

ROOT CANAL ISTHMUSES CLEANING REVISITED

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ABSTRACT

Background/Objectives: the present narrative review article endeavors to expose the updated principles of improved clinical approach dedicated to root canal isthmuses cleaning. Methods: the recent literature analysis is focused on both conventional comprehensive and innovative endodontic procedures aiming to come up to a better removal of tissue remnants and biofilms harbored in morphologic tooth niches of the endodontic system such as root canal isthmuses. Preoperative imagistic investigations are discussed related to their value in disclosing these morphologies. Results: findings emphasize the enhanced contribution of ultrasonic and laser activated antimicrobial irrigation accompanying the chemomechanical treatment of the infected root canals. Conclusion: given the impossibility of using in patients the microCT as gold standard imagistic diagnose, in clinical setting the current endodontic treatment of mesial roots in first permanent lower molars as well as of mesiobuccal roots in first permanent upper molars should consider the presence of isthmuses and the appropriate therapeutic strategy.

Key words: root canal isthmuses, mesial root of mandibular molars, mesiobuccal root of maxillary molars, CBCT diagnosis, endodontic irrigation, root canal filling

INTRODUCTION

Worldwide the clinical perception of chronic apical periodontitis is one of an asymptomatic disease. In recent years systematic reviews and meta-analysis highlight a prevalence of 52% at the individual level and 5% at tooth level. On the other hand the frequency of apical lesions is significantly higher in already root-filled teeth compared to untreated necrotic teeth [1].

Additionally, investigating the same parameters of chronic apical periodontitis regarding the disease prevalence at the individual and tooth level, a follow-up study in Belgian population underscored that no evident changes were recorded in the last 22

years despite the technological and professional progress in endodontics [2].

Despite the use of dental operating microscope, rotary Ni-Ti instruments and laser photoactivated irrigation improved a lot the removal of microbiota from infected root canals during orthograde nonsurgical management, the individual morphologic complexities of endodontic system, such as root canals isthmuses or missing middle mesial canal in lower molars, are substantiated the still existing therapeutic failures [3-10].

Actually, either neglecting the isthmus presence or its improper approach, finally result in clinical failure regardless the modern technology for

canal enlarging and disinfection were used [11,12].

Accordingly, while performing the root canal chemomechanical treatment in mesial roots of first permanent lower molars or in mesiobuccal roots of first permanent upper molars, currently the endodontist is confronting with the issue of identifying both the isthmus existence and its morphologic feature [8-10].

Subsequently, as this hidden anatomical structure can not be properly managed with endodontic instruments of utmost importance are the irrigation procedures in the apical third of tooth root where the isthmuses are usually located [13-15].

The aim of this review is to corroborate the available imagistic evidence with clinical studies in order to provide improved preoperative diagnosis, cleaning and filling of root canal isthmuses.

MATERIALS AND METHODS

PubMed database was searched using following keywords: root canal isthmuses, mesial root of mandibular molars, mesiobuccal root of maxillary molars, CBCT diagnosis, endodontic irrigation, and root canal filling. Only English written free full text papers were included. Duplicate or non relevant papers were excluded. From 203 initial papers, 82 were assessed for eligibility as follows from PRISMA flow diagram (Figure 1).

APICAL ROOT CANAL - TARGETED THERAPEUTIC AIM

Though as a general rule the debridement and enlargement are

addressed to the whole area of the root canal walls, actually the final prepared shape escapes some surfaces due to the anatomical irregularities of the endodontic system [16].

Some other additional unavoidable outcomes of the instrumental enlargement of root canals such as debris and smear layer are hindering a confident post operative sealing that would guarantee the maintenance of healthy periapical tissues. Moreover, in case of infected root canals the endodontic biofilms are not eradicated and a chronic apical periodontitis is developed over time [17,18].

Despite the experience and skill of endodontists the anatomic feature of the root canals in their apical third is pivotal for a successful endodontic treatment given the inescapable morphologic challenges such as additional canals, accessory canals, apical deltas and isthmuses [5,19].

