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Determination of Working Length in Endodontics: Epidemiological Survey of Dentists in the Private Sector in Casablanca

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Abstract

Introduction: The success of endodontic treatment relies on the respect of a strict but very well codified protocol. Thus, the determination of working length, a key factor in the success of endodontic therapy, remains one of the most significant challenges and a constant concern for practitioners. Several difficulties arise at this stage, both anatomical in terms of the limit to be adopted, and technical in regards to the diversity of methods for length determination. However, no method used on its own has demonstrated indisputable reliability.

Materials and Methods: This work is part of a descriptive cross-sectional epidemiological study conducted among 320 dentists in the private sector in the Casablanca Region over a period of 6 months.

Results: The apical limit most selected by dentists was the apical foramen (AF) (52.4%), followed by the apical constriction (AC) (31.8%). As for working length determination methods, Conventional Radiographs were found to be most used by Moroccan Dentists (63.4%). Practitioners using Electronic Apex Locators (EALs) (31%) felt that it did not consistently give accurate measurements (70%) and could not replace radiography (85.7%). It should be noted that 37% of dentists were not satisfied with their determination of working length. This dissatisfaction followed some of the difficulties they encountered at this stage. These difficulties could either be technical when taking radiographs (30.9%), related to the manipulation of Electronic Apex Locators (11.1%) or could be anatomical challenges related to endodontic anatomy (57.8%).

Discussion: It has been found that the ideal limit of the endodontic preparation is the dentin cemental junction (DCJ) and/or the apical constriction (AC). Whereas for cases where this area is damaged, then the limit of the preparation should be 0.5 mm below the apical foramen. Even today, radiography is a must in endodontics. However, clinical and laboratory studies have shown that the determination of the working length with an apex locator is more accurate and reliable than radiographic determination. It is faster and does not expose to ionizing radiation. Therefore, the method for determining the working length must be accurate, easy, and time efficient. It must also be comfortable for the practitioner and the patient and reasonably priced. No standalone method can satisfy all of these criteria. A combination of knowledge of apical anatomy, careful use of radiographs, and correct use of EALs can provide reliable results.

Keywords: *Endodontic Treatment; Working Length; Electronic Apex Locators; Apical Constriction; Apical Foramen*

Abbreviations

AC: Apical Constriction; AF: Apical Foramen; EALs: Electronic Apex Locators; DCJ: Dentinocemental Junction; FDC: Faculty of Dentistry of Casablanca; FDR: Faculty of Dentistry of Rabat; MD: Mesiodistal; BL: Buccolingual

Introduction

Endodontics is the discipline of dentistry that encompasses the prevention, diagnosis, and treatment of pulpal and periapical diseases. Its main objective is teeth preservation, after restoration to an ideal state of health that is biologically, clinically, and radiologically controllable. Its success depends on the respect of a strict but very well codified protocol. If we put aside the difficulty of the diagnosis and the technicalities of endodontic procedures, it is theoretically easy to respect this protocol. It implies the realization of the access route, the setting up of the operating field, the catheterization, the determination of the working length, the canal shaping, the irrigation, and the obturation of the root canal system as well as the coronal obturation. Each of these steps is well codified except for the determination of the working length. Indeed, several challenges are encountered during this step, both anatomical and technical [1].

The major problem faced by practitioners is to bring the shaping instruments, disinfection solutions, and obturation materials to the limits of the endodontium. Thus, a variety of techniques are needed to measure working length. This measurement will be essential throughout the treatment to guide the instruments and obturation materials [1]. Inadequate endodontic treatment does not eliminate bacteria from the root canal system and leads to the development or persistence of periradicular inflammatory lesions of endodontic origin. The prevalence of which varies from 30% to 75% depending on the country and the population studied [2]. This is mainly due to the incorrect determination of the working length [2]. Hence, the determination of the working length, a key factor in the success of endodontic therapy, remains one of the most significant challenges and a constant concern for practitioners despite the use of several means for its accurate determination. The choice of the apical preparation limit is one of the most important and controversial issues in endodontics. Mainly due to the complexity of the apical region. The different nature tissues overlap results in different opinions as to which limit should be adopted.

Until the late 70s, the determination of the working length was primarily based on radiographic interpretation. The latter has certain limits. The advent of apex locators ushered in a new era for working length measurement. Nevertheless, the accuracy of these devices has been questioned.

