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2 | November 2016 | Vol. 30 |

GIORNALE ITALIANO DI ENDODONZIA

Società Italiana di Endodonzia

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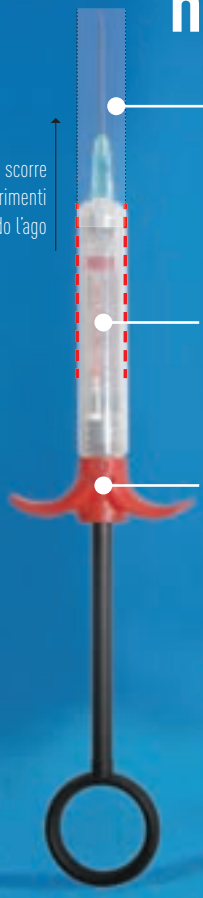

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Società Italiana di Endodonzia

GIORNALE ITALIANO DI ENDODONZIA

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Giornale Italiano di Endodonzia was founded in 1987 and is the official journal of the Italian Society of Endodontics (SIE). It is a peer-reviewed journal publishing original articles on clinical research and/or clinical methodology, case reports related to Endodontics. The Journal evaluates also contributes in restorative dentistry, dental traumatology, experimental pathophysiology, pharmacology and microbiology dealing with Endodontics. Giornale Italiano di Endodonzia is indexed in Scopus and Embase and published online only on ScienceDirect. SIE members can access the journal through the website: www.journals.elsevier.com/giornale-italiano-di-endodonzia/

REGISTRATION Court of Milan n ° 89, 3 March 2009

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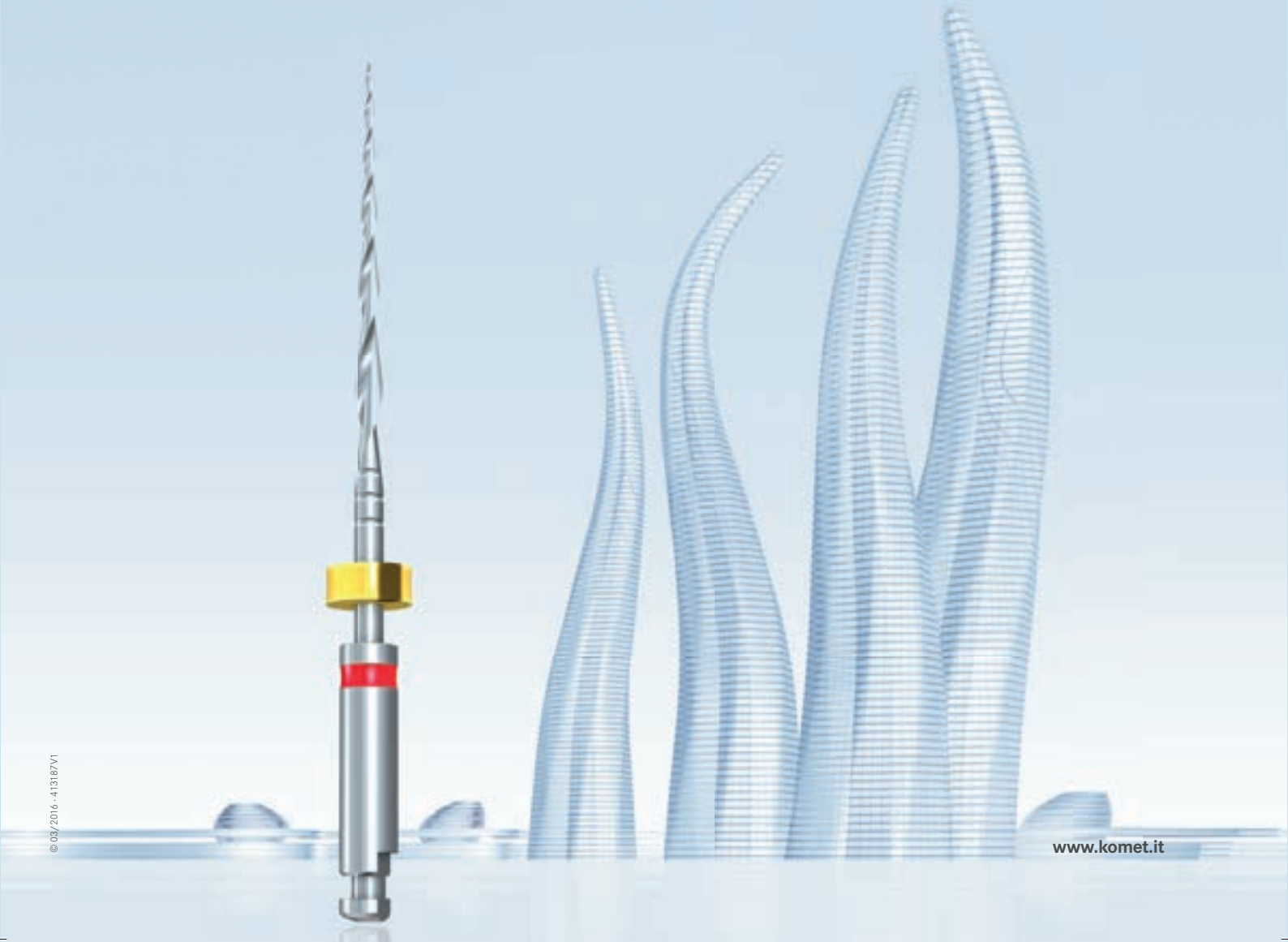

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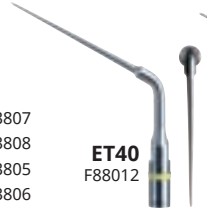

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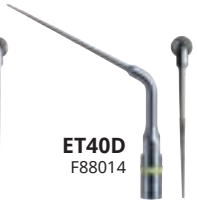

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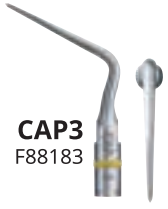
CAP1 F88181

CAP2 F88182



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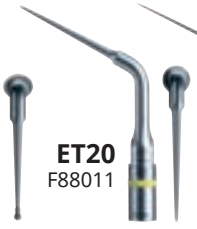

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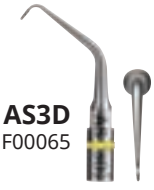

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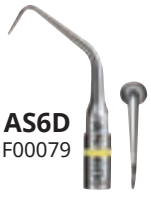

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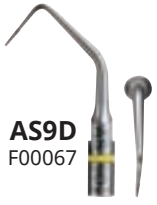

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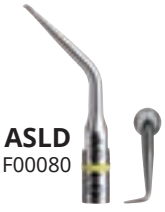

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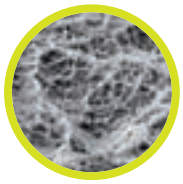

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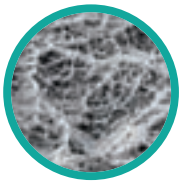

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T1 Tecnologia Bone

LA PRIMA SUPERFICIE NANOTECNOLOGICA
con cristalli DCD per sviluppare un alto livello di BIC nelle prime due settimane (70-80%)[1]

1. Nevins M, Nevins ML, Schupbach P, Fiorellini J, Lin Z, Kim DM. The Impact of Bone Compression on Bone-to-Implant Contact of an Osseointegrated Implant: A Canine Study. Int J Periodontics Restorative Dent. 2012 Dec;32(6):637-45.

Gobbato L, Arguello E, Martin IS, Hawley CE, Griffin TJ. Early bone healing around 2 different experimental, HA grit-blasted, and dual acid-etched titanium implant surfaces. A pilot study in rabbits. Implant Dent. 2012 Dec;21(6):454-60. doi: 10.1097/ID.0b013e3182611cd7.

Davies JE, Ajami E, Moineddin R, Mendes VC. The roles of different scale ranges of surface implant topography on the stability of the bone/implant interface. Biomaterials. 2013 Feb 14. pii: S0142-9612(13)00040-9. doi: 10.1016/j.biomaterials.2013.01.024. [Epub ahead of print]

T2 Tecnologia Safe

IL PRIMO IBRIDO DI NUOVA GENERAZIONE
per contrastare efficacemente la perimplantite[2]

2. Zetterqvist L, Feldman S, Rotter B, Vincenzi G, Wennström JL, Chierico A, Stach RM, Kenealy JN. A prospective, multicenter, randomized-controlled 5-year study of hybrid and fully etched implants for the incidence of peri-implantitis. J Periodontol. 2010 Apr;81(4):493-501.

Baldi D, Menini M, Pera F, Ravera G, Pera P. Plaque Accumulation on Exposed Titanium Surfaces and Peri-implant Tissue Behavior. A Preliminary 1-Year Clinical Study. Int J Prosthodont. 2009 Sep-Oct;22(5):447-55.

Rodriguez y Baena R, Arciola CR , Selan L, Battaglia R, Imbriani M, Rizzo S, Visai L. Evaluation of bacterial adhesion on machined titanium, Osseotite® and Nanotite® discs. Int J Artif Organs.2012 Oct;35(10):754-61. doi: 10.5301/ijao.5000143.

T3 Tecnologia Connection

LA PRIMA CONNESSIONE CON 3 LIVELLI DI INGAGGIO
per una tenuta a prova di test[3]

3. Suttin Z, Towse R, Cruz J. : Academy of Osseointegration, 27th A nnual Meeting, March 2012, Phoenix, Arizona, USA.

Al-Jadaa A, Attin T, Peltomäki T, Schmidlin PR. Confronto tra tre metodi di test in vitro di infiltrazione presso impianti Clin Oral Implants Res. 2013 Dec 16. doi: 10.1111/clr.12314. [Epub ahead of print]

Gubbi P, Suttin Z, Towse R. : Academy of Osseointegration 28th Annual Meeting, March 2013, Tampa, Florida, USA.

Suttin Z, Towse R. : European Academy of Osseointegratio n 20th Annual Meeting, October 2012, Copenhagen, Denmark.

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- La diagnosi endodontica: dall'esame obiettivo all'esame radiografico 3D (CBCT)
- Anatomia endodontica: classificazione e variabili principali

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- Isolamento del campo operatorio: la diga di gomma
- Workshop diga di gomma
- La cavità d'accesso "finestra" sull'anatomia endodontica: tecnica di preparazione
- Basi razionali della detersione canalare

TERZA GIORNATA — 9.00 - 13.00 | 14.00 - 18.00

- Basi razionali della sagomatura canalare
- Workshop di sagomatura canalare (in fase di definizione)

QUARTA GIORNATA — 9.00 - 13.00 | 14.00 - 18.00

- Workshop di sagomatura canalare (in fase di definizione)
- Il sigillo endodontico: materiali e tecniche

QUINTA GIORNATA — 9.00 - 13.00 | 14.00-18.00

- Il sigillo coronale: momento fondamentale per il successo a lungo termine
- Ritrattamento ortogrado o chirurgico: flow chart decisionale
- La documentazione dei casi clinici endodontici: come diventare socio ATTIVO e AGGREGATO della SIE
- Workshop di sagomatura canalare (in fase di definizione)

SESTA GIORNATA — 9.00 - 13.00

- Aspetti endodontici e parodontali del dente compromesso
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Fabio Gorni, Luigi Scagnoli

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Alberto Rieppi

La CBCT nella pianificazione e il trattamento di casi complessi
Roberto Fornara

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Interazione tra organo pulpare e biomateriali
Domenico Ricucci

Interazione tra materiali, organo pulpare e tessuti parodontali: aspetti innovativi e tecniche cliniche
Carlo Prati

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Francesco Riccitiello

L'OUTCOME IN ENDODONZIA
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Lucio Daniele

Il contributo dell'energia Laser usata nel trattamento endodontico: tipi e modi d'uso per migliorare i risultati clinici
Vasilios Kaitsas, Mario Mancini

Il trattamento endodontico ortogrado: quali i fattori che più influenzano il suo outcome?
Denise Pontoriero

IL RESTAURO POST-ENDODONTICO
L'utilizzo di materiali di nuova generazione nelle riabilitazioni protesiche post-endodontiche
Enrico Gherlone

Il Restauro Post-Endodontico: Evoluzione, indicazioni ed eventuali alternative ai mezzi di ancoraggio intracanalari
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EDITORIAL/EDITORIALE

Development in Endodontics

Evoluzione in Endodonzia

When Professor Giorgio Vogel welcomed me in his clinic in 1993 I had a smattering of endodontics; I looked at this discipline with such a discouragement, perceiving its principles, as someone who didn't stand a chance. Well, 23 years have passed from that day; with passion, I've tried to strengthen those principles and to contribute, in a very modest way, to their understanding by all. It has been a wonderful experience, this Editorial of mine is a goodbye. I've decided to quit the management of this Journal, this will be my last issue, because I guess I have had my day; there are young colleagues who deserve this chance and helping them to chase it will be my assignment from here on out.

I would have never imagined, during those early years, that I would have become the Editor of this Journal, which have been managed before by many Italian masters of endodontics; I've tried, to be honest with you, not to distance myself from the way they plotted. Sincerely, many thanks to all the SIE Members who have expressed me their appreciation and to all the SIE Boards that have renewed my assignment along the years.

Preserving this spirit, I believe that the Italian Journal of Endodontics will be able to maintain and, why-not, even improve its contents on a quality level; those you'll find published on this very issue are among the most stimulating: bioactive cements and their clinical use.

It deals with a different way of facing the usual problems, maybe it represents the solution to those old requests that previously we've not been able to give a proper answer to, yet.

Things work out over time, as usual.

Quando nel 1993 il Prof Giorgio Vogel mi accolse nella sua clinica masticavo l'endodonzia del marciapiede, guardavo a questa disciplina con lo sconforto di chi, intuendone i principi, pensava di essere in partenza sconfitto. Sono passati ventitré anni da quel giorno e, con passione, ho cercato di consolidare in me quei principi e di contribuire, in modestissima parte, alla loro comprensione da parte di tutti. E' stata una bellissima esperienza, questo mio editoriale un arrivederci. Lascio la direzione della rivista, con questo ultimo numero, perché ritengo di avere fatto il mio tempo; giovani bravissimi meritano questa opportunità e sarà mio compito aiutarli a perseguirla da qui in avanti.

Mai avrei immaginato, in quei primi anni, di poter diventare l'Editor di questa testata che ha visto i maestri dell'endodonzia italiana cimentarsi; ho cercato, con onestà, di non smarrire il solco da loro tracciato. Un sincero ringraziamento a tutti i Soci della SIE che mi hanno manifestato il loro apprezzamento e ai Consigli Direttivi che mi hanno rinnovato l'incarico negli anni.

Con questo spirito penso che il Giornale Italiano di Endodonzia potrà mantenere e, perché no, migliorare qualitativamente i suoi contenuti, quelli che presentiamo in questo numero sono tra i più stimolanti: i cementi bioattivi e il loro impiego clinico.

Un modo diverso di guardare agli stessi problemi, forse la soluzione a vecchie istanze a cui non abbiamo saputo dare una risposta convincente.

Il tempo sarà, come sempre, galantuomo.

Editor-in-Chief
Massimo Gagliani
Giornale Italiano di Endodonzia
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LITERATURE REVIEW/REVISIONE DELLA LETTERATURA

The use of premixed bioceramic materials in endodontics

L'utilizzo dei materiali bioceramici premiscelati in Endodonzia

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PAROLE CHIAVE
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Abstract With both antimicrobial and sealing properties, premixed bioceramic materials are unique materials available in endodontics that contribute to the success of both the microbial control phase (instrumentation, irrigation, intra-canal medication) and the filling phase (root and top filling) of root canal treatment.
Bioceramic material may be an essential element in the indirect and direct pulp capping and pulpotomy procedures that are an integral part of endodontic therapy's goal of maintaining the vital pulp to ensure a healthy periradicular periodontium.
For all these reasons, premixed bioceramic materials are now the material of choice for pulp capping, pulpotomy, perforation repair, root-end filling, and obturation of immature teeth with open apices, as well as for sealing root canal fillings of mature teeth with closed apices.

Riassunto
Scopo: Avendo sia proprietà antimicrobiche che sigillanti, i materiali bioceramici premiscelati sono materiali unici disponibili in endodonzia che possono contribuire al successo sia della fase di

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Trattamento;
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controllo microbico (strumentazione, irrigazione, medicazione intracanalare) che della fase di otturazione endodontica (ortograda e retrograda) del canale radicolare.
Materiali e metodi: I materiali bioceramici sono anche un elemento essenziale sia nelle procedure di incappucciamento pulpare diretto ed indiretto, che di pulpotomia, che sono a tutti gli effetti parte integrante dell'obiettivo primario di mantenere la polpa di vitale per garantire la salute dei tessuti periapicali e periradicolari.
Conclusioni: Risultati e Per questi motivi, i materiali bioceramici premiscelati rappresentano ad oggi il materiale di scelta per la le procedure di incappucciamento pulpare, pulpotomia, riparazione delle pèerforazioni, otturazione retrograda e otturazione dei denti immaturi con apici aperti, così come per l'ottenimento del sigillo apicale di denti maturi con apici chiusi.

Introduction

Microbes within the root canal system are the cause of apical and periradicular periodontitis (endodontic disease). The absence of microbes ensures that apical periodontitis of endodontic origin does not occur. Therefore, the aim of endodontic treatment is to prevent microbial contamination of the root canal system and/or to remove enough microbes to ensure clinical and radiographic success. A common misconception is that endodontics encompasses only root canal treatment, retreatment, or surgical treatment of post-endodontic disease. Nothing could be further from the truth. A major part of endodontics is maintaining the vital pulp to ensure a healthy periradicular periodontium. Thus, in addition to root canal treatment, indirect and direct pulp capping and pulpotomy procedures are integral parts of endodontic therapy. Root canal treatment is divided into the microbial control phase (instrumentation, irrigation, intra-canal medication) followed by the filling phase (root and top filling). With both antimicrobial and sealing properties, premixed bioceramic materials are one of the few materials available in endodontics that contribute to both critical phases for endodontic treatment success.

Bioceramics

Bioceramics are ceramic materials specifically designed for medical and dental use. During the 1960s and 1970s, these materials were developed for use in the human body such as joint replacement, bone plates, bone cement, artificial ligaments and tendons, blood vessel prostheses, heart valves, skin repair devices (artificial tissue), cochlear replacements, and contact lenses.[1] Bioceramics are inorganic, non-metallic, biocompatible materials that include alumina and zirconia, bioactive glass, coatings and composites, hydroxyapetite and resorbable calcium phosphates, and radiotherapy glasses.[2–4] They are chemically stable, non-corrosive, and interact well with organic tissue.

Bioceramics are classified as:

- bioinert—non-interactive with biologic systems;
- bioactive—durable in tissues that can undergo interfacial interactions with surrounding tissue;
- biodegradable, soluble, or resorbable—eventually replace or are incorporated into tissues.

There are numerous bioceramics currently in use in dentistry and medicine. Alumina and zirconia are bioinert ceramics used in prosthetics. Bioactive glass and glass ceramics are available for use in dentistry under various trade names. In addition, porous ceramics such as calcium phosphate-based materials have been used for filling bone defects. Some calcium silicates (mineral trioxide aggregate [MTA], ProRoot® MTA Root Repair, DENTSPLY Tulsa Dental Specialties) and bioaggregates (DiaRoot® BioAggregate, DiaDent) have also been used in dentistry as materials for root repair and for apical root filling.

Bioceramics in endodontics

Bioceramic materials used in endodontics can be categorized by composition, setting mechanism, and consistency. There are sealers and pastes, developed for use with gutta-percha, and putties, designed for use as the sole material, comparable to MTA. Some are powder/liquid systems that require manual mixing. The mixing and handling characteristics of the powder/liquid systems are very technique sensitive and produce a considerably waste. Premixed bioceramics require moisture from the surrounding tissues to set. The premixed sealer, paste, and putty have the advantage of uniform consistency and lack of waste. These premixed bioceramics are all hydrophilic.

Endodontic bioceramics are not sensitive to moisture and blood contamination and therefore are not technique sensitive.[5–9] They are dimensionally stable and expand slightly.[10] When set, they are hard, allowing full compaction of a final restoration, and they are insoluble over time, ensuring a superior long-term seal. When setting, the pH is above 12 due to the hydration reaction, which first forms calcium hydroxide and then dissociates into calcium and hydroxyl ions (Fig. 1a and b).[11] Therefore, when unset, the material has antibacterial properties. When fully set, it is biocompatible and even bioactive. When bioceramic materials come in contact with tissue fluids, they release calcium hydroxide, which can interact with phosphates in the tissue fluids to form hydroxyapatite (Fig. 1c). This property may explain some of the tissue-inductive properties of the material. For the reasons above, these materials are recommended for pulp capping, pulpotomy, perforation repair, root-end filling, and obturation of immature teeth with open apices,

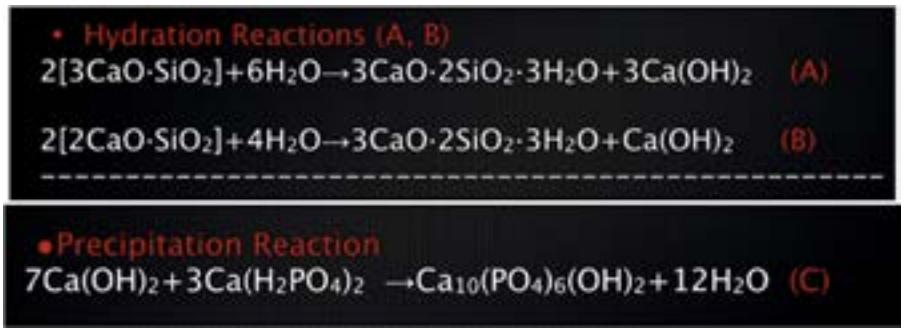

Figure 1 Hydration reaction of bioceramic material in contact with water (A and B). Precipitation reaction of the bioceramic (C).

as well as for sealing root canal fillings of mature teeth with closed apices.

Available bioceramic materials in endodontics

Mineral trioxide aggregate (MTA)

Few clinicians realize that original MTA is a classic bioceramic material with the addition of some heavy metals. MTA is one of the most extensively researched materials in the dental field.[12,13] It has the properties of all bioceramics—i.e., has a high pH when unset, is biocompatible and bioactive when set, and provides an excellent seal over time. It has some disadvantages, however. It requires mixing, resulting in considerable waste, is not easy to manipulate, and is difficult to remove from the root canal when set. Clinically, both gray and white MTA stain dentin, presumably due to the heavy metal content of the material or the inclusion of blood pigment while setting.[14,15] Finally, MTA is hard to apply in narrow canals, making the material poorly suited for use as a sealer together with gutta-percha. Efforts have been made to overcome these shortcomings with new compositions of MTA or with additives. However, these formulations affect MTA's physical and mechanical characteristics.

Biodentine

Biodentine® (Septodont) is considered a second-generation bioceramic material. It has properties similar to MTA and thus can be used for all the applications described above for MTA.[1,16] Its advantages over MTA are that it sets in a shorter period of time (approximately 10—12 min) and it has a compressive strength similar to dentin. A major disadvantage is that it is triturated for 30 s in a preset quantity (capsule), making waste inevitable, since in the vast majority of endodontic cases, only a small amount is required.

Endodontic premixed bioceramics

In 2007, a Canadian research and product development company (Innovative BioCeramix, Inc., Vancouver, Canada), developed a premixed, ready-to-use calcium silicate based material, iRoot® SP injectable root canal sealer (iRoot® SP).[1]

Since 2008 these endodontic pre-mixed bioceramic products are available in North America from Brasseler USA as EndoSequence® BC Sealer™, EndoSequence® BC RRM™ (Root Repair Material™, a syringable paste), and EndoSequence® BC RRM-Fast Set Putty™ (Fig. 2). Recently, these materials have also been marketed as Totalfill® BC Sealer™, TotalFill® BC RRM Paste™, and TotalFill® BC RRM Putty™/Fast Putty™ (Fig. 3) by FKG Dentaire, Switzerland.[16]

All three forms of bioceramic are similar in chemical composition (calcium silicates, zirconium oxide, tantalum oxide, calcium phosphate monobasic, and fillers), and they have excellent mechanical and biological properties and good handling properties. They are hydrophilic, insoluble, radiopaque, and aluminum free with a high pH, and require moisture to set and harden. The working time of the BC Sealer and BC RRM is more than 30 min, and the setting time is 4 h in normal conditions, depending on the amount of moisture available. The recently introduced EndoSequence BC RRM Fast-Set Putty has all the properties of the original putty but with a faster setting time (approximately 20 min). RRM putties and paste are recommended for perforation repair, apical surgery, apical plugging, and vital pulp therapy. Pre-mixed BC Sealer is the only pure medical-grade bioceramic product available as a sealer for endodontic obturation. It has the same basic chemical composition as the other premixed bioceramic products, but it is less viscous, which makes its consistency ideal for sealing root canals. It is used with a gutta-percha point, which is impregnated on the surface with a nano particle layer of bioceramic. The gutta-percha is used primarily as the delivery device (plugger) (Fig. 4) to allow hydraulic movement of the sealer into the irregularities of the root canal and accessory canals (Fig. 5). Interestingly when the taper is not excessive and the gutta-percha point is used primarily as a plugger to move the sealer into the canal irregularities and accessory canals, a radiographic picture similar to the classical vertical condensation technique is often seen (Fig. 6). In addition, its surface bonding to the sealer eliminates a critical pathway for coronal leakage of microbes if the coronal restoration has a defective seal. The gutta-percha also is used as a pathway for post preparation or for retreatment if necessary.

Properties of the bioceramic sealer and potential changes in root filling technique:

1 The bioceramic sealer is highly hydrophilic and thus the natural moisture in the canal and tubules is an advantage, unlike most other sealers where moisture is detrimental to their performance.

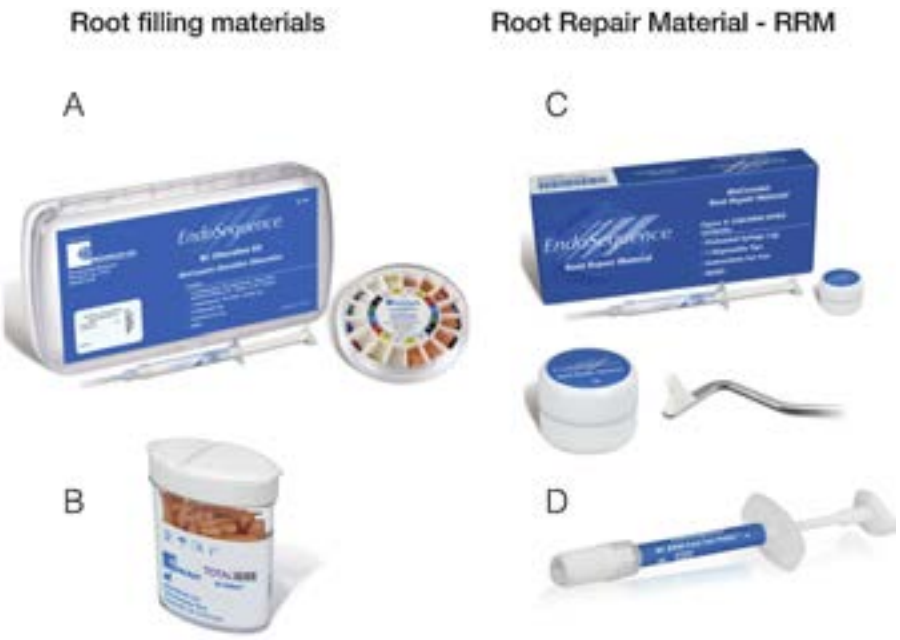

Figure 2 (A) EndoSequence obturation start kit by Brasseler USA. (B) EndoSequence gutta-percha pellets. (C) EndoSequence root repair materials (RRM). (D) EndoSequence RRM fast setting putty.

Figure 3 (A) TotalFill obturation start kit by FKG Dentaire Switzerland. (B) TotalFill gutta-percha pellets. (C) TotalFill RRM sealer. (D) TotalFill RRM putty and fast set putty.

2 When unset, the bioceramic sealer has a pH of above 12. Thus its antibacterial properties are similar to calcium hydroxide.[8,17–20] Setting is dependent on physiologic moisture in the canal, therefore it will set at different rates in different environments, but since it has a high pH any delay in setting can be argued as a benefit.
3 The sealer does not shrink, but expands slightly and it is insoluble in tissue fluids[8,17,21] (Fig. 7).
4 If used with a gutta-percha point that is impregnated and coated with nano particles of bioceramic, as suggested, it will bond to the core point thus eliminating the gap between the core and sealer.

The properties listed above, particularly in the presence of a sealer that does not shrink and is insoluble in tissue fluids, should change the longheld rule that in root filings the core material should take up as much space as possible in order to mask the shortcomings of the sealer and by keeping the sealer as thin as possible. In fact, if it were possible to fill the canal in a

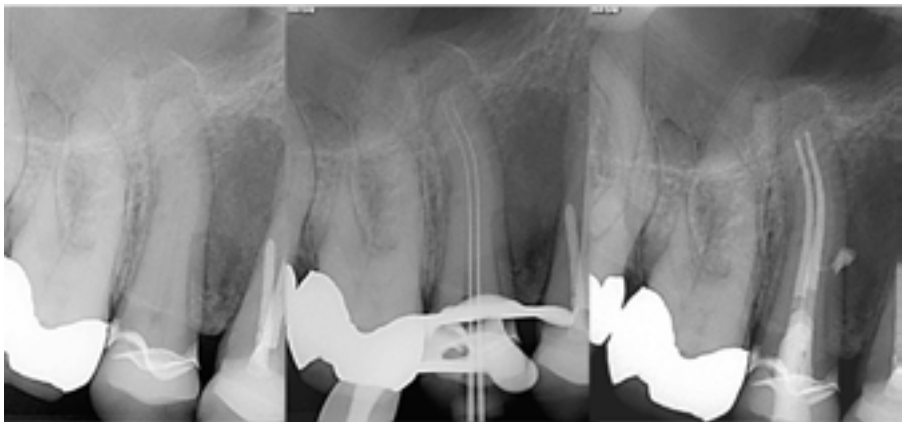

Figure 4 A representative radiograph of a root filled tooth with BC Sealer hydraulically moved with the gutta-percha point. Note that the cold hydraulic technique results in lateral canal ''puffs'' similar to the warm vertical technique.

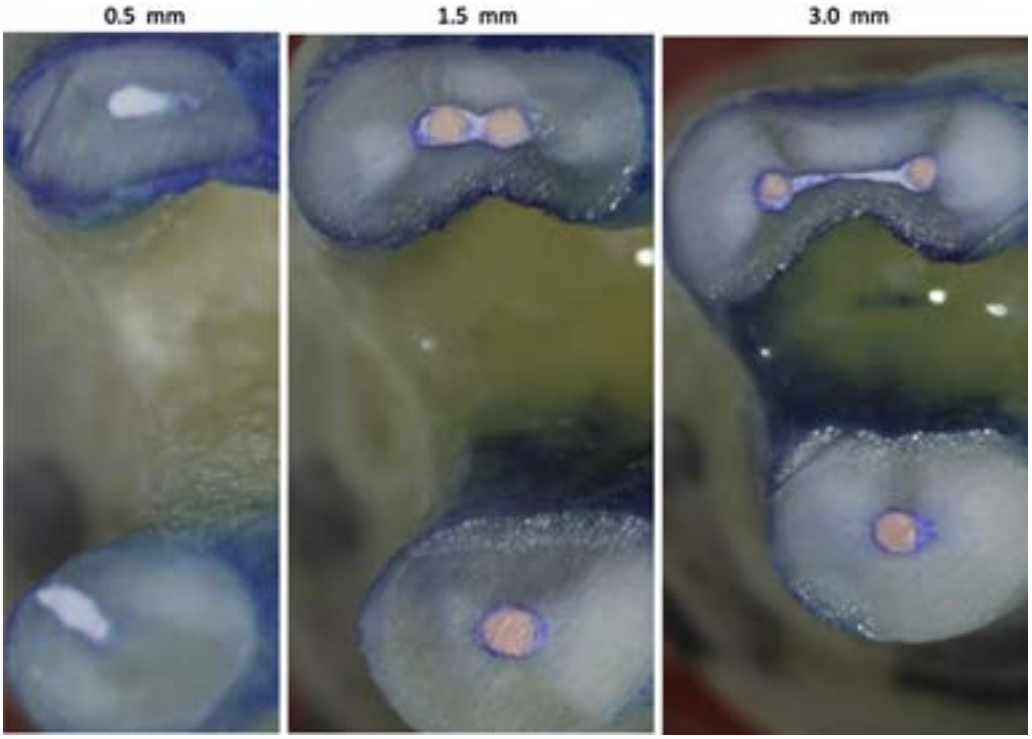

Figure 5 Molar roots filled with BC Sealer cut at different distances from the apex (0.5 mm, 1.5 mm and 3 mm). One gutta-percha point is used as a plugger to move the sealer using hydraulic pressure. Note the irregularities are very well filled with the sealer.

homogeneous way, the need for a core material at all is questionable.

Studies on endodontic premixed bioceramic materials

To date, more than 70 studies have been performed on premixed endodontic bioceramic materials. The vast majority of these studies have shown that the properties conform to those expected of a bioceramic material and are similar to MTA.

Biocompatibility and cytotoxicity

Several in vitro studies report that BC materials display biocompatibility and cytotoxicity that is similar to MTA.[22–32] Cells required for wound healing attach to the BC materials and produce replacement tissue.[23] In comparison to AH Plus® (Dentsply) and Tubli-Seal™ (SybronEndo), BC Sealer showed a lower cytotoxicity.[22,23] On the other hand, one study concluded that BC Sealer remained moderately cytotoxic over the 6-week period[32] and osteoblast like cells had reduced

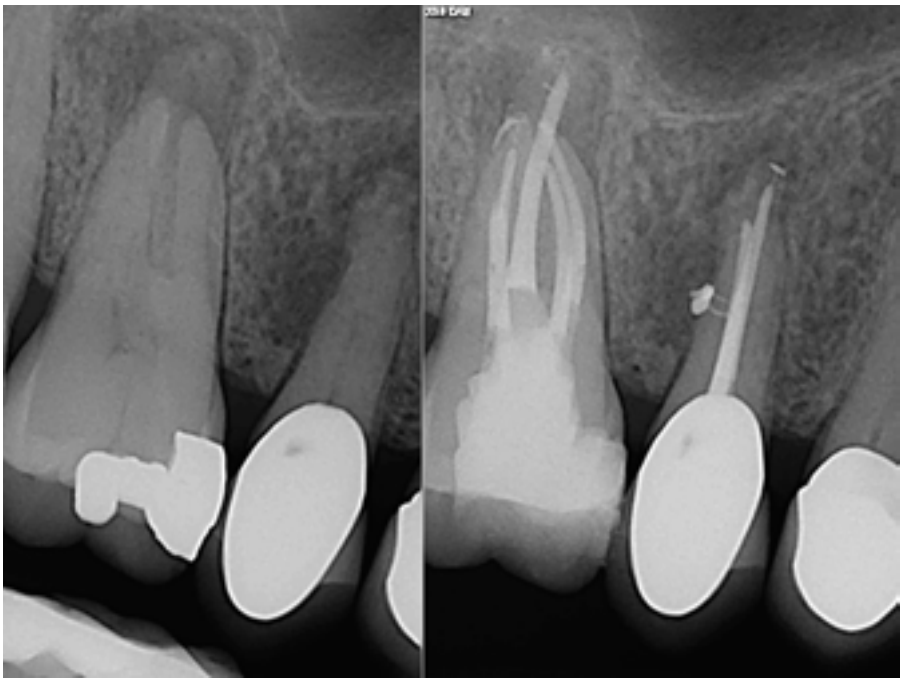

Figure 6 Endodontic treatment of a maxillary molar and pre-molar; root canals filled with a single gutta-percha cone and BC Sealer.

