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Role of endodontic treatment related signs for the forensic odontology practice considering real-life quality of comparable radiographs

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Abstract

Background. Real life quality of periapical radiographic images widely varies, while also periapical radiographs not always have been taken at the same angulation, especially in multirrooted tooth cases, which in turn potentially may limit the value of obtained information received during endodontic treatment for the further comparative dental identification.

Objective. To objectify possibility of using real-life quality periapical radiographs obtained during endodontic treatment for the comparative dental identification.

Materials and Methods. Research was organized in the form of cross-sectional hospital-based study. Copies of ten pairs of selected radiographs were distributed for the Set 1 (simulation of ante-mortem images), which contained 10 radiographs of before root canal treatment, and Set 2 (simulation of post-mortem images), which contained 10 radiographs of after endodontic interventions. Set 1 and Set 2 images were randomized, and structured via Google Form, and five teaching assistants from the Department of Restorative Dentistry were asked to match the images through provided Google Form.

Results. The range of 50-80% correct pre- and post-treatment images matching levels were registered among five operators. The mean correct matching level reached $68.0 \pm 7.2\%$. Experience within endodontics seems to be valuable regressor regarding outcome performance ($p < 0.05$), while additional Radiology specialization did not significantly improved performance level for matching pre- and post-treatment images ($p > 0.05$). Operator graded 5 out of 10 images pair as relatively easy to match, 2 images – as moderately difficult to match, and 3 images – as hard to match (Fig. 3), while their agreement on the obtained above-mentioned scores reached 0.8.

Conclusion. Significance of endodontics within forensic odontology field in most cases dictated by using the results of periapical radiology as evidences of ante-mortem origin, while also considering the fact of root canal morphology uniqueness and individualized endodontic treatment pattern consistency both ante- and post-mortem even under the influence of various disturbing factors. On the other hand identification role of endodontic signs may be diminished within the absence of proper quality radiographs, or when such were provided at critically different angulations, while also when endodontic-related evidences could not be supported by dental records.

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Introduction

The first publication with title mentioned dental identification provided considering endodontic-related evidences was authored by Weisman in 1996 [1, 2], nevertheless even earlier in 1990 Spyropoulos and Liakakoy described a case of positive dental identification based on endodontic treatment features and morphological specifics of maxillary right second premolar [3, 4, 5]. Nevertheless, during the period of 2005-2012 only three articles associated with conservative dentistry and endodontics were published within Journal of Forensic Odonto-Stomatology, as official periodical of International Organization for Forensic Odonto-Stomatology [6].

Provided survey revealed that only 6% of respondents had good awareness, while 32% had poor awareness regarding of role in endodontists in forensic odontology [7]. There is still a need in comprehensive evaluation regarding potential of endodontic-related signs being used as a part of evidence base during forensic odontology practice [8, 9].

Previous review on the topic dedicated to the endodontic images as a potential forensic identification evidences has been already provided [2], but not all aspects of endodontic-related signs and their role within forensic odontology practice were covered in available publication. Tooth root retain its primary configuration and relative integrity even under the high temperature exposure, which make it possible to use such for the identification of burnt victims [1, 10, 11]. Cross-sectional study demonstrated that obturated single root radiographic images characterized with high level of specificity and evidence significance for decision making within forensic dentistry practice and dental identification process [9]. However, real life quality of periapical radiographic images widely varies, while also periapical radiographs not always have been taken at the same angulation, especially in multirrooted tooth cases, which in turn potentially may limit the value of obtained information received during endodontic treatment for the further comparative dental identification.

Objective

To objectify possibility of using real-life quality periapical radiographs obtained during endodontic treatment for the comparative dental identification.