As there are several methods for determining the working length, none are indisputably reliable. Therefore, it is necessary to use various techniques during the same treatment [3].

This is why we suggested carrying out a survey aimed at dentists in the private sector in the Casablanca Region. Its main objective is to describe the different means and methods used by dentists during the determination of the working length.

Materials and Methods

To carry out this study, we conducted a descriptive cross-sectional survey that targeted dentists operating in the Casablanca Region throughout the year of 2019-2020. Based on the list of dentists provided by the Moroccan National Board of Dentists, we performed a simple random sampling.

Inclusion and exclusion criteria

The sample was selected according to the following inclusion criteria:

- Dentists practicing in the private sector in Casablanca.
- Dentists practicing endodontics in their private offices.

Excluded from our sample

- Dentists outside Casablanca.
- Retired Dentists.

In order to collect the necessary data for this study, we developed a questionnaire including 19 variables defined as follows

Socio-demographic data of dentists

- Gender, duration of practice, the origin of degree, continuous education in endodontics, the working length determination method taught during university training.

Knowledge of endodontic working length determination

- Importance of working length determination.
- Location of the apical preparation limit.
- Stability of the apical preparation limit.
- Change in the situation of the apical preparation limit due to the existence of apical pathology.

Daily practice of dentists regarding the determination of the working length

- Frequency of working length determination during endodontic treatment.
- Situations that prompt dentists to accurately determine the working length: at-risk patient, intraoperative accident, root canal retreatments.
- Methods used by dentists to determine the working length in daily practice; empirical method, radiographic method, or electronic method.
- Use of the operating field (dental dam) by dentists when determining the working length.
- Dentist's use of electronic apex locators for working length determination.
- Dentists' opinion on the reliability of the electronic method compared to the radiographic method in determining the working length.
- Dentist's satisfaction with the working length determination they make during endodontic treatment.
- Difficulties encountered by dentists during working length determination in daily practice.

Statistical analysis

- The study data were entered and analyzed using SPSS software at the Laboratory of Epidemiology and Biostatistics of the Faculty of Dentistry of Casablanca.
- The qualitative variables were described by their numbers and percentages.
- The quantitative variables were described by their numbers, means, and standard deviation.

Results

Out of 1625 dentists, 320 were selected by random draw.

Of the 320 questionnaires distributed, 47 were excluded from the study because they were not completed. Our study, therefore, focused on 273 questionnaires.

Variables	Headcount	Percentage %
Gender		
Female	150	54,9
Male	123	45,1
Duration of practice		
0-5 years	50	18,3
6-10 years	102	37,4
11-20 years	98	35,9
More than 20 years	23	8,4
Origin of degree		
FDC	220	80,6
FDR	20	7,3
Other	33	12,1
Continuous education in endodontics		
University Diploma	12	4,4
Graduate certification	24	8,8
Private Continuous Education	104	38,1
Other	7	2,6
None	131	48
Location of training		
Morocco	126	88,7
Abroad	16	11,3

Table 1: *General characteristics of the dentists in the study.*

Description of the sample (Table 1):

The dentists included in our study:

- Were female with a percentage of 54.9%.
- Had a duration of practice ranging from 6 - 10 years, 11 - 20 years for 37.4% and 35.9% respectively.
- 80.6% of practitioners were trained at the Faculty of Dentistry of Casablanca (FDC).

Variables	Headcount	Percentage %
Importance of working length determination.		
Fundamental	263	96,3
Optional	9	3,3
Location of the apical preparation limit.		
Apical Foramen	140	52,4
Apicale Constriction	85	31,8
Radiographic Apex	42	15,7
Other	0	0
Stability of the chosen apical preparation limit.		
Yes	75	27,5
No	198	72,5
Change in the situation of the apical preparation margin due to the existence of apical pathology.		
Yes	248	90,8
No	25	9,2

Table 2: *Dentists' knowledge of working length determination.*

- 48% have not followed any continuing education in endodontics while 38.1% have enrolled in continuing education.

Dentists' knowledge of working length determination (Table 2):

- 96.3% or 263 of the practitioners considered the working length determination step to be fundamental to the success of root canal treatments.
- The apical preparation limit most chosen by the dentists was the apical foramen (52.4%), the apical constriction came in second place (31.8%), and then the radiographic apex with a percentage of 15.7%.
- According to 72.5% of dentists, the apical preparation limit is not stable over time and could be affected by an apical pathology.

