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Comparison of two cone-beam computed tomography systems in the visualization of endodontic structures

An *in-vitro* study

SUMMARY

An important part of endodontic diagnosis and treatment is the adequate visualization of root canal anatomy. The objective of the present study was to compare two different three-dimensional cone-beam computed tomography (CBCT) systems, Scanora 3D and 3D Accuitomo 170, with respect to their visualization of endodontic canal systems and potential pathological alterations. Seventy extracted human teeth were investigated with regard to the radiographic detection of number of root canals, lateral canals, root canal fillings and posts, vertical root fractures, and the

occurrence of image artifacts. For each evaluation parameter under investigation the radiographic diagnoses obtained by the two different CBCT systems under investigation were similarly accurate, without statistically significant differences. The evaluation of teeth containing high-density foreign materials was impaired for both CBCT systems because of image artifacts. However, a difference between the CBCT systems was not observed. In conclusion, both CBCT systems were found to be similarly suitable for the visualization of endodontic structures *in vitro*.

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Introduction

The success of endodontic therapy depends on several factors, but one of the most important factors is the precise diagnostic imaging of endodontic structures and surrounding tissues, and their pathologies (Jeger et al. 2013; Ese et al. 2014; Mota de Almeida et al. 2014; Venskutonis et al. 2014; Patel et al. 2015). Conventionally used single-tooth radiographs produce two-dimensional images of three-dimensional areas, which is un-avoidably accompanied by a loss of information. Therefore, the use of three-dimensional cone-beam computed tomography in endodontics has been increasing worldwide, ever since its introduction in dental imaging by Mozzo et al. in 1998 (Mozzo et al. 1998). This has also been the case for other fields of dentistry as well, for example, in periodontology (Braun et al. 2014), oral and maxillofacial surgery (Flygare & Ohman 2008) and prostho-dontics (Poeschl et al. 2013).

Several studies have shown a higher diagnostic value and accuracy for CBCT in endodontics in comparison to conventional two-dimensional radiographs (Lofthag-Hansen et al. 2007; Stavropoulos & Wenzel 2007; Hedesiu et al. 2012; Jeger et al. 2013; Mota de Almeida et al. 2014; Venskutonis et al. 2014; Leonardi Dutra et al. 2016). CBCTs can have a great influence on decision-making in endodontic diagnosis and therapy, es-pecially with regard to complex anatomical structures or pa-thologies (Mota de Almeida et al. 2014; Neves et al. 2014; Patel et al. 2015; Leonardi Dutra et al. 2016). Examples include dens invaginatus or radix para- and entomolaris, vertical/horizontal root fractures or perforations, periodontitis apicalis or extra-neous material beyond the apex and internal or external re-sorptions. In addition, the relationship of anatomical struc-tures to root apices can also be evaluated more precisely (Patel et al. 2007).

In many challenging endodontic cases the additional infor-mation obtained by CBCT imaging has a significant impact on therapeutic decision and therapeutic outcome (Scarfe et al. 2009; Ese et al. 2014; Mota de Almeida et al. 2014; AAE & AAOMR 2011, 2015). Nevertheless, the use of CBCTs in dental practice has been primarily limited due to its high costs, radiation dose and the routine required for evaluating the data generated.

In the works of Bergmann & Kieschnick (2009) and Nemtoi et al. (2013), a total of 47 different CBCT devices are described, covering a broad range with regard to technical parameters and costs. In the current literature, only a few studies compared different CBCT devices with one another, each concerning only limited points of interest (Hassan et al. 2010; Hedesiu et al. 2012): for example canine impaction-induced external root re-sorption (Alqerban et al. 2009, 2011a, 2011b), detection of verti-cal root fractures (Hassan et al. 2010) or detection of periapical bone lesions (Hedesiu et al. 2012).

Due to this background the aim of the present study was to compare the basic diagnostic potential of two modern CBCT imaging systems, 3D Accuitomo 170 (J. Morita Europe GmbH, Dietzenbach, Germany) and Scanora 3D (Soredex, Tuusula, Finland) in visualizing endodontic structures and related pathologies.

Materials and Methods

In this *in-vitro* study, 70 extracted human teeth were investi-gated. The teeth were extracted in the local Department of Maxillo-Facial Surgery for non-study related reasons. Both single- and multi-rooted teeth with and without endodontic treatment were included. Written patient information consent was obtained and the study was approved by the ethics com-mittee of the University of Freiburg (604/14).

Prior to CBCT analysis all teeth were X-rayed with a digital imaging plate system (Gendex Oralix AC Kavo Dental GmbH, Biberach/Riß, Germany). The distance between phosphor stor-age plate and tooth was 2 cm using the right-angle technique. Tube voltage was 70 kV, tube current 7 mA and the recording time 0.26 s. The data were generated with Vistascan (Dürr Den-tal AG, Bietigheim-Bissingen, Germany) and saved in TIF for-mat. The X-rays are used to select an appropriate pool of teeth for the following CBCT examination.

The teeth were stored in a solution of thymol (1%) and em-bedded in a standardized plastic form (Technovit, Heraeus Kul-zer GmbH, Hanau, Germany). In total, 6 incisors, 18 premolars, and 46 molars were included. Root fillings (gutta-percha and sealer), posts and vertical fractures existed prior to extraction and were not artificially made after extraction. All parameters were determined on the basis of cross-sections of the extracted teeth as reference standard. The teeth were randomly num-bered and examined with two different CBCT systems, Scano-ra 3D and 3D Accuitomo 170. The technical data and the chosen adjustment for both CBCT systems are shown in Table I. Selec-tion of scanning parameters was performed according to the manufacturer standards for the same field of view. Minor modi-fications were necessary in comparison to clinical conditions, because the teeth had been extracted and were without sur-rounding bone and soft tissue.