Materials and Methods

Research was organized in the form of cross-sectional hospital-based study. One hundred pairs of X-ray images obtained before and after endodontic treatment of patients were extracted from database of University Dental Clinic (Faculty of Dentistry, Uzhhorod National University, Ukraine). At the stage of primary cohort formation all radiographs were anonymized and labeled via numbering manner. No criteria of selection were applied to quality of images, because study was aimed at assessment of agreement rate of pre- and after-treatment radiographs considering real-life conditions, except that image should contain full contour of root part for targeted tooth. Among selected one hundred pairs of radiographs ten pairs were randomly chosen for the study group, and corresponding ten pairs were stored in the folder and used as a reference.

Copies of ten pairs of selected radiographs were distributed for the Set 1 (simulation of ante-mortem images), which contained 10 radiographs of before root canal treatment, and Set 2 (simulation of post-mortem images), which contained 10 radiographs of after endodontic interventions, as was described in previous study. Set 1 and Set 2 images were randomized, and structured via Google Form, and five teaching assistants from the Department of Restorative Dentistry (Faculty of Dentistry, Uzhhorod National University) were asked to match the images through provided Google Form. Five teaching assistants were assigned with the role of Operators, and their results of matching also were anonymized, and associated only with labeled number of each subject (Operator 1, Operator 2, Operator 3, Operator 4, Operator 5). Among five Operators such labeled with

numbers of 1, 4 and 5 had practical experience in endodontics in the range of 3-5 years, while Operator 2 was a post-graduate student with less than 1 year experience in endodontics, and Operator 3 had experience in endodontics with more than 5 years of practice, while also had specialization of radiologist.

Google Form was structured in the manner of ten questions, where each question included pre-treatment radiograph and 10 variants of answers in forms of ten post-treatment radiographs. Each question could be answered by only 1 correct answer, and each question was provided on the separate page with no possibility to return to previous question (Figure 1).

Questions 1. Following pre-treatment image matches with which of post-treatment image?

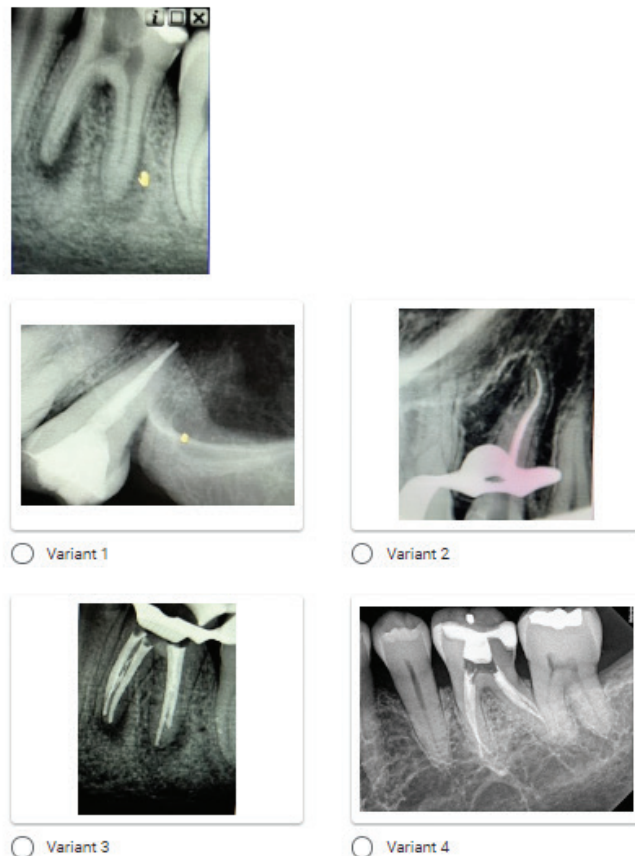


Figure 1. Screenshot of formulated Google Form with question and answers (variants) examples

Each pair of correct matching was counted as 10% from overall score, thus correct matching of all 10 images would give 100% result.

After completing the survey reference set of corresponding pairs were presented to operators, and they were asked to marked each pair from 1 to 10 by the difficulty for correct matching outcome (1-3 relatively easy to match, 4-6 – moderately difficult to match, 7-10 – hard to match).

