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PRACTICE

RESEARCH

Title picture hint: From the guideline "Surgical removal of wisdom teeth", here figure 1: surgical site after uncovery of a wisdom tooth surrounded by pericoronal cysts, p. 232–237; (photo: Martin Kunkel)
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E-cigarettes and oral health

Introduction

E-cigarettes are battery-operated devices that heat up chemical solutions, which are referred to as liquids. Aerosols in different flavors are produced, many of which can contain nicotine [6]. A survey in Germany indicated a population of 1,4 % that use e-cigarettes regularly, which corresponds to approximately one million people in Germany. The main users of e-cigarettes are between the ages of 20 and 60 years [5]. The American PATH-study of 2018 indicated, that 1,7 % of participants solely smoked e-cigarettes and 1,4 % smoked cigarettes as well as e-cigarettes in their daily lives. [1]. E-cigarettes are a common and established phenomenon in the population [11]. Due to frequent use and recent development, the question is raised of what effect this has on oral health.

Statement

The process of „vaping" produces aerosol, which contains fine particles, rather than tobacco smoke [1]. The basic ingredients include propylene glycol, glycol, nicotine and various flavors [3]. It is important to differentiate ingredients because liquids can differ greatly. Studies suggest that propylene glycol in general is harmless for children and adults, however, it can induce rhinitis, asthma, eczema and allergic reactions. Furthermore, nicotine extracts from tobacco contain impurities such as cotinine, anabasine, anatabine, myosmine and heavy metals [7].

Ganapathy et al. (2017) investigated the effect of e-cigarette extract in bronchial epithelial cells (NuLi-1) and in cells of the squamous cell carcinoma of the oral cavity (UM-SCC-1). The extracts testes induced significant increases of dose-dependent DNA-damage in cells. It was determined that extracts from e-cigarettes caused less DNA damages than extracts from regular cigarettes. E-cigarette extracts cause a significant increase of reactive oxygen species (ROS) and lower the cellular antioxidative capacity. This resulted in a significant increase in 8-hydroxydesoxyguanosin level, which causes one of the most common mutagenic DNA lesion [6]. Munakata et al. (2018) measured a rise in concentration of IL-8 and makrophage colony-stimulating factor (GM-CSF) in bronchial epithelial cells (BEAS-2B) [9]. In healthy study participants a one-time e-cigarette use caused an increased number of endothelial progenitor cells in the blood, which is a sign for a potential vascular change, according to Antoniewicz et al. (2016). After 24 h the progenitor cell count returned to the level of the control group [4].

Furthermore, first conclusions on the impact of e-cigarettes on the oral cavity and enamel were drawn. The working group of Sancilio et al. (2016) investigated the effect of e-liquids on humane gingiva fibroblasts (HGF). A dose-dependent reduction of 20 % of the HGF activity was determined for liquids with and without nicotine. The apoptotic percentage of HGF-cells increased just like the prevalence of the pro-apoptotic Bax protein [10]. Kim et al. (2018) examined how the use of e-cigarettes impacts healthy enamel and the oral flora. Enamel samples of extracted, cavity-free wisdom teeth were exposed to the aerosol of e-cigarettes (10 drags and 150 drags) and subsequently cultivated with S. mutans in corrugated sheets. The aerosols formed a viscous surface that significantly increased the adhesion of S. mutans on enamel surfaces. Besides facilitated bacteria adhesion, Kim et al. noted that the used flavors (such as sucralose, ethyl butyrate, triacetin, hexylacetate) and their metabolites have a significant impact on surface hardness of the enamel sample. It was found that the hardness decreased by up to 21,5 % [8]. The working group of Willershausen et al. (2014) investigated the effect of menthol as an additive: The menthol additive in the liquid causes a significant reduction of the proliferation rate of periodontal ligament cells (PDL). Due to these results the working group recommends to not use menthol as an additive in the liquid of e-cigarettes [13].

Besides the effect on the enamel, Al Qahtani et al. (2018) also determined insights on the impact on the periodontium. The percentage of probing depths ≥ 4 mm was increased significantly in hookah smokers (7,0 % ± 1,1 %) and cigarette smokers- (7,8 % ± 1,2 %) or rather e-cigarette smokers (5,3 % ± 1,5 %), when compared to non-smokers (4,4 % ± 0,6 %). The plaque index also showed significantly higher values for all smoking habits. E-cigarette smokers exhibit a plaque index of 51,9 % ± 10,2 %, while it was 34,1 % ± 14,7 % in non-smokers. The concentration of cytokines in the patients' periimplanted sulcus fluid was also examined. All smoking habits caused a significant rise of proinflammatory cytokines TNF-α, IL-1β and IL-6. The total volume of sulcus fluid also increased significantly [2].

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Summary

The present findings from in-vitro and in-vivo investigations allow an initial assessment of potential consequences of the use of e-cigarettes. Currently, electronic smoking devices cannot be seen as a safe means to quit smoking due to potentially harmful effects [12]. Longterm studies are necessary for substantiated statements concerning oral health. In addition, the assessment of e-cigarettes is hampered by the usage of additives and their relevant variations in composition and effect [8, 9, 13].

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Ultrasonic and sonic irrigant activation in endodontics: A fractographic examination

Introduction: The aim of the present study was to assess the failure mode of current sonic (EndoActivator, Dentsply Maillefer, Ballaigues, Switzerland; Eddy, VDW GmbH, Germany) and ultrasonic (Irri S, VDW GmbH, Germany, Endo Soft Intruments EMS, Nyon, Switzerland) tips in artificial and standardized root canals with different, representative radii of curvature.
Materials and Methods: 100 extracted human lower first and second molars were examined with regard to their 5 most common radii of curvature (2.5/ 3/ 6/ 9/ 11 mm) and the mean length of their root canals. In addition, a straight canal was chosen and served as control. The canals were milled into an artificial steel model. The cyclic fatigue testing took place with the Tiratest 2720 at 120 mm/min. Every file was tested for 12 min (8 cycles). A fractographic examination took place with a scanning electron microscope.
Results: All tested Irri-S instruments fractured in the canal with a 2.5 mm radius of curvature, 70 % of the IrriS fractured in the canal with a 3 mm radius of curvature. The ESI, EDDY and EndoActivator tips showed no fracture ($p < 0.05$), but surface wear and erosion of the instrument tips were visible. In addition, ESI and EndoActivator showed no signs of cavitation.
Conclusions: There is no existing irrigation activation system that provides surface quality of the tip and cleaning efficiency of the canal. Especially, in canals with a small radius of curvature the use of EDDY may be a safe advice.

Keywords: sonic application; ultrasonic application; root canal irrigation; curvature radius

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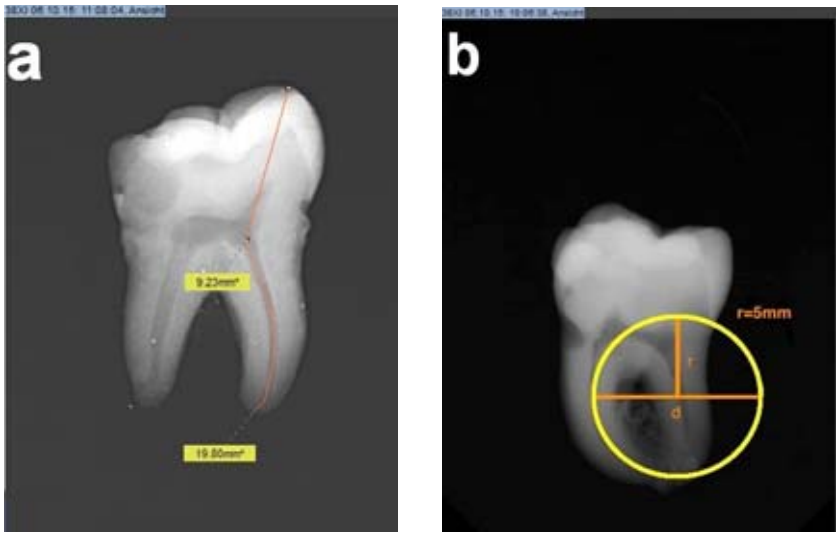
Introduction

Effective irrigation is a key factor for a successful root canal treatment. Thereby, the removal of the smear layer, remaining pulp tissue, bacteria and their endotoxins and decomposition products is essential for the endodontic success [2, 44, 53]. As a result, a reduction of bacteria can be achieved with a factor of 100–1000.

It has been known for years, that due to the difficult canal anatomy it is impossible to shape and clean the root canal system completely [6, 13, 17, 18, 21, 23–25, 43, 46, 49]. Therefore, chemical agents serve as irrigating solutions to clean untouched areas such as isthmi, dentinal tubules and complex apical structures [22, 46]. However, it is difficult to transport the irrigant to these specific areas, especially in the apical portion of the canal [21]. Previous studies have shown that sonic or ultrasonic activation of the irrigating solution can improve the agents' positive properties. In the past years, ultrasonic and sonic activation systems have been extensively examined [5, 15, 16, 20–22, 29–31, 33, 38, 45, 51]. Unfortunately, there are unpredictable treatment situations where activation tips fracture [32]. Especially, the fracture of the expensive ultrasonic irrigant activation tips result in complicated treatment situations. The removal of the fractured file cannot be guaranteed in all treatment cases. In the worst case, that scenario leads to the loss of the tooth and the failure of the root canal treatment. Screening the literature to our best knowledge, there is no study that determines the failure mode of irrigation activation devices.

To examine failure modes of sonic and ultrasonic tips, basic knowledge is necessary. Several parameters such as experience and performance of the dentist, the quality of the intraradicular dentin, the taper after root canal treatment, the curvature radius of the root, the material and the geometry of the irrigant activation tips influence the fracture characteristics of these tips. However, in order to achieve reproducible results with low scattering of the measurement values, a standardized model with few variables has been introduced in the present study. Hereby, the influencing parameters dentist, dentin and taper were substituted by constant parameters. The primary focus of the study was therefore the root canal curvature radius and its impact on the irrigation tips. Using the identical application mode, the reproducible failure of the tips was tested under standardized conditions.

The aim of this study was therefore to assess the failure mode of current sonic and ultrasonic tips in artificial and standardized root canals with different, representative radii of curvature.



(Fig. 1, 2 and 6: Kim Sina Reinauer)

Figure 1a–b Exemplary measured teeth by means of the X-ray program Sidexis (Heliodent Plus, Sirona, Germany). The depth of the access cavity (in the present example: 9.23 mm) and the root canal length (19.8 mm) were measured (**a**). In addition, the radius of curvature of the left distal canal was calculated (in the present example: 5 mm) by applying a various radius over the entire length of the distal root canal (**b**).

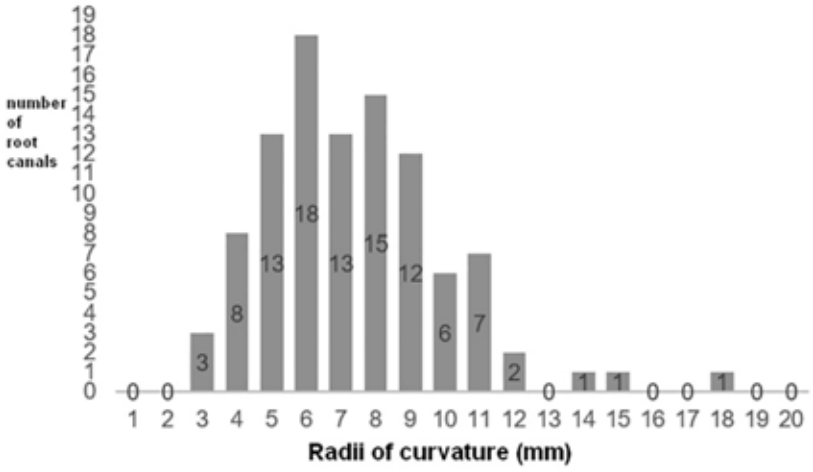
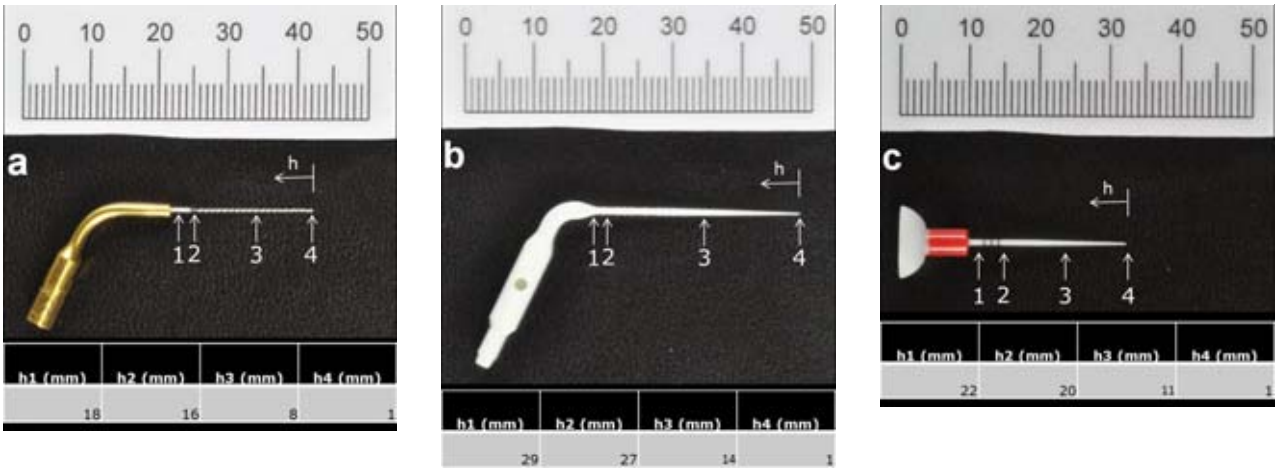


Figure 2 Distribution of the radius of curvature found in 100 lower molars' distal canals. The 3 mm radius of curvature was the smallest radius, which was found in the present radiographic examination, 6 mm was the most common radius of curvature and 8 mm was the second most common radius of curvature. In addition, an 11 mm radius of curvature was exemplary chosen to represent a large radius of curvature.

