Historical and contemporary rationale for the determination of the apical limit

Hani F. Ounsi, DCD, DESE, MSBM, FICD

إن احد اهداف المعالجة اللبية هو عزل الفراغ اللبي عن الأنسجة الداعمة، و يكون ذلك باحترام إعتبارات ميكيكية وبيولوجية محددة. إن إختيار الحدود الذروية للمعالجة اللبية لا تزال موضع بحث. تطورت وسائل تحديده مع مرور الزمن، و نستطيع اليوم الوصول الى نتائج دقيقة في هذا المجال. إلا ان هذه الوسائل تعطي في بعض الحالات نتائج متناقضة ، و هذا ما يطرح السوال على طبيب الأسنان. أي وسيلة يختار؟ وعلية اختيار قرار مبني على الوقائع العلمية للمعالجات اللبية وهذا من شأنه الإجابة على هذا السوال.

The aim of endodontic treatment is to seal off the pulpul space from the periodontal space. This is done with respect to biological and mechanical considerations. The choice of the actual apical limit for endodontic treatment remains a subject of controversy. Methods of determination of the apical limit have also evolved through the years and actually allow for a relatively precise determination of the root canal. However, these methods sometimes give contradictory information and leave the practitioner with a difficult choice: which one to believe? Only an evidence-based approach to endodontics that reflects both the biological basis and the mechanical approach to treatment is able to answer this question and to help in achieving excellence to meet our patients' ever growing expectations.

Introduction

The need to accurately determine the root canal length had been discussed by many authors.[1-3] As early as 1950, Coolidge advised practitioners to constrain the instrumentation to the dentinal part of the root canal.[4] Based on Kuttler's[1] research, the vast majority of authors has since reclaimed this concept.[5-11] The determination of the root canal length is thus a cornerstone of endodontic treatment. Root canal length is defined as the distance between the apical terminus of the root canal and a well defined and visible coronal landmark.[11] If selecting the coronal landmark is easy, choosing and locating the apical landmark remains controversial.

In 1955, Yuri Kuttler[1] publishes his research regarding the apical topography of the tooth apex. He described the apex as being formed of two cones opposed by their tip: a dentinal cone and a cemental cone (Fig.1). In 80% of the cases, these two cones are not aligned. According to Green,[12] the immediate consequence would be to offset the apical foramen 2mm away from the main axis of the canal in 50% of the cases. Laurichesse[13] estimated this same frequency to be much greater than 50%. Practically, there are three possible apical landmarks: the cementodentinal junction (CDJ), the apical constriction, and the apical foramen.

Kuttler[1] showed that the CDJ is microscopically visible in 96% of the cases and that it is located between 0.524 and 0.659 mm short of the apical foramen. From a histological standpoint, Grove[14] then Kuttler[15] presented the CDJ as the ideal point at which the endodontic treatment should be limited, inasmuch as it represented the point where the pulp tissue became periodontal tissue. Stopping the treatment at this level would allow a biological obliteration of the foramen by cementoïd tissue. According to Seltzer,[16] these observations concurred with the results of Blaney (1927), Nygaard Ostby (1944), Ketterl (1963), Sekine (1963), Nyborg and Tullin (1965), Engstrom and Spångberg (1967), as well as Holland and de Souza (1985). They showed that for an optimal repair in case of vital teeth, the instrumentation should be confined to the root canal while leaving a vital apical stump. The cells present in that stump

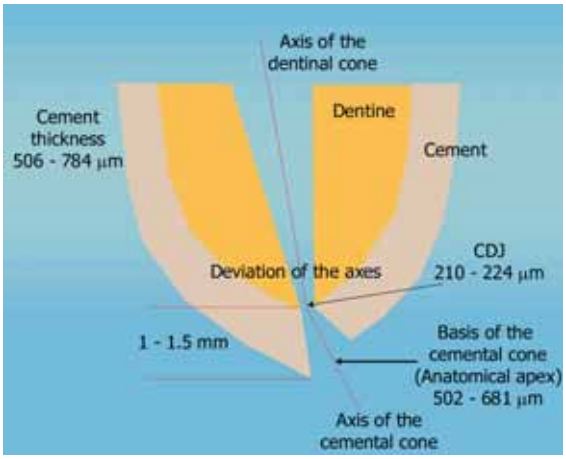

Fig. 1. Apical structures according to Kuttler (1955).