Statistical Analysis

Data received after filling up the Google-forms further was converted into the xls-spreadsheet, and in such format, it was analyzed via Microsoft Excel 2019 software (Microsoft Office 2019, Microsoft Corp., USA) with the additional use of XLSTAT add-in (Addinsoft Inc., Long Island, NY, USA) for the inferential statistics. Inter-rater agreement registered among operators regarding difficulty to obtain correct matching after analysis of reference set was measured by Cohen's kappa.

Ethical aspects

Provided research fully corresponds to the relevant ethical standards, which was approved by Institutional Review Board of Faculty of Dentistry at Uzhhorod National University (Ukraine). Provided research represents a part of complex scientific research project of the Department of Restorative Dentistry at Uzhhorod National University (Ukraine). All the X-ray images used for the study were fully anonymized, providing no information for potential patient identity disclosure.

Results

The range of 50-80% correct pre- and post-treatment

images matching levels were registered among five operators (Figure 2).

Significant difference was noted between results obtained by Operator 3 and other Operators ($p < 0.05$), while performance registered among Operators 1, 2, 4 and 5 was analogical ($p > 0.05$). The mean correct matching level reached $68.0 \pm 7.2\%$. Experience within endodontics seems to be valuable regressor regarding outcome performance ($p < 0.05$), while additional Radiology specialization did not significantly improved performance level for matching pre- and post-treatment images ($p > 0.05$).

Operator graded 5 out of 10 images pair as relatively easy to match, 2 images – as moderately difficult to match (Fig. 3), and 3 images – as hard to match (Fig. 4), while their agreement on the obtained above-mentioned scores reached 0.8.

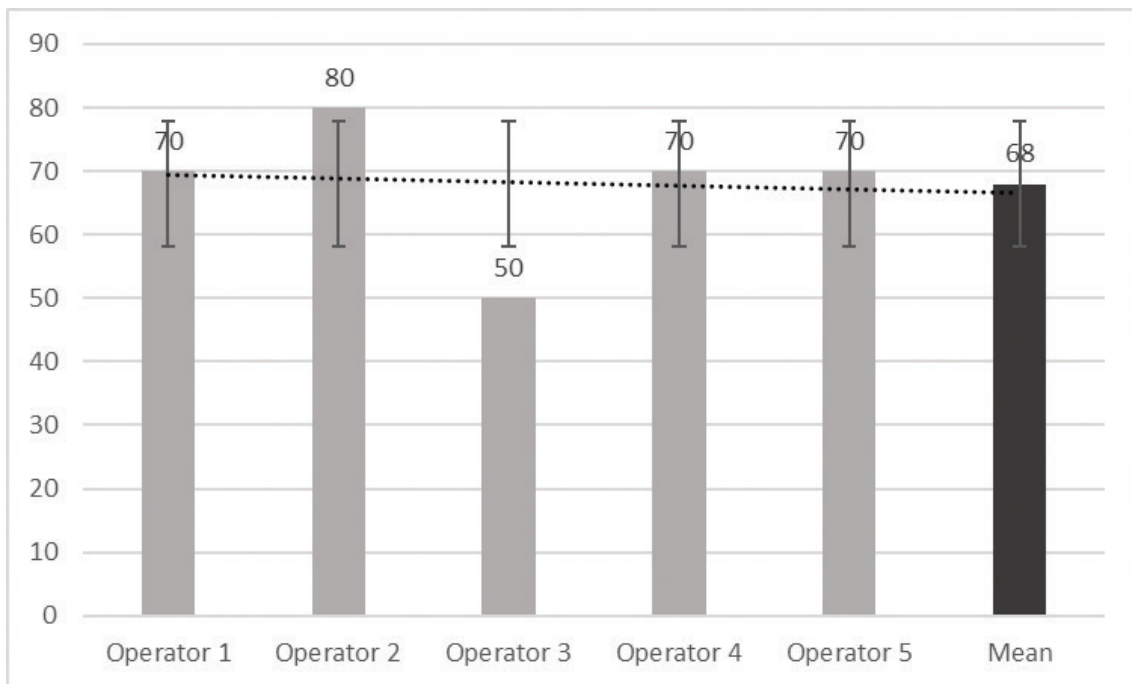


Figure 2. Distribution of correct matching in means of percentage among five operators

