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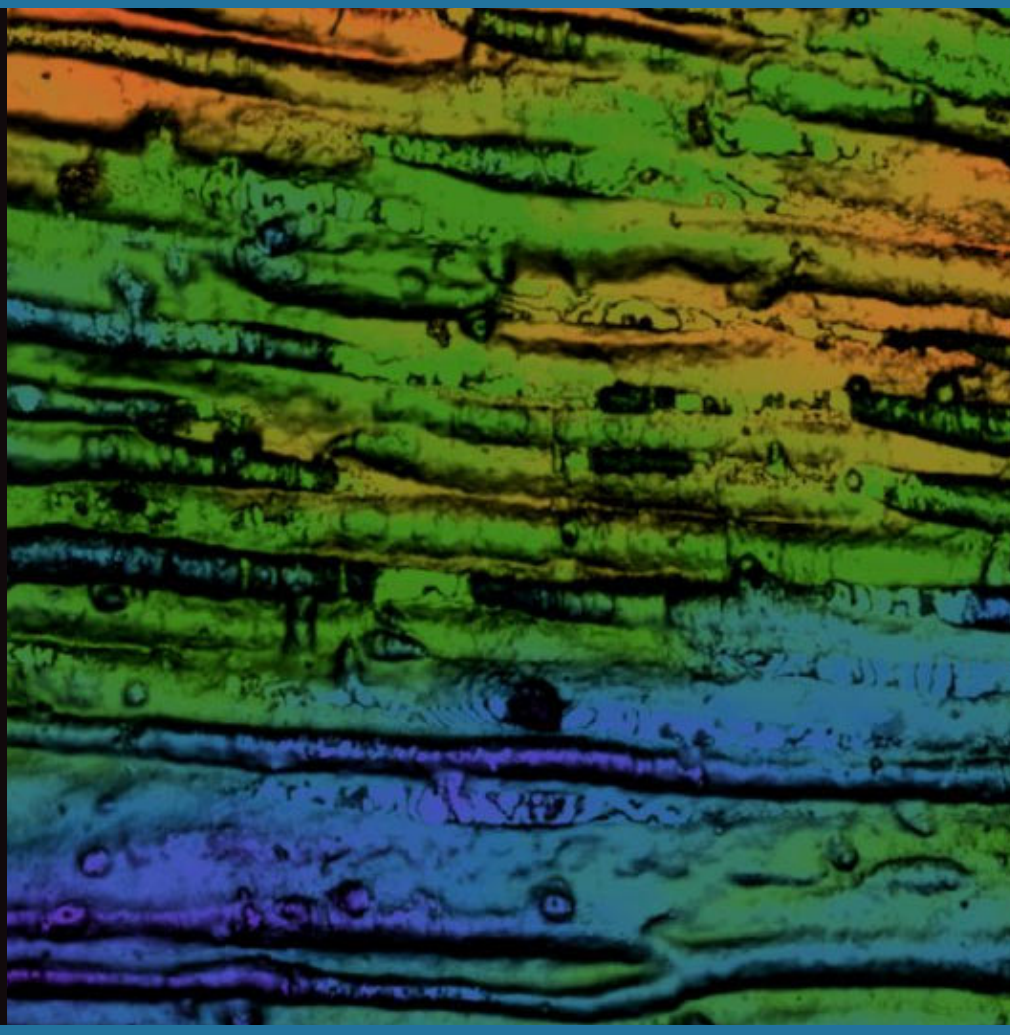
The 10 most popular mistakes in adhesive dentistry

Direct restorative technique in posterior teeth to treat erosion-induced tooth wear

The two-step direct composite restoration (R2 restoration) – a current review

Hermann Wolf (1889–1978) – Versatile DGZMK president and temporary member of the Nazi Party



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PRACTICE

RESEARCH

Title picture: From original article by Frankenberger, Dudek, Krämer, Winter, Roggendorf: The 10 most popular mistakes in adhesive dentistry, p. 111–117. Fig. 7: Sclerotic deposits in the dentinal tubules in the CLSM (3000× magnification). (Photo: R. Frankenberger)
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Roland Frankenberger, Marie-Christine Dudek, Norbert Krämer, Julia Winter, Matthias J. Roggendorf

The 10 most popular mistakes in adhesive dentistry

Abstract

Adhesive dentistry dominates the spectrum of restorative dentistry today. While there have been significant improvements in composites as well as adhesive systems, certain fundamental prerequisites are still essential to be clinically successful. This review highlights the 10 most important aspects of modern adhesive technology based on the "most popular" mistakes in the clinical protocol: Indication, Contamination, Moisture Control, Evaporation, Polymerization, Dentine Sclerosis, MMP Hype, Preparation, Repair and Function. If these 10 points are successfully addressed, the probability of success in the adhesive technique reaches almost 100%.

Keywords: adhesives; contamination; MMPs; resin composites; technique sensitivity

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Introduction

Figures from dental health care research impressively demonstrate that caries prevention has been successful in the Federal Republic of Germany [17]. Compared to 1991, 48% fewer fillings, 33% fewer extractions and 18% fewer endodontic procedures are performed (Fig. 1) [12, 17].

However, these curves are also an indication that the increasing move away from "Extension for Prevention" and the simultaneous focus on minimally invasive restorative measures from around 1992 onwards were important flanking measures that influenced the course of the curves shown. However, it is striking that at the beginning of this paradigm shift, the numbers of root canal fillings did not initially decrease but increased – a possible explanation for this is that the overwhelming majority of colleagues now working with adhesives had never learned fundamental content of adhesive dentistry in their studies. The "endo curve" thus reflects nothing more than an adhesive learning curve at the beginning of the restorative paradigm shift towards composites and ceramics. The fact that every dental adhesive technique is characterized by considerable technique sensitivity and at the same time benefits substantially from the skills of the practitioner has been amply demonstrated [8, 10]. Although the measurable reduction in polymerization shrinkage of composites over the past 30 years, as well as the evolution of adhesive systems, have simplified many daily routine steps today [2, 5, 6, 16], fundamentally important factors of successful adhesive technique still persist and are critical to clinical success. These are highlighted below.

1. Indication: composite first, ceramic second

The mean penetration time of proximal caries through the enamel is 6–8 years [18]. The prioritization of minimally invasive interventions therefore necessarily starts first with arresting, sealing or observing measures to protect healthy tooth structure [19]; minimally invasive excavation is only performed in the second step if these first measures were not successful [19, 23]. Thereafter, the concept of "composite first – ceramic second" is applied, which is based on the chronological preference of direct vs. indirect measures; this does not mean that composite is generally "better" than ceramic, but that composite should always be the first choice, especially in younger patients, in order to preserve a maximum amount of healthy tooth structure for as long as possible [6]. What is important initially is not how long the selected filling material "lasts" but how long the tooth survives in the oral cavity, and for this minimally invasive adhesive strategies are always preferable to aggressive preparations (and excavations) [11, 16, 19, 23, 25]. However, with increasing age, the described preferences shift toward indirect restorations in some cases, especially when adhesively bonded partial crowns provide effective stabilization of residual tooth structure in fractured cusps or those weakened by preexisting restorations (especially amalgam) [6, 11]. Today, crowns on vital teeth are a last resort because, apart from rare exceptions (circular defects), partial crowns are associated with significantly less dentin wounding and involve substantially fewer concomitant endodontic risks [1]. Another exception are root canal treated teeth with traditionally extensive loss of tooth structure – crowns are also a stable alternative for them [24].

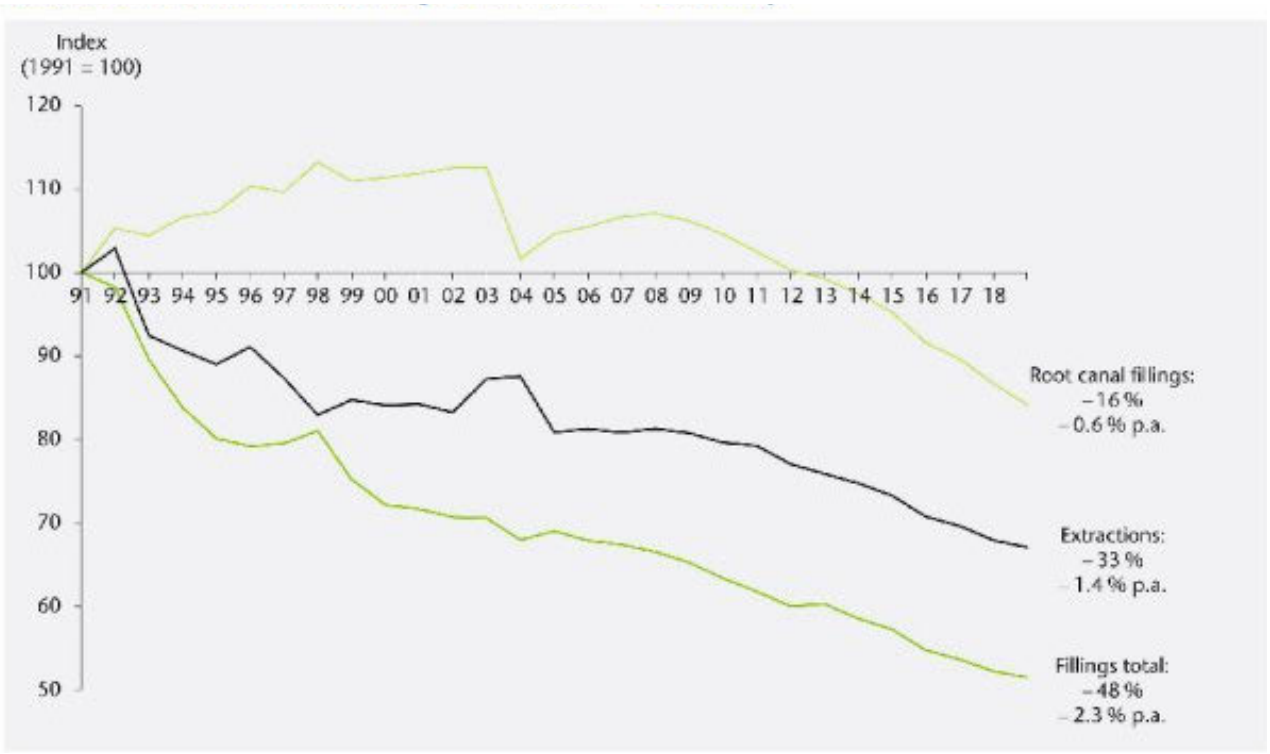

Fig. 1: KZBV Yearbook 2020, p. 101

Fig. 1 Fillings, extractions and root canal fillings in the Federal Republic of Germany since 1991.

2. Contamination

A contamination-free working field is the No. 1 fundamental prerequisite for adhesive techniques, or to put it the other way round: The No. 1 source of error in the adhesive protocol is contamination of the tooth structure substances by saliva, sulcus fluid, blood, detergents, astringents, lip and skin care products [14]. Even cavity disinfection must be mentioned in this context, as it also represents nothing other than contamination of the tooth structure in comparison with conventional, retentive techniques. A more than questionable disinfection of enamel and dentin is contrasted with a potential reduction in adhesion, which should be weighed up critically. In any case, the author of this review has not performed a "cavity toilet" for 25 years, which is supported by his own data on H_2O_2 or CHX (Fig. 2).

Rubber dam is often suggested as an "all-purpose weapon" against contamination. This is not realistic either, because especially in the proximally very deep cavities, where the risk of contamination is greatest, rubber dams are extremely difficult to place. Of course, rubber dam is a very good standard that makes many clinical situations much easier, but in the really tricky situations it is not helpful, because especially subgingivally, techniques such as "proximal box elevation" are much more effective than simply applying the rubber dam [7]. And finally, it should not be forgotten that if the proximal depth of the cavity can be controlled, in the event of bleeding, rubber dams work more easily, more quickly and with less contamination than astringents, which sometimes have devastating effects on dentin adhesion [14].

The most dangerous contamination is definitely that which the practitioner does not notice. Then any adhesive technique will hardly be successful. However, if the contamination is detected, decontamination is usually relatively easy to perform by spraying. The most unfavorable time slot for contamination is directly after application of the adhesive, as long as it has not yet polymerized – then the complete process, including finishing, must be repeated.

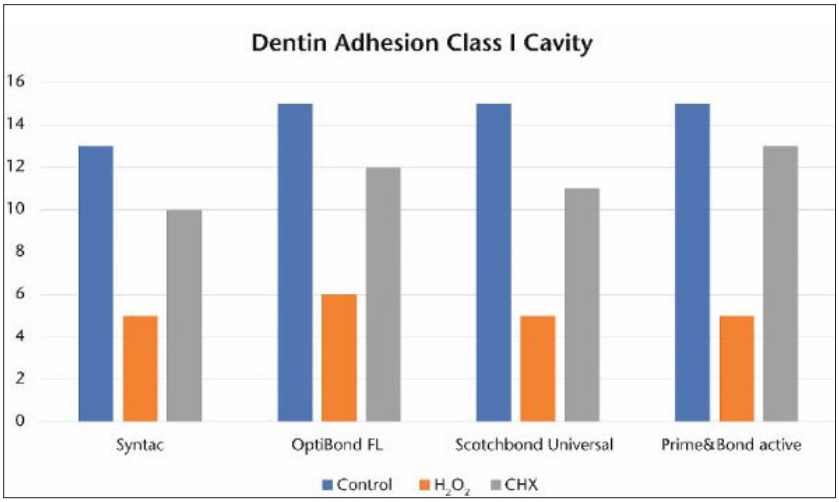

Fig. 2 Influence of "cavity toilet" on dentin adhesion in deep class I cavities (own data).