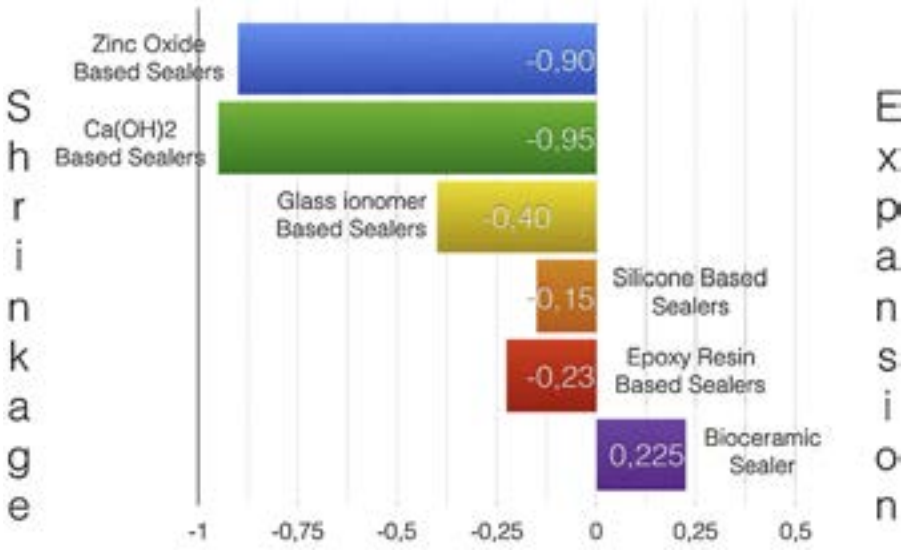

Figure 7 Table of expansion/shrinkage of popular sealers with the addition of bioceramic sealer. The BC Sealer expands slightly on setting but does not shrink.

bioactivity and alkaline phosphatase activity compared to MTA and Geristore® (DenMat).[33]

A recent study comparing the results of apicoectomies done with MTA or bioceramic putty on dogs showed the bioceramic putty to be slightly better than the MTA, presumably due to its superior handling properties.[34]

pH and antibacterial properties

BC materials have a pH of 12.7 while setting, similar to calcium hydroxide, resulting in antibacterial effects.[8] BC Sealer was shown to exhibit a significantly higher pH than AH Plus[35] for a longer duration.[36] Alkaline pH promotes elimination of bacteria such as *Enterococcus faecalis*. In vitro studies reported EndoSequence Paste produced a lower pH than white MTA in simulated root resorption defects[37] and EndoSequence Paste, Putty, and MTA had similar antibacterial efficacy against clinical strains of *E. faecalis*.[38]

Bioactivity

Several studies evaluated bioactivity. Exposure of MTA and EndoSequence Putty to phosphate-buffered saline (PBS)

resulted in precipitation of apatite crystalline structures that increased over time, suggesting that the materials are bioactive.[39] iRoot SP exhibited significantly lower cytotoxicity and a higher level of cell attachment than MTA Fillapex, a salicylate resin-based, MTA particles containing root canal sealer.[40] EndoSequence Sealer had higher pH and greater Ca^{2+} release than AH Plus[35] and was shown to release fewer calcium ions than BioDentine® (Septodont) and White MTA.[41]

Bond strength

A number of studies evaluated bond strength. One study reported that iRoot SP and AH Plus performed similarly, and better than EndoREZ® (Ultradent) and Sealapex™ (SybronEndo).[42] Another study found that iRoot SP displayed the highest bond strength to root dentin compared to AH Plus, Epiphany®, and MTA Fillapex, irrespective of moisture conditions.[43] In a push-out test, was similar to AH Plus and greater than MTA Fillapex.[44] When iRoot SP was used with a self-adhesive resin cement, the bond strength of fiber posts were not adversely affected.[45] Smear layer removal had no effect on bond strengths of EndoSequence Sealer and AH Plus, which had similar values.[46] The presence of phosphate-buffered saline (PBS) within the root canals increased the bond strength of EndoSequence Sealer/gutta percha at 1 week, but no difference was found at 2 months.[47] Because of the low bond values in these studies, it is doubtful that any of these findings are clinically significant.

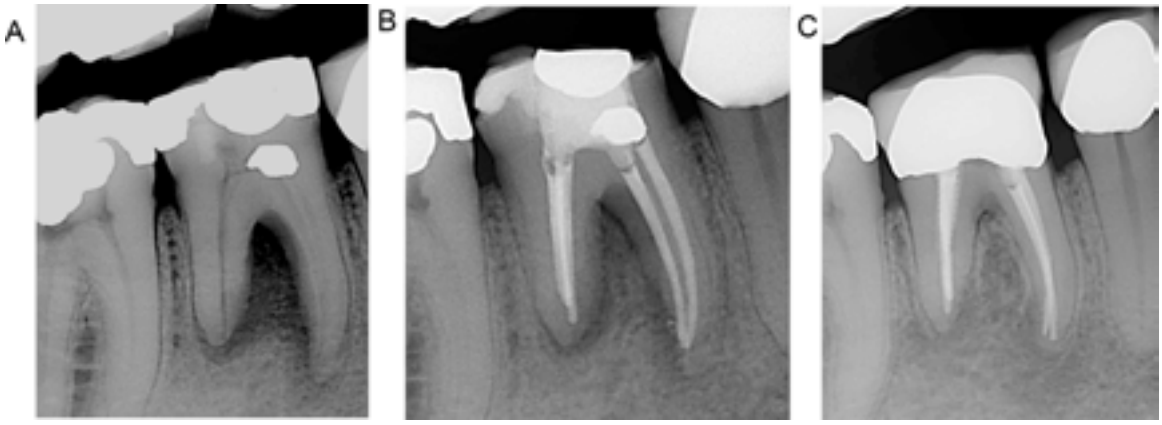

Figure 8 (A) Preoperative radiograph of a case demonstrating apical periodontitis. (B) Postoperative radiograph at 4 weeks. (C) 1-year follow-up with complete healing. Courtesy of Dr. Gilberto Debelian.

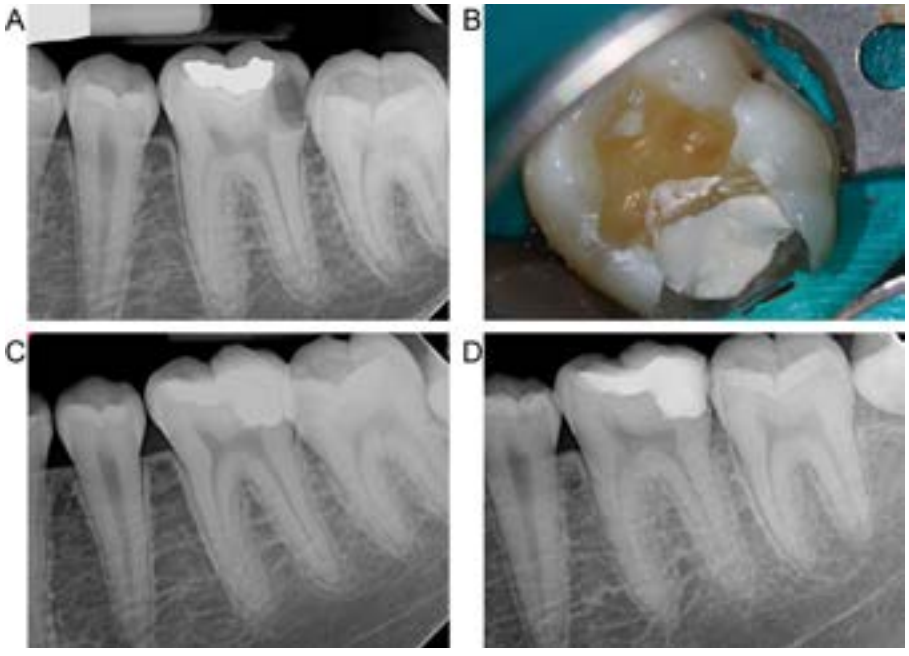

Figure 9 (A) Preoperative radiograph of carious exposure on tooth 36. (B) Direct pulp coverage with BC Sealer. (C) Immediate postoperative radiograph. (D) Radiograph taken at 6-month follow-up visit. Courtesy of Dr. Mohammed A. Alharbi.

Resistance to fracture

iRoot SP was shown in vitro to increase resistance to the fracture of endodontically treated roots, particularly when accompanied with bioceramic impregnated and coated gutta-percha cones.[48] Fracture resistance was increased in simulated immature roots in teeth with iRoot SP,[49] and in mature roots with AH Plus, EndoSequence Sealer, and MTA Fillapex.[51] Similar results were reported for EndoSequence Sealer and AH Plus Jet sealer in root-filled single-rooted premolar teeth.[52]

Microleakage

Microleakage was reported to be equivalent in canals obturated with iRoot SP with a single cone technique or continuous wave condensation, and in canals filled with AH Plus sealer with continuous wave condensation.[52] A recent study show a superior sealability of EndoSequence Putty compared with grey MTA.[53]

Solubility

High levels of Ca^{2+} release were reported from in a solubility from iRoot SP, MTA Fillapex, Sealapex, and MTA-Angelus, but not AH Plus. Release of Ca^{2+} ions is thought to result in higher solubility and surface changes.[54] However, the study tested the materials following ANSI/ADA spec. No. 57, which is not designed for premixed materials that require only the presence of moisture to set. This could be the reason for the difference in findings in this study and in vivo observations.

Retreatment

Removal of EndoSequence Sealer and AH Plus were comparable in a study comparing hand instruments and ProTaper Universal retreatment instruments.[55] None of the filling materials could be removed completely from the root canals, however.[56] Micro-computed tomography showed that none of the retreatment techniques completely removed the gutta-percha/iRootSP sealer from oval canals.[57]

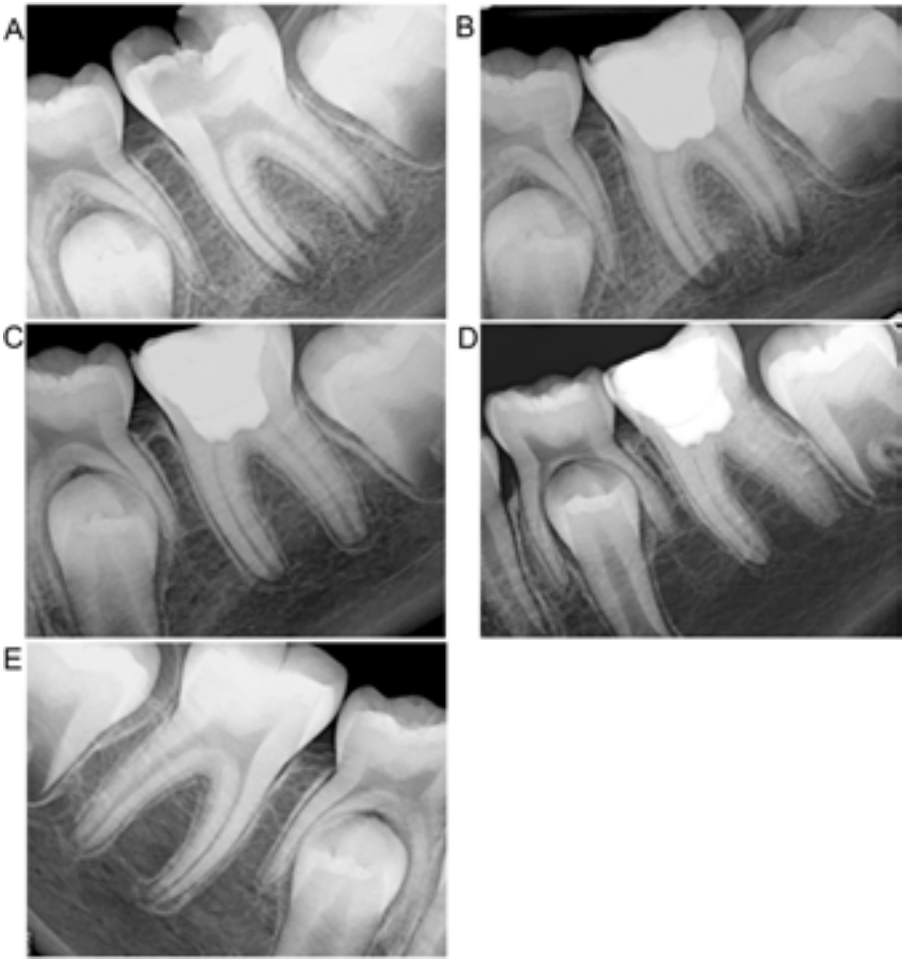

Figure 10 (A) Preoperative radiograph tooth 36. (B) Postoperative radiography after full pulpotomy with BC putty was performed. (C) Tooth was asymptomatic at 18-month follow-up. (D) Signs of root development after 24-month follow-up. (E) Contralateral tooth at 18-month follow-up. Courtesy of Dr. Guillaume Jouanny.

Clinical studies

A randomized clinical trial evaluated iRoot BP and white ProRoot MTA as direct pulp-capping materials.[58] The study evaluated clinical signs/symptoms and histological pulp reactions, such as inflammation and mineralized bridge formation. No significant differences were found in pulpal inflammation, or in the formation or appearance of a hard tissue bridge. However, clinical sensitivity to cold was significantly less for teeth treated with MTA ($p < 0.05$). All teeth formed a hard tissue bridge, and none of the specimens in either group had pulpal necrosis

Indications and case examples

Indirect and direct pulp capping and pulpotomy of carious exposures

Historically, endodontists have not recommended vital pulp therapy of cariously formed in the 1970s showed poor results for this procedure.[59,60] However, these studies used calcium hydroxide as the pulp-capping agent and amalgam as the coronal restoration; therefore, if/when the amalgam leaked, the calcium hydroxide base would wash out. This resulted in calcified canals—if the pulp survived—or necrotic pulps with infection and apical periodontitis. New studies and case series observations have shown that if the base used is antibacterial (such as calcium hydroxide), sets hard, and—most critically—seals well, both indirect and direct pulp-capping and pulpotomy procedures have a very good chance of a successful outcome.[61] In relatively young patients, these should be the treatment of choice.

Case 1: direct pulp cap

Fig. 8 shows the preoperative radiograph of an apparent carious exposure on tooth 46 of a 20-year-old male patient. A diagnosis of reversible pulpitis was made based on the history and clinical exam. After anesthesia and caries removal, the exposure was seen and covered with BC RRM-Fast Set. After the BC base had fully set, a bonded resin was placed and a postoperative radiograph taken. At the 6-month follow-up visit, the tooth was asymptomatic and tested vital. Radiographically, no signs of pathology were noted.

Case 2: pulpotomy

In this case (Fig. 9), the tooth tested vital but showed clinical signs of irreversible pulpitis. Treatment with a full pulpotomy was chosen to improve the chances the remaining pulp would

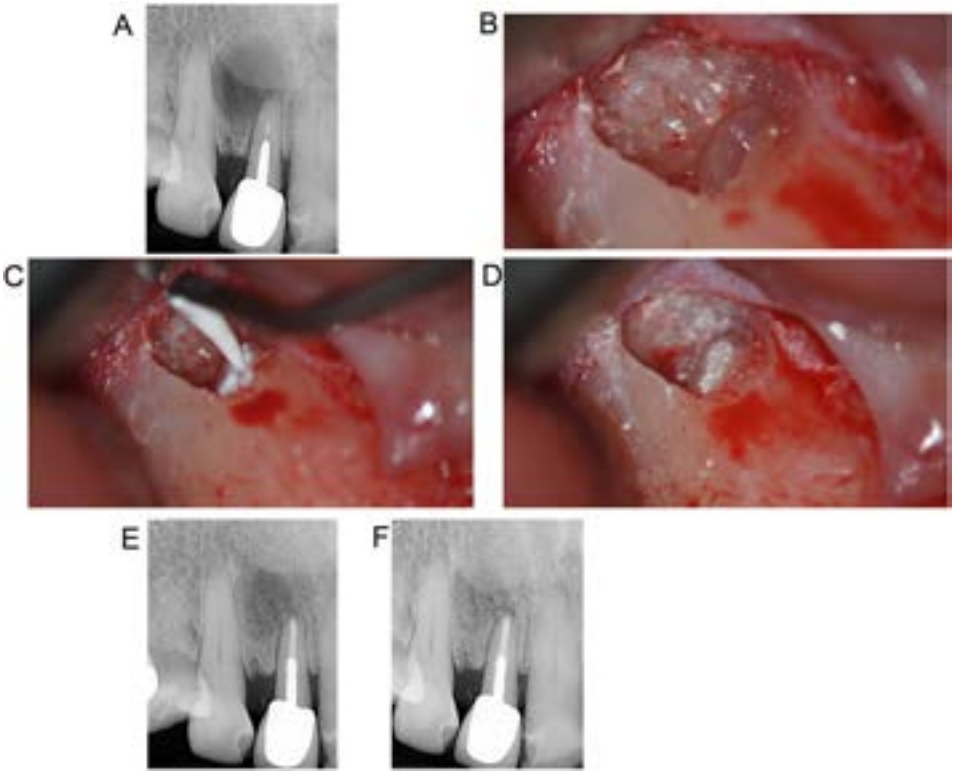

Figure 11 (A) Preoperative radiograph. (B) Post apicoectomy and retroprep. (C) Use of a BC putty over a retroprep cavity filled with BC Sealer. (D) Final placement and verification of BC putty retrofill. (E) Immediate postoperative radiograph, note the presence of BC Sealer along the post toward the coronal part. (F) 1-year-follow-up with advanced periapical healing. Courtesy of Dr. Gilberto Debelian.

survive and remain healthy. The preoperative radiograph shows extensive caries in the tooth and a slightly widened apical periodontal ligament. A full pulpotomy was performed using the BC putty. After the putty set, a coronal restoration was placed, and an immediate postoperative radiograph was taken and viewed. At the 1-year follow-up, the tooth was asymptomatic, and the radiograph showed continued root development, a healthy apical periodontium, and, importantly, no calcifications in the remaining pulp (as is often seen with a calcium hydroxide therapy). A radiograph taken of the contra-lateral tooth showed similar root development.

Case 3: primary endodontic treatment of a non-vital pulp

Lower first molar with signs and symptoms of periapical lesion (Fig. 10). The tooth was treated over 2 visit with an intra canal medication ($Ca(OH)_2$). Three weeks after the obturation was carried on with BC Sealer and gutta-percha using a single point technique. One year Follow-up radiograph showing signs of periapical healing.

Case 4: apicoectomy and retrofill

A patient presented with clinical symptoms and radiographic signs of post-endodontic disease (Fig. 11a). It was determined that the crown and the post was well adapted and an apicoectomy was to be performed. After apicoectomy the canal was instrumented with an ultrasonic tip to its length and until the tip of the post (b). The canal was filled with BC Sealer first and a 2 mm plug BC RRM-Putty was condensed inside the retrograde cavity (c). (d). Final placement and verification of BC Putty retrofill. (e) Immediate radiograph after the surgery, note the presence of the BC Sealer along the extension of the post. A 1 year follow-up shows radiograph signs of advanced periapical healing (f).

Conclusions

The premixed bioceramic materials are hydrophilic, they do not shrink and are insoluble in tissue fluids. With both antimicrobial and sealing properties, premixed bioceramics are unique materials available in endodontics that have changed the way we perform both vital pulp therapy and root canal treatment. For root canal treatment they contribute to the success of both the microbial control phase (instrumentation, irrigation, intra-canal medication) and the filling phase (root and top filling) of root canal treatment. This allows the practitioner to perform the microbial control without removing dentin unnecessarily and leaving a stronger root for restorative reconstruction. They are also an essential element in the indirect and direct pulp capping and pulpotomy procedures due to their sealing ability and also the fact that they do not discolor the surrounding dentin. Because of these properties more vital healthy pulps can be maintained ensuring a healthy surrounding periodontium. For these reasons, premixed bioceramic materials are now the material of choice for pulp capping, pulpotomy, perforation repair, root-end filling, and obturation of immature teeth with open apices, as well as for sealing root canal fillings of mature teeth with closed apices.

Conflict of interest

The authors are consultants from FKG Dentaire, Switzerland and Brasseler, USA.

References

1. Ree M, Schwartz R. Clinical applications of bioceramics materials in endodontics. *Endod Pract* 2014;**7**:32—40.
2. Best SM, Porter AE, Thian ES, Huang J. Bioceramics: past, present and for the future. *J Eur Ceram Soc* 2008;**28**:1319—27.
3. Dubok VA. Bioceramics: yesterday, today, tomorrow. *Powder Metall Metal Ceram* 2000;**39**:381—94.
4. Hench LL. Bioceramics: from concept to clinic. *J Am Ceram Soc* 1991;**74**:1487—510.
5. Jefferies S. Bioactive and biomimetic restorative materials: a comprehensive review. Part I. *J Esthet Restor Dent* 2014;**26**: 14—26.
6. Nekoofar MH, Stone DF, Dummer PM. The effect of blood contamination on the compressive strength and surface microstructure of mineral trioxide aggregate. *Int Endod J* 2010;**43**:782—91.
7. Koch K, Brave D. Bioceramic technology—the game changer in endodontics. *Endod Pract USA* 2009;**12**:7—11.
8. Zhang H, Shen Y, Ruse ND, Haapasalo M. Antibacterial activity of endodontic sealers by modified direct contact test against *Enterococcus faecalis*. *J Endod* 2009;**35**:1051—5.
9. Zhang W, Li Z, Peng B. Ex vivo cytotoxicity of a new calcium silicate based canal filling material. *Int Endod J* 2010;**43**: 769—74.
10. Trope M, Debelian G. Bioceramic technology in endodontics. *Inside Dent* 2014;**5**:53—60.
11. Islam I, Chng HK, Yap AU. Comparison of the physical and mechanical properties of MTA and Portland cement. *J Endod* 2006;**32**:193—7.
12. Torabinejad M, Parirokh M. Mineral trioxide aggregate: a comprehensive literature review: Part II. Leakage and biocompatibility investigations. *J Endod* 2010;**36**:190—202.
13. Parirokh M, Torabinejad M. Mineral trioxide aggregate: a comprehensive literature review: Part I. Chemical, physical, and antibacterial properties. *J Endod* 2010;**36**:16—27.
14. Parirokh M, Torabinejad M. Mineral trioxide aggregate: a comprehensive literature review: Part III. Clinical applications, drawbacks, and mechanism of action. *J Endod* 2010;**36**:400—13.
15. Belobrov I, Parashos P. Treatment of tooth discoloration after the use of white mineral trioxide aggregate. *J Endod* 2011;**37**: 1017—20.
16. Trope M, Bunæs A, Debelian G. Root filling materials and techniques: bioceramics a new hope? *Endod Top* 2015;**32**:86—96.
17. Zhang W, Li Z, Peng B. Ex vivo cytotoxicity of a new calcium silicate based canal filling material. *Int Endod J* 2010;**43**: 769—74.
18. Loushine BA, Bryan TE, Looney SW, Gillen BM, Loushine RJ, Weller RN, et al. Setting properties and cytotoxicity evaluation of a premixed bioceramic root canal sealer. *J Endod* 2011;**37**: 673—7.
19. Gandolfi MG, Iacono F, Agee K, Siboni F, Tay F, Pashley DH, et al. Setting time and expansion in different soaking media of experimental accelerated calcium-silicate cements and ProRoot MTA. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod* 2009;**108**: e39—45.
20. Candeiro GT, Correia FC, Duarte MA, Ribeiro-Siqueira DC, Gavini G. Evaluation of radiopacity, pH, release of calcium ions, and flow of a bioceramic root canal sealer. *J Endod* 2012;**38**:842—5.

21. Richardson IG. The calcium silicate hydrates. *Cem Conc Res* 2008;**38**:137—215.
22. Alanezi AZ, Jiang J, Safavi KE, Spangberg LS, Zhu Q. Cytotoxicity evaluation of EndoSequence root repair material. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod* 2010;**109**:e122—5.
23. Zhang W, Li Z, Peng. Ex vivo cytotoxicity of a new calcium silicate-based canal filling material. *Int Endod J* 2010;**43**: 769—74.
24. Zoufan K, Jiang J, Komabayashi T, Wang YH, Safavi KE, Zhu Q. Cytotoxicity evaluation of gutta flow and endo sequence BC Sealers. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod* 2011;**112**:657—61.
25. Ma J, Shen Y, Stojicic S, Haapasalo M. Biocompatibility of two novel root repair materials. *J Endod* 2011;**37**:793—8.
26. Ciasca M, Aminoshariae A, Jin G, Montagnese T, Mickel A. A comparison of the cytotoxicity and proinflammatory cytokine production of EndoSequence root repair material and ProRoot mineral trioxide aggregate in human osteoblast cell culture using reverse-transcriptase polymerase chain reaction. *J Endod* 2012;**38**:486—9.
27. Hirschman WR, Wheater MA, Bringas JS, Hoen NM. Cytotoxicity comparison of three current direct pulp-capping agents with a new bioceramic root repair putty. *J Endod* 2012;**38**:385—8.
28. Willershausen I, Callaway A, Briseno B, Willershausen B. In vitro analysis of the cytotoxicity and the antimicrobial effect of four endodontic sealers. *Head Face Med* 2011;**7**:15.
29. Damas BA, Wheater MA, Bringas JS, Hoen MM. Cytotoxicity comparison of mineral trioxide aggregates and EndoSequence bioceramic root repair materials. *J Endod* 2011;**37**:372—5.
30. Mukhtar-Fayyad D. Cytocompatibility of new bioceramic-based materials on human fibroblast cells (MRC-5). *Oral Surg Oral Med Oral Pathol Oral Radiol Endod* 2011;**112**:e137—42.
31. De-Deus G, Canabarro A, Alves GG, Marins JR, Linhares AB, Granjeiro JM. Cytocompatibility of the ready-to-use bioceramic putty repair cement iRoot BP Plus with primary human osteoblasts. *Int Endod J* 2012;**45**:508—13.
32. Willershausen I, Wolf T, Kasaj A, Weyer V, Willershausen B, Marroquin BB. Influence of a bioceramic root end material and mineral trioxide aggregates on fibroblasts and osteoblasts. *Arch Oral Biol* 2013;**58**:1232—7.
33. Modareszadeh MR, Di Fiore PM, Tipton DA, Salamat N. Cytotoxicity and alkaline phosphatase activity evaluation of EndoSequence root repair material. *J Endod* 2012;**38**:1101—5.
34. Chen I, Karabucak Bekir, Wang C, Wang HG, Koyama E, Koli MR, et al. Healing after root-end microsurgery by using mineral trioxide aggregate and a new calcium silicate-based bioceramic material as root-end filling materials in dogs. *J Endod* 2015;**41**: 390—9.
35. Candeiro GT, Correia FC, Duarte MA, Ribeiro-Sigueira DC, Gavini G. Evaluation of radiopacity, pH, release of calcium ions, and flow of a bioceramic root canal sealer. *J Endod* 2012;**38**:842—5.
36. Zhou HM, Shen Y, Zheng W, Li L, Zheng YF, Haapasalo M. Physical properties of 5 root canal sealers. *J Endod* 2013;**39**:1281—6.
37. Hansen SW, Marshall JG, Sedgley CM. Comparison of intracanal Endo-Sequence root repair material and ProRoot MTA to induce pH changes in simulated root resorption defects over 4 weeks in matched pairs of human teeth. *J Endod* 2011;**37**:502—6.
38. Lovato KF, Sedgley CM. Antibacterial activity of EndoSequence root repair material and ProRoot MTA against clinical isolates of *Enterococcus faecalis*. *J Endod* 2011;**37**:1542—6.
39. Shokouhinejad N, Nekoofar MH, Razmi H, Sajadi S, Davies TE, Saghiri MA, et al. Bioactivity of EndoSequence root repair material and bioaggregate. *Int Endod J* 2012;**45**:1127—34.
40. Güven EP, Yalvaç ME, Kayahan MB, Sunay H, Şahın F, Bayirli G. Human tooth germ stem cell response to calcium-silicate based endodontic cements. *J Appl Oral Sci* 2013;**21**:351—7.
41. Han L, Okiji T. Bioactivity evaluation of three calcium silicate-based endodontic materials. *Int Endod J* 2013;**46**:808—14.
42. Ersahan S, Aydin C. Dislocation resistance of iRoot SP, a calcium silicate based sealer, from radicular dentine. *J Endod* 2010;**36**:2000—2.
43. Nagas E, Uyanik MO, Eymirli A, Cehreli ZC, Vallittu PK, Lassila LV, et al. Dentin moisture conditions affect the adhesion of root canal sealers. *J Endod* 2012;**38**:240—4.
44. Sagsen B, Ustün Y, Demirbuga S, Pala K. Push-out bond strength of two new calcium silicate-based endodontic sealers to root canal dentine. *Int Endod J* 2011;**44**:1088—91.
45. Özcan E, Çapar İD, Çetin AR, Tunçdemir AR, Aydınbelge HA. The effect of calcium silicate-based sealer on the push-out bond strength of fibre posts. *Aust Dent J* 2012;**57**:166—70.
46. Shokouhinejad N, Gorjestani H, Nasseh AA, Hoseini A, Mohammadi M, Shamshiri AR. Push-out bond strength of gutta-percha with a new bioceramic sealer in the presence or absence of smear layer. *Aust Endod J* 2013;**39**:102—6.
47. Shokouhinejad N, Hoseini A, Gorjestani H, Raoof M, Assadian H, Shamshiri AR. Effect of phosphate-buffered saline on push-out bond strength of a new bioceramic sealer to root canal dentin. *Dent Res J (Isfahan)* 2012;**9**:595—959.
48. Ghoneim AG, Lutfy RA, Sabet NE, Fayyad DM. Resistance to fracture of roots obturated with novel canal-filling systems. *J Endod* 2011;**37**:1590—2.
49. Ulusoy Öİ, Nayır Y, Darendeliler-Yaman S. Effect of different root canal sealers on fracture strength of simulated immature roots. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod* 2011;**112**: 544—7.
51. Topçuoğlu HS, Tuncay Ö, Karataş E, Arslan H, Yeter K. In vitro fracture resistance of roots obturated with epoxy resin-based, mineral trioxide aggregate-based, and bioceramic root canal sealers. *J Endod* 2013;**39**:1630—3.
52. Zhang W, Li Z, Peng B. Assessment of a new root canal sealer's apical sealing ability. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod* 2009;**107**:79—82.
53. Antunes HS, Gominho LF, Andrade-Junior CV, Dessaune-Neto N, Alves FRF, Rôças IN, et al. Sealing ability of two root-end filling materials in a bacterial nutrient leakage model. *Int End J* 2015;**12**:30—7.
54. Borges RP, Sousa-Neto MD, Versiani MA, Rached-Júnior FA, De-Deus G, Miranda CE, et al. Changes in the surface of four calcium silicate-containing endodontic materials and an epoxy resin-based sealer after a solubility test. *Int Endod J* 2012;**45**:419—42.
55. Hess D, Solomon E, Spears R, He J. Retreatability of a bioceramic root canal sealing material. *J Endod* 2011;**37**:1547—50.
56. Ersev H, Yilmaz B, Dincol ME, Daglaroglu R. The efficacy of ProTaper University rotary retreatment instrumentation to remove single gutta-percha cones cemented with several endodontic sealers. *Int Endod J* 2012;**45**:756—62.
57. Ma J, Al-Ashaw AJ, Shen Y, Gao Y, Yang Y, Zhang C, et al. Efficacy of ProTaper universal rotary retreatment system for gutta-percha removal from oval root canals: a micro-computed tomography study. *J Endod* 2012;**38**:1516—20.
58. Azimi S, Fazlyab M, Sadri D, Saghiri MA, Khosravanifard B, Asgary S. Comparison of pulp response to mineral trioxide aggregate and a bioceramic paste in partial pulpotomy of sound human premolars: a randomized controlled trial. *Int Endod J* 2014.
59. Tronstad L, Mjör IA. Capping of the inflamed pulp. *Oral Surg Oral Med Oral Pathol* 1972;**34**:477—85.
60. Barthel CR, Rosenkranz B, Leuenberg A, Roulet JF. Pulp capping of carious exposures: treatment outcome after 5 and 10 years: a retrospective study. *J Endod* 2000;**26**:525—8.
61. Bogen G, Kim JS, Bakland LK. Direct pulp capping with mineral trioxide aggregate: an observational study. *J Am Dent Assoc* 2008;**139**:305—15.

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LITERATURE REVIEW/REVISIONE DELLA LETTERATURA

Biodentine: from biochemical and bioactive properties to clinical applications

Biodentine: dalle proprietà biochimiche e bioattive alle applicazioni cliniche

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KEYWORDS
Biodentine;
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Clinical applications.

Abstract Biodentine is a tricalcium silicate-based material designed as a permanent dentin substitute. It is biocompatible and bioactive material. Its interactions with both hard and soft tissues lead to a marginal sealing preventing marginal leakage and provide protection to the underlying pulp by inducing tertiary dentin synthesis. Unlike other dentin substitutes, Biodentine application does not require any conditioning of the dentin surface and the restoration sealing is provided by micromechanical retention as Biodentine penetrates into the dentin tubules forming tag-like structures. After setting, Biodentine can be cut and reshaped like natural dentin. It can also be bonded with different types of adhesives before finishing the final restoration with composite resin. Published clinical trials, histology of human teeth and clinical cases show that Biodentine has a wide spectrum of clinical applications as a permanent bulk dentin substitute in endodontics, in restorative dentistry, and pediatric dentistry as a possible replacement material of formecresol. This review brings a comprehensive understanding of Biodentine composition, preparation properties and the mechanism of interactions with hard and soft tissues. It explains the scientific mechanisms of the induction of these specific functions and illustrates the scientific basis beyond their clinical successful use. The article provides an overview of Biodentine clinical applications summarizing published clinical trials and reporting published clinical cases with this material in restorative and pediatric dentistry as well as in endodontics.

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PAROLE CHIAVE
Biodentine;
Cementi a base di trisilicato di calcio;
Sostituti della dentina;
Ricerca;
Applicazioni cliniche.

Riassunto Biodentine è un materiale a base di silicato tricalcico progettato come sostituto permanente della dentina. Si tratta di un materiale biocompatibile e bioattivo. Le sue interazioni con entrambi i tessuti duri e molli portano ad una sigillatura marginale in grado di prevenire l'infiltrazione marginale e forniscono una protezione alla polpa sottostante inducendo sintesi dentina terziaria. A differenza di altri sostituti della dentina, l'applicazione di Biodentine non richiede alcun condizionamento della superficie dentinale e la tenuta della restaurazione è fornito dalla ritenzione micromeccanica in quanto Biodentine penetra nei tubuli dentinali formando strutture di simili ai resin-tag. Dopo l'indurimento, il Biodentine può essere tagliato e rimodellato come dentina naturale. Può anche essere trattato con diversi tipi di adesivi prima di terminare il restauro definitivo. Studi clinici pubblicati, istologia di denti umani estratti e casi clinici dimostrano che Biodentine ha un ampio spettro di applicazioni cliniche, come sostituto permanente della dentina in endodonzia, in odontoiatria restaurativa e odontoiatria pediatrica. Questa review si propone di descrivere in maniera completa la composizione di Biodentine, le proprietà di preparazione e il meccanismo di interazione con i tessuti duri e molli. Essa spiega i meccanismi scientifici che caratterizzano queste funzioni specifiche e illustra la base scientifica del suo successo nell'utilizzo clinico. L'articolo fornisce inoltre una panoramica delle applicazioni cliniche di Biodentine riassumendo gli studi clinici e riportando i casi clinici pubblicati con questo materiale in odontoiatria restaurativa e pediatrica, così come in endodonzia.

