Vol. 15, No.1 January-March 2023

THE RELEVANCE OF ROOT CANAL ISTHMUSES IN ENDODONTIC REHABILITATION

Alexandru Andrei Iliescu[1*], Mihaela Georgiana Iliescu[2], Cristina Coralia Nistor[3], Iulia Roxana Marinescu[1], Irina Maria Gheorghiu[4],Tiutiucă Carmen[5*], Focșăneanu Sergiu Ciprian[5], Doriana Agop Forna[6]

[1]University of Medicine and Pharmacy of Craiova, Romania, Faculty of Dentistry, Department of Oral Rehabilitation
[2]Private practice, Bucharest, Romania
[3]Carol Davila University of Medicine and Pharmacy of Bucharest, Romania, Faculty of Dentistry, Department of Endodontics
[4]Carol Davila University of Medicine and Pharmacy of Bucharest, Romania, Faculty of Dentistry, Department of Operative Dentistry
[5]"Dunărea de Jos" University of Galați, Faculty of Medicine and Pharmacy, Department of Dentistry
[6] "Grigore T.Popa,, University of Medicine and Pharmacy of Iasi, Romania, Faculty of Dental Medicine

*Corresponding author; *e-mail:* dentalexro@gmail.com tiutiuca_carmen@yahoo.com

ABSTRACT

Though important in current endodontic practice the issue of root canal isthmuses is usually overlooked due to the inefficient means of imagistic identification in clinical setting and appropriate treatment approach. Canal isthmuses are still the dark face of the endodontic system regarding the efficacy of conventional orthograde treatment of the root canals especially in the roots having two or more main canal where these anatomies are chiefly located. Advances in CBCT equipments with small field of image capture (FOV) open a window to an improved treatment outcome.

Key words: root canal isthmuses, mesial root of mandibular molars, mesiobuccal root of maxillary molars

INTRODUCTION

The root canal isthmus is a particular morphological structure of the endodontic system that enables the communication between two ore more canals situated in the same tooth root [1]. Actually it might be also depicted as an anatomical transverse anastomosis or ribbon-shaped corridor connecting rather frequently the main root canals [2-4]. It is noteworthy that some studies revealed two features of isthmuses, a complete or a partial one, supporting the idea that the complete isthmuses occur less frequent as compared to the partial isthmuses [3-5].

Root isthmuses may contain vital or necrotic pulp tissue. Moreover, in case of non-vital teeth is a permanent and important reservoir of bacterial biofilms, impeding on long-term basis an efficient disinfection and successful outcome of the root canal treatment [6-8].

The clinical importance of canal isthmuses was highlighted in the apical surgery as these structures are mostly visualized on the resected root surface [1,5] and require proper instrumentation, disinfection and filling approach given that a continued post-surgical leakage

finally results in treatment failure [3, 9-13].

TYPES OF ROOT CANAL ISTHMUSES

An initial report describing the internal anatomy of the mesiobuccal root in maxillary first molars located the isthmuses at 3-5 mm from the apex and highlighted that always were observed either complete or partial isthmuses at 4 mm distance from the anatomical apex [3]. However, it seems that in mesial roots of mandibular molars the isthmuses are largely located in the middle and apical third of the root [14].

Extended *ex vivo* studies on extracted teeth and *in vivo* observation on resected root surfaces during apical surgery enabled the identification of various types of isthmuses. Hence a largely accepted systematic classification introduced by Hsu and Kim, depicts five categories, as follows:

Type I, including teeth roots that present two or three independent canals in the same root;

Type II, including roots with two canals that have a definite anatomical connection;

Type III, including roots that have this time three anatomically connected canals;

Type IV, including roots where the canals are expanded to the morphological area where isthmuses are usually observed;

Type V, including roots having a continuous anatomical connection observed throughout the whole transversal section of the root [5].

Type V is considered a true connection of pulp tissue between the two main canals of the mesial root in lower permanent molars [14].

Later on Fan proposed a micro-CT based three-dimensional classification that encloses four categories, as follows:

Type I, narrow sheet connection, which is completely joining both root canals along their whole top-bottom trajectory;

Type II, narrow separate and incomplete connection between canals;

Type III, mixed shape, revealing an incomplete isthmus located above or bellow a complete isthmus;

Type IV, narrow cannular-like connection between two main canals [15].