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Department of Endodontics
Faculty of Dental Medicine, Saint Joseph University
Beirut, Lebanon

Address reprint requestes to:
Dr. Hani F. Ounsi
Sodeco Square Center, Block C, Sodeco
2061-1211, Beirut, Lebanon
Fax: +961-1-380914
E-mail: ounsih@idm.net.lb

would in turn elaborate a cementoïd tissue that would block the root canal exit.[16] Nevertheless, these same studies showed that even in ideal conditions, the apical stump may undergo necrosis and chronic inflammation would persist. Another possible reaction is the proliferation of cell rests of Malassez forming in time a radicular cyst.[17] Finally, it has been clearly shown that even if the cementoid tissue would indeed block the portal of exit, it does not predictably seal it.[18]

Even if considered as the ideal apical limit, the CDJ remains a histological feature that cannot be determined clinically; it cannot be seen radiographically nor felt clinically. Based on his research and aiming to limit his treatment to the CDJ, Kuttler[15] suggested ending all preparations 1 to 2mm short of the canal terminus. However, one should keep in mind that the dimensions found by Kuttler are statistical measurements that can be applied as such to a whole population, but are absolutely useless clinically. A practitioner that would follow these measurements blindly would actually be either overtreating or undertreating his patient's root canal. Commenting upon this empiric technique of working length determination, Buchanan[10] wrote: "the prudent clinician uses concepts and procedures that address any possible root canal anatomy and not an unspecific average". From another standpoint, one must also note that the CDJ may differ with respect to dental anatomy and pathology.[19] It may be located at different levels on each root canal wall and even be located on the external root surface (Fig.2).[16,19]

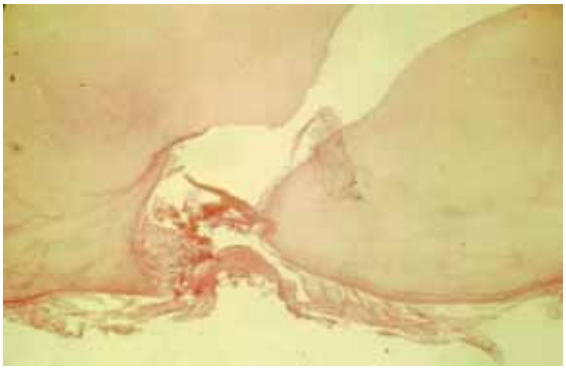

Fig. 2. Histological section of the apical area showing the position of the CDJ on opposite root canal walls. (Courtesy of Dr. Nada Naaman)

Thus, two apical landmarks remain: the apical constriction (AC) and the apical foramen (AF). From Soltanoff *et al.* (1962) to West (1994), an overwhelming majority of authors considered the AC as the optimal spot to which we should end our root canal treatment.[10] In fact, whether in dentin or cement,[20] the AC is the narrowest apical point of the root canal (210 to 224 microns according to age) and ideally often coincides with the location of the CDJ[1]. Furthermore, and from a procedural standpoint, we are required to keep our apical exit as small as practical,[10] and the AC can be located clinically using only tactile sense. According to Stabholtz *et al.*,[21] locating the AC is possible in 32% of the cases and it reaches 75% if preshaping is done prior to root canal length determination.

Even with the improvement of preshaping, 75% remains a low percentage that cannot be accepted clinically. On the other hand, Buchanan states that a working length short of the AF will unquestionably displace the foramen. This was confirmed by Machtou[22] and by Ruddle *et al.*[23] who proposed to shape, clean, and fill the root canal at least to the radiological foramen (i.e., at least to the apical foramen).[24] This is of course a personal opinion not supported by evidence-based research but nevertheless the clinical opinion of highly experienced practitioners. They base this affirmation on the fact that after a thorough shaping and cleaning procedure, a slight overinstrumentation and/or overfill will not negatively affect the final prognosis of the treatment (Fig.3).[25,26] It is also accepted since the works of DeDeus[27] that the highest anatomical complexity is located in the last apical millimeters, and as West[28] and Machtou[22] put it, voluntarily limiting the treatment 1mm short of the AF is in fact ignoring deliberately many millimeters of the root canal system, thus increasing the risk of failure (Fig.4). Biologically, treating to the canal terminus would most predictably eliminate pathogenic contents from the avascular areas inside the root structure.