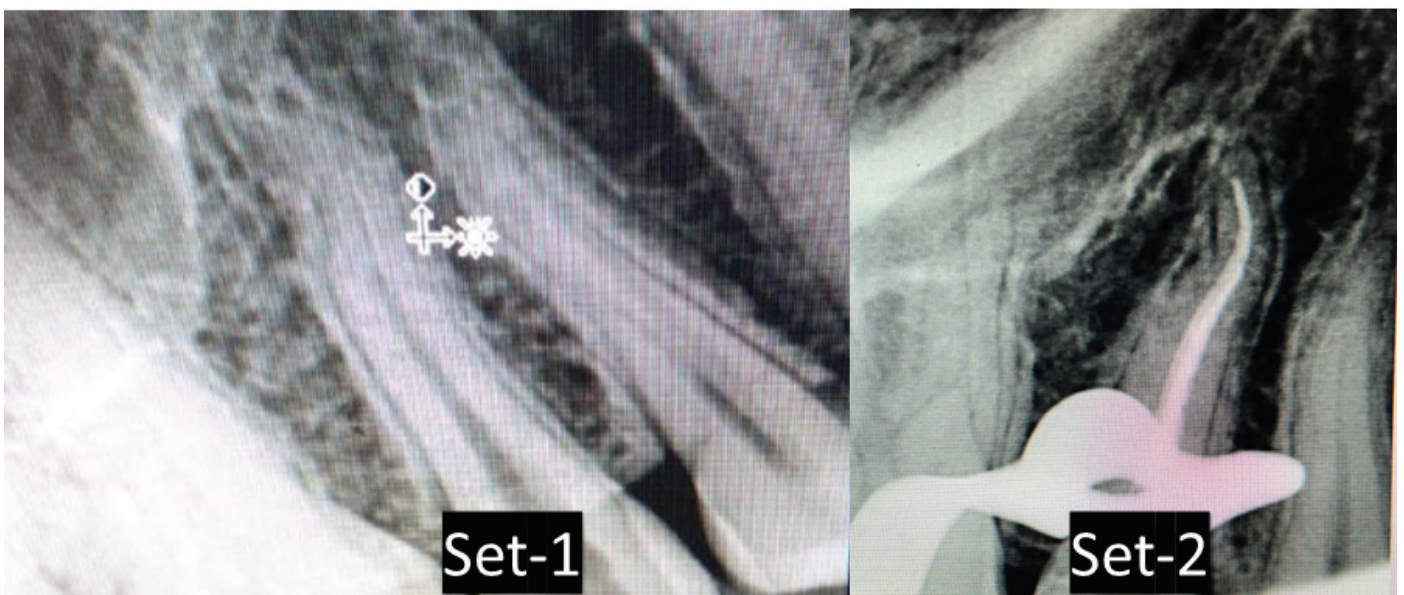


Figure 3. Example of images pair, which operators graded as moderately difficult to match