Accurate *ex vivo* micro computed tomography (μCT) investigations of mandibular molars discovered an incidence of root canal isthmuses between17.25% and 50.25% that achieved a maximum at 3 mm level from apex (50.25%). The incidence increased from 1 mm (17.25%) to 2 mm (36.75%) and afterwards decreased to 4 mm (33%) and 5 mm (34.75%) [16].

Actually the incidence of isthmuses in the apical third of lower molars roots approximates one third of these group of teeth, which definitely challenge the prognosis of conventional endodontic treatment and chiefly the outcome of surgical management, namely the apical resection [16]. Some other studies in Chinese population revealed in lower first molars a higher incidence of isthmuses in the apical 4-6 mm of their mesial roots (81%) and underlined that this value considerably decreased by aging [17].

According to another study, based on μCT three-dimensional analysis of isthmuses it seems that is encountered a considerable difference between the first and second mandibular molars since in first molars predominate

type II (29%) and type III (21%) as compared to second molars where predominate types I (46%) and types IV (27%) [15].

It was also observed the large connection area between mesiobuccal and mesiolingual canals in Fan type I sheet-like appearance unlike the Fan type IV, where the cannular-like connection area is much reduced. Moreover, type II has no connection between mesiobuccal and mesiolingual canals. However, the incidence of isthmuses in the apical 5 mm of the mesial roots was pretty similar in lower first and second molars, 86% and 84%, respectively [15].

Due to the great variability of the canal configurations actually in the same tooth root may be found different canal configurations at any anatomic level [18, 37-41].

TYPES OF CANAL CONFIGURATION

The types of root canal configuration settle the likelihood of the isthmuses occurrence. Anatomically the configurations Weine type II (two separate root canals merging short of the apex) and Weine type III (two entirely separated root canals) are prone to develop isthmuses. This opportunity may achieve in mesiobuccal root of maxillary first molars 20% or 34% in case of Weine type II and Weine type III, respectively [3,19].

Since according previous studies 15% of isthmuses are located in the apical third of the root it should be underlined that the occurrence in case of Weine type II depends on the convergence level of two root canals [20]. Subsequent findings concerning mesiobuccal root of maxillary first molars revealed the canals convergence of 40% at 2 mm level from the anatomical apex and 30% at 3 mm and 4 mm [3].

Conversely, two separate canals meaning the likelihood of connecting isthmuses were found at 1 mm level from the apex (26%) and continuing with an increased frequency at 2 mm (40%), 3 mm (42%), 4 mm (50%), and 5 mm (58%)[3].

Moreover, of maxillary first molars in addition to canal isthmuses in the apical 2-5 mm of mesiobuccal roots it was also observed a higher prevalence of accessory canals. Particularly these accessory canals are mainly located at the palatal side of the secondary mesiobuccal canal (MB_2) in the apical 2-5 mm with a prevalence ranging from 7.9% to 10.5% [18].

The second, but presently more used classification of canal configuration belongs to Vertucci and consists in 8 types, as follows:

Type I, including roots that present only one canal and apical terminus;

Type II, including roots that present two initially separate canals merging in one common apical terminus;

Type III, including roots initially presenting one separate canal that divides in two separate canals merging afterwards in one common apical terminus (Fig.1);

Type IV, including roots that present two separate canals having each of them their own apical terminus;

Type V, including roots that initially present one separate canal which divides afterwards in two separate canals having their own apical terminus;

Type VI, including roots that initially present two separate canals merging afterwards in one canal and lastly dividing in two separate canals,

each of them having their own apical terminus;

Type VII, including roots that initially present one separate canal which divides in two separate canals merging afterwards in one common canal and again dividing in two separate canals, each of them having their own apical terminus;

Type VIII, including roots that present two initially separate canals, one of them dividing afterwards in two separate canals, having their own apical terminus and the other remaining separate until its own apical terminus [2,20].

PREVALENCE OF THE ROOT CANAL ISTHMUSES

Canal isthmuses are anatomical structures that may be found in any tooth root that have two canals such as mesiobuccal root of upper molars, mesial and distal roots of lower molars, upper and lower first and second premolars, and lower incisors [16]. However, isthmuses also occur in roots presenting a C-shaped canal [15].