The AF can be located clinically by radiography,[29] apex locators,[30-32] and paper points.[10] Radiography yields an 82% precision according to Olson *et al.*[33] whereas that of electronic measurement is closer to 95%.[31-32] Comparison between the two techniques shows apex locators to be more accurate and more reliable than radiography for determining working length.[30] This is primarily due to the fact that electronic measurement is an objective technique whereas radiography is a subjective technique.[31-32] This was proven as early as 1989 in the study by Gelfand *et al.*[34] according to which almost 22% of operators disagreed with themselves while examining a set of x-rays for the second time. These findings clearly indicate that

Fig. 3a & b. A slight overfill does not inhibit healing.

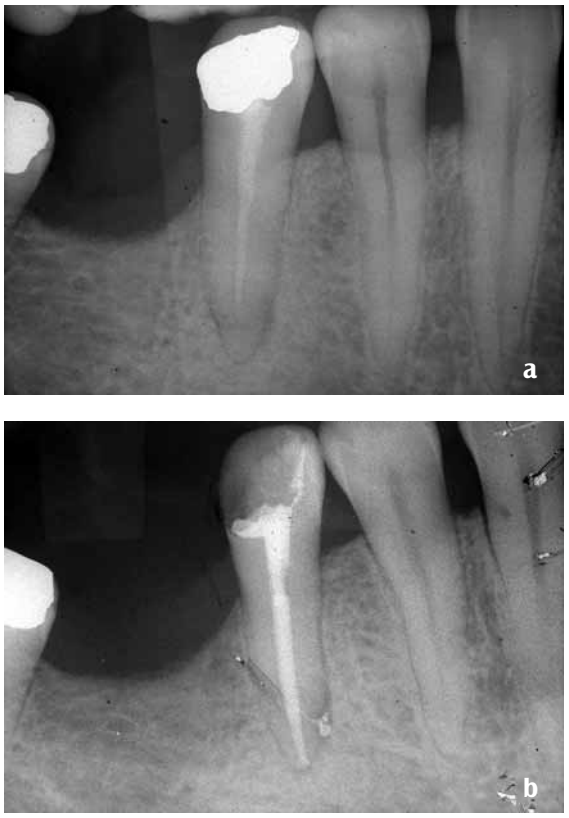

Fig. 4a & b. Ignored by the first treatment, the apical complexity provoked a recurrence. The retreatment dealt with the situation.

serious consideration should be given to the use of electronic measurement devices as a primary means of determining the root canal length during endodontic procedures. This shift to electronic measurement is also dictated by the difficulty on some teeth in obtaining a radiograph that can be exploitable clinically due to the presence of dental and/or anatomical obstacles blocking or blurring the view of the root apex on the x-ray (Fig.5). However, x-ray remain of paramount importance in endodontic procedures because electronic measurement devices give, it is true, accurate estimates of root canal length, but absolutely no information on the shape of the root, number of root canals, direction of curvatures, etc.

It is also obvious, that we basically perform endodontic treatments on teeth that underwent pathological processes which may result in apical root resorption and destruction of the natural apical constriction. This will in turn create difficulties in locating a biologically acceptable landmark at which to end our treatment. Resorptive processes generally produce uneven root ends which yield an unclear radiological image with little or no clue to the endpoint of the root canal. Even more, this appearance is only visible in the mesiodistal plane and mostly blurred lingually and buccally. Andreasen has shown that resorption cannot be discerned radiographically until 20 to 40 percent of the root structure has been demineralised.[35] This will further complicate working length determination and these are the cases where one should rely most on clinical judgement, experience, tactile sensations, and reliable radiographic techniques. If the root end is wide open from the resorptive destruction, electronic apex locators are of little clinical value. Therefore, the coronal-most point which exhibits sound radiodensity should be identified and used as apical landmark (Fig.6).[36] Paper points are extremely helpful in determining the canal exit if no exudation is present as periradicular tissues will moisten the tip of the point at the level of the root canal exit. In such extreme cases, the combination of radiographic assessment, paper point testing, and the experience of tactile sensation, may help in achieving a reasonable estimate of the working length.