For a standardized radiographic workflow all the teeth were placed using an individually designed holder to guarantee a constant distance between the tooth, the radiation source and the detector, thus minimizing any geometric artifacts (Schulze et al. 2011).

Tab. I Technical data of Scanora 3D and 3D Accuitomo 170		
	Scanora 3D	3D Accuitomo 170
Potential (kV)	**75** (60–90)	**60** (60–90)
Current (mA)	**8** (1–15)	**2** (1–10)
Scan time (s)	**4.5** (2–16)	**17.5** (5.4–30.8)
Voxel size (mm)	**0.2** (0.133–0.35)	**0.2** (0.08–0.25)
Field of view (FOV) (mm)	**60×60** 77×100 75×145	40×40 **60×60** 80×80 100×100 140×100 170×120
Detector type	CMOS flat panel	CMOS flat panel
Panoramic imaging	possible	not possible
Standard price	125,000 €	255,000 €
Reconstruction time (min)	max. 2	max. 5
Effective radiation dose	45–68 μSv	11–215 μSv
Technical data of both CBCT devices according to the manufacturers' official available data, Bergmann & Kieschnick 2009 and Nemtoi et al. 2013. The used adjustments in the present study are shown in bold letters.		

The two three-dimensional CBCT data sets of every tooth were evaluated entirely in all three possible views (axial, coronal, sagittal) as full volume by two general dentists, working in the Center for Dental Medicine, Department of Operative Dentistry and Periodontology (Fig. 1). The obtained images were evaluated with the help of a visualization software (3D OnDemand 1.0, Cybermed Inc., Irvine, USA) on a standardized dental radiograph screen (DIN 6868-57, Eizo Europe GmbH, Mönchengladbach, Germany). For standardization in dealing with the analysis software, the two investigators were trained in the investigation software, both theoretically and practically, before the start of the investigation. This was carried out by intensive training with the software, resulting in a one-hour briefing followed by an independent evaluation of five test cases before the actual evaluation began.

The order of presented data sets was randomized and equivalent contrast settings were chosen, in order to have the same technical conditions. The evaluators were blinded to the type of CBCT device, and the evaluation was done according to a questionnaire, with which the dentists could systematically evaluate the images. Upon examination, both evaluating dentists were permitted to independently operate the software in order to view the three-dimensional images without a time limit.

The following criteria were evaluated in the questionnaire:
1. Number of detectable roots, root canals and lateral canals
2. Presence of root canal fillings and posts
3. Presence of vertical fractures
4. Appearance of artifacts

The answers could be "yes", "no" or "uncertain".

After the evaluation of the cone-beam computed images, the extracted teeth were photographed and then cut into cross-sections with a machine for grinding and polishing (Knuth Rotor 3, Struers, Willich, Germany) to be used as a gold standard for the comparison and evaluation. The cross-sections were compared to the evaluated 3D-results of the CBCT systems by the study coordinator.

The results were descriptively summarized and then calculated using the SPSS Statistics 17.0 program (IBM, Armonk, New
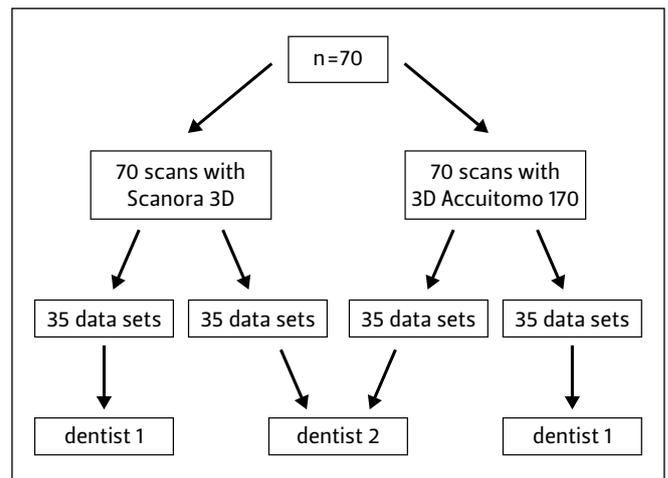

Fig. 1 Workflow of the evaluation process

York, USA). The statistical analysis was done by Fishers' Exact Test (Center for Medical Biometry and Medical Informatics, Institute for Medical Biometry and Statistics, Medical Center University Freiburg). The level of significance was set at $p < 0.05$.

Results

The cross-sections as reference standard showed a total of 129 roots, 185 root canals, 81 natural lateral canals, 86 roots with root fillings, 8 posts and 12 vertical fractures within the 70 teeth.

In comparison to the results of the cross-sections (gold standard) the overall range of correct diagnosis with the CBCT data ranged from 92% to 100% (Tab. II). The statistical analysis showed no statistically significant differences between Scanora 3D and 3D Accuitomo 170, for any of the tested criteria ($p > 0.05$). Within every evaluation parameter the diagnoses obtained with 3D Accuitomo 170 were at least as accurate or more accurate than with Scanora 3D. All of the results are listed as percentages, based on the number of correctly diagnosed teeth ($n = 70$). Cohen's kappa for total inter-rater variability was 0.771, and thus considered to be good.