Among the individual variations from normal internal anatomy of the root canals definitely isthmuses are potential causes of endodontic failures by containing bacterial biofilms, necrotic tissues and compacted filed dentine during mechanical instrumentation. Moreover, the root filling is cooperating in sealing the previous materials within the isthmuses [19].

The pathogenic potential of isthmuses content was clearly demonstrated by apical surgery studies that highlighted higher survival rates at 4 years for teeth without isthmuses compared to teeth with isthmuses (87.4 vs 61.5%)[20].

Though the isthmuses are preferentially found in fused teeth or

teeth with C-shaped canals, their most frequent location that largely ranges from 57.8% to 100% given to ethnic particularities, is confirmed in mesial root of the lower first molars [21-25].

Based on secondary dentine lay down, the tooth developmental continuity results in declining of isthmuses prevalence with age and consequently explains the increased success rate of endodontic treatment in older patients given the calcification of these anatomies

harboring necrotic pulp tissue and microbial biofilms [4,25,26].

Almost in all mesial root canals of first lower permanent molars mostly are found Weine type II configuration and rarely type III configuration. Accordingly, due to anatomic feature of type II configuration, usually is expected to regularly find isthmuses in the root apical third as the mesiobuccal and mesiolingual canals are joining in this region and end in single apical foramen [5,27].

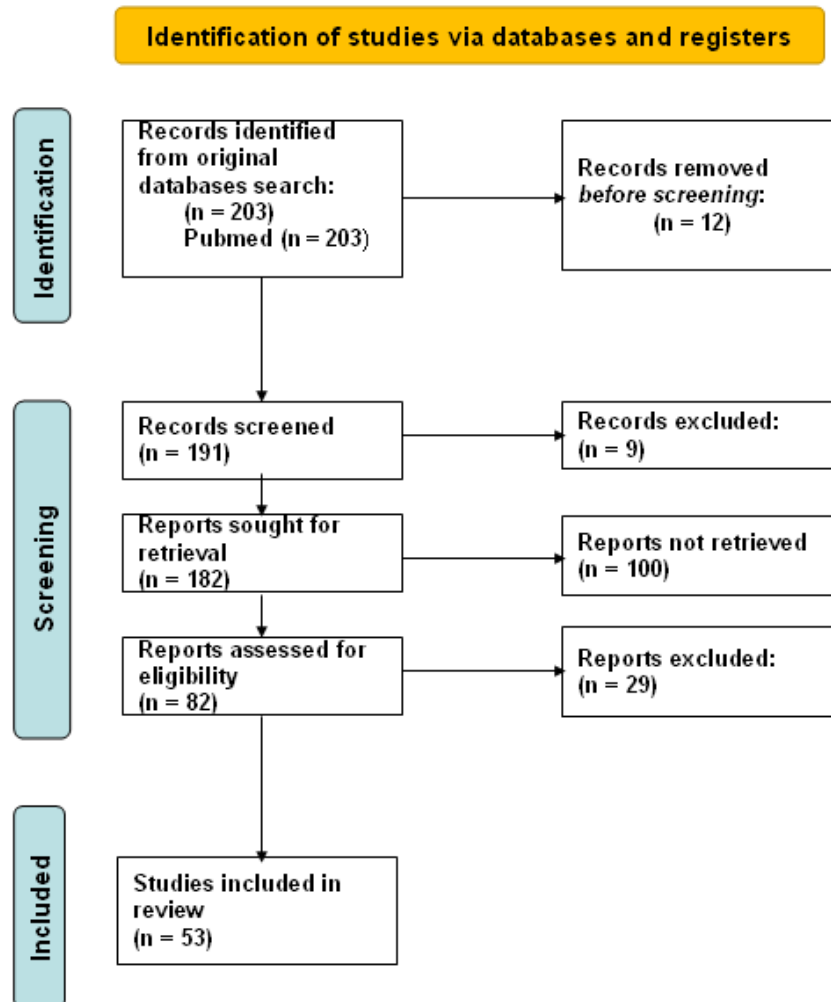


Figure 1. PRISMA flow diagram.

Obviously, for endodontists is challenging to identify this Weine type II canal configuration in clinical setting.

