2 | 2022
4. VOLUME

DZZ
INTERNATIONAL

German Dental Journal International – **www.online-dzz.com**
International Journal of the German Society of Dentistry and Oral Medicine

Interdisciplinary treatment approach in a class III patient with severe periodontitis: challenges and solutions in an University Dental Clinic

Vertical tooth surface loss – a narrative review
Part II: therapy and aftercare

Structured oral hygiene instruction in the treatment of periodontitis – an explorative study

Otto Walkhoff (1860–1934) – Model scientist and early National Socialist

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Deutscher Ärzteverlag

PRACTICE

RESEARCH

Title picture: From original article by Roesner, Rauch, Behr, Hahnel: Vertical tooth surface loss – a narrative review. Part II: Therapy and aftercare. p. 58–69. Figure 2: Initial situation before the start of treatment, intraoral. […] (Photo: S. Hahnel)
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Interdisciplinary treatment approach in a class III patient with severe periodontitis: challenges and solutions in an University Dental Clinic

Introduction: The orthodontic treatment of adult patients with interdisciplinary treatment needs often presents a challenge and it requires good cooperation between dental specialists in order to achieve an optimal result. The case report describes the joint interdisciplinary treatment of a 40-year-old patient with Angle class III occlusion, progenic forced bite, severely malpositioned teeth and periodontitis. Conservative dental treatment was also necessary due to insufficient restorations and carious lesions.

Treatment method: The therapy encompassed orthognatic surgery as well as orthodontic, periodontal and conservative treatments together with tooth recontouring at the end. Following thorough treatment planning, the first step involved systematic periodontal treatment. Once stable periodontal conditions were achieved and maintained, the position of the maxillary front teeth was corrected by means of a multibracket appliance, followed by bimaxillary orthognathic surgery. Finally, direct tooth recontouring using composite resins was performed in order to improve the esthetic appearance of the maxillary front teeth.

Result: Thanks to good interdisciplinary cooperation between specialists in various dental disciplines including maxillofacial surgery, periodontology, orthodontics and conservative dentistry, the healthy and painless functioning of the jaws could be restored under healthy periodontal conditions and an esthetically appealing appearance of the teeth could be achieved.

Conclusion: Shared objectives and treatment planning between dental specialists should be aimed for in patients requiring interdisciplinary treatment. In order to achieve optimal treatment outcomes, the individual treatment steps should always be planned and, if necessary, adjusted in terms of time and interim results.

Keywords: dysgnathia; periodontal treatment; preoperative and postoperative orthodontic treatment; orthognatic surgery; tooth recontouring

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Citation: Sonnenschein S, Lux CJ, Zingler S, Freudlsperger C: Interdisciplinary treatment approach in a class III patient with severe peridontitis: challenges and solutions in an University Dental Clinic. Dtsch Zahnärztl Z Int 2022; 4: 49–57
Peer-reviewed article: submitted: 04.02.2021, revised version accepted: 15.07.2021
DOI.org/10.53180/dzz-int.2022.0006

Introduction

Dental treatment of patients with interdisciplinary treatment needs is often challenging and it requires good cooperation between specialists in order to achieve an optimal result. The following case report presents the surgical, orthodontic, periodontal and conservative treatments of a patient with Angle class III occlusion, progenic forced bite, dental crowding and periodontitis. The patient also required conservative treatment due to various insufficient restorations and carious lesions.

Case presentation and choice of treatment

General medical history

In March 2013, the 40-year-old patient presented herself to the Department of Orthodontics and Dentofacial Orthopaedics of the Clinic for Oral, Dental and Maxillofacial Diseases at the Heidelberg University because she experienced severe temporomandibular pain. The general medical history was inconspicuous and the patient was a non-smoker. At that time, she had been living in Germany for 4 years and she worked as a saleswoman in retail. She had been married for 5 years.

Dental anamnesis

The patient reported that she had been experiencing temporomandibular pain for several years and that she had been suffering psychologically due to the esthetic appearance of her teeth. In her native country, she had previously undergone various tooth extractions due to caries and some of her teeth had been "filled". No further dental treatments had been performed to date. The patient stated that she brushed her teeth twice a day with an electric toothbrush and fluoride toothpaste and used toothpicks to clean her interdental spaces after each meal.

Main concerns of the patient

The patient's primary concerns were the desire for "straight" teeth and pain relief. Moreover, it was important for her to be able to practice more effective oral hygiene after treatment.

After her initial consultation, the patient was referred to the Department of Oral and Maxillofacial Surgery as well as to the Section of Periodontology of the Department of Conservative Dentistry for continued examination by dental specialists and interdisciplinary treatment planning.

Extraoral findings

A marked mandibular midline deviation to the left (left masticatory plane approximately 2 mm further cranially, Figure 1) and a positive lip overjet were particularly evident.

Fig. 1: S. K. Sonnenschein

Figure 1 Extraoral appearance at the time of the patient's initial consultation

Intraoral findings

Dental health status

Intraorally, a partially edentulous dentition that had been partially restored by means of conservative treatment was present, together with severely malpositioned teeth. The maxillary and mandibular front teeth displayed severe abrasion. A total of 23 teeth were present. The inspection of the tooth hard tissues revealed numerous insufficient restorations and wedge-shaped defects. Moreover, a number of open carious lesions were diagnosed (Figure 2). Vitality testing using cold spray revealed that all teeth were vital. Sensitivity on palpation and percussion of each individual tooth was not detected.

Periodontal findings

Localized gingival redness as well as hard and soft plaque were present. Pus discharged from the periodontium of the maxillary front teeth. The clinical attachment level (CAL) was between 3 and 7 mm in the maxilla and between 3 and 5 mm in the mandible (mean CAL: 3.5 mm). The general probing depths ranged between 3 and 4 mm, and at some sites in the maxilla, they were between 5 and 6 mm (mean probing depth: 2.5 mm). There was generalized bleeding on probing (BOP: 44 %). Generalized recessions were also particularly evident in the maxillary anterior region. No furcation involvement or pathological tooth mobility was diagnosed. The detailed periodontal findings together with the complete general dental findings are shown in Figure 3.

Orthodontic findings

Clinical functional examination: Sigmatism addentalis, crenated tongue, bruxism (mainly awake bruxism), occlusal plane shift with a cranial incli-

Fig. 2: S. K. Sonnenschein

Figure 2 Intraoral appearance at the time of the patient's initial consultation

nation of 2 mm on the left side, mandibular prognathic forced bite with protrusive mandibular excursion of 2 mm over tooth 24, mandibular deviation to left side during maximal mouth opening, intermediary clicking of the left temporomandibular joint during mouth opening, pain in the left temporomandibular joint during mouth opening, positive lip profile, straight "ante"-profile according to A. M. Schwartz.

Study model findings: upper jaw: overall arch length discrepancy: –22.4 mm, discrepancy posteriorly right: –3.8 mm, discrepancy posteriorly left: –5.6 mm, discrepancy anteriorly: –13 mm, anterior Tonn ratio: 0.78, palatally displaced lateral incisors 12 and 22, mesial rotation of teeth 15, 12, 22, and 25, distal rotation of tooth 21, mesial tipping inclination of teeth 17, 13, 23, 25 and 27, mesial drift of posterior teeth in the first and second quadrants, alveolar midline deviation of 2 mm to the right, labially displaced teeth 13, 11 and 23, supraposition of teeth 15, 14, 12 and 22; lower jaw: overall arch length discrepancy: –4.4 mm, discrepancy posteriorly right: –1.1 mm, discrepancy posteriorly left: –0.8 mm, discrepancy anteriorly: –2.5 mm, mesial rotation of teeth 35, 41 and 42, mesial inclination of teeth 38, 37, 47 and 48, lingual tipping of teeth 35, 42, 43, supraposition of teeth 32 and 42; occlusion: (modified) molar Angle Classification: on the right side 3/4 cusp Class III and on the left side full cusp Class III, mandibular midline deviation 2 mm to the left.

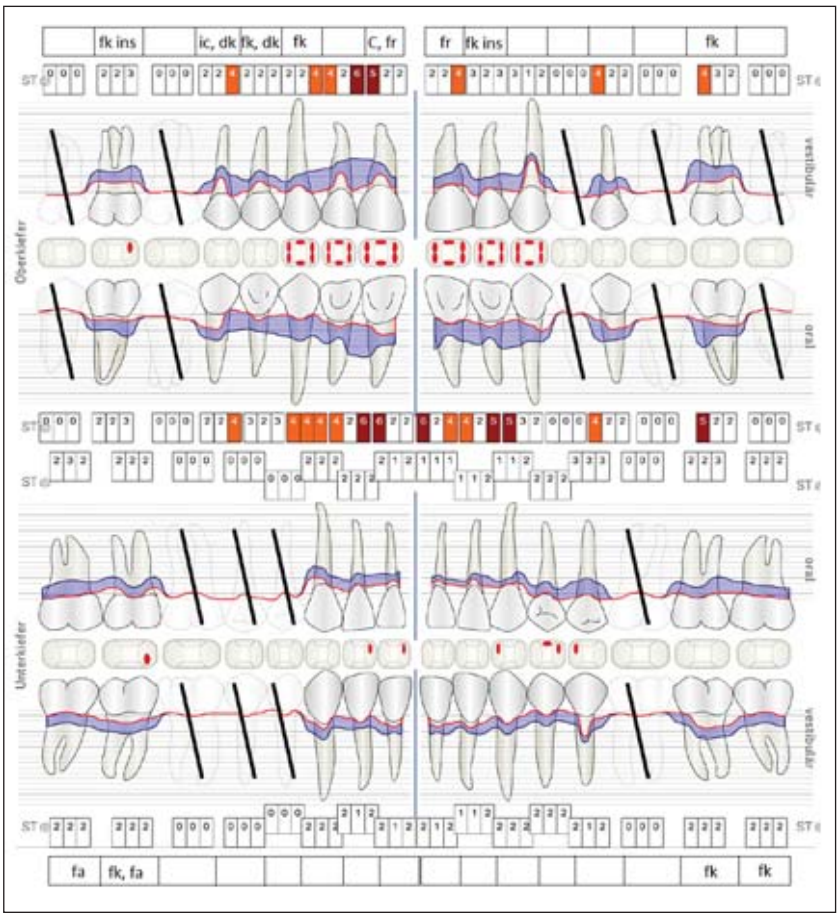

Figure 3 Detailed periodontal and dental findings. fk, composite restoration; C, caries; ic, initial caries; dk, wedge-shaped defect; fr, abfraction/heavy abrasion; fa, amalgam restoration; ins, insufficient

Radiological findings

Figure 4 shows the initial panoramic radiograph. Teeth 18, 16, 24, 26, 28, 36 and 44 to 46 are missing. Radiopaque areas indicating restorative restorations can be seen in the area of the dental crowns on teeth 17, 14, 13, 22, 26, 38, 37, 46 and 47. There is a generalized loss of alveolar bone up to the middle root third in the maxilla and up to the coronal root third in the mandible. Tooth 15 appears to show an apical radiolucency. The hard substance of tooth 22 shows a mesial radiolucency representing a secondary carious lesion.

Fig. 4: C. Lux, S. Zingler

Figure 4 Panoramic radiograph from February 2013 (created on site)

The heads of the maxillary branch appear asymmetrical. The maxillary sinus and other bony structures show no evidence of pathological changes. In order to better assess the apical situation of tooth 15, an additional periapical X-ray was made; it did not confirm an apical radiolucency at this tooth. Angular bone defects extending into the middle third of the root can be seen at teeth 25, 26 and 47. Hard deposits on the root surfaces which indicate subgingival tartar can be seen mesially at

Fig. 5: C. Lux, S. Zingler

Figure 5 Cephalometric X-ray from January 2014 (initial findings)

teeth 17, 27 and 37 and distally at tooth 38.

The lateral cephalogram (Figure 5) reveals a mesial basal relation and a neutral, vertically tending facial skull structure. The upper and lower jaws have a prognathic position. The maxillary front teeth are axis-aligned and in orthoposition. The mandibular front teeth are axis-aligned and in anteposition. The maxillary and mandibular bases are relatively oversized.

Diagnoses

- skeletal class III, occlusal plane canting (2 mm further cranially on the left side), mandibular midline deviation of 2 mm to the left, progenic forced bite, lack of space in the upper and lower jaw, severe teeth malalignment
- periodontitis (generalized stage III grade B [7]; according to the classification valid at the start of treatment: severe, generalized chronic periodontitis [1])
- caries at tooth 11
- initial carious lesion at tooth 15

Preliminary prognostic assessment

The patient was very open to the treatment suggestions and the anamnestic information regarding oral hygiene behavior indicated that good compliance could be expected. As there was also no general medical health risk, the patient-related factors were categorized as "favorable". From a periodontal perspective, except for tooth 12, the prognosis of all existing teeth was assessed as being "favorable" (prognosis system according to Kwok & Caton [6]). This assessment was mainly founded on the fact that no furcation involvement was present and good cleaning of the subgingival root surfaces appeared possible. In the case of tooth 12, due to its distal position and close proximity to the neighboring teeth, it would not be possible to perform sufficient subgingival cleaning. Consequently, it was assumed that home-based supragingival plaque removal at this tooth would not lead to satisfactory results in spite of the patient's strong determination. Thus, the initial prognosis of the tooth was considered questionable from a periodontal standpoint.

By extracting tooth 12 and retracting tooth 23 in order to create space, the resolution of the frontal crowding in the maxilla appeared to be possible. Similarly, it was expected that the frontal crowding could be corrected after the distalization of tooth 43 in the mandible. Given the fact that the extent of distalization of tooth 23 would be insufficient to completely correct the maxillary alveolar midline deviation preoperatively, the remaining correction of the maxillary dental midline would have to be taken into account as part of the surgical planning.

In relation to maxillofacial surgery, no contraindications for orthognathic surgery existed due to the patient's good general health status, the available bone supply and her compliance. The patient was very open to the treatment suggestion after being informed about the prospective repositioning of both jaws (bignathic repositioning osteotomy) as part of the interdisciplinary treatment, and the resulting effect on function and esthetics.

Treatment plan

The primary therapeutic goal was to establish a stable occlusion under healthy periodontal conditions. The treatment plan was based on the close consultation between all specialists of the dental disciplines involved.

1. Treatment with a bite splint for managing the temporomandibular pain
2. Systematic periodontal treatment: Anti-infective treatment including full mouth disinfection (FMD) according to the "Heidelberg Concept" (described in Sonnenschein et al. 2021 [9]); re-evaluation of the periodontal status 3 months after FMD; this was to be followed by closely scheduled supportive periodontal therapy (SPT) (every 6 to 8 weeks).
3. Composite restorations on teeth 17, 47 and 11 (if possible, during the hygiene phase of systematic periodontal treatment)
4. Based on the results of the ongoing periodontal treatment, the definitive extraction planning would need to be decided from an orthodontic standpoint.
5. After stable periodontal conditions were established, the decision was made to extract tooth 12 in order to create space and perform preoperative orthodontic treatment using a multibracket appliance.
6. After preoperative shaping of the dental arches and the transversal/sagittal adjustment of both jaws, the the bimaxillary orthognathic was performed in both jaws.
7. After postoperative orthodontic precision adjustments and the removal of the bands, shape corrections of the teeth in the anterior region and prosthetic rehabilitation of the interdental gap in quadrant 4 were to be performed at the beginning of the orthodontic retention phase.