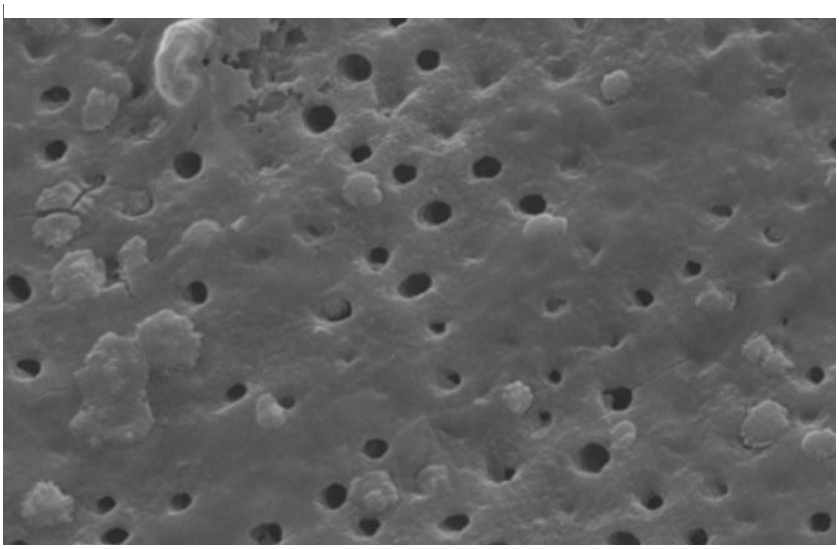

Fig. 3 Dentin surface after "removal" of a eugenol-free temporary cement with pumice powder and brush: almost half of the dentin tubules are still blocked (SEM, 3000× magnification).

Another contamination that should not be underestimated is provisional cement in indirect lab-fabricated restorations. It is difficult to remove completely from the dentin surface (Fig. 3). Therefore, approaches such as "Immediate Dentin Sealing" (IDS) make sense in indirect techniques to prevent dentin contamination [9].

3. Moisture control: why "wet bonding" failed

The term "wet bonding" has dominated adhesive dentistry for almost 30 years. If the collagen network is exposed during phosphoric acid etching of the dentin, it is very sensitive to drying and collapses. If an acetone-based adhesive is then used – as published by Kanca with All-Bond 2 [15] – (the same applies to ethanol-based systems), hybridization of the dentin surface can only succeed if the dentin is either not dried at all after phosphoric acid etching (which is clinically unwise, since one first wants to be convinced that it is free of contamination) or is re-wetted in a second step ("re-wetting"). However, re-wetting has 3 major clinical disadvantages: 1. It is hardly reproducible. 2. It is dependent on the cavity geometry. 3. It causes emotional problems for the practitioner, who actually wants to work "dry" in the adhesive technique. These 3 aspects mean that the

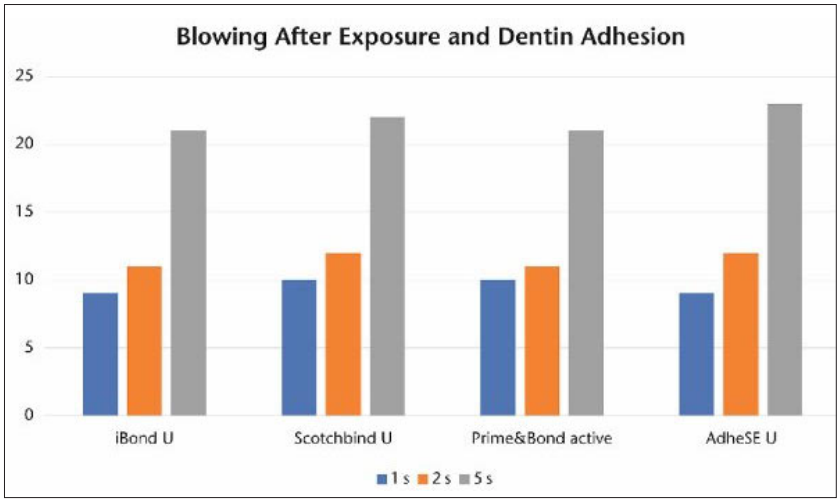

Fig. 4 Only complete blowing or better drying of the (universal) adhesive after the reaction time produces good adhesion to the cavity floor.

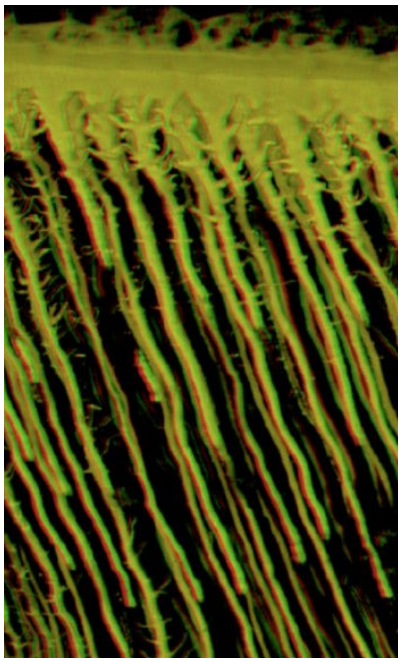

Fig. 5 Penetration of resin tags into the dentin during bonding (CLSM, 2000×).

Fig. 6 Sclerotic dentin in class V.

use of "wet bonding" has never been able to establish itself and will not do so in the future.

An important question to be discussed in the history of adhesive technology is: why were the classic multi-bottle adhesives (Syntac, Opti-Bond FL, ART Bond, EBS Multi, Gluma Solid Bond, Scotchbond Multi-Purpose etc.) so successful in the German market for over 30 years? The answer is simple: because they exhibited virtually no technique sensitivity: as long as the minimum requirement of using the appropriate vials in the correct sequence was met, one could hardly do anything wrong – especially with "wet bonding". All multi-bottle adhesives contained sufficient water to allow the re-wetting process to be carried out almost by itself without any additional step [21]. All further "developments" that followed in the adhesive sector were 100% marketing-driven "bogus simplifications" in the form of a simple reduction in the number of bottles. However, since all of these adhesives for chemical reasons could no longer contain water, the observed rate of postoperative hypersensitivity increased dramatically [3]. In other words: suddenly adhesive systems were technique sensitive – and many disappointed users returned to the multi-bottle adhesives because they had much fewer problems with them.

It was not until the evolution of universal adhesives about 8 years ago that an effective reduction in technique sensitivity was again observed, along with chemical coupling to the dentin [5]. In particular, the traditional advantage of the classic multi-bottle adhesives of functioning on etched as well as unetched dentin was again successfully realized, and in the event of unintentional or intentional dentin etching, the universal adhesives are just as successful thanks to innovative solvent concepts (water addition) even without explicit "re-wetting".

4. Evaporation: please do not "blow gently"

A term often heard in the course of adhesive application is "gently blowing". This expression is incorrect. Primers or adhesive mixtures contain solvents and often also water, and it is therefore not expedient to gently blow adhesives. "Drying" is the better expression in most cases, because only when there is no more liquid flow in the cavity has the solvent successfully evaporated and dentin adhesion to the cavity floor reaches a good level (Fig. 4).

5. Polymerization

After contamination, light curing ranks second among errors in the adhesive technique. The main sources of error are (a) too short polymerization of the adhesive, (b) unintentional swiveling of the light guide and (c) an ill-conceived polymerization protocol for indirect techniques.

To (a): If an averagely thick layer of composite is light-cured for 20 s according to the instructions for use, the same period of time for a 200-fold thinner layer of adhesive seems excessively long. However, this is not a question of polymerization of the adhesive layer at the cavity floor, but of curing of the "resin tags", which penetrate up to 300mm deep into the dentinal tubules – through-curing in the opaque dentin thus requires exactly the specified 10 (self-etch) or 20 (etch&rinse) seconds.

To (b): Tilting the light guide by as little as 10° reduces dentin adhesion to the cavity floor by more than 50%. Unfavorably bent light guides, reduced mouth opening and careless-

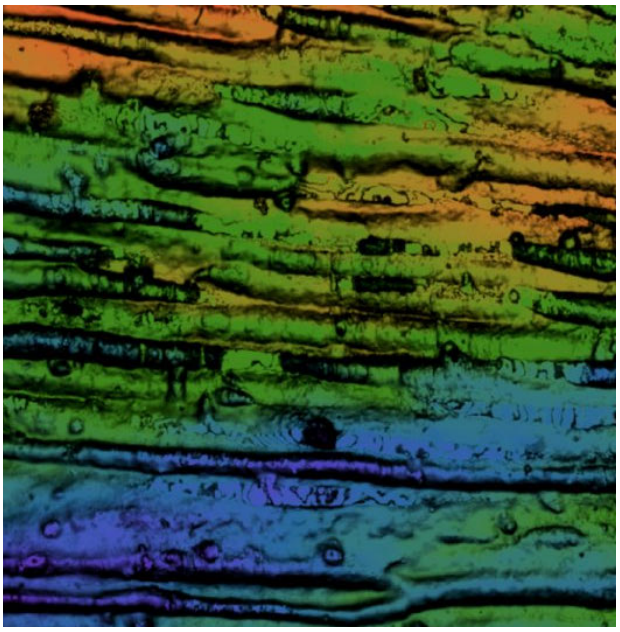

Fig. 7 Sclerotic deposits in the dentinal tubules in the CLSM (3000× magnification).

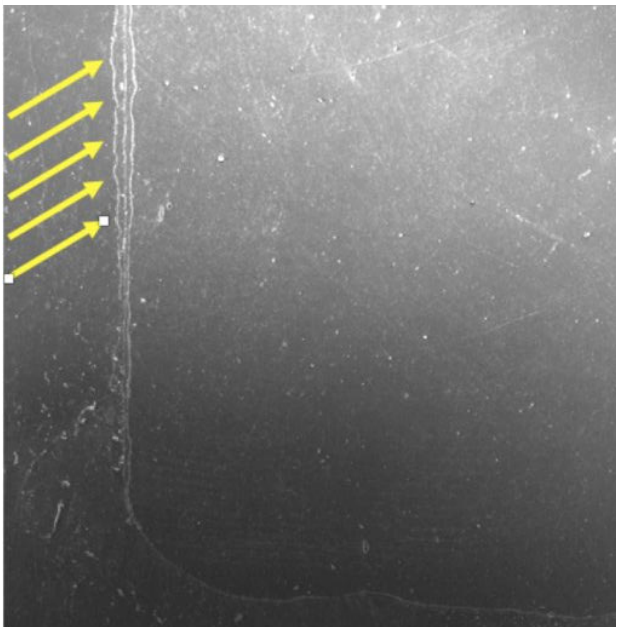

Fig. 8 Paramarginal fractures (arrows) in the absence of proximal enamel bevel (SEM, 100× magnification).

ness of the assistant can easily lead to such and even worse situations [20].

To (c): When adhesively cementing indirect restorations, it should be borne in mind that polymerization of light-curing materials through the ceramic is problematic. An average translucent glass-ceramic absorbs approx. 90% of the light energy at a thickness of 4 mm. Furthermore, it is practically impossible to polymerize an adhesive that has not been polymerized separately through the ceramic and luting composite 300 mm into the dentin [9]. One solution would be, for example, a completely dual-curing luting procedure, but this runs the risk of reducing the time required for clean excess removal. Alternatively, we recommend staying with light-curing materials but applying them with IDS and polymerizing a universal adhesive separately [9].

6. Dentinal sclerosis

Especially in cervical defects, the dentin is often hypermineralized (Figs 5, 6). It has been repeatedly shown that this type of dentin is an unfavorable bonding surface, which is responsible for numerous failures in class V restorations. The most effective approach in adhesive restorative therapy is to remove the hypermineralized surface with a coarse diamond bur; this improves adhesion enormously [22].

7. MMP hype

It has been known from basic science for over a decade that dentin adhesion has many enemies: intrinsic moisture, hydrolysis and enzymatic degradation [13]. Much research has been conducted on the latter in particular, in order to effectively combat a potential "weak link" in adhesive technology [13]. A widely favored agent is chlorhexidine digluconate, which is said to have MMP-inhibiting properties [4, 13].

These studies are scientifically interesting and in part quite innovative, but by no means justify a significant change in the clinical protocol [13]. As described under "contamination", the following still applies: CHX and other cavity disinfection or stabilization measures are primarily nothing more than contamination and are sufficiently suspected of reducing the effectiveness of the adhesive technique (Fig. 2). Therefore, nothing beats a clean, contamination-free cavity.

8. Preparation

Preparation errors can also contribute to the longevity of adhesive restorations. The main errors are (a) the handling of unground enamel, (b) beveling of the enamel margin and (c) too timid preparation geometries in indirect restorations.

To (a): When bonding to unpolished enamel, e.g. for diastema closure, 60 s of enamel etching are recommended. However, this only applies to very young patients, e.g. for diastema bonding after orthodontic treatment. If older patients are bonded to unprepared enamel, a more invasive procedure is recommended in relation to their age. In other words, for a 60-year-old, this may even involve roughening with a diamond bur. Bonding in self-etch mode without phosphoric acid is contraindicated in these cases anyway.

To (b): According to our clinical studies, an enamel margin chamfer is not an indispensable prerequisite for clinical success in composite restorations in the posterior region. However, since paramarginal fractures (so-called "white lines") are formed at the cavity margin without proximal beveling due to the polymerization "pull" (Fig. 8), a narrow beveling in the sense of "edge breaking" is still useful.

To (c): Leaving severely weakened cusps in (laboratory-fabricated) indirect restorations is usually a mistake in the long term (Fig. 9). The same

Fig. 2–9: R. Frankenberger

Fig. 9 Ceramic inlays with preparation margin of weakened cusps at cusp tip level, situation after 8 years.

applies to preparation margins at cusp tip level (regardless of whether direct or indirect restorations are used), as they almost always cause problems later on. In these cases, "minimal invasiveness" is counterproductive [11].