Variables	Headcount	Percentage %
Frequency of Working Length determination		
Once preoperatively	3	1,1
Once intraoperatively	87	31,9
Twice intraoperatively	133	48,7
Three or more times throughout the endodontic treatment	50	18,3
Situation prompting dentists to accurately determine working length		
Typ of method		
Empirical	4	1,5
Radiographic	173	63,4
Electronic	84	30,8
Radiographic and electronic	12	4,4
Radiographic method		
Conventional Radiography	39	22,3
Digital Radiography	136	77,7
Use of the dental dam is mandatory while determining the working length		
Yes	84	30,8
No	189	69,2
Use of EALs for working length determination is essential		
Yes	142	52
No	131	48
EALs always give accurate measurements		
Yes	51	30
No	119	70
The reliability of EALs makes the radiographic method unnecessary		
Yes	39	14,3
No	234	85,7
Satisfaction of Dentists' working length determination		
Yes	172	63
No	101	37
Difficulties related to root canal anatomy	88	57,9
Difficulties taking radiographs	47	30,9
Difficulties manipulating EALs	17	11,2

Table 3: *Daily practice of dentists during working determination.*

Daily practice of dentists during working length determination (Table 3):

The main results are as follows:

- During endodontic treatment, 69.2% of the dentists did not use the dental dam as an operating field. They justified their choice for the following reasons: discomfort for the patient and the practitioner, inappropriate for daily use.
- 48.7% of dentists evaluated the working length 2 or more times intraoperatively.
- 78.2% assessed the working length accurately for each endodontic treatment, while 11.4% determined the working length only in cases of intraoperative accidents.
- The most used method for determining the working length was radiography (63.4%), whether conventional (22.3%) or digital (77.7%).

Dentists using electronic apex locators (31%) think

1. That they did not always give accurate measurements (70%).
2. That they could not replace radiography (85.7%).
3. That thseir use was not essential for the determination of the working length (48%).

In their daily practice, 37% of the dentists were not satisfied with their working length determination. This dissatisfaction was due to certain difficulties they encountered during this step. These difficulties could be technical when taking radiographs (30.9%) or when handling the electronic apex locators (11.2%) or could be anatomical difficulties related to the root canal anatomy (57.9%).

Discussion

Discussion of Materials and Methods

In order to be able to assess our study, two essential points must be brought to light

- The representativeness of the population studied: the sample frame and the draw were respected in this survey. The results obtained are specific to the sample studied.
- The reliability of the information collected depends on several factors, including the degree of sincerity of the dentists, the accuracy of the measurement scales, and the validity of the results obtained. The results of our study are considered valid assuming an acceptable level of reliability of most of the information obtained and considering that the procedure, as well as the statistical and computer means used, are quite accurate and reliable.

Discussion of Results

Profile of dentists

The study population of dentists practicing in the city of Casablanca is distributed in a comparable way between females and males with a slight female predominance (54.9%). In an epidemiological study on the means of determining working length used by dentists in the private sector (2005), in a sample of 119 physicians practicing in the Casablanca region, the male gender was 1.6 times more preva-

lent than the female gender [4]. In 2018, an epidemiological study on the state of knowledge of dentists on antibiotic resistance that was conducted among private-sector physicians in the Casablanca region showed a female predominance of 74.6% [5]. In 2019, in a study conducted among students of the Faculty of Dentistry in Rabat that focused on the evolution of knowledge, attitudes, and practices in oral health among dental students, out of a randomly selected sample of 150 students, 67.7% were female [6].

The increase in the proportion of women in dentistry is arising across the world. Indeed, women have proven their competence in the field of dentistry, which is why in a 2015 survey of patients visiting private sector dentists in Australia, 64% of patients responded that they prefer to be treated by female dentists [7].

Undergraduate dental training leads to a diploma, which allows for practice. This training is based on theoretical and practical teaching, the information of which is general and can in no way constitute permanent knowledge. Therefore, as soon as the graduate leaves the faculty, a substantial "knowledge" source stops, and the aging of the knowledge begins, all the more so as the methods of diagnosis and treatment concerning common pathologies evolve. Continuing education is therefore essential in all fields, and more particularly in the medical field where fundamental and applied research is continuously changing our diagnostic and therapeutic concepts.