Neither the conventional periapical radiograph is useful. Though the imagistic progress of last decades allows

nondestructive analysis of the endodontic system complexity either by CBCT (cone-beam computed tomography) or micro-CT (micro-computed tomography) and nano-CT the access for patient investigation is limited [9,10].

Micro-CT and nano-CT are exclusively dedicated to *in vitro* examination due to highly dangerous irradiation values. On the other hand CBCT is not recommended as usual investigation procedure. However, a CBCT may be used to visualize the 3D tooth structure only in cases of pre-existing scans indicated for non-endodontic aims, such as maxillary bones pathology or implant-prosthetic planning [5,9,10,19].

Though definitely the sharpness of CBCT image is inferior to micro-CT or nano-CT large isthmuses may be seen on axial slices regardless their location related to the root length. Nevertheless, the highest probability of isthmuses presence in the apical third of mesial roots in lower first molars occurs in younger when the distance between mesiobuccal and mesiolingual canals, visualized on CBCT axial slices is too short [5].

Coming back to practical approach of the orthograde chemomechanical treatment of root canals with presumed Weine type II configuration, the efficient philosophy is to achieve a thorough instrumentation and irrigation [5].

If possible a tailored shape of the apical preparation harmonized with the individual morphological profile of the root canal in those roots with Weine type II configuration would warrant the most

desired debridement and cleaning [16,28].

In current practice the taper of apical preparation is corresponding to final Ni-Ti rotary files design, i.e. between 4% and 6% [16]. Whether the apical taper is agreed the item of apical size is still in debate, ranging from ISO 30-40 to larger size ISO 45-80 [29,30]. However, same cleaning efficiency was attained using manual K file ISO 35 or Ni-Ti rotary files 30/06 [29].

Despite the ongoing controversies it should be accepted that both are beneficial, the prevention of ledge formation or apical transportation as well as enhancing the debris removal and disinfection, the last objective above all in retreatments [31].

Reiterating the priority of irrigation versus mechanical debridement in cleaning the apical third of root canals it should be underscored the rather similar efficiency of manual K file ISO 30 enlargement and 27-G needle irrigation compared to larger K file ISO 45/50 instrumentation associated with irrigation needle of increased caliber 25/23-G [16].

Pivotal for a highly efficient clinical clearing is to achieve an apical enlargement at working length (WL) over ISO 25. Any instrumentation up to ISO 25 can not guarantee a proper irrigant flow to the apical terminus of the root canal [32].

Regrettably, none of the current mechanical enlargement procedures and irrigation protocols proved to completely clean the apical root canals and connected morphologic irregularities [33]. Accordingly, especially in younger patients, in difficult to approach apical areas of the endodontic system such as

mesial roots of lower first permanent molars, the more cautious and effective irrigation should be regarded as paradigm [5,32].

DYNAMIC OF IRRIGATION IN APICAL ROOT CANAL

The irrigation efficiency of infected apical root canal is the most demanded clinical goal for preventing the future development of chronic periapical lesions. As a rule the outcome relies on irrigant replacement from the apical preparation and a sufficient shear stress capable to achieve the mechanical debridement of microbial biofilms harbored within the root canal system [34].

The irrigant replacement, i.e. the reverse coronal flow, occurs regardless the size and taper of apical preparation or the type of irrigating needle, flat open-end or closed-end side-vented. However, the clinical efficiency is obvious if the irrigating flux velocity achieves values over 0.1 m s^{-1} [35].

The common tendency of practitioners is to achieve a proper apical size for the best debris removal and irrigant replacement [35,36].

Though at the first look the intracanal fluid replacement is related to the available room around the tip of the irrigation needle, actually the needle design is decisive. Compared to closed-end side-vented, in a rather expanded scale from 35/06 to 55/06 apical enlargement, the flat open-end needles proved to be more efficient. Along the same values of apical preparations, in case of closed-end side-vented needles the irrigant removal increased in apical

constriction direction only from 0.75 mm to 1.5 mm [35].