Tab. II Summary of percentage of correct diagnoses done with each of the CBCT systems				
Criterion	n criterion (in 70 teeth)	Overall correct diagnosis (n = 70)		p-values
		3D Accuitomo 170	Scanora 3D	
Number of roots	129	97.2%	98.6%	1.000
Number of root canals	185	100.0%	98.6%	1.000
Lateral canals	81	100.0%	98.6%	1.000
Root fillings	86	100.0%	92.9%	0.058
Posts	8	95.8%	95.8%	1.000
Vertical fractures	12	100.0%	98.6%	1.000
Enamel-dentin-differentiation	n/a (70)	78.6%	61.4%	0.086

The percentage value is related to a right or wrong diagnosis of each criterion and each tooth (n=70): there are no statistically significant differences between 3D Accuitomo 170 and Scanora 3D.
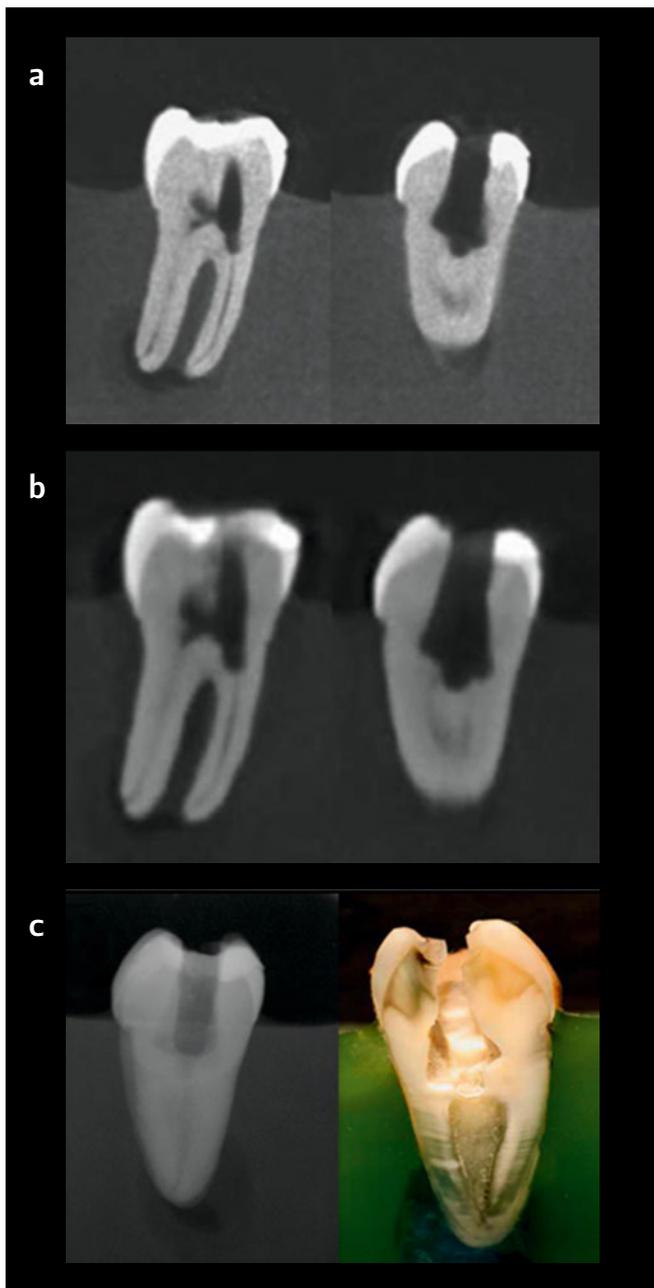
Fig. 2 Mandibular molar: sagittal and coronal view by Scanora 3D (a) and 3D Accuitomo 170 (b), an image of the X-ray and the prepared cross-section (c)

Number of roots, root canals and lateral canals

In Figure 2 different views of a mandibular molar are depicted, exemplarily: screenshots by Scanora (a) and Accuitomo (b), an image of the X-ray and the prepared cross-section (c) (Fig. 2).

With 3D Accuitomo 170 the correct root number was detected in 97.2% of the samples, and the correct number of root canals and natural lateral canals in 100%. With Scanora 3D all three criteria were evaluated correctly in 98.6%, so 1 tooth out of 70 (n = 70) was diagnosed wrong, respectively, upon comparison with the gold standard.

Number of root fillings and posts

*In Figures 3, 4 and 5 different cases are shown, exemplarily.*
With both 3D Accuitomo 170 and Scanora 3D metal posts were detected correctly in 95.8% of the samples. Both evaluating dentists classified two teeth as "not assessable" and one tooth as "false positive", irrespective of the CBCT system. However, the existence of root fillings was diagnosed correctly with 3D Accuitomo 170 100% of the time, but with Scanora 3D 92.9% of the time.

*Diagnosis of vertical fractures (Fig. 6)*
Within the 3D Accuitomo 170 scans vertical fractures could be detected 100% of the time. With the scans by Scanora 3D vertical fractures could be detected correctly 98.6% of the time. In the depicted comparisons of CBCT screenshots, the digital single-tooth radiograph and the extracted tooth, it is clear to see how difficult it is to clinically detect vertical fracture lines when using only conventional two-dimensional projections. In contrast, with the data of both CBCT devices, the fracture lines are easier to detect.