9. Repair

The 5 pillars of minimally invasive tooth preservation are prevention, excavation, preparation, sustainability and reparability. Especially the latter is fundamentally important for true minimal invasiveness in partially defective tooth-colored restorations. Why should a restoration that is 20% defective be 100% renewed and risk the removal of large amounts of healthy tooth structure? Therefore, minimal invasiveness is not possible without conclusive repair concepts.

10. Function

Good function is still a decisive factor for clinical success. Wherever reasonably possible, adhesive restorative measures should be accompanied by the establishment of good function. For example, the restoration of a sufficient anterior canine guidance with minimally invasive composite abutments is standard practice for us before more extensive restoration is carried out in the posterior region.

Conflict of interest

Prof. Frankenberger reports third-party funding from the companies 3M, Dentsply, Ivoclar and Kulzer as well as speaker fees from Dentsply, Kulzer, ADS and Ivoclar. Prof. Krämer discloses speaking engagements for Kulzer, Viadent, Densply, GC Europe and Oral B. In addition, the authors declare that there are no conflicts of interest as defined by the guidelines of the International Committee of Medical Journal Editors.

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Direct restorative technique in posterior teeth to treat erosion-induced tooth wear

Introduction: The restorative reconstruction of lost tooth structure and the restoration of the original vertical bite position in a dentition that has been severely affected by tooth erosion or abrasion always presents the dentist with problems in implementing the therapy. Traditionally, this therapy is carried out with laboratory-produced restaurations, which usually require preparation of the remaining tooth substance and result in high costs for the patient, so that alternative procedures should be considered. It should be emphasized that any restorative work, even minimally invasive, is only indicated in these patients if the preventive approach of inhibiting further loss of tooth structure is successful at the same time.

Treatment method: The following article presents a case study on the use of direct adhesive composite restorations as a possibility for reconstructing an erosively severely altered dentition. Transfer splints, which are fabricated on the basis of individual wax-up models, are used to reconstruct the occlusal surfaces.

Conclusion: The procedure described is a well-studied and proven method for restoring teeth with erosion-induced tooth wear. As with all new procedures, there will be a certain learning curve for the practicing dentist, after which high-quality restorations can be implemented using this technique.

Keywords: adhesive technique; composite; erosion; occlusal vertical dimension; tooth wear

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Figure 1 Dental situation of a 33-year-old patient with trough-shaped erosions at the cusp tips of the premolars and at the canine. Simultaneously, an abrasion facet is present at the cusp tip of the canine tooth.

Figure 2 Situation after filling the trough-shaped defects with flowable composite. The cusp tip of the canine was supplemented with a highly viscous composite.

1. Introduction

Increasingly, scientific studies as well as observations from daily practice are found to address the occurrence of non-caries-related tooth wear. New prevalence data also indicate that this type of tooth wear and the associated therapies are becoming increasingly important in dentistry [10]. In addition to mechanical wear of teeth by foreign bodies (abrasion) or direct tooth-to-tooth contact (attrition), chemical attacks (erosions) are mainly responsible for the observed tooth wear. The differentiated view of erosions has led to the term "erosive tooth wear" being used in recent scientific literature. This is understood to be the sum of irreversible (macroscopic) loss of tooth structure and (microscopic) softening or demineralization present at the tooth surface, triggered by mostly acidic agents without the involvement of microorganisms [22]. In the following article, the more commonly known term erosion is used partly synonymously.

The surfaces of enamel or dentin that have been demineralized by acid attack are particularly susceptible to mechanical stress, which leads to an acceleration of tooth structure loss. Furthermore, continuous attack on the dentin often leads to painful tooth hypersensitivity. However, other problems, such as difficulties with food grinding and speech, as well as headaches and jaw pain, can also severely affect the quality of life, especially the oral-health-related quality of life (OHRQoL) of those affected. In addition, poor aesthetic appearance of the anterior teeth associated with tooth wear can significantly increase the individual suffering of affected patients [1, 17].

1.1 Restorative therapy considerations

Restorative treatment of erosive tooth wear should always be accompanied by preventive measures to avoid further tooth structure loss. In principle, it should first be noted that physiological loss of tooth structure occurs in the course of life in all individuals and does not necessarily require restorative therapy. However, restorative therapy of such affected dentitions may become necessary for various reasons and to varying degrees. Reasons for restorative therapy may be: a loss of hard substance that is not commensurate with age or progressive loss of hard substance with extensively exposed dentin areas, the presence of pain, limited masticatory function, a threat to the integrity of the tooth or pulp, or compromised esthetics [13].

In the case of smaller, often trough-shaped dentin defects, it is usually sufficient to selectively fill and seal these surfaces with flowable composite materials to prevent further progression of the defect (Figs. 1 and 2).

For more extensive defects, often involving the entire dentition, restorative therapy ranges from direct adhesive composite restorations to indirect restorations using composite or ceramic workpieces [2, 4, 7, 12, 15, 21, 23, 24, 33]. The larger the defects, the more dentists tend to use indirect restorative methods [11]. The longest follow-ups for total restoration of dentitions with pronounced tooth structure loss are based on studies of up to eleven years each [8] for ceramic restorations and for direct composite restorations [30]. Both the long-term results obtained in these very long follow-up studies and the overall long-term results available are promising in the majority of the studies, despite the challenging nature of the problem. A conclusive assessment of which restorative material is most suitable under these multiple influences is currently not available [18]. A direct comparative study including different material types is not available.

1.2 Direct restorations

The advanced loss of tooth structure, which is often associated with the loss of vertical occlusal height, presents the practitioner with a particularly difficult task. It is also important to bear in mind that, in addition to the chemical-erosive component of tooth wear, mechanical influences and parafunctions such as existing bruxism can also have a major impact on tooth wear and the future stress on restorations. Therefore, it is predominantly recommended to protect

Figure 3 Occlusal view of the initial situation of the patient described in the case report.

Figure 4 Anterior situation of the patient.

Figure 5 Wax-up of the posterior teeth with omission of the last molar, which was later built up freehand. The "drainage grooves" modeled buccally and lingually with wax at the time are no longer provided by the authors today.

the often extensive restorations during the night by occlusal protective splints against the effects of nighttime, uncontrolled teeth grinding.

Continuous improvements in the material science of dental composite materials and the desire of patients for forms of therapy that are gentle on the tooth substance and financially affordable have led to a steady expansion of the range of indications for direct composite restorations. One advantage of direct restorations with composites is that composites allow a purely defect-oriented approach without having to sacrifice healthy tooth structure by additional preparation measures. In principle, this procedure is also possible with indirect approaches using ceramics or laboratory-processed composites in so-called "non-prep restorations", but it requires extraordinary skill on the part of the practitioner and dental technician and has therefore not been able to gain widespread acceptance to date.

The authors of this article have extensive experience with the direct restoration technique using composites to treat non-caries related tooth structure loss. Therefore, the following article will also deal with this approach and in particular with restorations in the posterior region. However, it should be emphasized that, as mentioned above, other techniques or materials can also be used to address these complex situations.

Preferably, nanohybrid composites or pure nanofiller composites are used. Relatively low occlusal wear and good physicomechanical properties have been demonstrated for this class of materials [9, 19].

The use of direct composite restorations for bite elevation has not been widespread to date, which can be explained, among other things, by the considerable time required and the difficulty of designing an accurate occlusal morphology when teeth are built up freehand. In order to circumvent the problems of the freehand technique and to simplify the readjustment of the vertical dimension, various methods have been presented and further developed with which an ideal occlusion, initially individually waxed up in the dental laboratory, can be transferred to the patient's mouth with the aid of transfer splints [3, 25, 32] or silicone stamps (stamp technique) [20]. This can also be used to fabricate provisional occlusal abutments in order to test a new occlusal position planned at a later date with ceramic workpieces in advance over a desired observation period [16]. A survey of dentists in private practice who have already carried out direct bite height reconstructions with composite in their practices with the aid of transfer splints showed that the technical implementation also works well and efficiently under practice conditions [28].

2. Case presentation

In the following, the technique of direct bite height reconstruction with composite using transfer splints is explained on the basis of a patient case with erosion-related tooth damage.

2.1 Initial situation

The patient, who was 31 years old at the time of the initial examination, stated that she had suffered from bulimia in adolescence. At the time of the initial examination, the disease had been successfully treated for several years without any relapses into the old behavioral pattern of the eating disorder. The patient's medical history was inconspicuous. Clinical

examination revealed no evidence of myofunctional complaints, and periodontal conditions were stable on all teeth without the presence of relevant probing depths or bleeding. Oral hygiene was excellent.

As shown in Figure 3, the patient had advanced erosive defects on all teeth, mostly with dentin involvement. In the posterior region, mainly the occlusal surfaces were affected. The maxillary anterior teeth showed shortened dental crowns as well as palatal and labial significant loss of tooth structure (Fig. 4). The patient was particularly disturbed by the appearance of her maxillary anterior teeth. In addition, the posterior teeth showed disturbing hypersensitivity. The patient was informed in detail about various treatment options and opted for a restoration with direct adhesive composite restorations, as she wanted the procedure to be as gentle on the teeth as possible.

For all restorations, including the subsequently fabricated anterior restorations, the nano-filler composite Filtek Supreme XTE (3M, Neuss, Germany) was used in combination with the three-step etch-and-rinse adhesive Optibond FL (Kerr, Bioggio, Switzerland).

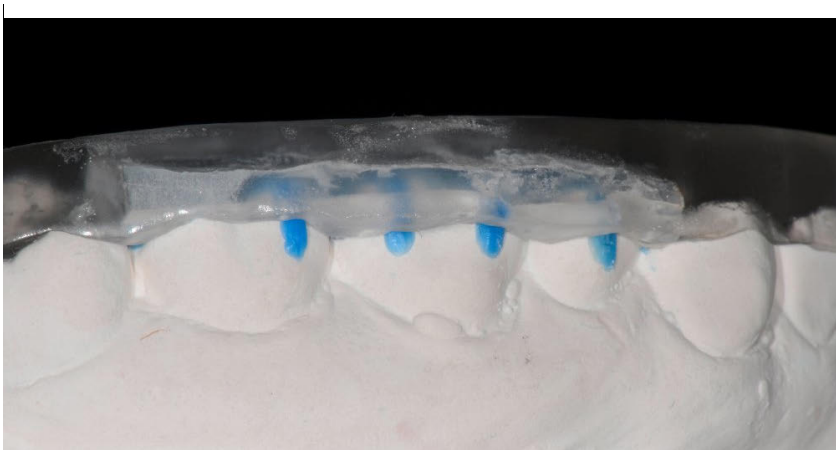

Figure 6 Wax-up model with transfer splint. In the vertical direction, the splint is extended as short as possible. This allows the composite filled in the splint to flow out after the splint has been pressed onto the tooth row.

Figure 7 Isolation of the adjacent teeth with Teflon tape.

2.2 Preparations

In the approach described below, caries lesions or buccal or palatal/lingual tooth structure defects are usually treated in a first step using conventional techniques. This is usually followed by the fabrication of the auxiliary splints mentioned below and the restoration of the occlusal surfaces or incisal edges. These first steps in the simplification of the form considerably facilitate later, sometimes demanding work steps, e.g. the application of the rubber dam and the concentrated execution of the restorations, which are then exclusively occlusal and incisal. In the case described, with the exception of the defects on the palatal surfaces of the maxillary anterior teeth, no such defects were present that would have necessitated such a two-stage procedure for the posterior region.

From the initial situation, alginate impressions of the maxilla and mandible were taken and a bite registration in habitual intercuspidation was performed. In the dental laboratory, the ideal occlusion was waxed up by approximately 2 mm with the anterior teeth blocked. During the fabrication of the wax-up models, the anterior teeth and the posterior portions of the terminal molars were not built up (Fig. 5). On these models, two translucent transfer splints each were fabricated from transparent acrylic for the maxilla and the mandible, which were relined with a transparent silicone-based bite registration material (Fig. 6). The non-waxed areas later allow stable support of the splints in the patient's mouth.

2.3 Isolation of the adjacent teeth and adhesive pretreatment

After placing rubber dams, the adjacent teeth of the teeth to be initially restored were isolated with Teflon tape to prevent interdental entanglement (Fig. 7). Existing composite surfaces of the teeth were roughened with an intraoral sandblaster with 50 µm aluminum oxide powder (Hager & Werken, Duisburg, Germany) in accordance with the procedure for corrective fillings. The eroded or sclerosed dentin surfaces were refreshed with a fine-grain diamond before application of the etch-and-rinse adhesive system. Studies have shown that such pretreatment significantly improves the bond strength to erosively or sclerotically altered dentin [5, 6]. Similarly, sandblasting the dentin at a pressure >5 bar with aluminum particles >30 µm can have a positive effect on the bond strength of adhesives [14].

2.4 Build-up of the occlusal surfaces

With the aid of the transfer splints, bite elevation was performed in the

Figure 8 Situation after completion of the occlusal composite restorations.

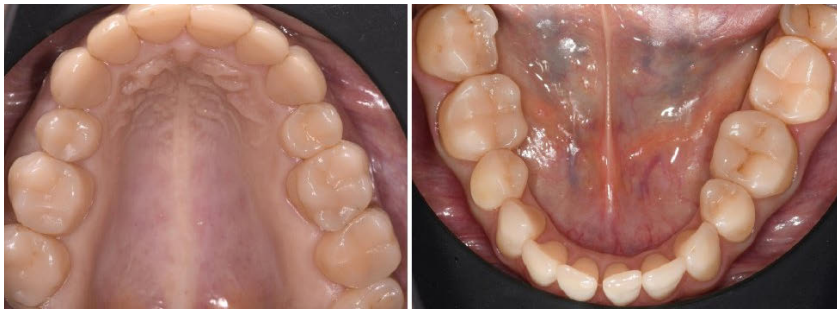

Figure 9 Situation eight years after insertion of the composite abutments with continued satisfactory results.