Material and Methods

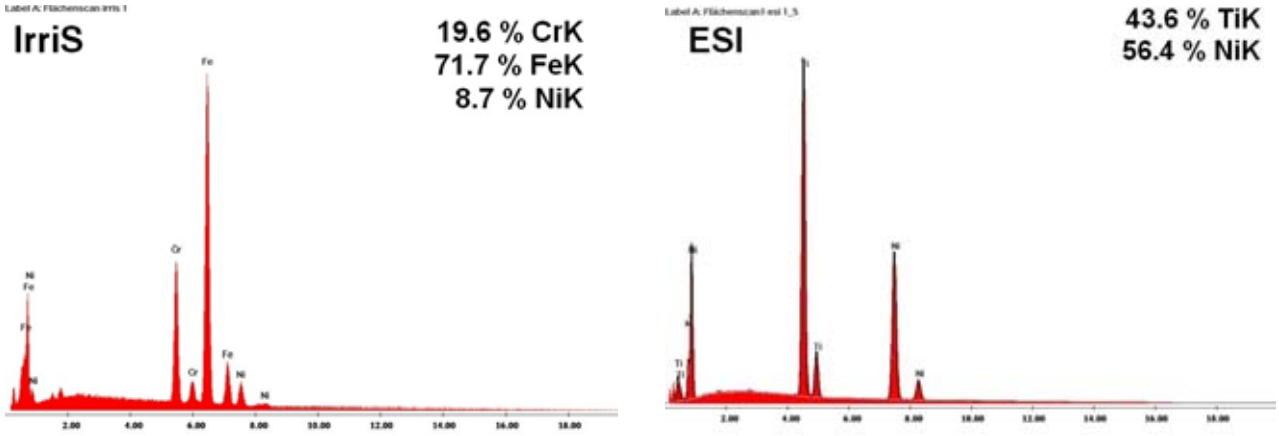
Prestudy

100 extracted human lower first and second molars of middle-aged donors were extracted during routine sur-



(Fig. 3 and 5: Michael Kucher)

Figure 3a–c The sonic and ultrasonic tips (a–c) were measured by an electronic outside micrometer to define the parameters (maximum and minimum diameter) for the artificial steel model. The diameter was measured in different spots (h1–h4; **a–c**). Every spot was measured 10 times. For the construction of the root canal model, the maximum diameter was determined. Thereby, the diameter measurement was conducted for the IRRI S ultrasonic tip (**a**), the Eddy sonic tip (**b**) and the EndoActivator sonic tip (**c**).



(Fig. 4 and 7–15: Heike Meissner)

element	weight percentage %
CrK	19.6
FeK	71.7
NiK	8.7
total	100

element	weight percentage %
TiK	43.6
NiK	56.4
total	100

Figure 4 Results of the Energy-dispersive X-ray spectroscopy (EDX) analysis of Irri S and ESI tips: The material composition was detected and showed that the Irri S consists of chromium, iron and nickel. In contrast, the ESI tip consists of nickel and titanium.

gical treatment in the department of maxillo-facial surgery. The teeth were stored in thymol solution at 4 C and analyzed by means of root canal curvature regarding the distal canal. Inclusion criteria for the study were: lower first and second molar, C-(entirely curved) and J-(apical curve) [34] shaped configuration of the molars' distal canal and an intact apex. Exclusion criteria were calcifications, previous root canal treatment, fractures, resorptions, S-(multicurved) and I-(straight) shaped configuration of the molars' distal root canal [34]. Hereby, 2-dimensional and orthograde radiographic visualization took place (Heliodent Plus, Sirona, Germany) (Fig. 1a). The aim of the chosen method was to facilitate the selection process of the included teeth.

Artificial root canal model

The teeth were measured by the x-ray program Sidexis (Heliodent Plus, Sirona, Germany). First, the depth of

the access cavity (distance between the reference cusp and root canal orifice) as well as the root canal length (distance between canal orifice and root canal apex) was determined (Fig. 1a). This calculation resulted in an average access cavity depth of 11 mm and an average root canal length of 9 mm. Consequently, an average total length of 20 mm was obtained for the standardized model (Fig. 2). Second, the radius of the distal canal curvature was calculated (Fig. 1b). Thereby, the radius of curvature was measured by approximating the distal root canal's curved section using a circle with varying radius. Different curvatures are represented by the size of the radius. A large radius stands for a small curvature and a small radius represents a strong curvature. Regarding the frequency of distribution, the statistical analysis was performed by the statistic program SPSS. Hereby, the mean values of the total root canal length, the depth of the access cavities as well as the radius of the curvature were calculated.

The following radii of curvature were chosen for the artificial root canal model (Fig. 2):

- 2.5 mm: this configuration was not detectable in the x-rays, it was chosen to test the load limit
- 3 mm: smallest radius of curvature
- 6 mm: most common radius of curvature
- 8 mm: second most common radius of curvature
- 11 mm: exemplary for a large radius of curvature
- R: representing a straight canal

In the following, the diameters of the sonic and ultrasonic tips were measured by an electronic outside micrometer (Holex, Hoffmann group, Munich, Germany). Thereby, the measuring range was between 0–25 mm, the accuracy was within 0.001 mm and the width of the stamp was 6 mm. The sonic and ultrasonic tips were measured in different spots and the maximum diameter was calculated for every position (Fig. 3 a-c). The measurement revealed a large range in diameter between the sonic and ultrasonic files. For this reason, 2 different test series were created for sonic (diameter: 1.2 mm) and ultrasonic files (diameter: 0.8 mm) (Fig. 5 and 6). The diameter of these artificial root canals was designed to fit the files in their oscillating mode and represent a curved root canal. Therefore, the size was created 4 ISO-sizes larger than the average original diameter of the sonic (maximum diameter: 1 mm) and ultrasonic (maximum diameter: 0.6 mm) files.

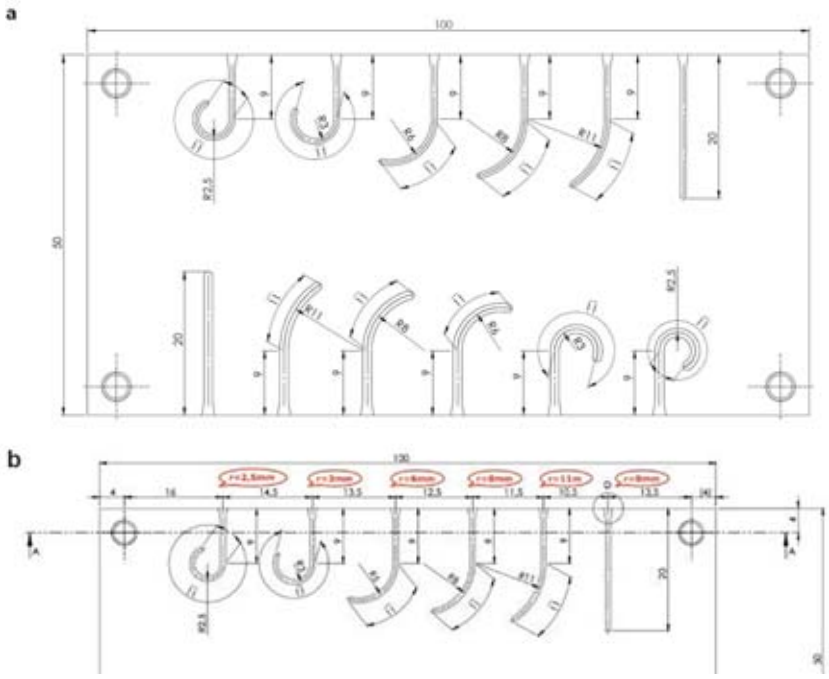


Figure 5a–b Design drawing of the root canal model. With the results of the diameter and radius of curvature measurements, a root canal model was obtained (**a–b**). The arc length of the artificial root canals was always defined at 20 mm, the root canal diameter at 0.8 mm for ultrasonic files (**b**) and 1.2 mm for sonic files (**a**; lower row).

With the acquired information, a root canal model was obtained (Fig. 5 and 6). The present study included a steel model (Fig. 6) with C- and J-shaped root canal configurations differing in the most distributed curvature radii calculated earlier by statistical analysis (Fig. 2). The artificial root canals had always the same access cavity and root canal's arc length (20 mm). The square cross-section throughout the root canals had an inner dimension of 0.8 mm for ultrasonic files and 1.2 mm for sonic files (Fig. 5 and 6).

Irrigation procedure

The cyclic fatigue testing took place with the Tiratest 2720 (Tira GmbH, Schalkau, Germany) at 120 mm/min with the following sonic and ultrasonic activation tips (Fig. 6b). The tips are driven in each case by means of the manufacturer's original tool holder. The stress of the irrigation tip results of the bending deformation during the penetration and the additional dynamic stress due to sonic and ultrasonic oscillations.

Sonic tips

EndoActivator (EA) group, (Dentsply Maillefer, Ballaigues, Switzerland), with a size 25, 4 % taper tip, 22 mm length, placed at working length (WL) –1 mm (n = 10 tips per tested radius of curvature).

Eddy (ED) group, (VDW, Munich, Germany), with a size 20, 2 % taper tip, 28 mm length, mounted on a scaler (Pferdefit Dental, Hohenstein-Breithardt, Germany). Tip placement and irrigation/activation times were identical to the EA group (n = 0 tips per tested radius of curvature).

Ultrasonic tips

In addition, Energy-dispersive X-ray spectroscopy (EDX) analysis of Irri S and ESI tips was carried out with an XL 30 ESEM (Philips, Eindhoven, The Netherlands) with an EDX system

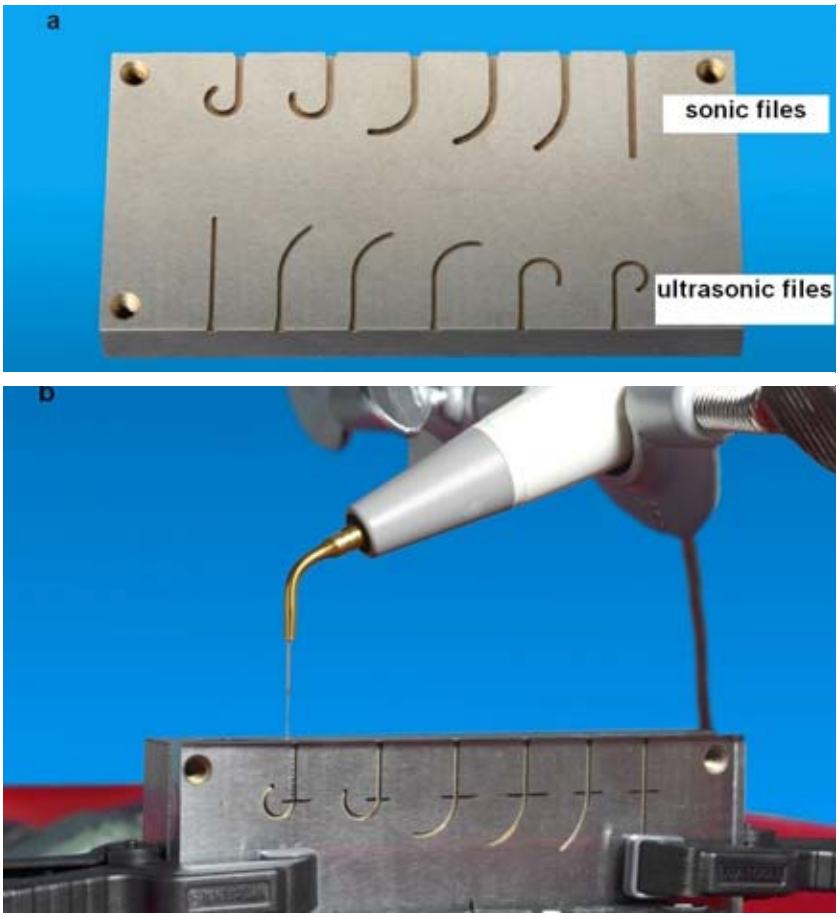


Figure 6a–b Figure 6 shows the obtained artificial steel root canal model for the testing of sonic files (**a**, 1.2 mm diameter, upper row) and ultrasonic files (**a**, 0.8 mm diameter, lower row). The cyclic fatigue testing took place with the Tiratest 2720 at 120 mm/min (**b**). The starting point was placed at the canal orifice at 9 mm (**b**, marked line). The file penetrated 10 mm into the canal and stopped 1 mm before reaching the apex to ensure the working length (19 mm).

(Phoenix, EDAX INC., Mahwah, N.J., USA) in order to detect the material composition of the 2 tips (Fig. 4).

Irri S, (Ultrasonic irrigant activation Group, VDW GmbH, Germany), with a size 20 tip, 0.3 % taper, 21 mm length, mounted on an ultrasonic unit (VDW Ultra, VDW GmbH, Germany) at a power setting of 30 % according to manufacturer's settings. Tip placement and irrigation/activation times were identical to the EA and Eddy groups (n = 10 tips per tested radius of curvature).

ESI, (Endo Soft Instruments EMS, Nyon, Switzerland), with a size 15 tip, 0,3 % taper, 22 mm length, tip placement and irrigation/activation times were identical to the EA, Eddy and Ultrasonic irrigant activation groups (n = 10 tips per tested radius of curvature).

After every cycle, a rinsing with water took place. Every file was tested for a total time of 12 min (representing 90 s for each of the 8 cycles). The starting point was placed at the canal orifice at 9 mm, clinically at the beginning of the root canal. When starting, the file penetrated 10 mm into the canal (Fig. 6b) and stopped 1 mm before the apex to ensure the whole working length.

During the irrigation procedure, a microscopic camera at a resolution of 2560 x 2048 pixel and a frame rate of 30 frames/second detected the presence of long-time cavitation phenomena for every tested tip.

Inspection of the instruments and fractographic examination

The instrument tips were autoclaved and then ultrasonically cleaned in absolute alcohol prior to scanning electron microscopic examination (SEM, XL 30 ESEM, Philips, Eindhoven, The Netherlands) as described earlier [8]. At different views, images of the fractured surface were obtained at high magnifications. Two examiners examined the fractographic images. Thereby, fatigue striations which are characteristic for metallic materials [8] were detected for the Irri S and ESI instrument tips.

According to Collins, the 4 recognized modes of fracture in metal [9, 10] were used to categorize the present failure mode of the Irri S and ESI tips:

1. Cleavage: "Refers to the cracking of a crystalline solid along slip planes" [8].
2. Dimple rupture: "The typical fractographic appearance of ductile failure; under (tensile or shear) load internal voids (due to inclusions, microporosities, precipitates or other microstructural heterogeneities) grow in size until the remaining material in between these 'holes' fails because of overload" [11].
3. Fatigue: "A form of transgranular fracture where the grain boundaries have little effect on the direction of crack propagation" [8, 41].
4. Decohesion: "The rupture of a material along grain boundaries, usually under the influence of environmental factors, such as hydrogen embrittlement or attack by corrosive agents"[11].

The mechanisms of fatigue [7, 47] and fatigue crack growth [36, 39] of polymeric materials are based on the general modes established for metals [7]. Interestingly, both materials show similar stress-life curves and fatigue crack growth curves [7]. Therefore, the fractographic examination of the Eddy and EndoActivator tips was carried out in a similar manner according to the failure modes of Irri S and ESI tips. In addition, the distance between the fractured ends and the tips of the instruments were measured to calculate the length of the fractured segment for each instrument.