Artifacts

Artifacts occurred in the majority of the CBCT images (87%), and were equally frequent within both tested CBCT systems. In the images created by Scanora 3D, the occurring artifacts seemed to be more distinctive. This is the subjective evaluation by the study participants analyzing the CBCT recordings, and not an objectively evaluated result. However, as can be seen in the comparison of the screenshots (Fig. 7), "beam-hardening artifacts" caused by any high-density material present in the scanned volume, such as root fillings with gutta-percha cones or metal restorations, seem to be more severe in the screenshots by Scanora 3D than in those by 3D Accuitomo 170. Within the beam-hardening artifacts, three different types were detected
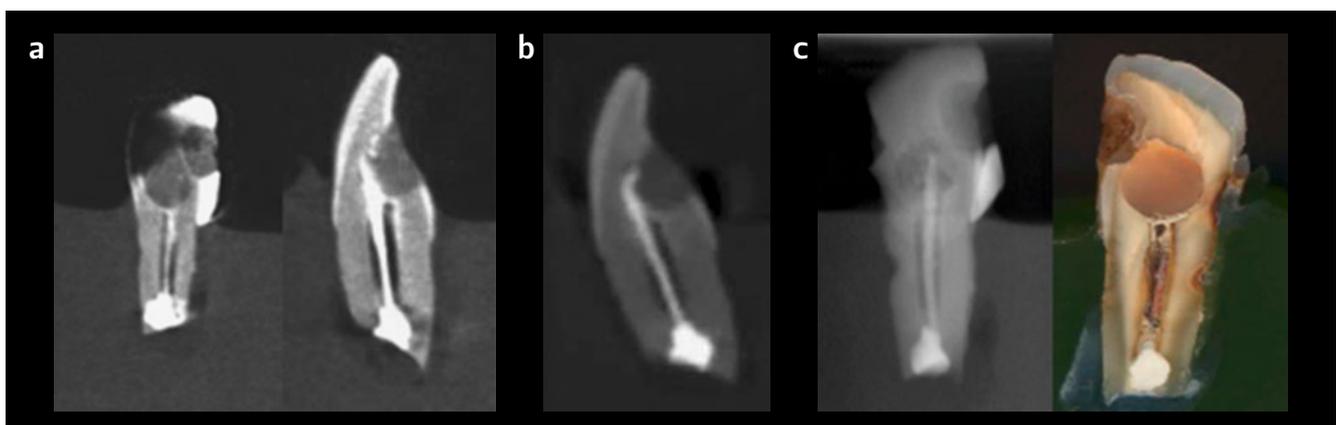