Fig. 1–10: T. Attin

Figure 10 Labial view of the anterior teeth restored with direct composite.

posterior region with direct occlusal composite build-ups. The highly viscous composite material used for the restoration was filled into the splint in a quantity corresponding to the missing tooth structure and heated to 68 °C for 5 min under light protection on a heating plate (Calset, AdDent, Danbury, USA). Heating reduces the viscosity of the composite material, thus facilitating the placement of the splint on the dentition. Laboratory tests have shown that heating the composite does not affect the material properties [31]. The short vertical design of the splints allows excess material to flow off well when the splint is placed and most of it can already be removed before polymerization. Before applying the filled splint, a thin layer of flowable composite (Filtek Flow, 3M) was applied to the tooth surfaces without curing it.

The splint was placed on the dentition with pressure. After removing the accessible excess, the composite material was light-polymerized through the transparent splint. The light polymerization was initially performed only briefly for approx. 3–5 s, so that after removal of the splint any remaining excess of the not yet fully cured composite could be easily removed with a scalpel. Subsequently, a second (long) light polymerization was performed with simultaneous cooling of the teeth for 60 s per tooth. It has been proven that such a two-phase polymerization does not negatively influence the curing of the materials [29].

The difficult-to-access proximal surfaces of the composite abutments were finished and smoothed with single-sided diamond files in a reciprocating angle piece (Swingle, Intensiv, Grancia, Switzerland). Subsequently, the now already restored teeth were isolated with Teflon tape and the remaining posterior teeth were built up as described above and finally polished. The areas not included in the wax-up and the splint were finally reconstructed freehand with composite (Fig. 8). The bite elevation in the posterior region created sufficient space for a subsequent reconstruction of the anterior teeth, which was then fabricated. To protect the restorations from nighttime grinding, the patient was given a grinding splint made of soft acrylic after completion of all restorations. The patient has regular recall appointments. Apart from minor maintenance work, e.g. occasional polishing of the margins of the restorations, no further reworking of the restorations was required during the follow-up visits, which have now lasted eight years. Moreover, the images taken after eight years of wear show only minor signs of wear on the restorations (Figs. 9 and 10).

3. Discussion and concluding remarks

The procedure described is now a well-studied and proven method for restoring teeth with erosion-induced loss of tooth structure. Points to be discussed about the procedure are included in the above text at the appropriate points and should not be repeated here.

In conclusion, however, it is important to point out that preventive measures and checks must be carried out to stop further acid-induced damage, not only because clinical observations have shown that the adhesive bond of restorations is subjected to a great deal of additional stress if strong acid attacks continue,

which often seems to contribute to the failure (loss) of the complete restoration. A conclusive explanation for this phenomenon is currently not available. However, it is conceivable that the repeated acid attacks degrade the hybrid layer of the adhesive bond of the restoration, first at the restoration margins and then gradually undermining it.

With regard to the frequent discussion about the most suitable restorative material for the cases described above, it should be noted that a randomised clinical trial with a split-mouth design is currently being completed with the cooperation of the authors. The long-term follow-up studies will provide further information on how the procedure presented here compares to the use of indirectly fabricated ceramic restorations.

Note

This original paper contains some modified minor text passages from previous publications of the authors [3, 26, 27, 34].

Conflict of interest

Prof. Attin is a consultant to the company Hager & Werken mentioned in the text. In addition, the authors declare that there are no conflicts of interest as defined by the guidelines of the International Committee of Medical Journal Editors.

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Clara Muscholl, Diana Wolff

The two-step direct composite restoration (R2 restoration) – a current review

Introduction: The treatment of subgingival cavities with direct composite restorations is a challenge in everyday dental practice. Many difficulties must be overcome in the course of treatment, including bleeding and tissue management, a flawless adhesive technique, step-free and margin-free application of the restorative material as well as anatomically correct crown shaping and contact area design. Each individual treatment step in the course of the restorative process is crucial for the long-term clinical success of the restoration.

Treatment methods: The R2 restorations divide this complex restorative process into two steps. In the first restorative step, only the deep subgingival portion of the cavity is restored, and the cavity floor is elevated to a paragingival or slightly supragingival level. In the second restorative step, the tooth's crown is reconstructed, and the contact area facing the neighboring tooth is designed. The two restorative steps require the use of various tools and techniques.

Result: The methodical, step-by-step approach makes the entire treatment process more manageable and easier to perform.

Conclusion: Teeth with extensive tooth substance loss as a result of deep subgingival cavities can be restored safely, predictably and with a good prognosis by means of the R2 restorations. Structured follow-up care which focuses on sufficient cleaning of the proximal area is essential for long-term success.

Keywords: adhesives; contamination; MMPs; resin composites; technique sensitivity

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1. Introduction

The clinical application of the two-step direct composite restoration (R2 restoration) was first presented in 2014 [12, 14, 32], and since then, it has been critically discussed and further developed. The R2 restoration differs from the proximal box elevation (PBE) [11, 18, 29], cervical margin relocation (CMR) or deep margin elevation (DME) [6], margin elevation technique [36] or sandwich technique [5, 8], in that composite is applied directly throughout the procedure, without the use of laboratory fabricated restorations. It is beyond question that the treatment of subgingival cavities must be managed and solved adequately in daily dental practice. In this regard, due to the further development of methods and materials as well as the increasing expertise in this field, patient demands can be addressed with increasingly more tooth preservation solutions. However, the requirements of adhesive systems and dental materials with respect to materials science and processing technology are in conflict with the requirements of the surrounding soft tissues when restoring critical subgingival areas [28]; an example of this is the need for irritation-free restoration margins and biocompatibility of the materials. The R2 restoration is a comprehensive treatment approach which helps overcome many of the difficulties encountered during restorative treatment. In this manner, the challenging task of reconstructing extensive and deep subgingival defects is broken down into manageable steps.

1.1 R2 restoration and the biological width

Special attention must be paid to the so-called "biological width", which represents the minimum distance between the marginal restoration edge and the bone, when restoring deep subgingival defects. As a rule, it is important not to fall below this distance in order to avoid irritation or inflammation of the periodontium. The concept of the biological width is based on the observations of Gargiulo et al. in 1961, who found an average gingival sulcus dimension of 0.69 mm, epithelial attachment of 0.97 mm, and supraalveolar-fiber apparatus of 1.07 mm [15]. These findings are considered to be the basis for the assumption that there is a physiological distance of 3 mm between the limbus alveolaris and the cementoenamel junction in healthy teeth [26]. However, the dimension of the biological width may differ depending on the position of the tooth as well as the tooth surface and the biotype of the gingiva and alveolar bone [28, 33]. Moreover, the dimensions of the dentogingival complex do not appear to be constant [30]. Nevertheless, a distance of 3 mm between the restoration margin and the limbus alveolaris is still a general requirement in order to prevent inflammatory reactions of the periodontium [16, 19, 24]. Surgical crown lengthening or orthodontic extrusion of teeth is recommended if the biological width falls short of 3 mm during the course of restorative treatment [3, 9, 25]. Deep subgingival restorations inevitably affect the area of the biological width. After the introduction of the R2 restoration and its classification in the context of biological width [14], there have been and continue to be controversial views on this subject. Clinically, it has been shown that periodontal conditions free of inflammation can be observed after treatment with composite restorations which violate the biologic width [13]. In this regard, it can be assumed that composite restoration margins which are smooth and free of excess material in the subgingival area can be tolerated by the periodontium without causing inflammation. The exact relationship has not been fully elucidated until now and are subject to further scientific investigation.

1.2 Classification of the R2 restoration based on current literature

Most of the recently published studies on deep restorations, which cross the cementoenamel junction, are in vitro studies that compare the marginal adaptation between indirect restorations, with and without box elevation [11, 23, 29, 31, 36]. The majority of these studies report no differences in marginal quality between cemented indirect restorations, which extend subgingivally, and direct restorations with a previous box elevation. Moreover, it has been demonstrated that composite material (flowable or viscous) can be applied in multiple layers [11, 29] or in one layer [36] for box elevation.

To date, only a few clinical studies are available. In addition to a systematic review from 2015 [18] and a literature review from 2018 [17], three other clinical studies can be found. In 2018, Ferrari et al. published their results from a 12-month, controlled study which investigated the impact of CMR on periodontal health [10]. The study compared 35 subjects who had received either a partial ceramic crown with CMR (test) or without CMR (control). The restoration margins of the CMR or the partial ceramic crown were placed within the range of the biological width. At the beginning, the subjects received a single oral hygiene instruction session and professional tooth cleaning. Clinical inflammatory parameters (gingival bleeding index, bleeding on probing, and probing depths) were measured at the start and after 12 months. The study did not provide information on the allocation of the subjects to the respective groups; rather, it only reported the initial gingival and plaque scores as well as bleeding on probing in all subjects at the beginning. After 12 months, the test group (partial ceramic crown with CMR) showed significantly more bleeding on probing ($p = 0.010$), whereas the gingival and plaque scores tended to be slightly higher in the test group than in the control group, but these values were not significantly different. The authors conclude that the procedure is rather technique-sensitive.

In a second clinical study which investigated the response of periodontal tissue to subgingival composite restorations, Bertoldi et al. included 29 subjects with subgingival carious defects who underwent restorative root canal treatment and were scheduled for subsequent crown restoration. CMRs were performed on the teeth, whereby only cases that were at least 3 mm from the alveolar bone were included, and thus, not within the range of the biological width. Over a 3-month observation period

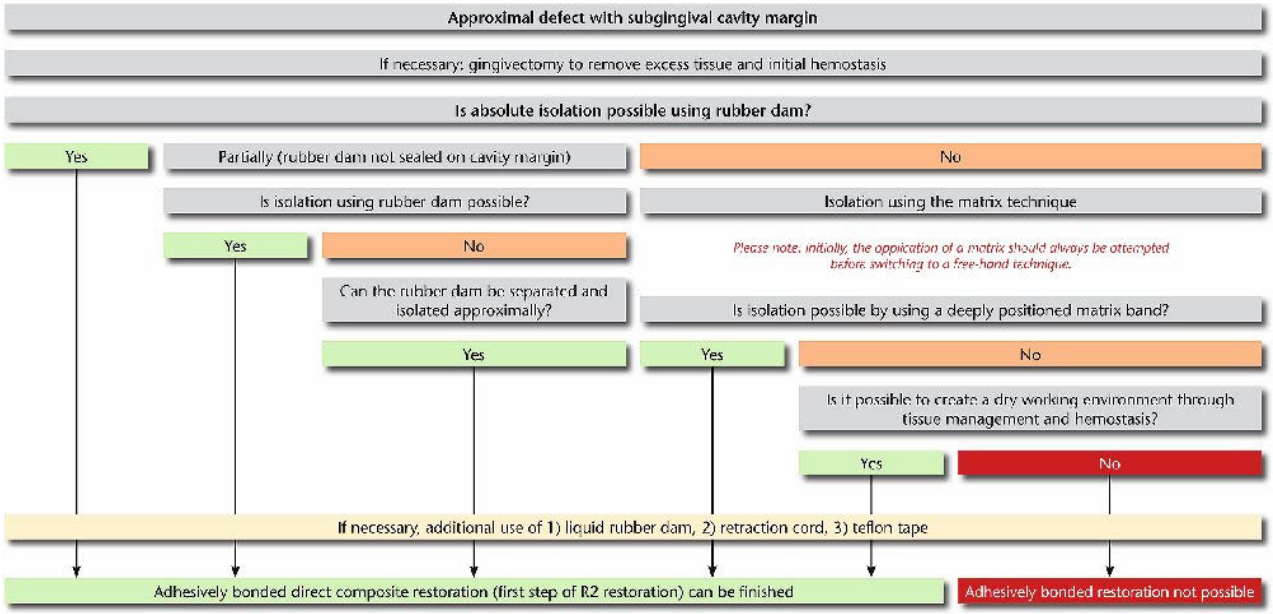

Figure 1 Flow chart illustrating treatment planning for approximal defects with subgingival margins.

which included a rigorous supportive periodontal therapy (SPT) program, a significant decrease in plaque index, bleeding on probing and probing depths was recorded. Histological specimens which were collected after 3 months showed no indication of inflammatory processes in the CMR area in comparison to control sites on the healthy side of the teeth [1]. The authors concluded that subgingival composite restorations are compatible with gingival health in relation to CMR, given that the biological width is not violated and rigorous SPT is implemented.

The two studies differ significantly in terms of the frequency and implementation of the SPT program. In the study by Ferrari et al., oral hygiene education and professional tooth cleaning were performed only once at the beginning; subsequently, a very significant increase in plaque and gingival indices and bleeding on probing was observed in both groups, with more pronounced effects seen in the test group with CMR. This indicates that subgingivally positioned composite restorations require adequate cleaning, which must be addressed as part of oral hygiene education preoperatively and as carefully planned follow-up care postoperatively.

Figure 2 Deep subgingival cavity at tooth 26. A matrix band is applied (Slick Bands Margin Elevation Matrix Bands, Garrison Dental Solutions) and teflon tape is used for mesial and distobuccal isolation.