Introduction

Over the past decades, search on restorative materials focused on replacing amalgams in small anterior restorations and on posterior restorations of moderate size by direct composite restorations. Opposed to amalgams, a micromechanical retention of resin composites can be achieved with these materials by applying different adhesives. However, some drawbacks have been reported with resin-based materials such as wear resistance under high stress, shrinkage upon polymerization leading to microleakage and toxic monomers release.[1,2] In order to protect the pulp from resin-based materials toxic components, Calcium hydroxide-based materials have been widely used in direct pulp capping procedures. In spite of a highly alkaline pH of this material, a dentin bridge can form within 3 months providing a protection to the underlying pulp with mild or moderate inflammation. However, several studies demonstrated a partial dissolution and that this bridge has tunnel defects.[3,4] The recent focus on biocompatible materials such as Portland led to the development of Mineral trioxide aggregate (MTA) as a root-end filling material and direct pulp capping. This material is mainly composed of tricalcium and dicalcium silicates.[5] When applied for pulp capping, it induces reparative dentin production leading to a regular tubular dentin bridge formation within 2 months with no signs of inflammation.[4] However, some shortcomings have been reported with this material. These are related to its long setting time of 2 h 45 min, weak mechanical properties and difficult handling properties.[6] Additionally, tooth discoloration has been reported when this material is used for revascularization.[7,8] Biodentine is a recently released tricalcium silicate-based material developed as a permanent dentin substitute to replace the damaged dentin.[9]

In this review, the material composition, preparation method and application, mechanical and physical properties will be described, its interactions with the soft and hard dental tissues will be explained and finally, Biodentine clinical applications based on published works will be reported.

Biodentine composition

Biodentine is a two components material. The powder is mainly composed of Tricalcium silicates. It also contains Di-Calcium Silicate as a second core material and Calcium Carbonate and Oxide as filler. The powder contains Zirconium oxide as a radio-opacifier. The liquid contains Calcium Chloride as a setting accelerator and a water reducing agent (Table 1). The presence of a setting accelerator allows the material setting in 12 min and the presence of a water reducing agent avoids the formation of cracks within the material. Such cracks are usually observed after setting of cements containing high percentage of water.[9] The material is prepared by adding 5 drops of liquid to the powder present in the capsule. These components are then triturated with an amalgamator for 30 s at 4000 rpm leading to the formation of a paste of creamy consistency. The preparation method and proportions between powder and liquid should

Table 1 Biodentine composition: two components: liquid and powder to be mixed with an amalgamator for 30 s at 4000 rpm.[9]

Powder	Role
Tri-calcium silicate (C_3S)	Main core material
Di-calcium silicate (C_2S)	Second core material
Calcium carbonate and oxide	Filler
Iron oxyde	Shade
Zirconium oxyde	Radio-opacifier
Liquid	
Calcium chloride	Setting accelerator
Hydrosoluble polymer	Water reducing agent

be respected and applied according to the manufacturer's instructions as these proportions greatly influence the material's setting and mechanical properties. This is of particular significance mainly for applications under mechanical loads such as applications in Class II cavities.

The setting reaction is a hydration reaction

When Biodentine powder and liquid are mixed with an amalgamator, the setting of the material is a hydration reaction. While Calcium silicates partially dissolve by adding the liquid, a hydrogel of hydrated silicate is produced. This will precipitate on the remaining Silicate particles' surface and in the spaces between the particles leading to a significant decrease in the material's porosity and an increase in its compressive strength over time.[9]

Biocompatibility

Like any other restorative material, Biodentine Biocompatibility was investigated to ensure its safety when applied onto the cells. Evaluation of its genotoxicity on bacteria strains by the Ames test and its effects on the formation of micronuclei by human lymphocytes demonstrated the absence of any mutagenic effect of the material. Similarly, when tested on target human pulp cells, no DNA breaks or damage was observed with the Comet assay. These results demonstrated no genotoxic effects of Biodentine *in vitro*. The biocompatibility of the material was also investigated through its direct application to human pulp cells simulating the direct pulp condition and indirectly through a dentin slice to simulate its indirect pulp capping *in vivo*. Under both conditions Biodentine was not found to affect target cell viability under *in vivo* application conditions.[9] Additionally, when Biodentine was applied onto human pulp cells to investigate its effects on their specific functions by studying expression of odontoblast specific functions such as expression of Nestin (a human odontoblast specific marker) and Dentin Sialoprotein, Biodentine was not found to inhibit the expression of these proteins but rather induce their expression and the cells mineralization capacity.[9–11] Further investigations demonstrated the absence of toxicity of Biodentine to human MG63 human osteoblast cells with the MTT assay with properties comparable to that of MTA.[12]

Interactions with hard tissues: no surface preparation is needed to apply Biodentine™

Clinical application of Biodentine in restorative dentistry implies an intimate interaction with hard and soft tissues as well as with other restorative materials. This should lead to a marginal sealing *in vivo* which provides pulp protection and marginal sealing. Thus investigating these properties in *ex vivo* is of prime importance.

An experimental work using third molar teeth was used to investigate the marginal sealing of Biodentine alone or in combination of other resin-based materials using the silver nitrate penetration method in Class II cavities. No marginal leakage was observed at the Biodentin/dentin interface or at the enamel/Biodentine interface when the whole cavity was filled with Biodentine alone as a bulk restorative material replacing dentin and enamel without any conditioning treatment. No leakage was observed when Biodentine surface was prepared with the total etch technique and resin composite application. The results of this investigation demonstrated that the results obtained with Biodentine were similar to those obtained with resin-modified glass ionomer cement (Fuji II LC) considered as a reference material in this type of indications.[13] An interesting study compared the shear bond strengths of different adhesive systems to Biodentine. Adhesive systems such as Prime & Bond NT: etch-and-rinse adhesive system, Clearfil SE Bond: 2-step self-etch adhesive system and Clearfil S3 Bond: 1-step self-etch adhesive system were applied onto Biodentine discs for 12 min and 24 h then a Composite (Clearfil Majesty) was applied. Data showed that the shear bond strengths were the same for different adhesive systems to Biodentine.[14] This confirms that the marginal sealing of Biodentine is equivalent to that of RMGIC (Fuji II LC) and that Biodentine can be etched and treated like natural dentin. Different restorative materials can be successfully applied on top of Biodentine. Whatever the surface treatment used on Biodentine, this material can be used in combination with composite resins.[13,14]

Biodentine interacts with hard tissues by micromechanical retention

Interactions of Biodentine with the dentin provided cues to understanding how this material provides a marginal sealing without any dentin surface preparation: no etching and no bonding. In an experimental work performed *ex vivo*, dentin slices were prepared and Biodentine was prepared and mixed with a fluorescent dye before its application onto the dentin surface. Confocal laser scanning electron microscopy and scanning electron microscopy were used to study the interface between Biodentine and dentin. Confocal laser scanning electron microscopy revealed that Biodentine penetrated into the dentin tubules forming tag-like structures into the dentin tubules. Scanning electron microscopy revealed that the dentin tubules appeared with plugs of mineralization crystals just beneath the interface obliterating the dentin tubules. These results explain the micromechanical retention of the material on the one side and the marginal sealing on the other side.[15]

Bioactive properties *in vitro*

An entire human tooth culture model was used to investigate both the material hydration when placed for pulp capping and its effects on the pulp response. The tooth culture model provides a useful tool to investigate the initial steps of dentin-pulp regeneration and the consequence of applying pulp capping materials. Since the teeth used are immature impacted third molars, they also have the advantage of a high regeneration potential and not to be in contact with the oral flora. Biodentine was applied into pulp cavities then an adhesive resin was applied onto Biodentine and overlayed with a composite resin. Hydration was allowed to proceed under conditions similar to those *in vivo* by incubating teeth in culture medium. After 14 days, back-scatter scanning electron micrographs revealed that the material was homogenous and appeared completely hydrated at all areas

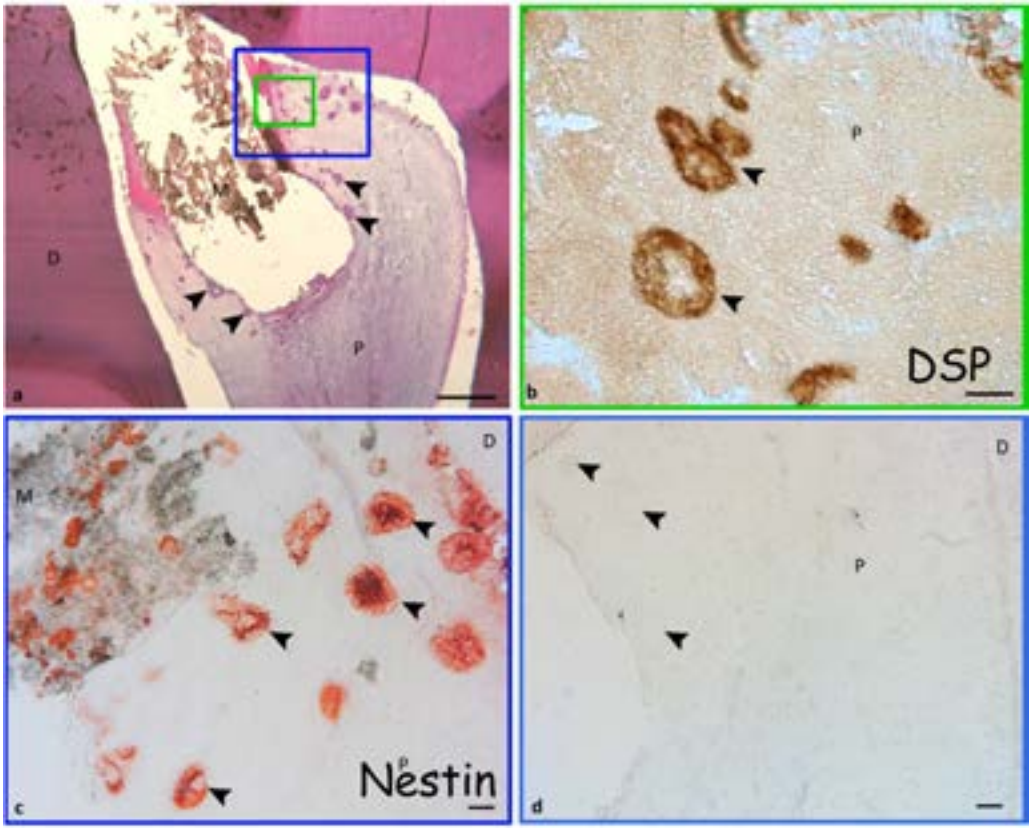

Figure 1 Biodentine direct application onto human pulp in human entire tooth culture for 4 weeks. Biodentine induced odontoblastic differentiation and reparative dentin secretion. Mineralization foci containing sequestered cells are observed in the dental pulp beneath Biodentine. The sequestered cells express odontoblast markers such as Dentin Sialoprotein (DSP) and nestin.[10]

examined: within the material, at the Biodentine/dentin interface, at Biodentine/composite resin interface and at the Biodentine/pulp interface. The hydration of this type of materials leads to the release of Calcium ions which are necessary for the mineralization. X-ray diffraction analysis of the material after setting demonstrated a significant peak of Calcium hydroxide formation which has long been used for pulp capping with a well demonstrated ability to induce dentin bridge formation.[16]

This culture model provided valuable information on the response to Biodentine application directly onto the pulp.

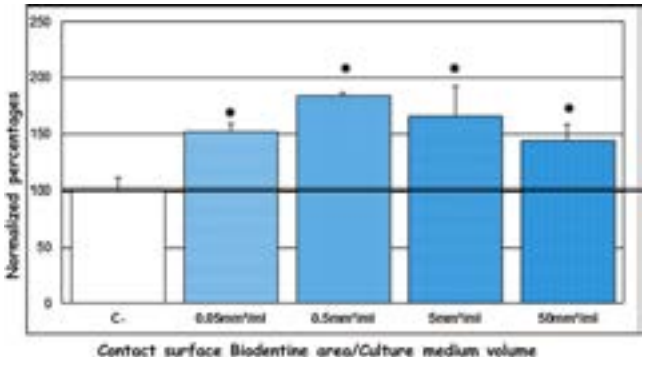

Figure 2 Effect of Biodentine on TGF-β1 release from human pulp cells. Biodentine induces release of TGF-β1 from human pulp cells. *Significant as compared to the control.[10]

Indeed, after application of Biodentine and culture for 14 days, mineralized structures appeared in the form of foci in close vicinity of the material. This mineralization seemed to be directly linked to Biodentine as some cement particles were seen within the mineralized structures but not in the neighboring pulp tissue. This mineralized tissue corresponds to an early form of reparative dentin as cells sequestered within these mineralizations express odontoblastic markers such as nestin and dentin sialoprotein (Fig. 1).

This mineralization seems to be due to the release of a growth factor, namely Transforming factor beta 1 (TGF-β1) from pulp cells incubated with Biodentine (Fig. 2). This factor has been shown to be involved in odontoblastic differentiation and recent investigations revealed that this factor is involved in the recruitment of pulp stem cells to TGF-β1production site[17] which is related to Biodentine application. Interestingly, increase in TGF-β1 was significant whatever the ratio between the Biodentine surface area and cell culture volume.[10] This has a clinical significance as it indicates that this cement can be applied onto the pulp whatever the injured pulp surface area (Fig. 2).

Biodentine interactions with soft tissues induce tertiary dentin synthesis

When Biodentine was used for vital pulp therapy *in vivo*, investigations carrier out on different animal models showed

that this material can be applied for both pulp capping and pulpotomy. Indeed, Biodentine induced tertiary dentin synthesis when applied as direct or indirect pulp capping material in rat teeth.[18,19] After direct pulp capping, the dentin bridge observed after 4 weeks in rat teeth was tubular and its porosity was similar to that of MTA.[19] Similar results demonstrated in miniature swine teeth. Indeed, after pulp capping with Biodentine, no pulp inflammation was observed while a thick dentin bridge formed after 3 and 8 weeks.[20] Similar results were reported in primary pig teeth after 4 weeks and 90 days. Application of Biodentine in pulpotomy was also investigated in primary pig teeth and compared to formecresol and white MTA (WMTA). The results with Biodentine showed no inflammation and a thick dentin bridge formed in 90% of the cases.[21] These data were comparable to the results obtained with WMTA and indicate the biocompatibility of these materials and their suitability for pulp capping and pulpotomy.

Clinical applications

Although Biodentine is a recently developed material as it has been released by the end of the year 2010 in Europe, different clinical applications have been so far published with this material. These include applications in restorative dentistry, pediatric dentistry and endodontics. Although it can be used as a temporary enamel substitute for upto 6 months, Biodentine is mainly used as a permanent dentin substitute. It can be used to replace the missing/damaged bulk dentin volume. It can also be used as an alternative to Formecresol in pulpotomy. The major clinical trials and histological studies in human teeth are detailed below and reported (Table 2) while the clinical case reports are only listed in the same table.

Table 2 Biodentine clinical applications and type of clinical works published on each application. Biodentine can be used in restorative dentistry, pediatric dentistry and endodontics as a permanent dentin substitute. It can be used to replace the missing/damaged whole dentin volume. It can also be used as an alternative to formecresol in pulpotomy.

Application	Type of investigations/ references
Crown	
Temporary enamel restoration	Clinical trials[22]
Permanent dentin substitute in	
Deep/large carious lesions	Clinical trials[22]
Deep cervical/radicular lesions	Case reports[36–38]
Indirect pulp capping	Clinical trials[22,23]
Direct pulp capping	Clinical and histological studies[25,26]
Pulpotomy	Clinical trials[27,39]
Root	
Root canal/furcation perforations	Case reports[40]
External resorption	Case reports[41]
Internal resorption	Case reports[42]
Regenerative endodontics	Case reports[43]
Apexogenesis after traumatic exposure	Case reports[33,44]
Apexification	Case reports[45–48]
Retrograde root canal obturation	Case reports[49,50]

Indirect pulp capping

A randomized clinical study was performed in the restoration of posterior teeth with Biodentine. 397 cases were included with a three years follow-up. Biodentine was applied as a bulk restorative material in deep dentin cavities in replacement of both dentin and enamel. The scoring scales included consistency, working time, adhesion to instruments, ease of handling, anatomic form, marginal adaption, quality of proximal contact, marginal discoloration, surface roughness, secondary caries and post-operative pain. The results of this trial reported that Biodentine was easy to handle, showed, a, excellent anatomic form, marginal adaptation and very good interproximal contact. During the follow-up, the restoration with Biodentine™ in comparison to the composite resin Z100 was well tolerated in all cases with no post-operative pain. The anatomic form, marginal adaptation and interproximal contact started to deteriorate only after 6 months. Due to the deterioration, a complementary treatment was performed. Biodentine was kept as dentin substitute as the pulp vitality test was positive. Biodentine presented a good resistance to burring and the composite Z100 was applied onto Biodentine surface and evaluated for up to 3 years. The conclusions of this study is that Biodentine can be used as a posterior restoration material for up to 6 months as a temporary enamel substitute. When covered with Z100®, it is a well-tolerated permanent dentin substitute. Additionally, Biodentine can be cut and shaped like the natural dentin.[22] In another clinical study, the efficacy of Biodentine as an indirect pulp capping material was evaluated and compared to a glass ionomer cement (Fuji IX) in irreversible pulpitis. 36 restorations with Biodentine and 36 Fuji IX were placed randomly in 53 patients. The clinical efficacy at 12 months revealed no statistically significant differences in clinical efficacy between Biodentine and Fuji IX.[23]

The reported absence of post-operative pain and post-operative sensitivity in the clinical trial[22] may be due at least to 2 factors:

1) The infiltration of Biodentine into the dentin tubules[15] due to the precipitation of crystals within the tubules decreases the dentin tubule permeability and fluid movement which may decrease post-operative sensitivity.
2) The reduction odontoblast pain receptor expression and function and the reduction of the secretion of pro-inflammatory cytokines. Indeed, odontoblasts express pain receptors of the transient receptor potential family of ion channels (TRP) namely TRPA1. These receptors play a significant role in nociception and neurogenic inflammation. When extracts of Biodentine were applied on odontoblast-like cells, expression of these receptors decreased together with their functional activity as measured by an intracellular calcium level increase. Additionally, Application of Biodentine decreased the pro-inflammatory tumor necrosis factor secretion (TNF-α) from odontoblast like cells[24] as measured by Enzyme-linked immunosorbent assay (ELISA).

Direct pulp capping

Pulps of 28 non-carious molars scheduled for orthodontic treatment were exposed mechanically and pulps capped directly with Biodentine or MTA in class I cavities. 7 patients complained from mild pain on the day of surgery. 4 of these patients were treated with Biodentine and 3 with MTA. No symptoms were reported in the other patients. Teeth were tested before extraction for cold and electro-sensitivity and all confirmed the pulp vitality. The absence of periapical pathology was confirmed radiographically before the treatment and just before the tooth extraction. The histological examination of the pulp state and response after direct pulp capping with Biodentine as compared to MTA in human teeth revealed an absence of pulp inflammation and the formation of a complete dentin bridge beneath both materials after 6 weeks.[25] Tomographic data evaluating the density and volume of reparative dentin revealed that these values were higher for Biodentine.[26] These results indicate that Biodentine can be safely applied directly onto the human vital pulp.

Pulpotomy

Clinical application of Biodentine in pulpotomy has been investigated in few clinical studies as a pulpotomy medicament. A randomized clinical study was performed in children of 4—9 years of age. 84 pulpotomies were performed and attributed to MTA or Biodentine. All teeth were restored with stainless steel crowns. Clinical and radiographic evaluations were performed after 6 and 12 months. Data showed that one molar of the MTA group had an internal resorption while 1 molar of Biodentine treated group had internal resorption and another showed a radiographic radiolucency. Over all, both materials had a very high clinical success rate[27] and the overall clinical success after 12 months is reported (Table 3). Another study evaluated Biodentine and compared it to MTA in a short term clinical study. Biodentine was applied in pulpotomy in 20 teeth followed by restoration with stainless steel crowns. At 3 and 6 months, patients were recalled and Biodentine was shown as equally efficient as MTA with similar radiographic success.[28] A similar study was performed comparing Biodentine to MTA and Propolis as pulpotomy medicaments. After 9 months, Biodentine and MTA showed comparable results with a high radiographic success rate and more favorable than Propolis.[29] Finally, a confirmation of all these data reported no significant differences between MTA and Biodentine used as pulpotomy medicaments even after 18 months with clinical success higher than 95% for both materials.[30] Taken together, although longer term clinical evaluations are required, these data indicate that Biodentine has the potential to be used as a substitute for formocresol in primary molar pulpotomies.

Table 3 Evaluation of Biodentine as compared to MTA in pulpotomy after 12 months. Clinical success rates are reported in number of cases and percentage showing a high clinical success rate of both MTA and Biodentine in pulpotomy after 12 months.[27]

	Success/total number of cases	Success (%)
MTA	36/39	92
Biodentine	38/39	97

Case reports on the other clinical applications

In addition to the above detailed indications, many case reports have been published with Biodentine in different clinical indications. These include deep cervical/radicular lesions, root canal/furcation perforations, external/internal resorption, regenerative endodontics, apexogenesis after traumatic exposure, apexification and retrograde root canal obturation. These applications are listed and corresponding case report references are provided (Table 2).

Discussion

Although Biodentine is among the most recently developed tricalcium silicate-based materials, a significant and increasing number of investigations have been published on this material. While many studies reported its biocompatibility and Bioactivity *in vitro* and *in vivo*, preclinical investigations shed the light on the mechanisms of its interaction with the dental hard tissue. Indeed, many investigations performed both *in vitro* and *in vivo* demonstrated that the interactions of Biodentine with both hard and soft tissues provide a hermetic seal protecting the dental pulp by preventing bacterial infiltration. These studies demonstrated that, through its interactions with the hard tissues, Biodentine provides a micro-mechanical retention by infiltrating the dentin tubules. On the other hand it induces the target tissue specific functions by inducing tertiary dentin synthesis which provides further protection to the pulp. These two combined effects might be responsible, at least in part, for the absence of post-operative pain and hypersensitivity. Another important investigation reported that the application of Biodentine reduces both TRPA1 pain receptor expression and function. More importantly, when applied on odontoblast-like cells Biodentine decreases pro-inflammatory TNF-α secretion. This indicates that, in addition to the abovementioned roles of Biodentine, its application onto the dentin/pulp reduces the inflammation and consequently the post-operative pain.

How does Biodentine compare to other widely used and common pulp capping materials

When compared to Calcium Hydroxide, Biodentine is stronger mechanically due to its composition and low porosity. It is less soluble and the produced dentin bridge shows no tunnel defects as compared to that under Calcium hydroxide thus it has a better sealing ability than Calcium hydroxide.[19,31] When Compared to MTA, Biodentine is easier to handle,[22] stronger mechanically and has a shorter setting time.[6] It can be used as a temporary enamel substitute up to 6 months and in different applications as a permanent dentin substitute without any surface treatment. Additionally, while discoloration with MTA[32] and its derivatives have been reported in regenerative endodontics and seem to be mainly due to the

presence of Bismuth oxide as a radio-opacifier,[7] no discoloration of tooth crown has been reported after 48 months with Biodentine which does not contain Bismuth oxide but Zirconium oxide as a radio-opacifier.[33–35]

Conclusions

Taken together, through *in vitro*, *in vivo*, clinical trials/reports, this review shows that Biodentine is biocompatible, has strong mechanical properties and can safely be applied in restorative dentistry, in pediatric dentistry (as a possible alternative to formecresol) and in endodontics. It is important to know that Biodentine does not require any surface conditioning treatment. It can be cut and reshaped like natural dentin. It can be used as a bulk permanent dentin substitute to replace the whole damaged/lost dentin and not only as a pulp capping material. Biodentine surface can be bonded like the natural dentin with different adhesives before final composite resins application.

Conflict of interest

The author's original works on Biodentine were partially supported by Septodont.

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References

1. Mitchell RJ, Osborne PB, Haubenreich JE. Dental amalgam restorations: daily mercury dose and biocompatibility. *J Long Term Eff Med Implants* 2005;**15**(6):709–21.
2. Lutz F, Phillips RW, Roulet JF, Setcos JC. In vivo and in vitro wear of potential posterior composites. *J Dent Res* 1984;**63**: 914–20.
3. Niinuma A. A newly developed resinous direct pulp capping agent containing calcium hydroxide. *Int Endod J* 1999;**32**:475–83.
4. Aienehchi M, Eslami B, Ghanbariha M, Saffar AS. Mineral trioxide aggregate and calcium hydroxide as pulp capping agent in human teeth: a preliminary report. *Int Endod J* 2002;**36**:225–31.
5. Camilleri J, Montesin FE, Brady K, Sweeney R, Curtis RV, Pitt Ford TR. The constitution of mineral trioxide aggregate. *Dent Mater* 2005;**21**:297–303.
6. Torabinejad M, Rastegar AF, Kettering JD, Pitt Ford DR. Bacterial leakage of mineral trioxide aggregate as root-end filling material. *J Endod* 1995;**21**:109–12.
7. Vallés M, Mercadé M, Duran-Sindreu F, Bourdelande JL, Roig M. Influence of light and oxygen on the color stability of five calcium silicate-based materials. *J Endod* 2013;**39**(4):525–8.
8. Camilleri J. Color stability of white mineral trioxide aggregate in contact with hypochlorite solution. *J Endod* 2014;**40**(3):436–40.
9. Laurent P, Camps J, De Méo M, Déjou J, About I. Induction of specific cell responses to a Ca(3)SiO(5)-based posterior restorative material. *Dent Mater* 2008;**24**(11):1486–94.
10. Laurent P, Camps J, About I. Biodentine(TM) induces TGF-β1 release from human pulp cells and early dental pulp mineralization. *Int Endod J* 2012;**45**(5):439–48.
11. Zanini M, Sautier JM, Berdal A, Simon S. Biodentine induces immortalized murine pulp cell differentiation into odontoblast-like cells and stimulates biomineralization. *JEndod* 2012;**38**:1220–6.
12. Attik GN, Villat C, Hallay F, Pradelle-Plasse N, Bonnet H, Moreau K, et al. In vitro biocompatibility of a dentine substitute cement on human MG63 osteoblasts cells: Biodentine™ versus MTA(®). *Int Endod J* 2014;**47**(12):1133–41.
13. Raskin A, Eschrich G, Dejou J, About I. In vitro microleakage of Biodentine as a dentin substitute compared to Fuji II LC in cervical lining restorations. *J Adhes Dent* 2012;**14**(6):535–42.
14. Odabaş ME, Bani M, Tirali RE. Shear bond strengths of different adhesive systems to Biodentine. *Sci World J* 2013;**10**:626103. http://dx.doi.org/http://dx.doi.org/10.1155/2013/626103.
15. Atmeh AR, Chong EZ, Richard G, Festy F, Watson TF. Dentin-cement interfacial interaction: calcium silicates and polyalkenoates. *J Dent Res* 2012;**91**(5):454–9.
16. Camilleri J, Laurent P, About I. Hydration of Biodentine, Theracal LC, and a prototype tricalcium silicate-based dentin replacement material after pulp capping in entire tooth cultures. *J Endod* 2014;**40**(11):1846–54.
17. Mathieu S, Jeanneau C, Sheibat-Othman N, Kalaji N, Fessi H, About I. Usefulness of controlled release of growth factors in investigating the early events of dentin-pulp regeneration. *J Endod* 2013;**39**(2):228–35.
18. Goldberg M, Pradelle-Plasse N, Tran XV, Colon P, Laurent P, Aubut V, et al. Emerging trends in (bio)material research. In: Goldberg M, editor. *Biocompatibility or cytotoxic effects of dental composites*. 1st ed. Oxford, UK: Coxmoor Publishing Company; 2009. p. 181–203.
19. Tran XV, Gorin C, Willig C, Baroukh B, Pellat B, Decup F, et al. Effect of a calcium-silicate based restorative cement on pulp repair. *J Dent Res* 2012;**91**:1166–71.
20. Tziafa C, Koliniotou-Koumpia E, Papadimitriou S, Tziafas D. Dentinogenic responses after direct pulp capping of miniature swine teeth with Biodentine. *J Endod* 2014;**40**(12):1967–71.
21. Shayegan A, Jurysta C, Atash R, Petein M, Abbeele AV. Biodentine used as a pulp-capping agent in primary pig teeth. *Pediatr Dent* 2012;**34**(7):e202–8.
22. Koubi G, Colon P, Franquin JC, Hartmann A, Richard G, Faure MO, et al. Clinical evaluation of the performance and safety of a new dentine substitute, Biodentine, in the restoration of posterior teeth – a prospective study. *Clin Oral Investig* 2013;**17**(1): 243–9.
23. Hashem D, Mannocci F, Patel S, Manoharan A, Brown JE, Watson TF, Banerjee A. Clinical and radiographic assessment of the efficacy of calcium silicate indirect pulp capping: a randomized controlled clinical trial. *J Dent Res* 2015;**94**(4):562–8.
24. El Karim IA, McCrudden MT, McGahon MK, Curtis TM, Jeanneau C, Giraud T, et al. Biodentine reduces tumor necrosis factor alpha-induced TRPA1 expression in odontoblastlike cells. *J Endod* 2016;**42**(4):589–95.
25. Nowicka A, Lipski M, Parafiniuk M, Sporniak-Tutak K, Lichota D, Kosierkiewicz A, et al. Response of human dental pulp capped with Biodentine and mineral trioxide aggregate. *J Endod* 2013;**39**(6):743–7.
26. Nowicka A, Wilk G, Lipski M, Kołecki J, Buczkowska-Radlińska J. Tomographic evaluation of reparative dentin formation after direct pulp capping with Ca(OH)2, MTA, Biodentine, and dentin bonding system in human teeth. *J Endod* 2015; **41**:1234–40.
27. Cuadros-Fernández C, Lorente Rodríguez AI, Sáez-Martínez S, García-Binimelis J, About I, Mercadé M. Short-term treatment outcome of pulpotomies in primary molars using mineral trioxide aggregate and Biodentine: a randomized clinical trial. *Clin Oral Investig* 2015 [Epub ahead of print] November 18.
28. Niranjani K, Prasad MG, Vasa AA, Divya G, Thakur MS, Saujanya K. Clinical evaluation of success of primary teeth pulpotomy using mineral trioxide aggregate(®), laser and Biodentine(TM) – an in vivo study. *J Clin Diagn Res* 2015;**9**(4):ZC35–7.

29. Kusum B, Rakesh K, Richa K. Clinical and radiographical evaluation of mineral trioxide aggregate, Biodentine and propolis as pulpotomy medicaments in primary teeth. *Restor Dent Endod* 2015;**40**(4):276—85.
30. Rajasekharan S, Martens L, Vandenbulcke J, Jacquet W, Bottenberg P, Cauwels R. Efficacy of three different pulpotomy agents in primary molars — a randomised control trial. *Int Endod J* 2016;11. http://dx.doi.org/http://dx.doi.org/10.1111/iej.12619.
31. Cox CF, Sübay RK, Ostro E, Suzuki S, Suzuki SH. Tunnel defects in dentin bridges: their formation following direct pulp capping. *Oper Dent* 1996;**21**(1):4—11.
32. Parirokh M, Torabinejad M. Mineral trioxide aggregate: a comprehensive literature review—Part III: Clinical applications, drawbacks, and mechanism of action. *J Endod* 2010;**36**(3):400—13.
33. Martens L, Rajasekharan S, Cauwels R. Pulp management after traumatic injuries with a tricalcium silicate-based cement (Biodentine™): a report of two cases, up to 48 months follow-up. *Eur Arch Paediatr Dent* 2015;**16**(6):491—6.
34. Vallés M, Roig M, Duran-Sindreu F, Martínez S, Mercadé M. Color stability of teeth restored with Biodentine: a 6-month in vitro study. *J Endod* 2015;**41**(7):1157—60.
35. Marconyak Jr LJ, Kirkpatrick TC, Roberts HW, Roberts MD, Aparicio A, Himel VT, et al. A comparison of coronal tooth discoloration elicited by various endodontic reparative materials. *J Endod* 2016;**42**(3):470—3.
36. Karypidou A, Chatzinikolaou ID, Kouros P, Koulaouzidou E, Economides N. Management of bilateral invasive cervical resorption lesions in maxillary incisors using a novel calcium silicate-based cement: a case report. *Quintessence Int* 2016;23. http://dx.doi.org/http://dx.doi.org/10.3290/j.qi.a36385.
37. Baranwal AK. Management of external invasive cervical resorption of tooth with Biodentine: a case report. *J Conserv Dent* 2016;**19**(3):296—9.
38. Salzano S, Tirone F. Conservative nonsurgical treatment of class 4 invasive cervical resorption: a case series. *J Endod* 2015;**41**(11):1907—12.
39. El Meligy OA, Allazzam S, Alamoudi NM. Comparison between Biodentine and formocresol for pulpotomy of primary teeth: a randomized clinical trial. *Quintessence Int* 2016;**47**(7):571—80.
40. Sinkar RC, Patil SS, Jogad NP, Gade VJ. Comparison of sealing ability of ProRoot MTA, RetroMTA, and Biodentine as furcation repair materials: an ultraviolet spectrophotometric analysis. *J Conserv Dent* 2015;**18**(6):445—8.
41. Pruthi PJ, Dharmani U, Roongta R, Talwar S. Management of external perforating root resorption by intentional replantation followed by Biodentine restoration. *Dent Res J* 2015;**12**(5):488—93.
42. Umashetty G, Hoshing U, Patil S, Ajgaonkar N. Management of inflammatory internal root resorption with Biodentine and thermoplasticised Gutta-Percha. *Case Rep Dent* 2015;**2015**:452609.
43. Khoshkhounejad M, Shokouhinejad N, Pirmoazen S. Regenerative endodontic treatment: report of two cases with different clinical management and outcomes. *J Dent* 2015;**12**(6):460—8.
44. Martens L, Rajasekharan S, Cauwels R. Endodontic treatment of trauma-induced necrotic immature teeth using a tricalcium silicate-based bioactive cement. A report of 3 cases with 24-month follow-up. *Eur J Paediatr Dent* 2016;**17**(1):24—8.
45. Nayak G, Hasan MF. Biodentine — a novel dentinal substitute for single visit apexification. *Restor Dent Endod* 2014;**39**(2):120—5.
46. Evren OK, Altunsoy M, Tanriver M, Capar ID, Kalkan A, Gok T. Fracture resistance of simulated immature teeth after apexification with calcium silicate-based materials. *Eur J Dent* 2016;**10**(2):188—92.
47. Vidal K, Martin G, Lozano O, Salas M, Trigueros J, Aguilar G. Apical closure in apexification: a review and case report of apexification treatment of an immature permanent tooth with Biodentine. *J Endod* 2016;**42**(5):730—4.
48. Bajwa NK, Jingarwar MM, Pathak A. Single visit apexification procedure of a traumatically injured tooth with a novel bioinductive material (Biodentine). *Int J Clin Pediatr Dent* 2015;**8**(1):58—61.
49. Caron G, Azérad J, Faure MO, Machtou P, Boucher Y. Use of a new retrograde filling material (Biodentine) for endodontic surgery: two case reports. *Int J Oral Sci* 2014;**6**(4):250—3.
50. Gupta PK, Garg G, Kalita C, Saikia A, Srinivasa TS, Satish G. Evaluation of sealing ability of Biodentine as retrograde filling material by using two different manipulation methods: an in vitro study. *J Int Oral Health* 2015;**7**(7):111—4.