Course of treatment

After the patient received a bite splint to alleviate her TMJ problems, systematic periodontal treatment began in February 2014. After 2 cleaning appointments, FMD (modified according to Quirynen [8]) was performed on 2 consecutive days in mid-March 2014. The insufficient fillings on teeth 11, 22, 17 and 47 were replaced with direct composite restorations as part of the supportive periodontal treatment (SPT) in August 2018. Furthermore, the wedge-shaped defect on tooth 14 was filled with a composite restora-

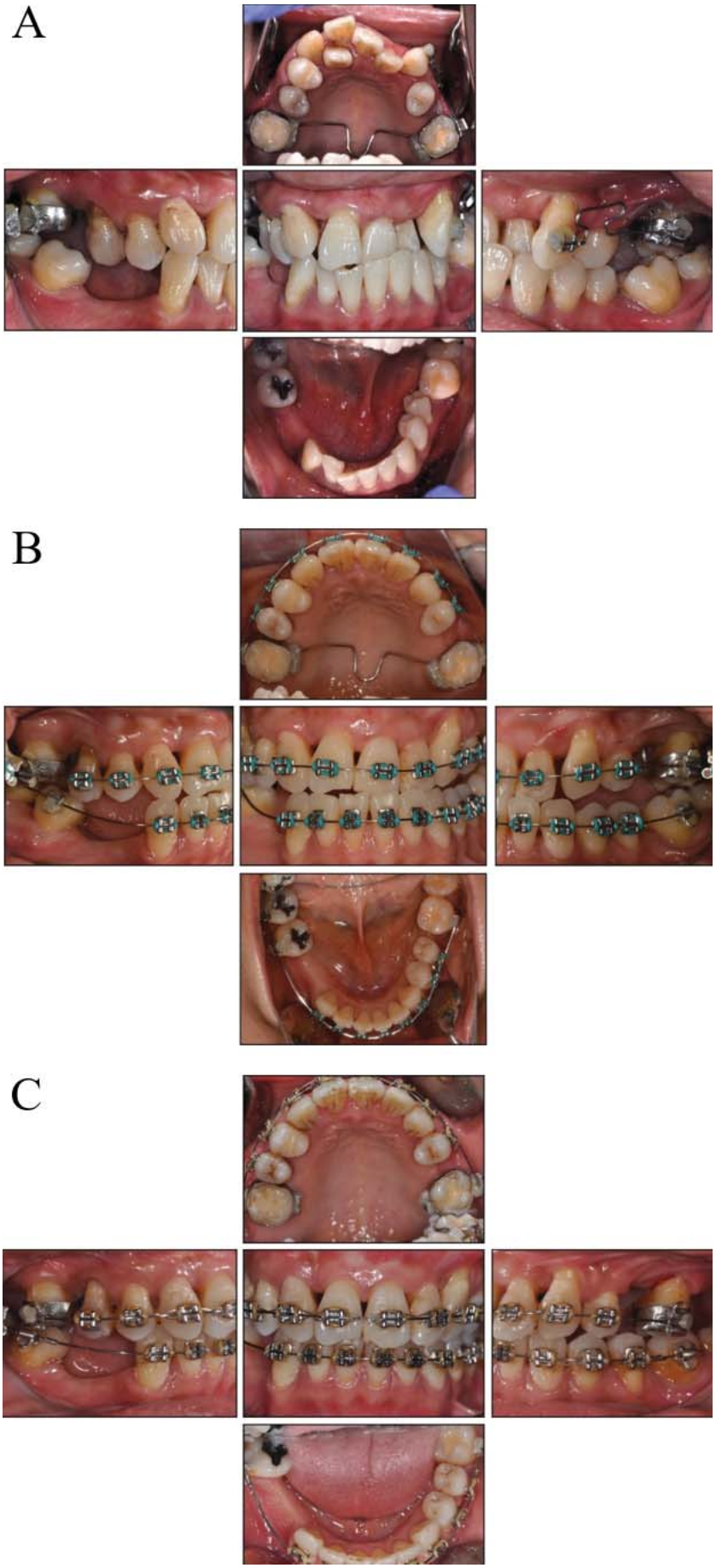

Fig. 6: S. K. Sonnenschein

Figure 6 (A) Intraoral photos presenting the clinical condition in February 2015, (B) December 2015, and (C) after bimaxillary orthognathic surgery in January 2017

tion in the course of SPT. After the re-evaluation of the periodontal status 3 months after FMD and final orthodontic planning, tooth 12 was ready for extraction. It was finally extracted using a minimally invasive procedure in April 2015. The re-evaluation of the periodontal status showed a reduction of all probing sites to 3 mm, with the exception of tooth 11 at the distolingual site. Tooth 11 displayed a probing pocket depth of 4 mm and no bleeding. Overall, BOP decreased to 10 %. The mean probing depth at the time of re-evaluation was 2.1 mm and the average CAL was 2.7 mm. Due to the remaining tooth malpositions, and the consequent inability to effectively maintain oral hygiene at home, as well as the additional difficulty in performing oral hygiene due to the planned multiband appliance, a SPT interval of 6–8 weeks was scheduled. After stable periodontal conditions were achieved just 6 months consecutive to FMD, the definitive orthodontic treatment planning began.

Orthodontic treatment

Orthodontic treatment began in December 2014 with partial fixed appliance in the upper jaw in order to achieve the isolated retraction of tooth 23. At the same time a transpalatal arch for maximal anchorage was inserted. A partial arch (23–26) with a T-loop was used in order to align and retract tooth 23 and to create space prior to the maxillary anterior alignment. Due to the mesial tipping of tooth 27, a partial space closure was carried out in region 025. In April 2015, tooth 12 was extracted (using a minimally invasive technique by the periodontist). In May 2015, a fully fixed multibracket appliance in both jaws was inserted. Regular check-ups and arch changes were made until the surgical planning began in October 2015. The intraoral clinical condition during the course of treatment is shown in Figure 6 A–C.

Maxillofacial surgery

In order to plan the bimaxillary orthognathic surgery, the documents (DVT, initial study models with the

Month or date	Orthodontics	Conservative treatment/ periodontal treatment	Maxillofacial surgery
March 2013	Initial consultation and planning of further interdisciplinary evaluation of TMD complaints, PA pretreatment		
December 2013	Orthodontic diagnosis and treatment plan; presentation in an interdisciplinary dysgnathia consultation, information about multibracket appliance + surgery, systematic prophylaxis program		
05.02.2014		Oral hygiene phase – appointment I (GBI: 10 %; PCR: 47 %; BOP: 41 %)	
27.02.2014		Oral hygiene phase – appointment II (GBI: 4 %; PCR: 20 %)	
20./21.03.2014		FMD with subsequent controls after 1 and 2 weeks	
25.06.2014		Re-evaluation PA-Status (GBI: 0 %; PCR: 24 %; BOP: 11 %)	
28.08.2014		Supportive periodontal therapy, composite resin restorations on teeth 11, 22, 17, 47	
August 2014	Re-evaluation, final orthodontic diagnostic and treatment plan		
October 2014	Presentation inthe orthognathic multidisciplinary consultation and discussion of the final treatment plan with patient		
December 2014	Maxillary partial banding left (bands on 16, 26, bracket on 23; transpalatal arch and partial arch with T-loop for retraction 23).		
07.01.2015	Follow-up appointment, activation of the T-Loop, local fluoridation	SPT (GBI: 3 %; PCR: 33 %)	
18.02.2015	Follow-up appointment, T-Loop activation	SPT (GBI: 9 %; PCR: 26 %)	
20.04.2015	Follow-up appointment, T-Loop activation	SPT (GBI: 3 %; PCR: 29 %)	
30.04.2015	Clinical re-evaluation and referral to extraction of tooth 12	Minimally invasive extraction of tooth 12	
May 2015	Maxillary/mandibular full banding, followed by further check-ups and wire changes		
08.06.2015	Follow-up check	SPT (GBI: 3 %; PCR: 27 %)	
08.07.2015	Follow-up check and maxillary/mandibular wire change		
10.08.2015	Follow-up check	SPT (GBI: 1 %; PCR: 39 %)	
21.09.2015	Follow-up and maxillary/mandibular wire change	SPT (GBI: 0 %; PCR: 15 %)	
October 2015	Orthodontic interim diagnosis		
06.11.2015	Follow-up check	Composite resin restorations of the wedge-shaped defects on teeth 14 and 15	
December 2015	Presentation in a dysgnathia consultation with planning of surgery appointments		

Table 1 Overview of the treatment process and the corresponding therapeutic procedures. BOP, bleeding on probing; TMD, temporomandibular dysfunction; FMD, full mouth disinfection; GBI, gingival bleeding index; PCR, plaque control record; PA, periodontal treatment; SPT, supportive periodontal therapy; Orth, orthodontics.

Month or date	Orthodontics	Conservative treatment/ periodontal treatment	Maxillofacial surgery
24.02.2016	Follow-up check		Preparation of planning documents for the surgery (DVT, study models with facebow registration, cephalometric evaluation)
08.03.2016	Follow-up check	SPT (GBI: 1 %; PCR: 18 %)	Inpatient admission
09.03.2016	Follow-up check		Bignathic repositioning osteotomy
11.03.2016	Further postoperative check-ups and postoperative orthodontic fine adjustments (setting)		
27.01.2017		SPT (GBI: 3 %; PCR: 27 %)	
21.02.2017	Debonding, temporary insertion of vacuum formed retainers (Essix retainers) for the duration of the scheduled tooth reshaping	Direct tooth recontouring using various composite resins, Part I	
28.02.2017	Insertion of maxillary/mandibular fixed retainer and removable retention appliance	Direct tooth recontouring using various composite resins, Part II	
28.03.2017	Check-up of retention		Removal of the osteosynthesis plates

Table 1 Overview of the treatment process and the corresponding therapeutic procedures. BOP, bleeding on probing; TMD, temporomandibular dysfunction; FMD, full mouth disinfection; GBI, gingival bleeding index; PCR, plaque control record; PA, periodontal treatment; SPT, supportive periodontal therapy; Orth, orthodontics.

facebow registration, cephalometric evaluation) were prepared on 24.02.2016. On 08.03.2016, the patient was admitted as an inpatient and the surgical preparations were completed. On 09.03.2016, the bimaxillary orthognathic surgery was performed under general anesthesia without complications. The maxilla was impacted by 2 mm on the left side to correct the canted occlusal plane after a Le Fort I osteotomy was performed in the usual manner. In order to correct the dental midline deviation and the maxilla's retrograde position, the maxilla was displaced 3 mm to the left in the transverse and 3 mm in the anterior direction, respectively. Four L-shaped miniplates (Medartis Modus 2.0) were used for osteosynthesis. The bilateral sagittal split osteotomy (BSSO) was performed according to Obwegeser-Dal Pont using the Hunsuck-Epker modification (Figure 7) in the mandible. Semi-rigid orthognathic plates (Medartis Modus 2.0) were used for osteosynthesis in the mandible. Postoperatively, the intended occlusion was secured with tight elastics in the splint. The postoperative X-ray confirmed that the osteosynthesis material was properly inserted (Figure 8). No complications occurred during the course of inpatient care. The patient was instructed about how to change the elastics by herself and she was discharged from the inpatient care unit on March 16, 2020. After good bone consolidation in the area of the osteotomies, the osteosynthesis material was removed 12 months postoperatively on March 28, 2017, under general anesthesia without complications. The change in the facial profile resulting from the surgery can be seen in Figure 9.

Tooth recontouring

The additive tooth recontouring of the maxillary front teeth (teeth 13 to

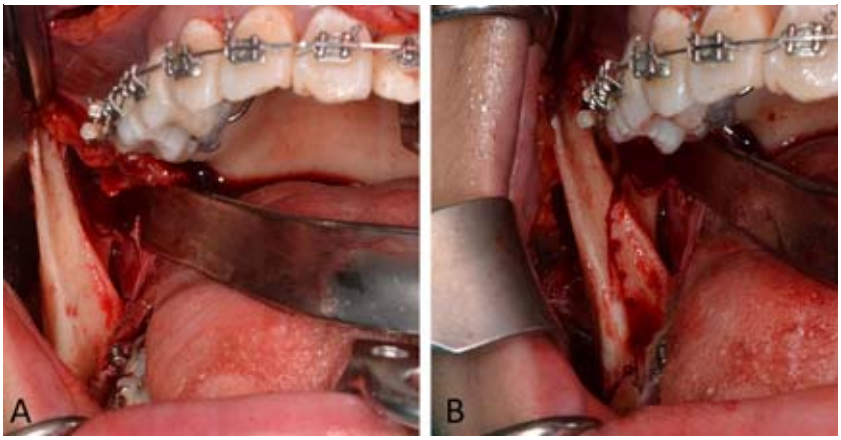

Fig. 7: C. Freudlsperger

Figure 7 Intraoperative X-ray images. (A) An illustration of the right ascending mandibular ramus (B) Sagittal split osteotomy (BSSO) according to Obwegeser-Dal Pont with modification according to Hunsuck-Epker

Fig. 8: C. Freudlsperger

Figure 8 Postoperative orthopantomogram in March 2016

23) using the direct composite layering technique (materials: OptiBond FL Primer and Adhesive, Kerr; Tetric Evo Ceram and Tetric Evo Flow, Ivoclar Vivadent) was performed in 2 steps in February 2017 (Figure 10). The detailed course of treatment is shown in Table 1. The diagnoses in February 2017 were:

- Angle class I after orthodontic treatment and maxillary/mandibular repositioning osteotomy of an Angle class III with a frontal progenic forced bite.
- Stable periodontal conditions after anti-infective treatment of periodontitis (generalized stage III grade B) with localized recurrence at the buccal site of tooth 23.

The chronological sequence of the treatment protocol and the specific procedures of each respective specialist discipline are summarized in Table 1.

Epicrisis

Studies have shown that in the presence of good plaque control, orthodontic treatment of patients with stabilized periodontitis, who have clinically healthy gingival conditions along with reduced periodontium, is possible without worsening the periodontal conditions or increasing the recurrence risk of periodontitis [11]. On the other hand, there also exist animal studies demonstrating that orthodontic forces on teeth with periodontal inflammation can lead to gingival recession and bone loss [4, 10]. For this reason, it is important to establish healthy and stable periodontal conditions prior to any orthodontic tooth movement [2, 3, 5]. In the case presented, the narrow and crowded position of the maxillary front teeth posed a particular challenge for anti-infective treatment. In addition to the difficulties of home-based oral hygiene, it was technically very challenging for the periodontist to access the entire subgingival surfaces in this area. Besides special curettes and airscalers, smaller, specially sharpened Mini-Five curettes were also used for subgingival debridement during FMD, as the teeth were sometimes so close together that the instruments did not fit between the teeth. Given the fact that the regeneration, or rather, repair of bony periodontal defects should largely be completed, and both the practitioner and patient should be confident about effective home-based plaque removal, orthodontic movements were not started until periodontal conditions were stable 6 months after anti-infective treatment. The orthodontic treatment of periodontally damaged adult dentitions presents a special challenge. This is because the involutive ageing processes of the desmodont and alveolar bone, as well as the type and extent of periodontal damage, create altered tissue responsiveness to orthodontic interventions [8, 9]. In the presence of attachment loss after periodontal treatment, it is important to note that the root surface which can absorb the orthodontic force is reduced and that the center of resistance is shifted apically, resulting in a longer lever arm; reduced forces must then be applied to account for these circumstances [2, 3, 5]. In order to correct a skeletal class III, orthodontic treatment and maxillofacial surgery is an established procedure; its aim is to achieve a class I dentition with stable

Fig. 9: C. Freudlsperger

Figure 9 Preoperative profile views: (A) frontal and (B) lateral as well as postoperative profile views: (C) frontal and (D) lateral

Fig. 10: S. K. Sonnenschein

Figure 10 Appearance after direct tooth recontouring using various composite resins in March 2017

occlusion and the simultaneous correction of the maxillary and mandibular positions based on cephalometric and facial landmarks which are esthetic. The patient in this case underwent bimaxillary orthognathic surgery after preoperative orthodontic treatment without any complications. Moreover, throughout the course of treatment, the patient showed a stable occlusion without any signs of relapse of the original class III occlusion. A good consolidation of the bone in the former areas of osteotomy was seen when the osteosynthesis material was removed, indicating that a good long-term outcome can be assumed from a surgical standpoint.