Another clinical study investigated 197 partial indirect composite restorations with DME in 120 subjects. The mean follow-up time was 57.7 months. In the cohort, 8 failures were observed, 5 of which were due to secondary caries. The overall survival rate of the restorations was 95.5% (standard deviation 2.9%) after 10 years or longer. Periodontal parameters were not recorded in the study, but quality criteria (USPHS criteria) at the baseline examination and at the last recall were reported. In this case, there was a deterioration in all categories. The authors of the study considered this to be a "normal phenomenon" of aging, as they saw more pronounced manifestations in the older restorations than in the younger ones. In this context, they pointed out that periodontal health (as a criterion of the USPHS analysis) could have deteriorated as a consequence of the biological width violation. However, this was notice-

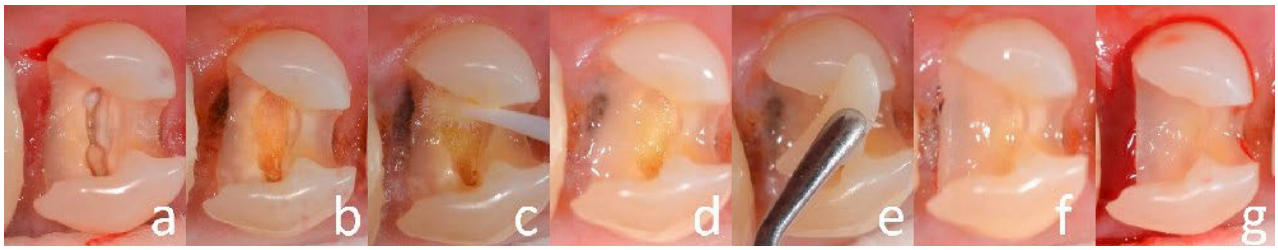

Figure 3 First step of the R2 restoration using the free-hand technique.
(a) Initial situation of distal subgingival cavity at tooth 14 and accompanying root canal treatment that was performed in parallel; **(b)** after successful hemostasis with ferric sulfate solution, the working field is dry; **(c)** after phosphoric acid etching, rinsing and drying, the adhesive system is applied and air drying and light curing is performed; **(d)** application of a small amount of flowable composite material onto the distal cavity floor, WITHOUT light curing; **(e)** application of viscous restorative composite onto the flowable material; **(f)** modeling of both the flowable and viscous composite material in parallel and removal of excess material; **(g)** after light curing, careful approximal finishing is performed, during which renewed bleeding is induced.

ably not the case. They concluded that indirect restorations with DME showed good survival rates in the observation period of up to 12 years [2].

Unpublished data from the working group of the authors of the present paper show promising results on the clinical quality of R2 restorations so far. Compared to control teeth, the plaque index, gingival bleeding index, and bleeding on probing were not significantly increased after an average of 2.7 years (min. 0.0 to max. 9.3 years) at 63 deep subgingival R2 restorations, which were located in range of the biological width. In contrast to the previously mentioned studies, subjects with previous periodontitis were not excluded from this study. The periodontium in this patient group showed no clinical signs of inflammatory processes at the R2 restorations. The subjects received supportive periodontal follow-up care. The evaluation also revealed that the regular use of interdental brushes during home-based oral hygiene leads to a significantly reduced tendency of the gingiva to bleed.

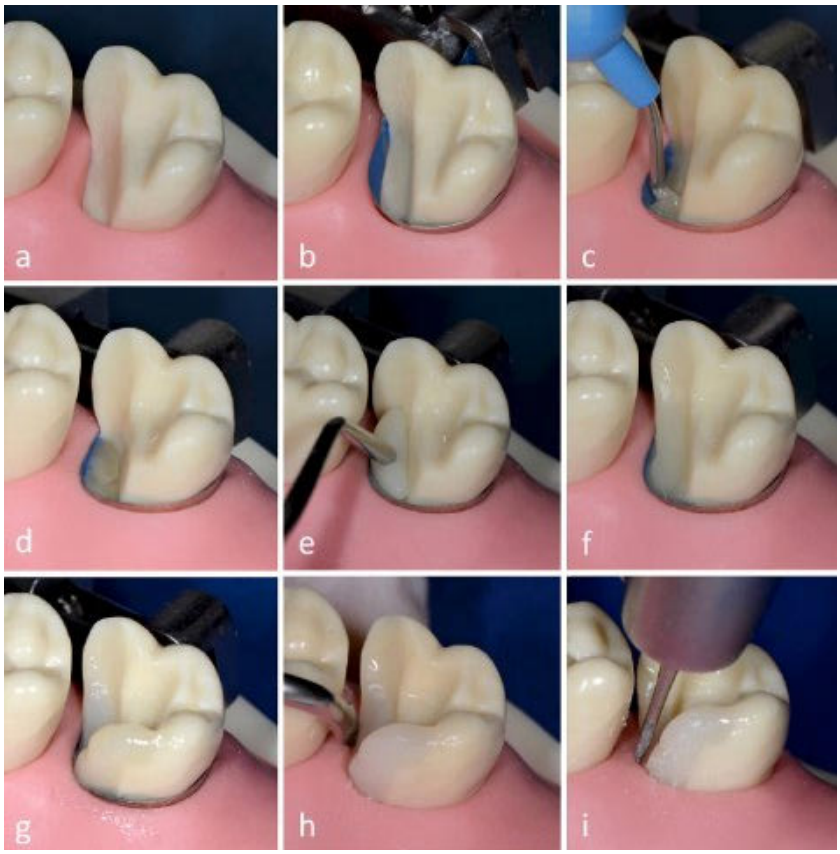

Figure 4 Step-by-step procedure of the first phase of the R2 restoration at model tooth 27.
(a) Initial situation of a cavity extending 2–3 mm subgingivally; **(b)** the matrix band is applied subgingivally (Slick Bands Margin Elevation Matrix Bands, Garrison Dental Solutions); **(c)** introduction of flowable composite after conditioning of the cavity with phosphoric acid and application of the adhesive system; **(d)** flowable composite is applied WITHOUT light curing; **(e)** restorative composite is placed on the uncured flowable material; **(f)** approximal step is elevated using composite; **(g)** free-hand build-up of the missing mesiopalatal enamel wall with restorative composite; **(h)** smoothening of the restoration margins with single-sided diamond-coated sonic tips (Sonicflex Stripping, Shaping No. 73, 74, 75, 76, KaVo); **(i)** removal of excess material using a flame-shaped diamond bur (No. 8889415 010, Komet).

2. Treatment with R2 restorations

2.1 Treatment planning

Decision-making and treatment planning is complex when dealing with extensive subgingival defects. The course of treatment can be assessed in advance based on the clinical findings and the X-ray [22, 34]. However, due to the complex clinical situations that are encountered during treatment, adjustments to the treatment strategy or the techniques and materials are also to be expected. In this respect, it is wise to outline a "best-case" and a "worst-case" treatment scenario for the patient. The former is based on the assessment of whether, depending on the remaining tooth substance, a rubber dam, partial iso-

lation, etc. can be applied in order to facilitate treatment with an adhesive restoration. The "worst-case" scenario should reflect the fact that the treatment attempt may fail, and thus may require additional measures such as surgical crown lengthening, orthodontic extrusion or extraction. An emphasis should be placed on explaining to patients that the treatment procedure is multifaceted and that the outcome depends on numerous factors which cannot (always) be fully assessed in advance.

2.2 Hemostasis and tissue management

The flow chart presented for approximal subgingival defects can be used to plan the procedure and prepare for the treatment (Fig. 1). Initially, the defect should be completely exposed. This includes the cleaning of the tooth and neighboring teeth, the removal of any disturbing soft tissue by means of gingivectomy and, if necessary, performing initial hemostasis. Inflamed tissue is frequently found in the area bordering the cavity. This requires hemostasis with effective hemostatic agents; preparations based on aluminum chloride, ferric sulfate or ferric subsulfate are suitable for this purpose. It is extremely important that the preparations are actively embedded into the surface of the soft tissue. In order to adequately stop bleeding and keep the blood vessels constricted during the adhesive procedure, they must be well sealed. Hemostasis is continued by actively rubbing or massaging gel or solution into the bleeding gingival surface. At the same time, excess is aspirated. If no more brownish precipitate/coagulum forms after a certain time, it can be assumed that the bleeding has stopped. The time required for this may vary (1–3 min.). The area is then rinsed vigorously with air-water spray. This is also the test to determine if hemostasis has been successful. If bleeding occurs again, hemostasis must be repeated. Common active ingredients found in commercial hemostatic agents include aluminum chloride and ferric sulfate. In addition to the hemostatic effect on soft tissues, these agents can also alter the tooth hard substance surface that comes in contact with them. Consequently, the residues, precipitates and surface changes can have a marked effect on subsequent adhesive bonding. Reference may be made at this point to a recent review on this subject [4]. Literature on this topic is inconclusive, as the extent to which adhesive forces are affected varies depending on the type of adhesive used and active substance. However, in order to ensure safe adhesion after the application of hemostatic agents, the use of an etch-and-rinse adhesive system is recommended according to current literature. This is because a cleaning effect on dentin and enamel is achieved by means of phosphoric acid etching, thus reducing the effect of the hemostatic agent on the adhesive forces and/or marginal qualities.

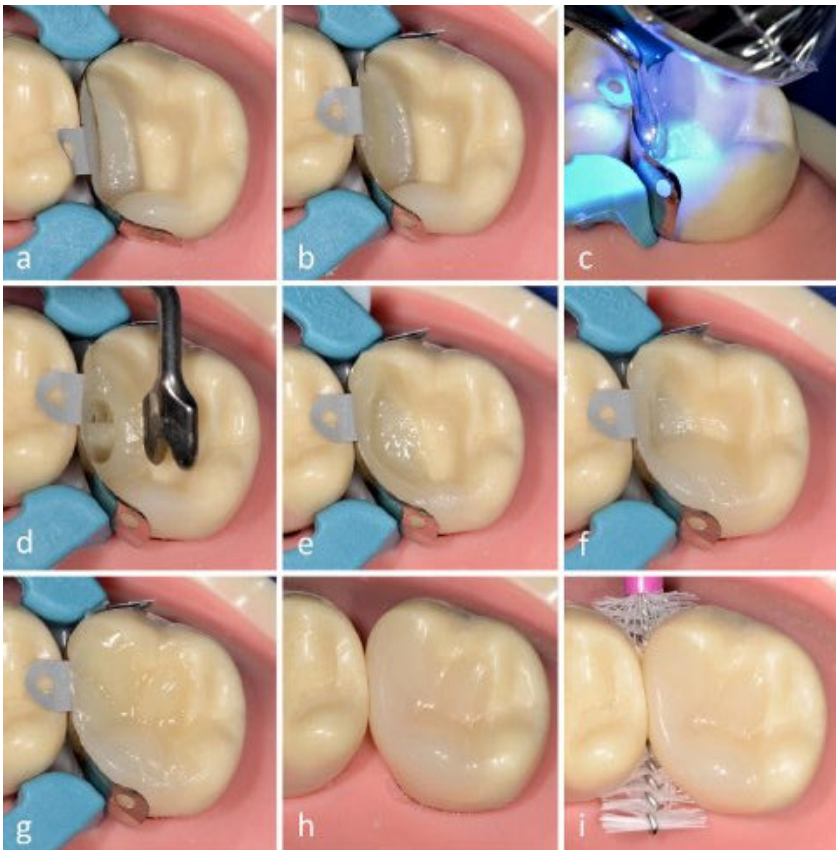

Figure 5 Step-by-step procedure of the second phase of the R2 restoration at model tooth 27.

(a) Application of an anatomically pre-contoured matrix band with a wedge and a separation ring (Palodent V3 partial matrix system, Dentsply Sirona); **(b)** after phosphoric acid etching and application of an adhesive system, flowable composite is applied WITHOUT light curing, followed by restorative composite; **(c)** pressing of the matrix band onto the adjacent tooth with an approximal contact former (Easy Contact Point hand instruments for molars, Zepf Dental) and light curing; **(d)** the polymerized composite adapts the matrix band to the adjacent tooth via a bar which is formed at the level of the contact point; **(e)** build-up of the approximal enamel wall with restorative composite; **(f)** finishing of the restoration with restorative composite using the oblique layering technique; **(g)** modeling of the fissure morphology; **(h)** finished and polished composite restoration; **(i)** fitting of an interdental brush to ensure hygiene compliance.

2.3 Rubber dam isolation

Absolute isolation using a rubber dam should be attempted. This can be achieved to some extent with the aid of subgingival rubber dam clamps (e.g. RDCM14 #14 Molar, RDCM1A #1A Premolar, HuFriedy, Tuttlingen, Germany) or special rubber dam clamps (e.g. new Haller clamps, Kentzler-Kaschner Dental GmbH, Ellwangen, Germany), thereby ensuring the possibility of an adhesive restoration. If the rubber dam cannot be adapted or sealed at a deep subgingi-

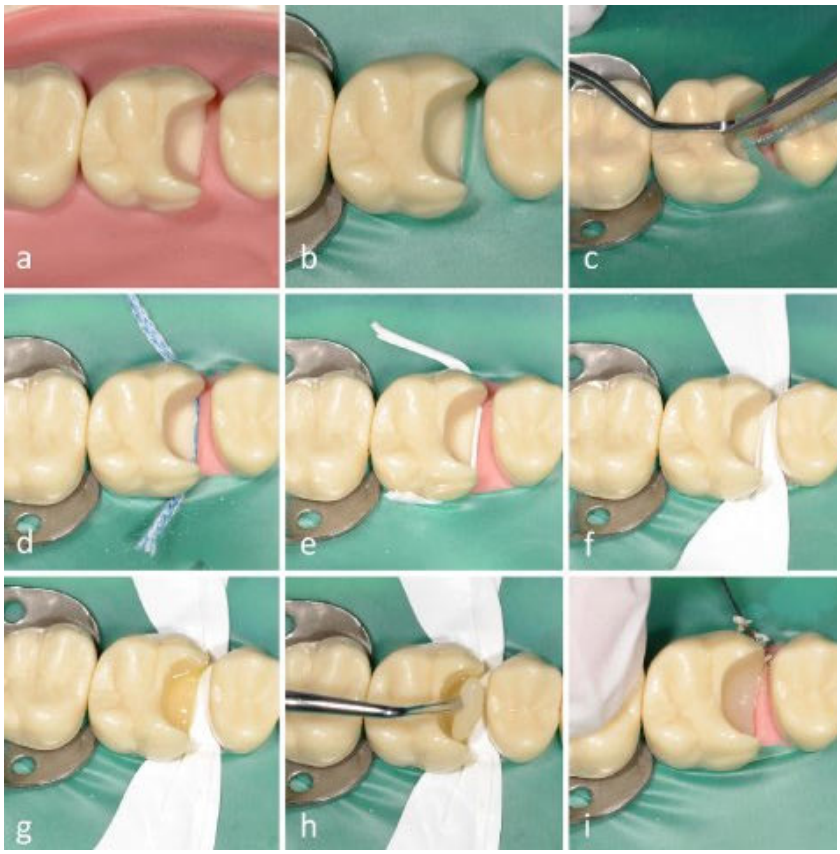

Figure 6 Step-by-step procedure of the first phase of the R2 restoration at model tooth 16.