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ORIGINAL ARTICLE/ARTICOLO ORIGINALE

The influence of antibiotics on the physical properties of endodontic cements

Influenza dell'utilizzo di soluzioni antibiotiche sulle proprietà meccaniche di cementi endodontici

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KEYWORDS
Antibiotic;
Chlorexidine;
Microhardness;
Push-out strength;
MTA.

Abstract
Aim: To evaluate the influence of Metronidazole, Minocycline and Ciprofloxacin as a mixture or individually and of chlorhexidine on the push-out bond strength and surface microhardness of calcium silicate cements of differing particle size.
Methodology: 120 extracted adult human premolars were decoronated and 2 mm dentin slices were prepared. Specimens were divided equally into the following groups: normal saline and CHX, Metronidazole, Minocycline, Ciprofloxacin, and combination of Metronidazole, Minocycline and Ciprofloxacin. The specimens were irrigated with solutions and filled with endodontic cements. In the second part, the endodontic cements were mixed, placed in plastic tubes

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and then irrigated for 1 or 5 min. Push-out and surface microhardness values were calculated and data were analyzed with three way ANOVA followed by Tukey's post-hoc test.
Results: The normal saline and ciprofloxacin groups showed significantly higher and lower, respectively, push-out bond strength among the experimental groups ($p < 0.001$ for all groups). Nano type cement showed higher push-out bond strength and microhardness than regular one at both time intervals. The mixture of antibiotics had significant effects on the push out and microhardness of calcium silicate cement.
Conclusions: Nano particle MTA resisted more than the conventional MTA to the effect of the irrigating solution and antibiotics in both hardness and push-out strength. Furthermore, the results of microhardness were consistent with the push-out strength in most cases. The microhardness test may be employed as a complimentary test to evaluate push-out strength of dental cements.

PAROLE CHIAVE
Antibiotici;
Clorexidina;
Microdurezza;
Resistenza alla dislocazione;
MTA.

Riassunto
Obiettivo: valutare l'influenza dell'uso di metronidazolo, minociclina e Ciprofloxacina come miscela di antibiotici o singolarmente e della clorexidina sulla forza di legame e la microdurezza superficiale di cementi di silicato di calcio di diversa granulometria.
Metodologia: 120 premolari umani adulti estratti sono stati decoronati e sono state preparate fette di dentina di 2 mm. I campioni sono stati divisi in parti uguali nei seguenti gruppi a seconda della soluzione irrigante utilizzata: soluzione fisiologica e CHX, metronidazolo, minociclina, ciprofloxacina, e una combinazione di Metronidazolo, minociclina e ciprofloxacina. I campioni sono stati irrigati con una di queste soluzioni e riempiti di cemento endodontico e poi sottoposti a test di push-out. Nella seconda parte, i cementi endodontici sono stati mescolati, messi in provette di plastica e poi posti in contatto per 1 o 5 min con le diverse soluzioni prima di essere testati per microdurezza superficiale. I valori push-out e microdurezza superficiale sono stati calcolati e i dati sono stati analizzati con test ANOVA a tre vie seguito dal test post hoc di Tukey.
Risultati: I gruppi trattati con soluzione saline e con la ciprofloxacina hanno mostrato rispettivamenteuna forza di legame significativamente più alta e più bassa tra i gruppi sperimentali ($p < 0.001$). Il cemento di tip nanao ha mostrato una maggiore forza di legame al test push-out e una maggiore microdurezza superficiale rispetto al cemento regolare nei due intervalli di tempo. La miscela di antibiotici ha avuto effetti significativi sulla resistenza alla dislocazione e sulla microdurezza superficiale dei cemento al silicato di calcio.
Conclusioni: Un MTA a nanoparticelle ha resistito amggiormente all'effetto nesativo delle soluzioi irriganti e antibiotiche rispetto al MTA convenzionale sia per quanto riguarda la durezza superficiale che la resistenza al push-out. Inoltre, i risultati di microdurezza superficiali sono risultati correlati alla forza di legame nella maggior parte dei casi. Il test microdurezza può essere impiegato come test complementare per valutare la forza al push-out dei cementi endodontici.

Introduction

Since the introduction of Mineral Trioxide Aggregate (MTA) to the field of dentistry[1] several variables, such as the powder-to-water ratio,[2] mixing technique,[3] humidity and setting time[4], storage temperature[5], and the pH value of applied area[6–8] have been shown to have an impact on different properties of MTA. Likewise, post-setting factors such as thermal fluctuation after cement application can have significant impact on the structural and physical properties of this material.[9] In addition to environmental variables, there are different materials that are used in root canal procedures which can produce similar alterations[10] and may affect biologically root canal treatment and regeneration.[11,12]

Chlorhexidine (CHX) is a cationic based antiseptic that is active against a wide range of microorganisms including aerobic and anaerobic gram-positive and negative bacteria, viruses, molds and yeasts.[13,14] The mutual effect of CHX and MTA cement has been questioned from antibacterial and cytotoxicity characteristics.[10] When 0.12% CHX was mixed with MTA cement, the antibacterial properties of CHX can be beneficial for MTA; however, MTA can increase the cytotoxicity of CHX as a result.[10]

Antimicrobial agents are frequently employed within root canals in form of liquids, pastes or solids. Investigations have confirmed the use of combination of Metronidazole, Minocycline and Ciprofloxacin for sterilization of root canal systems and are now acceptable in clinical practice.[14–16] An *in vitro* study[15] testing the antibacterial efficacy of these drugs alone and in combination indicated that these drugs individually could not completely eliminate bacterial contamination, however the mixture of these antibiotic was able to consistently sterilize all samples. Published studies

have claimed that this mixture is able to eradicate the tested microorganisms in vitro.[14]

Nano WMTA is a nano version of WMTA,[17] which in addition to having the nano particle size powder it has different additives to accelerate and amplify its hydration process.[18,19] Apart from some advantages of Nano WMTA, such as lower setting time and higher compressive and push-out strength in comparison with WMTA,[9,18,19] studies have investigated the changes in the physical properties of this cement in different settings.[3,9] Investigations have shown that similar to WMTA, alterations in setting condition can reduce the physical properties of Nano WMTA. However, Nano WMTA withstands these changes better than WMTA.[3,9]

The present study evaluated the effect of disinfectant and antibiotic materials such as CHX gel, Metronidazole, Minocycline, Ciprofloxacin and their combination on the push-out bond strength and micro-hardness of WMTA and Nano WMTA to the dentinal surface. The hypothesis tested was that the use of these agents as a canal irrigating material or intracanal medication, will affect the push-out bond strength and the surface micro-hardness of the cements, which could be deleterious to the desired sealing ability of the MTA materials.

Materials and methods

Antibiotic mixture preparation

Based on a previous study,[15] Metronidazole, Minocycline hydrochloride and Ciprofloxacin (all antibiotics purchased from Sigma—Aldrich, St. Louis, MO) were mixed under aseptic conditions and UV light using a spatula to prepare a mixture with proportions of 1:5:1, respectively, to yield 8.3 g, which was then mixed with a mortar and pestle to create a powder. The powder was added to 50 mL milli Q water and vortexed for 5 min to make a solution.

Push-out bond strength

This study was divided into two parts, the first part being similar to Saghiri et al.[19] Briefly, 120 extracted single-rooted human teeth were selected and sectioned horizontally using a low-speed Isomet diamond saw (Buehler, Lake Bluff, IL, USA) at the mid-root portion to prepare 2 mm thick dentin slices. The canal spaces were instrumented by using #2 through #5 Gates-Glidden burs (Mani, Tochigi, Japan) to form 1.3 mm diameter standardized spaces. Subsequently, debris and smear layer removal was done by immersion in 17% EDTA, then in 5.25% NaOCl for one minute in each. The specimens were divided into the following groups: Normal Saline, CHX (12 specimens irrigated for 1 min and randomly filled with WMTA or Nano WMTA), Metronidazole, Minocycline, Ciprofloxacin, and the combination of the antibiotics (12 specimens irrigated for 1 min randomly divided into two groups and filled with WMTA or Nano WMTA and 12 specimens irrigated for 5 min and similarly prepared).

Dentin slices were irrigated with distilled water, dried and irrigated with 3 mL of normal saline, CHX, Metronidazole, Minocycline, Ciprofloxacin, and the combination of the antibiotics for 1 or 5 min. After irrigation, the canals were filled with WMTA (Angelus Dental Industry Products, Londrina, Brazil) or Nano WMTA (Kamal Asgar Research Centre). Cements were mixed according to the manufacturers' instruction and transferred into the canal spaces using a manual MTA carrier and packed using a hand compactor. A piece of gauze soaked in synthetic tissue fluid, prepared from 1.7 g of KH_2PO_4, 11.8 g of Na_2HPO_4, 80.0 g of NaCl, and 2.0 g of KCl in 1 L of H_2O (pH 7.4), was placed on each sample and all dentin slices were incubated at 37 °C with 98% humidity for 3 days. The gauze was changed every 6 h to preserve the stability of the setting condition for the cement.

The push-out bond strength was evaluated using Universal testing machine (Sintech MTS, Eden Prairie, MN, USA). Samples were fixed on a metal slab with a central hole. A stainless steel plunger with 1 mm diameter was used to apply the downward compressive load with crosshead speed of 1 mm/min on the cement materials.

Vickers hardness test

The second part of the study was similar to Saghiri et al.[20] Briefly, 120 plastic tubes were divided into experimental groups same as the first part of the study. Subsequently, WMTA and Nano WMTA cements were mixed and packed by using a hand compactor into the plastic tubes as is shown in Fig. 1. Five minutes after packing the surface of the cements were exposed to one droplet of the following material: normal saline, CHX, Metronidazole, Minocycline, Ciprofloxacin, and the combination of the antibiotics. The droplets were cleaned 1 min or 5 min after exposure and the specimens were incubated for 24 h. The specimens were then ground as reported by Saghiri et al.[20] and prepared for Vickers hardness test.

Type of failure

Specimens used to test the 1 min time interval push-out bond strength were also evaluated to determine the type of bond

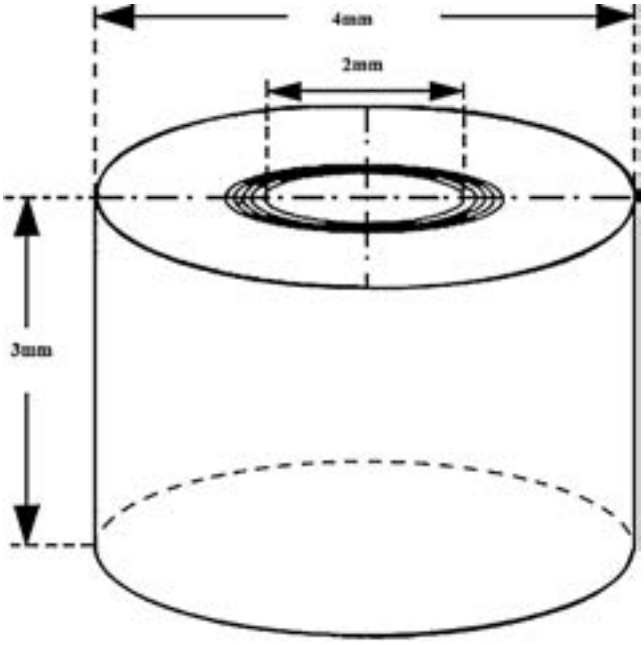

Figure 1 Tube used to determine surface hardness of experimental materials.

failure. Samples were analyzed with a digital camera attached to a stereomicroscope (Olympus, SZM9) at 16× magnification. The type of bond failure was determined by the area of cement remaining on the surface of canal dentin and then categorized as adhesive, mixed or cohesive. Bond failure analysis was performed by a single observer who was blind to the experimental groups.

Statistical analysis

Data showed normal distribution using a Kolmogorov–Smirnov test. To assess the impact of materials, antibiotics and time on the dependent variables push-out strength and hardness and their interactions three-way ANOVA followed by Tukey's post hoc was performed.

Results

Push-out strength

Mean ± SD of the data is presented in Fig. 2A. The Material × Antibiotic × Time three-way interaction was not found to be statistically significant, ($F = 0.70$, $p = 0.554$). Neither the Material × Antibiotic, Material × Time, Antibiotic × Time interactions were found to be statistically significant ([$F = 0.564$, $p = 0.728$], [$F = 0.056$, $p = 0.813$],

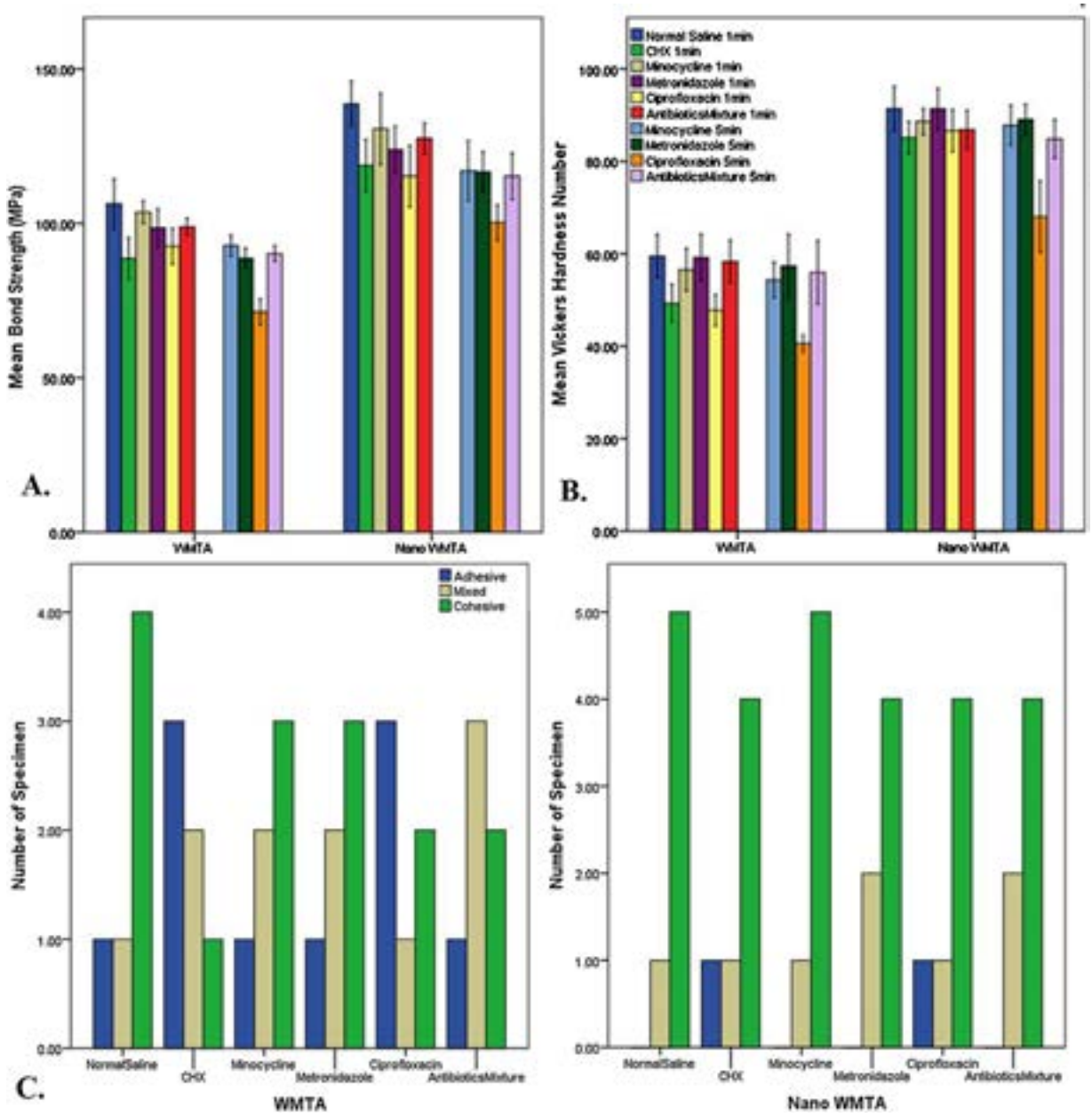

Figure 2 Mean ± SD of (A) Push-out Strength and (B) Vickers Hardness Number. (C) Failure mode in dentin–cement interface. Adhesive failure: less than 25% cement remnant on dentinal surface. Mixed adhesive/cohesive failure: 25–75% cement remnant on dentinal surface cohesive failure: More than 75% cement remnant on dentinal surface. Left. WMTA, Right. Nano WMTA.

[$F = 2.239$, $p = 0.088$] respectively). Statistically significant main effect was found for all factors (Material [$F = 463.533$, $p < 0.001$], Antibiotic [$F = 25.325$, $p < 0.001$], Time [$F = 79.264$, $p < 0.001$]). Simple main effects analyses, followed by post-hocs, were performed on the independent factors. For instance, the normal saline group showed statistically significant higher push-out strength compared to the other experimental groups ($p < 0.001$ for all groups), and ciprofloxacin showed significantly lower push-out strength among other groups ($p < 0.001$ for all groups). Nano WMTA showed significantly higher push-out strength than WMTA.

Vickers hardness test

Mean ± SD of the data is presented in Fig. 2B. The Material × Antibiotic × Time three-way interaction was not found to be statistically significant ($F = 2.424$, $p = 0.070$). Of the two-way interaction terms tested, the Antibiotic × Time was found to be statistically significant ($F = 8.184$, $p < 0.001$). In 1-min interval, the CHX and Ciprofloxacin groups showed significantly lower hardness compared to the other groups ($p < 0.001$, $p = 0.006$, $p < 0.001$ and $p = 0.006$ for normal saline, Minocycline, Metronidazole and antibiotic mixture respectively). Furthermore, in the 5-min time interval, ciprofloxacin also showed significantly lower hardness ($p < 0.001$). Statistically significant main effect was found for all factors (Material [$F = 1296.127$, $p < 0.001$], Antibiotic [$F = 27.212$, $p < 0.001$], Time [$F = 23.457$, $p < 0.001$]). Nano WMTA showed significantly higher hardness than WMTA in both time intervals.

Type of failure

The stereo microscope observations characterized the modes of bond failure of the experimental groups. The results are presented in Fig. 2C and D.

Discussion

The use of antibiotics has been widely accepted in endodontics. Despite some advance in this area, the effect of antibiotics on the physical properties of root end filling materials need future evaluation. The present study is an attempt to evaluate the influence of different antibiotics, including Ciprofloxacin, Metronidazole and Minocycline, on the physical properties of a well-known root end filling material WMTA.

Several studies have evaluated the physicochemical changes of these cements in different situations or against environmental variables.[3–9,21,22] The push-out test is closely related to the sealing characteristics of calcium silicate based cements.[21] Parameters such as pin diameter, specimen thickness, and the elastic modulus of tested material may affect the bond strength values.[23] Therefore, the dentin slices were 2 mm in thickness,[23] and the plunger used for applying the forces in push-out test was 1 mm in diameter that was also chosen to be 0.85 times smaller than the tested materials.[23] The push-out test methodology, samples preparation, and the concentrations of antibiotic mixture were selected as previously reported.[4,7,19,24] Moreover, because 2% CHX is an effective solution for disinfecting the root canal system,[25–27] this irrigating solution was also used here.

Our results indicated that the samples which were exposed to CHX showed significantly lower push-out strength values in 1 min time interval compared with other experimental groups except Ciprofloxacin. In addition, Ciprofloxacin showed significantly lower push-out bond strength values in both time intervals. These results were not consistent with previous studies, that indicated 2% CHX did not impact the push-out bond strength of MTA-dentin significantly.[27,28] This difference might be explained by the methodology used by these authors, as they noted a decrease in bond strength values of MTA-dentin in samples exposed to 2% CHX and 5.25% NaOCl. Furthermore, in other previous studies the effect of 0.12% CHX was tested on the antimicrobial activity of MTA cement.[10,29] Although 0.12% CHX can enhance the antimicrobial activity of MTA cement, the cytotoxicity of CHX was increased[10] and CHX produced some alterations on the dentinal surface.[29] These structural changes produced by CHX seem to be an important factor in decreasing the push-out bond strength value of tested calcium silicate-based cements.

The comparison between WMTA and Nano WTMA experimental groups showed that the push-out values in Nano WMTA subgroups were remarkably higher than WMTA samples. These outcomes were consistent with previous studies' results[9,19] where Nano WMTA showed higher dislodgement force in different tested environments than WMTA. This can be explained by the nano structure of this cement which provides more surface area for reaction between the powder particles and the liquid.[9,19] In addition, the additives of Nano WMTA such as zeolite, tricalcium aluminate, strontium carbonate and calcium sulfate can provide better distribution for powder particles and act as stabilizing agents in different situations.[9,19]

The results of the current study indicated that Nano WMTA has higher hardness than WMTA which was consistent with previous studies.[17,18] Statistical analysis of data revealed that CHX and Ciprofloxacin showed significantly lower hardness compared with other groups. As other authors pointed out, this may contribute to significant interaction between the cements and the environments where the cements hardened.[20,30] According to the present results, the Ciprofloxacin group showed the lowest pH value (pH 3.4) compared with Normal Saline, CHX, Minocycline, Metronidazole and the antibiotic mixture, which results in lower hardness (pH 6.5, 7.5, 4.5, 6.5 and 5.8 respectively). Therefore, the results of the current study illustrated that pH influenced hardness of calcium silicate based cements as other researchers have stated.[31]

It could be inferred from the results, that Nano WMTA with antibiotics mixture showed higher push-out bond strength than WMTA with Normal Saline. Indeed, if using CHX, antibiotics or their mixture is recommended clinically, Nano WMTA with antibiotic mixture could be used instead of the commercial WMTA while having higher push-out bond strength and hardness. This could be due to the nano sizing effect and increasing the surface area of the nano powder. The evaluation of types of bond failure was consistent with the push-out strength values of WMTA and Nano WMTA groups. In Nano WMTA samples the cohesive type of failure was more than WMTA specimen. This difference can

be explained by the higher dislodgement force of Nano WMTA samples that showed more resistance against the forces during push-out test. This finding is attributed to the better interlocking of Nano WMTA cement inside the dentinal structure[3,19] and can lead to cohesive type of failure, which is obviously seen through the Nano WMTA cement remnant on the surface of root canal dentin.

Conclusions

- Antibiotic solutions had significant influence on push-out bond strength and surface microhardness of calcium silicate cements.
- Nano particles resisted more than regular cement to irrigating solution and antibiotics in both terms of surface hardness and push-out bond strength.
- In most groups, surface microhardness was consistent with push-out results. Consequently, the microhardness test could be a complimentary test for the evaluation of push-out bond strength of dental cement.

Conflict of interest

This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors. M Ali Saghiri holds a US patent for Nano Cement.

Acknowledgments

This publication is dedicated to the memory of Dr. Hajar Afsar Lajevardi, a legendry Iranian Pediatrician (1955—2015) who passed away during the writing of this article. We will never forget Dr. H Afsar Lajevardi's kindness and support. She was the prominent clinician-scientist with a particular focus on infectious diseases of children in Iran. The authors also acknowledge the unrestricted award from Research to Prevent Blindness to the Department of Ophthalmology and Visual Sciences, Retina Research Foundation, P30 EY016665, P30 CA014520, EPA 83573701, and EY022883. In addition, we thank Drs. Ali Mohammad Saghiri and Mona Momeni Moghadam for their assistance with the manuscript. Also, none of the supporters have had any role in direction of this project.

References

1. Torabinejad M, White DJ. Tooth filling material and method of use: Google Patents; 1995.
2. Saghiri MA, Asgar K, Lotfi M, Karamifar K, Neelakantan P, Ricci JL. Application of mercury intrusion porosimetry for studying the porosity of mineral trioxide aggregate at two different pH. *Acta Odontol Scand* 2012;**70**:78—82.
3. Saghiri MA, Garcia-Godoy F, Gutmann JL, Lotfi M, Asatourian A. Effects of various mixing techniques on physical properties of white mineral trioxide aggregate. *Dent Traumatol* 2014;**30**:240—5.
4. Gancedo-Caravia L, Garcia-Barbero E. Influence of humidity and setting time on the push-out strength of mineral trioxide aggregate obturations. *J Endod* 2006;**32**:894—6.
5. Saghiri MA, Lotfi M, Joupari MD, Aeinehchi M, Saghiri AM. Effects of storage temperature on surface hardness, microstructure, and phase formation of white mineral trioxide aggregate. *J Endod* 2010;**36**:1414—8.
6. Hashem AAR, Amin SAW. The effect of acidity on dislodgment resistance of mineral trioxide aggregate and bioaggregate in furcation perforations: an in vitro comparative study. *J Endod* 2012;**38**:245—9.
7. Shokouhinejad N, Nekoofar MH, Iravani A, Kharrazifard MJ, Dummer PM. Effect of acidic environment on the push-out bond strength of mineral trioxide aggregate. *J Endod* 2010;**36**:871—4.
8. Saghiri MA, Lotfi M, Saghiri AM, Vosoughhosseini S, Fatemi A, Shiezadeh V, et al. Effect of pH on sealing ability of white mineral trioxide aggregate as a root-end filling material. *J Endod* 2008;**34**:1226—9.
9. Saghiri MA, Asatourian A, Garcia-Godoy F, Gutmann JL, Sheibani N. The impact of thermocycling process on the dislodgement force of different endodontic cements. *Biomed Res Int* 2013;2013.
10. Hernandez E, Botero T, Mantellini M, McDonald N, Nör J. Effect of ProRoot® MTA mixed with chlorhexidine on apoptosis and cell cycle of fibroblasts and macrophages in vitro. *Int Endod J* 2005;**38**:137—43.
11. Saghiri MA, Asatourian A, Sheibani N. Angiogenesis in regenerative dentistry. *Oral Surg Oral Med Oral Pathol Oral Radiol* 2015;**119**:122.
12. Saghiri MA, Asatourian A, Sorenson CM, Sheibani N. Role of angiogenesis in endodontics: contributions of stem cells and proangiogenic and antiangiogenic factors to dental pulp regeneration. *J Endod* 2015;**41**:797—803.
13. Hauman C, Love R. Biocompatibility of dental materials used in contemporary endodontic therapy: a review. Part 1. Intracanal drugs and substances. *Int Endod J* 2003;**36**:75—85.
14. Mehrvarzfar P, Saghiri MA, Asatourian A, Fekrazad R, Karamifar K, Eslami G, et al. Additive effect of a diode laser on the antibacterial activity of 2.5% NaOCl, 2% CHX and MTAD against *Enterococcus faecalis* contaminating root canals: an in vitro study. *J Oral Sci* 2011;**53**:355—60.
15. Hoshino E, Kurihara-Ando N, Sato I, Uematsu H, Sato M, Kota K, et al. In-vitro antibacterial susceptibility of bacteria taken from infected root dentine to a mixture of ciprofloxacin, metronidazole and minocycline. *Int Endod J* 1996;**29**:125—30.
16. Sato T, Hoshino E, Uematsu H, Kota K, Iwaku M, Noda T. Bactericidal efficacy of a mixture of ciprofloxacin, metronidazole, minocycline and rifampicin against bacteria of carious and endodontic lesions of human deciduous teeth in vitro. *Microb Ecol Health Dis* 1992;**5**:171—7.
17. Saghiri MA, Lotfi M, Aghili H. Dental cement composition: US Patent 8,668,770, 2014.
18. Saghiri M, Asgar K, Lotfi M, Garcia-Godoy F. Nanomodification of mineral trioxide aggregate for enhanced physiochemical properties. *Int Endod J* 2012;**45**:979—88.
19. Saghiri MA, Garcia-Godoy F, Gutmann JL, Lotfi M, Asatourian A, Ahmadi H. Push-out bond strength of a nano-modified mineral trioxide aggregate. *Dent Traumatol* 2013;**29**:323—7.
20. Saghiri MA, Lotfi M, Saghiri AM, Vosoughhosseini S, Aeinehchi M, Ranjkesh B. Scanning electron micrograph and surface hardness of mineral trioxide aggregate in the presence of alkaline pH. *J Endod* 2009;**35**:706—10.
21. Parirokh M, Torabinejad M. Mineral trioxide aggregate: a comprehensive literature review—part I: chemical, physical, and antibacterial properties. *J Endod* 2010;**36**:16—27.
22. VanderWeele RA, Schwartz SA, Beeson TJ. Effect of blood contamination on retention characteristics of MTA when mixed with different liquids. *J Endod* 2006;**32**:421—4.
23. Chen W-P, Chen Y-Y, Huang S-H, Lin C-P. Limitations of push-out test in bond strength measurement. *J Endod* 2013;**39**:283—7.
24. Sato I, Ando-Kurihara N, Kota K, Iwaku M, Hoshino E. Sterilization of infected root-canal dentine by topical application of a mixture of ciprofloxacin, metronidazole and minocycline in situ. *Int Endod J* 1996;**29**:118—24.

25. Leonardo M, Tanomaru Filho M, Silva L, Nelson Filho P, Bonifacio K, Ito I. In vivo antimicrobial activity of 2% chlorhexidine used as a root canal irrigating solution. *J Endod* 1999;**25**:167—71.
26. Wang CS, Arnold RR, Trope M, Teixeira FB. Clinical efficiency of 2% chlorhexidine gel in reducing intracanal bacteria. *J Endod* 2007;**33**:1283—9.
27. Yan P, Peng B, Fan B, Fan M, Bian Z. The effects of sodium hypochlorite (5.25%), Chlorhexidine (2%), and Glyde File Prep on the bond strength of MTA-dentin. *J Endod* 2006;**32**:58—60.
28. Guneser MB, Akbulut MB, Eldeniz AU. Effect of various endodontic irrigants on the push-out bond strength of biodentine and conventional root perforation repair materials. *J Endod* 2013;**39**:380—4.
29. Stowe TJ, Sedgley CM, Stowe B, Fenno JC. The effects of chlorhexidine gluconate (0.12%) on the antimicrobial properties of tooth-colored ProRoot mineral trioxide aggregate. *J Endod* 2004;**30**:429—31.
30. Giuliani V, Nieri M, Pace R, Pagavino G. Effects of pH on surface hardness and microstructure of mineral trioxide aggregate and Aureoseal: an in vitro study. *J Endod* 2010;**36**:1883—6.
31. Namazikhah MS, Nekoofar MH, Sheykhrezae MS, Salariyeh S, Hayes SJ, Bryant S, et al. The effect of pH on surface hardness and microstructure of mineral trioxide aggregate. *Int Endod J* 2008;**41**:108—16.

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ORIGINAL ARTICLE/ARTICOLO ORIGINALE

Effect of apical preparation on different needle depth penetration

Influenza della preparazione apicale sulla profondità di penetrazione di differenti aghi da irrigazione

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KEYWORDS
Apical shape;
Irrigation;
Needle;
Nickel—titanium;
Instruments.

Abstract
Aim: Shaping should be complemented by antiseptic solution. These are often delivered using a needle and syringe. But apical penetration of the irrigation solution is of only 1 mm beyond its tip. The aim of our study was to evaluate the influence of the apical preparation on the penetration depth of some needles.
Methodology: 24 teeth were divided randomly into two groups and prepared in continuous rotation (350 rpm) with Revo-S® or ProTaper® to sizes AS 30, 35 and 40 and F1, F2 and F3 respectively. Four types of endodontic needles were used. Three sizes of stainless steel needles:

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25, 27 and 30 gauge and one of nickel—titanium needle: 30 Gauge. Each needle was inserted and its length of penetration measured before the root canal preparation and after the finishing files.
Results: Multivariate analysis of variance showed significant differences for the finishers ($p < 0.0001$) and the kind of needle ($p < 0.0001$). The PLSD Fisher's test can highlight the differences between the six types of apical shaping used (independently of the needle type). The same differences were observed between the four types of needle (independently of the apical finish) ($p = 0.0232$).

Variance analysis between the four different needles is statistically significant for each apical shaping ($p < 0.0001 \times 6$). Variance analysis among the six types of finish is statistically significant for each type of needle ($p < 0.0001 \times 4$).
Conclusions: This study shows that the apical preparation influences the penetration depth of needles. The 27 gauge needles reach the last millimetre only with the Revo-S® system shaped with AS 40. Finally, the 30 gauge needles reach it for all finishers except the ProTaper® F1.

PAROLE CHIAVE
Preparazione apicale;
Irrigazione;
Aghi;
Nichel-titanio;
Strumenti.

Riassunto
Scopo: La preparazione canalare dovrebbe essere integrata dall'utilizzo di soluzioni antisettiche. Queste vengono rilasciate all'interno del canale utilizzando specifiche siringhe ed aghi endodontici, ma la penetrazione apicale della soluzione irrigante è di appena 1 mm oltre la punta dell'ago. Lo scopo del nostro studio è stato quello di valutare l'influenza della preparazione apicale sulla profondità di penetrazione di alcuni aghi endodontici.
Materiali e metodi: 24 denti sono stati divisi casualmente in due gruppi e preparati in rotazione continua (350 rpm) con Revo-S® o ProTaper® a 6 differenti dimensioni di preparazione, AS30, AS35 e AS40 e F1, F2 e F3 rispettivamente. Sono stati utilizzati quattro tipi di aghi endodonzia, tre in acciaio inossidabile di differenti dimensioni: 25, 27 e 30 gauge e uno in nichel-titanio da 30 Gauge. Ogni ago è stato inserito nel canale e la sua lunghezza di penetrazione misurata prima e dopo la preparazione canalare.
Risultati: L'analisi multivariata della varianza ha mostrato differenze significative per i l'ultimo strumento utilizzato ($p < 0{,}0001$) e il tipo di ago ($p < 0{,}0001$). Il test di Fisher ha evidenziato delle differenze tra i sei differenti tipi di sagomatura apicale utilizzati (indipendentemente dal tipo di ago) e tra i quattro tipi di aghi utilizzati (indipendentemente della finitura apicale) ($p = 0{,}0232$). L'analisi della varianza è statisticamente significativa tra i quattro aghi diversi per ogni differente tipo di sagomatura apicale ($p < 0{,}0001 \times 6$) e tra i sei differenti tipi di rifinitura per ogni tipo di ago ($p < 0{,}0001 \times 4$).
Conclusioni: In conclusione, questo studio dimostra che la preparazione apicale influenza la profondità di penetrazione degli aghi da irigazione. Gli aghi calibro 27 raggiungono il millimetro apicale solo con il sistema di Revo-S® di taglia 40. Gli aghi calibro 30 raggiungono il millimetro apicale per tutti gli strumenti da preparazione apicale utilizzati tranne che per il ProTaper® F1.