The prevalence and position of root canal isthmuses was explored by different means such as microscopic inspection of the serial transverse sections of mesial roots in mandibular permanent molars and mesiobuccal roots of maxillary first permanent molars previously stained with India ink, clearing technique, staining *in situ* of the resected root surface in apical surgery with 2% methylene blue dye, endoscopic inspection during periradicular surgery, in vivo cone-beam computed tomographic study, and micro-computed tomography [1,3,6,15,16,21-24].

The lowest incidence of canal isthmuses (15%) occurs in anterior teeth [2]. In upper premolars usually the incidence depends on the distance from the anatomical apex and is as high as 16% at 1 mm and 52% at 6 mm, respectively [2]. In lower premolars the incidence of isthmuses increases with the distance from the apex, reaching 30% at 2 mm and 45% at 3 mm, respectively [2].

Initial studies dedicated to the mesiobuccal root of maxillary first molars mention the isthmuses incidence ranging between 4.9% and 52% [25,26] and this is highly dependent on canal morphology of upper molars, as first molars may have two canals up to 93% and second molars up to 73.2% of teeth [23]. In mesiobuccal root of maxillary first molars Weine type II configuration was observed in 34% and Weine type III in 46.8% out of 80.8% first molars having two canals in this root [18].

Usually the incidence of isthmuses in mesiobuccal root of the first maxillary molars at 2-6 mm level from the anatomical apex was found to be around 15%. However, its value is increasing as the distance from the anatomical apex is higher, but not over passing 6 mm. The upper value was recorded at the apical 3-5 mm with a maximum of 31.58% at 5 mm and lower incidences of 23.68% and 11.43% at 6 mm and 11.43% at 3 mm apical level, respectively [4].

In mesial roots of the mandibular molars the highest incidence of isthmuses was located at 4-6 mm from the apex, as follows: 32.43% at 6 mm, 33.33% at 5 mm and 30.3% at 4 mm. Starting with 3 mm level from the apex where was recorded an incidence of 20.59%, the values progressively decreased to 11.9% and 6.7% at 2 mm and 1 mm, respectively [4].

Particularly in endodontic surgery both, the mesiobuccal root of

upper molars and mesial roots of lower molars should be always considered as having a high incidence of isthmuses in their apical 3-4 mm [4].

The incidence of type V isthmus in mesial roots of lower permanent first molars ranged from 23% to 77.4% and in distal ones from 8% to 55 % [9]. Another study using surgical endoscope found in mesial roots of mandibular molars 29% type V isthmuses out of 83% total isthmuses as compared to the lower incidence in the distal roots, 21% type V isthmuses out of 36%, respectively [6].

ROOT CANAL ISTHMUSES IN VERTUCCI TYPE II ROOT CANAL CONFIGURATION

Vertucci type II root canal configuration in mesial roots of lower permanent first molars is placed on the second position as incidence among the other configurations (30.8%). The isthmus roof of merging mesiobuccal and mesiolingual canals is located at the apical 4-6 mm of the root [28]. Meanwhile the major diameter of the isthmus roof is progressively reduced as far as the global root shape is narrowing toward the apex [29].

In this type of configuration the mean distance between merging point of former independent mesiobuccal and lesion lingual canals and apical constriction of the terminal common canal is 4.2 mm, although in 44.55% of teeth it was measured a distance between 0 and 3 mm [28].

Of special interest in Vetucci type II root canal configuration is the presence of Fan type I isthmus [15], which is depicted as a sheet-like feature connecting the isthmus roof with the isthmus floor, which in 15% of mesial roots was situated in the apical third [29]. Moreover, at least two main apical terminuses were detected on the isthmus floor. In the majority of cases (75%) were observed two canal orifices whilst in the remaining roots, one (10%) or three (15%) canal orifices [29].

IMAGISTIC DETECTION OF ISTHMUSES

The conventional radiography cannot identify the isthmuses due to the three-dimensional positioning in the bucco-lingual (bucco-palatal) direction [29]. On the other hand, though the ability of high resolution CBCT scanners with small field of image (FOV) to visualize number, length, diameter and 3-D orientation of the root canals or to identify morphological structures like isthmuses their clinical use is rather limited by the high cost and especially by the approved radiological position statements [29,30].