From a periodontal perspective, the continued prognosis is likewise considered to be good. The patient was able to establish a satisfactory home-based oral hygiene regime and the periodontal condition has remained stable over the entire period ensuing FMD. The patient claims to remain motivated.

For personal reasons, the patient changed her residence to a more distant location at the end of 2016. Although the treatment that had been started was completed, she searched for a new dentist in her new location from March 2017 in order to continue with the SPT appointments, for which an interval of 6 months was recommended. Further treatment planning includes, in addition to SPT, the closure of the dental gap in region 44–46 using implants or a bridge and orthodontic retention.

The case presented illustrates how a treatment goal can be achieved by the close interdisciplinary cooperation between specialists in the disciplines of orthodontics, oral and maxillofacial surgery, and periodontics/restorative dentistry. Following collective case analysis by all the specialists involved, a joint treatment strategy was planned and implemented in a coordinated sequence. The treatment aim which consisted of establishing a stable occlusion in a normal occlusal position, with the best possible pain-free function and good conditions for maintaining periodontal stability, as well as an esthetically pleasing appearance of the teeth could be achieved by this procedure through interdisciplinary cooperation.

Conflict of interest

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

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Photo: S. Sonnenschein

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Vertical tooth surface loss – a narrative review

Part II: therapy and aftercare

Introduction: Tooth surface loss (TSL) is a physiological process, which is multifactorial and progresses throughout life. Depending on the extent and progression of TSL, it may be necessary for the dental practitioner to initiate individualized preventive and/or therapeutic measures in cooperation with the affected patient.

Methods: In the first part of this narrative review, a literature search on PubMed and in the S3 guideline on bruxism was conducted; various studies appearing up to February 2020 were evaluated. Within this framework, the second part of this article explains when pre-restorative treatments are indicated, when a bite elevation should be performed, as well as, how it can be implemented and to what extent it is limited. Moreover, the various pre-prosthetic and restorative treatment options are elucidated. Additionally, the different dental materials and their advantages and disadvantages in terms of esthetics, function and long-term results are described.

Results: Although physiological, age-related TSL is an indication for treatment only in exceptional cases, extensive TSL affecting the supporting zone of the dentition or reaching far into the dentin usually must be treated. In such cases, it may be necessary to restore and secure the occlusal and vertical jaw relation by means of prosthetic rehabilitation. Most commonly, extensive TSL is treated by means of indirect restorations made of metal and ceramics. In this respect, tooth preparation for crowns and bridges can be seen as a disadvantage as it results in additional circular loss of tooth substance. Tooth-colored, minimally invasive restorations are considered a good alternative depending on the financial means of the patient.

Conclusion: At present, there is no universally suitable restorative therapy concept for patients with TSL; rather, highly individualized treatment decisions must be made for each patient whereby both esthetic and functional parameters are taken into consideration in the decision-making process.

Keywords: bite elevation; bridge; ceramic; composite; crown; non-cariogenic tooth surface loss (TSL); splint

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Citation: Roesner A, Rauch A, Behr M, Hahnel S: Vertical tooth surface loss – a narrative review. Part II: Therapy and aftercare. Dtsch Zahnärztl Z Int 2022; 4: 58–69
Peer-reviewed article: submitted: 09.03.2020, revised version accepted: 10.06.2020
DOI.org/10.53180/dzz-int.2022.0007

1. Introduction

According to the findings of the Fifth German Oral Health Study, the number of carious lesions in Germany is steadily declining. At the same time, younger seniors have fewer missing teeth in their dentitions compared to the findings in previous surveys (Third or Fourth German Oral Health Study; DMS III: 10.4 teeth, DMS V: 16.9 teeth) [22]. Meanwhile, a reverse trend is occurring with regard to the prevalence of non-cariogenic tooth surface loss, as it is steadily increasing [9]. Tooth surface loss (TSL) is a physiological process, which is multifactorial and progresses throughout life [5]. Depending on the extent and progression of TSL, especially when considering the specific age of the patient, it can be pathological, and therefore, oblige the dental practitioner to initiate individualized preventive or therapeutic measures in cooperation with the affected patient (Figures 1 and 2) [49]. In the first part of this narrative review (Dtsch Zahnärztl Z Int 2021; 3: 148–157), the causes of non-cariogenic TSL were examined, diagnostic options were presented, and a decision tree was used to summarize the particular cases in which different treatments may be indicated. For this purpose, various studies published on PubMed and in the S3 guideline on bruxism up to February 2020 were evaluated on the basis of topic-related search terms; a manual search of these studies' respective reference lists was also conducted. In this context, the second part of this narrative review aims to discuss the possible treatment options in more detail, focusing on pre-prosthetic and restorative measures.

Figure 1 Initial situation before the start of treatment, extraoral.

Figure 2 Initial situation before the start of treatment, intraoral. The 67-year-old patient presented himself with the wish for prosthetic rehabilitation. Pronounced non-cariogenic TSL and severe bruxism were present. Clinically, soft plaque, tartar and generalized gingivitis were identified. As specified in the medical history the clinical functional analysis confirmed that parafunctions were present, however these were asymptomatic. Furthermore, untreated interdental gaps in the missing tooth regions 014 and 046 were particularly noticeable. The maxillary incisors displayed reduced crown heights to varying degrees and dentin exposure was clinically evident.

Figure 3 Based on dentofacial and cast analyses, an increase in height by 10.5 mm and 7.5 mm was planned for the maxillary and mandibular central incisors, respectively, together with a 4 mm increase of the vertical jaw relation. Using splint therapy, the new jaw relation was tested for a period of 3 months (Figure 2). Meanwhile, extensive oral hygiene and prophylactic measures took place.

2. Pretreatment

2.1 Bite elevation – when and how?

In the majority of patients, TSL is accompanied by dentoalveolar compensation [5]. This physiological compensation mechanism ensures that, despite the loss of tooth structure, antagonist tooth contacts and the efficiency of his masticatory system are maintained [5]. Simultaneously, this process leads to a deficit of interocclusal space and creates a dilemma for the dental practitioner, especially in cases of localized TSL. One solution is to further reduce the occlusal surfaces of the affected teeth. Besides further loss of tooth substance, this procedure often results in a greatly reduced crown height of the abutment teeth, which in turn, reduces the potential retention and resistance forces needed for prospective prosthetic restorations [42]. Surgical crown lengthening can counteract this problem in certain circumstances, but it involves a risk of complications associated with the surgical procedure [42] and it always causes a

Direct composite restorations	
Advantages	**Disadvantages**
Low costs with an acceptable esthetic result	Polymerization shrinkage causes marginal gap formation and generates heat
Non-invasive procedure, conserves tooth substance and pulp	Faster wear compared to prosthetic restorations made of metal/ceramic
Suitable for diagnostic purposes	Low fracture strength
Minimally abrasive towards antagonist teeth	Esthetic deterioration due to discoloration
Simple to repair and expand	Technique sensitive (moisture control is mandatory)
	Result and long-term stability depend on the quantity and quality of the enamel
	Reduced potential for shaping proximal contacts compared to crowns
	For large restorations with changes in the vertical dimension, optimal fitting is difficult to achieve

Table 1 Advantages and disadvantages of direct composite restorations [31]

Indirect composite restorations	
Advantages	**Disadvantages**
Improved ability to shape occlusal morphology and proximal contacts	Reduced marginal fit compared to metal/ceramic restorations
Improved potential to adequately increase the vertical dimension for large restorations	More treatment steps necessary compared to direct composite restorations
Better esthetic results compared to metal restorations	Additional dental laboratory costs
Reduced treatment time for the dentist as intraoral modifications can be performed at the same time	Potential undercuts of the tooth substance must be corrected leading to additional tooth surface loss
Low abrasiveness towards antagonist teeth	Technique sensitive (moisture control mandatory)
Compared to direct composite restorations, increased fracture strength and longer durability	Lower long-term stability compared to ceramic/metal restorations
No or reduced intraoral polymerization shrinkage	

Table 2 Advantages and disadvantages of indirect composite restorations [31]

reduction in the periodontal attachment.

Bite elevation should be performed when dental treatment is needed for medical and/or esthetic reasons. For instance, this is the case when there are extensive defects affecting the entire dentition, with a considerable reduction of the vertical crown height and esthetic deficits (Figure 1 and 2), and these can no longer be selectively restored by means of direct or indirect measures, and when other alternatives to acquire space, such as a surgical crown extension, are not suitable. [21, 25, 45]. In spite of the fact that physiological, age-related abrasions/attritions are only an

indication for treatment in exceptional cases, TSL associated with parafunctions can frequently be treated just symptomatically. In cases of extensive TSL, which affects all supporting zones of the dentition or extends deep into dentin, it may be necessary to treat the affected teeth using prosthetic measures in order to restore and secure the occlusal and vertical jaw relation in the long-term [8, 13].

Before raising the vertical jaw relation using definitive restorations, depending on the extent of the desired change, a preliminary test phase should be considered in order to test this change using reversible procedures [9]. Beforehand, however, functional diseases should be excluded for forensic reasons; if necessary, the pre-restorative procedures should then be performed together with the functional treatment measures.

2.2 Determination of the vertical jaw relation

For all definitive restorative treatment options, regardless of whether they are non-invasive, minimally invasive, invasive or additive, the planned vertical jaw relation must be determined in advance. In the posterior tooth region, sufficient space should be created for the future restoration and the required minimum material thickness, while simultaneously, taking care not to exceed a crown/root ratio of 1:2. Also, in the context of an increase or change in the vertical jaw relation, an anterior canine guidance in dynamic occlusion should be pursued while also adhering to the Spee and Wilson curves. Frequently, in an abraded dentition, both jaws must be adjusted due to the heavy wear of the occlusal morphology. Especially in the anterior region, esthetic aspects play a decisive role in determining the vertical jaw relation. It is therefore recommended to simulate the treatment result with the help of a mock-up (Figure 4).

2.3 Pre-restorative options for simulating the treatment result

There are currently only a few scientific studies regarding the influence of changes in vertical jaw relation on the genesis of craniomandibular dysfunctions. In systematic reviews, however, various authors assume that raising the vertical jaw relation in the context of a bite elevation of up to 5 mm is not critical; generally speaking, patients would adapt well to the new jaw relation and only mild and temporary complaints would occur, if at all [1, 2, 37]. Nonetheless, in principle, care should be taken to ensure that a resting position is still present after the vertical jaw relation has been changed; major changes should be carried out incrementally [36]. According to current case law and the view of the German Society for Functional Diagnostics and Therapy (DGFDT), a functional examination of the craniomandibular system as part of a clinical functional analysis is indicated before reconstructive measures are performed in order to detect any latent functional problems and plan treatment. From a forensic perspective, the Higher Regional Court of Munich decided in 2017 (file number 3U 5039/13) that screening to clarify hidden craniomandibular dysfunction (CMD) prior to prosthetic treatment is a medical standard and that failure to carry out the required screening prior to the start of prosthetic treatment constitutes a diagnostic error.

A common pre-restorative pretreatment that is used for the scope of complex rehabilitation of patients with non-cariogenic TSL is splint therapy (Figure 3). Owing to their adjustable characteristic, splints have a wide range of indications and serve as a standard dental procedure during pre-prosthetic treatment. Especially in patients with parafunctions, occlusal splints such as equilibration splints (also known as Michigan splints, stabilizing splints, or relaxation splints) can eliminate occlusal interferences or reduce parafunctional activities [39]. Occlusal splints can be used to test possible changes in the vertical, and if needed, also in the horizontal jaw relation [13]. This allows the new intended bite position to be reversibly tested over a defined period. Based on the authors' knowledge, in these cases, there is no reliable evidence regarding the question of how long splint therapy should take place for the purpose of testing a new bite position. Depending on the clinical case, periods between 3 and 12 months have been shown to be effective based on the authors' experience. In the context of treatment planning, a generally reduced patient compliance should be taken into account during a prolonged wearing period. These steps enable the patient to adapt to the new vertical, and perhaps horizontal, jaw relation; readjustments are possible afterwards. According to the authors' experience, if pronounced wear facets that indicate parafunctional activity are visible on the splint, performing a bite elevation is associated with the risk of non-adaptation [36]. New digital technologies in the field of computer-aided design and computer-aided manufacturing (CAD/CAM) also make it possible to manufacture tooth-colored and flexible polycarbonate splints; they represent a non-invasive, removable, and thus reversible, functional and esthetic solution in contrast to conventional transparent splints or fixed long-term temporaries (Figure 9) [12, 13]. In this way, the esthetic appearance can be noticeably improved at an early stage of treatment; moreover, CAD/CAM-milled splints are dimensionally and chromatically stable, have better biocompatibility and show less wear while also displaying improved fitting accuracy compared to conventional polymethyl methacrylate splints [12, 13]. If there is severe TSL, the vertical dimension can be increased by manufacturing a separate polycarbonate splint for each jaw.

The Dahl concept represents an alternative approach. It describes an axial tooth movement that occurs when an appliance is introduced in supraocclusion; teeth that are not supported by the bite block elongate in a vertical direction [8]. Originally, Dahl described a removable cobalt-chromium bite platform [8, 42], but a wide variety of materials such as direct or indirect composite core build-ups or CAD/CAM milled table-tops are used nowadays. The thickness of the appliance corresponds to the later anticipated gain of interocclusal/incisal space [42]. The effect is achieved

Figure 4 After the fabrication of a conventional wax-up for the upper and lower jaws, the casts were duplicated and molds for an intraoral mock-up were created. The molds were then filled with tooth-colored composite-based temporary material and positioned over the existing tooth hard substance. In this manner, a quick and simple visualization of the prospective treatment result is possible.

Figure 5 Where necessary, the teeth were restored by means of adhesive composite core build-ups. After creating a retention form, preparation of the restored abutment teeth ensured.