Introduction

Endodontic cleaning needs to remove all pulp tissue, microorganisms and dentin debris from the canal during root canal shaping.[1] However, it was shown that the canal preparation is influenced by the great variability of root canal anatomy. Indeed the instruments (both manual and rotary) do not reach certain areas such as cracks, crevices, isthmus, accessory canals and apical deltas.[2,3]

The action of the instruments should be complemented by antiseptic solution.[3] These are often delivered using a needle and syringe. But studies indicate that the apical penetration of the irrigation solution is of only 1 mm beyond the tip of the needle.[2,4] The aim of our study was to evaluate the influence of the apical preparation on the penetration depth of some needles.

Materials and methods

24 teeth from the tooth bank of the Endodontic Department of the Dental Faculty of Toulouse were selected. Only single-rooted teeth having a mature apex and a root curvature less than 15° were included in this study. Those with cracked roots, root caries, resorbed or immature apex or endodontic treatment were excluded.

The teeth were divided randomly into two groups of 12. The access cavity was performed using a turbine, diamond bur (diameter 12) and endo-Z® (ref 801-012FG and E0152FG Stoner France, Toulouse, France). Then the initial penetration was performed using K files diameter 10 (Micro-Mega, Besancon, France). Working length (WL) was determined under a stereo-microscope (Wild M3B, Leica, Heerbrugg, Switzerland) at ×16 magnification. When this file reached

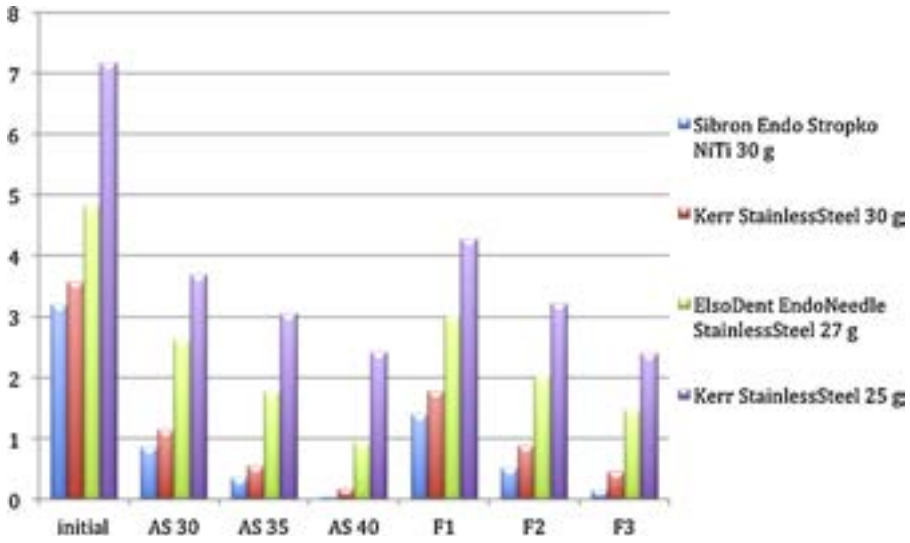

Figure 1 Mean difference depth to working length depending on needle and apical finish.

the apical foramen, half a millimetre was removed to determine the working length.

Secondly, root canals were prepared using nickel–titanium files in continuous rotation at a speed of 350 rpm (X-Smart®, Dentsply, Konstanz, Germany). Each group was shaped with a nickel–titanium system dedicated to initial treatment: the first with Revo-S® (Micro-Mega, Besancon, France), the second with ProTaper® (Maillefer, Ballaigues, Switzerland). Revo S®-sequence was used with a flaring file (EndoFlare®, Micro-Méga, Besançon, France) in the coronal part (3–4 mm maximum), then SC1 shaped the 2/3 of WL and the other files reached the WL (SC2, SU, AS 30, AS 35 and AS 40).

ProTaper® sequence was used with the Sx® in the coronal part and all the other files reached the WL (S1, S2, F1, F2 and F3). 2 mL of 2.6% NaOCl was used between each instrument.

Four types of endodontic needles were used. Three sizes of stainless steel needles: 25, 30 gauge (Irrigation Probe®, Kerr Hawe, Bioggio, Switzerland) and 27 gauge (Endoneedle®, Elsodent, G-Pharma, Cergy Pontoise, France) and one size of nickel–titanium needle: 30 Gauge (Stropko®, SybronEndo, Orange, CA). Each needle was inserted and its length of penetration measured before the root canal preparation and after the finishing files: AS 30, AS 35 and AS 40 for Revo-S®, and F1, F2 and F3 for ProTaper®. The depth of penetration was indicated by a double rubber stop on the needle and measured on a Polydentia gauge (Mezzovico, Switzerland) with the accuracy of a quarter of a millimeter.

Analysis of the variance and PLSD Fisher's tests were done with Statview 5.0 software (Sas Institute, Orange, CA) and alpha risk fixed at 5%.

Table 1 PLSD Fisher's test for the finishing parameter.

	Mean diff.	*P*-value	Significance
AS 30 vs AS 35	0.677	<0.0001	S
AS 30 vs AS40	1.199	<0.0001	S
AS 30 vs F1	−0.525	0.0003	S
AS 30 vs F2	0.429	0.0030	S
AS 30 vs F3	0.975	<0.0001	S
AS 35 vs AS 40	0.522	0.0004	S
AS 35 vs F1	−1.202	<0.0001	S
AS 35 vs F2	−0.248	0.0904	NS
AS 35 vs F3	0.298	0.0422	S
AS 40 vs F1	−1.724	<0.0001	S
AS 40 vs F2	−0.771	<0.0001	S
AS 40 vs F3	−0.224	0.1226	NS
F1 vs F2	0.953	<0.0001	S
F1 vs F3	1.500	<0.0001	S
F2 vs F3	0.547	0.0002	S

Results

Penetration depth of each needle is measured and the distance between the needle tip and the working length is calculated (Fig. 1). The PLSD Fisher's test can highlight the differences between the six types of apical shaping used (independently of the needle type) (Table 1). The same differences were observed between the four types of needle (independently of the apical finish) ($p = 0.0232$).

Multivariate analysis of variance showed significant differences for the finishers ($p < 0.0001$) and the kind of needle ($p < 0.0001$) (Table 2).

Table 2 Needles able to reach biological goals depending on apical shaping. (N1: Sibron Endo Stropko NiTi 30G; N2: Kerr Stainless steel 30G; N3: Kerr Stainless steel 25G; N4: Elsodent Endoneedle Stainless steel 27G).

	F1	F2	F3	AS 30	AS 35	AS 40
Recommended needle	No	N1 N2	N1 N2	N1	N1 N2	N1 N2 N4

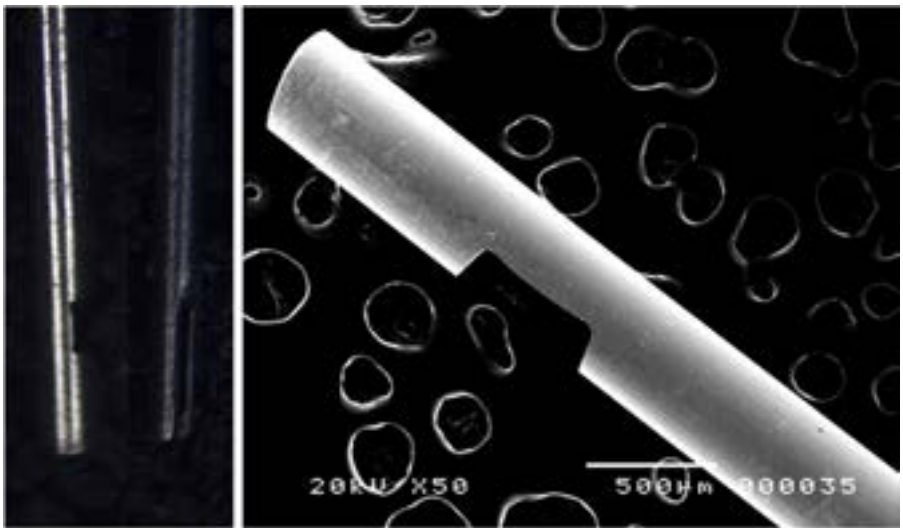

Figure 2 Photography and SEM picture of endodontic needle's tip design.

Variance analysis between the four different needles is statistically significant for each apical shaping ($p < 0.0001 \times 6$)

Finally, according to the apical finishing, all the needles did not reach the working length minus one millimetre corresponding to biological criteria defined previously.

Variance analysis among the six types of finish is statistically significant for each type of needle ($p < 0.0001 \times 4$).

Discussion

This study shows that the apical preparation influences the penetration depth of needles.

Natural teeth were chosen to take into account the variability of root canal anatomy[5] and the influence of shaping. The teeth chosen had low curvature. The results were not influenced by the angle and radius of curvature. Greater curvatures could block the needle above leading to increasing differences between the needles.

A total of 12 teeth per group were chosen as in other similar studies.[6,7] This is a small number but leads to a sufficient statistical power to take into account the variability of measurement.

Determining the working length was performed using stereo-microscope that allows accurate visualization of the file when it reaches the apex.[6] This technique is reliable, reproducible and avoids any bias or electronic measuring secondary to radiographic interpretation.

Measurement of working length as the needle penetration depth is done using a gauge. A digital calliper could be used.[6] Its accuracy reaches one-tenth of a millimetre in contrast to the gauge whose accuracy is only a quarter of a millimetre. However it was decided to use the gauge because it is a frequently used clinical tool.[8]

Needles of three diameters were used to evaluate the different penetration depths depending on the size. We also compared two needles of the same diameter but different material (stainless steel and nickel titanium). For the same gauge, representing the external diameter of the needle, the penetration capacity is different depending on the alloy of the needle ($p = 0.0179$). The use of a super-elastic alloy therefore optimizes the penetration of the irrigation needle. However the design of these apical needles is different (Fig. 2) with a true lateral deflection for the Kerr's 30 gauge stainless steel and a side discharge for the Sibron's 30 gauge NiTi Endo.

Although the protocol of the Revo-S has no flaring tool,[9] one (EndoFlare®, Micro-Mega, Besançon, France) was added into the sequence to mimic the ProTaper®'s one. This flaring tool eliminates interference and initial constraints of the canal. It therefore facilitates the action of endodontic instruments and the needle insertion. Its lack of use would little or not change needle penetration measures performed during the final apical preparation of the canal. The average length of tooth preparation is 21.60 mm. The canal length is about 13 mm long, which corresponds to a diameter of preparation for the canal entrance of 0.97 mm well above the preparation with an EndoFlare® even with a penetration of 4 mm (0.63 mm).

Conclusion

Our study shows that the apical preparation influences the penetration depth of needles that reach the biological criteria. The minimum apical preparation should vary depending on the type of needle used. It appears that the Revo-S system reaches these criteria regardless of the apical finish used for 30 gauge needles or with the AS 40 finisher for 27 gauge needles whereas the ProTaper system requires at least a F2 preparation and the use of 30 gauge needle.

Similarly, different needle types should be used depending on the apical preparation. 25 gauge needles are inconsistent with such biological criteria. Those over 27 reach it only with the Revo-S system shaped with AS 40. Finally, the 30 gauge needles reach it for all finishers (AS 30, AS 35, AS 40, F2 and F3) except the F1. But passive ultrasonic irrigation may be an adjunctive treatment for improving the root canal system cleaning.[4]

Conflict of interest

The authors have no conflicts of interest to declare.

References

1. Baugh D, Wallace J. The role of apical instrumentation in root canal treatment: a review of the literature. *J Endod* 2005;**31**:333—40.
2. Peters OA. Current challenges and concepts in the preparation of root canal systems: a review. *J Endod* 2004;**30**:559—67.
3. Tronstad L. Endodontie clinique. Paris: Flammarion Médecine; 1996: 235.
4. Van der Sluis LWM, Versluis M, Wu MK, Wesselink PR. Passive ultrasonic irrigation of the root canal: a review of the literature. *Int Endod J* 2007;**40**:415—26.
5. Vertucci FJ. Root canal morphology and its relationship to endodontic procedures. *Endod Top* 2005;**10**:3—29.
6. Diemer F, Sinan A, Calas P. Penetration depth of warm vertical Gutta-Percha pluggers: impact of apical preparation. *J Endod* 2006;**32**:123—6.
7. Albrecht LJ, Baumgartner C, Marshall JG. Evaluation of apical debris removal using various sizes and tapers of ProFile GT files. *J Endod* 2004;**30**:425—8.
8. Huang TY, Gulabivala K, NG YL. A bio-molecular film ex-vivo model to evaluate the influence of canal dimensions and irrigation variables on the efficacy of irrigation. *Int Endod J* 2008;**41**:60—71.
9. Mallet JP, Diemer F. An instrument innovation for primary endodontic treatment: the Revo-S® sequence. *Smile Dental J* 2009;**4**:24—6.

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CASE REPORT/CASO CLINICO

Nonsurgical management of complex endodontic cases with several periapical lesions: a case series

Gestione non-chirurgica di casi endodontici complessi con lesioni periapicali: case series

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KEYWORDS
Endodontic lesion;
Operative microscope;
Non-surgical approach;
Ultrasonic tips;
Three-dimensional obturation.

Abstract
Aim: Today, thanks to modern technologies as operative microscope, ultrasonic tips, devices to activate irrigation and tridimensional obturation performed with thermo plasticized gutta-percha, excellent results could be obtained.
Materials and methods: In this study, we present 5 patients with the presence of periapical lesions in molars and incisors with history of pain. Modern endodontic technologies were used. The rationale of using these technologies was to obtain a chemo-mechanical cleansing and obturation of the entire endodontic system and to gain the lesion resolution with a non-surgical approach.
Results: A success rate of 100% was obtained. Radiographs and clinical examinations were done until 10 years. All the cases highlighted the success achieved in the short and long term through the complete resolution of the lesions and therefore the reconstitution of the lamina dura.

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Conclusions: The positive results highlighted by these clinical cases demonstrate how the use of modern technologies is essential to avoid iatrogenic damage and to gain safe and reproducible results.

PAROLE CHIAVE
Lesione endodontica;
Microscopio operatorio;
Approccio non chirurgico;
Punte ultrasoniche;
Otturazione tridimensionale.

Riassunto
Introduzione: Oggi, grazie alle moderne tecnologie, microscopio operatorio, punte ultrasoniche, dispositivi per l'attivazione degli irriganti e all'otturazione tridimensionale si possono ottenere risultati ben più che soddisfacenti.
Materiali e Metodi: In questo studio presentiamo 5 pazienti con presenza di lesioni periapicali su molari e incisivi con storia di dolore. Il razionale nell'uso di queste tecnologie è stato nell'ottenere la detersione chemio-meccanica e l'otturazione tridimensionale dell'intero sistema endodontico con una completa risoluzione della lesione evitando l'approccio chirurgico.
Risultati: E' stato ottenuto un successo del 100%. Radiografie ed esami clinici sono stati effettuati su ogni paziente fino a 10 anni. Tutti i casi presentati hanno evidenziato il successo ottenuto nel breve e lungo termine attraverso la scomparsa completa delle lesioni e di conseguenza la ricostituzione della lamina dura.
Conclusioni: Gli esiti positivi, evidenziati da questi casi clinici, dimostrano come l'utilizzo delle moderne tecnologie siano indispensabili nell'evitare danni iatrogeni e garantire, invece, risultati sicuri e riproducibili.

Introduction

The rationale of the endodontic treatment is to eradicate the infection, prevent microorganisms from infecting or reinfecting the root and/or periradicular tissues by filling or obturating the cleaned and shaped systems, finally prevent future recontamination of sealed root canals.[1–3] Consequently, failure to achieve these criteria results in root canal therapy failure or continued presence of inflammation and infection.[4,5] Therefore, the prognosis for the endodontic therapy is based on several factors that can be divided into three categories: preoperative, operative, and postoperative causes.[6–8]

Preoperative causes that influence endodontic therapy outcome include misdiagnosis, errors in treatment planning, poor case selection, or treatment of a tooth with a poor prognosis.[9,10] Often, radiographic interpretation or lack of proper radiographs can interfere with the operator's ability to predict the outcome, resulting in poor operative execution.[11] Sjogren et al.[12] indicated that one of the most important factors influencing the prognosis of endodontic treatment was the preoperative status of the tooth. He, furthermore, referenced studies demonstrating that the success rate in endodontic therapy is significantly influenced by the presence or absence of a pretherapeutic radiographic lesion.[13] Teeth with an apical radiolucency may show up to a 20% lower success rate than teeth without such lesions. Regardless of how the tooth presents, proper interpretation and subsequent treatment planning prior to initiating endodontic therapy will allow for better care and outcome.[14,15]

Operative causes that influence the prognosis of the root canal therapy can be divided into two categories: mechanical and biological. Mechanical considerations include: cavity preparation/access, cleaning and shaping, instrument separation, perforation, missed canals, and obturation quality.[16,17] Biological objectives involve removal or reduction of existing and potential irritants from the pulp space, sealing of the space, microbial control, and management of periapical inflammation.[18] Understanding the complex endodontic microbiology, so that it could be most eradicated during endodontic therapy can ensure that the biological objectives can be met clinically.[19] Interestingly enough, there are several microorganisms that are self-sustaining and resistant to antimicrobial treatment and can survive in the root canal after biomechanical preparation.[20] So, the presence of persistent infection following the root canal therapy can be attributed to the presence of the aforementioned microorganisms.[21]

Postoperative causes that have an effect on the endodontic treatment outcome occur when (a) there has been a delay in the restoration of a tooth following root canal treatment; (b) the coronal temporary filling, placed immediately following root canal treatment, is compromised; (c) the tooth is fractured and the canal system is exposed prior to final restoration; (d) the final restoration, regardless of type or design, lacks ideal marginal integrity or cannot withstand the forces of occlusal function, and deteriorates; or (e) recurrent decay is present at the restoration margins. A combination of any of the aforementioned causes may ultimately dictate outcome.[22–24]

Prognosis with endodontic therapy and variability of treatment will dictate that each case be assessed individually, taking into account all relevant factors. Regular follow-up and subsequent restorative completion are, furthermore, recommended.[25]

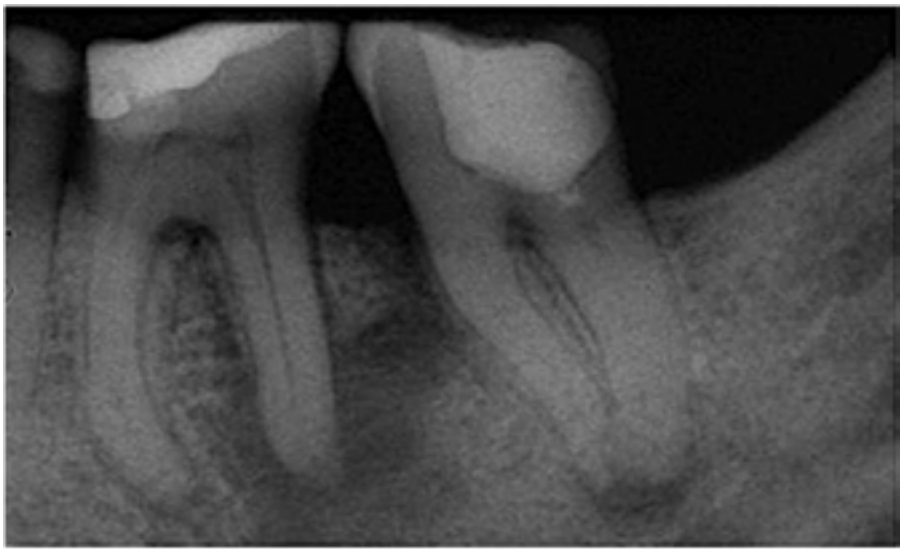

Figure 1 Pre-operative X-ray of teeth 3.6 and 3.7.

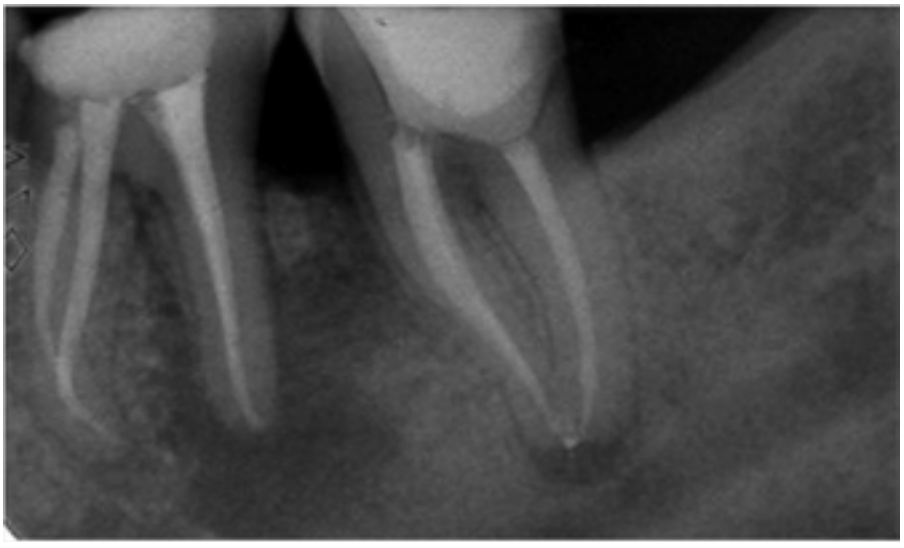

Figure 2 Post-operative X-ray of teeth 3.6 and 3.7.

The aim of this study was to show all the technology we have available today to increase the degree of chemo-mechanical debridement and obturation of the whole endodontic system. The purpose was to describe the treatment, orthograde and retrograde retreatment of complex endodontic cases with several periapical lesions.

Materials and methods

Several patients were referred to the Endodontic Department of the University Federico II of Naples with periapical lesions with history of pain. The patient's past medical and social history were non-contributory, and they had good oral hygiene, laboratory investigations were substantially normal. All the patients had no contraindications to the endodontic treatment.

Case 1

A male 65 years old patient came to our observation complaining of pain borne by chewing of the teeth 3.6 and 3.7. Radiographic examination showed a previous endodontic therapy with periapical lesion of 3.7 and a periapical lesion of medium size of 3.6 (Fig. 1). The percussion test was positive while the periodontal probe was negative. The diagnosis was of chronic apical periodontitis.

Endodontic treatment of 3.6 and orthograde retreatment of 3.7 were started under rubber dam isolation. Under constant magnification and lighting we performed a correct access cavity, removing calcifications and previous fillings. Having performed chemo-mechanical preparation of the root canal system with Ni-Ti files and three-dimensional irrigation sonically and heating activated, we proceeded with three-dimensional obturation with hot gutta-percha (Fig. 2).

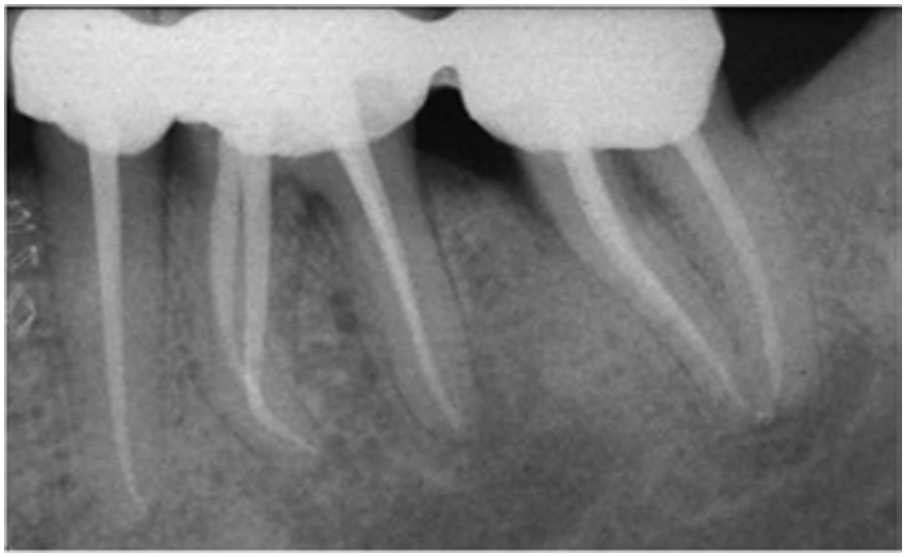

Figure 3 4 years follow-up.

Endodontic treatment and retreatment were performed in a single session. The patient was followed up at 4 and 8 years and a complete remission of the lesions was observed (Figs. 3 and 4).

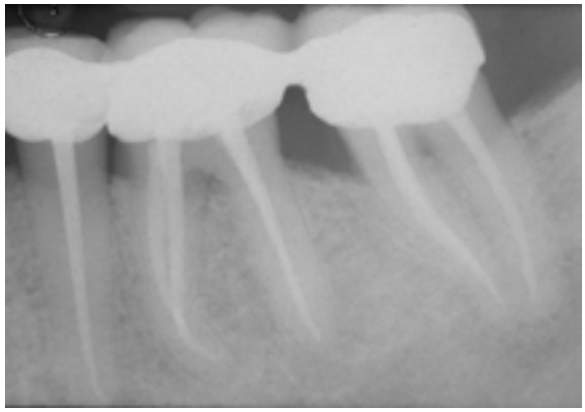

Figure 4 8 years follow-up.

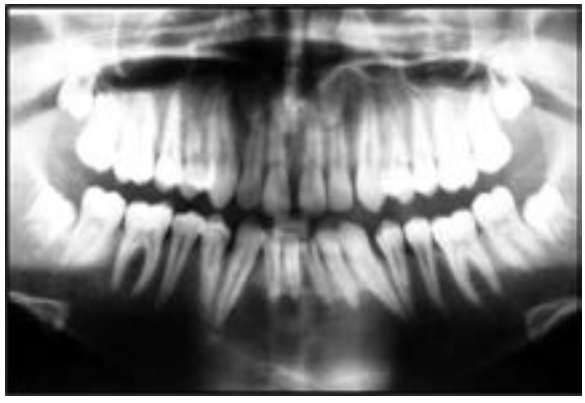

Figure 5 X-ray of teeth 3.3, 3.2, 3.1, 4.1, 4.2, 4.3 with extensive periapical lesion.

Case 2

A 50-year-old male patient came to our observation complaining of pain borne by chewing of the teeth 3.3, 3.2, 3.1, 4.1, 4.2, 4.3. The conventional X-ray examination showed extensive periapical lesion of all teeth mentioned above (Fig. 5). While a through 3D radiographic exam, the disappearance of the outer and inner cortices of the mandible was revealed (Fig. 6). In a previous dental examination an orthograde treatment of all teeth from 4.3 to 3.3 and then surgical removal of the lesion with apicoectomy of teeth was proposed to the patient. Thermal test and electric pulp test (EPT) were performed to all mentioned teeth and only 3.1 was not vital. Then we proceeded to root canal therapy of 3.1.

Under rubber dam isolation and constant magnification and lighting we performed a correct access cavity, three-dimensional irrigation sonically and heating activated and finally three-dimensional obturation with hot gutta-percha. Endodontic treatment was performed in a single session (Fig. 7). The patient was followed up at 4 years and a complete remission of the extended lesion was observed (Fig. 8).

Case 3

A 43-year-old male patient came to our observation complaining of pain borne by chewing of the teeth 4.6. Radiographic examination showed a previous endodontic therapy with a periapical lesion (Fig. 9). The percussion test was positive while the periodontal probe was negative. The diagnosis was of chronic apical periodontitis.

We proceeded with an orthograde retreatment of the tooth. After isolating the tooth with rubber dam the old obturation has been removed. Under magnification and lighting, specific ultrasonic tips have been used, the isthmus that connects the mesiobuccal mesio-lingual canals was prepared and the middle mesial canal identified (Fig. 10). Having

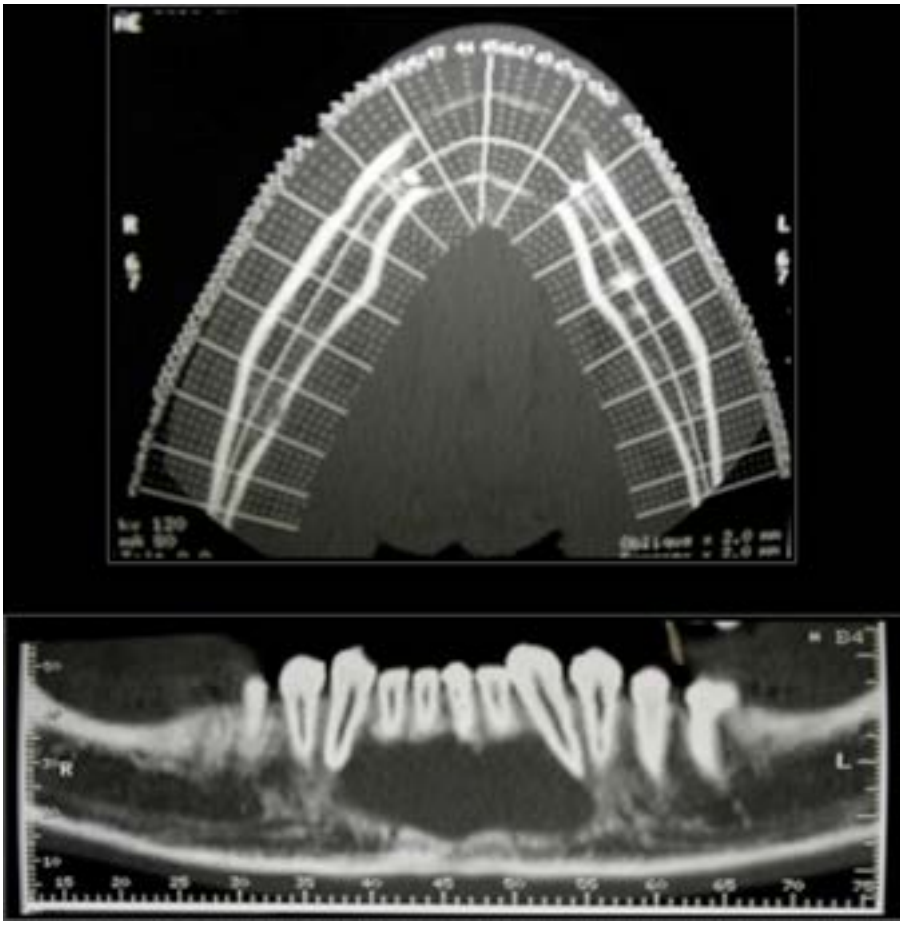

Figure 6 3D radiographic exam with disappearance of the outer and inner cortex of the mandible.

performed chemo-mechanical preparation of the complete root canal system three-dimensional obturation with hot gutta-percha was completed (Fig. 11). Endodontic retreatment was performed in a single session. The patient was followed up at 4 and 8 years and a complete remission of the lesion was observed (Figs. 12 and 13).

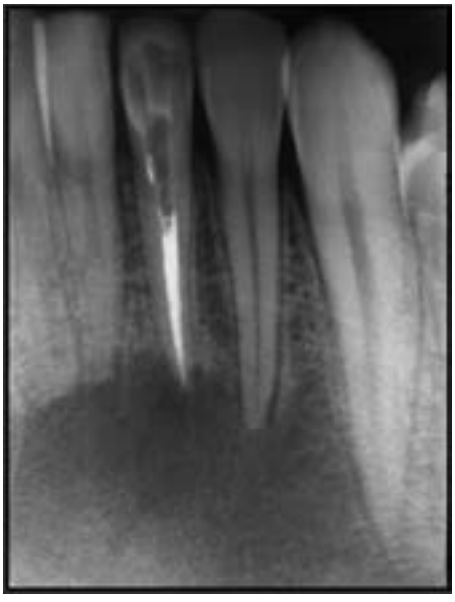

Figure 7 Post-operative X-ray of tooth 3.1.

Case 4

A 40-year-old female patient came to our observation complaining of pain borne by chewing of the teeth 2.6 and presence of swelling in correspondence of the tooth. Outside of the cheek the patient showed a cutaneous fistula (Fig. 14), which allowed to show through fistulography the responsible tooth. Radiographic examination showed a previous root canal therapy and a periapical lesion of 2.6. The percussion test was positive while the periodontal probe was negative. The diagnosis was of chronic apical periodontitis.

We proceeded with orthograde retreatment of the tooth. After isolating the tooth with rubber dam the pulp chamber access was performed under magnification and lighting, specific ultrasonic tips have been used. Performed chemo-mechanical preparation of the complete root canal system three-dimensional obturation with hot gutta-percha was completed. Endodontic retreatment was performed in a single session. The patient was followed up at 6 years and a complete remission of the lesion was observed (Fig. 15).

Case 5

A 44-year-old female patient came to our observation complaining of pain and swelling borne by chewing of the teeth

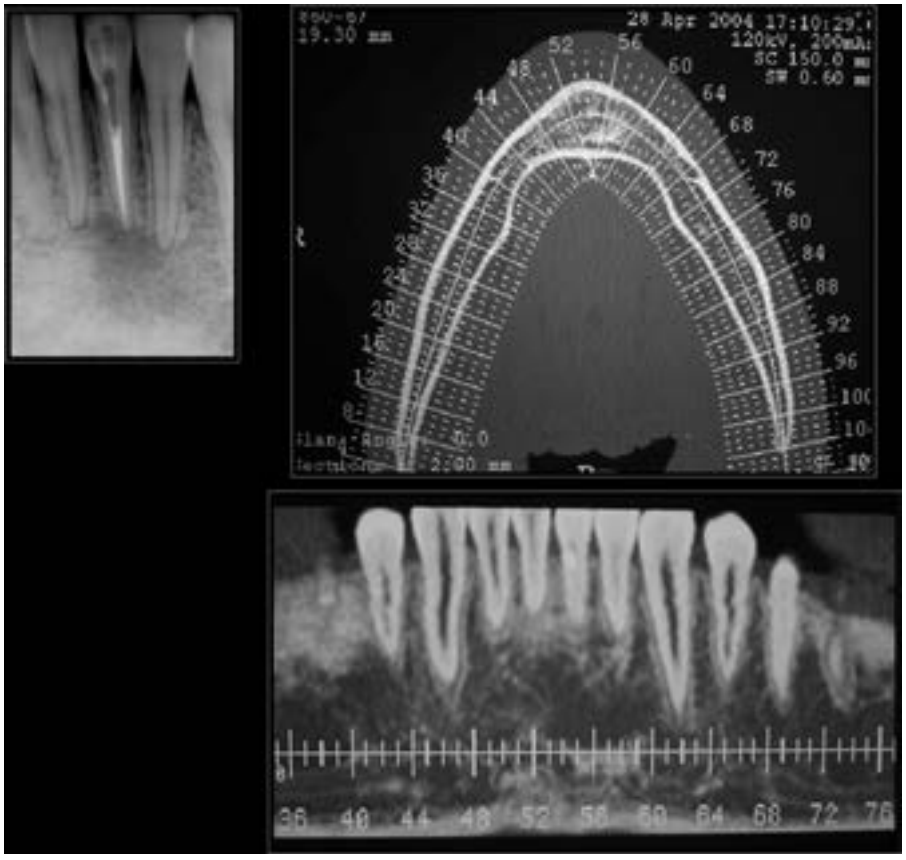

Figure 8 4 years follow-up.