No doubt that presently the micro-CT (micro-computed tomography), due to its high resolution, is currently used *ex vivo* for detailed anatomic survey of the endodontic system yielding the most accurate imagistic detection of isthmuses [21,31,32].

Unfortunately CBCT (cone-beam computed tomography), largely used *in vivo* in clinical settings, cannot deliver the same quality of imagistic details of the complex internal anatomy of the endodontic system such as such as the additional root canals separating at different locations, isthmuses, fins and other morphological features [21,22,31,32].

However, compared to digital radiography habitually used in endodontic practice, the modern CBCT equipments enabling a small field of image capture (FOV) provide the

identification of additional canals such as mesiopalatal (secondary mesiobuccal) canal in maxillary first molars, multiple canals in lower incisors or canal configurations Vertucci type I (an isthmus continuously connecting the mesiobuccal and mesiolingual canals before ending in a common apical foramen) and Vertucci type II (two initially separate mesiobuccal and mesiolingual canals merging short of the apex) [21].

A particular radiographic issue in detecting an isthmus in mesial root of mandibular first molar is the middle-mesial canal as on CBCT image this additional root canal located between mesiobuccal and mesiolingual canals sometimes may be confounded with former morphological structure [22,33].

According to a study using small field of view CBCT images having FOV of 50 x 37 mm and an isotropic voxel size of 76 μm the isthmuses in mesial root of mandibular molars were 44.3% located in the apical third, 14.8% in the middle third and 30.3% on the cervical third. In addition, a proportion of 11.5% of isthmuses were found as a continuous band from the cervix to the apex [22].

Even though is not possible to differentiate these anatomies on CBCT images it may be useful to consider them together as reaching 53.3% in the apical third of mesial root of mandibular molars in contrast to an *in vivo* survey of root end surgery that found a higher value of 83% [22].

CLINICAL CHALLENGES OF ISTHMUSES

The clinical issues regarding the root canal isthmuses are reflected in the outcome of conventional endodontic treatment, orthograde retreatments of the root canals and periradicular surgery [6].

During root canal enlargement by rotatory file systems a mixture of remnants consisting in hard and soft tissues are densely packed and pushed to the centre of isthmus area and presently no endodontic cleaning procedure either mechanical or activated irrigation can ensure the debris dislodgement [28,29].

Moreover, the accumulated tissue debris has another deleterious clinical consequence, by avoiding the appropriate seal of root canal filling. Mainly in Vertucci type II configuration of the endodontic system in roots with band-shaped isthmus the mechanical enlargement of both root canals may push alternatively the debris beneath the isthmus roof or even into canal orifices rendering improper to a complete sealing [29].

This still unavoidable procedure outcome is extremely challenging mainly in infected root canals as it was demonstrated that results in treatment failure due to surviving bacterial biofilms [29].

Despite the advances in rotary instrumentation and irrigation equipments the conventional orthograde chemomechanical treatment is still inefficient in rendering complete debridement, cleaning and disinfection of the root canals. It should be accepted that mostly the appropriate instrumentation of the isthmuses is unachievable due to their anatomies such as narrow band-shaped or cannular-like appearance [7,15,29].

Definitely in current endodontic practice to approaching Vertucii type II configuration in mandibular permanent molars have to be rigorously applied the practical rules for detecting the convergence level of mesiobuccal and mesiolingual canals in order to maintain a proper working length and avoid an

overfilling. However, in these teeth less is understood about the management of the common terminal segment located between the merging point and apical constriction of the root canal [28,29,34].

As already aforementioned, in Vertucci II configuration as a direct consequence of isthmus presence the terminal common canal has a long oval cross section at his roof located in the apical 4-6 mm, which is reduced farther toward the apex simultaneously with progressive thinning of the root [28,29].

Accordingly, this high incidence of long oval cross-sectional shape of root canals located in Vertucci II configuration, especially next to the apical constriction, emphasizes the failure risk associated to a poorer fit of apical filling as it was noticed that major diameter increased as far as the length of isthmus (distance between roof and floor) diminishes [29].

Additional to the large variability in length of the isthmuses, between 0.13-6.95 mm, another challenge for endodontic treatment mainly in band-shaped isthmuses is the possibility to be present two or more root canal apical orifices connected to the isthmus floor. This is happened rather rarely as the proportion between three and one apical foramina is 15% and 10%, respectively [29].