Figure 6 A diagnostic wax-up was used to check if he required amount of tooth substance was removed during preparation. With the help of the wax-up and the finished molds, temporary crowns and bridges could be made inexpensively by means of the chairside technique; these were worn for a period of 3 months to test the patient's adaptation to the new bite. The anterior mandibular teeth could be adjusted to the desired jaw relation using direct composite fillings.

by a combination of intrusion (40 %) and extrusion (60 %) of the teeth that are not in contact [7]. Scientific studies have substantiated a 94–100% probability of success, which appears to be independent of the patient's age and sex [7, 19, 20]. Moreover, it was shown that an increase in the vertical dimension of up to 5 mm could be achieved in this manner, whereby the result was achieved on average after 6 months. Nevertheless, depending on the amount of required space, periods between 18–24 months have been described [20, 46]. Additionally, there is of course the option of increasing the interocclusal space using orthodontic procedures [15].

Every definitive dental rehabilitation in patients with non-cariogenic TSL should be adequately tested in order to identify any potential problems with the occlusion at an early and reversible stage; this facilitates that any supplementary fine adjustments are made quickly and easily. As a rule, long-term temporaries are used during this phase [39]. They are indicated before the definitive prosthetic treatment in the case of therapeutic changes to the vertical and/or horizontal jaw relation, as they permit the testing of the changed vertical position to be performed with as little risk as possible [18]. The prosthetic requirements for long-term temporary restorations are in the broadest sense the same as those for permanent dentures. Conventional laboratory-fabricated long-term temporaries are made from non-precious alloys, which are veneered with composite according to requirements; however, with the emergence of CAD/CAM technology, these have been largely replaced by pre-polymerized polymethyl methacrylate in blank form and indirect composites. In concordance to the clinical findings and prognosis, long-term temporaries should be worn for a period of about half a year [39]. Especially in complex cases with craniomaxillofacial anomalies requiring interdisciplinary prosthetic-surgical treatment, such digital pre-prosthetic pretreatments can represent an important component [12]. In some treatment cases, it is also possible to directly handcraft a temporary restoration; for instance, the platinum foil technique can be applied to simulate the treatment results for a couple of months. Such an approach is considerably less expensive than laboratory-fabricated indirect restorations. Yet, both approaches still have the disadvantage of generally necessitating extensive and invasive measures for the fitting of the temporary restorations.

Metal restorations	
Advantages	**Disadvantages**
Can be fabricated even in very thin layers (0.5 mm)	Esthetic deficits – limited use in the anterior/visible region
Very good marginal fit	Intraoral modifications only possible to a limited extent
Low abrasiveness towards antagonist teeth	Additional dental laboratory costs compared to direct restorations
Good and stable long-term protection of the remaining tooth substance	Close proximal contacts with adjacent teeth in the posterior region can be a problem when using onlay restorations (YAP et al)
Especially suitable for posterior restorations in patients with parafunctions	Additional removal of tooth hard substance compared to adhesive composite restorations
More conservative tooth preparation design compared to ceramic crowns	

Table 3 Advantages and disadvantages of metal restorations made from gold and Co-Cr [31]

Ceramic restorations	
Advantages	**Disadvantages**
Very good esthetic results	Good polish necessary, otherwise high abrasion of the antagonists
High flexural strength and fracture toughness for ceramic restorations made from zirconia	High costs (compared to direct restorations)
Different ceramic materials for different requirements	Silicate ceramics are technique sensitive
Can be produced in very thin layers (0.5 mm zirconium dioxide)	
Very good marginal fit	
Good and stable long-term protection of the remaining tooth substance	
Different preparation designs possible (partial crowns, crowns or onlays) using adhesive cementation, minimally invasive preparation also possible	

Table 4 Advantages and disadvantages of of ceramic restorations [31]

In contrast, in some cases, when tooth preparation is not desired, it is possible to apply alternative temporary restorations in the form of chairside-produced or laboratory-fabricated veneers or table-tops made of polymethyl methacrylate or PMMA-based polymers that can be milled using various CAD/CAM systems (e.g. Telio CAD, Ivoclar Vivadent; CAD-Temp, Vita Zahnfabrik). They can be fixed on the tooth areas in form of a non-prep solution; self-adhesive luting composites are generally used for this purpose [10].

The basic prerequisite for the changeover from a temporary to a definitive jaw relation is the func-

Figure 7 Due to the patient's limited financial means and his desire for a long-term restoration given the existing parafunctions, crowns and bridges made from non-precious metals were fabricated by sintering (Sintron, Amann Girrbach, Koblach, Austria). Within the vestibular veneering limits, ceramic was used (dental technology: Polyakov and Müller, Regensburg). The sintering process was chosen in this case due to the abundant supply of non-noble alloys and the possibility of producing highly homogeneous restorations without voids using the CAD/CAM process.

Fig 1–8: S. Hahnel

Figure 8 After the successful try-in, the restorations were cemented using conventional zinc oxide-phosphate cement (Figure 6) and the patient was included in a recall system that included closely spaced check-ups.

Fig. 9: O. Schierz, Leipzig

Figure 9 Tooth-colored mandibular splint composed of polyoxymethylene.

tional freedom from symptoms of the patient [4]. Finally, it is recommended to record the initial, and when necessary, intermediate, and final functional findings in a standardized data entry form (for example, the clinical functional status of the DGFDT or similar documents) for forensic reasons. Material selection according to the clinical needs and conditions is essential for the subsequent restorative procedure; the required tooth preparation design, the manufacturing technology and the intended type of cementation of the final restoration should be reflected in the selection [4].

3. Definitive restorative phase

3.1 The right material for the definitive restoration

Currently there is no single restorative treatment concept for patients with TSL. On the contrary, a highly individualized treatment decision must be made for each patient. In order to be able to make a goal-oriented treatment concept and choose the correct material, various parameters should be taken into account in the decision-making process; these include the extent of the TSL, the additional loss of substance that is expected due to preparation, the final functional findings, the desired occlusion concept and the esthetic expectations regarding the restoration. Depending on the condition of the antagonists, the required minimum layer thickness and the material-related luting technique employed, a distinction must be made between the different available materials [4]. In addition, the type of material used in patients with bruxism is also important for example, as many manufacturers list bruxism as a contraindication. A retrospective clinical study followed 1335 all-ceramic restorations and found that the risk of material-related failure is 2.3 times higher in patients with bruxism [33]. Currently, there is no generally applicable rule. It is however worth considering to keep the treatment options as simple as possible and to favor non-veneered restorations in patients with pronounced TSL and additional parafunctions.

3.1.1 Composite

Minimally invasive, yet esthetically pleasing results, can be achieved with direct composite restorations [9]. Particularly milder forms of TSL need no additional preparation measures as this is a purely defect-oriented ap-

proach (Table 1). However, this procedure often requires preliminary work in the indirect process such as creating a wax-up/mock-up when a new jaw relation is to be set-up. Using nano-filler composites and nanohybrid composites, extended occlusal TSL can be treated by cusp replacement therapy using direct composite restorations [9]. This procedure represents a substance-preserving and cost-effective form of treatment for patients and it produces a good esthetic result with minimal occlusal wear in the long-term [9]. Furthermore, direct composite restorations can be used for diagnostic pretreatment in the case of a reconstruction of the bite height and they are much easier to repair than indirect restorations made of ceramic or metal (Table 1). A case-control study demonstrated that reconstructions of the vertical jaw relation with direct composite restorations was clinically satisfactory even after more than 5 years; however, negative changes such as marginal gaps, wear and discoloration were also evident [3]. Based on the Radboud Tooth Wear Project, a study by Loomans et al. showed that the clinical evidence for an increase of the vertical dimension in patients with severe TSL using direct composite restorations has so far been limited to a 5-year follow-up [27]. In this manner a study in which 34 patients with pathological TSL were treated with 1256 direct composite restorations (687 anterior, 324 premolar and 245 molar restorations) showed that the survival rate of direct restorations depended on which tooth the restoration was applied. Molars showed the worst prognosis [28]. In patients with parafunctions such as bruxism, TSL often progresses faster than in patients without additional parafunctions. Moreover, the materials used must be able to withstand additional parafunctional activities. This is the reason why the application range of direct composite restorations is often limited in patients with parafunctions. Other drawbacks are polymerization shrinkage, which can lead to gap formation at the edges of fillings, discoloration, as well as, high technique sensitivity (moisture control, ensuring enamel adhesion) [24, 32]. When direct composite restorations are used to reconstruct the vertical jaw relation, the high time expenditure and the difficulty in accurately reproducing the occlusal morphology is often criticized [4]. Clinical approaches to solving this challenge make use of template-based techniques such as splints or silicone indices [3,53]. In areas with high occlusal load, the material should also have a minimum layer thickness of 1.5–2 mm [42].

Currently, indirect composite restorations are rarely used in everyday clinical practice, but they do have some advantages over direct restorations. This includes reduced polymerization shrinkage due to the fact that polymerization of CAD/CAM composites already occurs during the manufacturing process. This eliminates the negative effect of clinical polymerization shrinkage which occurs with direct composites. Other advantages include reduced treatment duration, simple adjustment possibilities in the patient‘s mouth as well as lower abrasiveness towards the antagonists compared to ceramic restorations [32]. Some drawbacks include reduced marginal fit compared to metal or ceramic restorations and the higher costs compared to direct restorations (Table 2).

3.1.2 Indirect metal and ceramic restorations

Extended TSL is still most frequently treated with indirect restorations made from metal and ceramics (Figures 5 – 8). To date, it is worth mentioning that little scientific data is available regarding the clinical performance of restorations in the context of bite elevation [11].

In principle, metal crowns and bridges display very good long-term results (Table 5) [40]. Restorations made of metallic materials exhibit high elasticity and tensile strength as well as a good accuracy of fit with less tooth preparation compared to restorations made of ceramic. From an esthetic point of view, however, the grey/silver color and metallic luster must be criticized, which is why these restorations are generally veneered with an additional ceramic material in the visible area (Table 3). Ceramic restorations reflect the initially required material properties most broadly (Table 4). Ceramics, particularly glass-ceramics, show a more stable maintenance of the physiological occlusion in the long term compared to composite restorations, although again, losses are more frequent described in the posterior region than in the anterior region [40]. In order to combine proven conventional restorations with less invasive preparation designs, minimally invasive ceramic restorations such as table tops have been developed [9]. In this case, the preparation margin ends far supragingivally and usually at the level of the prosthetic equator. Silicate ceramics provide the best esthetic results and can be used in the anterior region as veneers and in the posterior region as smaller restorations [17, 29, 54]. In a long-term study, 34 patients were treated with 96 silicate ceramic inlays and onlays. After an observation period of 12 years, the survival rate was 84 % and it was shown that restorations cemented with dual-curing luting composites had a better survival rate than restorations cemented with light-curing luting composites [17]. Lithium disilicate ceramics have a higher flexural strength than classical silicate ceramics and can therefore sometimes be used as a material for 3-unit bridges (up to the 2nd premolar). To date, no manufacturers have indicated that these materials can be used for rehabilitating posterior areas [6, 14, 23, 30, 40, 43, 50]. In a prospective, non-randomized clinical study, 7 patients were treated with a total of 103 adhesively luted occlusal onlays made of lithium disilicate ceramic (IPS e.max Press, Ivoclar Vivadent). After 11 years, a survival rate of 100 % (Table 5) was observed, whereby 4 restorations in one patient showed slight discoloration at the restoration margin and one restoration exhibited marginal fissures after 10 years; however, no biological complications, decementation or carious lesions could be identified at the crown margins [11]. It should be noted that the study included a total of only 7 patients with no periodontal disease and optimal oral hygiene. In addition, lithium disilicate

Survival data for various treatments				
Study	**Restoration**	**Material**	**Observation period (years)**	**Survival rate**
Pjetursson und Lang 2008 [40]	Crowns/Bridges (N = 2088/1218)	Not further specified	5/10	93,8 %/ 89,2 %
	Extension bridges (N = 432/239)	Not further specified	5/10	91,4 %/ 80,3 %
	Implant-supported fixed partial dentures (N = 1384/219)	Not further specified	5/10	95,2 %/ 86,7 %
	Implant-supported fixed partial dentures (N = 199/72)	Not further specified	5/10	95,5 %/ 77,8 %
	Implant-supported crowns (N = 465/69)	Not further specified	5/10	94,5 %/ 89,4 %
	Adhesive bridges (N = 1374/51)	Not further specified	5/10	87,0 %/ 65,0 %
Sailer et al. 2015 [48]	Single crowns (N = 4663)	Metal-ceramic	5	94,7 %
	Single crowns (N = 9434)	Full ceramic – Lithium disilicate – Glass-infiltrated aluminum oxide – densely sintered aluminum & zirconium dioxide	5	96,6 % 94,6 % 96,0 %
Pjetursson et al. 2015 [41]	Fixed partial dentures (N = 1796)	Metal-ceramic	5	94,4 %
	Fixed partial dentures (N = 1110)	Full ceramic – Glass ceramic – glass-infiltrated aluminum oxide – zirconium dioxide	5	89,1 % 86,2 % 90,4 %
Rinke et al. 2018 [47]	Veneers (N = 101)	Pressed glass ceramic	7	93,6 %
	Extended veneers (N = 101)	Pressed glass ceramic	7	95,0 % im OK 91,2 % im UK
	Veneers with less than 50 % exposed dentin	Pressed glass ceramic	7	94,3 %
	Veneers with more than 50 % exposed dentin	Pressed glass ceramic	7	71,8 %
Edelhoff et al. 2019 [11]	Onlays (N = 103)	Lithium disilicate ceramic	11	100,0 %

Table 5 Summary of several scientific studies with survival data pertaining to various types of prosthetic restorations.
(Fig. 1–8, Tab. 1–5: A. Roesner)

ceramics have a higher flexural strength and fracture toughness than classical silicate ceramics which therefore facilitates a more minimally invasive preparation [16]. Restorations made of zirconia are used for both crown and bridge restorations of anterior and posterior teeth [44]. Zirconia is characterized by its high strength and fracture toughness, low minimal layer thickness, good marginal seal and esthetics combined with acceptable light transparency as well as the simultaneous possibility of masking tooth discoloration. Since the introduction of CAD/CAM technology, production has been simplified and manufacturing costs have been significantly reduced [38]. Also, the formerly well-known chipping issues related to veneered zirconia restorations [26, 52] have largely been offset by adapting the firing parameters and the establishment of an anatomical framework design [38]. Furthermore, continued advances in zirconia-based material sciences has made it possible to produce monolithic versions for patients with high esthetic demands. Overall, studies have shown a survival probability of 90.0–96.8% over an observation period of at least 5 years for 3-unit zirconia bridges (Table 5) [6, 14, 23, 30, 40, 43, 50]. According to the S3 guideline, there is insufficient scientific evidence regarding all-ceramic two- or multiple-unit bridges [35].

Metal-ceramics combine the positive properties of metals and ceramics (Figures 7 and 8). Their advantages include high elasticity due to the metallic framework, high tensile strength, good accuracy of fit combined with good esthetics and oral stability due to the ceramic veneering [51].