(a) Initial situation of a cavity extending 2–3 mm subgingivally; **(b)** an attempt to place a rubber dam reveals inadequate mesial isolation; **(c)** cutting of the rubber dam's septum using scissors; **(d)–(f)** various options for secondary isolation of the rubber dam at the mesial margin: insertion of a retraction cord, a rolled-up piece of teflon tape or application of teflon tape over the entire surface to retract the papilla, the tape is also pressed into the sulcus and adapted; **(g)** after phosphoric acid etching and application of an adhesive system, flowable composite is introduced WITHOUT subsequent light curing; **(h)** application of restorative composite onto the still soft remaining flowable material and simultaneous modeling of both materials in the area of the step, excess material is removed carefully using a Heidemann spatula that is guided vertically along the tooth neck, followed by light curing; **(i)** removal of excess material with a scalpel.

val site, it can be cut at the respective site (Fig. 1 and 6c). The rubber dam is then sealed with additional aids such as liquid rubber dam, teflon tape (Figs. 6e and 6f) or retraction cord (Fig. 6d). If it is not possible to apply a rubber dam, the cavity can be isolated by applying a matrix band. Matrix bands which are especially designed for elevating the approximal box or step (e.g. Slick BandsTM Margin Elevation Matrix Bands, Garrison Dental Solutions, Übach-Palenberg, Germany) have proven to be very useful for this purpose (Fig. 4b). The band is applied tightly around the cervical area of the tooth and pressed down along the cavity margin. A Heidemann spatula can be inserted vertically in the sulcus on the inside of the band as a guiding instrument. Due to its special shape, the band descends apically around the neck of the tooth and in this way manages to seal even very deep defects. The coronal edge of the matrix band often lies at the gingival level or slightly above it. The base of the box should be elevated in such a manner so as to serve as a prop for the separation wedge during the subsequent application of a partial matrix band in the second step of the R2 restoration. If leakage appears at the matrix band, for example due to difficult root morphologies with furcations, a seal can be achieved using a piece of teflon tape (Fig. 2). The tape is plugged into the periodontal gap from the outside of the matrix, either using a Heidemann spatula or a retraction cord applicator, so as to act as a prop that presses the matrix band against the tooth. One of the advantages of teflon tape, among other things, is its ability to be removed without leaving any residue after the box has been restored [21]. If the application of a matrix band is not possible, the free-hand technique must be considered [14, 32] (Fig. 6). For this objective, thorough hemostasis must be repeated, as described above. In addition, the insertion of a retraction cord should be considered in order to absorb ascending sulcus fluid. However, the retraction cord should be positioned in such a way that it is not polymerized during the adhesive procedure and composite application (Fig. 6d). Alternatively, teflon tape (Figs. 6e and 6f) or liquid rubber dam can be used. During the adhesive process and composite application, a micro suction device should be readily available (e.g. Surgitip-endo, Roeko, Coltène, Langenau, Germany). It can be held in a suitable position in case of minor bleeding and to maintain a dry working field during the adhesive and composite application step.

Figures 4 to 7 show two methods for reconstructing extensive and deep subgingival defects. In the first, the first step of the R2 restorative procedure is prepared with the help of a subgingival matrix band. In the second, the free-hand technique is used to elevate the approximal box base.

2.4 First step of the R2 restoration

After the adhesive procedure with an etch-and-rinse adhesive system has been performed (Fig. 3a–c), the first step of restorative process can begin. The use of a matrix band for the procedure (Figs. 4 and 5) should always be preferred, as the free-hand technique (Figs. 6 and 7) is clearly more demanding.

In both cases, the snowplow technique is used to introduce the restorative material [27]. (VIDEO LINK). This is accomplished by applying a moderate amount of flowable composite

material on the cavity floor and then distributing it (Fig. 3d); next, viscous restorative composite is applied to the uncured, flowable material (Fig. 3e) and both materials are modeled together. In this way, the harder material pushes the more fluid material across all the areas of the cavity floor and up to the cavity margin. The combination of the two materials achieves better homogeneity and marginal integrity, even when more difficult cavity configurations are present. When using the free-hand technique, overfilling and spreading of the material beyond the cavity margins into the sulcus is unavoidable. Large amounts of excess material should be removed before light curing. This is achieved by carefully guiding a large Heidemann spatula in a vertical direction along the cavity margin (Fig. 3f). Sufficient light curing follows; depending on the light curing lamp used, and the depth of the cavity, the light-curing time should be prolonged for up to at least 40 seconds [7]. Smaller amounts of excess material can be smoothened out later during finishing (Fig. 3g). Finishing is performed in difficult-to-reach approximal areas using a scalpel blade (No. 12) [35], approximal files (e.g. Sonicflex Stripping, Shaping No. 73, 74, 75, 76, KaVo, Biberach, Germany) (Fig. 4h), and a fine-grained diamond-coated flame bur (e.g. No. 8889314 010, Komet, Gebr. Brasseler, Lemgo, Germany) (Fig. 4i) (VIDEO LINK). An X-ray image can be taken after treatment in order to check for marginal integrity and for any overhanging filling material. Further restorative treatment of the tooth is performed either during the same appointment or in the subsequent appointment.

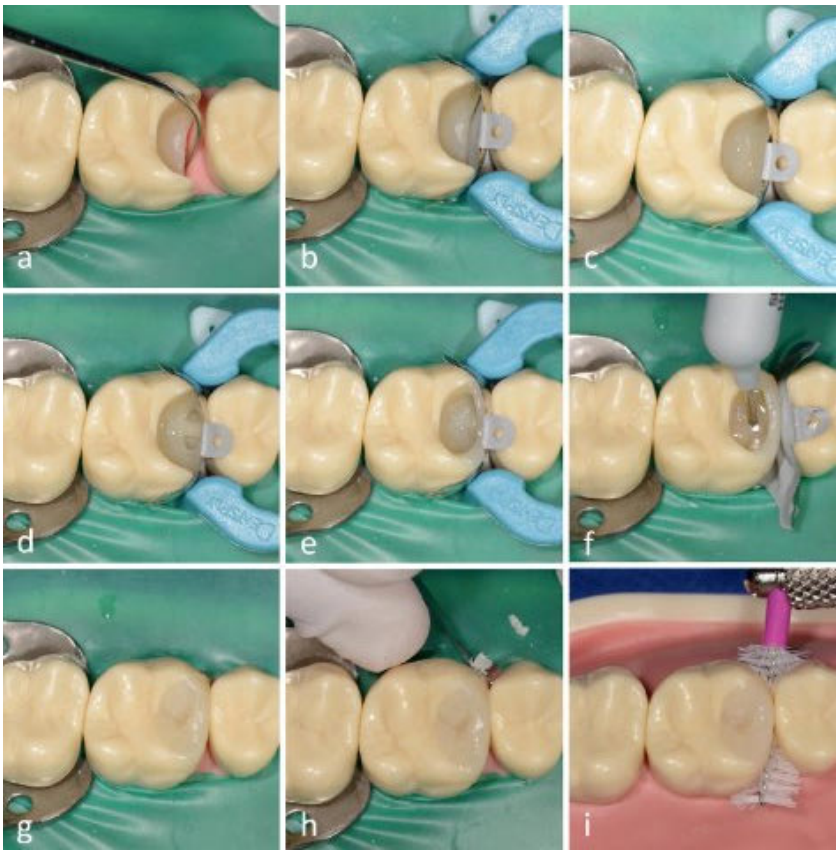

Fig. 1–7: University Clinic Heidelberg

Figure 7 Step-by-step procedure of the second phase of the R2 restoration at model tooth 16.

(a) Checking of the smooth, step-free restoration margin with the aid of a probe; if there is uncertainty regarding the quality of the restoration margin, an X-ray can be made at this point; **(b)** insertion of an anatomically pre-formed matrix band with a wedge and separation ring (Palodent V3 partial matrix system, Dentsply Sirona); **(c)** application of flowable composite WITHOUT light curing and subsequent application of restorative composite; **(d)** situation after removal of the approximal contact former, the cured bar of composite presses the matrix against the adjacent tooth at the level of the contact point; **(e)** build-up of the approximal enamel wall with restorative composite; **(f)** removal of the wedge and separation ring for a clearer working field (the partial matrix was folded away, but still left in the approximal space in case isolation would have been necessary once again at a later stage, for example for any corrections in the area of the approximal surface) and filling of the cavity with bulkfill composite (SDR Flow+, Dentsply Sirona) for efficient working; **(g)** after occlusal modeling with restorative composite; **(h)** removal of excess with scalpel blade no. 12; **(i)** fitting of an interdental brush into the interdental space that borders the finished and polished composite restoration.

2.5 Second step of the R2 restoration

The second step of restoration is also performed using the direct technique. Given that significant bleeding can once again be triggered after the subgingival restoration margin has been finished, ideally, a rubber dam should be applied at first, and then the matrix system. For this purpose, an anatomically pre-formed partial matrix band with a wedge and ring is suitable (e.g. Palodent V3 partial matrix system, Dentsply Sirona, Bensheim, Germany) (Figs. 5a and 7b). The matrix band must be adapted securely and tightly to the first part of the restoration in depth using the wedge. It is possible for a space to taper into the apical direction between the inner side of the matrix and the approximal wall of the already existing restoration (i.e. overcontouring) during the shaping of the matrix band in the direction of the approximal surface of the neighboring tooth. Thus, it is necessary to ensure that the wedge seals the matrix band in depth, so that overfilling does not occur when the composite material is applied. The filling of this space is needed so that the restoration acquires an anatomically correct emergence profile in the approximal area. The cavity is then completely etched with phosphoric acid. Phosphoric acid does not have a direct surface altering effect on composite, but merely cleans it of residual blood and saliva or other possible contaminants [20]. This step is then followed by application of the adhesive system and light curing. Subsequently, through the use of the

snowplow technique described above, flowable and viscous composite material is used to fill the area between the matrix and the cavity margin into the depth (Figs. 5b and 7c). An approximal contact point former (e.g. Easy Contact Point hand instruments for molars/premolars, Zepf Dental, Seitingen-Oberflacht, Germany) is introduced into the still soft remaining material and inclined towards the adjacent tooth (Fig. 5c). Light curing is then performed (VIDEO LINK). After the removal of the contact point former, the matrix remains fixed at the level of the contact point through the composite bar (Figs. 5d and 7d). The approximal wall is then built up (5e and 7e) and the cavity is filled using the oblique layering technique (Fig. 5f). If the cavity is very deep, such as in the case of endodontic therapy, a bulkfill composite can be of practical use (Fig. 7f). The time and effort required for the layering technique is thus reduced. It is also possible to apply flowable bulkfill composite as an alternative to flowable composite during the earlier stage using the snowplow technique. In this manner, an efficient use and combination of materials is possible. Finishing, shaping and high-gloss polishing are carried out in the conventional manner using a scalpel (No. 12) (Fig. 7h), fine-grain diamond burs (e.g. No. 8889415 010, No. 8830L314 012, Komet Gebr. Brasseler, Lemgo, Germany), polishing discs (e.g. Sof-Lex polishing discs, 3M Deutschland GmbH, Neuss) and a multi-step polishing system (e.g. Astropol polisher, Ivoclar Vivadent, Schaan, Liechtenstein).

3. Conclusion

The treatment of deep subgingival defects close to the bone presents the dentist with technical and operative challenges. The two-step restorative approach facilitates safe treatment planning and implementation, by providing flexible solutions that are in accordance with the degree of difficulty of the clinical situation. Clinical experience and initial evidence from a small number of studies to date lead to the assumption that smooth and irritation-free composite restoration margins of deep subgingival defects close to the bone can be tolerated by the periodontium, even when the biological width is disregarded. However, this requires strong patient compliance with regard to home-based oral hygiene with interdental brushes and carefully planned long-term follow-up care.

Note

For certain treatment steps marked with (VIDEO LINK) in this article, you will find the corresponding video sequences at online-dzz.de.

Conflict 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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Dominik Groß

Hermann Wolf (1889–1978) – Versatile DGZMK president and temporary member of the Nazi Party

Introduction: As a university lecturer and president of the DGZMK, Hermann Wolf attained a high level of popularity which still continues. Nevertheless, little is known about his actual contribution to the development of dentistry. This applies all the more to his relationship to National Socialism. Against this background, this article sheds light on Wolf's professional œuvre, his developments and discoveries and, in particular, on his role in the "Third Reich".