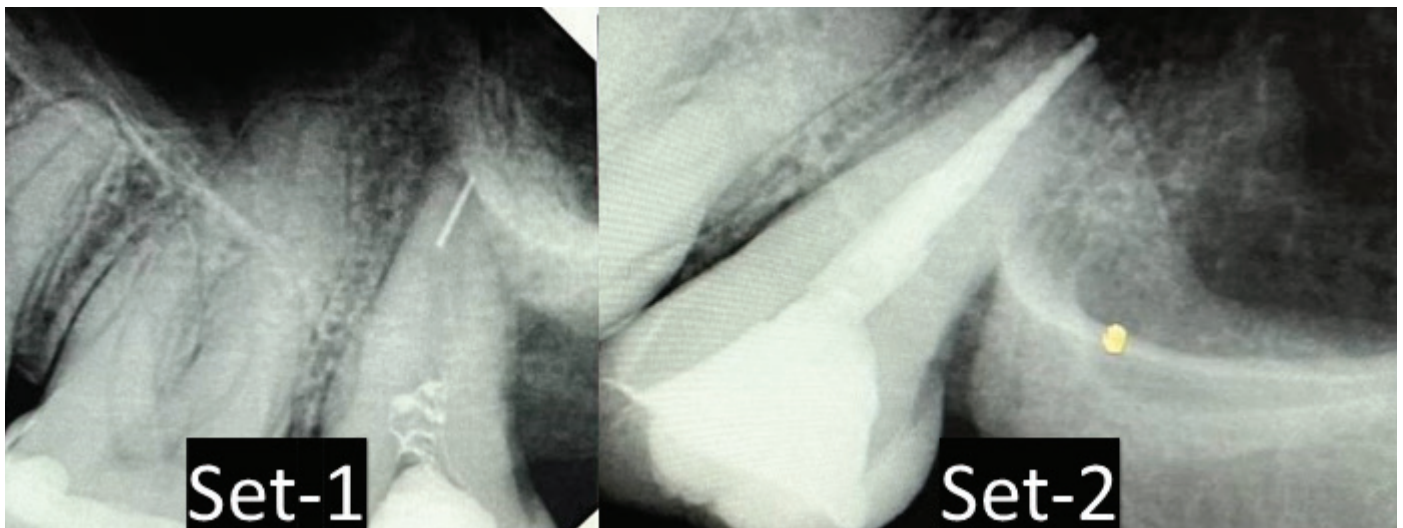


Figure 3. Example of images pair, which operators graded as hard to match

Discussion

Endodontics treatment records and materials used during endodontic interventions could serve as significant identifiers within forensic odontology practice. Jethi et al. systematized next endodontic-related features which may be considered during identification process [12]:

1. Diversity within root morphology and anatomy.
2. Identification of root filling material.
3. Identification of post-endo restorations.
4. Endodontic morphology evaluation using tomographic approaches for age estimation purposes.
5. Application of periapical images as potential source of evidences.
6. Complications during endodontic treatment which may be categorized as personalized identification features [12].

Endodontic treatment results presented by the periapical radiographs seems to be highly valuable for the forensic odontology practice, and consistency of such argued by the number of experimental studies. It was previously established that 800 °C exposure causing white appearance of tooth root, which may be used as criteria for assessing conditions of burning. 1000 °C exposure caused greyish white color of the roots, while they were keeping relatively integrated conditions with deep fractured lines [13]. Results of the in-vitro study has revealed that even under the 800 °C exposure root portion of tooth in contrast to crown portion remained enough intact for being used for the analysis even though vertical crack present along root were present, while also gutta-percha could be identified within root canal as a result of previous endodontic treatment, which was also proved by CBCT scan analysis [11]. Other study also approve root crack formation when tooth was exposed to 800 °C temperature [14]. Root cementum characterized with loss of brightness at 200 °C exposure, turns into brown colored substance at 400 °C exposure, and becomes whitish starting at 800 °C exposure, while dentin is getting brownish hue at 200 °C, blackish hue – at 400 °C, grayish – at 600 °C, with black streaks – at 800 °C, and whitish – at 1000 °C [15]. In Savio et al. study it was revealed that till 600°C there were no visible changes within root, but at 600°C fissure within root started to develop, while it was deepening into dentin up to reaching 1100°C [16].