Fig. 3 Incisor with root amputation, insufficient root canal treatment and a cavity: coronal and sagittal view by Scanora 3D (a), sagittal view by 3D Accuitomo 170 (b), image of X-ray and cross-section (c)
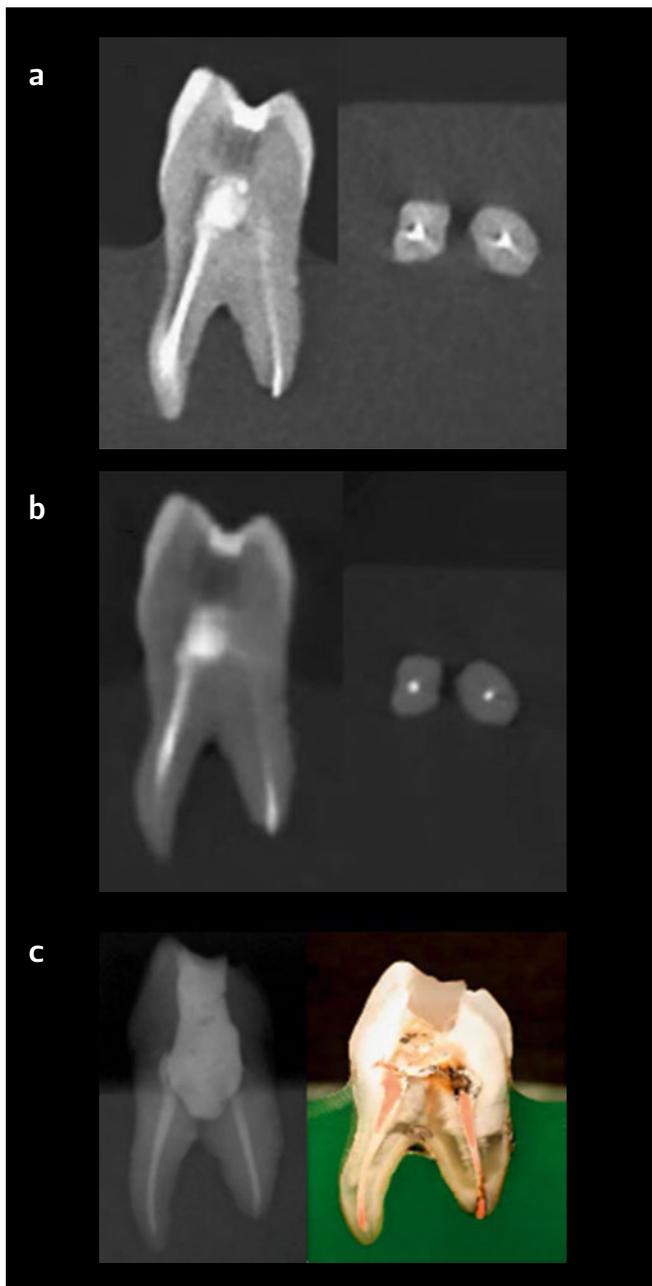
Fig. 4 Maxillary premolar with extruded root filling material: coronal and axial view by Scanora 3D (a) and 3D Accuitomo 170 (b), image of X-ray and cross-section (c)
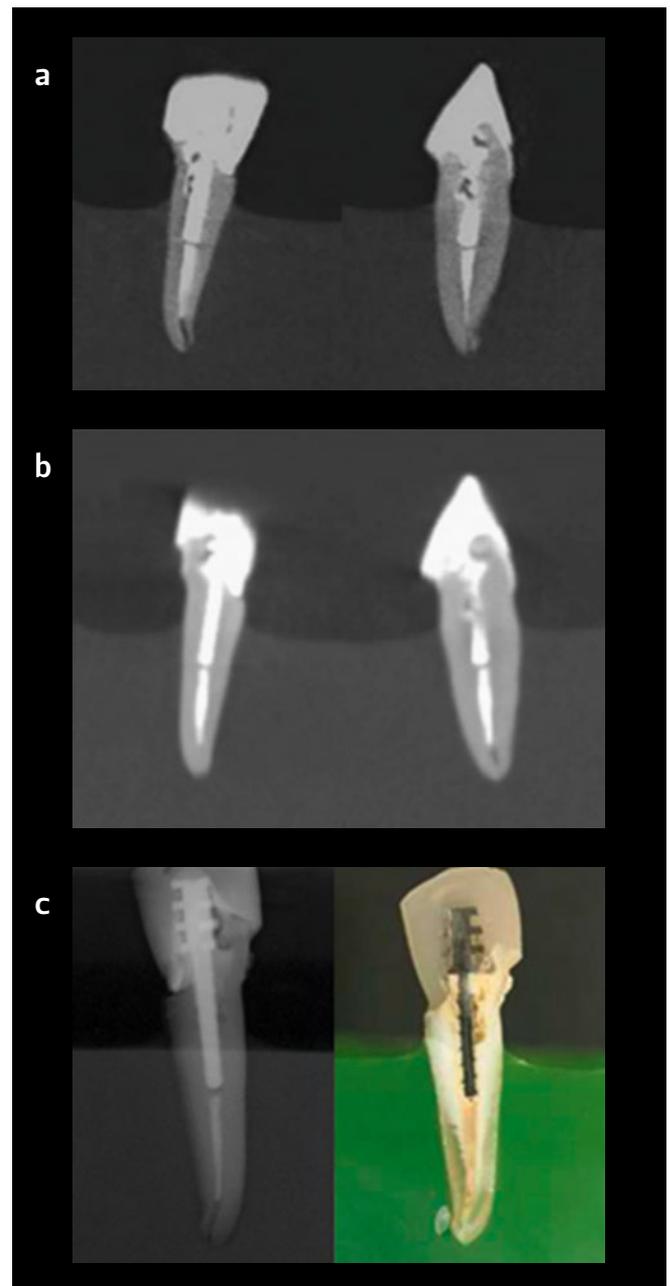
Fig. 5 Incisor with a short root filling and a intracanal screw: coronal and sagittal view by Scanora 3D (a) and 3D Accuitomo 170 (b), image of X-ray and cross-section (c)
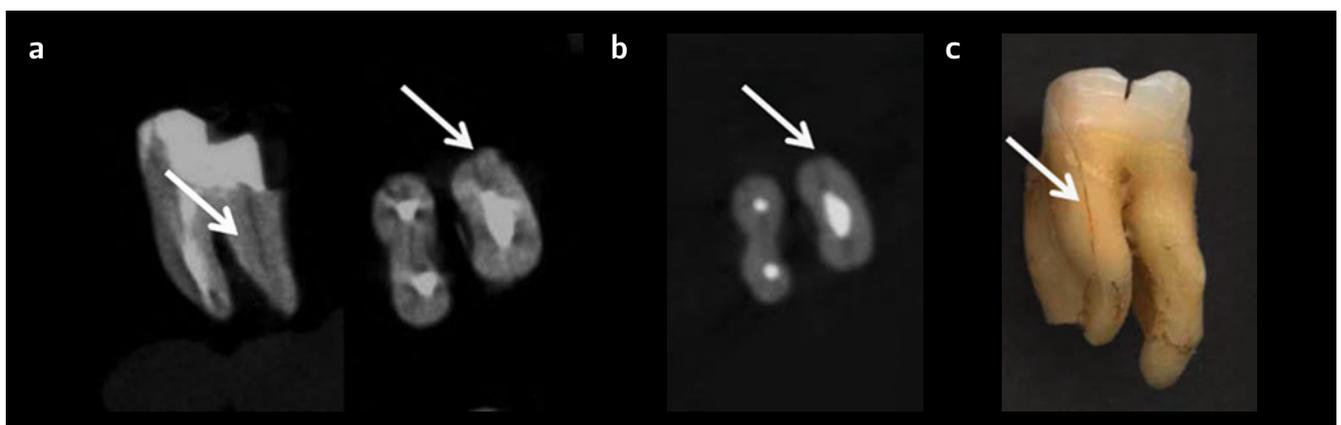
Fig. 6 Visualization of a vertical root fracture line (arrows) in the distal root of a mandibular molar: coronal and axial view by Scanora 3D (a), axial view by 3D Accuitomo 170 (b), image of the actual fracture line (c)
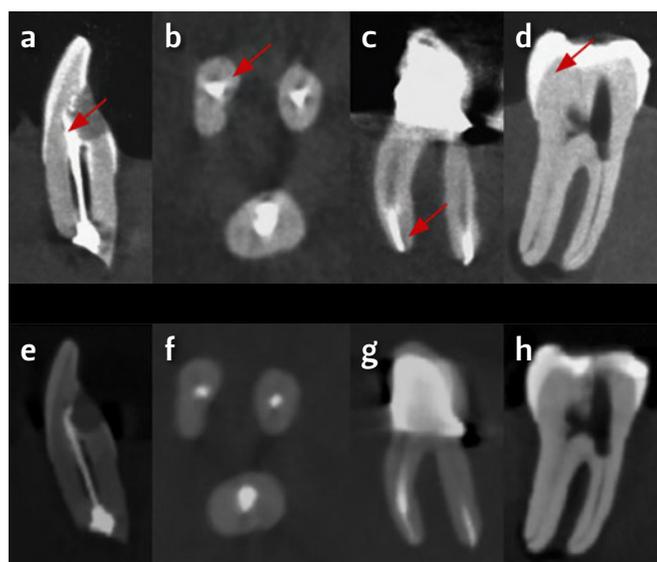
Fig. 7 Occurrence of artifacts in scans by the Scanora 3D (a–d) and the 3D Accuitomo 170 (e–h): three different types of beam hardening artifacts can be seen (arrows): cupping artifacts (a), hypodense halo (c, d) and streaks (b). The artifacts are more evident in the screenshots by Scanora 3D.

