Ceramics-based sealers as new alternative to currently used endodontic sealers

Authors_ Deyan Kossev & Valeri Stefanov, Bulgaria

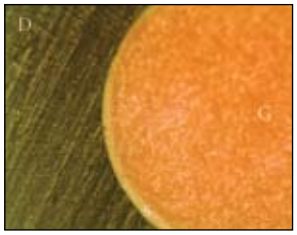

Fig. 1_Polarisation microscopy. Horizontal cut. Dark green — dentin, white — bioceramic-based sealer iRoot SP, orange — gutta-percha cone.

The most ideal outcome of an endodontic treatment is hard tissue closure, which permanently separates the root canal content – the root filling – from the periapical tissues and prevents chronic irritation and foreign body reactions by material components.[7] Good instrumentation and cleaning of root canal combined with perfect hermetic closure of its apical third are decisive preconditions for achieving of full closure of root canal apical orifice with cementoid tissue. Closure of the root canal in this way ensures non-problematic and long-term function of the root in naturally wet environment surrounding it.

Today's "golden" standard for endodontic treatment are warm condensation multi phase (gutta-percha – sealer) techniques. These techniques, however, result in a friction fit, "cork-in-the-bottle" type sealing only. In the era of adhesive techniques in dentistry we have an endodontic standard, which lacks adhesion and chemical bond between root canal dentin walls and root canal filling materials. Visualization of sealer "puff" in periapical space on radiography does not give enough grounds to say that seemingly adequate root canal filling is an absolute guarantee of successful healing result.[1] Shrinking of gutta-percha after the end of warm condensation and lack of adhesion of the root filling materials to dentinal root canal walls are factors creating enough predispositions for micro leakage. The known fact is that the human body's immune system can easily deal with this situation when titer of microorganisms is low. That capability of immune system is demonstrated by lack of periapical pathology and subjective complaints. This equilibrium can easily be destroyed when due to different reasons human body's reactivity is changed and existing balance is "pushed" toward appearance of pathologic periapical changes.

That is why the quest for endodontic sealers that adhesively and chemically bond to root canal walls continues. Clinical use of Bis-GMA based sealers in combination with polycaprolactone made cones is a promising step ahead,[5,10] but in the area of the root canal apical third these materials are in constant contact with wet environment of periodontium and are subjected to action of enzyme systems there. Reported data about alkaline and enzyme hydrolysis of polycaprolactone and the shrinkage of Bis-GMA based sealer question the long-term stability of apical third hermetic seal achieved by these endodontic sealers.[2,8,9]

'Endodontic grafting'

Filling of the root canal apical third must be looked upon separately from the filling of the rest of the canal having under consideration the active and constant metabolic processes occurring in the periapical area. Special attention must be paid to the interface formed between dentinal root canal walls, gutta-percha and sealer on one side and periodontium and body fluids on the other side. Long-term hermetic sealing of apical third achieved in constantly wet environment is an obligatory condition to ensure lack of microbial growth. Another extremely important factor promoting hard tissue closure of the canal is presence of osseoconductivity as sealer's feature. Perfect and lasting in wet environment hermetic seal of apical third combined with osseoconductivity of endodontic sealer ensure

conditions for hard tissue closure of root canal apical orifice in time. Filling of the root canal with ceramic sealer, which due to its osseoconductivity action promotes the physiological closure of the canal by cementoid hard tissue, can be called "endodontic grafting." Such endodontic grafting can ensure the lasting root's health while it constantly remains in contact with body fluids.

The use of bioceramic-based sealers with their features – osseoconductivity, hydrophylity, adhesiveness and chemical bonding to root canal dentinal walls – appears to be an effective approach to eliminate (Fig. 1) on long term, the microspace, otherwise remaining between the root canal walls and the materials filling the root canal. Such microspace is a potential place for possible microbial growth, because of microleakage observed with other kind of sealers.

Sealers for 'endodontic grafting'

Endodontic sealers that set hard and are stable in constantly wet environment are :

a. Recently created calcium – silicate – phosphate-based bioceramic nano-compositions – BioAggregate, iRoot SP and iRoot BP (IBC, Canada).

b. MTA-based products – "MTA – Angelus" (ANGELUS, Brazil), ProRoot (Dentsply, USA), Aureoseal (OGNA, Italy).