Fernandes A.P. et al. concluded that burial conditions do not significantly affects optical density of root canal filling materials compare to ante-mortem situation, but simulation of drowning cause of death has an impact on above-mentioned parameter [17]. Specific trend of apical portion of root canal filling having lower optical density compared to middle and cervical ones was noted, while middle and cervical portions radiopacity decrease pattern was noted compared to ante-mortem situation [17]. Generally it

may be resumed that roots tends to preserve unique morphological information for the longer period of time and by better retention quality compared to the crown part of tooth. Such morphology preservation phenomenon together with uniqueness of endodontic treatment results argument the significance of endodontic features for the forensic odontology practice [4, 5].

Zinc-oxide eugenol (ZOE) as a root filling material becomes whitish hue during 400 °C exposure, chalk with whitish hue during 800 °C exposure, and not possible to differentiate with dentine during more than 1000 °C, while gutta percha may show black colored and white strikes during 400 °C exposure and is totally incinerated during 1000°C exposure [15]. “Honeycomb” effect caused by endodontic filling materials softening and melting (fluidification) could be observed at the temperature of 600°C and above, even though recognition of root canal filling remains radiovisible even under tooth exposure to 1100°C [16]. Other researches demonstrated that when temperature rises to 800°C and over intracanal fillings become hardly recognizable. It should be noted that elemental analysis of different root filling materials after incineration revealed presence of phosphorus and calcium which was not typical for pre-incineration samples, and such outcome may be cause by heat-induced changes within surrounding dentine [18]. Review of Bansode et al. demonstrated that endodontic filling materials by the radiopaque criteria may be differentiated on radiopaque, slightly radiopaque, and radiolucent, even though such cauterization is lacking quantitative argumentation, and each case of obturation even if provided with the same material may differ by optical density represented on radiographs [19].

Elemental fingerprints may be established out of several root filling materials, such as Gray ProRoot MTA, AH26, Epiphany and other, while also out of stainless steel and nickel-titanium files with the usage of scanning electron microscopy (SEM)/energy dispersive X ray analysis methods, or other more portable-adapted approaches (X ray fluorescence spectrometry) [17]. Elemental fingerprints database formed on the findings of Bonavilla et al. may be further use within forensic odontology practice for identification of different root filling materials and endodontic files [17]. Broken endodontic instrument also may be served as unique evidence during dental identification, since it consists of complex individualized characteristics (localization of broken instrument within specific root canal, design of the broken file, length of fractured fragment). But again cases of broken endodontic instrument should be well recorded both radiologically and descriptively at the patients dental form.

Practice of successful murder victims identification based on the available endodontic radiographs has been previously described within the literature [5]. Rare case of extruded endodontic material used as identifier in person with maxillary edentulism

which was verified both at ante- and post-mortem radiographs was described by Berketa and colleagues [20], and such outcome raises the significance and potential of endodontic treatment results being adequately used within forensic dental identification in cases where by the first view no or really small dental evidences may be received [10]. Authors also mentioned that due to the fact that radiographs were made within various angulations and by different methodologies it was not possible to provide proper metric analysis, but comparative approach may be implemented, which also is of high value in cases with limited available data [20]. Analogical outcome could also be made from our study, where variations within angulations caused complications for the correct image matching.

Awareness regarding tooth root anatomical variations could support process of dental identification and enhance potential for positive identification outcome, while in most cases such features were registered by the use of CBCT scans [21]. Endodontic features also have a great potential during identification of human's remains or in cases of identification during multiple fragmentation of skull [22].

Computer-aided identification based on root morphology and anatomical pattern shown promising results for being used within routine forensic odontology practice by not just enhancing identification process itself but giving a chance to quantify the outcomes of comparison [23].

It is beneficial to use subtraction imaging approach while also superimposition method to demonstrate similarities between ante-mortem and post-mortem periapical radiographs [24]. Nevertheless, different projections, angulations and positioning parameters of X-ray images obtained during planning or after provision of endodontic treatment may cause problems during their comparison and metric-based assessment [2, 24, 25].