In order to calculate the development of the failure intensity, the following steps were performed:

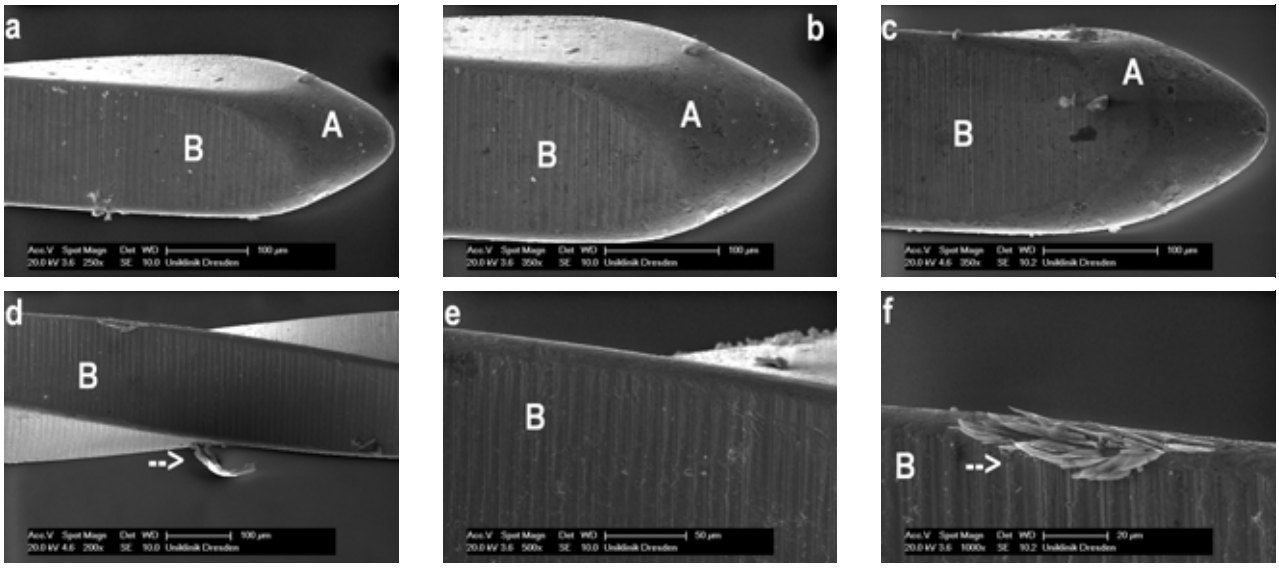


Figure 7a–f Initial state of the Irri S instrument tip: Instrument surface showing no surface wear (**a–c**; A) but manufacturer-dependent material characteristics (**a–f**; B). In addition, fanned out areas were detected at the material surface (**d, f**; arrow).

A) No surface wear
B) Manufacturer-dependent material characteristics
Arrow: Fanning out of the material surface

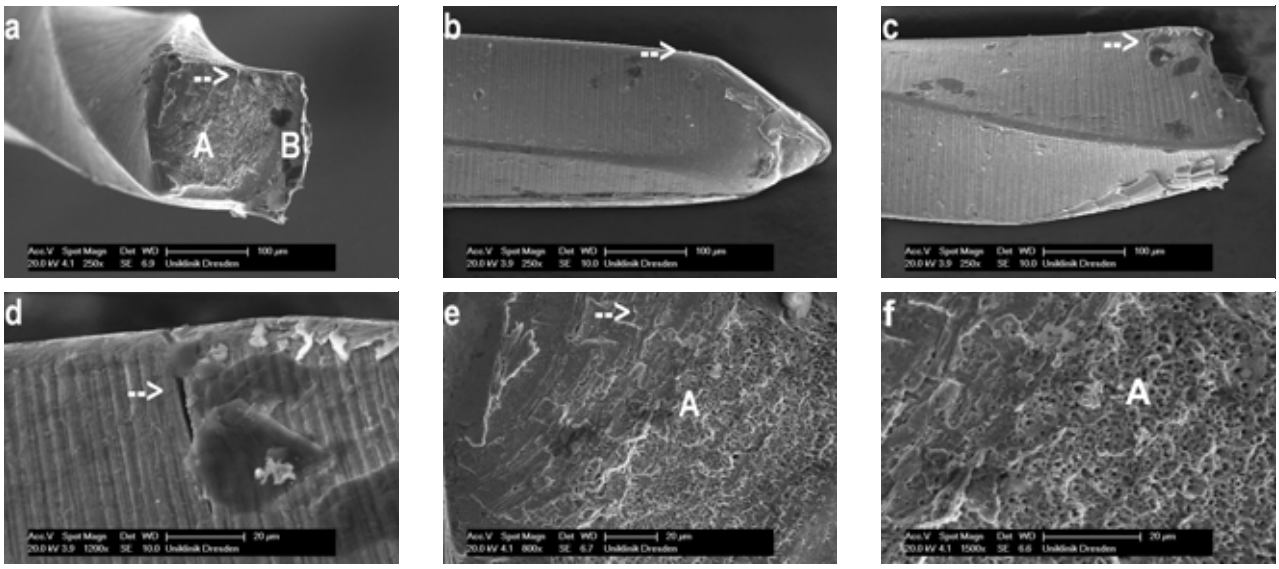


Figure 8a–f Fracture surface of an Irri S tip (**a, e, f**) showing fatigue striations, crack initiations (arrows) and areas not involved in fatigue striations (**a**; B). The profile of the tip reveals the presence of further crack initiations at the periphery of the instrument (**b, c, d**; arrows). Note the areas with skewed dimples on high power view (**f**; A).

A) Skewed dimples
B) Areas not involved in fatigue-crack propagation
Arrow: Crack initiation

- Evaluation of the failures, failure frequency and failure intensity
- Evaluation of the differences between the different sides of each tip (numerical – by calculating the 4 sides) coefficient of variation (mean squared deviation, referred to the mean value) of the mean failure intensity respectively to the number of failures.

Data analysis

Statistical analysis was performed by Anova ($\alpha = 0.05$) and Bonferroni holm correction ($p = 0.01$) using SPSS 22.0 software (SPSS, IBM, Germany). In the present study, the following null hypothesis is tested: No fractures of the sonic and ultrasonic tips occur in the different shaped canals.

Results

The analysis of the radii of curvature demonstrated that the 3 mm radius

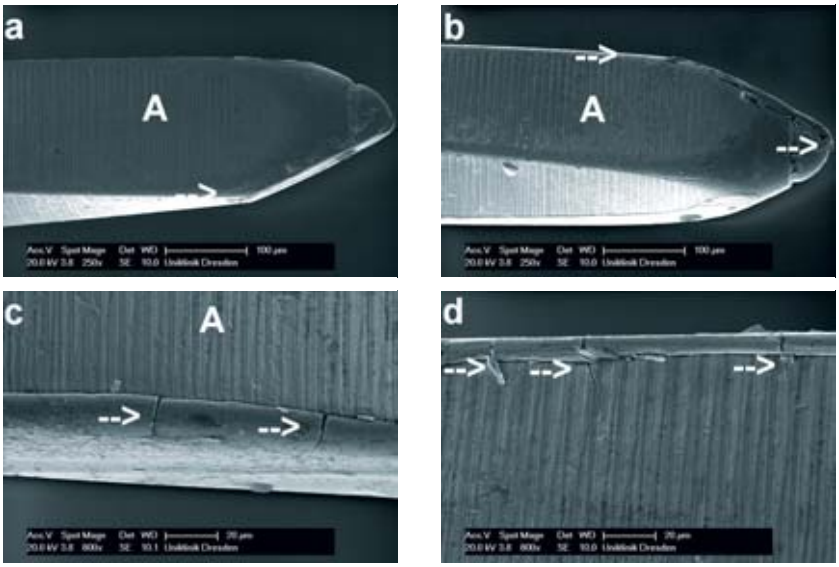


Figure 9a–d Irri S tip showing signs of crack initiation at the periphery of the instrument without the fracture of the tip (**a–d**; arrow). Presence of manufacturer dependent material characteristics on the surface of the instrument (A).

A) Manufacturer-dependent material characteristics
Arrow: Crack initiation

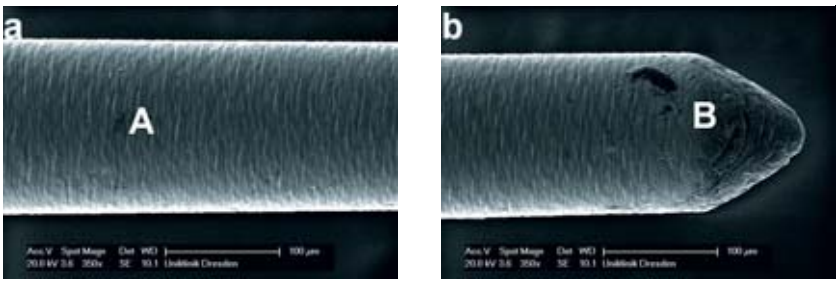


Figure 10a–b Initial state of the ESI-instrument tip: Instrument surface showing no surface wear (**a**; A) but manufacturer-dependent material characteristics (**b**; B).

A) No surface wear
B) Manufacturer-dependent material characteristics

of curvature was the smallest radius, which was found in the present radiographic examination (3 teeth) of 100 lower molars' distal canals examined. A 6 mm radius of curvature was the most common radius (18 teeth), followed by 8 mm, the second most common radius of curvature (15 teeth, Fig. 2). In addition, an 11 mm radius of curvature was exemplary chosen to represent a large radius of curvature (7 teeth, Fig. 2).

The results of the Energy-dispersive X-ray spectroscopy (EDX) analysis of Irri S and ESI tips showed that the Irri S consists of chromium, iron and nickel. In contrast, the ESI tip consists of nickel and titanium.

As determined by Anova and Bonferroni tests, there were significant differences ($p < 0.01$) between the tested instrument tips. Thereby, all Irri S tips fractured in the 2.5 mm radius canal (n = 10) and 70 % of the Irri S tips fractured in the 3 mm radius canal (n = 10). All other tested systems achieved significant better results, since there were no fractures of the EDDY-, EndoActivator- and ESI-tips in the examined canals with different radii of curvature.

A pre-inspection of the Irri S tips showed that these tips displayed more surface defects on the surface than the other tested tips. These defects were unevenly distributed on the 4 surfaces of the instrument and concentrated on the tips edges. Therefore, the inspection and examination of the instruments had to take place in 4 directions (each rotation around 90°).

At high magnification of the initial state of the Irri S instrument tip, the surface showed manufacturer-dependent material characteristics (Fig. 7) with fanned out areas (Fig. 7d, f). In all cases (n = 10; 100 %) the fracture surface of the Irri S tips showed fatigue striations (Fig. 8) after application of the tip into the 2.5 mm radius of curvature canal. These fatigue striations indicate a fatigue failure mode. After the application into the 3 mm radius of curvature canal, 7 cases (70 %) showed fractured Irri S tips. In lateral view, further crack initiations at the periphery of the instrument (Fig. 8c–d) as well as skewed dimples in areas not involved in fatigue crack initiation were visible (Fig. 8e–f). Further, Irri S tips without fracture of the tip showed crack initiations at the periphery of the instrument (Fig. 9a–d, arrow). The mean length of the fractured segments was 7.9 mm ± 2.2 mm in the 2.5 mm radius-canal and 7.2 mm ± 2 mm in the 3 mm radius-canal measured from the tip's free end. At the edges of the Irri S tip's deformation areas, many transverse cracks were observed. Subsequently, further material spalling is possible. Furthermore, these massive and irregular edge deformations were also detectable in the unfractured Irri S tips.

The microscopic analysis of the ESI-instrument tip surface also showed manufacturer-dependent material characteristics in the initial state (Fig. 10b). In contrast to the other tested tips, this series (NiTiAl-material) displayed a cylindrically symmetric, non-angle shaped form and the surfaces showed lower machining grooves. Only the taper surfaces had noticeable process-induced transverse grooves. After the usage of the tip, low surface wear and a levelled surface relief with scratches, material abrasion and an erosion of the instrument tip were visible (Fig. 11a–d). The different radii of curvature had almost no impact on the fracture pattern and frequency.

The surfaces of the EDDY and EndoActivator instrument tips also showed manufacturer-dependent material characteristics (Fig. 12 and 14). Thereby, polymer structures were detectable at the tip of the Eddy instrument (Fig. 12a–c) and at the synthetic joint of the EndoActivator (Fig. 14 a, c–f). After Application of these 2 sonic activation devices, surface wear, a levelled surface relief and material abrasion were visible (Fig. 13 and 15).

All Eddy activation tips displayed a casting seam caused by the casting of the polymer material. Throughout the experiments, this casting seam was exposed to particular stress and showed cracks and spalling. The first SEM images were taken with 20 keV primary energy. Thereby, higher magnification (2000x and higher) caused defects in the material (porosities, cracks). Consequently, all the SEM images which were analyzed in the present study were taken with 5 keV primary energy. Thereby, all EDDY samples displayed a strong erosion of the instrument tip (Fig. 13a–c). On the surface of the blunt EndoActivator tip a lower erosion of the instrument tip was visible, too (Fig. 15a–b). Besides, crack initiation at the periphery of the instrument was detectable (Fig. 15c, arrow). The examination with the microscopic camera showed cavitation of the Irri S tip and Eddy tip but no signs of cavitation for the ESI and EndoActivator tips.

Discussion

The removal of bacteria and their endotoxins from the complex root canal system is one of the goals of root canal therapy. Different strategies such as delivery or irrigant activation systems can enhance the effect of the disinfection procedure. Thus, practitioner can safely use these helpful techniques, it is necessary to ensure a certain user and patient safety. Therefore, the aim of the present in vitro study was to evaluate

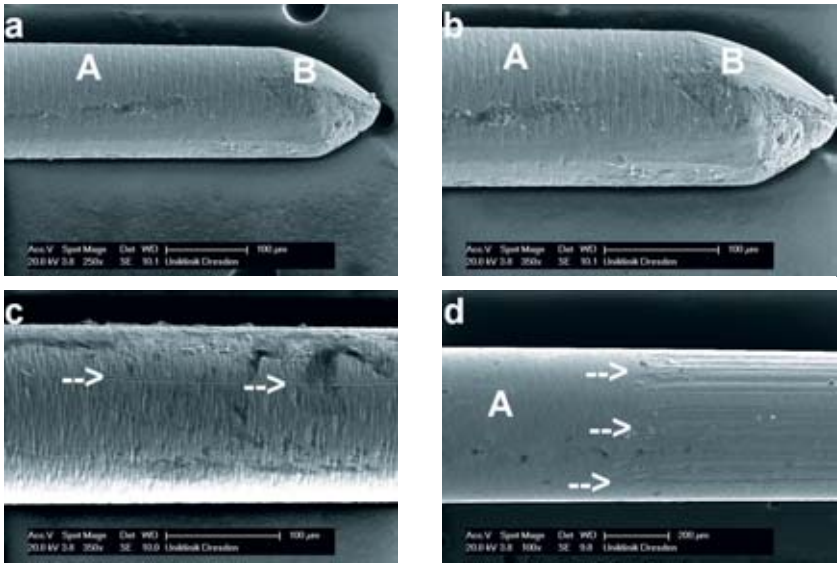


Figure 11a–d ESI-tip showing no signs of fracture or crack initiation at the periphery of the instrument. Although, low surface wear (**a, b, d**; A) and a levelled surface relief (**a–b**; B) with scratches, material abrasion (**c**; arrow) and erosion of the instrument tip are visible (**a–b**; B).