The common feature of all these products is that when used to fill the apical third of the root canal, they guarantee adhesive hermetic seal.[4] They do not get destroyed during their hardening and afterward while being constantly in contact with the wet periapical environment. They are very stable in time. Ceramic-based sealers ensure much better apical seal than IRM, amalgam or Super EBA materials, and this excellent seal is combined with excellent biocompatibility and significant stimulation of periodontal regeneration.[5,6] Until recently the application of all these materials, except for iRoot SP and iRoot BP, required significant widening of the root canal apical third – up to #60–70 – and use of specially developed instruments to carry the materials to apical third of the canal. These purely technological limitations were reducing ceramic-based materials use as regular antegrade root canal filling materials.

The first author has developed an innovative method for filling of apical third of the root canal with MTA- and bioceramic-based sealers he has called the "capillary condensation" technique. This new technique does not require enlargement of the canal's apical third more than # 35-40 / 04. Apical third of canal space is widened based on its original size and shape only.

Method for 'capillary condensation' of ceramics-based endodontic sealers to fill the root canal

Method comprises of several stages:

I. Preparation of "coronal reservoir" from which ceramic sealer to be condensed aside to canal walls and toward and into canal's apical third so that to seal the canal's apical orifice.

Using RGG or GG drills, the coronal third of the root canal is conically widened to form a "coronal reservoir," which is subsequently to be filled with MTA, BioAggregate, iRoot SP or iRoot BP material.

From this point on, there are two different approaches:

A. "Coronal reservoir" is filled directly with ready-to-use material packed into syringes (iRoot SP or iRoot BP). Mini applicators included in the package are used for direct filling of reservoir with factory premixed material.

B. Powder-like ceramic material (MTA or bioceramic-based BioAggregate) is mixed with distilled water to form a paste with suitable viscosity to allow carrying it into the "reservoir" by plastic carrier designed by the author. Micro applicator handle, with "fluffy" head cut, may be used instead, too. (Fig. 2)

The dentist can fold the plastic carrier as needed to make it suitable to easily get inside the "coronal reservoir." Small portions of "ex tempore" mixed sealer are carried into the "reservoir" until it gets full. It is important to work in constantly slightly wet root canal. Before putting next small portion of MTA or BioAggregate sealer into reservoir, the dentist visually controls the moisture of the sealer mass. If necessary the tip of the plastic carrier is wetted with distilled water and put inside the reservoir to increase the humidity of the sealer mass inside. Thus the risk of drying of material at the bottom of the reservoir is avoided and ceramic sealer is prepared for condensation further inside the root canal.

II. "Capillary condensation" of the sealer to fill the root canal

This stage is valid for both (A and B) types of ceramic sealers. Condensation of the sealer is made with "condensor" – an instrument designed by the authors (Fig. 3). The basic rule is correctly chosen instrument to get freely inside into root canal within 1 mm less than canal's measured working length (WL). In case of straight canals the number (#) of the instrument must be one number (#) less than MAF. In slightly or severely curved canals the number (#) of the used instrument must be two to three numbers (#) less than MAF. It is preferable to use NiTi made instruments, especially in curved canals.

By pushing the condensor slowly in and then getting it out, without taking it totally out of "coronal reservoir," the sealer is condensed inside the canal, aside to canal's walls and at the same time toward its apical orifice, down to previously defined depth of 1 mm less than WL. Condensation must be done slowly and with maximum possible amplitude of the "push-in" and "take-out" movements (Fig. 4).

Fig. 2_Plastic applicator inside simulated root canal "coronal reservoir."

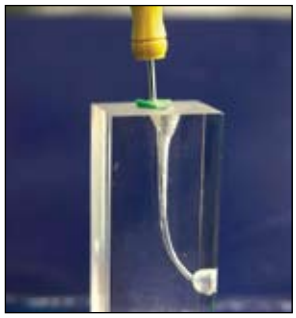

Fig. 3_Condensor inside simulated root canal down to 1 mm less than WL.

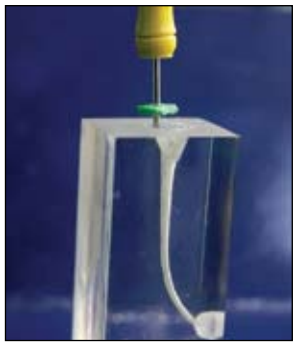

Fig. 4_Condensor in the moment of "take-out" movement start (compare to Fig. 3).