In Morocco, continuing dental education is still poorly organized and not regulated by law. To achieve its full designated purpose, it must be based on a forward-looking approach integrating a reflection on the foreseeable, conceivable, or desirable developments in dental practice in all its implications. It will take into account the inevitable changes in initial training [8].

Endodontic treatment is a real challenge in dentists' daily practice. Hence the importance of using and maintaining postgraduate training, especially with the continuous medical and technological evolution in this field. 52% of the dentists in our population are enrolled in endodontics continuing education courses. In a previous study conducted in Casablanca in 2005 on working length determination, the investigators found that among the 119 dentists surveyed, 110 doctors, or 92.4%, had no postgraduate training in endodontics.

In order to assess the continuing education needs of dentists in Morocco, a national survey of both private and public sector practitioners was conducted in 2006 [8]. Among the results collected: 94.2% defined continuing education as an update of knowledge and that it would complement the dentists' initial training. 88.6% had already attended various national congresses. 42.6% had attended foreign congresses, mainly the ADF congress. The investigators also noted that 82.2% of dentists want continuing education to be mandatory and 30.7% think that it should begin after one year of practice [8]. Undoubtedly, Moroccan dentists are aware of the need for continuing medical education. This confirms the concern shared by all to be able to maintain their competence to ensure the quality of care. Its obligation became legal in France in 1996, before being reformed by the law of 4 March 2002 [9]. Since 2003, it has become mandatory in Quebec for investigation and under the responsibility of the profession itself. This had already resulted in the creation of a body of inspectors -themselves practitioners- in charge of controlling dental offices, practices, respect of protocols, and standards under the aegis of the Board of Dentists of Québec "Ordre des Dentistes du Québec" (ODQ) [10]. In line with these results, dentists are concerned about their continuing medical education and the quality of care they want to provide to their patients through this latter, which must now be regulated. It is one of the most important issues affecting the profession as it is an integral element of the ethical responsibility of every practitioner. Mandatory continuing education should be a priority in our country. It will allow dentists to update their knowledge to ensure a high quality of care, especially as medical information evolves becoming obsolete after five years.

Dentists' knowledge of working length determination

Importance of working length determination for dentists

In our study population, 96.3% of the dentists considered that the working length determination step is a fundamental stage of endodontic treatments. However, 3.3% so 9 dentists thought of this step as optional. The determination of the working length must be a

constant concern throughout the treatment from preoperative to postoperative radiographs. The variety of instruments used and the repetition of measurement taking ensure that the working length is accurately determined to conduct a successful endodontic treatment. Indeed, the determination of the working length is a key step in endodontics. It allows us to operate strictly in the endodontic region while respecting the periapical structures during the shaping and root canal filling phases. Chugal and al were interested in the follow-up and success rate of endodontic treatments of 200 teeth (441 roots) after four and a half years. They describe in their study, that for infected teeth, working length determination is a factor that significantly influences the success rate. Thus, one millimeter of lost working length can correspond to several millimeters of unobturated root canal system causing endodontic failure [11].

Choice of the apical limit preparation

The choice of the apical limit is one of the most contentious topics in endodontics. The concept of limiting the preparation to the root canal space without over instrumentation is universally accepted. Yet, an ongoing controversy regarding the appropriate limit is to be noted.

Many authors, including Kuttler (1955) and Harran Ponce (2003), have suggested limiting endodontic maneuvers to the dentin cemental junction since this is where the endodontium ends and the periodontium begins [12,13]. Therefore, shaping should be stopped at this level and the cementum cone should be left free to allow cemental repair after endodontic treatment. Indeed, it is considered the ideal limit of preparation for most authors. However, it is a histological structure that cannot be determined clinically. In addition, the DCJ is irregular and the extension of cementum into the canal varies significantly [14]. The apical construction could match the DCJ or be very close to it, therefore, it seems to be an ideal limit intended to serve as a matrix to support the obturation material and to avoid overfilling.

On another hand, Gordon and Chandler (2004) advocate for an apical limit of 1 to 2 mm to the radiographic apex [16]. Trope and Debelian (2005) reported that the highest success rates following endodontic treatments would be obtained for vital teeth with an apical margin between 1 and 2 mm from the radiographic apex [17].