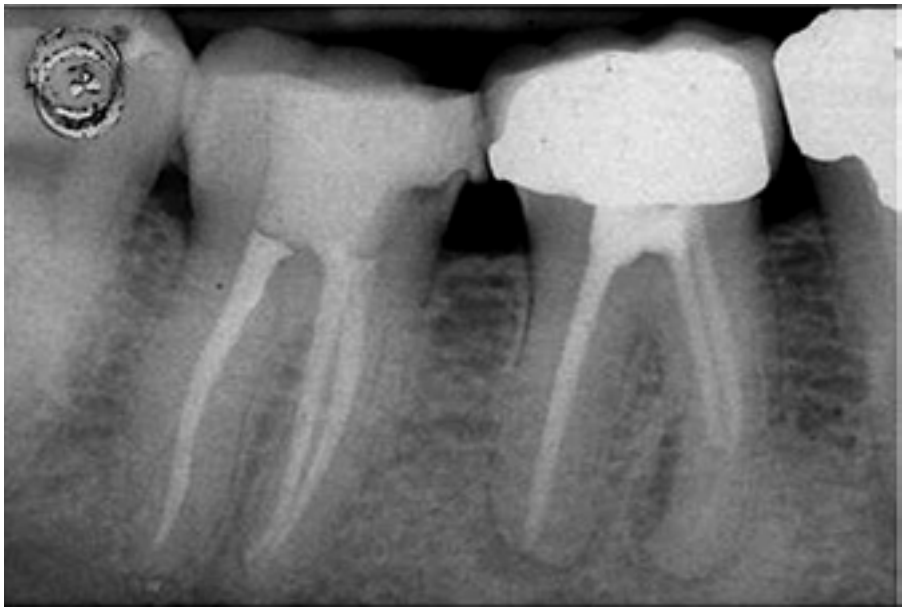

Figure 9 Pre-operative X-ray of tooth 4.6.

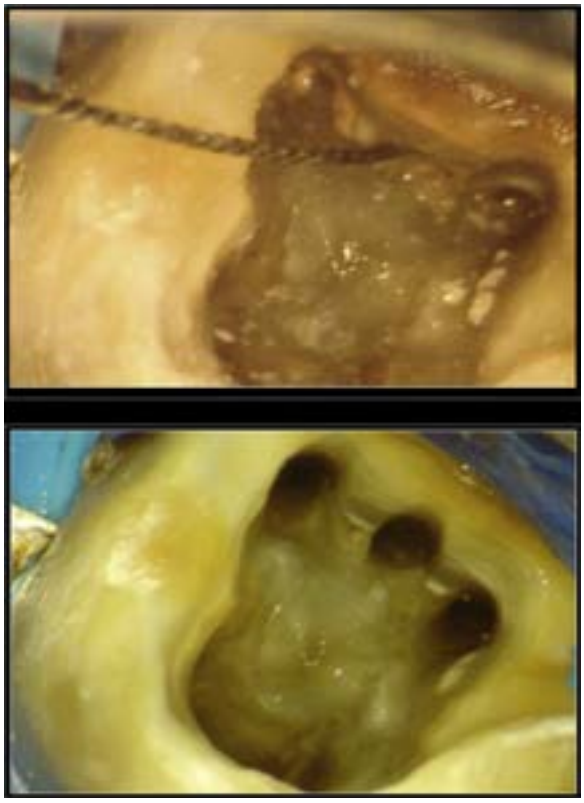

Figure 10 Identification of middle mesial canal under magnification.

4.6. Radiographic examination showed a previous endodontic therapy with a silver cone in the mesial root of 4.6 and a periapical lesion (Fig. 16). The percussion test was positive while the periodontal probe was negative. The diagnosis was of chronic apical periodontitis.

At first clinical examination the tooth had already heavy losses at the structural level of the crown, hence to avoid further damage of the tooth during orthograde retreatment we opted for a surgical retreatment. The endodontic surgery was performed under constant magnification and lighting and with appropriate ultrasonic tips (''retrotips''). Finally, as retrograde obturation was used super Eba (Fig. 17). The patient was followed up at 10 years and a complete remission of the lesion was observed (Fig. 18).

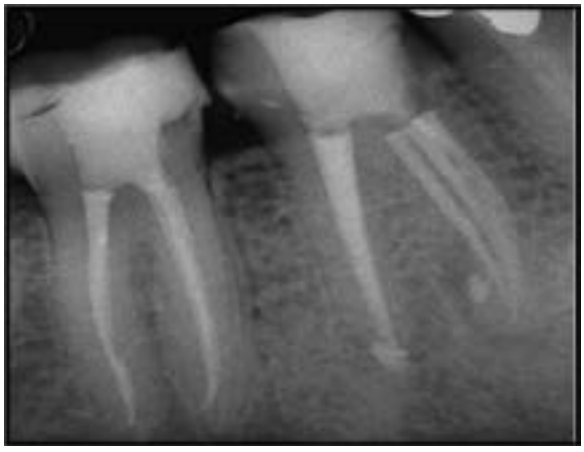

Figure 11 Post-operative X-ray of tooth 4.6.

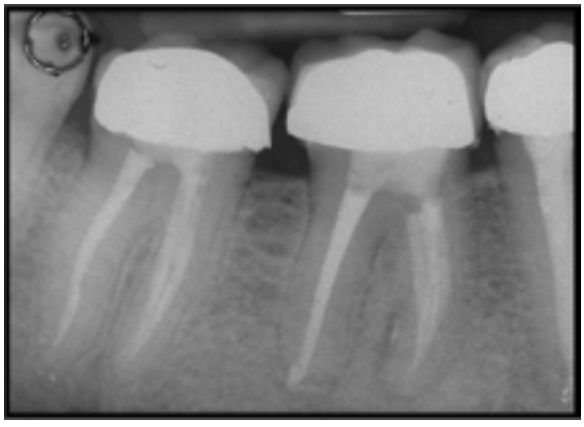

Figure 12 4 years follow-up.

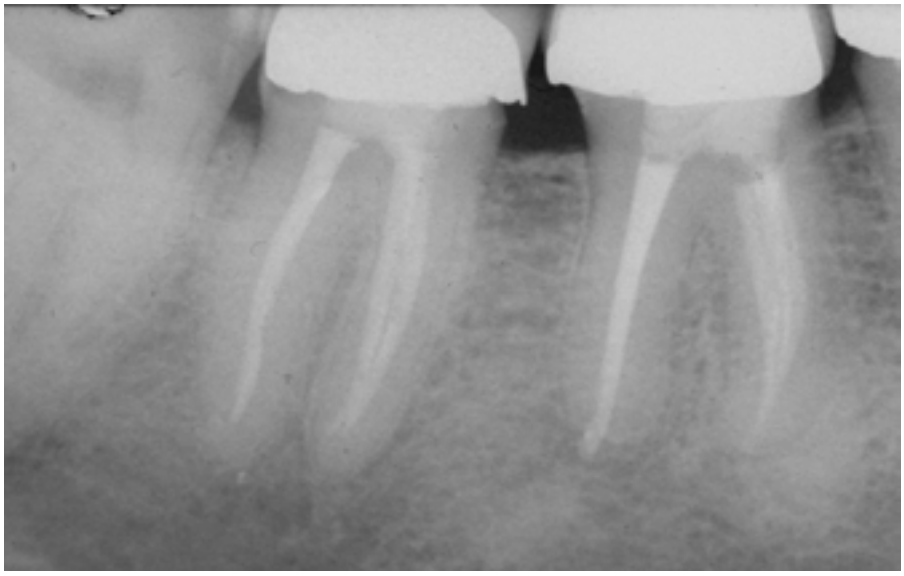

Figure 13 8 years follow-up.

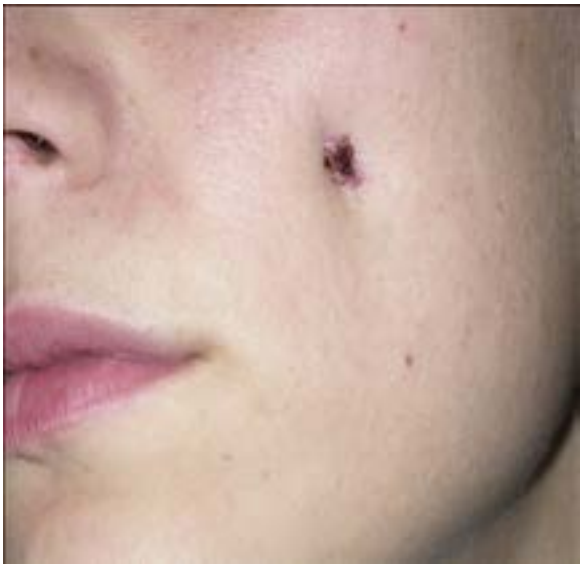

Figure 14 Cutaneous fistula.

Results

A success rate of 100% was obtained. Radiographs and clinical examinations were done until 10 years. All the cases highlighted the success achieved in the short and long term through the complete resolution of the lesions and therefore the reconstitution of the lamina dura. The positive results highlighted by these clinical cases demonstrate how the use of modern technologies, operating microscope, ultrasonic tips, rotary files of new generation, systems enhancing cleansing and methods used to obtain a valid tridimensional seal, are essential to avoid iatrogenic damage and ensure, however, safe and reproducible results.

Discussion

The complete cleansing (complete removal of organic and inorganic substrate) of endodontic systems is currently a difficult goal to achieve.[26] The irrigants have difficult access

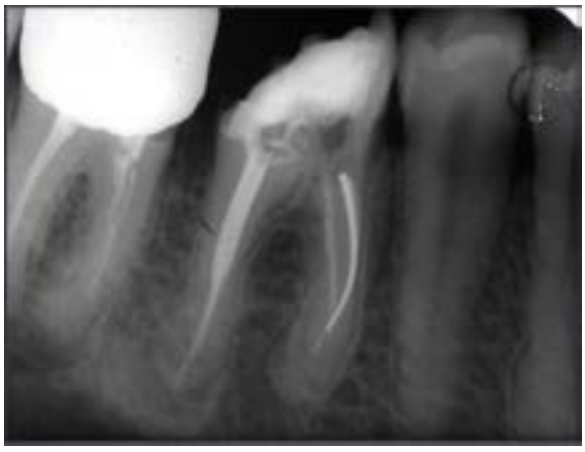

Figure 16 Pre-operative X-ray of tooth 4.6.

in some canals for the anatomical complexity and their action is reduced.[27,28]

Gutarts et al.[29] have demonstrated that, by carrying out ultrasonic irrigation after rotary or manual instrumentation, a much more effective cleansing of canals and isthmuses was obtained. Jensen et al.[30] have not detected any significant difference between the use of a sonic and ultrasonic irrigation.

Moreover, thanks to the heating irrigant its action could be increased and enhanced by obtaining a nearly complete three-dimensional cleansing of the endodontic space.[31] The irrigants, in this way, are able to gain most of the complex anatomical space, unreachable with conventional irrigation techniques.[32]

To significantly improve the clinical outcome is fundamental proper preparation of the root canal system, through chemical and mechanical properties.[33] Only in this way the infection will be reduced by preventing the bacterial invasion and recolonization of the filled endodontic space.[34]

Instead, in reference to the type of approach in the presence of periapical lesion or endodontic failure, Torabinejad et al.[35] showed that nonsurgical retreatment generally is prioritized before surgical endodontic treatment. Microsurgical endodontic treatment is superior to traditional surgical endodontic treatment and has high survival rates, hence

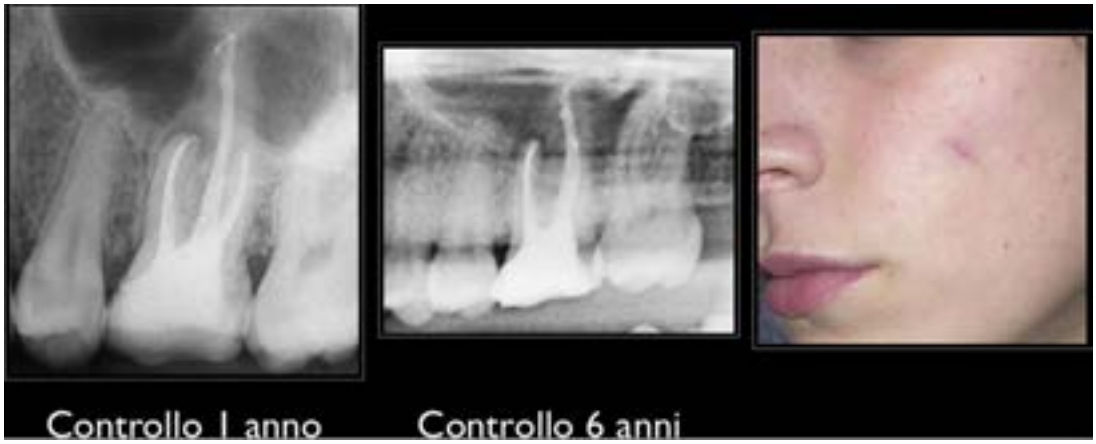

Figure 15 6 years follow-up.

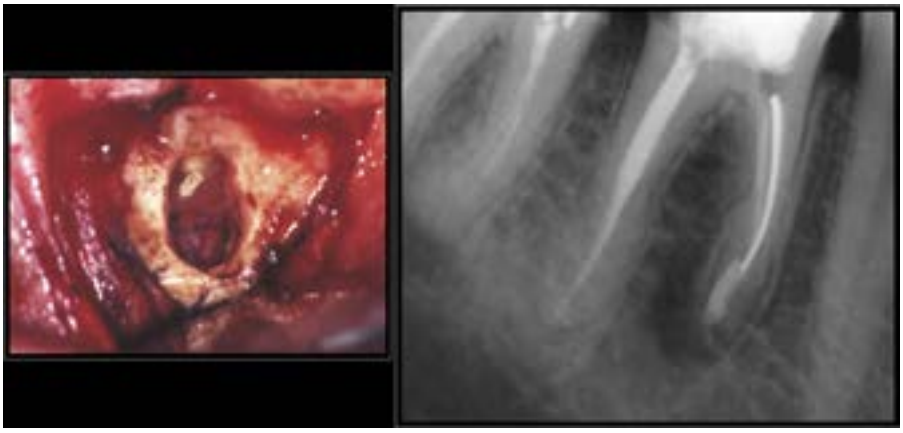

Figure 17 Post-operative X-ray of tooth 4.6.

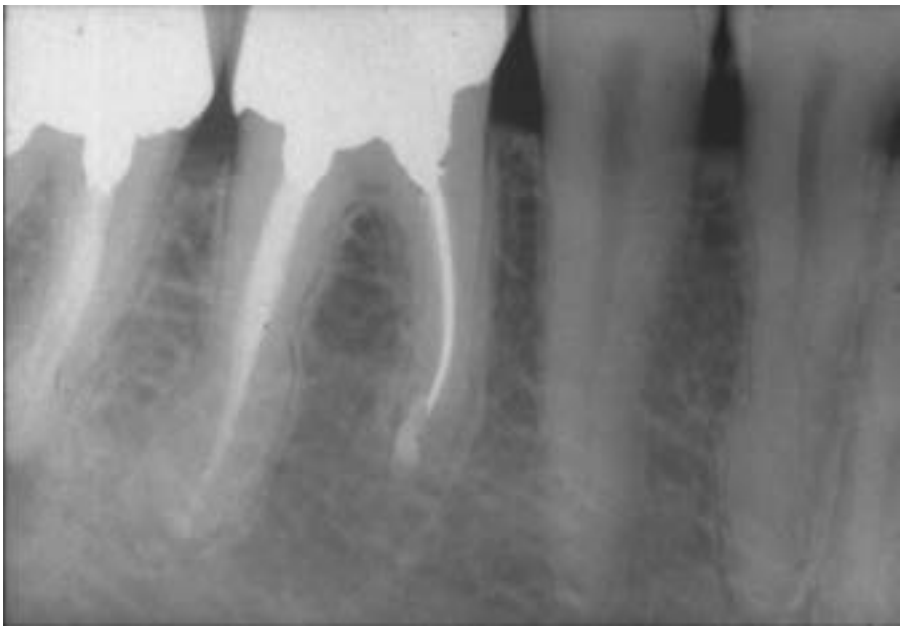

Figure 18 10 years follow-up.

the first-line treatment option after failure of initial root canal treatment is nonsurgical retreatment, and this is what our study wants to demonstrate.

Moreover, clinical and radiographic evaluation was recommended by other researchers, to evaluate the endodontic treatment outcome.[36] The presence of anatomical noise, the two-dimensional image, and geometric distortion are the major drawbacks of periapical radiographs that remain so far the routinely employed method. In some cases CBCT (Cone-Beam Computed Tomography) provides more significant information than periapical images and eliminates the superimposition of anatomical structures.[37,38] A digital intraoral radiography was used in this study rather than a conventional X-ray film. Thus, the resulting image of digital periapical radiography could be easily enhanced (brightness and contrast) to improve the interpretation of the image. Several studies have shown no significance difference between both techniques.[39,40]

Conclusions

The key to achieving long-term success in developmental anomalies is accurate diagnosis. Clinician's awareness of existence of such a situation may help to avoid misdiagnosis and improper treatment of the tooth.

Conflict of interest

The authors have no conflict of interest.

References

1. Shilder H. Cleaning and shaping the root canal. *Dent Clin North Am* 1974;**18**:269.

2. Carratù P, Amato M, Riccitiello F, Rengo S. Evaluation of leakage of bacteria and endotoxins in teeth treated endodontically by two different techniques. *J Endod* 2002;**28**(4):272—5.
3. Silvani M, Brambilla E, Cerutti A, Amato M, Gagliani M. Root canal treatment quality in undergraduate program: a preliminar report on NiTi reciprocating files. *G Ital Endod* 2013;**27**:33—7.
4. Dalton BC, Orstavik D, Phillips C, Pettiette M, Trope M. Bacterial reduction with nickel-titanium rotary instrumentation. *J Endod* 1998;**24**(11):763—7.
5. Ametrano G, Riccitiello F, Amato M, Formisano A, Muto M, Grassi R, et al. μCT analysis of mandibular molars before and after instrumentation by Reciproc files. *Recenti Prog Med* 2013;**104**:420—4.
6. Iandolo A, Iandolo G, Malvano M, Pantaleo G, Simeone M. Modern technologies in endodontics. *G Ital Endod* 2016. http://dx.doi.org/10.1016/j.gien.2015.12. 001 [in press].
7. Siqueira JF, Lima KC, Magalhaes FAC, Lopes HP, de Uzeda M. Mechanical reduction of the bacterial population in the root canal by three instrumentation techniques. *J Endod* 1999;**25**(5):332—5.
8. Paduano S, Uomo R, Amato M, Riccitiello F, Simeone M, Valletta R. Cyst-like periapical lesion healing in an orthodontic patient: a case report with five-year follow-up. *G Ital Endod* 2013;**27**(2):95—104.
9. Spagnuolo G, Ametrano G, D'Antò V, Formisano A, Simeone M, Riccitiello F, et al. Microcomputed tomography analysis of mesiobuccal orifices and major apical foramen in first maxillary molars. *Open Dent J* 2012;**6**:118—25.
10. Di Lorenzo P, Niola M, Buccelli C, Re D, Cortese A, Pantaleo G, et al. Professional responsibility in dentistry: analysis of an interdepartmental case study. *Dent Cadmos* 2015;**83**:324—40.
11. Senia ES. Endodontic success: it' s all about the apical third. *Roots* 2008;**4**:14—9.
12. Sjogren U, Hagglund B, Sundqvist G, Wing K. Factors affecting the long-term results of endodontic treatment. *J Endod* 1990;**16**(10):498—504.
13. Riccitiello F, Stabile P, Amato M, Rengo S, D'Ambrosio C. The treatment of the large periradicular endodontic injury. *Minerva Stomatol* 2011;**60**(9):417—26.
14. Iandolo A, Ametrano G, Amato M, Rengo S, Simeone M. IG-File: un nuovo strumento per l'ottimizzazione della detersione canalare e per la misurazione del diametro apicale. *G Ital Endod* 2011;**25**(2):72—81.
15. Lo Giudice G, Cutroneo G, Centofanti A, Artemisia A, Bramanti E, Militi A, et al. Dentin morphology of root canal surface: a quantitative evaluation based on a scanning electronic microscopy study. *BioMed Res Int* 2015;**2015**:164065.
16. Simeone M, Valletta A, Giudice A, Di Lorenzo P, Iandolo A. The activation of irrigation solutions in endodontics: a perfected technique. *G Ital Endod* 2015;**29**:65—9.
17. Spagnuolo G, Desiderio C, Rivieccio V, Amato M, Rossetti DV, D'Antò V, et al. In vitro cellular detoxification of triethylene glycol dimethacrylate by adduct formation with N-acetylcysteine. *G Dent Mater* 2013;**29**(8):e153—60.
18. Baumgartner JC, Cuenin PR. Efficacy of several concentrations of sodium hypochlorite for root canal irrigation. *J Endod* 1992;**18**:605—11.
19. Amato M, Scaravilli MS, Farella M, Riccitiello F. Bleaching teeth treated endodontically: long-term evaluation of a case series. *J Endod* 2006;**32**(4):376—8.
20. D'Antò V, Valletta R, Amato M, Schweikl H, Simeone M, Paduano S, et al. Effect of nickel chloride on cell proliferation. *Open Dent J* 2012;**6**:177—81.
21. Mohammadi Z, Giardino L, Palazzi F, Shalavi S, Alikhani MY, Lo Giudice G, et al. Effect of sodium hypochlorite on the substantivity of chlorhexidine. *Int J Clin Dent* 2013;**6**:173—8.
22. Dahlen G, Bergenholtz G. Endodontic activity in teeth with necrotic pulps. *J Endod* 1980;**59**:1033—9.
23. Riccitiello F, Di Caprio MP, D'Amora M, Pizza NL, Vallone G, D'Ambrosio C, et al. Repair of a root perforation by using MTA: a case report. *Recenti Prog Med* 2013;**104**:453—8.
24. Di Lorenzo P, Niola M, Pantaleo G, Buccelli C, Amato M. On the comparison of age determination methods based on dental development radiographic studies in a sample of Italian population. *Dent Cadmos* 2015;**83**:38—45.
25. Lo Giudice R, Pantaleo G, Lizio A, Romeo U, Castiello G, Spagnuolo G, et al. Clinical and spectrophotometric evaluation of LED and laser activated teeth bleaching. *Open Dent J* 2016;**10**(1):242—50.
26. Ruddle CJ. Hydrodinamic disinfection tsunami endodontics. *Dent Today* 2007;**26**(5):112—6.
27. Simeone M, Valletta A, Giudice A, Di Lorenzo P, Iandolo A. The activation of irrigation solutions in endodontics: a perfected technique. *G Ital Endod* 2015;**29**(2):65—9.
28. Spagnuolo G, Ametrano G, D'Antò V, Rengo C, Simeone M, Riccitiello F, et al. Effect of autoclaving on the surfaces of TiN-coated and conventional nickel-titanium rotary instruments. *Int Endod J* 2012;**45**(12):1148—55.
29. Gutarts R, Nusstein J, Reader A, Beck M. In vivo debridement efficacy of ultrasonic irrigation following hand-rotary instrumentation in human mandibular molars. *J Endod* 2005;**31**:166—70.
30. Jensen SA, Walzer TL, Hutter JW, Nicoll BK. Comparison of the cleaning efficacy of passive sonic activation and passive ultrasonic activation after hand instrumentation in molar root canals. *J Endod* 1995;**25**:735—8.
31. Iandolo A. L'utilizzo degli ultrasuoni per una maggiore predicibilità nella rimozione delle calcificazioni. *G Ital Endod* 2009;**23**:269—75.
32. Lee SJ, Wu MK, Wesselink PR. The effectiveness of syringe irrigation and ultrasonics to remove debris from simulated irregularities within prepared root canals walls. *Int Endod J* 2004;**37**:672—8.
33. Riccitiello F, Maddaloni G, D'Ambrosio C, Amato M, Rengo S, Simeone M. Operating microscope: diffusion and limits. *G Ital Endod* 2012;**26**(2):67—72.
34. Lo Giudice G, Lo Giudice R, Matarese G, Isola G, Cicciù M, Terranova A, et al. Evaluation of magnification systems in restorative dentistry. An in-vitro study. *Dent Cadmos* 2015;**83**(5):296—305.
35. Torabinejad M, White SN. Endodontic treatment options after unsuccessful initial root canal treatment: alternatives to single-tooth implants. *J Am Dent Assoc* 2016;**147**(3):214—20.
36. Saidi A, Naaman A, Zogheib C. Accuracy of cone-beam computed tomography and periapical radiography in endodontically treated teeth evaluation: a five-year retrospective study. *J Int Oral Health* 2015;**7**(3):15—9.
37. Scolari G, Lazzarin F, Fornaseri C, Carbone V, Rengo S, Amato M, et al. A comparison of nimesulide beta cyclodextrin and nimesulide in postoperative dental pain. *Int J Clin Pract* 1999;**53**(5):345—8.
38. Scarfe WC, Levin MD, Gane D, Farman AG. Use of cone beam computed tomography in endodontics. *Int J Dent* 2009;**2009**:634567.
39. Ball RL, Barbizam JV, Cohenca N. Intraoperative endodontic applications of cone-beam computed tomography. *J Endod* 2013;**39**(4):548—57.
40. Tyndall DA, Kohltfarber H. Application of cone beam volumetric tomography in endodontics. *Aust Dent J* 2012;**57**(Suppl. 1):72—81.

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ORIGINAL ARTICLE/ARTICOLO ORIGINALE

Resistance of endodontically treated roots restored with different fibre post systems with or without post space preparation: in vitro analysis and SEM investigation

Resistenza di radici trattate endodonticamente e restaurate con sistematiche diverse di perni in fibra con o senza preparazione del post space: analisi in vitro e al SEM

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KEYWORDS
Fibre post;
Fracture resistance;
Post space preparation;

Abstract
Aim: To compare the mechanical resistance to fracture of two conical post systems placed with no preparation of the root canal with that of double taper fibre posts seated in endodontically treated single roots after standard post space preparation using dedicated drills.

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Preservation of root dentine;
Self-adhesive cement;
Taper.

Methodology: Thirty fibre posts with double (G1, $n = 10$, DT Light Post) and single taper (G2, $n = 10$, SurgiPost Multiconical; G3, $n = 10$, Tech ES Endoshape) were luted with self-adhesive cement in endodontically treated single roots using different post space preparation techniques. The bonded posts were experimentally loaded until failure and the maximum load to fracture was registered. Fracture patterns were qualitatively evaluated and SEM analysis was performed to assess the quality of endodontic treatments and cementation. Data were statistically analysed by means of one-way ANOVA.
Results: The mean maximum load to fracture was 165.05 ± 23.46 N in G1, 151.52 ± 16.23 N in G2 and 129.09 ± 15.25 N in G3. Statistically significant differences were pointed out between G1 and G3 ($p < 0.01$) and G2 and G3 ($p < 0.05$). No root fractures were evidenced. SEM analyses showed slightly thicker cement layers at the apical and middle thirds of single taper posts (G2 and G3).
Conclusions: DT Light Post and SurgiPost Multiconical fibre posts showed similar properties in terms of mechanical resistance to fracture and higher than those of Tech ES Endoshape. Unrestorable root fractures did not occur with any of the tested posts.

PAROLE CHIAVE
Perno in fibra;
Resistenza a frattura;
Preparazione del post space;
Risparmio di dentina canalare;
Cemento autoadesivo;
Conicità.

Riassunto
Obiettivi: Confrontare la resistenza meccanica a frattura di due sistemi di perni conici posizionati senza preparazione del canale con quella di perni in fibra a conicità doppia posizionati in radici trattate endodonticamente dopo preparazione di un post space standard con frese dedicate.
Materiali e metodi: Trenta perni a conicità doppia (G1, n = 10, DT Light Post) e singola (G2, n = 10, SurgiPost Multiconical; G3, n = 10, Tech ES Endoshape) sono stati cementati con un cemento autoadesivo in radici singole trattate endodonticamente usando diverse tecniche di preparazione del post space. I perni cementati sono stati sottoposti a test di carico a frattura ed è stato registrato il carico massimo. I pattern di frattura sono stati valutati qualitativamente ed è stata svolta un'analisi SEM per la verifica della qualità dei trattamenti endodontici e della cementazione. I dati sono stati analizzati statisticamente con ANOVA a una via.
Risultati: I valori medi di carico massimo a frattura erano i seguenti: $165{,}05 \pm 23{,}46$ N in G1, $151{,}52 \pm 16{,}23$ N in G2 and $129{,}09 \pm 15{,}25$ N in G3. Sono emerse differenze statisticamente significative tra G1 e G3 ($p < 0{,}01$) e tra G2 e G3 ($p < 0{,}05$). Non sono state osservate fratture radicolari. L'analisi al SEM ha mostrato strati di cemento leggermente più spessi nei terzi medio e apicale dei perni a conicità singola (G2 e G3).
Conclusioni: I perni in fibra DT Light Post e SurgiPost Multiconical hanno fatto riscontrare proprietà simili in termini di resistenza meccanica a frattura, le quali sono risultate superiori a quelle dei Tech ES Endoshape. Non si sono verificate fratture radicolari non restaurabili con alcuno dei sistemi di perni testati.

Introduction

Over the last decade, the failure of severely compromised teeth has been reported to be dramatically reduced[1,2] thanks to progress in material engineering and restorative techniques. The most frequent cause of tooth weakening is the loss of dental structure due to decay, trauma and cavity preparation, in particular in cases where the integrity of the roof of the pulp chamber is lost.[3] Furthermore, it is generally accepted that the loss of enamel and dentine is the most critical factor affecting the retention of the restoration.[4,5]

The mechanical resistance of the restored tooth is influenced by the amount of residual tooth structure,[6] the properties of the restorative materials, the presence of a ferrule,[7] the force pattern and distribution, as well as the occlusion of the patient.[4,8] The literature has not clarified yet whether the endodontic treatment by itself could weaken a tooth,[9] but it certainly does not strengthen the root.[10] The removal of intra-canal dentine could affect the deformability of the root; hence, it is conceivable that the more invasive the endodontic treatment is, as in the case of post space preparation, the less stable and resistant the root will be.[11] Consequently, minimally invasive treatments are recommended in both the preparation of the access cavity and in the shaping of the root canal system,[11] in order to avoid the detrimental removal of sound tooth structure.

To restore a tooth affected by a critical loss of dental structure, the use of one or more posts is useful to improve the retention of the restorative material. The mechanical properties of the posts are paramount for the determination of possible fractures of the restored tooth, and the post system was proved to have a significant influence on fracture resistance.[2,12] Some authors have reported that the presence of a fibre post enhances the mechanical resistance to fracture

Table 1 Mean values (± standard deviations) in mm of the length and diameters of the specimens divided per group.

	Group 1	Group 2	Group 3
Length	23.3 ± 1.8	23.1 ± 2.5	22.9 ± 1.9
Buccal-palatal diameter	7.0 ± 0.6	7.1 ± 1.0	7.3 ± 0.4
Mesial-distal diameter	5.5 ± 0.5	5.9 ± 0.5	5.8 ± 0.7

of a tooth and reduces the risk of unrestorable failures in comparison with teeth restored without fibre posts.[6,13] The main advantage of fibre posts is represented by their elastic modulus that is very close to that of dentine and allows a stress distribution similar to that of a natural sound tooth; on the contrary, metal posts exert high stress levels at the post-dentine interface.[6,14–16] Further advantages of fibre posts include biocompatibility, resistance to corrosion and fatigue, aesthetic properties and retrievability, since they can easily be removed from the root canal if necessary.[1] Fibre posts are usually luted inside the root canal by means of dentine adhesives and resin cements, allowing for a conservative preparation of the post space.[17] Moreover, the adhesive cementation provides the restorative system with an elastic modulus similar to that of dentine, resulting in a stress distribution pattern comparable to those arising during the occlusal load of a natural sound tooth.[15,18,19]

Ni–Ti rotary instruments are routinely used in endodontics to give a predefined taper to root canals and preserve radicular dentine, thus performing a minimally invasive canal shaping.[11] Consequently, it would be desirable to use a post with the same taper of the last endodontic instrument used to shape the canal, without any further preparation of the coronal and middle canal thirds.

The aim of the present in vitro study was to compare the mechanical resistance to fracture of standard double taper fibre posts luted with self-adhesive cement after dedicated post space preparation with that of two conical post systems placed in endodontically-treated single roots with no preparation of the post space. The null hypothesis was that there was no difference in the resistance to fracture among the three post systems.

Materials and methods

Collection of the specimens

Thirty straight single-rooted permanent teeth with complete apex, no decays or previous restorations, extracted for periodontal reasons, were selected from a pool of freshly extracted teeth. Dental plaque, calculus and external debris were removed using manual and ultrasonic scalers. The teeth were stored in 1% thymol solution at 37 °C.

For each tooth, two silicone impressions (Aquasil Putty, Dentsply DeTrey, Konstanz, Germany) were taken, one in buccolingual and one in mesiodistal direction to make the position of each sample repeatable during the radiographic phases. Radiographs were taken with a digital sensor (Kodak RVG 6100, Kodak Dental Systems, Rochester, NY, USA) and a radiographic digital system (2200 Intraoral X Ray System, Kodak Dental Systems) set at 70 kV, 7 mA and 0.12 s. Teeth with more than one canal, with a single oval and/or irregular canal were excluded from the study in order to limit the anatomical variables affecting the biomechanical behaviour of the restorations.

The length and diameters of the selected teeth were measured with a digital caliper (Absolute Digimatatic Caliper, Mitutoyo Digimatic, Sakado, Japan); specifically, the buccolingual and mesiodistal diameters were measured at the level of the cemento-enamel junction (CEJ).

The specimens were randomly divided into 3 groups of 10 teeth each. The similarity among groups in terms of length and diameter was assessed by means of one-way analysis of variance ($p < 0.05$). The mean measurements (± standard deviation) of the specimens included in the study and the outcome of the statistical analysis are shown in Table 1.

Preparation of the specimens

The crown of each tooth was removed by cutting the tooth 1 mm above the CEJ with a microtome (Micromet, Remet, Casalecchio di Reno, Italy) under constant water irrigation. During all the preparation stages, the specimens were manipulated with wet gauzes in order to avoid dentine dehydration.

A size #10 K file (Dentsply-Maillefer, Ballaigues, Switzerland) was inserted into the canal orifice to scout the canal and check the apical patency, by leading the file in apical direction until its tip was visible at the apical foramen under 4× magnifications and marking this length with a rubber stop. The endodontic working length was established 0.5 mm short of this length.[6] The root canals were shaped using Ni–Ti rotary instruments (Mtwo, Sweden & Martina, Due Carrare, Italy) to ISO size 40, 0.06 taper (300 rpm at maximum torque). Once activated, each instrument was progressively taken to working length using a single-length technique without any pressure in apical direction; the instrument was removed once it rotated freely at the working length.[20] During canal instrumentation, constant irrigation was carried out with 2.5 mL 5.25% sodium hypochlorite (Niclor 5, Ogna, Muggiò, Italy). All canals were finally rinsed with 5 mL 17% EDTA (Pulpdent, Watertown, MA, USA) for 120 s, followed by 5 mL 5.25% sodium hypochlorite and abundant rinsing with saline solution, and dried with paper points (Roeko Paper, Coltene Whaledent, Langenau, Germany). Each set of Ni–Ti instruments was discarded after preparing 10 canals. The canals were filled with the continuous wave of condensation technique (System B, Elements Obturation Unit, Sybron Endo, Orange, CA, USA). An XF or F Buchanan plugger (SybronEndo) was chosen to fit 3 mm short of the working length, avoiding contact with the canal walls. This depth was marked using a rubber stop at the reference point. The System B unit was set at full power at 200 °C with the switch in touch mode. For each specimen, the tug-back of a 40/.06 gutta-percha master point (Mtwo Gutta, Sweden & Martina) was checked 0.5 mm short of the working length and

Table 2 Post characteristics declared by the manufacturers.