When condensing the powder-like ceramic sealers (MTA-based or BioAggregate) that are mixed "ex tempore" before use, there should not be a tactile feeling of "tightening" of the instrument inside the canal during condensation. If such a feeling appears, the dentist must take the condensor totally out of the canal and must wet the tip of the instrument with water before inserting it inside the canal again. The total time for the sealer's condensation is approximately 10–15 seconds. Between 12 and 15 "push-in/take out" movements are needed to achieve a good filling of the canal's apical third and to ensure good adhesion of the sealer to canal's walls, too. Ten seconds after the start of condensation (approximately 10 "push-in" movements) the dentist must take the instrument out of canal. There should not be hardened aggregates on the instrument's surface, but only liquid white solution. Then one must look at the bottom of the "coronal reservoir." If there is a "black hole," this means more water must be added to the sealer inside the reservoir. The tip of plastic carrier is wetted with water and is put inside the reservoir. This is to be immediately followed by adding one more small portion of the mixed sealer into the reservoir. Important note: Do not add water when using bioceramic-based iRoot SP and iRoot BP sealers! Only the additional portion of sealer must be added when using iRoot SP or iRoot BP! These two sealers are supplied premixed and "ready to use" and do not need additional water, they have already been factory mixed to optimal viscosity to fill the canal properly.

III. Insertion of gutta-percha cones

At the moment of choosing the correct size condensor, the dentist must also choose the same size gutta-percha master cone. Inserting of the gutta-percha cone inside the canal will serve three functions simultaneously.

A. It will finish the condensation of the sealer inside the root canal and will make sealer layer along the canal's length even. It will eliminate any air still entrapped inside the canal, too.

B. It will create a pliable space inside the canal with which to accommodate the stress created by expansion of the ceramic sealers during their hardening. Bioceramic-based sealers BioAggregate, iRoot SP and iRoot BP have significant expansion of 0.20 percent.

C. By inserting the gutta-percha cones the possibility for re-entering the canal is maintained, and easier preparation of calibrated "bed," for cementing a fiberglass post inside, is ensured.

The master gutta-percha cone is inserted slowly with "push-in" and "take-out" motions down to 1 mm less than WL. Additional smaller diameter gutta-percha cones may be added, if necessary. The ends of gutta-percha cones extending out of the root canal are cut and cones are condensed with round head metal instrument. During gutta-percha condensation excessive water and excessive sealer remnants are also pushed outside and are wiped out with small cotton pellet. A temporary filling is placed in the tooth cavity. After the ceramic sealer is hardened, preferably 24 hours after canals are filled, the final restoration is made.

Clinical application of 'capillary condensation' technique

1. Filling with MTA

Fig. 5a_Before (Rx made on Nov. 24, 2006)

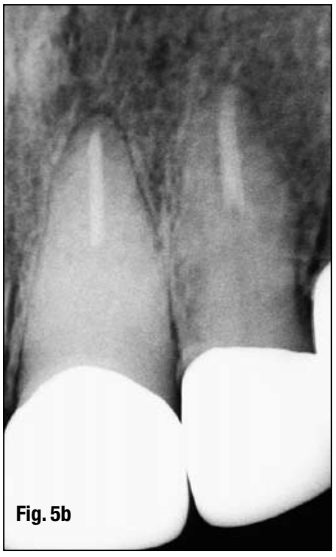

Fig 5b_After (Rx made on March 30, 2007)

Fig. 6a_Before (Rx made on June 8, 2006)

Fig. 6b_After (Rx made on June 25, 2006)

2. Filling of root canals with BioAggregate.

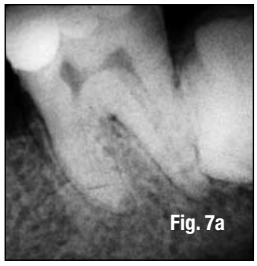

Fig. 7a_Before.

Fig.7b_After — three mesial canals filled.

Fig. 9a_Before.

Fig. 9b_After.

3. Filling of root canals with iRoot SP. Note excellent radiopacity of this bioceramic sealer.

Fig. 10a_Before.

Fig. 10b_Three weeks after filling.

Fig. 11a_Before.

Fig. 11b_One month after the filling.

Fig. 8a_Before.

Fig. 8b_After — see the difference in radiopacity of gutta-percha cones and bioceramic-based BioAggregate sealer (arrows).