In our study, the apical preparation margin most chosen by dentists was the apical foramen (52.4%), with apical constriction coming in second place (31.8%), while the radiographic apex remained the margin chosen by 15.7% of the practitioners in our population. According to Laurichess, "the problem of the apical limit of root canal preparations is one of the most important and complex" [18]. In a 2006 literature review by Dominique Martin and Sandrine Dahan, the authors concluded that ideally, treatment should end at the endo-periodontal margin, i.e., the dentinocemental junction. This is the ideal theoretical limit for root canal preparation [19,20]. Unfortunately, this limit is only detectable histologically. In 1955, Kuttler performed an anatomical reference study in which he showed that the DCJ is on average located 0.5 mm from the anatomical apex. Some authors then suggested working at 0.5 mm from the apex. In the same year, Kuttler performed a second morphometric study of the apical area in order to improve endodontic techniques and to specify the particular anatomy of this terminal portion of the canals. He examined 268 teeth under the light microscope, i.e. 402 apexes divided into 2 groups: 18 - 25 years and over 55 years. According to his work, the maximum narrowing of the canal, i.e. apical constriction, is most often located at the level of the DCJ (73%). Kuttler, therefore, concluded from his studies that the apical limit where the endodontic treatment should end is the apical constriction. However, according to Langeland, the histological structure of the DCJ is very irregular and does not coincide at all with the apical constriction. Cementum reaches the same level on all canal walls only in 5% of cases [21]. Furthermore, DCJ cannot be localized clinically. It is only a separation site between two tissues within the canal. According to a study by Dummer, the traditional concept of a single apical constriction mentioned by Kuttler exists in less than 50% of the teeth observed. More often the canal walls are parallel, tapered, or have multiple constrictions. The classical apical anatomy described by Kuttler thus appears to be more conceptual than real [22].

The foramen represents the apical preparation limit most chosen by the dentists in our study, followed by the apical constriction, which is chosen by 31.8% of our population. Some authors such as Dummer advocate the apical foramen as the most reliable preparation

margin since it is the boundary between the tooth and the periodontal tissue and since it is clinically detectable. This may justify that the foramen represents the most chosen apical preparation margin by the practitioners in our study. On the other hand, the literature review shows that the apical constriction regularly coincides with or is close to the DCJ, and is most often located 0.5 to 1 mm from the apex. It constitutes the maximum narrowing of the root canal and represents a natural barrier that should not be crossed and therefore a barrier where the root canal preparation and obturation should stop [22]. This may explain the preference of 31.8% of dentists in our population.

For many years, it has been proven that the ideal limit of endodontic preparation is the JCD and/or apical constriction. It is recognized that the working length should be assessed by receding 0.5 mm to the actual tooth length. In cases where the DCJ and apical constriction are absent or altered, the preparation limit should be chosen slightly distanced from the apical foramen, at about 0.5 mm or more. The practitioner should make a stop cone, and the preparation should form a dentin base, a kind of artificial constriction, in order to ideally accommodate the filling [22]. It is recommended to limit the root canal preparation to the apical constriction, except in cases where this area is altered, in which case the preparation limit should stop 0.5 mm away from the apical foramen.

Daily practice of dentists during working length determination

According to our study, 63.4% of practitioners only use the radiographic method for working length determination. Conventional radiography is still a widely used technique for working length determination in endodontics. This technique requires preoperative, intraoperative, and postoperative radiographs. The first preoperative radiograph is essential in endodontics to determine the anatomy of the root canal system, the number and curvature of the roots, the presence or absence of disease, and to serve as an initial guide for determining the working length with millimeter accuracy [23]. Ingle, in 1957, suggested that the distance from the radiographic apex to a coronal landmark should be measured on the preoperative radiograph [24]. The radiographic apex or radiographic dome is the image of the anatomical root tip as it appears on the radiographic image. It may be different from the anatomical apex, which corresponds to the morphological end of the root [25]. However, this preoperative measurement may be potentially erroneous. Indeed, the radiograph takes into account mesial and distal curvatures but not vestibular and lingual curvatures [26].