(Schulze et al. 2011; Vasconcelos et al. 2015): cupping artifacts which make it impossible to see the clear shape of the hyperdense material, the hypodense halo, the dark area adjacent to the hyper-dense structure, and streaks (Fig. 7).

Differentiation of enamel and dentin

A differentiation between enamel and dentin in the scans by 3D Accuitomo 170 was possible in 78.6% and in scans by Scanora 3D in 61.4% of the samples.

Total number of false diagnoses

The inter-rate variability of both dentists concerning false decisions was very small: both dentists achieved a higher number of correct diagnoses with 3D Accuitomo 170 (Tab. III).

In total, 24 false diagnoses were made with Scanora 3D (out of 140) with respect to the gold standard, while 9 were made with 3D Accuitomo 170.

Discussion

In summary, both CBCT systems are very convenient for the depiction of endodontic structures. Both were very well-suited for the visualization of complex endodontic structures *in-vitro*. In agreement with the current literature, the present results show that CBCT scans can successfully be used to detect vertical root fractures (Avsever et al. 2014). Very consistent results were also achieved with regard to the number of roots and lateral canals or the presence of root canal fillings and posts.

Regarding posts, both evaluating dentists classified two teeth as "not assessable" and one tooth as "false positive", irrespective of the CBCT system. That means both dentists detected a post within the three-dimensional data set of one tooth, although there was none actually. This could be due to the root canal anatomy (or a prior existing but removed post) and/or a very thick and well condensed root filling.

A big challenge in comparing different CBCT devices with each other is, that the devices are very different and that the manufacturers often do not give information about hard- and software components. Additionally, in Germany, there are no special guidelines for adjusting CBCT devices, but it is recommended to keep strictly to the manufacturers' instructions (Bundeszahnärztekammer 2014). Therefore, we tried to choose as similar adjustments as possible within the limits of the manufacturers' recommendations, as for example the same voxel size and field of view. This procedure can be considered as first step in the comparison of these two CBCT devices. A further possible approach is a comparison of devices with different adjustments according to specialized radiologists beyond the manufacturers' recommendations. In addition, a group of more than two evaluating dentists could be favorable. Maybe then results are different.

A further point of concern is the visualizing monitor and surrounding conditions like the (interior) light. The two operators used a standardized dental radiograph screen (DIN 6868-57); the surrounding light could be adjusted individually.

Most of the current literature compares CBCTs with conventional two-dimensional single-tooth radiographs (Stavropoulos & Wenzel 2007; Poeschl et al. 2013; Leonardi Dutra et al. 2016) or with computer tomographies (CT) (Loubele et al. 2009; Avsever et al. 2014; Hofmann et al. 2014). Only a few studies have compared different CBCT systems with each other with regard to endodontic issues (Hassan et al. 2010; Alqerban et al. 2009, 2011a, 2011b; Hedesiu et al. 2012). Hedesiu et al. (2012) compared three CBCT devices, among them 3D Accuitomo 170 and Scanora 3D, for the detection of simulated periapical bone lesions *in vitro*. As in the present study, they couldn't find a statistically significant difference in the diagnostic accuracy of the devices. Another *in vitro* comparison of five different CBCT systems for the detection of vertical root fractures found differences between the systems due to the detector designs of the devices (Hassan et al. 2010): flat-panel detectors (FPD) were superior to image intensifier tube/charged coupled device combinations (IIT/CCD). Both devices in the present study, 3D Accuitomo 170 and Scanora 3D, were equipped with FPDs, as are almost all CBCTs in the current market. Alqerban et al. compared up to six different CBCTs *in vitro* (Alqerban et al. 2009) and *in vivo* (Alqerban et al. 2011b) with each other and with two-dimensional panoramic radiographs concerning the detection of simulated canine impaction-induced external root resorption. They found

Tab. III Overall false decisions made by the two calibrated dentists with Scanora 3D and 3D Accuitomo 170

	Scanora 3D			3D Accuitomo 170			n
	false positive	false negative	total	false positive	false negative	total	
Dentist A	1	11	12	2	4	6	70
Dentist B	3	9	12	0	3	3	70

CBCT to be more sensitive than conventional radiography. An interesting fact was that a significant difference could be found with regard to the subjective image quality of the different CBCT systems but no difference in the diagnostic accuracy.

Therefore, a lot of experience with CBCT imaging is certainly one key in making accurate diagnoses (Alqerban et al. 2011a). This was shown in one study where the performance of radiologists was compared to that of dentists: the radiologists scored higher because they had more experience and were more familiar with three-dimensional images.

In data sets of both CBCT systems investigated here artifacts occurred. Most of the artifacts in CBCTs are unavoidable because of the recording and reconstruction process (software). In general, artifacts lead to a loss of image quality, complicating the diagnostic evaluation of adjacent structures or even masking pathological results (Scarfe & Farman 2008; Schulze et al. 2011).