Features of ceramic-based endodontic sealers

1. Ceramic-based sealers are highly hydrophilic and have low contact angle. These features allow them to spread easily over the dentin walls of the root canal and to get inside and fill the lateral micro canals, too. Thus necessity to instrument the canals with 06 or higher taper becomes no longer needed. Tooth tissues are preserved, and risk of root fractures is reduced.

Very well-filled lateral micro canals can be seen on experimental samples. Filling is done with iRoot SP (Figs. 12, 13).

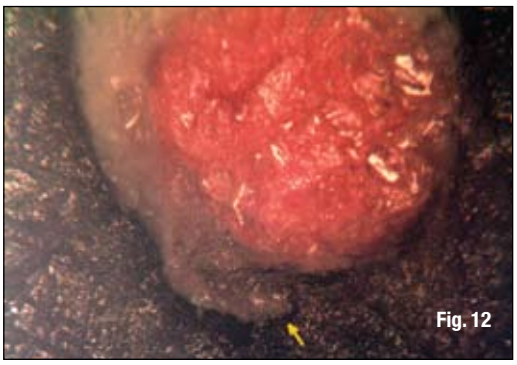

Fig. 12_Small micro canal filled with iRoot SP (arrow). Horizontal cut. Polarisation microscopy. Black — root dentin, white — iRoot SP sealer, orange — gutta-percha cone.

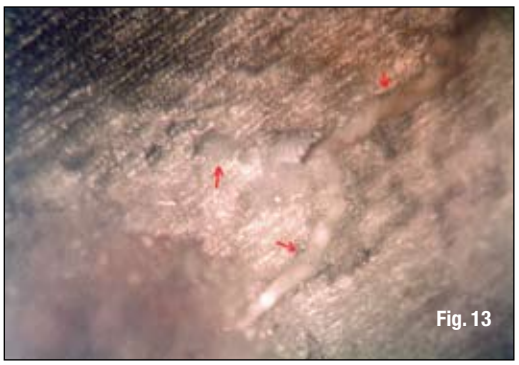

Fig. 13_Lateral micro canal with an additional branch perfectly filled by iRoot SP sealer (arrows). Horizontal cut. Polarisation microscopy. Black — root dentin, white — iRoot SP inside micro canal.

2. During setting hard ceramic-based sealers expand. Expansion of BioAggregate and iRoot SP and iRoot BP is significant – 0.20 percent. These new bioceramic sealers also form chemical bond with the canal's dentin walls. That is why no space is left between the sealer and dentin walls. This is well demonstrated by light polimerization microscopy and much better demonstrated by large magnification scanning

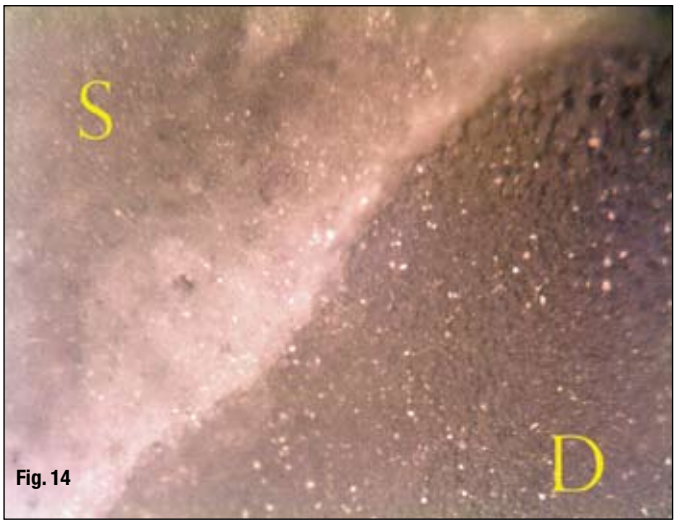

Fig. 14_Polarisation microscopy. Horisontal cut. S — Bioceramic sealer iRoot SP. D — Root dentin.