A) Low surface wear
B) Levelled surface relief and erosion of the instrument tip
Arrow: Scratches and material abrasion

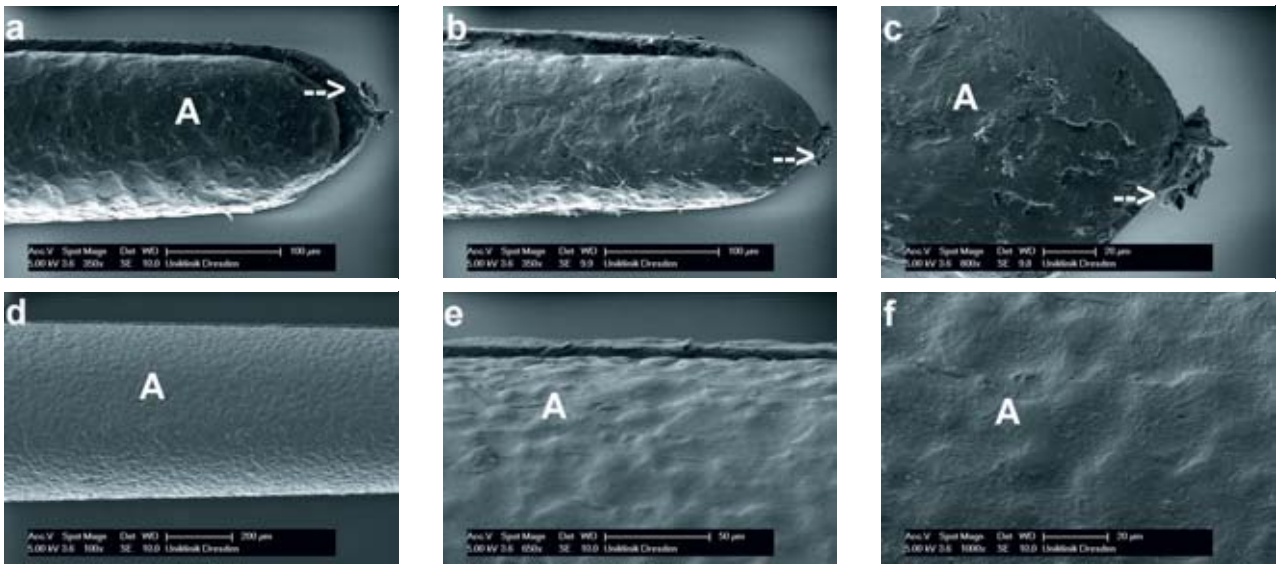


Figure 12a–f Initial state of the Eddy-instrument tip: Instrument surface showing no surface wear but manufacturer-dependent material characteristics like adhesion of polymer structures at the tip of the instrument (**a–c**; arrow) and a structured surface (**a, c, d, e, f**; A).

A) Manufacturer-dependent material characteristics
Arrow: polymer structure adhesion

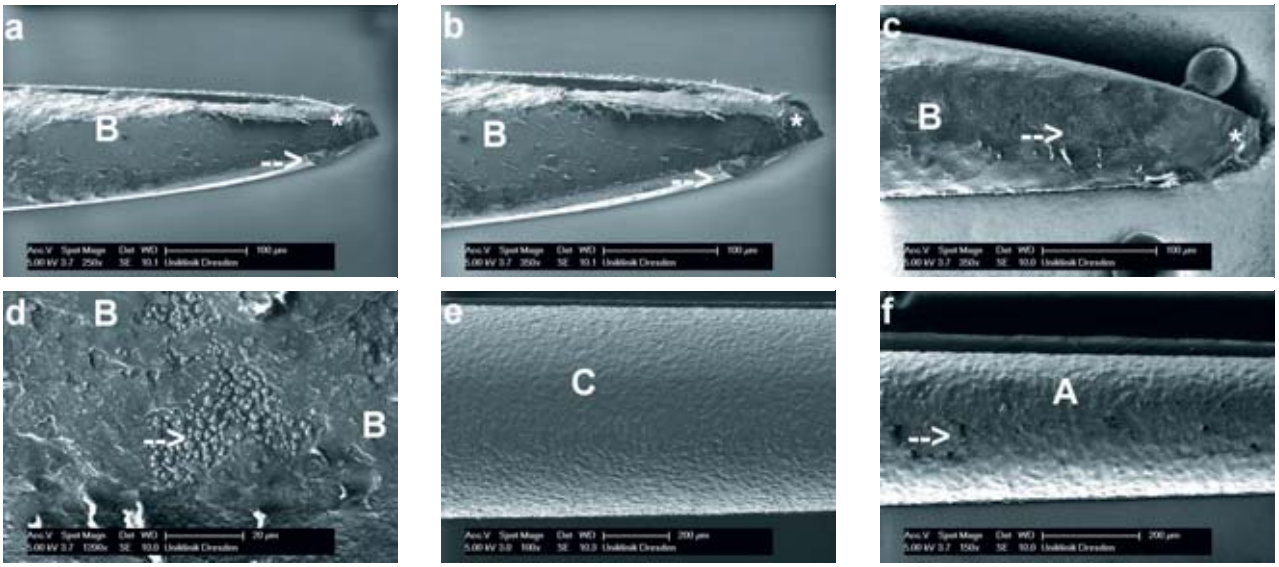


Figure 13a–f Eddy tip showing no signs of fracture or crack initiation at the periphery of the instrument. Although, surface wear (**a–d, f**; A) and a levelled surface relief (**a–d**; B) with scratches (**a–b, f**; arrow), material abrasion (**c, d**; arrow) and strong erosion of the instrument tip are visible (**a–c**; *).

A) Surface wear
B) Levelled surface relief
C) Area with low surface wear
* Erosion of the instrument tip
Arrow: scratches (a–b, f) and material abrasion (c–d)

the failure mode of current sonic (EndoActivator, Dentsply Maillefer, Ballaigues, Switzerland; Eddy,VDW GmbH, Germany) and ultrasonic (Irri S, VDW GmbH, Germany, Endo Soft Intruments EMS, Nyon, Switzerland) tips in artificial and standardized root canals with different, representative radii of curvature. The null hypothesis stated that no fractures of the sonic and ultrasonic tips occur in the different shaped canals. However, the results of the present study showed that the null hypothesis can be rejected. The ultrasonic steel tip Irri S fractured in 70 % of the 3 mm radius-canals and in 100 % of the 2.5 mm radius-canals. Although, the 2.5 mm radius represents an extreme curvature, the other tips showed no fracture. This canal configuration might be rare but not uncommon [52].

The radius of curvature, which determines the stress field for the tips, is a more important factor in the susceptibility of the instrument to fracture, than the number of treated root canals as described by Kuhn for bending tests of NiTi rotary files [28]. Thus, in this context, Cheung et al. [8] stated that correct assessment of the root canal curvature cannot be over emphasized. The most common strategy to determine the canal curvature is the method of Schneider [42]. In the present study out of 100 lower first and second molars, merely 2 teeth were suitable to determine the Schneider angle. The reason was the curved canal geometry, which cannot be completely represented by an angle. Since it is not always possible to determine the angle of the curvature by the Schneider method, the Schneider method was rejected and a more important parameter needed to be taken into consideration.

Until now, no study determined the canal curvature using only the radius of curvature as a descriptive parameter of the root canal shape. The use of the radius of curvature specifies the root canal curvature characteristics and therefore improves the standardized representation of the different root canal types in the artificial model. This model is required to obtain an assessment cyclic fatigue of ultrasonic and sonic irrigation activation devices.

In the present study, the curvature radius was measured just from a two-dimensional and facial view. Three-dimensional radiographic imaging like µ-CT would of course improve the analysis of the exact root canal curvature [14]. However, the study of Schäfer et al. [40] showed that 71 % of the distal canals were canals with one curve and S-shaped canals could be found in 18 % of the determined canals (n = 50 first mandibular canals) [40]. As a result, the majority of lower molars dispose one-shaped canals, although this should be manifested in further studies with a greater number of cases. Furthermore, the following requirements for the present artificial and standardized root canal model were selected to meet specific needs.

First, the model was designed to ensure mechanical resistance to the tested sonic and ultrasonic tips. Second, a non-altering surface guaranteed a root canal surface integrity at the beginning and at the end of the examination. The model was therefore manufactured in stainless steel and not with bovine or human dentin, which is very common for cyclic

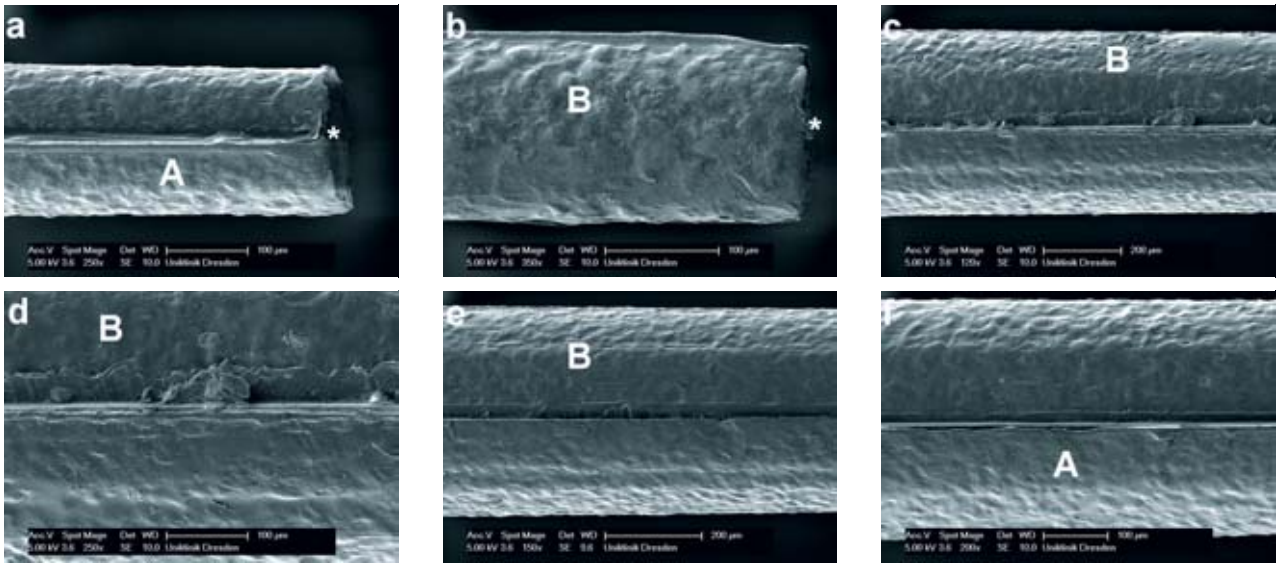


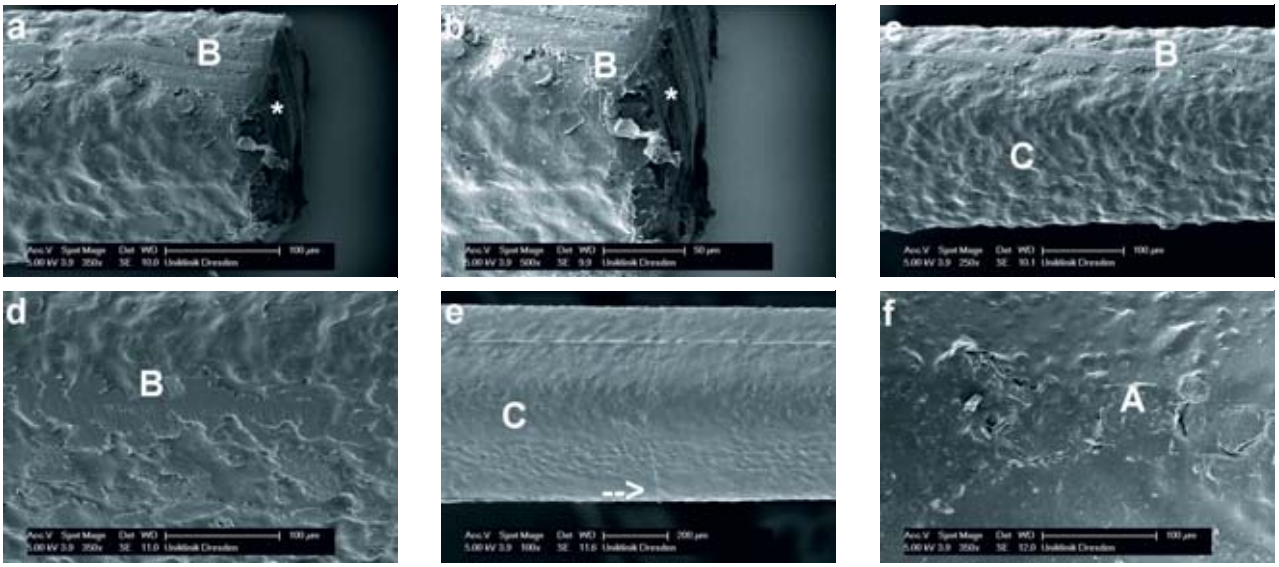
Figure 14a–f Initial state of the EndoActivator-instrument tip: Instrument surface showing no surface wear (**a, f**; A) but manufacturer-dependent material characteristics like the blunt tip (**a–b**; *) and polymer structure adhesion at the synthetic joint (**a, c–f**).

A) No surface wear
B) Manufacturer-dependent material characteristics
* Blunt tip

fatigue resistance testing of endodontic file systems [48]. In laboratory studies, artificial canals have been widely used to evaluate the cyclic fatigue resistance of nickel titanium files to ensure the standardization of experimental conditions [26, 27, 35, 48]. Thereby, stainless steel serves as a stable base material and guarantees identical conditions for the cyclic fatigue testing. Structural differences of the human and bovine dentinal hard tissue (sclerotic dentin, demineralization, amount and density of dentinal tubules) have a potentially high impact on the fracture mode, leading to scattered measurement values. The use of human molars' distal canals was rejected because of the high inter- and intraindividual differences of the root canal geometry, the canal length and the differences in dentin hardness [1, 48]. These unpredictable parameters were excluded in the present study by using a stainless steel model. Furthermore, it should be noted that the square cross-section of the artificial canals is not equivalent to the geometry of human root canals, but it enabled to simulate the almost two-dimensional bending of the endodontic instruments and thus was adapted to examine the failure mode of sonic and ultrasonic tips. However, the results of studies that use artificial canals must be extrapolated to clinical conditions with care because of the differences between a stainless steel block and dentin [4, 48].