In order to avoid apical extrusion mishaps in usual apical 35/06 preparation is preferable to insert closed-end side-vented irrigation needles within 1 mm short of WL but the flat open-end needles somewhat farther, at 2-3 mm short of WL. Moreover, it should be reminded that if the irrigation needle binds into the canal lumen, the anatomical still clinically hidden features, namely in case of oval canals, might be definitely useful by allowing the irrigating fluid reflux [35,36].

On the other hand, in both flat open-end and closed-end side-vented irrigating needles was observed an unsteady irrigant flow [35]. The difference consists in a more effective cleaning of flat open-end needles given the apically directed jet they provide as compared to closed-end side-vented needles which display various size vortices variously dispersed in apical direction [37].

Though regardless the design of irrigating needle, the irrigant flow may reach the root canal terminus when the apical enlargement is instrumented from 35 to 55 ISO size, some other irrigation related factors such as flux velocity and shear stress should be also considered [36].

The irrigation shear stress is pivotal in apical third of infected root canals particularly in location of isthmuses facilitating the removal of necrotic tissue remnants, compacted dentin debris and microbial biofilms [38]. Interesting, the flow rate of conventional sodium hypochlorite irrigant is more

efficient in biofilm physical removal than in its antimicrobial action [37].

Fortunately for improved root canal debridement and disinfection the highest shear forces were recorded in the apical third of the root canals regardless the irrigating needle design [38]. More exactly, both open end and closed side-vented irrigating needles expressed in 25/06 apically enlarged root canals comparable pattern of shear forces, achieving maximal value of 1000 N m^{-2} [35].

A proper selection of irrigation needle tailored to apical preparation size is crucial as the indirect correlation observed between shear stresses and apical size of the root canal preparation. An excessively enlarged apical preparation results in deficient cleaning given the decrease of shear stresses [35].

It is also useful to know that in open-end needles the maximal shear stress is located apical to the needle tip whereas in the closed-end side-vented ones is recorded on the canal wall facing the lateral needle outlet [35].

The open-end irrigating needles regardless the tip design, flat, beveled or notched demonstrated comparable shear stress but beveled and notched ones did not achieve the highest value in the direction their irrigating flux was directed [38].

Typically for both closed-end needles either single side-vented or double side-vented outlet, the shear stresses occur on the canal wall oriented to the outlets in contrast with multi-vented needles that developed the maximal shear stress of irrigation flow on restricted area of canal walls facing the outlets [38].

CLINICAL INQUIRING ISSUES IN ISTHMUSES CLEANING

Though not yet predictable practically the chemical debridement, frequently based on increased efficacy of passive ultrasonic irrigation compared to conventional syringe use, is the sole handy procedure for isthmuses cleaning [39-41].

Despite its limits, over a century in clinical setting the capability of endodontic irrigation to penetrate in isthmuses area, solve the necrotic tissue remnants and remove the microbial biofilms is highly dependent on the gold irrigant, which is sodium hypochlorite. Excepting the appreciate antimicrobial activity, the long lasting governance of this irrigant basically is explained by its proficient tissue dissolving effect that could not be matched by any other chemical compounds [39,40,42,43].

Despite the technical progress in root canal irrigation, chiefly based on kinetic energy systems, until now no unique irrigant proved to efficiently clean the isthmuses without side effects and moreover no clear guidelines are yet recommended [43].

In order to enhance the cleaning beneficial effects of sodium hypochlorite the key clinical therapeutic means are higher irrigant concentration and volume as well as the extended direct contact with isthmus walls [43].

Compared to conventional syringe irrigation in mesial roots of first lower molars the negative pressure technique provides a better delivery of irrigant next to WL. Nevertheless, roughly at 3 mm from WL, in this clinically pivotal

location of isthmuses, no significant clearing difference was observed [41].

Moreover, as the root canal plays the role of a hydrodynamic closed-end system is crucial to provide both the proper irrigant delivery to isthmuses and debris removal [30]. Given the capillary forces governing the fluid movements in the apical third of the root canal and the release of gas bubbles as outcome of chemical reactions between sodium hypochlorite and necrotic pulp remnants, frequently an additional issue, vapor lock effect, is locally hindering the irrigation [46,47].