The clinical opportunity to elucidate these anatomies presently still can not be improved as the number of apical foramina is not influenced neither by major and minor diameter of the isthmus nor by its roundness [29]. All it was so far assessed due to μCT investigations is that the major and minor diameter values of isthmus roof are higher than of the isthmus floor. However, no differences were proved concerning their roundness [29].

In addition to the isthmus presence the instrumentation of root canals with long oval cross-sectional shape, either manual or rotary, is challenged in the great majority of cases (90%) by its coronal accessibility which enable not only a communication with two canals as in Vertucci type II configuration but also with three separate canals [29].

As far as the unique apical segment of the root canal is concerned, in clinical practice is preferred an apical enlargement up to ISO 40, which is in contrast to previous recommendation to using smaller ISO number instruments since it was proved that the larger files allow an increased access of irrigants and finally improve the cleaning of apical area [28,34].

However, in Vertucci type II configuration of mesial roots in mandibular permanent first molars this approach should be carefully evaluated in order to establish, according to the root width, whether is recommended a # 40 file with grater taper for apical enlargement, as it may result in an risky iatrogenic strip perforation [28].

Another clinical challenge occurs when two main apical canals run off the isthmus floor, as in Vertucci type V, VI and VII configuration. Even more complicated morphological issue is encountered in Vertucci type VIII configuration, illustrated by three main apical canals leaving the isthmus floor [2,29].

In all these configurations the varying angles in which these main canals leave the isthmus floor worsen or even impede the insertion of endodontic files along the natural trajectory to adequately reaching the apical constriction as the enlargement file even easy accessing the isthmus area

afterwards may uncontrolled cross it diagonally and do not approach the targeted apical canal [29].

Accordingly, the most typical issue is illustrated by comparing Vertucci type II and type VI configurations. Both of them allow the isthmus approach by two canals ending on its roof extremities. However, unlike the type II configuration where the isthmus floor is connected by a unique canal to the apical constriction, in type VI configuration from the isthmus floor are running off two separate main canals each one having its own apical constriction and a length ranging from 1.05 to 1.51 mm [2].

In everyday practice it is extremely difficult to differentiate Vertucci type II and type VI configuration as the branching level of terminal canals, due to their buccolingual orientation, might not be visualized on conventional radiographs. Neither the clinical maneuver by introducing separate gutta-percha cones in both mesiobuccal and mesiolingual canals, actually efficient in type II configuration in detection of merging point in lower permanent molars, in case of type VI configuration it proved that does not work, resulting in loss of working length and subsequent failures of the root fillings [29].

Though obviously the presence of isthmuses, in contrast to isthmus-missing root canals, still result in higher risk of endodontic surgical approaches as well, presently the modern microsurgical equipment and surgical microscope with coaxial illumination avoid to be overlooked an isthmus [7,29, 43-51].

The advances in periradicular microsurgery due to the proper illumination and magnification enable after root end resection the accurate identification and fine management of isthmuses located on the resected surface of the root by using miniature ultrasonic tips. Accordingly, in Hsu and Kim Type II, III, IV and V isthmuses these structures are easily observed, instrumented and filled. Additionally also in Types IV and V the ultrasonic tips may appropriately used [7].

Caution has to be taken in Types II and III since the isthmus trajectory is not definite and should be artificially carved on the resected root surface by placing several dots along an imaginary line between canal orifices and subsequently connecting them. This is the reason why in type II isthmus the treatment failure is higher than in type IV and V [7].

A real improvement of the surgical approach outcome in last decade relies on the bioceramic cements that are presently used for filling the retrograde preparation in order to guarantee an efficient barrier against failure by reinfection [35,36].

CONCLUSIONS

Presently regardless the location the identification of a root canal isthmus and its morphologic features is approachable only *ex vivo* by micro-computed tomography. Modern CBCT equipments with small field of image capture (FOV) open a window to identification of some anatomies such as isthmuses in clinical setting. However in clinical practice the recognition of an isthmus often encounters high challenges for conventional orthograde root canal treatment. Especially in the apical third of root canals with oval shape of the isthmus floor the accurate chemomechanical preparation appears might be doubtful. Canal isthmuses are still the dark face of the endodontic

system regarding the outcome of conservative treatment.