As a result the Irri S tip fractured only at the 2.5 mm radius and 3 mm radius canal. The other investigated sonic and ultrasonic irrigant activation devices endured the cyclic fatigue testing procedure but showed, particularly for polymer tips, surface erosion due to interaction with the canals' walls. The reason might be the contact with the stainless steel models' walls. Apparently, the flattening at the edges of the Irri S tip refers to the square diameter of this instrument. It can be assumed, that a high contact pressure is caused by the small contact surface of the tips edges with the artificial root canal. Consequently, the contact pressure exceeds the yield stress of the material and results in plastic deformation. Thereby, the model does not represent a realistic reproduction of the clinical conditions. However, after shaping and rinsing the canal system, it is conceivable that the surface roughness of the dentine can create comparable surface erosions of the polymer tips.

A fractographic examination aims to identify features on the fracture surface that would indicate the origin and the direction of propagation of the cracks leading to material failure (ASM International 1987). According to the classification of Collins [10], the present failure mode was fatigue failure. This failure mode mainly occurs in the area of maximum curvature, particular in small radii, after a certain number of cycles [37]. Starting from an initial crack at the instrument's surface, due to manufacturing defects, repeated plastic deformation enables the crack to propagate and a dimple configuration is created. Once a crack is formed, tension leads to pull the material apart and compression pushes the structure together [8, 50]. With increasing load cycles, these cracks propagate until they reach a critical size and the surrounding material is no longer able to resist the load and the fracture of the ma-



(Fig. 4, and 7–15: Heike Meissner)

Figure 15a–f EndoActivator-tip showing no signs of fracture but crack initiation at the periphery of the instrument (**e**; arrow). Although, surface wear (**f**; A) and a levelled surface relief (**a–d**; B) with erosion of the instrument tip and crack initiation at the periphery of the instrument are visible (**e**; arrow).

A) Surface wear
B) Levelled surface relief
C) Area with low surface wear
* Erosion of the instrument tip
Arrow: crack initiation

terial occurs [8]. Thereby, areas not involved in the crack propagation process do not reveal the dimple configuration [8] as shown in figure 8a. The fracture surfaces of the Irri S tips showed typical examples of mixed fracture modes with parts of fatigue failure and zones of skewed dimple fractures. The skewed dimple ruptures can develop from forced rupture. Afterwards, the starting point for a fracture can always be found at one of the edges. Throughout the ultrasonic activation, the starting point for the fracture progresses and reduces the diameter to an extent that leads to a more ductile skewed dimple fracture mode. Three out of 10 Irri S tips showed no fracture of the instruments after the application in the 3 mm radius of curvature canal. The length of the fractured segments was 7.9 mm in the canal with 2.5 mm radius of curvature and 7.2 mm in the canal with 3 mm radius of curvature. This region of the canal represents the area with the beginning of the curvature for a fully penetrated device. Manufacturer dependent material characteristics like machining grooves and scratches were detected on the whole surface of the instruments working part (Fig. 9 a–d; arrow). These are irregularities that serve as "stress-raisers" [41] and therefore as "initiators" of micro cracks. Fatigue failure only accounted for the Irri S tip, which might be explained with the material characteristics of these tips. The Irri S tip consists of chromium, iron and nickel (Fig. 4).

In contrast, ESI represents a NiTi-tip (Fig. 4). It has already been pointed out in the literature, that NiTi alloy appears highly flexible, elastic and works superior in curved canals [8, 19] compared to stainless steel instruments. A major disadvantage of this tip is the incompatibility of the tip and the intended device. It was not possible to attach the tip completely firm to the manufacturer's mounting, so all tested Endo Soft tips had a loose attachment during the experiments. This clearly affected the results as the energy transfer from the handpiece to the tip was impaired. Considering that ultrasonic irrigant activation may also result in uncontrolled removal of dentin [3], it is important to investigate the less aggressive sonic activation systems [12].

Eddy tips are made of polyamide and are longer (28 mm length) than the EndoActivator tips (21 mm/ 25 mm length), which are made of an unreinforced, low-viscosity acetal copolymer [12]. They showed no signs of fracture. However, the present study determined erosion of the instrument tips and levelled surface reliefs in both instruments. That raises the question of the whereabouts of the missing material. However, a rough tip surface could also provide advantages in terms of irrigant activation by enhancing the local streaming. According to manufacturer information, fractured Eddy tip fragments macroscopically visible move up in the canal with the irrigation solution. Nevertheless, under certain conditions it might be possible that microscopically visible material components remain in the ramified root canal system or are even transported with the irrigant flow to and beyond the apical region.

The present study showed that canals with small radii of curvature are difficult to manage with ultrasonic

irrigating activation in vitro. The Irri S tip broke more often than the sonic irrigation files. Consequently, Eddy seems like a promising system. Nevertheless, it is a relatively new device so case reports about treatment difficulties are missing.

Conclusively, the present study provides a basis for the establishment of further studies with additional parameters study by study in order to counteract the often-performed "trial and error"-study designs in medicine and dentistry. In this particular case, a follow-up study should implement artificial canals milled in bovine dentin with the curvature radii of the current study. However, this investigation enables a defined comparative assessment of different sonic and ultrasonic irrigation activation devices under completely standardized conditions.

Conclusions

An artificial and standardized root canal model was successfully introduced with different radii of curvature, based on evaluations of human molars, for a comparative assessment of different sonic and ultrasonic irrigant activation devices. For a predefined cyclic fatigue test, it was demonstrated that the investigated polymeric sonic and NiTi-ultrasonic irrigant activation devices did not fracture due to the combined bending deformation with additional dynamic stress. Only the stainless steel ultrasonic device Irri S showed fatigue failure in canals with a small radius of curvature. However, the newly implemented approach is a model system that does not represent a realistic reproduction of the clinical conditions during irrigation procedures performed by a dentist. Thus, direct extrapolation to a clinical situation must be exercised with caution and further studies with additional influencing parameters are necessary.

Conflicts of interest:

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

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Administration of systemic adjunctive antibiotics in periodontology – a nationwide online survey

Introduction: For the last 30 years, the central pathomechanical path of periodontitis has been described as a polymicrobial infection by an oral biofilm containing specific pathogens. Consequently, a combination of microbiological tests followed by systemic antibiotics has been used as an adjunct to mechanical removal of the biofilm. According to current knowledge, however, conversion of the originally physiological and symbiotic biofilm into a dysbiotic biofilm is crucial for the pathogenicity. Hence, testing for the presence of specific microorganisms is of less clinical relevance. Systemic administration of antibiotics after prior mechanical debridement undeniably has an added benefit in severe manifestations of periodontitis. In light of this, it is unclear how the decision to administer systemic antibiotics as part of periodontitis therapy is made in dental practices. Evaluating this decision process was the subject of this study.

Methods: The preferences for prescribing adjunctive systemic antibiotics in periodontal therapy were determined with 29 question items using a web-based software (Unipark, Questback GmbH, Germany). The anonymous survey was advertised throughout Germany and conducted from May to October, 2018. Data organization, descriptive evaluation, and contingency analysis (Pearson's chi-squared test, Cramer's V) were performed with PASW Statistics 18 (SPSS Statistics 18, IBM, Chicago, USA). The significance level was defined as $p = 0.05$.

Results: The online survey was accessed by 5745 interested persons. Of these, 425 (7.4 %) completed the survey in full. Most frequently, these respondents reported prescribing antibiotics in periodontitis treatment in patients with rapidly progressive (aggressive) periodontitis (34 %), with necrotizing ulcerative gingivitis/periodontitis with pronounced general symptoms (56 %) and with acute periodontal abscesses with tendency to spread or with pronounced general symptoms (76 %). 58 % of respondents started with the antibiotic therapy prior to root surface instrumentation and 28 % indicated using a microbiological test. The group of survey participants with a specialization reported more frequent use of national statements/guidelines compared to dentists without a specialization (90 % vs. 77 %).

Discussion: According to the results, the majority of dentists participating in the survey used systemic antibiotics in periodontal therapy in a prudent and indication-related manner. However, this should not be generalized, since the study design with its unclear response rate is not sufficiently representative.

Conclusion: The results suggest that the available recommendations from professional associations have largely been implemented.

Keywords: periodontitis; antibiotics; guidelines; online survey

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1. Background

Scientific statements and guidelines are the foundation on which dentists can make decisions for a particular patient that is based on current knowledge. This does assume, however, that the relevant publications are known to the practicing dentist, who carry the main load of dental care in Germany. Without doubt, the treatment of patients with advanced and complex periodontitis is a therapeutic challenge for the entire practice team. Even using the latest technology for mechanical subgingival biofilm removal, complete removal cannot be expected. Although it is not known precisely how much biofilm has to be removed to achieve healthy periodontal conditions, various adjunctive measures to improve the effectiveness are suggested. Along with antiseptics, these measures notably include prescribing adjunctive systemic antibiotics. The extent of the additional clinical effect is, however, the subject of vigorous debate. While some authors described significant clinical effects of systemic administration of adjunctive antibiotics and thus question the necessity of further periodontal surgery measures [23], such a clear treatment effect could not be confirmed in the German AB-PARO study [17]. In this randomized multi-center study, 402 patients were prospectively examined using a parallel group design. All subjects underwent mechanical biofilm treatment that was supplemented in the test group by additional administration of oral antibiotics (500 mg amoxicillin and 400 mg metronidazole). According to the clinical results, the patients in the test group developed less attachment loss in the follow-up observation period compared to the control group (test/control group: 5.3 %/7.8 % further attachment loss). On the other hand, this revealed just how efficient mechanical periodontitis therapy actually is and that only a minor additive effect was achieved by administering antibiotics. The clinical relevance of antibiotic therapy depends on when the antibiotics were taken [18], the parameters recorded, and the severity of the periodontitis [17]. For the practice, this means that without an adequate treatment concept adapted in each case to the particular patient's situation, not only will the long-term success of therapy fail to materialize but statistically verifiable additional benefits of adjunctive antibiotics in periodontitis therapy will also be brought into question [27]. This means that particularly those patients with only moderate periodontitis would gain very little in the way of benefit from antibiotic therapy [21]. Likewise, adverse drug reactions associated with the administration of antibiotics must also be viewed critically [29] because any additional benefits are contrasted with the potentially severe adverse reactions to the antibiotics as well as the significant issue of the development of antibiotic resistance. Many authors therefore recommend restricted handling of adjunctive systemic antibiotics, reserving them for the most severe cases of rapidly progressive periodontitis [17, 21, 27].

Because of the controversies mentioned regarding the assessment of benefits and adverse reactions, an evidence-based guideline (S3) [4] based on a systematic literature review with concrete instructions for the administration of antibiotics as part of periodontitis therapy was initiated to determine the indications for and implementation of adjunctive systemic antibiotic administration. It does raise the question, however, of how decisions regarding the systemic administration of antibiotics as part of systematic periodontitis therapy are made in practice. Evaluating the decision-making process was the subject of this online survey.

2. Method

To determine the procedure used by German dentists when prescribing adjunctive systemic antibiotics as part of periodontitis therapy, 29 relevant question items were developed in a dental focus group. Along with 9 questions aimed at specifically describing the participant, 20 questions were asked to determine the prescribing practices in the dental practice and to subsequently compare the responses with the evidence confirmed in studies on the benefits of systemic adjunctive administration of antibiotics after mechanical biofilm removal. These specific technical questions were classified by indication regarding the type and severity of the periodontitis, the presence of comorbidities, the point of antibiotic prescription, and the specific choice of antibiotic. The design of the questions was based on the recommendations made in the Kiel treatment concept [26], which is characterized by restrictive use of adjunctive antibiotic prescriptions and is comparable to the Göteburg concept [28]. Both concepts assume that ultimately only a few patients would benefit significantly from adjunctive antimicrobial measures whereas the primary therapy is infection control and non-/surgical root instrumentation. Furthermore, the current findings from the ABPARO study [17] and other studies on the adjunctive use of antibiotics in non-surgical periodontitis therapy [27] as well as the statement by the DGZMK from 2003, which was still available at the time of the survey [7], were incorporated into the preparation of the questions.

All the questions were converted to an anonymous online survey using a web-based software (Unipark, QuestBack GmbH). After a positive vote on the research project by the ethics committee of the Faculty of Medicine of the Christian Albrechts University in Kiel (ref.: 452/18), the first version of the online survey was validated by 28 practicing dentists from various federals states of Germany and analyzed using the test/retest method for its reliability. According to the results of this pretest and the comments made by the participants, the survey was modified slightly in terms of its content and formulation. The final version included inclusion and exclusion criteria used at the start of the survey to ensure that only dentists who are employed in a dental practice and treat patients with periodontitis participated in the survey. The first 7 questions related to specific personal parameters relating to age group, sex, German federa state, location of the practice, specialization, university education, and the use of guidelines. These were followed by 20 specific technical questions. The online survey was advertised throughout Germany

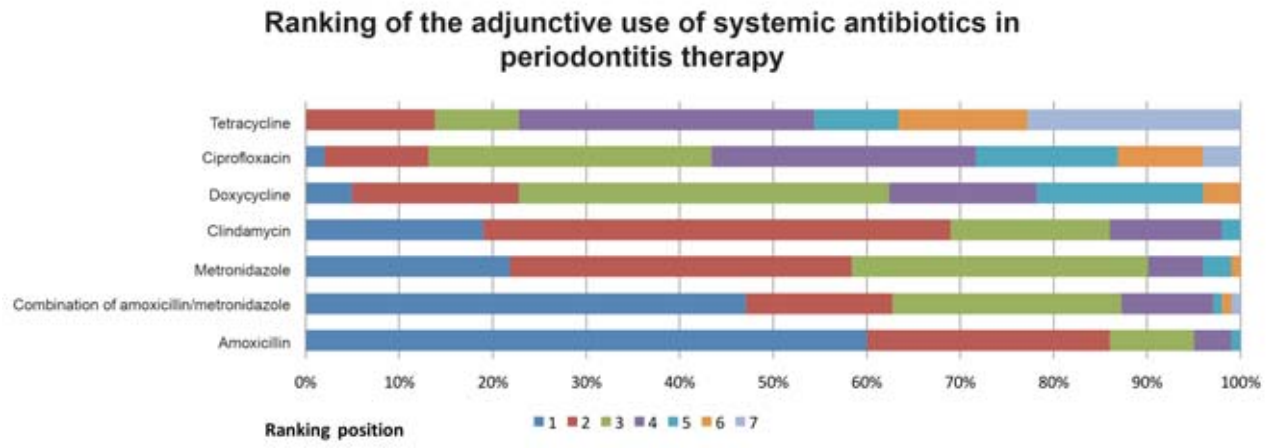

Figure 1 Ranking of the adjunctive use of systemic antibiotics in periodontitis therapy (the participants arranged the possible options according to their frequency of use).

using various advertisements and brief notifications in cross-regional dental journals, newsletters from state dental regulatory bodies and professional associations, lectures and email distribution lists from state dental regulatory bodies over 5 months between May 28 and October 31, 2018.

The calls for participants and the introductory text for the survey briefly explained the research project and assured anonymous participation. No financial incentives or gifts were offered for participating in the survey.