Material and methods: The scientific basis of the study is provided by various archival records and an autobiographical document of Wolf with reference to the year 1945. In addition, a complete evaluation of the available secondary literature on Wolf (biographies, lexical contributions, specialist essays, eulogies and obituaries) was carried out.

Results: Wolf was not only a leading lecturer and dental politician, but also a pioneer of postgraduate education and an inventive developer. However, the majority of his innovations in dentistry were only of passing importance. Contemporaries also emphasised his high level of social competence and his international networking. His role in the "Third Reich" was complex: Wolf joined the NSDAP but was expelled from the party in 1942 because his wife was not "purely Aryan". Nevertheless, he did not suffer a career setback.

Discussion and conclusion: Wolf biography offers a prototypical example of discrepancies between contemporary and retrospective perception: While at the time he was appreciated as a promoter of postgraduate education, as an exemplary academic mentor and as an ingenious developer, today he is remembered primarily as a technically versatile DGZMK president of Austrian origin. Besides his case demonstrates that exclusion from the NSDAP was not necessarily accompanied by professional and social degradation. Rather, the appointment procedures in the field of dentistry show that Wolf was considered for high-profile positions until the end of the "Third Reich".

Keywords: DGZMK; endodontics; maxillofacial surgery; National Socialism; NSDAP

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Introduction

Contemporaries called Hermann Wolf one of the last "generalists" among university teachers in the German-speaking world. He was considered an accomplished oral and maxillofacial surgeon, but also devoted himself to tooth conservation and other areas of dentistry. As president and vice-president of the "Deutsche Gesellschaft für Zahn-, Mund- und Kieferheilkunde" (German Society for Dental and Oral Medicine, DGZMK) (Table 1), he achieved great popularity, which continues to have an impact today thanks to his academic students.

Nevertheless, Wolf's concrete contributions to the field and his influence on the development of dentistry are little known. Knowledge about Wolf's relationship to National Socialism, his party-political positioning and his assessment by National Socialist decision-makers in the Third Reich is also limited.

Against this background, this article is dedicated to Wolf's professional œuvre, his work and research foci, his diagnostic and therapeutic innovations and, in particular, his political stance and role during the Nazi regime.

Material and methods

This article is mainly based on various archival files of the Federal Archives in Berlin, some of which have been analysed for the first time, including the membership card index of the NSDAP. Wolf's numerous publications and an autobiographical document in which Wolf refers to the year 1945 were also analysed. In addition, a comprehensive, critical evaluation of the secondary sources available on Wolf was carried out, in particular lexical contributions, specialist essays, laudations, necrologies as well as the thesis on Hermann Wolf submitted by Scheiderer in 1985 [57].

Results and discussion

1. Hermann Wolf – a biographical outline

Hermann Wolf (Fig. 1; [11]) was born on September 27, 1889 in Pula (Pola) in Istria [30–34, 36–39, 41–50, 56–62]. He was the youngest son of Anton Wolf (1847–1919), a naval surgeon general from Silesia, and his wife Anna Wolf (1858–1938). Since Hermann Wolf initially had the right of domicile in Weißbach (Bílý Potok) despite his birth in Pula, he was a Czechoslovak citizen after the end of the Danube Monarchy, "only to become an Austrian with the right of domicile in Vienna by option on 15.9.1920" [57].

Wolf attended primary schools in Pula and in 1899 he transferred to the German "Humanistisches k.k. Staats-Real-Gymnasium". He passed his school-leaving examination there in 1907 and in the same year enrolled at the University of Vienna to study medicine. In January 1913 he passed the final examination in Vienna, which included a doctorate in medicine. This was followed by a short period of surgical work at the public hospital in Neunkirchen in Niederösterreich (Lower Austria). As early as April 1913 he began his military service as a one-year volunteer with the infantry regiments No. 99 and No. 4; subsequently he became an assistant in the surgical department of the garrison hospital No. 2 in Vienna (as an assistant doctor in the reserve). In April 1914 he began training as a "surgical pupil" under Anton von Eiselsberg (1860–1939) at the "I. Chirurgische Klinik" (I Surgical Clinic) of the University of Vienna, which he continued until 1918.

However, there was a first interruption due to the war as early as August 1914, when Wolf was deployed as division chief physician with the "Kaiser Dragoons" on the Eastern front. In 1916 he became chief surgeon in (reserve) hospitals; at the same time, he remained active – as far as time allowed – as an operating surgeon with von Eiselsberg. In 1918 he moved to the "Kieferstation" (jaw ward) of the I. Chirurgische Klinik to Hans Pichler (1877–1949), who went down in specialist history as the "founder of jaw surgery in Austria" and of the "Vienna Dental School" [12]. Wolf was initially employed there as a military contract doctor, then from 1920 as an assistant doctor and from 1922 as an assistant. In addition, he worked as a trainee in

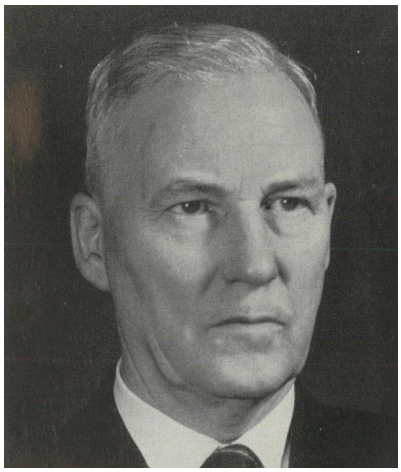

Figure 1 Hermann Wolf (around 1960) [11].

Pichler's private practice in Vienna from July 1919 to July 1920. Wolf also sought further training to become a "specialist in dentistry, oral and maxillofacial medicine". For this purpose, he was also employed at the Vienna University Institute of Dentistry headed by Rudolf Weiser (1859–1928). There he met such dental luminaries as Bernhard Gottlieb (1885–1950) [64], Rudolf Kronfeld (1901–1940) [55], and Bálint Orbán (1899–1960) [1] whose studies on oral histopathology attracted international attention at the time.

Wolf also made key decisions in his private life during this period: He had married Hedwig Wolf, née Wolf (sic!) (1888–1974) from Vienna in 1916, and their daughter Erika was born in 1922. Around that time, Wolf decided to set up a private practice in Vienna, following his role model Hans Pichler. Hedwig Wolf had been trained as a dental assistant by Pichler and was thus able to support her husband in his practice in the 1920s and 30s.

Despite his practice, Wolf maintained his foothold at the University of Vienna, where he was able to habilitate in dentistry in November 1927. As a qualifying thesis he was allowed to submit a paper on the treatment of trigeminal neuralgia, which had already been published in 1925 [65]. Also still in November 1927, Wolf was appointed "Privatdozent" (private lecturer). Further career steps soon followed: In Novem-

Term of office	Name	NSDAP Membership	Life data
1906–1926	Otto Walkhoff	+	1860–1934
1926–1928	Wilhelm Herrenknecht	+	1865–1941
1928–45, 1949–54	Hermann Euler	+	1878–1961
1954–1957	**Hermann Wolf**	**+**	**1889–1978**
1957–1965	Ewald Harndt	+	1901–1996
1965–1969	Gerhard Steinhardt	+	1904–1995
1969–1971	Eugen Fröhlich	+	1910–1971
1972–1977	Rudolf Naujoks	–	1919–2004
1977–1981	Werner Ketterl	+	1925–2010

Table 1 The presidents of the CVDZ (from 1933: DGZMK) who experienced the "Third Reich" as adults and their party-political orientation

ber 1930 Wolf became "Erster Assistent" (first assistant) of the jaw ward as well as head of the conservative department of the university dental clinic – both institutions had been managed in personal union by Hans Pichler since Weiser's death (1928) – and in October 1935 he became "Hochschulassistent erster Klasse" (university assistant first class) there. In September 1937 he received the title of professor – also in Vienna. Two years later – the Second World War had broken out in the meantime – Wolf began his service as a reserve medical officer of the air force at the Vienna Jaw Station in September 1939. But only one month later – in October 1939 – he was able to take on an associate professorship at the University of Würzburg. Linked to this was the establishment and management of the maxillofacial surgery department of the dental clinic there. The dental clinic itself was headed by Joseph Münch (1894–1977); however, Wolf's department was organisationally independent. Wolf retained this position until the end of the war.

After the Second World War, Wolf obtained German citizenship with effect from April 27, 1945 [57]. Also in April 1945, he became the – initially provisional – head of the dental clinic at the University of Würzburg. Subsequently, Wolf acted as provisional head of all departments of the Würzburg dental clinic, which was subsequently rebuilt and successively expanded after considerable war damage. In the end, the construction measures were to last until 1966. Wolf also acted as provisional head of the Institute for Forensic Medicine and Criminology from 1947 to the beginning of 1949. From March 1949, Wolf was officially managing director of the entire dental clinic in Würzburg and in September 1950 he arrived as a personal full professor. Although Wolf officially became emeritus professor in September 1957, he remained active as provisional clinic director until March 1959. In July 1962, Wolf then moved to Bad Reichenhall. There he died of old age on December 11, 1978 in his 90th year. He was buried at the Vienna Central Cemetery.

2. Wolf's importance as a scientist, professional representative and networker

Wolf's activity as a university lecturer can be divided into two phases – the Vienna period and the subsequent Würzburg period:

During his years in Vienna, he stood out mainly due to his successful commitment in the field of further medical training to become a "Specialist in Dentistry, Oral Medicine and Maxillofacial Surgery". This further training was necessary because dentists in Austria first completed a full course of medical studies before specialising in dentistry postgradually [22]. Against this background, Wolf established – in close coordination with his mentor Hans Pichler – a 4-semester postgraduate training course to become a dental specialist in 1925, which was soon regarded as exemplary throughout Austria. Wolf wrote several publications on this further training course, which attracted great interest [67, 68]. For example, the Viennese colleagues Richard Grohs (1896–1966) and Otto Hofer (1892–1972) stated: "Wolf has rendered imperishable services to Austrian dentistry under Hans Pichler, when he established and organised the course for Austrian dental specialists for their special training (translated by DG)" [16]. The Austrian Hans Langer (1907–1974) expressed a similar opinion: "Wolf knew how to organise a training that must be addressed as one of the best for that time. He himself taught the subjects of dental conservation and, together with Pichler, dental surgery in a didactically excellent lecture and a propaedeutic course" [49]. Due to his professional closeness to Pichler, Wolf was considered a representative of the "Viennese Dental School" or the "Pichler School" [49].

In addition, Wolf established his reputation in Vienna as a creative developer and designer. In fact, he developed and modified a number of devices and instruments, for example, as early as 1916/17 "Wolf's device for Bier's stasis", which was used for gas phlegmons. It aimed at rhythmic congestion of the extremities with moderate pressure, "causing hyperaemia due to the lack of venous outflow, accelerating the inflammation and healing process" [57]. In 1919, he also modified the "Extensionsklammer nach Schmerz" (extension clamp according to Schmerz) – later also called "extension clamp according to Schmerz-

Wolf" – in which he produced a higher clamping force by means of screw pressure [57]. The "Wolfsches Gnathotom" (Wolf's Gnathotome) (1928) was considered his most important development: It was a strong pair of forceps, also operated by screw pressure, for cutting through the lower jaw ("cutting-squeezing method") (Fig. 2, [40]). Wolf had the device "made according to his ideas by the instrument maker Kutill in Vienna" [57] and presented it in more detail in a publication [66]. Further constructions were the "Keilzange nach Wolf" (Wolf's wedge forceps) (1925) – e.g. for removing plaster casts from the mouth –, the "Dreischnittbeil nach Wolf" (Wolf's three-bladed axe) (1937) as a "hand instrument for conservative dentistry" and the "Nasenklemme nach Wolf" (Wolf's nose clamp) for closing the nose when inducing inhalation anaesthesia through the oral cavity [57]. However, most of his developments were not a resounding success, as can be seen from the fact that only Wolf's gnathotome was included in the "Zahnärztliches Lexikon" (Dental encyclopaedia) by Walter Hoffmann-Axthelm (1908–2001) published in 1983 [40]. However, the gnathotome has long since been replaced by bone saws or other techniques that are less traumatic to the tissue in question.

When a successor to Rudolf Weiser, the late director of the renowned Vienna Dental Institute, was sought in 1929, Wolf was already being discussed as a possible candidate. But the call ultimately went to his mentor Pichler, who was 12 years older, not habilitated, but professionally established [35]. In 1935, Wolf received a call from Zurich, which failed, however, because a local candidate, Pierre Schmuziger (1894–1971), was eventually preferred.

Instead, Wolf became an extraordinary professor and head of the Department of Maxillofacial Surgery at the Dental Institute of the University of Würzburg in 1939. There he was supposed to establish a surgery ward. But he found adverse conditions – also due to the war – and was primarily concerned with establishing a military hospital. So, at first he had "to be content with a few beds in the Red Cross Clinic and Brod's Clinic. Part of the military hospital was housed in the rooms of the dental clinic and the lecture theatre during the war" [14]. In Würzburg, Wolf ushered in a new phase of his work. While he had acquired profound knowledge of maxillofacial surgery under Pichler in Vienna, he now also emerged with contributions on endodontics and apicoectomy, thus establishing his reputation as a "generalist" in dentistry. Contemporary colleagues such as Hermann Euler (1878–1961) [21] and David Haunfelder (1912–1989) paid particular tribute to Wolf's numerous studies on root canal treatment by (hydroxyl) iontophoresis [13, 34]. In 1950 and 1951 alone, Wolf published more than half a dozen articles on apicoectomy and especially on iontophoresis of the root canals (e.g. [69–71]). This labour-intensive method received a great deal of attention around the middle of the century but was soon largely abandoned ("The question is whether the equipment and time required are in a rational relationship to the success that can be achieved": [57]). Hans Hermann Rebel (1889–1967) praised Wolf's contributions to apicoectomy and his "being at home in all areas of dentistry" [54]. Otto Hofer also emphasised that Wolf made "noteworthy achievements in all areas of dentistry" [38].