The principle is to measure this length using an endodontic instrument introduced into the canal and whose position is adjusted with the help of a series of retro alveolar radiographs on which the practitioner mainly looks for the radiological apex. However, according to literature, the radiological apex does not represent a reliable limit for apical preparation and several studies have shown that it does not coincide with the apical foramen in 80% of the cases. Thus, it can be concluded that the radiographic method alone does not provide an accurate determination of the working length.

Radiovisiography (RVG), developed by Dr. Francis Mouyen in 1987, could replace conventional radiography. Indeed, the RVG allows to obtain a good quality image and is especially easier to exploit clinically and to archive. Digitized radiography has made it possible to reduce radiation doses, decrease image acquisition time and play with contrast variation. This allows for better identification of the anatomical structures, as well as the possibility of editing and storing them [27].

63.4% of our study population use the radiographic method for the determination of the working length, the majority of which use digital radiography and only a minority of 39 dentists or 14.29% of our population still use conventional radiography. Nevertheless, the literature does not provide a clear indication of whether digital radiography is more effective than conventional radiography for determining working length [28]. The results showed no significant difference between conventional and digital radiography in measuring working length. Shearer., *et al* stated that there was no statistically significant difference between the percentage of root canal length visible on conventional film and that visible on RVG images. Thus, RVG can be considered to have the same value as conventional radiography for in-vitro root canal imaging [29]. According to the study conducted by Martinez-Lozano, the accuracy of conventional and digital imaging was found to be 50.6% and 61.4%, respectively, when establishing working length [30]. Working length measurement must be performed with the operative field (dam) in place to maintain aseptic conditions and protect the patient from ingestion or inhalation of

instruments.

Disadvantages and limitations of intraoral radiography

The ideal method for determining working length should be accurate, easy, and quick to apply. It should prevent additional radiation. It should be comfortable for the patient and the clinician. So far, no method that meets all these criteria has been found [31]. In 2001, Elayouti conducted a study on the accuracy and reliability of intraoral radiography in working length. By placing endodontic files at a distance of up to 2 mm from the radiographic dome, he found that in 51% of premolars and 33% of molars, the file was engaged beyond the apical foramen, and thus the radiologically determined working length was overestimated. He also observed that the likelihood of over instrumentation is greater for maxillary molars than for mandibular molars because of the anatomy of the root canal system [32]. It is well known that the apical foramen is not always located at the radiographic apex of the root. It is most often located in the buccolingual (BL) or mesiodistal (MD) planes. If the foramen deviates in the BL plane, it is difficult to localize its position using radiographs alone, even with multiple angles [33]. The curvature and eccentric position of the apical foramen relative to the anatomical apex is common in more than 30% of teeth. Other studies show that the canal foramen is located at the radiological apex in only 20% to 32% of cases depending on the age of the patient [34]. Conventional radiography compresses three-dimensional structures into a two-dimensional image. A good view of the anatomy in the MD plane is obtained, but a poor appreciation in the BL plane. The compression of the three-dimensional anatomy associated with the retro alveolar radiograph prevents a good appreciation of the surrounding anatomical relationships with the observed tooth root. Anatomical features such as cancellous bone thickness, bone cortex, the relationship between root apices and their surroundings, and the superimposition of roots with anatomical structures such as the mental foramen or the zygomatic process of the maxilla can complicate the interpretation of the images [35]. On the other hand, radiographic images are subject to distortions that are related to the radiograph angulation, the curvatures, and inclinations of the roots, the film position, the cone, and the sensor. We can also underline the difficulty of placing and stabilizing the film or the sensor in the mouth in the presence of an operating field, one or more endodontic files, the shape of the patient's palatal arch, as well as a possible gag reflex or a limited mouth opening [33]. In addition, the comparison of different successive images is difficult, because it is impossible to place the angulator precisely in the same position each time. In addition to this problem of reproducibility, there are possible interpretation errors inherent in any clinical activity and which vary according to the experience, visual acuity, and equipment of the practitioner [36]. Several intraoral images taken with different angulations may be essential to see the different anatomical structures, and there is a constant need to reduce exposure to ionizing radiation whenever possible. Even if the delivered radiation dose is very low (between 0.02 and 0.08 mSv), due to the frequency of this type of imaging, it may represent a risk, in particular for the nursing staff [36]. The order of March 28, 2010, relating to the transposition of Community Directives in the field of Protection against Ionizing Radiation, states that "the exposure of individuals to ionizing radiation must be kept as low as reasonably achievable, taking into account the state of technical progress, economic factors and the medical intent pursued". While three radiographs are medicolegally required, the legislation encourages practitioners to use an alternative technique to radiography as often as possible. In its September 2012 evaluation report on endodontics, the HAS recommends reducing the number of images by using electronic apex locators [37].