The entrapment of gas bubbles directly increases in relation with curvature angle of the root canal. Furthermore, the irrigant film interposed between gas bubble and root canal wall is rather stagnant and can not generate a turbulent flow enabling the debris removal [46].

Clinically, for gas bubbles removal should be approached the apical third of the root canal either by mechanical agitation using a well-fitting gutta-percha master point or a patency file and subsequent passive ultrasonic activation of a fresh sodium hypochlorite irrigant [47,48]. Negative pressure irrigation might be also practical [34].

The routine cleaning procedure of root canals is still accomplished in 3-steps sequential manner consisting in sodium hypochlorite use during chemomechanical instrumentation followed by 17% EDTA chelating solution and finalized by passive ultrasonic activation of refreshed sodium hypochlorite.

However, the endodontic system cleanliness is far to be volumetric

acceptable as even after last flush with sodium hypochlorite ultrasonically activated round 50% of initial debris is not removed [41]. Moreover, the improper delivery of irrigant is dramatically decreasing the disinfection potential [47]. Accordingly, if not perfect the passive ultrasonic irrigation may play the role of an acceptable means for isthmuses cleaning [44,45].

In line with isthmuses chemical cleaning of utmost importance is also the management of infected root canals, which is addressed to three complex targets: planktonic bacteria, microbial adherent biofilms and the already penetrated microorganisms and toxins in neighboring dentinal tubules. Additionally, the infection control should eliminate confusing indications for disinfecting root canal medication [43].

Appreciate remote antimicrobial efficacy in infected root canals has erbium family laser, such as Er:YAG and Er,Cr:YSGG though the optomechanical efficiency unfortunately is progressively decreasing to the anatomical location of isthmuses. It should be emphasized that the irrigant penetration into the dentinal tubules is chiefly accomplished by another kind of laser activated irrigation, PIPS (photon-initiated photoacoustic streaming), which proved to have a superior disinfection potential to ultrasounds [43,49,50].

Within the current limits, the infection control of isthmuses should chiefly rely on appropriate chemomechanical treatment and to consider the intracanal medication an additional approach, not an alternative [43].

Photodynamic therapy (PDT), which is based on suitable photosensitizer with optimum concentration activated by light radiation, might be useful as adjunctive disinfection procedure of isthmuses area [51].

In consonance is also providing a better antimicrobial efficiency the ultrasonic activation of epoxy resin-based sealers used in root canal filling by increasing the penetration in isthmus area of infected root canals and entombing action targeted on surviving microorganisms harbored in dentinal tubules [52].

Certainly the progress of adjunctive procedures in cleaning and disinfecting the isthmuses area are encouraging. However, it should be considered that in current endodontic practice these novel techniques are not yet financially accessible.

Accordingly, especially when considering the apical third of lower permanent first molars where occurs the highest prevalence of isthmuses, the final clinical target still consists in as much as possible tight sealed root canal which in contemporary limits is continuous wave condensation of gutta-percha [53].

Furthermore, crucial for providing appropriate endodontic treatment is to quit common other procedures of root

canal filling such as lateral condensation or single cone technique given the possibility of atypical isthmus variants even more difficult to be approached than the already classified ones [53].

Practically in infected root canals such delicate anatomies of the endodontic system, root canal isthmuses, which are hard to identify, clean, disinfect and fill require as last hope for a successful treatment outcome the best sealers and obturation technique that allow a long lasting entombing effect on residual microbiota.

CONCLUSIONS

The unfeasibility of microCT as gold standard diagnostic investigation, any endodontic treatment of mesial roots in first permanent lower molars and mesiobuccal roots in first permanent upper molars should consider the presence of isthmuses and the appropriate therapeutic strategy. The ultrasonic passive irrigation with sodium hypochlorite is highly recommended for better cleaning. Adjunctive therapies such as PIPS or PDT are welcomed. When root canal isthmuses are suspected the continuous wave condensation of gutta-percha and epoxy resin-based sealers are the approach of choice for root canal filling.

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