The collected data were automatically saved in the software-specific database (Unipark, QuestBack GmbH, Berlin, Germany) and exported for further data organization as an SPSS dataset (SPSS Statistics 18, IBM, Chicago, USA). A plausibility check of the data was followed by a descriptive analysis in which each question was considered separately along with question-related contingency analyses (Pearson's chi-squared test, Cramer's V). The level of significance was defined as $p = 0.05$.

3. Results

3.1. Population data

The first page of the online survey with the introductory text and a brief explanation of the research project was accessed by 5745 interested persons. Because it was not compulsory to answer every question, the number of responses obtained for each question varied across all questions between 512 and 397. The sociodemographic and professional characteristics of the survey participants are described in Table 1.

3.2 Specific technical questions

The analyses of the specific technical questions on the indication and procedure for periodontitis treatment are shown in Tables 2 and 3. According to the information from the online survey, antibiotics were most commonly prescribed in periodontitis treatment for patients with acute periodontal abscesses with a tendency to spread to adjacent regions, pronounced general symptoms such as fever and/or pronounced general symptoms (75 %), necrotizing ulcerative gingivitis or periodontitis with pronounced general symptoms such as fever and/or pronounced lymphadenopathy (56 %), and rapidly progressive (aggressive) periodontitis (34 %). A microbiological test was used by 28 % of the survey participants to select the antibiotic. Fifty-eight percent of the survey respondents already start the antibiotic therapy before carrying out the root surface instrumentation.

3.3 Choice of antibiotic

In the ranking of adjunctive use (multiple answers possible) the antibiotic amoxicillin took first place. It was listed by 60 % of the respondents as the preferred antibiotic. It was followed by the combination of amoxicillin and metronidazole, which was cited by 48 % of respondents as their first choice. Metronidazole (22 %), clindamycin (19 %), doxycycline (5 %), and ciprofloxacin (2 %) followed. Tetracycline was not named by any of those surveyed as the antibiotic of first choice (see Fig. 1).

In the ranking of the sources of information, most participants (65 %) indicated that they use antibiotics in periodontitis therapy on the basis of scientific statements, national guidelines, or directives (Fig. 2). A dentist's own experience (35 %), the results of clinical trials (24 %), systematic reviews (metaanalyses) (19 %), and narrative reviews (6 %) were cited considerably less often as primary sources of information.

3.4 Relationship between indication/therapeutic procedure and clinicians with specific characteristics

The contingency analyses using Pearson's chisquared test and subsequent Cramer's V test yielded a highly significant association with weak manifestation between the group of survey respondents specializing in an area of dentistry (all specialisms consolidated) and the behavior relating to the use of national statements/guidelines for therapy (planning) (χ^2 (1) = 10.69, $p < 0.001$ and Cramer's V = 0.156, $p = 0.001$).

The analysis of associations between one or no specialization and the specific technical questions about

behavior regarding the use of antibiotics by the survey respondents yielded a significant result in the following cases.

- Clinicians who indicated having one specialization tended to use supportive antibiotic therapy more often/always in patients with rapidly progressive (aggressive) periodontitis (χ^2 (1) = 6.77, p = 0.009 and Cramer's V = 0.122, p = 0.009)
- Clinicians who indicated not having any specialization tended to use supportive antibiotic therapy more often/always in patients with acute periodontal abscesses with a tendency to spread to adjacent regions (χ^2 (1) = 4.71, p = 0.03 and Cramer's V = 0.106, p = 0.03) but never/rarely for patients with multiple teeth with probing pocket depths > 6 mm (χ^2 (1) = 3.99, p = 0.046 and Cramer's V = 0.099, p = 0.046). Likewise, they tended to never/rarely use a microbiological test (χ^2 [1] = 4.44, p = 0.035 and Cramer's V = 0.105, p = 0.035).

A general analysis of the associations between the use or not of statements/guidelines and the specific technical questions about behavior regarding the use of antibiotics by the survey respondents yielded a significant result in the following cases:

- There is a significant association with weak manifestation between the use of guidelines/statements and the application of supportive antibiotic therapy in patients with therapy-resistant periodontitis (χ^2 [1] = 4.52, p = 0.03 and Cramer's V = 0.101, p = 0.03). Clinicians who used statements/guidelines tended to use antibiotic therapy more often/always.
- There is a significant association with weak manifestation between the use of guidelines/statements and the application of supportive antibiotic therapy in patients with periodontitis and diabetes mellitus (χ^2 [1] = 5.01, p = 0.02 and Cramer's V = 0.110, p = 0.02). Clinicians who used statements/guidelines tended to use antibiotic therapy less often/never.
- There is a significant association with weak manifestation between the use of guidelines/statements

Sociodemographic and professional characteristics		Number (proportion as %)
Do you work in a dental practice?		
	Yes	496 (97 %)
	No	16 (3 %)
Do you carry out periodontitis treatments in your practice / for your patients?		
	Yes	500 (98 %)
	No	12 (2 %)
How old are you?		
	< 40 years	190 (40 %)
	40–50 years	95 (20 %)
	51–68 years	185 (39 %)
	> 68 years	5 (1 %)
Please indicate your sex:		
	Female	217 (46 %)
	Male	257 (54 %)
In which urban environment do you work?		
	Baden-Württemberg	40 (8.4%)
	Bavaria	63 (13.2%)
	Berlin	10 (2.1%)
	Brandenburg	6 (1.3%)
	Bremen	2 (0.4%)
	Hamburg	32 (6.7%)
	Hesse	21 (4.4%)
	Mecklenburg-Western Pomerania	20 (4.2%)
	Lower Saxony	16 (3.4%)
	North Rhine-Westphalia	47 (9.9%)
	Rhineland-Palatinate	9 (1.9%)
	Saarland	2 (0.4%)
	Saxony	11 (2.3%)

	Saxony-Anhalt	8 (1.7%)
	Schleswig-Holstein	183 (38.4%)
	Thuringia	7 (1.6%)
Do you have one of the following specializations/fields? (If several, please select only those most relevant to your current employment.)		
	None	339 (71.2%)
	Endodontics	28 (5.9%)
	Orthodontics	2 (0.4%)
	Pediatric dentistry	9 (1.9%)
	Oral and maxillofacial surgery	1 (0.2%)
	Oral surgery	21 (4.4%)
	Public health	0 (0%)
	Periodontology	63 (13.2%)
	Prosthetics	13 (2.7%)
Do you regularly use national statements and guidelines for your therapy (planning)?		
	Yes	382 (81 %)
	No	89 (19 %)

Table 1 Sociodemographic and professional characteristics of survey participants

and the application of supportive antibiotic therapy in patients with periodontitis who smoke or consume nicotine/drugs in another form (χ^2 [1] = 6.32, p = 0.01 and Cramer's V = 0.124, p = 0.01). Clinicians who used statements/guidelines tended to use antibiotic therapy less often/never.

- There is a significant association with weak manifestation between the use of guidelines/statements and carrying out full-mouth scaling (FMS) (χ^2 [1] = 6.05, p = 0.014 and Cramer's V = 0.123, p = 0.01). Clinicians who used statements/guidelines tended to carry out root surface instrumentation in the form of FMS more often/always.
- There is a significant association with weak manifestation between the use of guidelines/statements and the use of a microbiological analysis of the subgingival plaque ("microbiological test") (χ^2 [1] = 5.16, p = 0.02 and Cramer's V = 0.113, p = 0.02). Respondents who indicated that they use national statements or guidelines used a "microbiological test" less often or never.

4. Discussion

The results of this study show clearly that most of the responding dentists, who tend to belong to urban service areas, despite having a balanced age structure and practices located across all German federal states (with a focus on northern Germany), take a cautious and indication-focused approach to the use of adjunctive systemic antibiotics in periodontitis therapy. However, or precisely because of this, the results should not be generalized because the study design with its unclear responder rate means that a representative participant group cannot be assumed. It is also apparent that respondents who indicated having a specialization tended to use national statements and guidelines in their therapy (planning). It was also observed that all the options used to design the questions in this survey do not make any claim in terms of completeness or in any event, the questions reflect the opinion of the authors. It must be emphasized in particular that the scientific statement from 2003 [7] was available on various portals at the time of the survey but had never been updated since its publication. An S3 guideline on the adjunctive application of systemic antibiotics in periodontitis therapy only appeared at the end of 2018 after the survey period for this study had closed [4]. Unlike the guidelines that are now issued, there was no obligation for previously established scientific statements to be updated at least every 5 years.

4.1 Periodontitis and adjunctive systemic antibiotics administration – theory and practice

Based on the current understanding of periodontal pathogenesis as a manifestation of a proinflammatory bacterial dysbiosis in the oral biofilm, the indication for adjunctive systemic antibiotics in periodontitis therapy is rather restricted. Effectiveness against Gram-negative bacteria is only assumed if the protective biofilm has first been mechanically destroyed. This explains one of the requirements of the current guidelines on adjunctive use of systemic antibiotics in periodontitis therapy [4] that the quantity of bacteria on the teeth must be reduced by regular professional and at-home cleaning. Nevertheless, to increase the effectiveness of this mechanical therapy,

Specific technical questions about the indication				
	Number (proportion as %)			
	Never	Rarely	Often	Always
I use supportive antibiotic therapy in periodontitis treatment in my practice / for my patients:				
... with rapidly progressive (aggressive) periodontitis	18 (4%)	114 (25%)	171 (37%)	158 (34%)
... with severe, slowly progressive (chronic) periodontitis	82 (18%)	245 (54%)	103 (22%)	103 (6%)
... with therapy-resistant periodontitis (recurrent or progressive attachment loss despite previously adequate treatment)	38 (8%)	152 (34%)	187 (41%)	75 (17%)
... with submucosal, acute periodontal abscesses with no tendency to spread or pronounced general symptoms such as fever	163 (37%)	156 (36%)	76 (17%)	46 (10%)
... with moderate to severe periodontitis associated with systemic diseases or conditions that impair the function of the immune system	25 (6%)	143 (33%)	180 (42%)	82 (19%)
... with periodontitis who are older than 60 years	148 (34%)	243 (57%)	29 (7%)	10 (2%)
... with necrotizing ulcerative gingivitis or periodontitis with pronounced general symptoms such as fever and/or pronounced lymphadenopathy	13 (3%)	45 (11%)	129 (30%)	236 (56%)
... with acute periodontal abscesses with a tendency to spread to adjacent regions, with pronounced general symptoms such as fever and/or pronounced lymphadenopathy	4 (1%)	19 (5%)	80 (19%)	318 (75%)
... with plaque-associated gingivitis (systematically healthy)	398 (94%)	17 (4%)	5 (1%)	2 (1%)
... with mild or moderate periodontitis (systematically healthy)	322 (77%)	78 (18%)	12 (3%)	7 (2%)
... with periodontitis who are younger than 35 years and have deep periodontal pockets	85 (20%)	197 (47%)	104 (25%)	31 (8%)
... with periodontitis in which pus is found in the gingival pockets	72 (17%)	229 (55%)	90 (22%)	26 (6%)
... with periodontitis and diabetes mellitus	86 (21%)	239 (58%)	71 (17%)	19 (4%)
... with periodontitis who smoke or consume nicotine/drugs in another form	187 (45%)	187 (45%)	32 (8%)	10 (2%)
... with multiple teeth with probing pocket depths > 6 mm	77 (19%)	232 (56%)	74 (18%)	30 (7%)

Table 2 Descriptive evaluation of the subject-specific questions concerning the indication

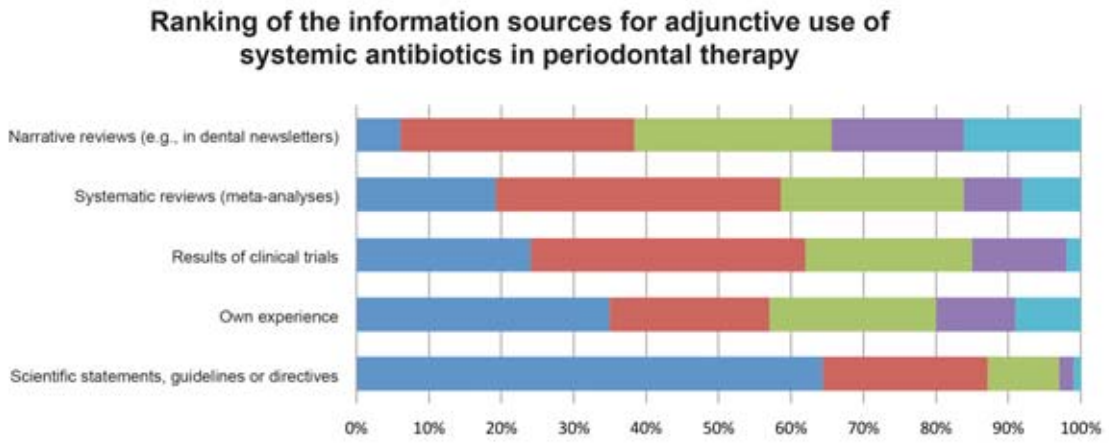

Figure 2 Ranking of the information sources used for the adjunctive use of antibiotics in periodontal therapy (the participants arranged the possible options according to their frequency of use).

adjunctive administration of systemic antibiotics is established for deep gingival pockets and rapidly progressive forms of periodontitis. Their effectiveness is, however, considerably increased if they are taken after mechanical biofilm removal and microorganisms penetrating the surrounding soft tissues are to be treated [11, 18]. The practical implementation of this knowledge was the subject of this study. Interestingly, 58 % of the survey respondents used an antibiotic as an adjunct before the actual mechanical biofilm disintegration and not after. This approach is possibly analogous to that described in the recommendations for endocarditis prophylaxis [13] or even pre-operative administration as part of oral implantation procedures or measures [2]. Although this is not explicitly described, it can be assumed that during the mechanical biofilm removal an adequate level of active substance is already present in the target tissues. For the current issue within periodontology, it must therefore be emphasized that the antibiotic must be administered shortly before or after mechanical disintegration of the biofilm in order to achieve an adjunctive effect. What is critical is the concentration of the active substance in the periodontium. Studies conducted by Sedlacek and Walker [30] also showed that biofilm-mediated antibiotic resistance can rise dramatically again just 24 h after initial bacterial colonization of surfaces and therefore temporal proximity to subgingival instrumentation is essential [18]. On the other hand, however, there is a significant, albeit weak, association between those respondents who indicated that they regularly use national statements and guidelines and those who tend to carry out fullmouth scaling (FMS), that is, mechanical treatment of all exposed root surfaces, within 24 h. This should assure the temporal proximity between the antibiotics administration and the mechanical destruction of the biofilm. The systematic analysis of all available data did not reveal any evidence of a significant difference between a quadrant-based procedure and FMS [14]. In the practice, therefore, both the patient's desires as well as the logistics of making appointments can also be considered when choosing the procedure.