Most of the artifacts in this study are beam-hardening artifacts created by hyper-dense structures such as root fillings, posts and metallic restorations. With respect to this parameter, 3D Accuitomo 170 and Scanora 3D showed similar outcomes, with no statistically significant differences. This result agrees with that from a study comparing the occurrence of artifacts using several CBCT machines when imaging root filled-teeth (Vasconcelos et al. 2015).

The subjective impression of the evaluating dentists about minor artifacts in scans by 3D Accuitomo 170 can be an explanation for the lower number of false diagnoses made using 3D Accuitomo 170 (Tab. III). It is possible that this impression is due to the higher current used in the visualizations by Scanora 3D. However, the scanning time was less, and the voltage used was higher in comparison to 3D Accuitomo 170, with both adjustments tending to introduce fewer artifacts (Scarfe & Farman 2008; Chindasombatjaroen et al. 2011; Schulze et al. 2011). In addition to these variable adjustments, artifacts are also caused by device-dependent variables or the physical process of reconstruction, respectively, of the software used. In the near future a further development in CBCT software is to be expected with regard to software-based automated artifact reduction and post-processing in order to improve image quality (Scarfe & Farman 2008; Schulze et al. 2011; Vasconcelos et al. 2015).

In summary, both systems seem to be equally useful in endodontics, which is a very interesting finding regarding other CBCT-related factors such as installation and maintenance costs, possible FOV and range of application, and additional options (i.e. panoramic imaging). For example, the higher acquisition costs of 3D Accuitomo 170 are noticeable, being close to twice that of Scanora 3D (Tab. I).

One limitation of the present study is the imaging of extracted teeth without surrounding bone and soft tissue. However, due to dosimetric and ethical considerations it would not be suitable to perform a prospective clinical trial on this topic. Other options could be retrospective investigations with a 2-D and a 3-D data set, or investigations with human cadavers. In these cases for example, criteria such as scan time would certainly be of more significance with regard to impairment of data by motion artifacts.

As the radiation dose to the patient must always be taken into consideration, endodontic cases should be judged individually (Loubele et al. 2008; Pauwels et al. 2012). A CBCT should only be applied after a comprehensive clinical examination, and a conventional two-dimensional single-tooth radiograph. A CBCT can only be considered appropriate if the conventional radiograph is insufficient making three-dimensional images necessary for precise and accurate endodontic diagnosis and treatment. The dimensions of the FOV should be adapted to the patient and the specific area of interest to obtain the lowest radiation dose possible, according to the principle "as low as reasonably achievable" (Loubele et al. 2008; Hedesiu et al. 2012; Pauwels et al. 2012). The European Society of Endodontology recently published a position statement about the use of CBCT in endodontics in order to give clinicians evidence-based criteria about when to use a CBCT in endodontics (Ese et al. 2014; AAE & AAOMR 2011, 2015).

Conclusions

In comparison with cross-sectioned teeth as reference standard (without histomorphometric measurements), both of the CBCT devices examined in this study, 3D Accuitomo 170 and Scanora 3D, were found to be equally suitable to visualize endodontically relevant structures *in vitro.*

Acknowledgements

Résumé

Introduction
La représentation précise des structures internes des racines dentaires est indispensable pour le diagnostic et le succès de la thérapie endodontique. L'image obtenue sur un film de radiographie dentaire est une superposition de l'ensemble des structures tridimensionnelles, donc des informations importantes peuvent être perdues. Pour cette raison, l'utilisation de l'imagerie volumique 3D numérisée à base d'un faisceau radiographique conique a continuellement progressé depuis l'introduction sur le marché en 1998, notamment dans les cas complexes comme les résorptions ou des variations anatomiques rares.

En raison d'un nombre toujours plus grand de tomographes volumiques 3D, on peut se poser la question si tous les appareils sont qualifiés pour la représentation de l'anatomie radiculaire.

Le but de la présente étude est de comparer deux tomographes volumiques largement utilisés, Scanora 3D et 3D Accuitomo 170, afin de comparer la représentation des structures endodontiques et ses changements pathologiques.

Matériaux et méthodes
Septante dents humaines ont été examinées par les deux tomographes volumiques. Deux dentistes standardisés ont porté indépendamment un jugement sur les caractéristiques suivantes: nombre des racines et canaux radiculaires, présence des canaux latéraux, d'obturations canalaires, des pivots, de fractures radiculaires et apparition des artefacts. Après l'exposition aux tomographes, les dents expérimentales ont été sectionnées transversalement et examinées par une tiers personne, puis comparées aux résultats des examinateurs.

Résultats

Les fractures verticales des racines et les canaux latéraux étaient diagnostiqués correctement par le 3D Accuitomo 170 dans 100% et par le Scanora 3D dans 98,6% des cas. Les résultats obtenus avec le 3D Accuitomo 170 étaient supérieurs ou au moins identiques à ceux obtenus avec Scanora 3D. Les deux dentistes ont établi avec le 3D Accuitomo 170 plus de diagnostics corrects qu'avec le Scanora 3D. Toutefois, la différence n'était pas statistiquement significative.

L'évaluation des données, des dents avec du matériel radioopaque comme une obturation canalaire ou des pivots a été compliquée en raison des artefacts. Selon une estimation subjective, ces artefacts étaient plus marqués dans les données obtenues avec le Scanora 3D.

Discussion

Dans le domaine de l'endodontologie, les images radiologiques tridimensionnelles apportent des nouvelles possibilités et avantages, surtout dans les cas difficiles et les cas rares. Avant d'exécuter ces images, un diagnostic radiologique à base d'un film conventionnel à deux dimensions devrait être fait. Selon le principe ALARA (as low as reasonably achievable), le dentiste décide au cas par cas si un DVT apporte une franche plus-value diagnostique et des informations déterminantes concernant la thérapie.