In Khalid-Khalid's study it was shown that single rooted endodontically treated teeth characterized with high potential of being correctly identified within experimental conditions of ante-mortem and post-mortem radiographs sets comparison, reaching the mean correct score of comparison $9.78 + 0.53$ out of 10 [9]. Results of this study also demonstrated that general dentists shown higher rate of full identification of endodontically-treated teeth (100%), while specialists – the lowest one (71.4%) [9]. In our study mean rate of correct matching reached $68.0 \pm 7.2\%$, which was lower than in Khalid-Khalid's study, but such difference could be argued by the fact that in our study we analyze radiographs of single rooted, while also of multi-rooted teeth. Also, Khalid-Khalid's study demonstrated that general dentists had the highest rate of identification [9], while in our study experience within endodontic practice seems to be valuable regressor for the positive identification.

It is important to highlight that significance of endodontic treatment results and of tooth roots' morphology itself could be realized only under condition of proper quality radiographs being available and correct treatment record being approachable either for metrical, or at least for qualitatively comparative analysis [4]. Responsibility of endodontists is of not only providing proper quality endodontic treatment, but guaranteeing corresponding recording of all the provided manipulations, their outcomes and individual anatomical features, while concisely understanding the role of such in cases of needed forensic identification.

Such endodontic-related parameters as different pulp-tooth ratio could be effectively used for the age estimation practice, effectiveness of which have been widely described within adult and pediatric population cohorts during analysis of planimetric, while also of volumetric images [26, 27, 28].

Significance of root canal as a source for potential DNA extraction after provided endodontic treatment remains subject of discussion, but for sure possibility of such is lowering after root canal obturation. Only one study have demonstrated the chance of DNA extraction from organic remnants available after pulp extirpation in 3 months period, on the other hand dentin and cementum also may be the potential sources of DNA [2, 25, 29, 30]. Based on 10 samples study DNA quantity in the range of 0.355–39.42 ng/ml may be received from STR-profiled endodontically treated teeth [31].

Preservation of avulsed tooth also potentially may be helpful for DNA material extraction [12].

Possible outcomes of dental identification based on endodontic-related sign which may be compared between ante- and post-mortem datasets include following: identity established (full concordance, no unexplained discrepancies present); identity consistent (full concordance of available evidences, but deficient quantity or quality of compared features to fully exclude all doubts); identity possible; insufficient information available; exclusion [24, 32]. In present study 50% of images were categorized as easy to match, so they may be used for identity established criteria, but other 50% of images may fall into different categories of identity consistent, identity possible, insufficient information available, or exclusion. Such ratio could be used for the argumentation for providing further in-detail studies dedicated to the quantification of peri-apical radiographs impact within forensic odontology practice, considering their real-life quality and adherence of the radiographs both for the single rooted, while also for multirouted teeth.

Limitations of present study associated with relatively small study sample of images used for matching, while also no quality criteria for selected images were applied. On the other hand, drawback of small study sample was partially overcome by the randomized extraction of 10 image pairs from 100 previously selected. Also approach with no image quality criteria applied helped to demonstrated real-life conditions, which specialists are facing while providing comparison of radiographs obtained before and after endodontic treatment. Another limitation is related to the fact that background of operators was not detailed, but such limitation was due only to pilot study design, while in further studies such information would be taken into consideration.

Conclusion

Significance of endodontics within forensic odontology field in most cases dictated by using the results of periapical radiology as evidences of ante-mortem origin, while also by considering the fact of root canal morphology uniqueness and individualized endodontic treatment pattern consistency both ante- and post-mortem even under the influence of various disturbing factors. On the other hand identification role of endodontic signs may be diminished within the absence of proper quality radiographs, or when such were provided at critically different angulations, while also when endodontic-related evidences could not be supported by dental records. Factual quality of periapical radiographs obtained during endodontic treatment support potential of positive identification in up to $68.0 \pm 7.2\%$ cases, while only 50% of analyzed cases could be interpreted with established consistent identity.