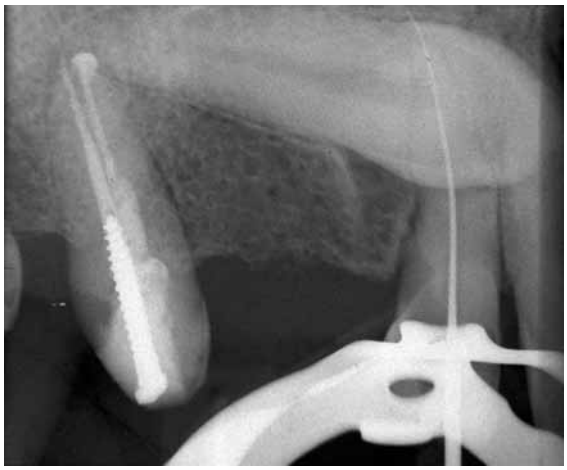

Fig. 5a. Impacted canine overlapping with the apical area making working length determination impossible by radiography.

Fig. 5b. Postoperative radiograph showing the actual exit of the root canal system.

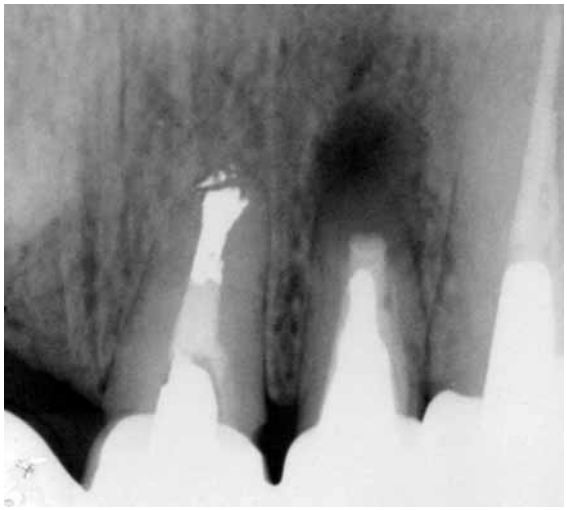

Fig. 6a. Tooth that underwent two consecutive apical surgeries treated by conventional endodontics according to the patient's wish. Preoperative x-ray.

Fig. 6b. Conventional retreatment. Only a chemical dam was used for isolation.

Fig. 6c. Master-cone.

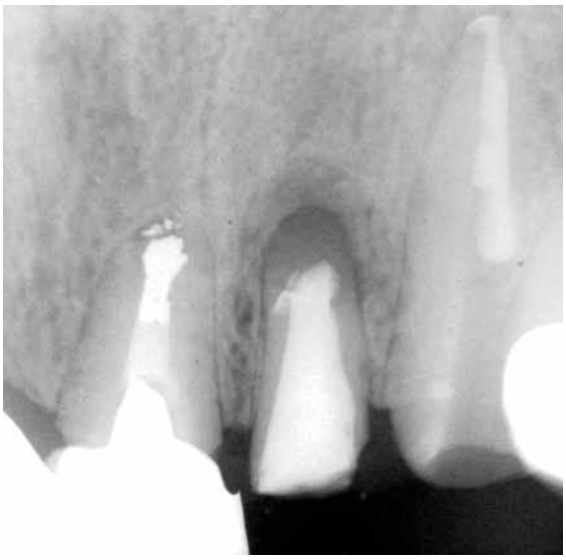

Fig. 6d. Immediate post-op x-ray. Note the distance between the foramen and the radiological apex. Note also that the canine was also retreated to serve as main abutment to a fused crown in response to the poor biomechanical properties of the lateral.

Fig. 6e. 6-year recall.

The success of endodontic procedures is dependent on thorough debridement of the entire root canal system. This includes all the anatomical complexities, most of which are located in the apical region, and emphasizes the importance of correct working length determination. Controversies will continue to surround the management of the root apex area despite the high success rate of modern endodontic procedures. With patients ever demanding better and more reliable dental treatments, techniques and materials will continue to improve in a way to increase the chances of successful root canal treatment. However, an evidence-based approach to endodontics that reflects a biological basis for the therapy rendered, complimentary to the mechanical approach that prevails to date, is paramount for achieving such expectations.

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