4.2 Periodontitis and adjunctive systemic antibiotics administration – when?

It is undisputed that for determining the indication and selecting an antibiotic certain clinical and microbiological aspects should be noted but in particular the benefits and drawbacks of antibiotic therapy for the patient must be weighed up [21]. Although most studies showed that the adjunctive administration of systemic antibiotics achieved a significant reduction in the probing pocket depths compared to mechanical periodontitis therapy alone, the clinical relevance of this slight difference is nevertheless questionable [27]. In particular, for only mild to moderately periodontitis the relevance is considered highly controversial in light of the adverse reactions associated with systemic antibiotic therapy and the development of bacterial resistance [31, 32]. Clinically, the extent of this additional change is highly dependent on the age of the patient and the severity of the characteristics of the disease [17]. These aspects were not adequately discussed in the statement available at the time of this survey [7] but encouragingly the prescribing practices largely correspond to the current state of knowledge according to the results presented here. Only a small percentage of the respondents (2 %) regularly prescribed adjunctive antibiotics in patients over 60 years of age, whereas 8 % of all respondents indicated that they prescribe antibiotics for periodontitis patients younger than 35 years with deep gingival pockets (≥ 5 mm). The latter corresponds explicitly to the current guideline-compliant procedure [4]. This implies that particularly younger patients under 35 years and with aggressive periodontitis [1], that is, based on a recent classification of periodontal diseases rather with moderate to rapid progression (grade B–C) [25], and patients younger than 56 years who have a probing pocket depth of ≥ 5 mm at more than 35 %

Specific technical questions about the procedure				
	Number (proportion as %)			
	Never	Rarely	Often	Always
I carry out root surface treatment using fullmouth scaling (FMS):	30 (8 %)	74 (18 %)	107 (26 %)	195 (48 %)
When selecting an antibiotic for periodontitis treatment, I use a microbiological analysis of the subgingival plaque ("microbial test"):	111 (27 %)	115 (28 %)	68 (17 %)	112 (28 %)

	Number (proportion as %)
I use supportive antibiotic therapy in periodontitis treatment in my practice / for my patients:	
– immediately before the root surface instrumentation	229 (58 %)
– upon completion of the root surface instrumentation	168 (42 %)

Table 3 Descriptive evaluation of the subject-specific questions regarding the procedure for the treatment of periodontitis

of all measured sites would benefit from adjunctive antibiotic administration after subgingival instrumentation. In contrast, there was no evidence of additional benefits for patients who are older than 56 years and/or have a smaller proportion of periodontal lesions, for which reason treatment should be primarily without adjunctive antibiotics.

The studies relating to specific indications in patients with diabetes or who smoke is described as inadequate or too heterogeneous to enable a specific recommendation for adjunctive antibiotic use [27]. Encouragingly, this fact is again reflected in the current results on prescribing practices. Those clinicians who used guidelines/statements tended to prescribe adjunctive antibiotic therapy less often/never for patients who smoke or have diabetes ($p = 0.02$).

4.3 Periodontitis and microbiological diagnostics before adjunctive systemic antibiotic administration – necessary or not?

Survey respondents who did not indicate having any specialization as well as those who indicated that they base their treatments on national statements/guidelines never or rarely carried out microbiological diagnostics. They thus acted counter to the national scientific statement from 2003 [7] available at the time of the survey, which endorsed microbiological testing. However, this statement had also never been updated and would not be considered valid according to current criteria. Over the past few years in all continuing education programs the current state of knowledge and the resulting changes to the diagnostic procedure have been rigorously discussed, meaning it can be assumed that this professional group is generally closely involved in the development of the discipline. The point must be made here, however, that those persons interested in this issue participated in the survey, which will certainly have influenced the results and therefore the representativeness of the study, an issue that will be addressed in the final section.

The aim of the microbiological analysis should be to select antibiotics specifically in accordance with the complex of periodontal pathogens present [8]. Even though in comparison to other odontogenic infections specific microorganisms may be more commonly associated with periodontitis [12], only a fraction of these are detected using a commercial microbiological test. The pathological relevance of other bacteria that cannot be identified using these tests has not yet been clarified. The therapeutic benefits of a commercial microbiological analysis as part of systematic periodontitis therapy has thus increasingly been questioned over the last 10 years or so and adjunctive antibiotic treatment is no longer considered useful for the indication [10, 24]. Based on our current understanding, the decision for the indication should be made based on the clinical symptoms. A specific microbiological diagnostic can, however, be recommended in case of complications of odontogenic infections with a tendency to spread after previous therapy with aminopenicillin as the treatment of choice [3], which does not involve a primarily periodontological indication.

4.4 Periodontitis and adjunctive systemic antibiotic administration – which one?

According to a study by Hussein et al. [19] that was based on pseudonym-

ized calculation data from statutory insured persons from 2013, clindamycin is prescribed in Germany in more than half of cases of dental treatments with an antibiotic. Furthermore, in the report from the Drug Commission, dentists accounted for the highest proportion of reportable adverse drug reactions (ADR) for antibiotics with 25 cases for clindamycin in 2017, and it is particularly noteworthy that almost 60 % of all clindamycin therapies were prescribed by dentists in Germany [16]. This runs counter to current recommendations for odontogenic infections that describe aminopenicillin with beta-lactamase inhibitor, where applicable, as the treatment of choice [3] and clindamycin is considered to have less therapeutic relevance. In other European countries the proportion of prescribed clindamycin is less than 10 % with a few exceptions such as Spain where it makes up to 38 % of all prescriptions [15]. According to the results of this survey, clindamycin is fortunately only prescribed by 19 % of the respondents as part of periodontitis therapy. There was also no significant association found between participants who indicated that they carry out a microbiological test and a preference for clindamycin as the treatment of choice.

It should be remembered, however, that an evidence-based statement about possible therapeutic superiority of a specific antibiotic or a specific combination of antibiotics cannot currently be made [27]. The greatest evidence is available for the combination of amoxicillin and metronidazole, metronidazole alone, or azithromycin. Even though from a pharmacological perspective they may be favorable therapeutic options, there is up to date no marketing authorization available for either azithromycin or the combination of ampicillin/sulbactam for the dental sector.

According to the S3 guideline published after the survey, with an appropriate indication the dosage should be 500 mg amoxicillin and 400 mg metronidazole 3 times a day for 7 days. In case of penicillin allergy and/or drug exanthema, administering metronidazole alone is recommended [4].

4.5 Representativeness

This study is not representative according to traditional methods in which a random sample of the population to be investigated is generated using a register of all possible survey participants. Due to the non-specific recruitment of the participants over the internet, the current survey, like all online surveys, is affected by distortions [9]. On one hand, any dentists without internet access would not be able to participate in this survey. This is likely to be a relatively small proportion of dentists because as of 2016 93 % of all Germans with a university degree used the internet [20] and in addition all dental practices in Germany will also be connected to the internet as part of the current rollout of the telematics infrastructure. Certainly what is more critical here therefore is distortion of the results due to self-selection (self-selection bias) by the participating dentists. Experience shows that persons take part in voluntary online surveys are interested in the subject, which can positively affect the results. It must therefore be noted that the largest group of the participants (13 %) with a specialization in this survey were specialized in periodontology and as part of their specialization have been trained considerably more intensively in the handling of scientific evidence and its necessity than is possible under the current conditions in education.

4.6 Implementation of scientific evidence in practice

Evidence-based medicine has increasingly gained importance in recent years in the discussion of the quality of medical and dental care. Nevertheless, its implementation in practice is still lagging [5]. For example, a survey in French-speaking Switzerland indicated that only 14 % of those surveyed regularly considered scientific evidence in their therapy decision (pharmacists 12 %, nurses 22 %, physicians 36 %) [22]. Barriers to application include a lack of knowledge and skills as well as a lack of time [6].

According to the current survey, about 81 % of the participants encouragingly made regular use of national statements and guidelines for therapy (planning). This proportion appears relatively high in light of the previous remarks. For this reason, it will be interesting to observe how quickly the new information in the guideline published after the survey for the indication regarding the use of microbiological diagnostics and adjunctive systemic antibiotic therapy and its choice as part of periodontitis therapy are implemented in practice.

Conflict of interest:
The authors state that they have no conflict of interest as defined by the guidelines of the International Committee of Medical Journal Editors.

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Update of the S2k guideline

Surgical removal of wisdom teeth

The second update of the S2k guideline „Surgical removal of wisdom teeth“ was completed in August 2019. It was originally one of the three pilot guidelines of the German Medical Association (BZÄK) and has now been revised in collaboration with the German Society of Dentistry and Oral Medicine (DGZMK) and the German Association for Oral and Maxillofacial Surgery (DGMKG).

The revision of the guideline was previously added to the list of priority topics by the quality task force, consisting of representatives from the DGZMK, KZBV and BZÄK. Findings from the literature from 2012 to June 2017, the results of an interdisciplinary consensus conference of the various associations (see box on page 235) in Bochum on December 13, 2017, and additional contributions from a Delphi procedure from February 2018 to April 2019 have been included. The guideline updates the status of the recommendations in the following specific areas:

- Indications for removing wisdom teeth and for leaving them in situ
- Significance of CB-CT diagnostics
- Significance of perioperative antibiotic prophylaxis
- Significance of piezosurgery
- Significance of coronectomy
- Selecting the time for extracting the tooth

As in the previous version, the principles for selection of the recommendations are explained in background text, which is included in the long version of the guideline. The text is reproduced here for information.

Indications for extraction and preserving teeth

The second update still retains basically unchanged the core statement of the guideline, particularly with reference to (dental) medical indications, possible indications and contraindications with reference to the scientific literature of the period to June 2017.

However, the structured consensus of the expert group has made the following changes:

a) The „Exposure of pulp by caries“ has been deleted from the group of „Indications for removal of wisdom teeth“ and transferred to the „Possible indications for removal of wisdom teeth“. This has made it correspond to the option of retaining the tooth by endodontic treatment as an alternative.

b) “Halitosis requiring treatment“ has been added to the possible indications if other treatments for retention of teeth were not successful.

c) Similar to the indications for removal, the indications for leaving wisdom teeth are classified as indications and possible indications (see box on page 80).

Background: indications

Traditionally a distinction has been made between clinically or radiologically symptomless and symptomatic teeth in the indications for treatment. While the removal of clinically or radiologically symptomatic teeth is generally approved in the literature, a general recommendation for the removal of clinically symptomless wisdom teeth cannot be justified based on scientific evidence.

However, following more recent investigations the strict division by clinical symptoms cannot be justified without further study. Regardless of the presence of a clinically detectable pericoronitis and radiologically confirmed pericoronal radiolucency, a relevant proportion of wisdom teeth (20 to 60 percent) show pathological changes [Baycul et al., 2005; Blakey et al., 2002; Simsek-Kaya et al., 2011; Yildirim et al., 2008], which may affect the periodontal situation of the adjacent molars and may also have further effects [Blakey et al., 2010]. In addition, a high rate of distal caries must also be expected in adjacent 12-year molars (in the range of 50 percent) as a result of a close spatial relationship to the wisdom teeth [McArdle et al., 2016; Kang et al., 2016]. As a result, a fundamental distinction between removal of wisdom teeth for prophylactic and therapeutic reasons does no longer appear to be justified.

Longitudinal studies show that around 30 percent of wisdom teeth planned for removal at the age of 18 tend to become a regular part of the dentition by the age of 30 [Kruger et al., 2001]. On the other hand, two developments in opposing directions show themselves with increasing age. While the frequency of inflammatory complications reaches a maximum in the age group between 18 and 35 years and then decreases with age

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[Fernandes et al., 2009], simultaneously with increasing age complications with surgical extraction tend to increase [Chuang et al., 2007; Baensch et al., 2017].

The benefit of removing wisdom teeth to prevent a tertiary crowding of the anterior teeth in the mandible on conclusion of the orthodontic treatment has been a subject of controversy for a longtime [Linquist & Thilander, 1982; Ades et al., 1990] and is still not fully clarified. A prospective, randomized study did not show a significant influence on tertiary crowding, but the length of the anterior dental arch was significantly reduced if the wisdom teeth were left in place [Harradine et al., 1998]. However, because more than 50 percent of the patients in this study had premolars extracted beforehand, the results cannot be applied to patients with complete dentition.

The primary influences on the likelihood of eruption of wisdom teeth are the retromolar space and premolar extraction [Artun et al., 2005; Kim et al., 2003].

Longitudinal data from the „Veterans Affairs Normative Aging Study" show a relevant, unfavorable influence of impacted wisdom teeth on the prognosis of adjacent molars over a period of up to 25 years and in particular an unfavorable influence on the distal periodontal situation [Nunn et al., 2013]. The current Cochrane Review (CD003879: Surgical removal versus retention for the management of asymptomatic disease-free impacted wisdom teeth) with reference to inadequate „evidence" according to the criteria of the Cochrane methodology refers to consulting with the patient to reach a decision subject to clinical experience.

Photo: M. Kunkel

Figure 1 Surgical site after uncovery of a wisdom tooth surrounded by pericoronal cysts

Tooth resorption:

The evaluation of resorption at the distal radix of second molars is extremely uncertain due to the superimposition by impacted teeth in the conventional panoramic image. The increased use of DVT imaging means that resorptions on 12-year molars are likely to be detected more often and will have to be considered when deciding whether to remove wisdom teeth. Epidemiological data on the frequency are still not available, but patient series with a prevalence of 20 % with horizontal and mesioangular inclined third molars lead to the expectation that the problem of external resorption will have a more prominent place in deciding the treatment in future [Oenning et al., 2014; Oenning et al., 2014; Wang et al., 2017]. For example, in the case of resorption at the distal root of the 12-year molar, it would be possible to remove or if applicable reposition the wisdom tooth by orthodontic treatment.

DVT diagnostics

In spite of the wide range of new publications on DVT diagnostics, there have been no relevant changes to the indications for three-dimensional imaging. The guideline shows this in a statement and a recommendation:

Statement.

Three-dimensional imaging before removing a wisdom tooth is not required if conventional two-dimensional imaging shows no indication of any specific risks.