Conflict of Interest

Authors do not have any potential conflict of interests that may influence the decision to publish this article.

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Роль ознак, пов'язаних з ендодонтичним лікуванням, у практиці судової стоматології з врахуванням фактичної якості порівнюваних рентгенограм

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A – розробка концепції та дизайну дослідження, B – збір та або систематизація даних дослідження, C – аналіз та тлумачення даних дослідження, D – написання публікації, E – критичне доопрацювання тексту публікації, F – остаточне затвердження.

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Анотація

Вступ. Фактична якість периапікальних рентгенографічних зображень є доволі варіативною, крім того рентгенограми не завжди вдається отримати під однаковим кутом позиціонування, особливо у випадках обстеження багатокорневих зубів, що в своїй сукупності може обмежити значущість інформації, отриманої в ході проведення ендодонтичного лікування, для порівняльної дентальної ідентифікації.

Мета. Об'єктивізувати можливість використання периапікальних рентгенограм фактичної якості, які були отримані під час ендодонтичного лікування, для порівняльної дентальної ідентифікації.

Матеріали та методи. Дослідження було організовано у формі крос-секційного і проведено на базі клініки. Копії десяти пар відібраних рентгенограм були розподілені між набором даних 1 (імітація набору прижиттєвих даних), який містив 10 рентгенограм до лікування корневих каналів, і набором даних 2 (імітація набору посмертних даних), який містив 10 рентгенограм після ендодонтичного втручання. Зображення у структурі наборів даних 1 і 2 були рандомізовані та структуровані у форматі Google-форми; п'ять асистентів кафедри терапевтичної стоматології проводили зіставлення зображень у форматі відповідей на питання сформульованої Google-форми.

Результати. Діапазон рівнів коректного зіставлення відповідних рентгенограм до та після лікування, зареєстрований серед п'яти операторів, варіював в межах 50-80%. Середній рівень коректного співставлення зображень складав $68,0 \pm 7,2\%$. Тривалість досвіду проведення ендодонтичного лікування виявилася значущим регресором по відношенню до ефективності результатів співставлення рентгенограм ($p < 0,05$), в той час як наявність додаткової спеціалізації з радіології суттєво не покращила результати порівняння та коректного співставлення зображень до та після лікування ($p > 0,05$). Оператори оцінили 5 із 10 пар зображень як відносно легкі для зіставлення, 2 пари зображень – як помірно складні для зіставлення, та 3 пари зображень – як такі, які важко було коректно співставити, при цьому коефіцієнт узгодженості вищезазначених оцінок сягав 0,8.

Висновки. Значущість ендодонтії для судової одонтології в більшості випадків продиктована використанням результатів периапікальної рентгенографії як доказів, що можуть бути отримані прижиттєво, а також унікальністю морфології корневих каналів та збереженням

цілісності індивідуалізованого патерну результатів ендодонтичного лікування прижиттєво та помертно навіть під впливом різних факторів. З іншого боку, ідентифікаційна значущість ендодонтичних ознак може бути зменшена по причині відсутності рентгенограм належної якості, або ж в умовах, коли такі були отримані під критично різними кутами позиціонування, і у випадках, коли докази пов'язані із ендодонтичним лікуванням не можуть бути підтверджені відповідними записами у стоматологічній документації пацієнта.

Заява про конфлікт інтересів

Цим автори підтверджують відсутність зв'язку з будь-якою організацією чи компанією, яка може мати будь-який фінансовий або нефінансовий інтерес до матеріалів дослідження, розглянутих в цій статті.

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Заява про фінансування

Не було отримано жодного фінансування для допомоги в підготовці та проведенні цього дослідження, а також для написання цієї статті.