Regardless of the used material, the extended circular tooth substance loss is a disadvantage of conventional crown and bridge restorations. It has been shown that up to 70% of the tooth structure may be removed during tooth preparation for a conventional crown; this can be significantly reduced if table-top, partial crown or onlay preparation designs are selected [9]. In the case of endodontically treated teeth, the decision in favor of a partial crown instead of a crown can preserve up to 45% of the tooth substance [9]. Due to the high risk of chipping, the veneering layer should only be extended vestibularly or should be avoided completely. In case of extensive tooth structure loss, the standard care offered by the statutory health insurance covers a crown restoration made of non-precious metal with the veneering limited to the vestibular surface up to the premolars. In addition, a prospective study has shown that the annual failure rate of direct and indirect composite restorations is between 6.9–26.3 %. However, the 26.3 % rate of loss that is specified as being unacceptable by the authors is based on the results from a single study on microfilled composites. In summary, it should be noted that no clear evidence is available to suggest that one material is better than the other [34].

4. Conclusion

Although physiological, age-related TSL is an indication for treatment only in exceptional cases, extensive TSL affecting the supporting zones of the dentition or extending far into dentin must normally be treated. In such cases, it may be necessary to rehabilitate the affected teeth by prosthetic means in order to restore and secure the occlusal and vertical jaw relation in the long term. Various treatment options are available for increasing the vertical jaw relation such as splint therapy, temporary restorations or the Dahl concept. The basic prerequisite for the transfer of the jaw relation defined in the pre-restorative phase is the functional freedom from symptoms of the patient. Different types of restorations and materials can be used for the ensuing definitive restoration. At the moment, there is no universally suitable restorative therapy concept for patients with TSL. Rather, a very individualized treatment decision must be made for each patient, in which both esthetic and functional parameters are taken into account in the decision-making process. The most common treatment for extended TSL are indirect restorations made of metal and ceramics. Nevertheless, studies based on the Radboud-Tooth-Wear-Project have shown that, even in patients with severe TSL, restorative treatment is not always indicated. If patients have no complaints or esthetic concerns, close monitoring and aftercare are also possible options. In general, the extensive circular loss of tooth substance during tooth preparation for crown and bridge restorations can be considered a drawback. Tooth-colored, minimally invasive restorations can thus represent a good alternative, depending on the financial resources of the patient. Restorations, including permanent ones, may have a limited life span in patients with severe tooth wear due to bruxism and erosion. A detailed explanation of the possible treatment options and the potential complications should be included in the informed consent form.

5. Acknowledgements

The authors would like to thank the private lecturer Dr. Oliver Schierz for kindly providing Figure 9, Department of Dental Prosthodontics and Materials Science, University of Leipzig.

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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Structured oral hygiene instruction in the treatment of periodontitis – an explorative study

Introduction: According to the actual EFP guidelines, first step of periodontal therapy should include oral hygiene instructions (OHI), comprising the use of interdental brushes (IDBs). Yet, non-conclusive evidence exists for their effect. The present multicentric clinical controlled explorative study compared the clinical outcomes of two NSPT (non-surgical periodontal therapy) concepts under university settings, one with (in Germany (NSPT-G)) and one without IDBs (in Egypt (NSPT-E)).

Methods: 23 stage III/IV periodontitis patients (NSPT-G/NSPT-E:11/12) were examined before (T0) and after NSPT (T1). Patients' demographic data, tooth loss, clinical attachment loss (CAL), probing depths (PD) and bleeding on probing (BOP) were assessed. ANOVA and Mann-Whitney-U tests were used for statistical analysis.

Results: Baseline differences were observed in terms of age, severity and tooth number per patients. NSPT duration was 1.6 times longer in NSPT-G vs. NSPT-E. Improvements of BOP, PD and CAL were observed in both groups, with greater mean percentage reduction of PD for NSPT-G vs. NSPT-E (–26.86 (9.29) %/–12.61 (9.38) %; p=0.004). Similar effects were observed for changes in CAL, with higher improvement in NSPT-G vs. NSPT-E (–34.84 (11.18) %/–10.98 (10.6) %; p<0.001).

Conclusion: Both NSPT concepts achieved significantly beneficial clinical effects for patients within their socio-economic circumstance. However, according to the limitations of the explorative study, a clear benefit for a treatment concept comprised of NSPT in combination with comprehensive OHI and IDC during periodontal treatment remains unconfirmed.

Keywords: bleeding on probing; instruction; motivation; non-surgical periodontal therapy; oral hygiene; periodontitis

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Citation: Graetz C, Saleh N, Kahl M, Cyris M, Mashaly M, Elzanaty M, Dörfer CE, Sälzer S, Fawzy El-Sayed K: Structured oral hygiene instruction in the treatment of periodontitis – an explorative study. Dtsch Zahnärztl Z Int 2022; 4: 70–76
Peer-reviewed article: submitted: 26.04.2021, revised version accepted: 20.09.2021
DOI.org/10.53180/dzz-int.2022.0008

Introduction

Periodontitis is one of the most prevalent inflammatory diseases, affecting more than 65 % of the worldwide population [2]. Untreated, a progressive periodontal destruction [12] could lead to functional and aesthetic constraints, discomfort and ultimately tooth loss [7]. The primary goal of periodontal therapy, either non-surgical or surgical, remains the removal of the microbial biofilm and its mineralized forms, thereby reversing the associated bacterial dysbiosis to arrest the inflammatory destructive disease process. Systematic non-surgical periodontal therapy (NSPT) is still the gold standard of a successful periodontal treatment [16]. Health behavioral strategies directed at patient's motivation for self-performed supra-gingival plaque control or smoking cessation should accompany NSPT [17]. Failure to control these factors could be detrimental on the progression of periodontal inflammatory destructive processes [1, 10], following active periodontal therapy [21].

Recently published guidelines by the EFP for the treatment of periodontitis stages I–III [21] recommend for each step of therapy the same procedures for oral hygiene practices to control gingival inflammation, including mechanical self-performed plaque control, employing regular tooth brushing supplemented by interdental cleaning devices, including dental floss, interdental brushes (IDBs), oral irrigators and wood sticks [19]. Although professional oral hygiene instructions (OHI), including advise on self-performed home-use interdental cleaning (IDC) with IDBs, should be professionally taught to patients [23], the use of IDBs is not common in all countries worldwide, depending on their availability, cost or social aspects. Yet, there are specific treatment approaches that emphasize to varying degrees the importance of OHI or other procedures during NSPT, often without sufficient internal or external evidence of their clinical effectiveness.

Over the last nine years, the two periodontal departments at the Faculty of Dentistry, Cairo University, Egypt and at the Christian Albrechts University of Kiel, Germany aligned and standardized in a long-term project their periodontal curricula and treatment concepts. Yet, two differences remained between their NSPT concepts, namely the higher number of visits for supragingival professional mechanical plaque removal (PMPR) and the regular instruction of all patients for the use of interdental cleaning devices at Kiel University as compared to Cairo University. The aim of the explorative study was to compare stage-III/IV periodontitis patients receiving NSPT in university setting either (1) in Germany (NSPT-G) with IDBs or (2) in Egypt (NSPT-E) without IDBs, as a first step towards the design of a future large-scale multicenter randomized controlled trial on this topic.

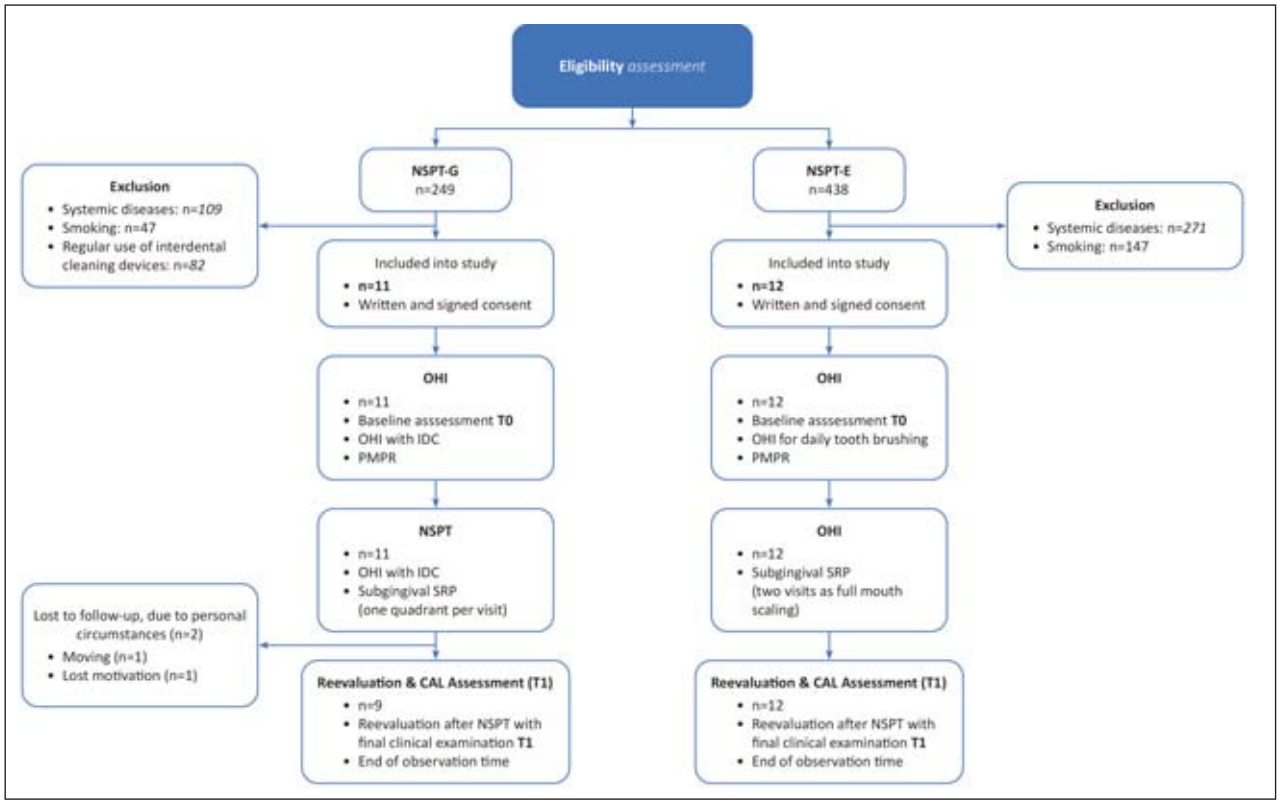

Figure 1 Flowchart of the recruitment and treatment protocol during observation time.

T0: Initial treatment visit, T1: reevaluation after treatment phase; bleeding on probing (BOP), clinical attachment loss (CAL), professional interdental cleaning instruction (IDC), non-surgical periodontal therapy (NSPT), non-surgical periodontal therapy in Kiel, Germany (NSPT-G), non-surgical periodontal therapy in Cairo, Egypt (NSPT-E), supragingival professional mechanical plaque removal (PMPR), professional oral hygiene instructions (OHI)

Methods

Study population

The present explorative study included 23 patients at two university clinics, who were diagnosed with periodontitis stages III or IV and scheduled for periodontal therapy between July 2018 and July 2019 at the Clinic of Conservative Dentistry and Periodontology, Christian Albrechts University Kiel, Germany or at the Oral Medicine and Periodontology Department, Faculty of Dentistry, Cairo University, Giza, Egypt.

Participants were eligible if they met the following inclusion criteria: (1) ≥18 and ≤70 years of age at the time of start of the periodontal therapy; (2) stages III or IV periodontitis and ≥16 scorable teeth without root caries (3) available for NSPT and reevaluation after 6±1 months; (4) no physical or mental impairment; (5) no medication influencing salivary flow and (6) no special dietary restrictions.

Possible participants were excluded if they (1) presented with oral diseases other than periodontal disease (forms of acute necrotizing ulcerating periodontitis or periodontitis of stage I); (2) suffered systemic diseases that could influence the outcome of therapy (e.g. uncontrolled diabetes mellitus, tumor of hard or soft oral tissue) or with specific conditions to treat (e.g. prophylaxis of endocarditis); (3) women who are aware of being pregnant or who are breast-feeding; (4) patients who were active smokers at T0 or quit smoking <5 years ago; (5) patients who were already using any interdental cleaning devices regularly at T0.

At both centers, stage-III/IV periodontitis patients were consecutively included without randomization, as the aim of the study was to compare the effect of each clinical concept of NSPT without influencing the internal procedures at each treatment center. At the center of Kiel, 232 patients were assessed first for eligibility of this study. Regarding the abovementioned inclusion and exclusion criteria eleven patients were included into the study, from whom two dropped out until T1 (Figure 1). In the meantime, 438 patients were initially screened for their eligibility for the study at the Cairo center, and after applying both inclusion and exclusion criteria, twelve patients were included and completed the study (Figure 1). Before starting the clinical trial, all investigators were internally calibrated by one dentist (C.G.) during a two-week practical training in the department of periodontology at the University of Kiel as part of the international collaboration between the two universities. In each group all treatments and evaluations were conducted by only one calibrated investigator (NSPT-G: M.K., NSPT-E: M.M.), using a PCPUNC15 probe (Hu-Friedy, Chicago Ill, USA).

Oral hygiene instruction (OHI) and supragingival professional mechanical plaque removal (PMPR)

Following baseline examination with a full attachment level status, all subjects received a PMPR and a center-standard OHI for daily tooth brushing, including (NSPT-G) or excluding (NSPT-E) IDC. For NSPT-G, initial periodontal therapy with 1–2 visits of PMPR and OHI, focused on IDC with IDBs and took up to three weeks in total before subgingival debridement started (NSPT-E: one visit in the first week). During the instruction and motivation phase, special care was taken for the adequate use and correct choice of size of the IDBs (TePe D-A-CH GmbH, Hamburg, Germany), repeatedly. For NSPT-G, an additionally reevaluation of bleeding on probing (BOP) and PD was performed at week 4 (T0a).

Non-surgical periodontal therapy phase

All subjects received a standard NSPT under local anesthesia, which consisted of scaling and root planing (SRP) with hand instruments and with ultra-/sonic scaler. Further treatments, e.g. extraction, endodontic treatments, splinting of mobile teeth were carried out in individual cases. According to the internal guideline of both centers, NSPT followed at individualized intervals of one quadrant per visit for NSPT-G (maximum of around 4–5 weeks in total) versus two visits as full mouth debridement for NSPT-E (maximum of 1–2 weeks in total).

Reevaluation and CAL Assessment

A reevaluation (T1) was performed for all subjects 8±2 weeks after NSPT at both centers and marked the end of our observation time.

Independent variables

All patients were classified according the classification of 2018 [15] at T0. In addition to gender and age, the following variables were measured for statistical analysis; (1) number of missing teeth (T0, T1), (2) PDs, (3) BOP, and (4) CAL (T0, T1) at six sites per tooth with a PCPUNC15 probe (Hu-Friedy, Chicago Ill, USA). CAL was calculated as the sum of PD and the distance from the cementum-enamel-junction to the gingival margin. The surrogate parameters plaque, mobility, furcation involvement and bone loss were not consistently measured in NSPT-E at T0 and had therefore to be excluded from the statistical analysis. At T1, a range of further variables was recorded by the treating dentist; including (5) tooth loss during T0–T1, (6) number of visits (T0–T1) for periodontal treatment and (7) duration (in days) for NSPT.

