificity due to the insufficient standardisation of the experimental groups. Relevant inclusion and exclusion criteria that are known to go along with higher mercaptan values were not considered in this investigation. There is no evidence on how much an existing halitosis, the periodontal status or liver and gastric diseases were considered during recruitment of patients and distribution into both groups.

Conclusions

The tests for mercaptans/thioethers regulations currently provided are all nonspecific, because the origin of the detected mercaptans and thioethers cannot be unequivocally verified. If a dental cause is responsible for the allegedly increased mercaptans and thioethers values can be concluded under no circumstances. Therefore, these tests are unfit in the decision-making for teeth with non-vital pulps and root canal treatments and in no way justify a recommendation for extraction.

For the Executive Board of the German Society of Endodontology and Dental Traumatology

Prof. Dr. Edgar Schäfer, Münster
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