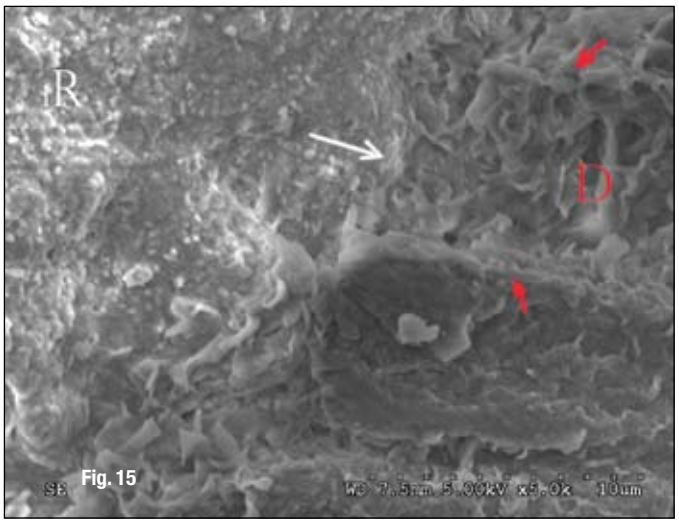

Fig. 15_SEM x 5000. iR — bioceramic sealer iRoot SP. D-dentinal tubules of root canal wall. Points bar is equal to 10 microns. Distance between dots is equal to 1 micron only. White arrow shows the interface between sealer and dentin without presence of any voids because of chemical bond between dentin and sealer.

electron microscopy (Figs. 14, 15).

3. Bioceramic-based sealers are capable of achieving fast alleviation of the pain syndrome in cases of acute periapical inflammation. After appropriate instrumentation and cleaning of the root canal, followed by immediate filling with iRoot SP, pain rapidly diminishes and most often is totally gone within a period of 50 minutes to few hours.

4. In cases of MTA-based materials extrusion outside the root canal is associated with severe pain felt by the patient. When bioceramic-based sealers BioAggregate or iRoot SP are extruded, the pain is relatively small or totally absent. Such lack of pain may be explained with the characteristics of these new materials. During hardening they "produce" hydroxylapatite and after the end of hardening process they exhibit the same features as non-resorbable hydroxylapatite-based bioceramics used for bone replacement in oral surgery. Due to the hydroxylapatite formed, they are also osseoconductive (Figs. 16–18).

Fig. 16a_Right after filling (Rx made on Dec. 19, 2008).

Fig. 16b_Note significant bone recovery only 20 days after filling (Rx made on Jan. 9, 2009).

Fig. 17a_Large diffuse exacerbated periapical bone lesion. After instrumentation and cleaning root canals were filled with CaOH for three days with no improvement. After third day CaOH was removed and canals were cleaned and filled directly with iRootSP. Pain was gone in several hours after the filling with iRootSP was done and palpable intraorally subperiosteal swelling was resolved totally within 24 hours (Rx made on Dec. 16, 2008).

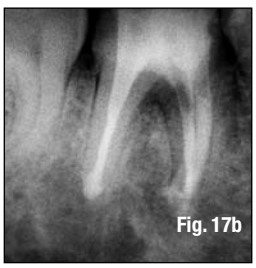

Fig. 17b_Only three weeks later, a significant bone lesion improvement can be seen, too (Rx made on Jan. 9, 2009).

Fig. 18a_Periapical bone lesions around roots of lower incisors (Rx made on Jan. 7, 2008).

Fig. 18b_Significant bone recovery is seen just about one month after canals were instrumented, cleaned and filled with BioAggregate. Lateral incisor was instrumented, cleaned and filled with iRootSP due to an acute pulpitis (iR). In fact second radiography was made to evaluate the filling with iRootSP, but revealed nice bone healing around central incisors for such a short period of time, too (Rx made on Feb. 11, 2008).

Fig. 20_Canal filled with iRoot SP.

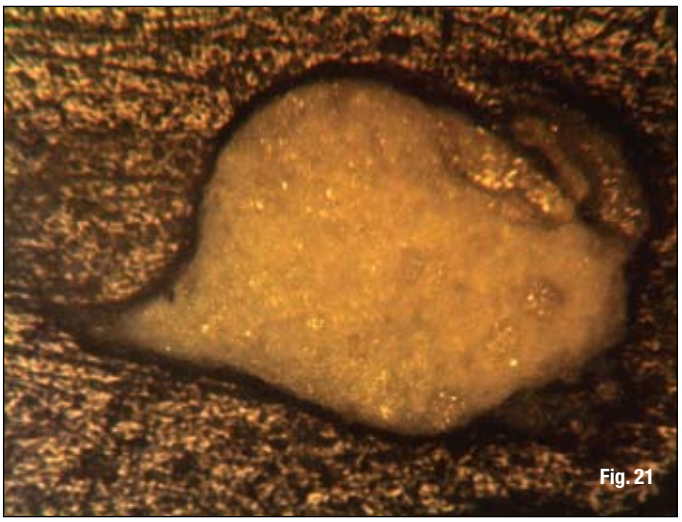

Fig. 21_Canal filled with BioAggregate.