Data management and statistical analysis

Data were managed using electronic case report forms. Statistical evaluation was performed with SPSS 22 (SPSS, Chicago, IL, USA). Descriptive analyses were conducted. ANOVA, Mann-Whitney U were used to compare the two treatment groups and a binary logistic regression analysis was performed with BOP as dependent variable. Regression coefficients, standard errors (SE), p-values and 95 % Confidence Intervals (CI) were used as effect estimates. The sample size was calculated considering a mean difference of 20 % in BOP reduction [24], power of 80 %, and α of 5 %.

Results

Sample and base line characteristics

In this hypothesis-generating explorative study, at baseline (T0), 23 patients (NSPT-G/NSPT-E: n=11/n=12, male/female: 10/13) with a mean (±SD) age of 46.6 (10.5) years

(NSPT-G/NSPT-E: 54.8 (9.9)/42.1 (7.8) years) with 648 teeth (NSPT-G/NSPT-E: 302/346 teeth) were enrolled. The mean number of teeth (±SD) at T0 per patient was significantly lower at 24.8 (2.9) teeth/patient for NSPT-G compared to NSPT-E (28.8 (2.4) teeth/patient; p<0.001). None of the 23 patients had implants. Further details on patients and periodontal parameters (e.g. PD, CAL and BOP) at T0 are shown in Table 1.

Comparing baseline data, the NSPT-G group demonstrated older age (p=0.003), with a non-statistically significant higher prevalence of stage IV periodontitis, whereas NSPT-E group showed a higher prevalence of stage III periodontitis (p=0.069). No differences between both examined groups were detected according to prevalence of grades B/C at T0 (p=0.640).

During the observation phase, two participants (male/female: 1/1) of the NSPT-G cohort stopped participating (please see recruitment flow chart figure 1a). Both patients were diagnosed at baseline with stage IV periodontitis, one with grade B and the other one with grade C.

The duration of NSPT-G treatment (T0–T1) was with 148.8 (46.1) days significantly longer (NSPT-E treatment: 90.2 (20.1) days; p=0.002). During observation time, a total of eight teeth were extracted in five NSPT-G patients (NSPT-E: n=0). In detail, three patients lost one tooth, one patient lost two teeth and one patient three teeth in NSPT-G. NSPT-E patients showed non-significantly higher prevalence of teeth surviving between T0 and T1 (Table 1, p=0.079).

Inter- and intragroup analyses during different treatment stages (T0, T1) were conducted to detect treatment effects regarding BOP, PD and CAL (Table 2). At T0 patients of the NSPT-G group showed a higher mean PD and CAL than patients of the NSPT-E group (p<0.001 and p=0.026), while NSPT-E patients showed a significantly higher prevalence of BOP (p<0.001). For NSPT-G, results concerning the intermediate PMPR and OHI evaluation (T0 and T0a) showed statistically significant decreases in the prevalence of BOP, mean PD and CAL (Table 2). In addition, statistically significant decreases for BOP and PD were observed between T0a and T1 (Table 2).

In general, treatment outcomes at T1 for both groups (NSPT-G and NSPT-E) showed a statistically significant improvement in all three parameters (PD, CAL and BOP). The observed effect for PD and CAL was higher in the NSPT-G group (Table 2). For PD, the NSPT-G group showed a significantly higher mean percentage reduction (–26.86 (9.29) %) compared to the NSPT-E group (–12.61 (9.38) %; p=0.004). The CAL mean percentage reduction demonstrated a similar significant difference (NSPT-G/NSPT-E: –34.84 (11.18) %/–10.98 (10.6) %; p<0.001). Interestingly, the observed effect for the mean percentage reduction of 12.6 % for BOP in the NSPT-G group between T0 and T0a (p<0.001) was comparable with results of the whole observation time (T0–T1) in the NSPT-E group of 19.6 % BOP reduction (p<0.001). For NSPT-G, between T0a and T1 a further reduction of 29.1 % of teeth with BOP were measurable (p<0.001) leading to a nearly doubled reduction of BOP in the NSPT-G group for the whole observation time (T0–T1: 41.7 %, p<0.001) compared to the NSPT-E group (p<0.001).

	NSPT-G	NSPT-E	
Baseline characteristics (T0)	Kiel (n=11)	Cairo (n=12)	*P*-value
Gender (n)			
Male	4	6	0.680
Female	7	6	
Age (Years)			
Mean (SD)	54.8 (9.9)	42.1 (8.3)	0.003*
Periodontitis stage (n)			
Stage III	6	11	0.069
Stage IV	5	1	
Periodontitis grade (n)			
Grade B	8	10	0.640
Grade C	3	2	
Periodontitis extent (n)			
Localized	1	0	0.478
Generalized	10	12	
Teeth status (n)			
Not available at T0	48	38	0.079
Survived from T0 to T1	296	346	
Removed during T0 to T1	8	0	
Mean number of teeth per patient at T0 (SD)	24.8 (2.9)	28.8 (2.4)	<0.001
Mean number of teeth per patient at T1 (SD)	24.2 (2.3)	28.8 (2.4)	
Time from T0 to T1 (Days)			
Mean (SD)	148.8 (46.1)	90.2 (20.1)	0.002*

Table 1 Demographic and clinical data of both groups at T0 and T1.

Mean, standard deviation (SD), frequencies (n) and results of Student's t-test, Chi-square test and Fisher's Exact test for comparisons of baseline characteristics in the two centers; *: Significant at P ≤ 0.05, **: Fisher's Exact test,
NSPT-G: non-surgical periodontal therapy including instruction/motivation of oral hygiene at home; NSPT-E: non-surgical periodontal therapy without instruction/motivation of oral hygiene at home; T0: baseline; T1: reevaluation visit after end of NSPT-G/NSPT-E

Visit	NSPT-G	NSPT-E	Mean Difference (95% CI for Difference)	P-value between NSPT-G and NSPT-E (Effect size (Partial Eta squared or OR)
Mean (SD) PD at T0	5.67 (0.88)	3.56 (0.61)	2.1 (1.42–2.78)	<0.001 (0.689)*
Mean (SD) PD at T0a	5.34 (1.07)	n.a.		
Mean (SD) PD at T1	4.09 (0.44)	3.1 (0.56)	0.99 (0.52–1.47)	<0.001 (0.500)*
P-value (Effect size, Partial Eta squared) for PD at T0 vs. T0a	0.010 (0.589)*	n.a.		
P-value (Effect size, Partial Eta squared) for PD at T0a vs. T1	<0.001 (2.415)*	n.a.		
P-value (Effect size, Partial Eta squared) for PD at T0 vs. T1	<0.001 (0.776)*	0.012 (0.289)*		
Mean (SD) CAL at T0	4.67 (1.34)	3.52 (0.84)	1.81 (0.93–2.68)	0.026 (0.236)*
Mean (SD) CAL at T1	4.19 (1.46)	3.13 (0.79)	1.61 (0.69–2.52)	0.044 (0.197)*
P-value (Effect size, Partial Eta squared) for CAL at T0 vs. T1	0.001 (0.455)*	0.001 (0.428)*		
N of teeth with BOP (%) at T0	234 (77.5)	334 (96.5)		<0.001 (2.063)**
N of teeth with BOP (%) at T0a	196 (64.9)	n.a.		
N of teeth with BOP (%) at T1	86 (35.8)	266 (76.9)		<0.001 (2.694)**
P-value (Effect size, v) for BOP at T0 vs. T0a	<0.001 (0.527)*	n.a.		
P-value (Effect size, v) for BOP at T0a vs. T1	<0.001 (0.915)*	n.a.		
P-value (Effect size, v) for BOP at T0 vs. T1	<0.001 (0.207)*	<0.001 (0.233)*		

Table 2 Descriptive statistics and results for comparison between both groups of treatment as well as visits (T0, T1) for PD (mm), CAL (mm) (subject level) and for BOP (tooth level).

NSPT-G: non-surgical periodontal therapy including instruction/motivation of oral hygiene at home; NSPT-E: non-surgical periodontal therapy without instruction/motivation of oral hygiene at home; PD: pocket probing depth; CAL: clinical attachment loss; T0: baseline; T0a: intermediate reevaluation visit after PMPR and OHI in the NSPT-G group (only PD and BOP, no data for CAL); T1: reevaluation visit after end of NSPT-G/NSPT-E. *: Partial Eta squared; **: Odds Ratio (OR)

Discussion

The aim of the present explorative study was to investigate the clinical benefits of two different concepts for NSPT, namely with as well as without the inclusion of IDBs in the oral hygiene regimes, at two university centers in Egypt and in Germany, as a first step towards the design of a future large-scale multicenter randomized controlled trial on this topic. Both treatment concepts improved all periodontal parameters, namely PD, CAL and BOP in patients diagnosed with stage III or IV periodontitis, in accordance with earlier studies about the efficacy of NSPT [22]. Yet, apart from initially different periodontal baseline characteristics of both groups (e.g., number of teeth per patient, mean PD, etc.), the NSPT-G employing the OHI/IDC focusing on IDBs, demonstrated a significantly higher mean PD percentage reduction (p=0.004) and a higher mean improvement of CAL (p<0.001) compared to the NSPT-E group.

Although dental plaque is believed to be a primary etiological factor in the development of periodontal diseases [9], scoring of BOP could deliver more crucial information for further attachment loss [6,8]. In this context, we decided to exclude smokers from this study, to minimize external interferences on this sensitive parameter [13, 14]. NSPT-G patients showed more stage-IV periodontitis cases, yet BOP at baseline (T0) and throughout the follow-up visit (T1) was significantly lower than in the NSPT-E group. A possible explanation could rely on the higher adherence of the NSPT-G patients to the OHI/IDC training given at baseline and during all visits as well as their behavioral compliance in a university setting [4], whereas the NSPT-E patients, who mostly visited university clinics to receive symptomatic therapy, were probably less compliant with the procedure. Aside from such special socioeconomic conduct, the present findings are in accordance with data of a multilevel analysis from Japan on the importance of OHI, demonstrating that factors related to the treating centers, such as length of oral health instruction and number of dental hygienists, could clearly affect a patient's tooth loss [18]. The study recommended sufficient time for dental hygienists to provide OHI, as patients attending dental clinics, who were provided with OHI for 20 min or more, had a significantly lower risk of tooth loss (OR 0.69, 95 % CI 0.50–0.96). In the present investi-

gation, NSPT-G performed similar OHI procedures, with a clearly positive impact on all periodontal parameters, except tooth loss. However, this increased tooth loss observed in the NSPT-G patients must be interpreted in light of the significant differences between the two treatment groups, regarding the initial severity of periodontal diseases (Table 1), as well as the fact that for the NSPT-E group previous tooth extractions before/at T0 were not documented. Yet, all in all it underlines the beneficial effects of OHI/IDC, in accordance with actual guidelines of the EFP [21], especially for IDC [19], as a first step of NSPT.

A greater reduction of PD was noted in the NSPT-G group. However, this could have been partially influenced by the generally higher baseline values of PD and CAL, with higher expectancy for a clinical improvement following NSPT [22]. To overcome this limitation, the percentage reduction in addition to the absolute clinical reduction in millimeters of PD and CAL was compared. In accordance with earlier studies [3] this could be attributed to a more intensified OHI/IDC. In this context it remains important to emphasize that, apart from a higher number of visits used for PMPR in the NSPT-G, an earlier investigation demonstrated that PMPR performed prior to SRP does not improve clinical results of the subsequent SRP [5]. Therefore, our study negates the effect of the higher number of visits of PMPR in the NSPT-G as a factor affecting the difference in the measured periodontal outcomes. The subsequent subgingival debridement was performed in the NSPT-E group in a full-mouth manner and in the NSPT-G over up to four visits, with no substantial clinical differences reported between the two treatment approaches [20].

A number of definitive procedures, including alignment and standardization of the periodontal treatment concepts of the two centers over the last nine years and consecutive recruitment of participants with rigid inclusion criteria and additional pre-study investigators' calibration, were performed to achieve a high degree of standardization and reduce possible sources of bias. Nevertheless, the results of this study cannot be generalized due to its limitations. First, a sample of well-compliant patients in the NSPT-G group in Germany [4] was compared with a sample of assumingly less compliant younger-aged patients with low socio-economic status and unequal gender distribution in the NSPT-E group in Egypt, attending the university clinic for symptomatic dental therapy with no interest in long-term periodontal maintenance visits. Second, NSPT-G showed initially more severe periodontitis stages with significant higher PD and clinical attachment loss than the patients in the NSPT-E group (Table 2). Third, although the current explorative investigation is a clinically controlled trial, no randomization or observer blinding was performed. Fourth, plaque scores were not considered in this study, due to inconsistent scoring, and BOP was employed as an indicator for an active periodontal destruction [6, 8]. Notwithstanding, we staged and graded the participants using the data available, similar to other authors groups like Nascimento, Dahlen [11].

Conclusion

Patients with stages III and IV periodontitis at baseline, who were systematically treated during NSPT, showed a significant clinical improvement in PD, CAL and BOP. However, because of the limitations of this exploratory study, including baseline differences among the subjects studied, a clear benefit of a treatment approach consisting of NSPT combined with comprehensive OHI and IDC during periodontal treatment remains unconfirmed. Where devices such as IDBs are not available, e.g., due to socioeconomic circumstances, performing appropriate NSPT on its own could be an evidence-based and effective method for treating periodontitis, as shown by the results of the current study. Further investigations with a higher number of comparable participants have to be conducted to validate the presented results, i.e. compare it with other national healthcare systems for generalization.

Acknowledgements

The authors are grateful to Dr. Khaled Keraa for the excellent statistical evaluation.

Conflict of interest

All authors declare that they have no competing interests. The work was supported by the Clinic of Conservative Dentistry and Periodontology, University of Kiel, Germany and the Clinic of Oral Medicine and Periodontology, Cairo University, Giza, Egypt.

All procedures performed in studies with human participants were in accordance with the ethical standards of the institutional and/or national research committee (approved locally by the ethics committees of the Faculty of Medicine, Kiel University (AZ: 428/15) and Cairo University (AZ: 39/7/20)) and the 1964 Declaration of Helsinki and its subsequent amendments or comparable ethical standards. Written informed consent was obtained from all individual participants included in the study. A clinical trial registration was done retrospectively: ClinicalTrials.gov (NCT04339309).

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Photo: C. Graetz

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Dominik Groß

Otto Walkhoff (1860–1934) – Model scientist and early National Socialist

Introduction: Otto Walkhoff is considered one of the most important dentists of the early 20th century. But while he gained lasting fame as the eponym of scientific developments ("Walkhoff-Paste", "Walkhoff-Aufreiber"), the knowledge about his personality and the background of his retirement is rather fragmentary. His relationship to National Socialism has received even less attention. The present contribution takes the existing gaps in research as an opportunity for a synoptic analysis of Walkhoff's life and work.

Material and methods: Archival files, an autobiographical writing by Walkhoff (1934) and the "History of the Walkhoff Family" published in 1939 are the basis of this study. In addition, a comprehensive re-analysis of secondary sources (doctoral theses, specialist essays, eulogies, necrologists) on Walkhoff and his environment was carried out.

Results: Walkhoff was a pioneer in dental radiology and endodontics and the doyen of the dental doctorate. On the other hand, he was in clinches with colleagues and authorities for decades, which ultimately led to his forced early retirement. In political terms, Walkhoff joined the National Socialist German Workers' Party (NSDAP) at an unusually early stage (1929).