AKNOWLEDGEMENTS

For this paper the authors have equal contribution.

REFERENCES

1. Cambruzzi J.V., Marshall F.J., Molar endodontic surgery. J Canad Dent Assoc 1983;1:61-66.
2. Vertucci F.J., Root canal morphology and its relationship to endodontic procedures. Endod Topics 2005;10:3-29.
3. Weller R.N., Niemczyk S.P., Kim S., Incidence and position of the canal isthmus. Part 1. Mesiobuccal root of the maxillary first molar. J Endod 1995;21:380-383.
4. Teixeira F.B., Sano C.L., Gomes B.P.F.A., Zaia A.A., Ferraz C.C.R., Souza-Filho F.J., A preliminary *in vitro* study of the incidence and position of the root canal isthmus in maxillary and mandibular first molars. Int Endod J 2003;36:276-280.
5. Hsu Y., Kim S., The resected root surface: the issue of canal isthmuses. Dent Clin N Am 1997;3:529-540.
6. Von Arx T., Frequency and type of canal isthmuses in first molars detected by endoscopic inspection during periradicular surgery. Int Endod J 2005;38:160-168.
7. Kim S., Jung H., Kim S., Shin S.J., Kim E., The influence of an isthmus on the outcomes of surgically treated molars: a retrospective study. J Endod 2016;42:1029-1034.
8. Paqué F., Laib A., Gautschi H., Zehnder M., Hard-tissue debris accumulation analysis by high-resolution compared tomography scans. J Endod 2009;35:1044-1047.
9. Susin L., Liu Y., Yoon J.C., Parente J.M., Loushine R.J., Ricucci D., Bryan T., Weller R.N., Pashley D.H., Tay F.R., Canal and isthmus debridement efficacies of two irrigant agitation techniques in a closed system. Int Endod J 2010;43:1077-1090.
10. Adcock J.M., Sidow S.J., Looney S.W., Liu Y., McNally K., Lindsey K., Tay F.R., Histologic evaluation of canal and isthmus debridement efficacies of two different irrigant delivery techniques in a closed system. J Endod 2011;37:544-548.
11. Neelakantan P., Devaraj S., Jagannathan N., Histologic assessment of debridement of the root canal isthmus of mandibular molars by irrigant activation techniques *ex vivo*. J Endod 2016;42:1268-1272.
12. Keles A., Alcin H., Sousa-Neto M.D., Versiani M.A., Supplementary steps for removing hard tissue debris from isthmus-containing canal systems. J Endod 2016;42;1677-1682.
13. Pereira T.C., Boutsioukis C., Dijkstra R.J.B., Petridis X., Versluis M., de Andrade F.B., van de Meer W.J., Sharma P.K., van der Sluis L.W.M., So M.V.R., Biofilm removal from a simulated isthmus and lateral canal during syringe irrigation at various flow rates: a combined experimental and computational fluid dynamics approach. Int Endod J 2021;54:427-438.
14. De Pablo O.V., Estevez R., Peix Sanchez M., Heilborn C., Cohenca N., Root anatomy and canal configuration of the permanent mandibular first molar: a systematic review. J Endod 2010;36:1919-1931.