35.2% of dentists in our population use the electronic method to determine Working Length. They believe that EALs are more reliable and rapid compared to the radiographic method. This accurate and reproducible technique reduces exposure to ionizing radiation by decreasing the number of intra-operative radiographic views when adjusting the working length. The apex locators offer valuable aid to patients who have apices obscured by anatomical structures or objects and for patients with nausea reflexes, film intolerance, or medical problems that prohibit the use of film holders or digital detectors [38]. EALs have the advantage of allowing dynamic reading of the Working Length during root canal shaping. However, as with any medical device, the use of Apex Locators requires pushing through a learning curve as well as the respect of a precise therapeutic protocol.

Biological phenomena such as inflammation can influence the accuracy of EALs. Inflammatory exudates and blood can create current conduction and cause errors when determining the working length. Other conductors that can create a short circuit are metal restorations, caries, saliva, and instruments in a second canal. The shape of the canal, canal permeability, accumulation of dentinal debris, and calcifications can affect the function of an EAL. The diameter of the apical foramen also affects the measurement of an Apex Locator. Huang found that a foramen with a diameter of less than 0.2 mm does not affect the measurement, even in the presence of conductive irrigants, whereas when the diameter is greater than 0.2 mm, the measured distances of the foramen increase [49]. Due to the insulating nature of the filling materials, locators can only be used in endodontic retreatment after the canal has been completely cleared [40].

Currently, there is no consensus as to which of the methods for determining the working length offers the best results. It has already been discussed that the ideal apical anatomical landmark recommended for instrumentation and root canal obturation is the DCJ/AC. Historically, the radiographic method has been the first-line technique for determining working length during an endodontic treatment despite the inherent disadvantages of intra-oral radiography. Indeed, the localization of the apical foramen is sometimes made difficult because of the lateral emergence of the canal. Therefore, the apical foramen does not coincide with the anatomical apex on the radiograph. This can lead to over-or underfilling, which increases the probability of treatment failure by 10 to 50% after 10 years. Nowadays, EALs have good reliability and accuracy in locating the apical foramen and are recognized as an alternative method to intraoral radiography. These devices have undergone a strong evolution in recent years due to scientific advancements. In a study conducted in 2018 at the University of Bordeaux, two operators determined the working length for a total of 23 canals using both radiographic and electronic techniques, the comparative study showed the following results: 14 measurements are identical between the two methods (i.e., 61%), 7 measurements have a difference of 0.5 mm which is considered insignificant (i.e., 30%) and 2 measurements are significantly different (more than 1 mm, i.e., 9%). They reported that the majority of the differences obtained are related to an overestimation of the working length with the radiographic method. However, it is possible to underestimate the working length in case of significant root curvature or difficulties for the operator to correctly locate the apex on the radiograph. This highlights one of the main limitations of the radiographic technique, namely the impossibility of locating the apical foramen and the variability of its position, which favors over-or under-instrumentation of the operated canal. The fact that the distance between the apical foramen and the radiological apex varies (from 0.2 to 3 mm) makes the radiographic method less reliable than the apex locators, which are not affected by these particular cases and always detect the apical foramen. EALs, therefore, seem to be the most suitable in complex situations. In addition, the use of the electronic method allows time saving that varies between 20 to 40% depending on the group of teeth compared to the radiographic method [41].