Discussion and conclusion: Walkhoff was exceptionally well recognised in his field, but highly controversial as a personality. He joined the NSDAP at a time when it was neither politically opportune nor career-enhancing. He remained faithful to Nazi ideology until his death, and in 1934 – and thus one year after the change of power – he explicitly positioned himself as a supporter of Hitler. At the same time, he placed himself at a critical distance from two democratic parties, the BVB and SPD, which both were dissolved in 1933.

Keywords: DGZMK; National Socialism; NSDAP; radiology; tooth preservation

PRWTH Aachen University, Medical School, Aachen: Prof. Dr. Dr. Dr. Dominik Groß
Citation: Groß D: Otto Walkhoff (1860–1934) – Model scientist and early National Socialist. Dtsch Zahnärztl Z Int 2022; 4: 77–85
Peer-reviewed article: submitted: 30.11.2020, version accepted: 15.12.2020
DOI.org/10.53180/dzz-int.2022.0009

Introduction

Otto Walkhoff is considered one of the most important dentists in the history of the discipline and, moreover, the most influential and prominent German representative in the first third of the 20th century. He not only set important scientific accents – especially in dental radiology and tooth preservation – but was also active in professional politics as longtime president of the "Deutsche Gesellschaft für Zahn-, Mund- und Kieferheilkunde" (German Society for Dental and Oral Medicine, DGZMK) (1906–1926, cf. Tab. 1): Among other things, he paved the way for the right to confer doctoral degrees in dentistry, which was introduced in 1919. Nevertheless, he was considered uncompromising and unbending, and his activities at the universities of Munich and Würzburg were marked by continuous quarrels with colleagues and authorities.

While Walkhoff's œuvre is comparatively well documented, there is only scanty and sometimes contradictory information on his willingness to argue and on the reasons for his dismissal in Würzburg. In addition, Walkhoff's political views have received little attention: although his curriculum vitae and academic career were the subject of two dissertations (1954 and 1985), his relationship to National Socialism was completely omitted.

The present article takes the gaps in research outlined above as an opportunity for a synoptic analysis of Walkhoff's life and work. The aim is to highlight his extraordinary achievements in science and professional politics, his multifaceted personality, but also his political stance, and to place them in the contemporary context.

Material and methods

Central parts of the study are based on various primary sources, some of which were evaluated for the first time.

These include archival records (Federal Archives Berlin and Secret State Archives Prussian Cultural Heritage Foundation), an autobiographical account by Otto Walkhoff published in 1934 (kept in the Bavarian State Library in Munich), as well as the "History of the Walkhoff Family" published by Erich Walkhoff in 1939.

The numerous publications by Walkhoff and his cooperation partners were also analysed. In addition, a re-analysis of more than 40 secondary sources (dissertations, professional essays, laudations, obituaries) on Walkhoff and his professional and political environment was carried out.

Results and discussion

Otto Walkhoff – life and career stages

Friedrich Otto Walkhoff was born on April 23, 1860 in Braunschweig (Fig. 1 [16]) [6, 15, 16, 19, 25, 27, 43, 46, 48]. He was the son of the civil auditor Friedrich Julius Walkhoff (1813–1884) and his wife Christiane Bruer (1825–1862). Otto had an older brother – Friedrich Wilhelm Walkhoff (1848–1899), who later became a physician and "Sanitätsrat" (medical councilor) in Dresden – and an older sister named Mathilde (1846–1921), who remained unmarried.

Otto Walkhoff attended the elementary school in Braunschweig and (from 1870) the grammar school in Höxter, which he left in 1877 a year before taking his Abitur. A family friend – the Braunschweig dentist Wilhelm Niemeyer – had advised him to study dentistry. At that time, prospective dentists did not need a school-leaving certificate (Abitur) for this training, as Walkhoff himself pointed out: "As the son of a small civil servant, I had worked my way up from not having a school-leaving certificate in almost 50 years of intensive work in my field to the reputation and position I now occupied in it, quite apart from my academic career from dental practice to personal full professor" – something I am particularly proud of, because only very few others succeeded in doing so (translated by DG) [59].

In 1878 Walkhoff began his training as a dentist in the private practice of Carl Sauer (1835–1892) in Berlin. It was Niemeyer who got him the job with Sauer, a renowned prosthodontist [16]. At the same time, Walkhoff attended occasional lectures at the Berlin Charité. During this time, while still a student, he also founded "the first association of students of dentistry at the University of Berlin" [44].

At the beginning of 1881 he passed the dental examination, obtained his licence to practise dentistry and soon became an assistant in the practice of dentist D. Koser in Berlin. In October 1881 he then entered military service as a one-year volunteer, which he completed in September 1882. From October 1882 he again worked in Sauer's practice. At the same time he was an assistant in the technical department (1882/83) and the restorative department of the Dental Institute of the University of Berlin (1883–1885). Walkhoff remained with Sauer until 1885 – and thus just until the year in which Sauer was elected president of the Central Association of German Dentists (CVDZ, today: DGZMK). But the year 1885 was also significant for Sauer and Walkhoff in another respect: On September 18, 1885, Walkhoff married Gertrud Sauer – the daughter of his mentor – and thus became Sauer's son-in-law and at the same time the brother-in-law of Franz Sauer, who had also chosen the dental profession. In the same year, Walkhoff took over Wilhelm Niemeyer's practice, which he ran until 1900. Walkhoff was thus already excellently networked in terms of professional politics at a young age: In addition to his father-in-law Sauer, Niemeyer (as a temporary CVDZ vice president) was also an outstanding representative of the dental profession.

In May 1897, Walkhoff received his doctorate (Dr. phil.) – parallel to his practice – at the University of Erlangen with the thesis "Contributions to the finer structure of the enamel and to the development of the dentine" (the doctorate "Dr. med. dent." was only introduced later). At the beginning of 1900 he was able to habilitate in dentistry in Erlangen. He was then appointed as a private lecturer and – still in February 1900 – as "II. teacher" at the Dental Institute of the University of Munich, which was then headed by Professor Jakob Berten (1855–1934). In June 1901 he

was promoted to "I. teacher" and in December 1901 to titular professor. This was followed in 1903 by a non-tenured associate professorship (as a reaction of the Munich University to a call to Berlin, which Walkhoff rejected) and in 1907 by a tenured associate professorship and the appointment as Royal Bavarian Court Councillor (in response to another call to Leipzig, which he also declined).

At the end of 1921, Walkhoff received a call from Würzburg, where they were looking for a successor to the unexpectedly deceased director of the institute, Andreas Michel (1861–1921). In April 1922 – at the age of 62 – Walkhoff actually took up the post as personal full professor and director of the Würzburg Dental Institute. His (premature) retirement came in 1927.

He subsequently moved into his wife's parental home in Berlin-Lichterfelde. Here he continued his scientific studies until shortly before his death.

Walkhoff died on June 8, 1934 in Berlin-Lichterfelde at his parents-in-law's house as a result of a cerebral stroke followed by heart failure "after a prolonged agonising suffering" [26]. He was buried at the Parkfriedhof (Park Cemetery) Lichterfelde (gravesite FiW-40, [21]).

Walkhoff as a scientist, professional politician and colleague

Walkhoff's professional importance can already be guessed from his numerous calls: Before he accepted the call from Munich (1900), he had already turned down offers of lectureships in Freiburg (1896), Marburg (1897) and Breslau (1900) – later, as already mentioned, he also rejected calls from Berlin (1903) and Leipzig (1906) [43].

Even before his move to the University of Munich, Walkhoff had made his first professional pioneering achievements: In January 1896, he introduced X-rays to dentistry in his practice in Braunschweig. Shortly after the discovery of X-rays by Wilhelm Conrad Röntgen (1845–1923) in November 1895, he had made the first dental X-rays in Braunschweig together with his friend, the chemist Friedrich Giesel (1852–1927), which still required an exposure time of 25 minutes. As early as April 1896, he presented improved results at a dentists' conference. In the years that followed, he "made all the radiographs for the doctors and dentists in his own X-ray laboratory" [26]. In addition, Walkhoff soon tested the use of radium, discovered by Marie and Pierre Curie in 1898, in (dental) medicine, initially undertaking self-experiments to investigate the (side) effects of radium. For example, he fixed a radium preparation provided by Giesel to his arm, causing skin inflammations. In 1900, he published a paper on "Invisible Photographic Rays". There he outlined similarities between the effects of X-rays and the radiation emanating from radium and assumed that both forms of radiation had tissue-altering effects [53]. Walkhoff also observed in experiments that mice suffering from cancer died significantly later when exposed to radium radiation, thus contributing to the development of radium therapy in tumour treatment. In 1928, he then looked back on the "first application of X-rays and radium in dentistry" and summarised his findings [56].

In addition, Walkhoff made a significant contribution to root canal treatment: In 1928, he introduced the "iodoform paste" ("Walkhoff paste") to dentistry, which was mixed with chlorophenol-camphor-menthol and is still partly used today [19]. Due to its absorbability, it also seemed "particularly suitable for milk teeth" [30]. Moreover, he gave his name to the "Walkhoffsche Kortikalschicht" (Walkhoff cortical layer) [9] and the "Walkhoff-Auftreiber" (Walkhoff tappers). The latter were "angular, elastic steel needles of various strengths for preparing narrow root canals" ("Reibahlen", comparable with modern reamers), which he had introduced into dentistry [30]. Further research concerned cariology and the effect of vitamins on tooth development and maintenance. Walkhoff also positioned himself resolutely "against the then rampant surgical radical therapy of dental focal infection" [28]. Moreover,

Figure 1 Portrait of Otto Walkhoff [16].

Walkhoff was "interested in the history of medicine and stomatology" and, among other things, wrote an appeal at the beginning of 1902 to contribute objects of dental historical interest for an exhibition of the CVDZ [4].

Walkhoff has published around 160 publications, including a double-digit number of monographs. In addition to his histological thesis [51] and the above-mentioned writings on radiology, his two atlases on the histo(patho)logy of human teeth [50, 52] attracted special attention. They have often been described as groundbreaking [13, 35]. The same applies to his "Lehrbuch der konservierenden Zahnheilkunde" (Textbook of Dental Conservation, 1921) [54] – it was published from 1931 under the title "Walkhoff's Lehrbuch der konservierenden Zahnheilkunde" with the involvement of Walter Hess and reached six editions by 1960 – as well as to his works on dentin sensitivity [55] and endodontics [57, 58]. The specialist book series "Deutsche Zahnheilkunde" (German Dentistry), which Walkhoff edited from 1915 onwards, also developed into a great success, and a commemorative publication in Walkhoff's honour was published in 1920 [5].

Walkhoff was extremely hard-working and productive throughout his life. Even at the end of his days in Berlin, he remained scientifically active, as evidenced by some 30 late publications. A vivid impression of

Walkhoff's creative power was provided by his student Josef Münch (1894–1977): "And how Walkhoff worked in Würzburg! He was the first one at the Institute in the morning and the last to leave in the evening, a shining, unprecedented role model for his assistants and co-workers" [39].

However, Walkhoff was also considered to be extremely disputatious, unbending and difficult in his personal dealings. Thus, soon after his appointment, there were ongoing disputes at the Munich Institute, which probably also had something to do with the fact that Walkhoff, as an associate professor in Munich, found it difficult to cope with "the subordinate position and dependence on the head of the Institute" – in this very case Jakob Berten (1855–1934) [33]. Walkhoff got into polemical and very personal disputes with Berten, but also with the second colleague Professor Fritz Meder (1862–1945) ("a sharp-tongued dispute conducted with biting criticism": [33]). Walkhoff accused Meder of "scientific inferiority", among other things [33].

Undoubtedly, Walkhoff was more knowledgeable and (as chairman of the CVDZ) also more powerful than Meder, whose publishing activities consisted "mainly in the publication of clinical cases" [33]. Nevertheless, Meder was a respected university lecturer; moreover, Berten had his back: both fought Walkhoff together for years. The dispute, which was also carried out in public, could not be contained even by interventions of the university administration.

Finally, in 1922 Walkhoff accepted a call to Würzburg. But here, too, persistent quarrels arose. On the one hand, they concerned Walkhoff's actions as president of the CVDZ. Board members gave up their posts in the Central-Verein. The reason for this was Walkhoff's "autocratic style of leadership" [24]. Hermann Euler described the situation in 1924 as follows [5, 15]: "Schaeffer-Stuckert, Dieck and Cohn had resigned from their board positions, partly in connection with previous differences, so that apart from Köhler and Parreidt the old guard was represented only by Walkhoff [...]. He watched all the more closely over the preservation of the old tradition and proposals that could change something in the internal structure of the Centralverein did not find a sympathetic ear with him." In 1926, Walkhoff finally reacted to the persistent criticism of his person by resigning from office after 20 years.

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

At the Würzburg Institute, too, fierce conflicts began in 1923 at the latest with Gustav Heinrich (1877–1964), the then head of the department of prosthetics and orthodontics: Heinrich had come to the Würzburg Institute in 1921 at the instigation of Andreas Michel (1861–1921) to complete his habilitation. However, Heinrich and Walkhoff already knew each other from their days together in Munich. Since Walkhoff succeeded Michel as head of the institute, he continued to supervise Heinrich's habilitation and acted as a reviewer. The habilitation procedure was successfully completed in February 1923, and already at the end of 1923 Heinrich was also promoted to associate professor – albeit against Walkhoff's will. Shortly afterwards, a plagiarism scandal broke concerning Heinrich's habilitation thesis. The accusations of deception concerned the animal experiments and methods presented there, as well as the attached visual material. As the responsible peer reviewer, Walkhoff was also involved in the affair: he was accused that the problem would not have arisen if he had "read the habilitation thesis more carefully and checked the results, as would have been his official duty" [43]. Walkhoff then distanced himself from Heinrich, referring to the unfavourable working conditions he had to cope with in Würzburg and to continuing disputes he had had with Heinrich. In fact, the two had fallen out in 1923 after Heinrich had demanded his own budget and the same rank as Walkhoff. Walkhoff wrote: "H. wanted complete independence for his department at that time, also in the budget, and thus the division of the Institute, whereas earlier the rights of Professor Michel as head of the Institute had been promised to me by the Minister himself!" [59].

In the end, the faculty found the accusation of plagiarism against Heinrich substantiated and had him dismissed in 1925. But Walkhoff also remained under fire: Heinrich accused him in 1925 (to the faculty) and in 1926 (to the Bavarian parliament) of "serious plagiarism" and also claimed that Walkhoff had "il-

legally helped his brother-in-law Franz Sauer to his doctorate": "The thesis was prepared according to Walkhoff's preparations and dictation" [59]. Walkhoff firmly denied both accusations, and indeed there were no further investigations into the matter. Nevertheless, the ongoing quarrels and mutual, public accusations also led to the end of Walkhoff's career: the ministry demanded Walkhoff's early retirement. Walkhoff held the leaders of the "Bavarian People's Party" (BVB) responsible for his "dismissal from office". In 1934, he still stated that he had been "removed from my office at the instigation and with the help [of the party]" [59].