15. Fan B., Pan Y., Gao Y., Fang F., Wu Q., Gutmann J.L., Three-dimensional morphologic analysis of isthmuses in the mesial roots of mandibular molars. J Endod 2010;36;1866-1869.
16. Mannocci F., Peru M., Sheriff M., Cook R., Pitt Ford T.R., The isthmuses of the mesial root of mandibular molars: a micro-computed tomographic study. Int Endod J 2005;38:558-563.
17. Gu L.S., Wei X., Ling J.Q., Huang X., A microcomputed tomographic study of canal isthmuses in the mesial root of mandibular first molars in a Chinese population. J Endod 2009;35:353-356.
18. Jung I.Y., Seo M.A., Fouad A.F., Spangberg L.S.W., Lee S.J., Kim H.J., Kum K.Y., Apical anatomy in mesial and mesiobuccal roots of permanent first molars. J Endod 2005;31:364-368.
19. Weine F.S., Healey H.J., Gerstein H., Evanson L., Canal configuration in the mesiobuccal root of the maxillary first molar and its endodontic significance. Oral Surg 1969;28:419-425.
20. Vertucci F.J., Root canal anatomy of the human permanent teeth. Oral Surg 1984;58:588-589.
21. Ordinola-Zapata R., Bramante C.M., Versiani M.A., Moldauer B.I., Topham G., Gutman J.L., Nunez A., Hungaro Duarte M.A., Abella F., Comparative accuracy of the clearing technique, CBCT and micro-CT methods in studying the mesial root canal configuration of mandibular first molars. Int Endod J 2017;50:90-96.
22. Tahmasbi M., Jalali P., Nair M.K., Barghan S., Nair U.P., Prevalence of the middle mesial canals and isthmi in the mesial root of mandibular molars: an in vivo cone-beam computed tomographic study. J Endod 2017;43:1080-1083.
23. Endal U., Shen Y., Knut A., Gao Y., Haapasalo M., A high-resolution computed tomographic study of changes in root canal isthmus area by instrumentation and root filling. J Endod 2011;37:223-227.
24. Villas-Boas M.H., Bernardineli N., Cavenago B.C., Marciano M., Cario-Perochena A., Moraes I.G., Duarte M.H., Bramante C.M., Ordinola-Zapata R., Micro-computed tomography study of the internal anatomy of mesial root canals of mandibular molars. J Endod 2011;37:1682-1686.
25. Green D., Double canals in single roots. Oral Surg 1973;35:689-696.
26. Pineda F., Roentgenographic investigation of the mesiobuccal root of the maxillary first molar. Oral Surg 1973;36:253-260.
27. Stropko J.J., Canal morphology of maxillary molars: clinical observations and canal configurations. J Endod 1999;25:446-450.
28. Keles A., Keskin C., Mandibular first molar teeth with Vertucci Type II configuration by means of micro-computed tomography. J Endod 2017;43:481-485.
29. Keles A., Keskin C., A micro-computed tomographic study on band-shaped root canal isthmuses, having their floor in the apical third of mesial roots of mandibular first molars. Int Endod J 2018;51:240-246.
30. Patel S., Durack C., Abella F., Roig M., Shemesh H., Lambrechts P., Lemberg K., European Society of Endodontology position statement: the use of CBCT in endodontics. Int Endod J 2014;47:502-504.

31. Iliescu Al.A., Gheorghiu I.M., Iliescu M.G., Examenul imagistic în endodonţie. In: Iliescu A. (ed), Tratat de endodonţie - vol.II, Ed.Medicală, Bucureşti, 2014, pag.931-959.
32. Iliescu Al.A., Tuluş G., Perlea P., Gheorghiu I.M., Iliescu M.G., Manolea H.O., Bioceramics and endodontics: present and expectations in clinical use. Trans Tech Publications 2017;376:29-38.
33. Filip, C., Socolov, D.G., Albu, E.,Filip, C., Serban, R., Popa, R.F. , Serological Parameters and Vascular Investigation for a Better Assessment in DVT during Pregnancy-A Systematic Review, Feb 2021, Medicina-Lithuania 57 (2)
34. Gireada, R., Socolov, D., Mihalceanu, E., Matasariu, R, Ursache, A , Akad, M , Bujor, I ,Scripcariu,I , Popa,R.F. ,Socolov,R. ,The Additional Role of the 3-Vessels and Trachea View in Screening for Congenital Heart Disease, Feb 2022 , Medicina-Lithuania, 58 (2)
35. Gradinaru, I.,Buzea, C.G. , Eva, L. , Agop, M., Ochiuz, L. Solovastru, L.G. , Popa, R.F., Malignant Invasion Model with Small Amount of Diffusion in the Framework of Scale Relativity Theory, 2015,Reviews in Theoretical Science 3 (4) , pp.399-417
36. Mirestean, C.C. ,Crisan, A. , Buzea, C. , Iancu, R.I., Iancu, D.T. , Synergies Radiotherapy-Immunotherapy in Head and Neck Cancers. A New Concept for Radiotherapy Target Volumes-"Immunological Dose Painting", 2021,Medicina-Lithuania 57 (1)
37. Murariu, A., Dinu, C., Forna, D.A. , Stefanescu, V. , Topor, G .,Forna, N.C. , Fotea, S. , Gurau, G. , Iordache, C. , Composite Resins - Multifunctional Restorative Material and Practical Approaches in Dental Field, Jun 2020, Materiale Plastice 57 (2) , pp.276-284
38. Bolat, M. Nicolae, B.D. , Baciu, E.R. , Forna, D.A., Bosinceanu, D.G. ,Forna, N.C. , Partial Dentures-Succeses and Failures, Oct-dec 2017 ,Romanian Journal of Oral Rehabilitation 9 (4) , pp.93-96
39. Gradinaru, I., Hurjui, L. , Macovei, G. , Antohe, M.E., Interrelations between skeletal removable prostheses and the improvement of patient' s quality of life, 2019, Romanian Journal Of Oral Rehabilitation 11 (4) , pp.85-92
40. Dascalu, CG , Antohe, M.E. , Golovcencu, L., Zegan, G. , Interaction Schemes for the Analysis of Combined Action of Risk Factors, 6th IEEE International Conference on E-Health and Bioengineering (EHB), 2017 IEEE INTERNATIONAL CONFERENCE ON E-HEALTH AND BIOENGINEERING CONFERENCE (EHB) , pp.462-465
41. Virvescu D. , Fratila D.N., Physiological and pathological aspects of the aging process, medicine and materials ,Volume 2, Issue 1, 2022: 39-44 | ISSN: 2784 – 1499 & e-ISSN: 2784 – 1537
42. Ciocan-Pendefunda, A.A. ; Apostu, A. M.; Antohe, M. E.; et al., **T**he aspects of morpho - functional restoration of endodontically treated teeth**,** Romanian Journal of Oral Rehabilitation, Volume: 2020), 2 (12 , Pages: 128-136
43. Petcu, A .,Savin,C.,Balan, A., Mihalas, E., Gavrila, L.M. , Balcos, C., Antohe, M.E., Biomaterials Involved in Frontal Area Restorations in Pediatric Dentistry, Dec 2018, | Revista de Chimie, 69 (12) , pp.3473-3476