In our study, 48% of the dentists in our population believe that the radiographic method is the most reliable method for determining the working length, as well as 70% of the dentists who use the electronic method in their daily practice report that sometimes EALs do not give accurate measurements. According to the literature, exposure to ionizing radiation should be as low as possible. In endodontics, the number of radiographs can be reduced by using apex locators according to the HAS [36]. However, this does not mean any radiographic examination at all. The number of three radiographs - one preoperative to evaluate the initial situation, one intraoperative to control the procedure (especially in case of doubt about the apical integrity), and one postoperative to verify the final result - is considered adequate and justified by the HAS. Thus, we will use a sequence combining several techniques to determine the working length. First, the preoperative radiograph provides information on the endodontic anatomy: number of canals, their possible divisions, their degree of curvature, and their approximate length. The elimination of parietal canal interference in the coronal 1/3 is then performed. This is an important step before any electronic measurement. It would not only allow an easier insertion of the instruments but also an increase in the accuracy of the determination of the working length. Then, a first electronic measurement allows us to determine the working length during the catheterization stage. Then an intraoperative file-in-place radiograph can be taken to materialize the instruments at the length given by the apex locator, to visualize the canal trajectory, the degree of curvature and to minimize the risk of missed canals. Instrumental shaping may result in the straightening of the root canal curvatures. The rectification of these curves results in a decrease of the working length which can sometimes exceed one millimeter. It is therefore advisable to check the working length at the end of the preparation by

a second electronic measurement.

The radiograph of the master cone in place before obturation allows for visualization of the tip of the cone in relation to the radiographic apex. Finally, the absorbent paper cones, during root canal drying, represent the last check before obturation, and their tip must be dry, free of any bleeding or exudate. If this is not the case, the working length will be reassessed.

Let's not forget that the endodontic act is a source of many failures. The practitioner must often face various difficulties during treatment. A 2015 Hong Kong study aimed to analyze the possible causes of endodontic treatment failure during retrograde re-intervention. 238 canals were analyzed microscopically. The results showed that incorrect working length determination accounted for 19.75% of the causes of endodontic treatment failure [42]. In our study, 37% of dentists were not satisfied with the working length determination they made. This dissatisfaction follows some difficulties they encounter which are mainly related to the anatomical complexity of the root canal system (57.8%). In his work, Vertucci described in 1984 the large number of anatomical variations found in 2400 permanent human teeth and highlighted the complexity of the root canal anatomy [43]. The practitioner must not only be familiar with standard cases but also be able to analyze the information provided by the radiological examination to construct a mental image of a root canal system that can only be considered in 3 dimensions. Since the work of Walter Hess, all morphological studies have shown that a root with a single straight canal, with a single foramen centered on the apical dome, is the exception rather than the rule [44].

Anatomical irregularities in endodontics are frequently encountered in daily endodontic practice. The practitioner must constantly be on the lookout for additional canals and be aware of the risks of particular anatomies when performing endodontic treatment. With the knowledge of basic root canal anatomy and the use of an operating microscope, the localization of additional canals and anatomical features is facilitated. Knowledge of internal anatomy and careful reading of preoperative radiographs are necessary to properly approach endodontic treatment. The quality of endodontic treatment depends mainly on correct shaping and measurement of the working length, which allows for effective cleaning and obturation. It should be kept in mind that no aspect of endodontics is more important than the clinician's willingness to do the job right.

Conclusion

One of the fundamental steps in endodontic treatment is the determination of the working length, which can be particularly difficult in certain clinical situations. Our study has shown that there is no perfectly satisfactory technique for determining the root canal working length. This step is a delicate moment for the odontologist, since its result conditions the success of the endodontic treatment. Deprived of visual control, they must rely on technology. The diversity of techniques we use and the repetition of measurements ensure that we can determine the working length with great precision. Radiography is still a must in endodontics today. 63.4% of the practitioners in our study use the radiological method for working length determination. And 85.7% of all dentists in our population, i.e. those who use the radiological or electronic method, confirm that radiography can never be surpassed even with the technological evolution and advanced systems of EALs. However, Apex Locators offer a real alternative, because the measurements they deliver are not influenced by the position of the foramen. This technique also saves time and provides better comfort for the patient. It should be noted, however, that the proper use of these devices requires care and following a clinical protocol. In our study, 70% of the dentists who use the electronic method reported that sometimes the EALs do not give accurate measurements. This can be explained by the lack of experience and training of operators on the principle of function and protocol of using EALs when determining working length. However, due to legislation, EALs should not be used as the sole means of determining working length, but rather as the most effective element of a set of investigative techniques. It is by cross-referencing the EAL measurement with the information provided by the radiograph that the odontologist can assess the working length.

The method of determining the working length must be accurate, easy, and quick to apply, it must prevent additional radiation, its use must be comfortable for the practitioner and the patient and it must be reasonably priced. No single method can satisfy all these criteria. Repeated measurements should be made during the treatment with different techniques, such as the radiographic method and the electronic method.

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