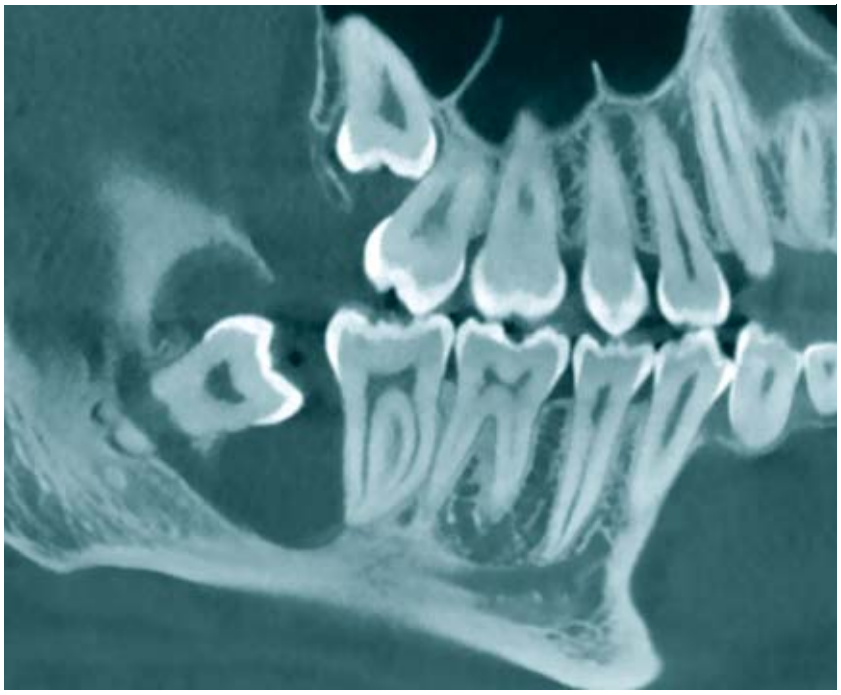

Photo: Kunkel

Figure 2a Course of the inferior alveolar nerve in the root region (sagittal reconstruction)

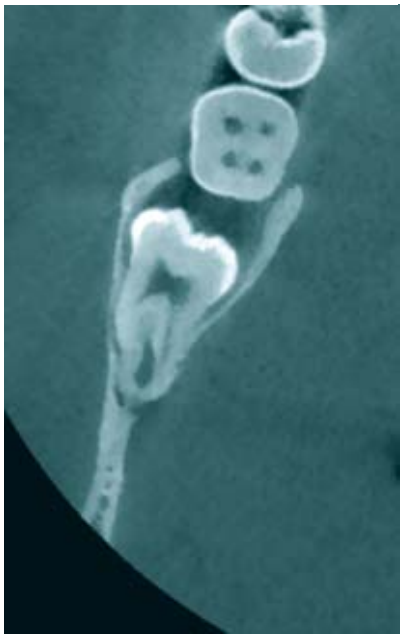

Photo: Kunkel

Figure 2b The frontal reconstruction shows the very unusual intraradicular course of the inferior alveolar nerve

Recommendation:

Three-dimensional imaging (such as DVT/CT) may be indicated if the conventional two-dimensional imaging suggests an immediate spatial relationship to risk structures or pathological changes and at the same time the dentist considers that additional spatial information may be required for the risk assessment of the patient, planning the procedure or also for orientation during the procedure.

Background:

Digital volume tomography (DVT) has become established as the three-dimensional imaging methodology used for indications and treatment in dentistry, oral surgery and maxillofacial surgery. The advantages of DVT diagnostics with reference to topographical information, resolution and dimensional accuracy have been described in great detail in recent years. The availability of DVT has placed the question of the necessity of 3D diagnostics before surgical extraction of wisdom teeth in a central position.

A number of studies has shown that DVT is suitable for showing specific morphological features, positional anomalies and in particular the lack of a boundary between alveolus and nerve canal and thus can be used to assess the risk of nerve damage [Ghaeminia et al., 2009; Lübbers et al., 2011; Neugebauer et al., 2008; Suomalainen et al., 2010; Sursala and Dodson, 2007; Tantanapornkul et al., 2007]. The authors therefore derive the indication of 3D imaging before surgery from the fact that these features are clearly shown in the 3D images. There are also preliminary indications that the surgical procedure may be changed in specific cases due to the inclusion of the DVT information [Ghaeminia et al., 2011]. Critical findings such as the resorption of 12-year molars by impacted wisdom teeth can also only be evaluated by three-dimensional imaging [Oenning et al., 2015].

Photo: Kunkel

Figure 3 Tooth resorption

However, it has so far not been possible to demonstrate that the increased information on the root morphology and topography found with the 3D diagnostics has actually resulted in changes to the surgical procedure and that this has resulted in a reduced rate of nerve damage. Due to the low frequency of such a result, confirmation of a reduction in the risk of nerve damage is practically impossible to obtain under the conditions of a randomized study, because plausible assumptions for the study parameters would result in a sample size of more than 150,000 patients [Roeder et al., 2012]. In practice, an evaluation of the necessity is possible only with the use of surrogate parameters, such as the display of risk indicators.

A prospective randomized study by Ghaeminia et al. contradicts this evaluation and reports of a sample size of 268 patients with 320 wisdom teeth [Ghaeminia et al., 2015]. However, the calculation of the sample size by this working group by implausible assumptions of basic frequencies of damage (12 percent) is not appropriate and is clearly faulty due to the actual frequency of nerve damage of 1.2 percent for the control group within the study population. In addition, the inclusion criteria for

the study (wisdom teeth with increased risk of nerve damage based on the panoramic image (PSA)) contradict the evaluation by the surgeons, who assessed the extraction as difficult in only 20 percent of cases. The times required for the operation (DVT group: 11.1 min versus PSA group: 11.9 min) were virtually the same in both study groups. It is not clear that the information derived from the DVT has influenced the surgical procedure.

The perioperative antibiotic prophylaxis

The recommendation for the perioperative antibiotic prophylaxis has been reduced from the clear endorsement („should") to an open recommendation („may").

Recommendation:

Perioperative antibiotic prophylaxis may be applied during removal of a wisdom tooth.

Background:

The discussion of the benefits of a prophylactic antibiotic therapy has been part of every surgical specialty since the beginning of the antibiotic era. The benefits of prophylactic antibiotic therapy have been a subject of dispute for a long time in the field of removal of wisdom teeth. Overall, a majority of methodologically high quality, systematic reviews confirm the benefits of prophylactic antibiotic therapy for the reduction of alveolar osteitis and also a reduction in infections from wounds [Ren and Malmstrom, 2007; Lodi et al., 2012; Ramos et al., 2016; Marcussen et al., 2016], but not all reviews show a significant therapeutic effect [Isiordia-Espinoza et al., 2015].

On the other hand, some authors point to the problems of potential resistance and changes in the microbiome even with short-term administration of antibiotics [Zaura et al., 2015; Aragon-Martinez et al., 2016]. Against this background there are also reviews in which the authors do not advise prophylactic antibiotic therapy, in spite of significant reductions in infectious complications (even in their own meta-analysis) [Lodi et al., 2012; Arteagoitia et al., 2016]. Although the overall data situation confirms the benefits of a prophylactic antibiotic therapy and in the meantime a methodologically acceptable cohort study on the benefits of a prophylactic antibiotic therapy under practice conditions is now available [Lang et al., 2017], the endorsement and also the rejection of prophylactic antibiotic therapy can both be scientifically supported.

Indications and possible indications for removing wisdom teeth and for leaving them in situ

Indications for removing wisdom teeth

One indication is present with:
- acute or chronic infections (dentitio difficilis)
- teeth destroyed by caries that cannot be restored or untreatable pulpitis
- in the case of patients with diffuse facial pain if there are indications that the wisdom tooth is a relevant cause of pain
- untreatable periapical changes
- manifest pathological structures in connection with tooth follicles (such as cysts, tumors) or suspicion of such changes
- in connection with the treatment of/and limitation of the progress of periodontal diseases
- teeth that interfere with orthodontic and/or reconstructive surgery
- teeth in the fracture gap that interfere with treatment of a fracture
- use of the tooth for transplantation

Possible indications for removing wisdom teeth

One indication may be present:
- to simplify orthodontic tooth movements and/or to simplify orthodontic retention or to secure a completed orthodontic treatment.
- for prophylactic tooth extraction for higher-level reasons to improve quality of life (for example, poor availability of medical treatment, etc.)
- with resorption at neighboring teeth
- pulp exposed by caries
- Teeth that interfere with a planned prosthetic restoration, for example expected due to a secondary eruption due to continuing atrophy of the alveolar ridge or due to pressure from removable dentures
- if other measures are implemented under anesthesia and renewed anesthesia is required to remove a wisdom tooth
- if the elongated/tilted wisdom tooth interferes with the dynamic occlusion
- if the wisdom tooth is the cause of halitosis that requires treatment and other measures for retention of teeth were not successful.

Indications for leaving wisdom teeth in place

One indication for leaving wisdom teeth in place is present if:
- orthodontic treatment of the tooth is planned
- it is to be used for a prosthetic restoration

One indication for leaving wisdom teeth in place may be present if:
- a spontaneous regular setting of the wisdom teeth in the dental arch can be expected
- with deep impacted and displaced teeth without clinically or radiologically confirmed findings of a high risk of surgical complications.

Source: DGMKG, DGZMK: S2k guideline for surgical removal of wisdom teeth, 2019.
AWMF register number: 007–003

Piezosurgery

The scientific evidence for piezosurgery has significantly increased in the last five years, with the result that the significance of this method will continue to increase. However, the data on relevant clinical conclusions are not yet so unified that application of piezosurgery can be generally promoted.

Recommendation:

Piezo osteotomy can be used as an alternative or supplement to conventional osteotomy for removal of wisdom teeth where neighboring anatomical structures are in danger.

Background:

Piezosurgical applications have been described in recent years as an alternative for numerous types of procedures in maxillofacial surgery and dental surgery, because due to the technical principle the danger to neighboring structures is likely to be reduced. In the case of wisdom tooth removal a number of prospective randomized studies and also results from systematic reviews [Jiang et al., 2015;

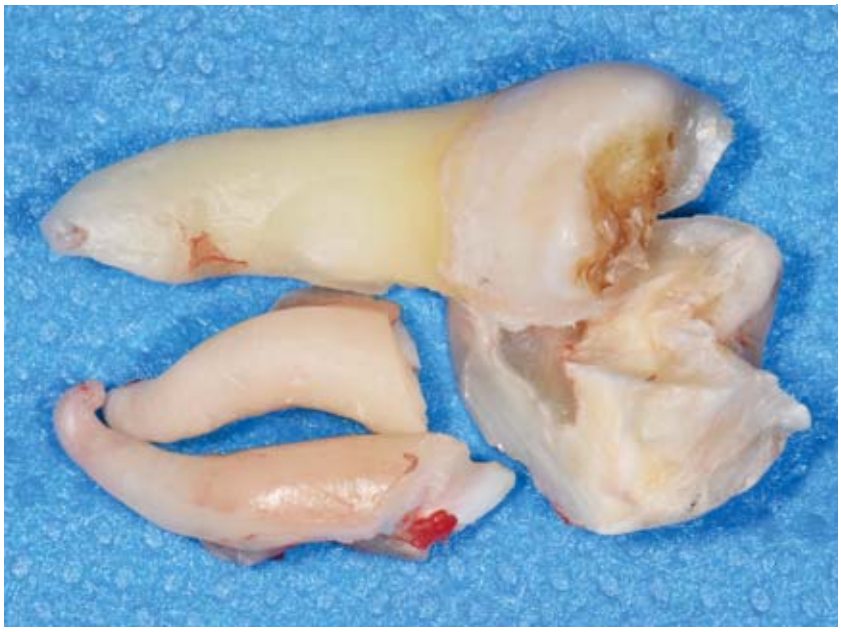

Photo: Kunkel

Figure 4 Variations of tooth morphology

Moraissi et al., 2016; Badenoch-Jones et al., 2016] are now available. However, the selection of studies and parts of the evaluation methodology of Al-Moraissi et al. have been criticized in the literature [Badenoch-Jones et al., 2016]. The meta-analyses have consistently shown significant advantages with pain reduction, oral opening, swelling, but also significantly longer operation times compared to conventional osteotomy techniques. Initial evaluations for „nerve damage" as the clinical outcome parameter [Badenoch-Jones et al., 2016] indicate that piezosurgery may also reduce the risk of nerve damage.

Coronectomy

There have been no significant new insights into coronectomy over the period of this update. The scope of observations has certainly improved and post-operative observation periods over more than five years with low complications have been described. However, data on the longer-term effects over the life of patients are still not available, for example in the case of subsequent treatment with antiresorptives, immune suppression, diabetes, dialysis, tumor therapy and much more. To this extent coronectomy remains an alternative treatment with narrow limits in the indications.

Involved professional bodies and associations

– German Association for Oral and Maxillofacial Surgery (DGMKG)
– German Society of Dentistry and Oral Medicine (DGZMK)
– German Association for Orthodontics (DGKFO)
– German Academy of Oral and Maxillofacial Surgery (AGKi)
– Professional Association of German Oral Surgeons (BDO)
– National Association for Patient Integration (BAGP)
– German Medical Association (BZÄK)
– Interdisciplinary Working Group for Oral Pathology and Oral Medicine (AKOPOM)
– Federal Association for Statutory Health Insurance Dentists (KZBV)

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Recommendation:

As an alternative to complete tooth extraction a coronectomy can be conducted in the case of restricted space to the inferior alveolar nerve where there is a high risk of damage.

Background:

In recent years the method of selectively removing the crown while leaving the root of the wisdom tooth has been revisited . This treatment concept is based on the fact that where the risk of injuring the inferior alveolar nerve is high, complete removal of the root can be avoided and only the crown and the follicular tissue of the wisdom tooth as a cause of pericoronitis are removed. In the meantime, some case series, a number of comparative cohort studies [Cilasun et al., 2011; Hatano et al., 2009; O´Riordan, 2004; Pogrel et al., 2004] and also prospective randomized studies [Leung and Cheung, 2009; Renton et al., 2005] have been published. These studies indicate that the risk of damage to the inferior alveolar nerve is reduced by the coronectomy. However, the long-term effects of leaving parts of the tooth, such as with reference to subsequent radiotherapy or antiresorptive treatment or even therapeutic immunosuppression, have not yet been adequately studied. Only very minor secondary complications were observed over a post-surgical observation period of up to five years [Leung and Cheung, 2016].

In additional to the classical coronectomy, modifications such as a planned two-stage removal after partial removal of the tooth crown [Landi et al., 2010], after partial removal of the bone [Tolstunov et al., 2011] or supplemented by orthodontic treatments [Wang et al., 2012] or Guided Bone Regeneration [Leung, 2016] have been described. So far, only results from small patient cohorts are available for the various modifications.

Preferred time for tooth removal

A recommendation for selecting the time for tooth removal has now been added. This recommendation is based primarily on the significantly in-

creased perioperative morbidity/comorbidity and the poorer periodontal regeneration at neighboring 12-year molars in advanced age.

Recommendation:

If there is an indication for removal of the wisdom tooth or an indication is foreseeable and the time of tooth extraction can be planned, this wisdom tooth should be removed during the time of development of the root, preferably before the age of 25.

Background:

For the decision on the time of surgical removal, in addition to the option of regular setting in the dental arch [Kruger et al., 2001] the primary focus for consideration is the stage of development of the tooth root and its current and anticipated relationship to the inferior alveolar nerve, the danger of resorption at neighboring teeth [Wang et al., 2017], the age-dependent local operational risk [Chuang et al., 2007; Baensch et al., 2017] and the age-dependent periodontal regeneration on the neighboring 12-year molar [Kugelberg et al., 1991].

In addition to the long version of the guideline, a detailed guideline report is also available as a source of information. The documents can be downloaded from the web sites of the German Medical Association, the DGZMK and the AWMF. The next revision of the guideline is planned for 2024.

The literature list can be found at www.zm-online.de or www.online-dzz.com.

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