44. Leca, D., Calin, A.M ., Earar, K , Nechita, A., Chiscop, I. Dorobat, G., Dorobat, C., Ilie, M., Debita, M., Biochemical Changes of Cerebrospinal Liquid in Viral Meningitis, Dec 2015 , Revista de Chimie 66 (12) , pp.2005-2008
45. Dirtu, D., Lungu, N.C., Chirita,P., et al., Synthesis of Novel 4-(3,5-Dibromo-2-hydroxyphenyl)-5-Methyl-1,3-Dithiol-2-ylideneDerivatives, Rev.Chim. ,67, no. 3 , 2016, p.: 534-537
46. Earar, K., Gradinaru,S., Pariza,G., et al., Effect of the Sterilization Procedures of Different Surgical Meshes for Abdominal Surgery, Rev.Chim., 68(8),2017, Pages: 1868-1873
47. Armencia, A.O. , Hurjui, J. , Tarniceriu C.C. Lese, A. , Feier, R. , Scutariu, M.M. Balcos, C., The study of roughness and resistance to corrosion of dental alloys in the oral environment, Romanian Journal of Oral Rehabilitation,2020, Volume 12, Issue 2, Page 190-197
48. Iliescu Al.A., Gheorghiu I., Iliescu M.G., Mironiuc-Cureu M., Comes C., Iliescu A., Imagistic examination in chronic apical periodontitis. Retroalveolar radiography versus CBCT. Ro J Stomatol 2014;60:64-66.
49. Perlea P., Nistor C.C., Imre M., Gheorghiu I.M., Iliescu Al.A., Middle mesial canal of the permanent mandibular first molars: an anatomical challenge directly related to the outcome of endodontic treatment. Rom J Morphol Embryol 2017;58:1083-1089.
50. Peters O.A., Koka R.S., Preparation of coronal and radicular space. In: Ingle J.I., Bakland L.K., Baumgartner J.C., Ingle Endodontics 6, BC Deker, Hamilton, 2008,pag.877-991.
51. Iliescu Al.A., Perlea P., Tulus G., Iliescu M.G., Gheorghiu I.M., Manolea H.O., Bioceramics in endodontics. In: Iulian Antoniac. Bioceramics and biocomposites: from research to clinical practice. 1st Edition, Wiley, Hoboken, New Jersey, 2019, pag.241-290.

Fig.1 – Vertucci type III root canal configuration after root canal filling (25).