Wolf published a total of more than 180 papers; many were dedicated to the aforementioned topics, but some were also devoted to electrical pulp diagnostics, oral pathology and histology, tumours of the oral cavity and dental anaesthesia and narcosis. All in all, Wolf was unquestionably one of the leading scientific authors of his time.

Wolf was also highly regarded as a candidate for a chair in the post-war period: In 1946/47 he was in discussion in Frankfurt for the vacant chair and the associated "reconstruction of the Frankfurt Institute"; however, no agreement was reached [29]. In 1949 he received a call from Vienna, where an important professorship was up for decision as Pichler's successor. Pichler in particular had praised Wolf "in the highest terms"


Gnathotom (*Wolf*): Instrument zur Unterkieferresektion, das mittels zweier durch ein Schraubengewinde gegeneinandergeführter kräftiger Schneiden den Unterkieferkörper durchtrennt (Abb.).

Figure 2 The "Gnathotome" by Hermann Wolf [40]

and accordingly recommended him as a possible successor [52]. However, Vienna could not promise "even an approximately equivalent salary" compared to Würzburg [57]. Since Wolf "ultimately did not want to follow his calling to Vienna" but wanted to remain in Lower Franconia [52], the house candidate Fritz Driak (1900–1959) was appointed there. In 1950, Wolf then received a call to Cologne. Again, he declined the call; in return, he was appointed full professor in Würzburg [57]. In the same year, the Würzburg dental clinic was renamed "Universitätsklinik und Poliklinik für Zahn-, Mund- und Kieferkrankheiten Würzburg" (University Clinic and Polyclinic for Dental, Oral and Jaw Diseases Würzburg). In the years that followed, Wolf was mainly responsible for the structural expansion and modernisation of the Würzburg clinic and for the organisation of teaching. Above all, the "Bayerische Landeszahnärztekammer" (Bavarian Dental Association) was "sincerely grateful" to Wolf that he remained in Würzburg despite calls from other universities [58]: As a long-standing board member of the chamber, he was involved in continuing and further education in dentistry, as he had been earlier in Vienna. However, he failed with his wishful thinking to tie future dentists, as in Austria, to a complete medical degree and subsequent further training to become a specialist ("The dentist should be a full doctor. The reasons for this are the same as those that

united surgery with medicine in its time" [68]).

Wolf was considered very well connected, approachable and popular among colleagues. Thus, Rebel emphasised: "It is his human qualities, kindness, modesty, helpfulness and manly disposition that we particularly love" [54]. Wolf's colleague and friend Hans Schlampp (1900–1962) called him a "doctor of the highest moral character" [61], the aforementioned Haunfelder saw him as "filled with deep humanity" [33], and Hermann Mathis (1897–1981), also a friend of Wolf, described him as an "eminently modest and kind person" [51]. The Viennese university lecturer Koloman Keresztesi (1916–2000) praised Wolf's "often critical, but because of his distinguished and noble character, never personally hurtful comments" [42] and his colleague from Mainz, Werner Ketterl (1925–2010), wrote about Wolf's "deeply religious attitude and humanistic education" [43]. Günther Ködel (*1932) had an additional explanation for Wolf's ability make friends beyond the German-speaking world. He paid tribute to Wolf's "extraordinary knowledge of languages, which enabled him to engage in lively […] exchange with numerous foreign professional colleagues" [57].

Wolf's popularity and professional recognition was also reflected in a large number of honours and awards, of which only a few can be mentioned here as examples. In 1934, he became honorary vice-president of the "International Association for Dental Research" (IADR) (until 1936), in 1947 he was a member of the board of the "Bayerische Landeszahnärztekammer" as "Hochschulreferent" (university representative) (until 1958), in 1953 he was dean of the medical faculty in Würzburg (until 1954), and in 1956 he was a member of the expert committee of the "Deutsche Forschungsgemeinschaft" (German Research Foundation, DFG), in 1957 corresponding member of the "Académie Nationale de Chirurgie Dentaire" in Paris, in 1959 honorary member of the "Vereinigung der Hochschullehrer für Zahn-, Mund- und Kieferheilkunde" (Association of University Teachers of Dentistry, Oral Medicine and Maxillofacial Surgery) and in 1961 honorary member of the "Zentralverband der wissenschaftlichen Vereinigungen Österreichs" (Central Federation of Scientific Associations of Austria). In 1964 he received the Bavarian order of merit (for the reorganisation and expansion of the Würzburg Dental Clinic) and in 1971 he became an honorary member of the "Deutsche Gesellschaft für Mund-, Kiefer- und Gesichtschirurgie" (German Society for Oral and Maxillofacial Surgery, DGMKG). However, Wolf became best known for his successful work at the top of the DGZMK: From 1952 to 1954 he served as vice-president and from 1954 to 1957 as president (Table 1). In 1959 he was appointed honorary member of the DGZMK and in 1974 he was awarded the DGZMK pin of honour [17, 28].

In his private life, Wolf was enthusiastic about "home music he practised himself" [47]. His inventiveness was matched by another hobby: tinkering [15]. And Mathis added: "Wolf […] loves languages, is a bibliophile, a cellist and last but not least a poet, as which he particularly cultivates the witty shaking rhyme" [51, 57].

3. Wolf's relationship to National Socialism

Wolf's role in the "Third Reich" is very complex and cannot be outlined in a few sentences. At the time of the "Anschluss" (annexation) of Austria to the German Reich in March 1938, Wolf was working in Vienna. It is a fact that he joined the NSDAP shortly after this annexation (application 14.06.1938, admission 01.05.1938 [retroactive]; no. 6,295,130); in 1939 he also became a member of the "NS-Dozentenbund" (Nazi lecturer association) (admission 04.02.1939) [9].

Whether Wolf took these steps out of political opportunism or conviction is difficult to say. However, it is clear that Wolf was one of the favourites for professorships in 1938 and 1939. In 1938, for example, he was on the "appointment lists of the universities of Innsbruck and Graz"; however, in the end, no appointments were made [42, 57]. Instead, Wolf was appointed to Würzburg the following year, while his Viennese colleague Otto Hofer was called to Berlin in the same year.

The almost simultaneous appointments of the two Pichler students – and NSDAP members – Wolf and Hofer to Germany were definitely politically motivated and stood in the context of the 1938 "Anschluss" of Austria to the "Greater German Reich", as Scheiderer elaborated: "The exchange of scientists from both countries was intended to bind them closer together. In the field of dentistry, it was also important to bring the leading Viennese school of the time, closely associated with the name of Pichler, to the German universities, which was done with the appointments of Otto Hofer and Hermann Wolf" [57].

It is certain that Wolf was highly regarded by the political decision-makers at the "Reichsdeutsche" (German Reich) universities in this period: He was not only appointed in Würzburg in 1939, but was also considered as a candidate for the chair to be filled in Hamburg in 1940/41. He took up the professorship in Würzburg in October 1939. In Hamburg, however, the final decision was complicated: While the Hamburg faculty favoured an in-house appointment and wanted to "push through" one of the two Hamburg candidates – the National Socialists Hans Pflüger (1884–1967) or Heinrich Fabian (1889–1970) [23] – the higher-level ministry explicitly suggested Hermann Wolf, since he, unlike Pflüger and Fabian, was a proven maxillofacial surgeon and they wanted to "insist on the appointment of a maxillofacial surgeon" [10]. The "NS-Dozentenbund" had also explicitly recommended Wolf. But the Hamburg faculty "remained unbending" [10] and was ultimately successful: In 1941, Pflüger, a member of the "Waffen-SS" (Armed SS), received the call to the chair. Nevertheless, both appointment procedures proved that Wolf was classified by the political decision-makers as loyal to the regime – because this was a central prerequisite for such nominations.

Wolf thus remained in Würzburg, where he came under suspicion at the beginning of the 1940s: He was accused that his wife "was not of pure German-blooded descent" [7]. Finally, on 24 March 1942, he was expelled from the party because his wife was classified as "1/8 Jewish" [6]. In fact, the note "admission invalid" is also found on his NSDAP card, although the reason given is not legible [9]. In addition, a political report by the "Gauleitung Mainfranken" stated that there were doubts about his "commitment to the NS state […]" [3]. It is unclear to what extent the then director of the Würzburg dental clinic, Josef Münch, supported this assessment. In any case, it is known that Wolf's relationship with Münch was strained. Wolf's biographer Scheiderer describes Münch – who was also a member of the NSDAP [2, 8] – as a clinic director with a National Socialist appearance who behaved in a "very distanced" manner towards Wolf. Scheiderer further notes that Wolf was "rather reserved" towards "the leading forces" of the "Third Reich" [57]. The latter could be explained by Wolf's exclusion from the party. However, in his 158-page biography of Wolf, Scheiderer remarkably mentions neither Wolf's party membership nor his later exclusion from the party – be it consciously or unknowingly.

It is also a fact that Wolf retained his position as extraordinary professor in Würzburg until the end of the "Third Reich" – in contrast to dental university professors such as Karl Zilkens (1876–1967) and Hermann Peckert (1876–1940), who were considered politically suspect, or Wolfgang Rosenthal (1882–1971), who was also expelled from the party and suspected of being a "quarter Jew" [20]: They all lost their university positions in the course of the "Third Reich".

Wolf, on the other hand, not only remained in his professorship, but was apparently – despite the discussion about his wife's parentage – also considered ordinariable in the period that followed: In 1942, for example, he turned down "notable calls" to Vienna and Munich [57]. He also received an offer of appointment from Switzerland – in July 1942 from Basel – which he also declined, although it would have offered him the opportunity to turn his back on the "Third Reich". At the turn of the year 1943/44, a decision had to be made about the renowned chair at the German University in Prague, which had become vacant due to Karl Häupl's (1893–1960) move to the Charité in Berlin [25, 26]. In the process, four people were shortlisted: Josef Eschler (1908–1969) and Wolf, who were jointly ranked first, Arnold Ehricke (1890–1970), who was ranked second, and Konrad Thielemann (1898–1985), who was ranked third. In addition, the dental "Reichsdozentenführer" (Reich lecturer leader) Karl Pieper (1886–1951) [24] brought in the Viennese Otto Preissecker (1898–1963). Max de Crinis (1889–1945), the responsible ministerial advisor for medical matters in the Science Office of the Reich Ministry for Science, Education and National Training, intervened directly in the procedure on February 23, 1944 with a trend-setting statement and explicitly emphasised Wolf's research achievements: "In my opinion, only the university lecturers named in the first place can be considered for an appointment to Prague. Scientifically, Professor Wolf is without doubt better than Prof. Eschler". However, de Crinis also expressed the request to investigate the rumour that Wolf's wife was "not of pure German blood" [7]. This request proves that knowledge of Wolf's wife's ancestry had spread little by 1944. In any case, Wolf had not become persona non grata. But time was obviously pressing, as Karl Pieper emphasised in a letter to Max de Crinis on May 17, 1944: "Should Prague now wait with the occupation until Wolf's matter is settled? I can imagine that this will take a considerable amount of time and that under present conditions it will not be settled at all; at least not too soon." [4] It was probably against this background that Wolf was no longer considered as Häupl's successor [5] – but the chair was not filled anyway due to the turmoil of the war.

After the end of the war, Wolf's exclusion from the party in 1942 was to his advantage: He was considered politically unencumbered and on August 24, 1945 was confirmed as provisional director of the Würzburg Dental Clinic by the Bavarian State Ministry for Education and Cultural Affairs with the approval of the American military government. However, the Würzburg Medical Faculty as a whole was "severely decimated" [57]: Wolf belonged to a small group of only 5 (of a total of 59) lecturers at the Würzburg Medical Faculty who were allowed to remain in office after 1945 – while his former opponent Josef Münch, for example, was dismissed. Wolf later wrote about this in his memoirs of 1945: "Prof. Münch visited me after he had been released from a prison camp at Tegernsee, […] thanked me for representing him and wanted to stay away for a short time to put his affairs in order. However, he did not return, as he was […] dismissed soon afterwards" [53]. In contrast, Wolf was officially exonerated politically by a judgement of the Würzburg "Spruchkammer" (chamber) on October 13, 1948 [57, 63].

Conclusions

Wolf provides an impressive example of how the contemporary and retrospective image of a person can diverge: By his contemporaries, he was perceived and appreciated as a pioneer of continuing dental education, as an ingenious developer and name giver of various devices, as a forerunner in the field of iontophoresis therapy of infected root canals and as an internationally popular and networked specialist. But his leading role in postgraduate education and his various inventions fell into oblivion over time. This obviously also had to do with the fact that hardly any of the developments and innovations became permanently established in dentistry or were able to set new diagnostic or therapeutic standards. This distinguished him from other presidents of the DGZMK or the CVDZ – such as Willoughby D. Miller (1853–1907), the originator of the modern caries theory [18], Otto Walkhoff (1860–1934), the initiator of den-

tal radiology [19], or Ewald Harndt (1901–1996), the developer of the "pulpitis scheme" [27]. Miller, Walkhoff, and Harndt also succeeded in publishing widely known, high-circulation textbooks. Nowadays, Wolf is remembered above all as a professionally versatile DGZMK president of Austrian origin who enjoyed great popularity.

Secondly, the Wolf case shows that joining the party had a positive effect on career development, but that exclusion from the NSDAP did not necessarily mean the end of a career or [professional and social] degradation. Rather, the appointment procedures of the years 1942 to 1944 prove that Wolf was discussed and nominated for prominent positions even after his exclusion from the party.

Conflict of interest

The author declares 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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