5. MTA-based materials and BioAggregate have quite poor radiopacity, different from bioceramic based iRoot SP and iRoot BP sealers. This difference is easily demonstrated by the following experiment. Root canals of extracted teeth have been instrumented with TF files (SybronEndo) and cleaned. Two of the canals were filled with iRoot SP, and the other two with BioAggregate, respectively (Fig. 19). Note the excellent radiopacity of iRoot SP (left) compared to BioAggregate (right).

When roots' apical thirds of same tooth, which does not contain gutta-percha, were cut and investigated under polarization microscopy, no difference in quality of achieved canal seal have been found (Figs. 20, 21).

Based on the above findings, it is preferable that bioceramic-based iRoot SP sealer be used for "endodontic grafting" (i.e., filling of root canals) because of its excellent radiopacity. It is not possible to verify the quality of root canal filling achieved with MTA-based materials or BioAggregate using radiographies only, due to poor radiopacity of these materials.

Discussion

Cantatore[3] define ideal conditions for endodontic sealers as follows:

1. Adequate consistency and adhesion to dentinal walls
2. Adequate working time.
3. Capacity to produce a hermetic seal.
4. Easy handling.
5. Radiopacity.
6. Expansion at the time of set.
7. Antibacterial action.
8. Biocompatibility.
9. Insolubillity in tissue fluids.
10. To allow retreatment of the canal.
11. Do not discolor dental tissues.
12. No antigenic action.
13. No mutagenic action.

Sealers routinely used in endodontics and based on epoxy resin, calcium hydroxide, glass ionomer, zinc oxide – eugenol, formalin-resorcine pastes, polycaprolactone and Bis-GMA ± do not meet one or more of above listed requirements.

MTA-based materials (MTA-Angelush, ProRoot – Dentsply, Aureoseal – OGNA) exhibit good adhesion to dentinal walls of root canal, but until recently they required very big enlargement of canal's apical third to be easily applied. With the method for "capillary condensation" developed by the first author for filling of root canals, these materials became easy to apply into the canal space.

Bioceramic-based materials having nano-sized particles (BioAggregate, iRoot SP, iRoot Bp) achieve excellent adhesion to the canal's dentinal walls and, more importantly, form a chemical bond with dentin. Structure of these materials during their mixing with water allows a very good consistency to be achieved (BioAggregate) or optimal consistency is already guaranteed by manufacturer by offering premixed "ready-to-use" products (iRoot SP, iRoot BP). All ceramic-based sealers are hardening slowly. This feature gives the dentist the possibility to do corrections of the filling, if control radiography has revealed any problems. Due to their hydrophilicity and low contact angle, all ceramic-based sealers achieve extremely good hermetic seal. All MTA- and bioceramic-based sealers are quite easy to use when the dentist has mastered the "capillary condensation" technique for filling of root canals. MTA-based materials and BioAggregate have poor radiopacity, differently from iRoot SP and iRoot BP. All ceramic-based sealers expand during the time of set. They exhibit potent antimicrobial action, too. All ceramic sealers are biocompatible and insoluble in tissue fluids. They have not demonstrated until now any antigenic or mutagenic action. When used in combination with gutta-percha cones, re-entering of the canal space is possible and a calibrated "bed"

may be drilled to accommodate a fiberglass post into the canal.

Conclusions

Potent antibacterial activity, absolute biocompatibility, osseoconductivity, ability to achieve excellent hermetic seal in constantly wet environment, formation of chemical bond with dentin, insolubility in tissue fluids, expansion during time of set, very good radiopacity, easy handling are the features that make bioceramic-based sealers an up-to-date alternative to current "golden" standard of multi-phase (gutta-percha – epoxy sealer) warm techniques.

Thanks to its very good features, iRoot SP is currently probably the best product to be used with "capillary condensation" technique for "endodontic grafting" of apical third and for hermetic sealing of complex root canals space.