Group	*n*	Post	Taper	Composition	Tensile strength (MPa)	Elasticity modulus (GPa)
G1	10	DT Light Post	.02—.10	Pretensioned quartz fibres (64% vol.) Epoxy resin Silane	2050	15
G2	10	SurgiPost Multiconical	.10	Glass fibre (80% vol.) Epoxy resin	3100	80
G3	10	Tech ES Endoshape	.10	Silica fibres (60% vol.) Diphenylpropane + methyloxirane Barium sulphate	1426	14

improved, if needed, by trimming the point with a scalpel. The point was then inserted into the canal with its tip covered with resin sealer (AH26, Dentsply-Maillefer). The gutta-percha master point was slowly down-packed driving the activated plugger through the point 1 mm shorter of the depth marked with the rubber stopper; at that level, heat activation was interrupted and the plugger pushed apically for 10 s. A further heat activation of 1 s was performed to detach the compacted apical gutta-percha from the rest of the point and then the plugger was extracted. The back-filling was performed using an Obtura syringe (Obtura Spartan Endodontics, Algonquin, IL, USA) and hand pluggers, leaving a coronal empty space of 9 mm. The quality of the endodontic obturation was verified radiographically. The orifice of the root canal was sealed with glass ionomer cement (Fuji II, GC Corporation, Tokyo, Japan).[21]

The specimens were stored in sterile saline solution at 37 °C. After 24 h, the glass ionomer cement was abraded with #240 silicon carbide discs under constant water irrigation.[21]

The characteristics of the tested posts are described in Table 2. Double taper (.02—.10) quartz fibre posts (DT Light Post #3, RTD, St-Egreve, France) were used in Group 1 (G1) (Fig. 1). The post space was prepared using a #3 calibrated bur mounted on a low speed handpiece under constant water irrigation. The post diameter at 9 mm from the apical tip was measured, resulting in 1.70 mm.

In Group 2 (G2) and Group 3 (G3), single taper (.10) glass (SurgiPost Multiconical, MC Italia, Lainate, Italy) and silica fibre posts (Tech ES Endoshape, ISASAN, Rovello Porro, Italy) were used (Fig. 1). In order to compare the fracture resistance values among groups, the diameter of all the posts at the canal orifice was standardised by marking all single taper posts at the point where the diameter was 1.70 mm and cutting their tips 9 mm from this reference point with a 0.2 mm thick silicon carbide separating disc (Dedeco International Inc., Long Eddy, NY, USA) (Fig. 1). The fit of each post in the root canal was verified by means of standardised radiographs in both the buccolingual and mesiodistal directions using the positioning silicon templates as described above. Before cementation, all the posts were removed from the root canals and sectioned at 14 mm from the tip using the separating discs, so that each post protruded 5 mm from the canal orifice.

The post space was cleaned with an endodontic rotary brush (Versa Brush, Vista Dental Products, Racine, WI, USA) and then dried with paper points. A self-adhesive luting agent (RelyX Unicem Aplicap, 3M ESPE, St. Paul, MN, USA) was used to cement all the posts using specific intra-canal tips. After extruding the luting cement into the post space, the post was seated with a gentle rotation. The resin cement excess was removed with a manual instrument and the cement was light-cured for 40 s using a halogen unit at 600 mW/cm^2 (Elipar 2500, 3M ESPE). After cementation, the specimens were kept at 37 °C and 100% relative humidity for 24 h.

Simulation of the supporting periodontal tissues

The external surfaces of the roots were isolated using glycerin gel. Each specimen was embedded in a mass of self-curing acrylic resin (Jet Kit, Lang Dental Manufacturing, Wheeling, IL, USA) and poured into a steel hollow cylinder having a height and diameter of 30 mm and a lumen of 15 mm. The coronal portion of the root protruded 2 mm from

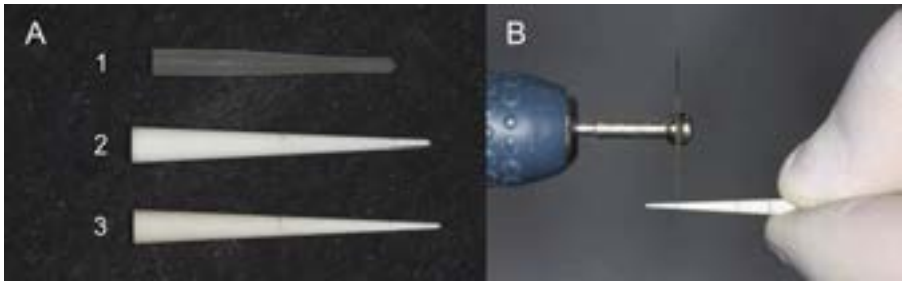

Figure 1 (A) The tested fibre posts as received by the manufacturers; 1: DT Light Post (Group 1); 2: SurgiPost Multiconical (Group 2); 3: Tech ES Endoshape (Group 3). (B) The cut of the tip of an experimental post.

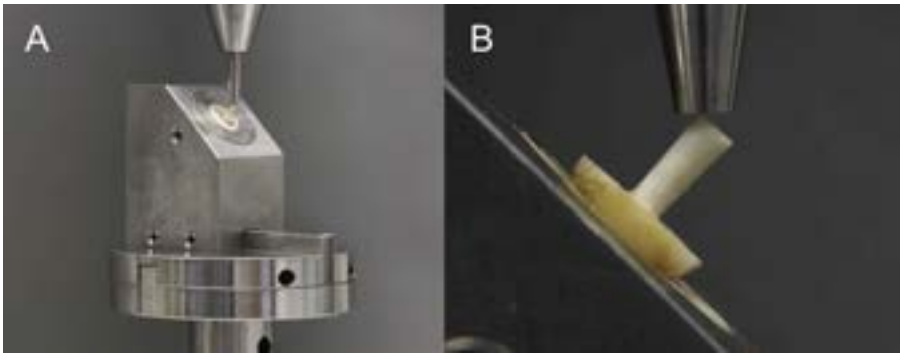

Figure 2 (A) The universal testing system used for the loading test. (B) A detail of the flat head stylus of the universal testing machine loading the specimens at 45° to the longitudinal axis of each tooth.

the surface of the acrylic resin. As soon as the resin started to set, each specimen was removed from the block, so as to avoid dehydration caused by the exothermic reaction of polymerisation. In order to simulate the viscoelastic behaviour of the periodontal ligament, a polyvinyl siloxane impression material (Flexitime, Heraeus Kulzer, Hanau, Germany) was injected in the space created by the roots in the resin; then each specimen was inserted again in the same space before the polymerisation of the impression material, allowing the polyvinyl siloxane to set in a thickness of about 200—400 μm. Excess impression material was carefully trimmed after its complete polymerisation.

Load to failure

A static controlled load was applied on the lingual surface of the head of each post at 45° to the longitudinal axis of the tooth by means of a universal testing machine (Galdabini Sun 500, Cardano al Campo, VA, Italy). A flat head stylus with a diameter of 3 mm and a crosshead speed of 0.75 mm/min was used (Fig. 2). All samples were loaded until fracture and the maximum failure loads were recorded in Newtons. After mechanical failure, the fracture mode was evaluated at 4× magnifications.

Scanning electron microscope analysis

A further evaluation of the quality of endodontic treatment and cementation of the posts was performed by means of a Scanning Electron Microscope (SEM) analysis (Quanta 250, Fei Company, Hillsboro, NE, USA).

Two representative specimens per group were prepared for SEM observation after the mechanical testing. Two grooves were created on the mesial and distal surfaces of the roots with a cutting disc, avoiding contact between the cutting disc and canal walls. The roots were then split into halves with a chisel. Samples were fixed in a 0.2 M buffered solution of 4% glutaraldehyde, dehydrated through multiple steps in alcoholic solutions with increasing concentrations, dried and sputter-coated with gold (Sputter Coater K550X, Fei Company). Images at 11× and 250× were acquired at the coronal, middle and apical third of each post.

Statistical analysis

The data obtained from the mechanical tests were statistically analysed by means of dedicated software (Statistical Package for Social Sciences v.15, SPSS Inc., Chicago, IL, USA). All the datasets were analysed for distribution normality and variance equality with Shapiro—Wilk test and Levene test, respectively, to verify the assumptions for the use of parametric tests. A one-way analysis of variance and a Sheffè post hoc test for pairwise comparisons were used to assess the significance of the difference among groups in terms of mean maximum breaking load. In all the analyses, the level of significance was set at $p < 0.05$.

Results

The mean values (± standard deviations) of the fracture loads recorded in N in each experimental group are shown in Table 3. The highest values of fracture resistance were recorded in G1, followed by G2 and G3 respectively. No statistically significant differences were reported between G1 and G2 ($p > 0.05$), while significant differences were evidenced between G1 and G3 ($p < 0.01$) and G2 and G3 ($p < 0.05$). The qualitative analysis of the failure pattern only showed coronal fractures of the posts bending to failure at the canal orifice, while no root fractures were observed.

Comparing the SEM images of the various groups (Fig. 3), differences were noticed in terms of preservation of the original root canal anatomy and cement thickness at the post/dentine interface. Slight discontinuities in the root canal taper in the area of the post tip were observed in G1 and were ascribable to the action of the calibrated drill used to prepare the post space. Furthermore, thicker layers

Table 3 Mean values (± standard deviations) of the fracture loads (N) recorded in the experimental groups.

Group	Post	Fracture load
G1	DT Light Post	165.05 ± 23.46
G2	SurgiPost Multiconical	151.52 ± 16.23
G3	Tech ES Endoshape	129.09 ± 15.25[a]

[a] Statistically significant difference compared to G1 and G2 ($p < 0.05$).

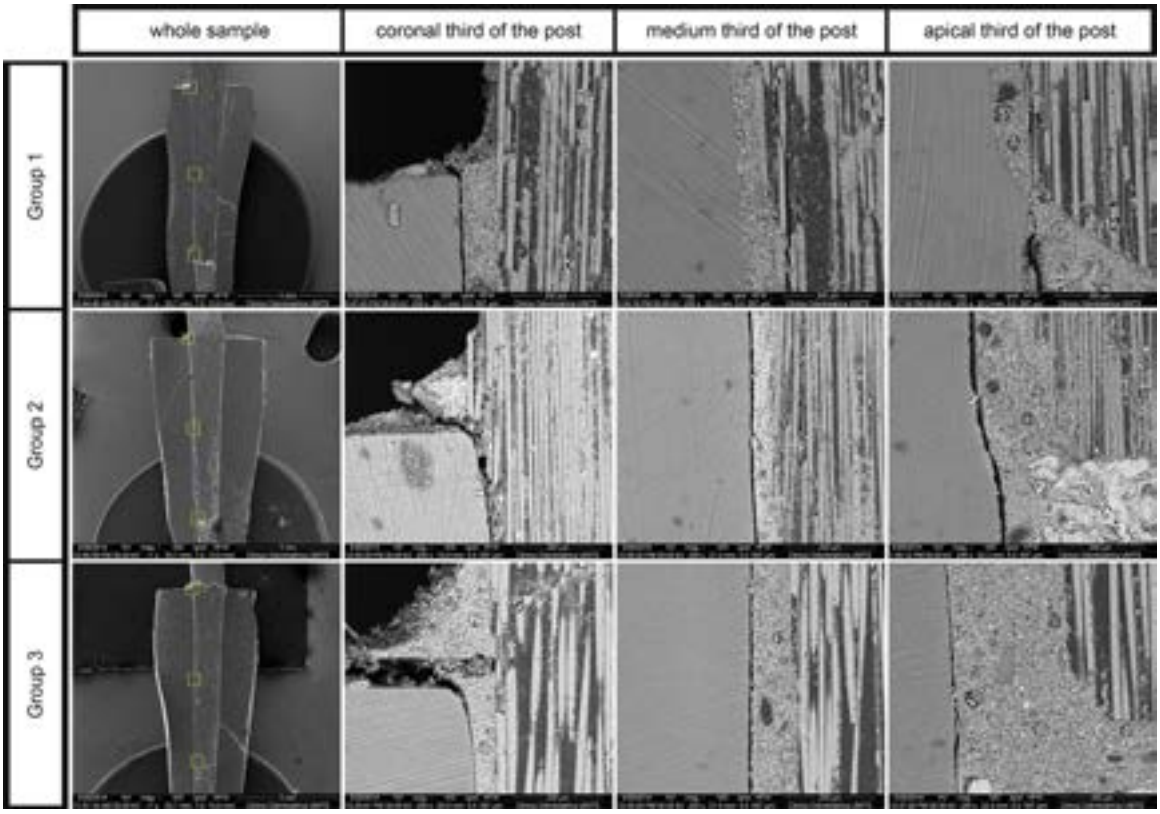

Figure 3 Scanning electron microscope (SEM) microphotographs of Group 1 (DT Light Post), Group 2 (SurgiPost Multiconical) and Group 3 (Tech ES Endoshape). The yellow rectangles marked on the secondary SEM view of the whole sample (11×) highlight the areas of backscattered SEM magnification (250×) of the coronal, middle and apical thirds of the sample posts.

of cement were evident between posts and canal walls both in the apical area and at the middle third of the posts in G2 and G3 rather than in G1.

Discussion

According to the results of the load-to-failure testing, the null hypothesis was rejected, since statistically significant differences were evidenced among groups in terms of mechanical resistance to fracture. DT Light Post and SurgiPost Multiconical fibre posts showed similar mechanical resistance to fracture and greater than Tech ES Endoshape. As widely demonstrated in literature, the post system has a relevant influence on fracture resistance.[2] With regard to fibre posts, there is a host of factors that act simultaneously and can further affect their mechanical properties, namely the diameter of the post at the canal orifice, the fibre/matrix ratio, dimensions, orientation, density and chemo-physical treatment of the fibres.[22] Our findings suggest that the fibre content alone is not indicative of the fracture resistance of the bonded post, since SurgiPost Multiconical posts have the highest fibre/matrix ratio (80%), followed by the DT Light Post system (64%) and Tech ES Endoshape (60%). The great mechanical resistance found in G1, despite the relatively low fibre content, could be justified by the number of quartz fibres per surface unit and their mechanical treatment; in fact, DT Light Posts have a very high density of pre-tensioned fibres (diameter 12 μm, 32 fibres per mm^2).[23] Furthermore, this post system is the only one that makes use of a silane to improve the bond strength between the fibres and the resin matrix, and this could also contribute to improve the mechanical performance. According to the knowledge of the authors, to date no data are available in literature about the mechanical performance of SurgiPost Multiconical and Tech ES Endoshape posts, so a comparison of the results is not feasible. It is nonetheless noteworthy that the resistance values we obtained in all groups are considerably greater than those registered in previous studies with similar experimental set-up, testing the fracture resistance of other fibre post systems with comparable or slightly smaller diameters (1.38—1.70 mm).[21,24] In addition, during the mechanical tests performed in the present investigation, no root fractures were noticed in any of the experimental groups; such an occurrence could be explained considering that the elastic modulus of fibre posts is lower than metallic or zirconia posts and can be close to that of dentine. Fibre posts are known to cause significantly less catastrophic failures than other kinds of posts.[25] In light of these considerations, all the tested post systems exhibited a performance that supports their use in the clinical setting.

Changes in the experimental set-up can considerably affect the findings of the in vitro fracture resistance tests. An insertion depth of 9 mm was chosen in order to achieve the best post retention avoiding to weaken the root, as reported in recent investigations that showed no differences in fracture resistance seating fibre posts at depths of 5, 7 and 9 mm.[26,27] Posts with main taper of.10 were selected

because the single canal of single-rooted teeth is generally wide enough to receive such posts. Also, according to the instructions of the manufacturer, Mtwo files were used with a brushing motion against canal walls, thus causing a slight widening of the canal that increased the final taper of the coronal and middle canal thirds, exceeding that of the last rotary file.

The worst scenario was obtained by applying the experimental load directly on the post, in order to eliminate any interference of other variables involving the restorative materials and/or the residual tooth structure.[21,24] The simulation of the periodontal ligament was performed as it had already been demonstrated that it could influence both fracture resistance and the failure pattern of endodontically treated teeth.[28] Moreover, several three-dimensional anisotropic Finite Element Analysis (FEA) investigations have proved the paramount role of the periodontal ligament in distributing strains and dissipating stresses in post and core restored teeth.[15,18] In an FEA study[29] it was evidenced that the occurrence of root fractures was reduced in the presence of the periodontal ligament, due to the fact that its elastic modulus is much lower than that of the alveolar bone and ensures a more uniform stress distribution on both the tooth and the surrounding tissues.

The mean cement thickness around the post mainly depends on the congruence achieved between the shape of the post and the root canal walls. The preparation of a circular post space in tight, oval or irregular root canals with the aim of achieving the best fit for a post necessitates the removal of a significant amount of dentine, weakening the root and increasing the risk of perforations.[30] For this reason, the post space preparation should be minimally invasive, with minimum or no widening of the shaped root canal. The dimensions of the posts used in the experimental groups with single taper posts were standardised in length and diameter in order to compare the fracture values among different post systems: mechanical comparability was achieved by standardising the diameter at the canal orifice and the taper of the main portion of the post. Therefore, while the coronal fit of the single taper posts was optimal, the SEM observation revealed that the layer of cement around the post was moderately thicker at the middle and apical thirds of the posts in G2 and G3. Considering the optimal mechanical and adhesive properties of contemporary resin cements, the partially uneven distribution of the luting agent at the middle and apical thirds of the posts does not interfere with the mechanical performance of the restorative system.[1,31,32] It has already been shown that a fitting post is not an essential requirement for the improvement of fracture resistance.[33] In addition, the presence of a thicker layer of cement at the tip of the post would result in an improved passive fit, preventing the negative influence of the well-known ''wedge effect''.[34,35] Clinically, the post size should be chosen according to the best passive fit and the minimal taper, ideally corresponding to that of the root canal shaping with no further post space preparation. Despite all the operative efforts to prepare the root canal to receive the post and, vice versa, adapt the post to the canal, standardised shapes of prefabricated posts do not fit exactly with the complex anatomy of root canals. Consequently, the thickness of the resin cement around the post could differ significantly.[36] As to the possible loss of retention, some authors have performed in vitro analyses on the influence of different cement thicknesses on the retentive forces of fibre posts to intra-canal dentine; however, no consensus has been reported about the ideal cement thickness to improve post retention.[37]

As a result of the dehydration caused by the preparation of the samples for the SEM analysis, cracks and ostensible gaps appeared at the interface between the dentine and the resin cement, as already observed in previous studies.[38,39] Owing to such a phenomenon, the interface between dentine and cement usually presents microcracks, since the dentine desiccates because of its hydrophilic characteristics while the cement and the post, both hydrophobic, keep the adhesive interface intact.

With regard to the cementation of fibre posts, resin cements have to be preferred to zinc oxide luting agents, since they provide better adhesion and are not affected by significant resorption. Moreover, resin cements present mechanical properties similar to those of fibre posts and dentine.[3,40] In the present study, RelyX Unicem self-adhesive cement was used: no significant differences were reported between its bonding strength and that provided by Panavia F (Kuraray), a dual cure cement with self-etching primer adhesive system.[41] Furthermore, RelyX Unicem showed values of adhesion comparable to those achieved with resin cements using etch-and-rinse adhesive systems.[42] The push-out force recorded for RelyX Unicem resulted to be comparable to that of Panavia F 2.0[43] and Variolink II dual curing cement.[41] According to a recent review that took into consideration the in vitro data available in literature, it is possible to state that the bonding strength of the most validated self-adhesive cements is comparable with the adhesion of different multi-step resin cements and satisfactory for clinical use.[44] Moreover, easy handling, repeatability and reduced chair-side time, as well as less operator- and technique-sensitivity, could explain how widespread self-adhesive cements have become in clinical practice.[1,45]

Conclusion

Within the limitations of the present in vitro investigation, DT Light Post and SurgiPost Multiconical fibre posts showed similar mechanical resistance to fracture, which was higher than Tech ES Endoshape. Nevertheless, all the tested posts had high fracture resistance and none of the tested posts caused unrestorable root fractures.

In the same anatomical conditions, the use of single taper conical posts would be preferable than double taper posts, since they allowed for a more conservative post space preparation or no preparation at all. The slightly uneven cement distribution around the middle and apical third of the single taper conical posts can be minimised in the clinical setting by choosing a post with lower taper.

The findings of the present study lay the ground for further investigations to evaluate the clinical performance of the tested post systems.

Conflict of interest

The authors have no conflicts of interest to declare.

References

1. Goracci C, Ferrari M. Current perspectives on post systems: a literature review. *Aust Dent J* 2011;**56**(Suppl. 1):77—83.
2. Barcellos RR, Correia DP, Farina AP, Mesquita MF, Ferraz CC, Cecchin D. Fracture resistance of endodontically treated teeth restored with intra-radicular post: the effects of post system and dentine thickness. *J Biomech* 2013;**46**:2572—7.
3. Assif D, Gorfil C. Biomechanical considerations in restoring endodontically treated teeth. *J Prosthet Dent* 1994;**71**:565—7.
4. Juloski J, Radovic I, Goracci C, Vulicevic ZR, Ferrari M. Ferrule effect: a literature review. *J Endod* 2012;**38**:11—9.
5. Samran A, El Bahra S, Kern M. The influence of substance loss and ferrule height on the fracture resistance of endodontically treated premolars. An in vitro study. *Dent Mater* 2013;**29**: 1280—6.
6. Sorrentino R, Monticelli F, Goracci C, Zarone F, Tay FR, Garcia-Godoy F, et al. Effect of post-retained composite restorations and amount of coronal residual structure on the fracture resistance of endodontically-treated teeth. *Am J Dent* 2007;**20**: 269—74.
7. Santos-Filho PC, Verissimo C, Soares PV, Saltarelo RC, Soares CJ, Marcondes Martins LR. Influence of ferrule, post system, and length on biomechanical behavior of endodontically treated anterior teeth. *J Endod* 2014;**40**:119—23.
8. Le Bell-Ronnlof AM, Lassila LV, Kangasniemi I, Vallittu PK. Load-bearing capacity of human incisor restored with various fiber-reinforced composite posts. *Dent Mater* 2011;**27**:e107—15.
9. Cheron RA, Marshall SJ, Goodis HE, Peters OA. Nanomechanical properties of endodontically treated teeth. *J Endod* 2011;**37**:1562—5.
10. Sagsen B, Zortuk M, Ertas H, Er O, Demirbuga S, Arslan H. In vitro fracture resistance of endodontically treated roots filled with a bonded filling material or different types of posts. *J Endod* 2013;**39**:1435—7.
11. Lang H, Korkmaz Y, Schneider K, Raab WH. Impact of endodontic treatments on the rigidity of the root. *J Dent Res* 2006;**85**: 364—8.
12. Zhou L, Wang Q. Comparison of fracture resistance between cast posts and fiber posts: a meta-analysis of literature. *J Endod* 2013;**39**:11—5.
13. Salameh Z, Sorrentino R, Papacchini F, Ounsi HF, Tashkandi E, Goracci C, et al. Fracture resistance and failure patterns of endodontically treated mandibular molars restored using resin composite with or without translucent glass fiber posts. *J Endod* 2006;**32**:752—5.
14. Schwartz RS, Robbins JW. Post placement and restoration of endodontically treated teeth: a literature review. *J Endod* 2004;**30**:289—301.
15. Sorrentino R, Salameh Z, Apicella D, Auriemma T, Zarone F, Apicella A, et al. Three-dimensional finite element analysis of stress and strain distributions in post-and-core treated maxillary central incisors. *J Adhes Dent* 2007;**9**:527—36.
16. Ferrari M, Breschi L, Grandini S. Fiber posts and endodontically treated teeth: a compendium of scientific and clinical perspectives. Wendywood: Modern Dentistry Media; 2008.
17. Grandini S, Chieffi N, Cagidiaco MC, Goracci C, Ferrari M. Fatigue resistance and structural integrity of different types of fiber posts. *Dent Mater J* 2008;**27**:687—94.
18. Aversa R, Apicella D, Perillo L, Sorrentino R, Zarone F, Ferrari M, et al. Non-linear elastic three-dimensional finite element analysis on the effect of endocrown material rigidity on alveolar bone remodeling process. *Dent Mater* 2009;**25**:678—90.
19. Verissimo C, Simamoto Junior PC, Soares CJ, Noritomi PY, Santos-Filho PC. Effect of the crown, post, and remaining coronal dentin on the biomechanical behavior of endodontically treated maxillary central incisors. *J Prosthet Dent* 2014;**111**:234—46.
20. Burklein S, Hinschitza K, Dammaschke T, Schafer E. Shaping ability and cleaning effectiveness of two single-file systems in severely curved root canals of extracted teeth: Reciproc and WaveOne versus Mtwo and ProTaper. *Int Endod J* 2012;**45**: 449—61.
21. Schiavetti R, Garcia-Godoy F, Toledano M, Mazzitelli C, Barlattani A, Ferrari M, et al. Comparison of fracture resistance of bonded glass fiber posts at different lengths. *Am J Dent* 2010;**23**:227—30.
22. Grandini S, Goracci C, Monticelli F, Tay FR, Ferrari M. Fatigue resistance and structural characteristics of fiber posts: three-point bending test and SEM evaluation. *Dent Mater* 2005;**21**: 75—82.
23. Grandini S, Goracci C, Monticelli F, Borracchini A, Ferrari M. SEM evaluation of the cement layer thickness after luting two different posts. *J Adhes Dent* 2005;**7**:235—40.
24. Newman MP, Yaman P, Dennison J, Rafter M, Billy E. Fracture resistance of endodontically treated teeth restored with composite posts. *J Prosthet Dent* 2003;**89**:360—7.
25. Baldissara P, Zicari F, Valandro LF. Effect of fiber posts with different emerging diameters on the fracture strength of restored crownless teeth. *Gen Dent* 2011;**59**:e67—71.
26. Borelli B, Sorrentino R, Zarone F, Ferrari M. Effect of the length of glass fiber posts on the fracture resistance of restored maxillary central incisors. *Am J Dent* 2012;**25**:79—83.
27. Mobilio N, Borelli B, Sorrentino R, Catapano S. Effect of fiber post length and bone level on the fracture resistance of endodontically treated teeth. *Dent Mater J* 2013;**32**:816—21.
28. Sterzenbach G, Karajouli G, Naumann M, Peroz I, Bitter K. Fiber post placement with core build-up materials or resin cements-an evaluation of different adhesive approaches. *Acta Odontol Scand* 2012;**70**:368—76.
29. Uddanwadiker RV, Padole PM, Arya H. Effect of variation of root post in different layers of tooth: linear vs nonlinear finite element stress analysis. *J Biosci Bioeng* 2007;**104**:363—70.
30. Krastl G, Gugger J, Deyhle H, Zitzmann NU, Weiger R, Muller B. Impact of adhesive surface and volume of luting resin on fracture resistance of root filled teeth. *Int Endod J* 2011;**44**:432—9.
31. Radovic I, Mazzitelli C, Chieffi N, Ferrari M. Evaluation of the adhesion of fiber posts cemented using different adhesive approaches. *Eur J Oral Sci* 2008;**116**:557—63.
32. Juloski J, Goracci C, Radovic I, Chieffi N, Vichi A, Vulicevic ZR, et al. Post-retentive ability of new flowable resin composites. *Am J Dent* 2013;**26**:324—8.
33. Buttel L, Krastl G, Lorch H, Naumann M, Zitzmann NU, Weiger R. Influence of post fit and post length on fracture resistance. *Int Endod J* 2009;**42**:47—53.
34. Theodosopoulou JN, Chochlidakis KM. A systematic review of dowel (post) and core materials and systems. *J Prosthodont* 2009;**18**:464—72.
35. Naumann M, Metzdorf G, Fokkinga W, Watzke R, Sterzenbach G, Bayne S, et al. Influence of test parameters on in vitro fracture resistance of post-endodontic restorations: a structured review. *J Oral Rehabil* 2009;**36**:299—312.
36. Coniglio I, Garcia-Godoy F, Magni E, Carvalho CA, Ferrari M. Resin cement thickness in oval-shaped canals: oval vs. circular fiber posts in combination with different tips/drills for post space preparation. *Am J Dent* 2009;**22**:290—4.
37. Egilmez F, Ergun G, Cekic-Nagas I, Vallittu PK, Lassila LV. Influence of cement thickness on the bond strength of tooth-colored posts to root dentin after thermal cycling. *Acta Odontol Scand* 2013;**71**:175—82.
38. Zapletalova Z, Kubinek R, Vujtek M, Novotny R. Examination of dentin surface using AFM (our experience). *Acta Med (Hradec Kralove)* 2004;**47**:343—6.
39. Gjorgievska E, Nicholson JW, Iljovska S, Slipper IJ. Marginal adaptation and performance of bioactive dental restorative

materials in deciduous and young permanent teeth. *J Appl Oral Sci* 2008;**16**:1—6.
40. Bolhuis P, de Gee A, Feilzer A. The influence of fatigue loading on the quality of the cement layer and retention strength of carbon fiber post-resin composite core restorations. *Oper Dent* 2005; **30**:220—7.
41. Piwowarczyk A, Bender R, Ottl P, Lauer H-C. Long-term bond between dual-polymerizing cementing agents and human hard dental tissue. *Dent Mater* 2007;**23**:211—7.
42. Tian Y, Mu Y, Setzer FC, Lu H, Qu T, Yu Q. Failure of fiber posts after cementation with different adhesives with or without silanization investigated by pullout tests and scanning electron microscopy. *J Endod* 2012;**38**:1279—82.
43. Yang B, Ludwig K, Adelung R, Kern M. Micro-tensile bond strength of three luting resins to human regional dentin. *Dent Mater* 2006;**22**:45—56.
44. Radovic I, Monticelli F, Goracci C, Vulicevic ZR, Ferrari M. Self-adhesive resin cements: a literature review. *J Adhes Dent* 2008;**10**:251—8.
45. Cuadros-Sanchez J, Szesz A, Hass V, Patzlaff RT, Reis A, Loguercio AD. Effects of sonic application of adhesive systems on bonding fiber posts to root canals. *J Endod* 2014;**40**:1201—5.

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VINCITORE DEL CONCORSO "Miglior caso clinico Under 32"
CASE REPORT/CASO CLINICO

The Radix Entomolaris: management of the distolingual root canal

La Radix Entomolaris: trattamento del canale distolinguale

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KEYWORDS
Radix Entomolaris;
Fourth canal;
Missed anatomy;
Distolingual root;
Mandibular first molar.

Abstract
Aim: To present a case of mandibular first molar with addictional distolingual root (Radix Entomolaris).
Introduction: Radix Entomolaris is an additional third root that can be found lingually in first mandibular molars; in European population it has be reported that separate Radix Entomolaris is present with a frequency of 5%.[1]

It is of utmost importance that the clinician be familiar with root and root canal anatomy. It allows mechanical and chemical cleaning of the entire pulp cavity and its complete three-dimensional obturation. One of the main reasons for root canal treatment failure in molars is because the clinicians has not removed all the pulp tissue and microorganisms from the root canal system.[2] The knowledge of endodontic anatomy is also important to prevent procedural errors such as instrument separations, zips and root perforations.
Materials and methods: In this article an orthograde retreatment of mandibular first molar with Radix Entomolaris is described.
Discussion: Clinicians should be aware of Radix Entomolaris through

1. a thorough inspection of the pre-treatment radiograph
2. a trapezoidal opening cavity
3. a conservative instrumentation because RE often presents a moderate/severe curvature in the coronal third that could be masked on regular periapical radiographs.

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PAROLE CHIAVE
Radix Entomolaris;
Quarto canale;
Varianti anatomiche;
Radice distolinguale;
Primo molare mandibolare.

Riassunto
Scopo: Presentare il caso di un primo molare mandibolare avente una radice sovrannumeraria, la Radix Entomolaris.
Introduzione: La Radix Entomolaris è una radice sovrannumeraria presente sul versante linguale di molari mandibolari che si presenta con una frequenza del 5% nella popolazione europea.[1]

La conoscenza della variabilità dell'anatomia endodontica è di vitale importanza per il clinico. Questo permette infatti di sagomare e detergere tutti i canali radicolari e di eseguire un'otturazione completa e tridimensionale degli stessi. Una delle più frequenti cause di fallimento endodontico è rappresentata dalla mancata rimozione di tutto il tessuto pulpare e dei microrganismi da sistema di canali radicolari.[2] La conoscenza della anatomia endodontica è anche importante per evitare di incorrere in errori iatrogeni quali separazioni di strumenti e perforazioni.
Materiali e Metodi: Nell'articolo viene descritto il ritrattamento ortogrado di un primo molare mandibolare con Radix Entomolaris.
Discussione: Quando ci si trova a dover eseguire una terapia endodontica su un elemento con Radix Entomolaris è necessario adottare alcuni accorgimenti, quali:

1. una attenta valutazione della radiografia pre-operatoria
2. un accesso trapezoidale alla camera pulpare
3. la strumentazione conservativa di tale radice perché essa presenta in molti casi una curvatura accentuata nel III coronale non visibile nella radiografia periapicale.

Introduction

The prevention or healing of endodontic disease depends on a thorough chemo-mechanical cleaning and shaping of the root canal system before a root canal filling. The awareness and understanding of the presence of unusual canal morphology can thus contribute to the successful outcome of endodontic treatment.

Most mandibular first molar have two roots located mesially and distally and three root canals, but variations in the number of roots and in canal morphology are not uncommon. The major variant is the occurrence of an additional third root: this extra root was first reported by Carabelli and was called Radix Entomolaris (RE).[3]

This supernumerary root is located on the lingual aspect of mandibular molars, as opposed to Radix Paramolaris located buccally.[3]

In European, African, Eurasian and Indian populations it has been reported that a separate RE is present in the mandibular first molar with a frequency $<5\%$, while in population with Mongoloid traits the RE occurs with a frequency between 5% and 40%.[1]

The majority of the Radices Entomolaris are smaller than the distobuccal root[4] and curved.[1] A pronounced curvature is very common in the middle part of the root canal of the RE: it is greater in a buccal-lingual orientation than in a mesial-distal orientation.

Indeed DL roots with severe curvature are seen mostly from mesial-distal radiographs; however only buccal-lingual radiographs can be performed clinically. Clinicians should be aware of the curvature of DL roots that could be masked on regular periapical radiographs.[4]

An invasive instrumentation can result in instrument breakage, canal transportation and root perforation.[5]

Materials and methods

A 60-years old woman was referred to me for endodontic/restorative treatment of left mandibular first molar. The medical history was non-contributory. Clinical examination of tooth 3.6 showed an inadequate occlusal restoration and tooth decay in the distal part of the crown. The tooth was free of symptoms and did not respond to vitality test (both cold and electrical). Percussion test was negative and at the periapical X-ray there was no periapical lesion.