Les résultats rapportés par ce travail sont limités par le fait que les images ont été réalisées in vitro sans l'entourage de l'os ou du tissu mou. Cependant, l'efficacité de ces deux tomographes pour l'endodontologie devait être testée. En outre, une étude clinique est difficilement réalisable pour des raisons éthiques et de rayonnement.

En résumé, on peut constater des différences minimes entre les deux appareils, et que tant le 3D Accuitomo 170 que le Scanora 3D sont qualifiés pour une représentation des structures endodontiques in vitro.

Zusammenfassung

Einleitung

Für nachhaltige und erfolgreiche endodontische Massnahmen mit dem Ziel des Zahnerhalts ist die adäquate röntgenologische Darstellung der Anatomie des Wurzelkanalsystems ein wichtiger Teil, sowohl zur Diagnosestellung als auch zur anschliessenden Behandlung. Da die in der Regel verwendeten Einzelzahnaufnahmen zweidimensionale Abbildungen von in natura dreidimensionaler Gebiete sind, gehen unweigerlich Informationen verloren. Daher ist der Einsatz der digitalen dentalen Volumentomografie (DVT) in der Endodontie zur dreidimensionalen Darstellung von Wurzelkanalsystemen seit der Markteinführung 1998 stetig zunehmend, insbesondere bei komplexen Fällen wie z.B. Resorptionen oder seltenen anatomischen Variationen. Aufgrund der zunehmenden Vielzahl der auf dem Markt befindlichen DVT-Geräte stellt sich die Frage, ob alle Geräte gleichermassen zur Darstellung der Wurzelkanalanatomie geeignet sind. In der vorliegenden Untersuchung wurden daher zwei verbreitete digitale Volumentomografen, Scanora 3D (Soredex, Schutterwald, Deutschland) und 3D Accuitomo 170 (J. Morita Europe GmbH, Dietzenbach, Deutschland), im Hinblick auf die grundlegende Darstellbarkeit endodontischer Strukturen und ihrer pathologischen Veränderungen miteinander verglichen.

Material und Methoden

Siebzig extrahierte humane Zähne wurden jeweils mit beiden digitalen Volumentomografen untersucht. Dabei wurden die folgenden Punkte unabhängig voneinander von zwei kalibrierten Zahnärzten betrachtet: die Anzahl der Wurzeln und der Wurzelkanäle, das Vorhandensein von Seitenkanälen, Wurzelkanalfüllungen und Wurzelstiften sowie vertikale Wurzelfrakturen und das Auftreten von Artefakten. Die dreidimensionalen Datensätze wurden anschliessend mit von den Versuchszähnen hergestellten Schliffpräparaten als Goldstandard verglichen.

Resultate

Vertikale Wurzelfrakturen und Seitenkanäle wurden von 3D Accuitomo 170 zu 100% und von Scanora 3D zu 98,6% richtig diagnostiziert (p = 0,5). Bei allen untersuchten Gesichtspunkten waren die mit 3D Accuitomo 170 erreichten Ergebnisse besser als oder mindestens ebenso gut wie diejenigen mit Scanora 3D; beide Zahnärzte stellten mit 3D Accuitomo 170 mehr korrekte Diagnosen als mit Scanora 3D, allerdings ohne statistisch signifikante Unterschiede.

Die Auswertung der Daten von Zähnen mit röntgendichtem Material wie Wurzelfüllungen oder -stiften, war mit beiden dentalen Volumentomografen aufgrund auftretender Artefakte erschwert. Subjektiv bewertet waren diese aufgetretenen Artefakte bei den Datensätzen von Scanora 3D ausgeprägter.

Diskussion

Auf dem Gebiet der Endodontologie können dreidimensionale röntgenologische Aufnahmen durch digitale Volumentomografen neue Möglichkeiten und Vorteile eröffnen, insbesondere in schwierigen, nicht alltäglichen Fällen. Vor der Anfertigung solcher Aufnahmen sollte stets eine konventionelle zweidimensionale Röntgendiagnostik erfolgen und nach dem ALARA-Prinzip (as low as reasonably achievable) individuell entschieden werden, ob eine DVT einen eindeutigen diagnostischen Mehrwert bieten und therapieentscheidende Informationen liefern kann.

Eine Einschränkung der hier gewonnenen Daten ist, dass die Aufnahmen in-vitro ohne umgebenden Knochen oder Weichgewebe gemacht wurden, jedoch sollte in der vorliegenden Studie zunächst die grundlegende Eignung beider Geräte im endodontischen Bereich getestet werden. Zudem ist hinsichtlich dosimetrischer und ethischer Gesichtspunkte eine klinische Studie in diesem Bereich nur schwer zu realisieren.

Zusammenfassend lässt sich festhalten, dass unter den Bedingungen der vorliegenden Studie beide untersuchten dentalen Volumentomografen, 3D Accuitomo 170 und Scanora 3D, sehr gut zur grundlegenden Darstellung feiner endodontischer Strukturen geeignet sind. Es konnten nur geringe, nicht signifikante Unterschiede zwischen beiden Geräten festgestellt werden. Dies ist auch interessant im Hinblick auf andere Geräte-spezifische Variablen, wie Anschaffungs- und Instandhaltungskosten, mögliche FOVs (fields of view) und damit Einsatzgebiete sowie zusätzliche Optionen wie Erstellung eines Orthopantomogramms.

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