Aknowledgments

Scanning electron microscopy has been kindly offered for use in this article by IBC – Canada. It is the property of INNOVATIVE BIOCERAMIX.

The authors would like to express their thankfulness to Marlena Tchimpilska, Medical Library, Medical University of Pleven, for help with literature search; Vesselin Nedelcev for preparation of polarisation microscopy samples; and to Elena Stoyanova, dental assistant.

References:

1. Bergenholz, G. et al. Controversies in Endodontics / G. Bergenholz, L. Spangberg. // Crit. Rev. Oral Biol. Med, 15, 2004, 2 : 99–114.
2. Bodrumlu, E. et al. Apical leakage of Resilon obturation material / E. Bodrumlu, U. Tunga. // J. Contemp. Dent. Pract., 7, 2006, 4 : 45–52.
3. Cantatore, G. Obturation canalaire et preservation radiculaire / G. Cantatore. // Realites Cliniques, 15, 2004, 1 : 33–53.
4. Gohring, K.S. Indications for use of MTA, a review. Part 1: Chemical, physical and biological properties of MTA / K.S. Gohring, B. Lehnert, M. Zehnder. // Schweiz. Monatsschr. Zahnmed., 114, 2004, 2 :143–53.
5. Maltezos, C. et al. Comparison of the sealing of Resilon, Pro Root MTA, and Super-EBA as root-end filling materials: a bacterial leakage study / C. Maltezos, G.N. Glickman, P. Ezzo, J. He. // J. Endod., 32, 2006, 4 :324–327.
6. Rafter, M. Apexification: a review / Mary Rafter // Dental Traumatology, 21, 2005, 1 : 1–8.
7. Ricucci D. et al. Apical limit of root canal instrumentation and obturation : Part 2. A histological Study / D. Ricucci, K. Langeland. // Int. Endod. Journal, 31, 1998: 394–409.
8. Tay, F.R. et al. Suseptibility of a polycaprolactone based root canal filling material to degradation. I. Alkaline Hydrolysis / F.R. Tay, D.H. Pashley, M.C. Williams, R. Raina, R.J. Loushine, R.N. Weller, W.F. Kimbrough, N.M. King. // J. Endod., 31, 2005 : 593–598.
9. Tay, F.R. et al. Susceptibility of a polycaprolactone-based root canal filling material to degradation. II. Gravimetric evaluation of enzymatic hydrolysis / F.R. Tay, D.H. Pashley, C.K. Yiu, J.Y. Yau, M. Yiu-fai, R.J. Loushine, R.N. Weller, W.F. Kimbrough, N.M. King. // J. Endod., 31, 2005, 10 : 737–41.
10. Verissimo, D.M. et al. Comparison of Apical Leakage between Canals Filled with Gutta-Percha/AH-Plus and the Resilon/Epiphany System, When Submitted to Two Filling Techniques / D.M. Verissimo, M. Sampaio do Vale, A.J. Monteiro. // J. Endod., 33, 2007, 3 :291–294.

_About the authors

Dr. Deyan Kossev

Dr. Deyan Kossev graduated from the Dental Faculty of Medical University of Plovdiv in 1991. Between 1991 and 1995 he practiced as a GP, and between 1995 and 2001 as a staff member of Oral Surgery Department of Municipal Dental Clinic, Kazanlik. Since 2002 he has been working exclusively in private practice, specializing in endodontics, restorative dentistry and implantology. Kossev may be contacted at drkosev@gmail.com.

Dr. Valeri Stefanov

Dr. Valeri Stefanov graduated from the Dental Faculty of Medical Academy of Sofia in 1982. He practiced as a GP from 1982 to 1986 at the Dentistry Department of Municipal Hospital of Levski. Between 1986 and 1992 he practiced as an oral surgeon at OMS Department of Municipal Hospital of Pleven. Since 1993 he has been exclusively in private practice, specializing in oral surgery, implantology, endodontics and restorative dentistry. In 1990 Stefanov was awarded the Leibinger Prize for extraordinary contribution to the specialty of OMFS by the European Association of Cranio-Maxillo-Facial Surgery. He is an honorary member and diplomate of the German Society for Implant Dentistry (DGZI). He has been a member of Editorial Board of IJOMFS. He is founder and former president of the Bulgarian Society of Oral Implantology and Biomaterials. He lectures nationally and internationally. Stefanov may be contacted at stefanov.valeri@abv.bg.