In fact, in 1934, the year of his death, Walkhoff published a 113-page autobiographical essay. There he described – among other aspects of his life and career – his view of his forced dismissal in 1927, raising considerable accusations against the BVB, the Ministry of Culture and Gustav Heinrich, but also against his former Munich colleagues Berten and Meder. The latter had given him the reputation of being a "troublemaker" with the "oddity" that "I could not easily work together with others" [59]. In a family history published in 1939, the genealogist Erich Walkhoff – a distant relative of Walkhoff – followed this account, claiming that the "leaders of the Bavarian People's Party" had used the Heinrich case to "get rid of the Walkhoff they disliked", while Heinrich had been treated with leniency [1]. In fact, however, this view falls short, as Rohrmeier rightly pointed out: "In no way could Heinrich have been a favourite of the Bavarian People's Party, since their representatives in the Landtag unanimously demanded his dismissal. Therefore it is also [...] not correct for Erich and Otto Walkhoff to interpret the ministry's demand for his resignation as a game of intrigue by the Bavarian People's Party" [43].

Among Walkhoff's contemporaries, interestingly enough, his readiness for conflict was a recurring theme: Hermann Euler (1878–1961) [17, 20, 25, 47], a long-time companion of Walkhoff, explicitly praised Walkhoff's professional achievements, but did not fail to mention "that I have often been offended by his [Walkhoff's] oddity" [8, 45]. Oskar Römer (1866–1952) – an avowed friend of Walkhoff – on the other hand at least tried to arouse understanding for Walkhoff's behavior: "It is acutally self-evident that a man who pursues his life's goal with such iron energy as Walkhoff also gets many enemies on his course of life; especially when one considers that Walkhoff does not make concessions easily. Instead, he defends what he has recognised as right with ruthless energy. After all, he has [...] often been called a thick-headed man from Lower Saxony" [44].

After 1950, however, there was a proliferation of articles in which Walkhoff's disputatiousness and his forced end in Würzburg were glossed over and reinterpreted. Werner Schubert, for example, wrote about Walkhoff in 1954: "In 1927, at the age of 67, he retired from teaching to spend his retirement in Berlin-Lichterfelde, the home of his wife" [46]. Hans-Dietrich Mierau (1930–2019) also provided a shortened version of the circumstances in 2012: "On 30.9.1927 Walkhoff had applied for his retirement. His request was granted in a letter from the State Ministry on October 1, 1927" [36].

However, it should also be noted that the relentlessness and unbendingness of the CVDZ chairman in dental professional politics sometimes brought advantages: Thus Walkhoff was able "in 1925 to push through the beginnings of the great reorganisation" by initiating the merger of the CVZD with the "Vereinsbund Deutscher Zahnärzte": "In this way he laid the foundation for a powerful edifice which the Central Association represents today, together with its sub-associations" [29]. Besides, Walkhoff was also the strongest and most enduring voice in the demand for a right to doctorate in dentistry [14]. On the way to this goal, he also had fierce disputes with those colleagues who advocated full medical studies for future dentists and thus a "full doctorate" (Dr. med.). These included Professors Paul Adloff (1870–1944), Matthäus Reinmöller (1886–1977) and especially Johannes Reinmöller (1877–1955) [37, 41, 42]. Walkhoff, on the other hand, categorically rejected a 10-semester full course of study in medicine instead of the 7-semester "special course of study" in dentistry. According to him, such a long medical course of training held the danger that "with this scope of study, the student would not sufficiently absorb the teaching needs of his profession" [32] and that, in comparison with the competing dentists, he would "lose some years of professional experience" [19]. Walkhoff ultimately prevailed with his demand for a separate doctorate for dentists in the form of the Dr. med. dent. – not only among his colleagues, but subsequently also among the German medical faculties: In 1919, these faculties opened the way for the "Dr. med. dent.", thus suddenly making dentistry more attractive and causing an influx of students. The introduction of the Abitur in 1909 as a prerequisite for studying dentistry was also a success of the "Walkhoff era".

Walkhoff not only relentlessly advocated the Dr. med. dent., but was similarly resolute in his opposition to the competing "Dentisten" (non-academic dentists) and to the "unification of the two professions" that some colleagues were calling for [34, 38]. In doing so, he did not spare with horror scenarios: according to Walkhoff, any dentist who supported such an approach would "commit suicide". An integration of dentists into the dental profession would basically "mean a setback of at least 50 years" [49]. Ultimately, both professions were to remain until the middle of the century. Only then was the profession of "Dentisten" abolished and a "unified profession" of dentists established.

In his private life, Walkhoff enjoyed gymnastics and bowling [10]. He also loved nature and art. During his time in Munich, he acquired a "country estate in Leoni on Lake Starnberg", where he led an upper middle-class life, as Oskar Römer mentioned: "The beautiful villa in the lake with its bathing house, its vegetable gardens, parks, its poultry and rabbit breeding and the whole

equipment in the rooms with the antique furniture and art objects, has something [...] uniquely homely [...]" [44].

In 1934, the year of his death, Walkhoff could look back on a highly successful professional life despite all the quarrels. By the time he was 60, he had advanced to the position of court dentist (1898), winner of the Golden Medal of the CVDZ (1901), Hofrat (court councilor) (1907), winner of the "Herbst Award" (1902), honorary doctor of the universities of Munich (1903) and Marburg (1920) and CVDZ president (1906–1926). Later, he was admitted to the National Academy Leopoldina (1927) and became honorary president of the DGZMK (1930). In addition, he held a double-digit number of honorary memberships in national and international dental associations. Walkhoff's career highlights included his appointment as "Chairman and Senator of the Odontology Section" of the Leopoldina in 1933 [40].

To this day, Otto Walkhoff is one of the few representatives of the discipline of dentistry who found inclusion in the "Neue Deutsche Biographie" (New German Biography) [21]. In fact, he developed a considerable posthumous fame that continues to this day – not least due to the fact that the DGZ established the "Otto Walkhoff Award" in 2000. However, the prize became the subject of a debate in 2020. The background to this discourse is the focus of the following concluding analysis.

Richtung „hätte sagen lassen müssen". — Denn ich gehörte weder der Bayerischen Volkspartei, noch der Sozialdemokratie an, war weder partikularistisch, noch international, sondern zwar sehr gut bayerisch, aber anderseits „national bis auf die Knochen gesinnt"! — Das hatte ich nicht nur schon früher jenem zahnärztlichen Kritiker, sondern auch sonst häufig genug in Ansprachen etc. in und außerhalb Bayerns erklärt! Vielleicht aber war ich auch dadurch bei manchen maßgebenden Kreisen anderer Parteien „suspekt" geworden! Im übrigen bin ich infolge meiner früheren allgemein politischen Einstellung teilweise aber auch infolge meiner eigenartigen Behandlung in Bayern schon vor vielen Jahren Mitglied der NSDAP. geworden, weil ich erkannt hatte, daß diese Partei im Gegensatz zu anderen das Prinzip der Arbeit und Leistung und nicht Protektion, Religion, Kriecherei und Liebedienerei an die Spitze stellt! — Nicht alle Menschen urteilen über

Die neue Zeit unter unserem Reichskanzler Adolf Hitler hat gründlichen Wandel geschaffen! Das frühere Staatsministerium, wie der damalige Landtag sind verschwunden und aufgeflogen, und die klerikale Parteiwirtschaft hat damit in beiden aufgehört, ebenso der Partikularismus und Nepotismus, drei Faktoren, die viele Jahrzehnte in Bayern eigentlich alles beherrschten, besonders aber im bayerischen Landtag und im Geschäftsbereiche des Kultusministeriums blühten! Intensivste Arbeit und von anderen Personen anerkannte Leistungen für das betreffende Fach oder für die Einrichtungen des Staates waren nebensächlich, ja „ein Dreck" gegenüber einem klerikalen Parteibuche und der guten Bekanntschaft von klerikalen Ministern oder Abgeordneten, besonders wenn sie Geistliche oder Gymnasialprofessoren waren! — Auf deren Unterstützung habe ich allerdings nie gerechnet, bin auch mit ihrer Hilfe niemals Professor geworden, sondern vielmehr auf ihr Betreiben und mit ihrer Hilfe aus meinem Amte entfernt!

Fig. 1 and 2, Table 1: D. Groß

Figure 2a and b Walkhoff's political confessions [59]

Walkhoff's political stance and his relationship to National Socialism

Although Walkhoff's life and work have been the subject of two extensive dissertations [43, 46], his relationship to National Socialism has been completely omitted. Yet Walkhoff himself provided written statements on his political stance. In addition, archival sources can be found that support and complete Walkhoff's self-image. Walkhoff described himself as "national to the bone" [59]. Against this background, it is not surprising that he belonged to the circle of academics who signed the "Erklärung der Hochschullehrer des Deutschen Reiches" (Declaration of the University Teachers of the German Reich) on October 16, 1914. This was a declaration that interpreted and justified the starting of the First World War as a defensive struggle of German culture [7].

During the Weimar Republic – at the end of 1929 – he joined the NSDAP (admission 01.12.1929; party no. 172,024) [2, 3, 11]. Walkhoff thus belongs to the group of "Alte Kämpfer" (old fighters): This was a designation introduced in October 1933 for early members of the NSDAP from the period before the so-called "seizure of power" in January 1933. The designation applied to those who carried a membership number below 300,000. The "Alte Kämpfer" saw themselves as an (elite) National Socialist core group who had joined the movement out of ideological conviction. Only a few dental university teachers became party members before Hitler came to power; the majority joined the NSDAP in spring 1933 [18, 23].

Wahlhoff died in mid-1934, just over a year after Hitler came to power. However, in the last months of his life he still publicly declared his support for National Socialism. He also described himself as a convinced opponent of the (democratic, Catholic and federalist) BVB and also distanced himself from the "Sozialdemokratische Partei Deutschlands" (Social Democratic Party of Germany, SPD). At the same time, he emphasised in his last writing that in 1900 and 1922, despite political unpopularity, he had managed to get appointments at the universities of Munich and Würzburg (Fig. 2a, [59]): "For I belonged neither to the Bavarian People's Party nor to Social Democracy, was neither particular-

istic nor international, but very well Bavarian, but on the other hand 'nationally minded to the bone' – I had not only explained this [attitude] to every dental critic in the past, but also often enough in speeches etc. in and outside Bavaria! But perhaps this also made me 'suspect' in some authoritative circles of other parties! Incidentally, as a result of my earlier general political attitude, but partly also as a result of my peculiar treatment in Bavaria, I became a member of the NSDAP many years ago, because I had recognised that this party, in contrast to others, puts the principle of work and achievement first and not protection, religion, sycophancy and servility."

Moreover, in the same writing he praised Hitler's drive after he came to power (Fig. 2b, [59]): "The new era under our Reich Chancellor Adolf Hitler has brought about thorough change! The former Ministry of State, like the then Landtag, have disappeared and blown up, and the clerical party economy has thus ceased in both, as have particularism and nepotism, three factors which for many decades actually dominated everything in Bavaria, but which flourished especially in the Bavarian Landtag and in the areas of activity of the Ministry of Culture!"

It was not until the end of 2019 that Walkhoff's early party membership and Nazi confessions became known: The occasion was a press conference in Berlin on the conclusion of the national project on the dental profession under National Socialism and a corresponding entry on Walkhoff in the "Neue Deutsche Biographie" (New German Biography) [12, 21]. The new findings were then the subject of a cover story ("Otto Walkhoff – Luminary and National Sozialist") in the "Zahnärztliche Mitteilungen" (Dental News) [31, 22]. This report in turn triggered a discourse about the Walkhoff Award, which was expressed in various letters to the editor in the "Zahnärztliche Mitteilungen" [61–64]. For example, the dentist Raimo Modler stated: "But to fabricate, as in the case of Walkhoff, that he was an ardent National Socialist because of his early party membership, is really abstruse [...] Since Walkhoff does not seem to have brought any guilt upon himself, renaming the Walkhoff Award is simply silly. This is not coming to terms with history, it is running away from it!" [62]. However, this view did not go unchallenged. Giesbert Schulz-Freywald, former Vice-President of the State Dental Association of Hesse, emphasised: "Walkhoff was a stirrup holder [...] we in the profession must now ask ourselves whether Walkhoff as a person should continue to be honoured by the ward given the current state of knowledge. [...] Is the eponym suitable for an award?" [64].

The board of the "Deutsche Gesellschaft für Zahnerhaltung" (German Society for Restorative Dentistry, DGZ), chaired by Christian Hannig, had already answered this question at that time – and subsequently published the following press release: "As a dental professional society, the DGZ also represents values such as humanity, respect for human dignity and free democratic values. As dentists and scientists, we not only have a great professional responsibility, but also a responsibility to society as a whole. Consequently, we will rename the Walkhoff Award of the DGZ to the DGZ Publication Award. All previous winners of the Walkhoff Award will receive an amended certificate" [60].

Conclusions

The findings lead to the conclusion that Walkhoff not only made significant contributions to the professionalisation of the German dentists (such as the right to obtain a doctorate) and to the further development of dentistry (radiology, dental conservation, histology), but also enjoyed a high professional reputation among contemporary colleagues. However, it is equally evident that Walkhoff was highly controversial as a personality and had the reputation of being quite uncomfortable and uncompromising.

Furthermore, the sources prove his early commitment to National Socialism and his classification as an "old fighter": Walkhoff joined the National Socialist Party during the Weimar Republic – and thus at a time when such a decision was politically not in vogue. On the contrary: the NSDAP was banned for a time in the Weimar Republic, was considered undemocratic at an early stage and was viewed critically by large sections of the intelligentsia and the educated middle classes. Moreover, Hitler's political goals were well known in 1929 – "Mein Kampf" (My Struggle) was published as early as 1925. Thus the argument of political ignorance or lack of predictability of the NSDAP agenda, which has been widely circulated up to the recent past, falls short as an explanation for party membership.

Walkhoff also had no need to join the NSDAP in 1929 for career reasons – this distinguished him from young university lecturers who, after Hitler's "seizure of power" (1933), became party members in droves to further their own careers or to escape feared personal disadvantages.

Walkhoff remained loyal to Nazi ideology until his death and still positioned himself explicitly as a supporter of Hitler in 1934 – and thus one year after the political change of power. At the same time, he kept a critical distance from the two democratic parties, BVB and SPD, which were dissolved in 1933.

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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DZZ International
German Dental Journal International

Publishing Institution
International Journal of the German Society of Dentistry and Oral Medicine/Deutsche Gesellschaft für Zahn-, Mund- und Kieferheilkunde e.V. (Zentralverein, gegr. 1859), Liesegangstr. 17a, 40211 Düsseldorf, Phone: +49 211 610198-0, Fax: +49 211 610198-11

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German Society for Prosthetic Dentistry and Biomaterials
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Group of Basic Science in Dentistry

Publisher
Deutscher Ärzteverlag GmbH
Dieselstr. 2, 50859 Köln;
Postfach 40 02 65, 50832 Köln
Phone: +49 2234 7011-0; Fax: +49 2234 7011-6508
www.aerzteverlag.de

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Frequency
6 times a year

Layout
Larissa Arts

Account
Deutsche Apotheker- und Ärztebank, Köln,
Kto. 010 1107410 (BLZ 370 606 15),
IBAN: DE 2830 0606 0101 0110 7410,
BIC: DAAEDEDD,
Postbank Köln 192 50–506 (BLZ 370 100 50),
IBAN: DE 8337 0100 5000 1925 0506,
BIC: PBNKDEFF

4. Volume
ISSN 2627-3489