X-ray exam obtained through the paralleling technique showing that the restoration started from the floor of the pulp chamber and that the root canals appeared radiolucent; it suggested both the tooth is necrotic either the previous endodontic treatment was not correct (Fig. 1).

Becouse of 3.6 needed a prosthetic restoration of the crown the endodontic retreatment had been carried out.[6]

After isolation of the operative field with dental dam, the decayed tissue and the previous restoration was removed. A trapezoidal opening cavity was performed. Four root canals

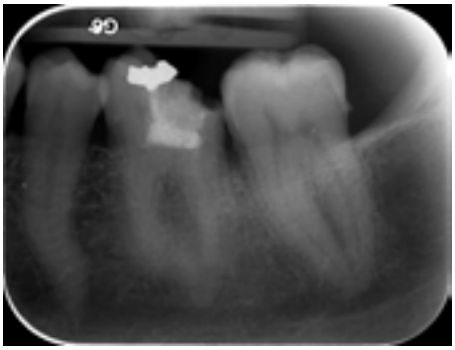

Figure 1 Pre-operative X-ray of 3.6.

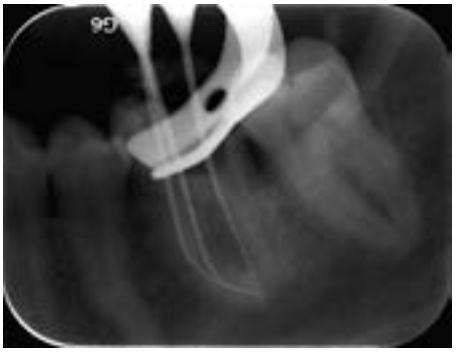

Figure 2 Intra-operative X-ray for working lengths confirmation of ML, MV, DV canals.

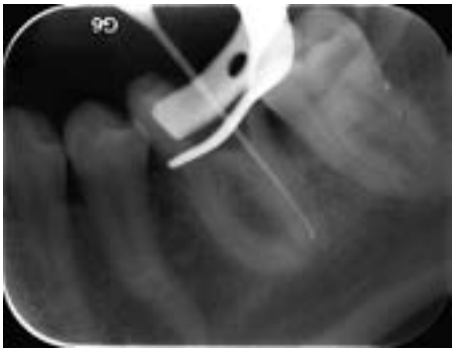

Figure 3 Intra-operative X-ray for working length confirmation of DL canal.

were found (MV, ML, DV and DL); MV, ML and DV had been previously endodontically treated and incompletely obturated with a sealer.

A distolingual extension of the contour of the pulp chamber was necessary in order to localize the orifice of the distolingual root and to have optimal access.

The lengths of these canals were measured electronically. Periapical X-ray for working length confirmation showed a separate lingual root, identified as RE (Figs. 2 and 3). The four root canals were disinfected with sodium hypochlorite solution (5,25%) and EDTA and shaped with k-files, Pathfile and Protaper Universal (*Dentsply Maillefer, Ballaigues, Switzerland*) instruments S1, S2, F1, F2.

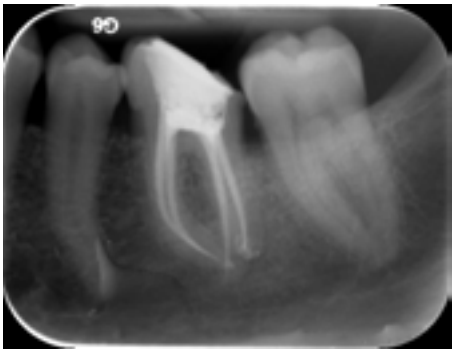

Figure 4 Postoperative X-ray of 3.6.

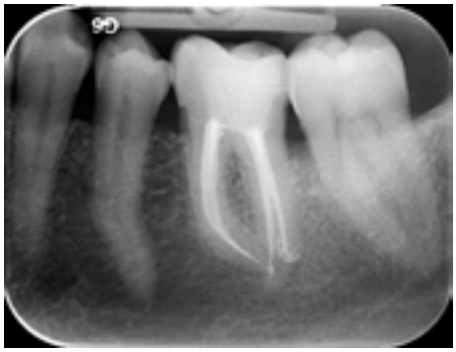

Figure 5 X-ray after restoration with a composite onlay.

DL canal was shaped with hybrid technique using Protaper Universal S1, S2, F1 and Profile 25.06 (*Dentsply Maillefer, Ballaigues, Switzerland*).

The lower taper of Profile was necessary to prevent errors like stripping instrument breakage or root perforation.

MV, DV and DL were obturated with Thermafil 25, ML with Thermafil 30 (the root canal converged in MV 1 mm before the apex) (Figs. 4 and 5).

Discussion and conclusions

Clinically a missing canal is one of the major reasons for post-treatment disease.[2] Failure in recognize the presence of an extra DL root in root canal treatment may lead to incomplete debridement of the root canal system and eventually treatment failure. Therefore a thorough inspection of the pre-treatment radiograph and interpretation of certain characteristic, such as an unclear view of the distal root/canal, could assist in identifying the presence of DL roots (Fig. 1).

Predictably successful in a RE root canal treatment is depending both on a proper angulation and interpretation of radiographs, and on a straight line access with a trapezoidal opening cavity, a correct cleaning, shaping and obturation system.

Most RE are thinner than other roots and present, in a proximal view, a severe curvature with a lingual orientation starting from the coronal third. According to the classification of De Moor et al.,[1] the RE could be classified into three groups on the basis of the root/canal curve. Type I refers to a straight root canal, Type 2 refers to an initially curved entrance that continues as a straight canal and Type III refers to an initially lingual curve in the coronal third of the root canal and a second buccal curve beginning in the middle and continuing to the apical third. Type III is found more frequently than the other anatomical types.[7]

Conventional X-ray images compress the three-dimensional anatomy into a two-dimensional image. Important features of the tooth are visualized in the mesio-distal plane only. However, similar features shown in the bucco-lingual plane may not be fully appreciated.[8]

These findings deserve attention as far as the biomechanical preparation is concerned: a non-conservative instrumentation technique can result in instrument breakage and other procedural errors such as ledges, zips and root perforations. A canal preparation with taper 06 reduces those risks

without affect the ability to disinfect root canals[9–12] and allows an adequate obturation.

Conflict of interest

The author denies any conflict of interest.

References

1. De Moor RJG, Deroose CAJG, Calberson FLG. The radix entomolaris in mandibular first molars: an endodontic challenge. *Int Endod J* 2004;**37**:789–99.
2. Cohen AS, Brown DC. Orofacial dental pain emergencies: endodontic diagnoses and management. In: Cohen S, Burns RC, editors. *Pathways of the pulp*. 8th ed. Boston, MA, USA: Mosby; 2002. p. 31–75.
3. Stamfelj I. Who coined the term radix entomolaris? Letter to the editor. *Int Endod J* 2014;**47**:810–1.
4. Chen Y, Lee Y, Pai S, Yang S. The morphologic characteristic of the distolingual roots of mandibular first molars in a Taiwanese population. *J Endod* 2009;**35**:643–5.
5. Souza-Flamini LE, Leoni GB, Mazzi Chaves JF, Versiani MA, Cruz-Filho AM, Pécora JD, et al. The radix entomolaris and paramolaris: a micro-computed tomographic study of 3 rooted mandibular first molars. *J Endod* 2014;**40**:1616–21.
6. Società Italiana di Endodonzia "Manuale di Endodonzia"; 2013.
7. Wang Q, Yu G, Zhou XD, Peters OA, Zeng Q-H, Huang D-M. Evaluation of X-ray projection angulation for successful radix entomolaris diagnosis in mandibular first molars in vitro. *J Endod* 2011;**27**:1063–8.
8. Abella F, Mercadè M, Duran-Sindreu F, Roig M. Managing severe curvature of radix entomolaris: three-dimensional analysis with cone beam computed tomography. *Int Endod J* 2011;**44**:876–85.
9. Siqueira JF, Lima KC, Magalhaes FAC, Lopes HP, de Uzeda M. Mechanical reduction of the bacterial population in the root canal by three instrumentation techniques. *J Endod* 1999;**25**:332–5.
10. de Lima Machado ME, Sapia LAB, Cai S, Martins GHR, Nabeshima CK. Comparison of two rotary systems in root canal preparation regarding disinfection. *J Endod* 2010;**36**:1238–40.
11. Aydin C, Tunca YM, Senses Z, Baysallar M, Kayaoglu G, Orstavik D. Bacterial reduction by extensive versus conservative root canal instrumentation in vitro. *Acta Odontostomatol Scand* 2007;**65**:167–70.
12. Arvaniti IS, Khabbaz MG. Influence of root canal taper on its clearness: a scanning electron microscopic study. *J Endod* 2011;**37**:871–4.

LETTERA DEL PRESIDENTE

Carissimi Soci,

si sta ormai per concludere il terzo anno del mandato di questo Consiglio. Tutti i punti programmatici sono stati portati a termine e c'è stata la possibilità e la volontà di lavorare anche ad altre iniziative.

È stata notevolmente aumentata la partecipazione degli associati alla vita della SIE, tramite le Commissioni, che hanno lavorato benissimo, con grande armonia e con una produttività al di là delle più rosee aspettative.

Tramite il notevole aumento delle tavole cliniche, molti di voi hanno dato un eccezionale contributo alla riuscita del Congresso dello scorso anno a Bologna.

Abbiamo migliorato e rafforzato il nostro rapporto con l'Università.

Abbiamo acquisito nuovi soci e abbiamo dato più spazio ai giovani, la vera linfa del nostro futuro. Il concorso loro dedicato ha funzionato molto bene e anche quest'anno lo ripeteremo, con la presentazione di un caso clinico che oltretutto permetterà loro di partecipare al nostro Closed Meeting. Mi auguro che la partecipazione a questo momento importantissimo di incontro e di lavoro continui con il costante aumento registrato negli ultimi anni.

Tutte le attività culturali di questi tre anni sono state coronate da una partecipazione e da un successo crescenti, sia in ambito locale che nazionale. Due anni fa, a Parma, abbiamo fatto la prova generale del Congresso Internazionale invitando alcuni graditissimi ospiti stranieri. Quest'anno il Congresso sarà significativamente internazionale. Avremo Relatori da tutto il mondo di altissimo livello e, in numero paritario, altrettanto importanti relatori italiani, per un programma veramente di altissimo livello in ambito endodontico. Avremo la traduzione simultanea sia dall'italiano che dall'inglese per poter accogliere il maggior numero di persone, in special modo anche graditissimi appassionati di Endodonzia di tutto il mondo.

Il tema di tutte queste giornate sarà il salvataggio del dente naturale, filo conduttore di questo nostro triennio. L'importanza di scegliere di salvare il dente e le sue importantissime strutture di sostegno, prima di prendere in esame qualsiasi possibilità di sostituzione. Ricerche recenti ci fanno capire come il dente naturale sia, oltre che un semplice strumento meccanico per la masticazione, anche un importante organo sensoriale, delle cui connessioni probabilmente dobbiamo sapere ancora molto.

Per un Congresso internazionale una sede internazionale. Torniamo a Roma per accogliere, oltre a tutti voi, speriamo una nutrita rappresentanza di colleghi stranieri, in una città inimitabile.

Un caro saluto e arrivederci a Roma!

Il Presidente SIE **Pio Bertani**

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CRITERI DI VALUTAZIONE

Il singolo caso clinico nel suo complesso, coerentemente con gli scopi e i fini della SIE, deve essere presentato considerando non solo l'aspetto clinico del caso, ma anche quello formale della documentazione presentata.

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La domanda di ammissione allo "status" di Socio Aggregato/Attivo, rivolta al Presidente della SIE, **dovrà pervenire**, insieme alla documentazione di seguito elencata, **alla Segretaria della SIE con un anticipo di 20 giorni sulle date di riunione della CAS**, sufficiente per poter organizzare il materiale dei candidati. Le date di scadenza saranno rese note sul sito.
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PRESENTAZIONE DEI CASI ALLA COMMISSIONE ACCETTAZIONE SOCI

La presenza del candidato è obbligatoria durante la riunione della CAS; è altresì consigliabile la presenza del Socio presentatore.

LA COMMISSIONE ACCETTAZIONE SOCI

La CAS (Commissione Accettazione Soci), eletta ad ogni scadenza elettorale dall'Assemblea dei Soci Attivi ed Onorari, è formata da 5 Soci Attivi, con almeno 5 anni di anzianità in questo ruolo e di indiscussa esperienza clinica. Compito della CAS è quello di esaminare e valutare i Casi Clinici presentati dagli aspiranti Soci Aggregati e Soci Attivi. Per rispetto del lavoro dei Candidati e per omogeneità di giudizio, in ogni riunione verranno valutati non più di 5 candidati a Socio Attivo. Resta libero, invece, il numero dei candidati a Socio Aggregato valutabili in una singola riunione della CAS.
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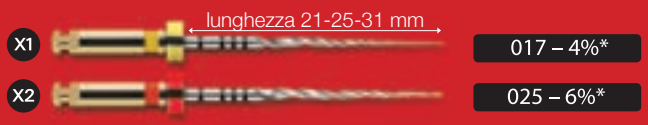

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Realizzazione della cavità d'accesso all'endodonto con strumenti specifici KOMET

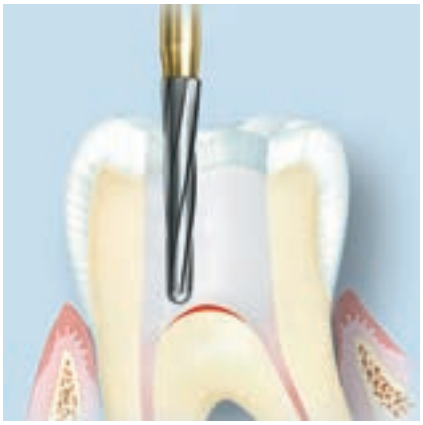
La preparazione della cavità di accesso è senza dubbio la chiave del successo in endodonzia.

Per reperire tutti gli imbocchi è importante conoscere l'anatomia di ogni singolo dente e disporre di strumenti che rendano facile e sicura la ricerca degli imbocchi e la susseguente rettifica delle pareti cavitarie, senza sfondare il pavimento camerale.

Strumenti utilissimi per trovare gli imbocchi e rifinire le pareti della cavità d'accesso sono:

1. La fresa H1SML KOMET è una rosetta endodontica
- a gambo lungo ISO 205 lunghezza globale 31 mm diametri 006 008 010 012 014
- ed extra lungo ISO 206 lunghezza globale 34 mm diametri 006 010 014
per la ricerca degli imbocchi e la lavorazione degli istmi.
Essendo provvista di un collo sottile consente un controllo visivo eccezionale, garantendo insieme elevata sicurezza ed efficienza di taglio.

2. La fresa EndoGuard KOMET con punta liscia di sicurezza nasce per la rettifica delle pareti cavitarie.
Si distingue da frese analoghe della concorrenza perché non presenta alcun gradino tra la testa liscia e le lame taglienti. In questo modo non produce a sua volta mini-interferenze, che disturbano l'accesso degli strumenti all'apice e il successivo flusso della guttaperca.



La EndoGuard KOMET esiste in una versione a lame continue art. H269GK

e in una versione a lame tacchettate H269QGK.

Questa seconda versione possiede un taglio ancora più dolce e controllato rispetto alla versione tradizionale.

24-26 GIUGNO 2016, PADOVA

Closed Meeting SIE

Hotel Majestic – Radisson Blu Resort – Terme di Galzignano, Padova

Resoconto a cura del Dott. Flavio Palazzi

Il *Closed Meeting* della SIE ha avuto sede anche quest'anno nella suggestiva cornice dell'**Hotel Majestic - Radisson Blu Resort Terme di Galzignano** (Padova): un'occasione rinnovata per validare e consolidare appartenenza, solidarietà, condivisione e collaborazione. Semplicità, Intesa, Emozioni costituiscono il registro di sviluppo leggero ed armonico delle attività scientifiche e culturali della Società. Il Venerdì mattina (24/6) si è riunito nella Sala Pedrocchi il Consiglio Direttivo. Il Venerdì pomeriggio il Prof. Paolo Vescovi, ospite della SIE per l'occasione ed esperto di fama internazionale sul tema, ha presentato la relazione dal titolo "*Gestione Odontoiatrica del paziente in terapia con bifosfonati e altri farmaci antiriassorbitivi ossei*". L'utilizzo nel trattamento di osteoporosi, morbo di Paget, osteogenesi imperfecta, mieloma multiplo, metastasi osteolitiche etc, ha collocato i bifosfonati e gli antiriassorbitivi ossei tra i venti farmaci più prescritti al mondo. Da alcuni anni sono stati peraltro acquisiti dati conclusivi a supporto di una relazione significativa tra l'utilizzo dei suddetti farmaci e l'insorgenza di osteonecrosi avascolari localizzate alle ossa mascellari. Nella relazione e nel dibattito seguente, sono stati approfonditi gli aspetti preventivi e diagnostici, definite linee guida odontoiatriche per pazienti in terapia, nonché norme di approccio terapeutico alle osteonecrosi dei mascellari conclamate. Le presentazioni di un "Caso Clinico" a cura del neo Socio Attivo SIE Dott. Matteo Papaleoni e del "Miglior Caso Clinico Under 32" a cura del vincitore del concorso, la Dott.ssa Sarah Abrami, hanno sancito la fine della giornata scientifica. Alle 18.00 si è svolta la mitica partita di calcetto NORD vs SUD: solo dopo il gol del 4-0 a favore della Squadra Gialla (NORD), gli Azzurri (SUD), distratti ripetutamente dall'arbitro, hanno finalmente realizzato di essere prossimi alla fine del secondo tempo e non alla fine del riscaldamento pre-partita. Gli ultimi 5 minuti non sono però bastati per vincere l'inganno e sovvertire l'esito della sfida. Inutilmente il nostro Presidente ha riorganizzato la squadra chiamando la Bl-Zona del maestro Canà. Onorando la filosofia dello sport e della SIE insieme abbiamo quindi festeggiato i vincitori della Coppa. L'epilogo della giornata, un vivace aperitivo a bordo piscina e la fresca cena presso il ristorante del **Resort**. all'insegna della convivialità. Protagonisti ancora il linguaggio della natura, dell'acqua, della musica e la potenzialità comunicativa di gesti elementari… sorrisi… abbracci. Il Sabato mattina (25/6) la conferenza sul tema "*Controllo dell'asepsi in Endodonzia: position statement della SIE*" ha rappresentato l'inizio di un percorso, verso la maturazione di linee guida della Società, sul tema del controllo dell'asepsi in endodonzia. Il coordinamento della Commissione culturale e la discussione libera con i Soci Attivi hanno consentito l'elaborazione critica dei primi orientamenti nella definizione di un *position statement*. Nella seconda parte della mattina è iniziata l'attività della

LA DOTT.SSA ABRAMI E IL PRESIDENTE DOTT. BERTANI

IL PROF. VESCOVI E IL PRESIDENTE DOTT. BERTANI

VITA SOCIETARIA

Commissione Accettazione Soci Attivi (CAS) protrattasi anche nel pomeriggio: i nuovi Soci Attivi della SIE sono il Dr. Roberto Gallo, il Dr Alfredo Iandolo, il Dr Manuele Mancini e il Dr. Flavio Palazzi. Le riunioni della Commissione Culturale, della Commissione per la Ricerca, della Commissione Web e dei Segretari Regionali hanno quindi impegnato il pomeriggio del Sabato. Attività sportive e momenti distensivi nel Physiosal Center hanno sempre accompagnato e sfumato l'attività culturale e scientifica. Così la seconda giornata di lavori è stata stemperata in piscina e nella colorata cornice dei Colli Euganei, che ci ha accompagnato verso la cena, presso il ristorante "La Montanella" di Borin Giorgio & C.. La mattina della Domenica (26/6) ha chiuso il *Closed Meeting* SIE 2016 con un programma libero culturale e sportivo. Il Golf Club della Montecchia ha ospitato il torneo di Golf per gli appassionati. Una valida alternativa la gita organizzata presso la Basilica Abbaziale di Santa Giustina, la Basilica di Sant'Antonio ed il Palazzo della Ragione, l'antica sede dei tribunali di Padova, con lo splendido "salone" pensile. La passeggiata nel centro storico, il fascino delle piazze ed il Caffè Pedrocchi, il giusto cameo prima dei saluti.

PALAZZO DELLA RAGIONE


LE SQUADRE SCHIERATE


LA SEDE DEL CLOSED MEETING


LA GITA A PADOVA

VITA SOCIETARIA

SIE ENDODONTIC COURSES 2016 – Sede di Ancona

Corsi di formazione teorico/pratici della Società Italiana di Endodonzia

Dott. Roberto Mancini

Con l'incontro del 24 settembre si è concluso l'Endodontic Course della Sezione Marchigiana della SIE, articolato in 5 date con un programma comune alle sedi di Brescia, Genova e Roma. Il corso, svoltosi ad Ancona nella sede della Kavo, ha visto la partecipazione di 17 odontoiatri provenienti da diverse regioni del centro Italia. Oltre al sottoscritto, i diversi argomenti di Endodonzia Clinica sono stati trattati dai Soci Attivi della SME, tra i quali il Dr. Filippo Cardinali, il Dr. Eugenio Tosco, il Dr. Marco Forestali, il Dr. Daniele Natalini, il Dr. Mario Mancini ed il Dr. Stefano Bottacchiari; ho avuto anche il piacere di ospitare in qualità di docenti il Segretatrio della sezione Emilia-na-Romagnola della SIE Dr. Enrico Cassai, e il Segretario della sezione abruzzese della SIE Dr. Lucio Daniele.

Il corso è stato arricchito da diversi Workshop riguardanti l'utilizzo della Diga di gomma e la sagomatura canalare: il coinvolgimento diretto da parte dei corsisti ha suscitato entusiasmo e apprezzamento.

Con questo progetto la SIE ha offerto la possibilità di approfondire le conoscenze in campo endodontico avvalendosi di specialisti della materia che operano nel territorio marchigiano, attraverso i quali verrà garantito altresì ai corsisti, il supporto necessario per acquisire la qualifica di Socio aggregato o attivo.

I PARTECIPANTI

LE ATTIVITÀ PRATICHE

VITA SOCIETARIA

SIE ENDODONTIC COURSES 2016 – Sede di Brescia

Corsi di formazione teorico/pratici della Società Italiana di Endodonzia

Dott. Stefano Gaffuri

L'Endodontic Course SIE 2016 in Lombardia si è svolto a Brescia presso Astidental SPA in via San Zeno 145, grazie alla preziosa collaborazione del Sig. Lorenzo Zelaschi che con grande ospitalità ha risolto ogni evenienza che durante il corso si è presentata.
Nel primo incontro, con la solita grande maestria ed esperienza, il Dr. Cavalli ha trattato il fondamentale tema della diagnosi in endodonzia, tema che stato completato per quanto riguarda la l'interpretazione più moderna dell'imaging diagnostico, dal Dr. Fornara grande esperto sull'utilizzo della CBCT in Endodonzia.
Nel secondo incontro, il Dr. Venturi ha trattato un tema importantissimo, molto spesso non considerato sufficientemente, eppure fondamento di ogni trattamento endodontico cioè l'utilizzo della diga di gomma.
A seguire il sottoscritto ha trattato il tema, altrettanto importante, della cavità d'accesso al sistema endodontico, sottolineando come spesso questa procedura se non correttamente eseguita, rappresenti l'anticamera dell'insuccesso.
A chiudere il secondo incontro, il Dr. Tonini che ha affrontato in chiave modernissima l'argomento della detersione, uno dei paradigmi della moderna endodonzia in grande fermento e ricco di grandi cambiamenti ed innovazioni.
Il terzo incontro, ha visto protagonista il Dr. Cecchinato che ha passato in rassegna i concetti basilari della moderna sagomatura meccanica.
La ditta Komet ha messo a disposizione dei partecipanti al corso, numerosi motori endodontici e strumenti per una prova pratica ricca di spunti.
Nel quarto incontro, è stata trattata dal Dr. Fassi l'importantissima fase dell'otturazione canalare realizzabile con tante tecniche diverse ma che hanno tutte ancora oggi in comune, l'utilizzo della guttaperca calda.
Le ditte Simit e Morita hanno messo a disposizione dei partecipanti al corso, numerosi motori endodontici e strumenti per le prove pratiche riservate ai corsisti.
Nel quinto incontro, il Dr. Tonini ha coinvolto tutti i partecipanti mostrando ai corsisti le modalità e le problematiche che si incontrano nella composizione dei casi da presentare alla Commissione SIE preposta, per essere accettati come Soci Attivi.
Ha concluso il quinto e penultimo incontro il bravissimo Dr. Coraini che con grande padronanza ed ampie conoscenze sull'argomento, ha parlato del sigillo coronale, fase conclusiva e garante nei confronti del trattamento endodontico, del successo a lungo termine.
Arrivederci a Roma in Novembre per l'ultimo incontro comune a tutti i partecipanti delle altre regioni, che verterà sull'Endodonzia Chirurgica.

I PARTECIPANTI

UN WORKSHOP

VITA SOCIETARIA

SIE ENDODONTIC COURSES 2016 – Sede di Genova

Corsi di formazione teorico/pratici della Società Italiana di Endodonzia

Dott.ssa Denise Pontoriero

Il 24 di Settembre si è conclusa l'avventura genovese del SIE ENDODONTIC COURSE 2016 .
Il corso, teorico pratico si è tenuto nell'attrezzata e comodissima aula manichini dell'Università degli Studi di Genova, concessaci grazie al professor Stefano Benedicenti, che è sempre disponibile a promuovere ed ospitare gli eventi SIE e che, di conseguenza, ringrazio personalmente.
Nella prima giornata abbiamo inaugurato il corso in presenza di tutti i soci attivi della Regione Liguria e la dottoressa Maria Teresa Sberna ha fornito ai 24 iscritti le basi per una corretta diagnosi endodontica in maniera approfondita e mai noiosa; successivamente il dott. Marco Bonelli ha parlato del ruolo importante della CBCT.
Nel pomeriggio il dott. Vaid Hazini ha trattato un argomento fondamentale: l'anatomia endodontica.
Nella seconda giornata il dottor Massimo Zerbinati ha parlato dell'importanza fondamentale dell'isolamento del campo operatorio con diga di gomma e delle tecniche per ottenerlo nel modo più semplice, tecniche che sono state messe in pratica durante l'"hands on" in cui i partecipanti sono stati guidati step by step dalle esperte mani dei soci attivi presenti: il dott. Andrea Cascone, il dott. Luca Ivaldi, il dott. Massimo Zerbinati, il dott. Vaid Hazini, la sottoscritta ed il dott. Andrea Polesel.
A lui si deve la bellissima relazione sull'apertura della camera pulpare, seguita dall'altrettanto importante ed interessante argomento, la detersione, di cui ha parlato il dott. Andrea Cascone.
Il terzo e quarto incontro sono stati dedicati alla sagomatura canalare e all'otturazione tridimensionale del sistema endodontico con le relazioni del dottori Andrea Polesel, Massimo Zerbinati e Vaid Hazini, sempre seguite dalla parte pratica con la possibilità da parte dei partecipanti di provare diversi strumenti e protocolli forniti dai numerosi sponsor di questo corso.
Nell'ultima giornata, oltre all'importante argomento riguardante la ricostruzione post endodontica, il dott. Andrea Polesel ha spiegato ai corsisti come si presenta un caso endodontico e quali sono le regole per diventare socio aggregato ed attivo della Sie e, con nostra grandissima soddisfazione, per quattro ore i corsisti hanno mostrato i loro casi, dando la possibilità a tutti di approfondire gli argomenti endodontici più disparati.
Il grande successo di questa nuova formula di formazione che la SIE ha messo a disposizione dei suoi soci è stata per noi il frutto di un grande lavoro di squadra, in un clima di armonia e collaborazione mai scontati.
Pronti per la Giornata Endodontica della SEL che si terrà il 10 Giugno 2017 a Genova. Ringrazio: per il supporto e la fiducia il dott. Pio Bertani, il dott. Vittorio Franco e il dott. Roberto Fornara; per il supporto tecnico e l'infinita pazienza la nostra insostituibile Segretaria Gaia Garlasché; per i consigli e l'aiuto concreto il mio predecessore dott. Andrea Polesel.

I PARTECIPANTI

I WORKSHOP

VITA SOCIETARIA

SIE ENDODONTIC COURSES 2016 – Sede di Roma

Corsi di formazione teorico/pratici della Società Italiana di Endodonzia

Dott.ssa Emanuela Faitelli

Questo è il reportage fotografico dell'Endodontic Course SER.
Ringrazio in particolare il dott. Malentacca per la inesauribile disponibilità, tutti i relatori che hanno messo a disposizione il loro sapere, tutti i partecipanti assolutamente attenti e desiderosi di imparare, gli sponsor e la dott.ssa Campo e il dott. Schianchi per il sostegno e l'aiuto.

I WORKSHOP

ALCUNI PARTECIPANTI

UNA RELAZIONE

GIORNALE ITALIANO DI ENDODONZIA

INSTRUCTION AUTHOR

CONTENT OF AUTHOR GUIDELINES:

The journal to which you are submitting your manuscript employs a plagiarism detection system. By submitting your manuscript to this journal you accept that your manuscript may be screened for plagiarism against previously published works.

1. GENERAL

Giornale Italiano di Endodonzia publishes original scientific articles, reviews, clinical articles and case reports in the field of Endodontology. Scientific contributions dealing with health, injuries to and diseases of the pulp and periradicular region, and their relationship with systemic well-being and health. Original scientific articles are published in the areas of biomedical science, applied materials science, bioengineering, epidemiology and social science relevant to endodontic disease and its management, and to the restoration of root-treated teeth. In addition, review articles, reports of clinical cases, book reviews, summaries and abstracts of scientific meetings and news items are accepted.

Please read the instructions below carefully for details on the submission of manuscripts, the journal's requirements and standards as well as information concerning the procedure after a manuscript has been accepted for publication in *Giornale Italiano di Endodonzia*. Authors are encouraged to visit GIE web site **gi-endodonzia.com** for further information on the preparation and submission of articles and figures.

2. ETHICAL GUIDELINES

Giornale Italiano di Endodonzia adheres to the below ethical guidelines for publication and research.

2.1. Authorship and Acknowledgements

Authors submitting a paper do so on the understanding that the manuscript has been read and approved by all authors and that all authors agree to the submission of the manuscript to the *Giornale Italiano di Endodonzia*.

Giornale Italiano di Endodonzia adheres to the definition of authorship set up by The International Committee of Medical Journal Editors (ICMJE). According to the ICMJE, authorship criteria should be based on 1) substantial contributions to conception and design of, or acquisiation of data or analysis and interpretation of data, 2) drafting the article or revising it critically for important intellectual content and 3) final approval of the version to be published. Authors should meet conditions 1, 2 and 3.

It is a requirement that all authors have been accredited as appropriate upon submission of the manuscript. Contributors who do not qualify as authors should be mentioned under Acknowledgements.

Acknowledgements:
Under acknowledgements please specify contributors to the article other than the authors accredited. Please also include specifications of the source of funding for the study and any potential conflict of interests if appropriate.

2.2. Ethical Approvals

Experimentation involving human subjects will only be published if such research has been conducted in full accordance with ethical principles, including the World Medical Association Declaration of Helsinki (version 2008) and the additional requirements, if any, of the country where the research has been carried out.

Manuscripts must be accompanied by a statement that the experiments were undertaken with the understanding and written consent of each subject and according to the above mentioned principles. A statement regarding the fact that the study has been independently reviewed and approved by an ethical board should also be included. Editors reserve the right to reject papers if there are doubts as to whether appropriate procedures have been used.

When experimental animals are used the methods section must clearly indicate that adequate measures were taken to minimize pain or discomfort. Experiments should be carried out in accordance with the Guidelines laid down by the National Institute of Health (NIH) in the USA regarding the care and use of animals for experimental procedures or with the European Communities Council Directive of 24 November 1986 (86/609/EEC) and in accordance with local laws and regulations.

All studies using human or animal subjects should include an explicit statement in the Material and Methods section identifying the review and ethics committee approval for each study, if applicable. Editors reserve the right to reject papers if there is doubt as to whether appropriate procedures have been used.

2.3 Clinical Trials

Clinical trials should be reported using the guidelines available at www.consort-statement.org.
A CONSORT checklist and flow diagram (as a Figure) should also be included in the submission material.

The *Giornale Italiano di Endodonzia* encourages authors submitting manuscripts reporting from a clinical trial to register the trials in any of the following free, public clinical trials registries: www.clinicaltrials.gov, http://clinicaltrials.ifpma.org/clinicaltrials/, http://isrctn.org/. The clinical trial registration number and name of the trial register will then be published with the paper.

2.4 Systematic Reviews

Systematic reviews should be reported using the PRISMA guidelines available at http://prisma-statement.org/. A PRISMA checklist and flow diagram (as a Figure) should also be included in the submission material.

2.5 Conflict of Interest and Source of Funding

Giornale Italiano di Endodonzia requires that all sources of institutional, private and corporate financial support for the work within the manuscript must be fully acknowledged, and any potential conflicts of interest noted. Grant or contribution numbers may be acknowledged, and principal grant holders should be listed. Please include the information under Acknowledgements.

2.6 Appeal of Decision

The decision on a paper is final and cannot be appealed.

2.7 Permissions

If all or parts of previously published illustrations are used, permission must be obtained from the copyright holder concerned. It is the author's responsibility to obtain these in writing and provide copies to the Publishers.

3. MANUSCRIPT SUBMISSION PROCEDURE

Manuscripts should be submitted electronically by e-mail:
editor.giornale@endodonzia.it

3.1. Manuscript Files Accepted

Manuscripts should be uploaded as Word (.doc) or Rich Text Format (.rft) files (not write-protected) plus separate figure files. GIF, JPEG, PICT or Bitmap files are acceptable for submission, but only high-resolution TIF or EPS files are suitable for printing.

The text file must contain the abstract, main text, references, tables, and figure legends, but no embedded figures or Title page. The Title page should be provided as a separate file.
In the main text, please reference figures as for instance 'Figure 1', 'Figure 2' etc to match the tag name you choose for the individual figure files uploaded. Manuscripts should be formatted as described in the Author Guidelines below.

3.2. Blinded Review

Manuscript that do not conform to the general aims and scope of the journal will be returned immediately without review.
All other manuscripts will be reviewed by experts in the field (generally two referees).
Giornale Italiano di Endodonzia aims to forward referees´ comments and to inform the corresponding author of the result of the review process.

Manuscripts will be considered for fast-track publication under special circumstances after consultation with the Editor.

Giornale Italiano di Endodonzia uses double blinded review. The names of the reviewers will thus not be disclosed to the author submitting a paper and the name(s) of the author(s) will not be disclosed to the reviewers.

To allow double blinded review, please submit your main manuscript and title page as separate files.

3.3. E-mail Confirmation of Submission

After submission you will receive an e-mail to confirm receipt of your man-

uscript. If you do not receive the confirmation e-mail after 24 hours, please send an e-mail once again to editor.giornale@endodonzia.it or contact segreteria.sie@me.com.

3.4. Submission of Revised Manuscripts

All the revised manuscripts will be sent to the author; to submit a revised masucript please re-contact the e-mail address of the journal: editor.giornale@endodonzia.it.

4. MANUSCRIPT TYPES ACCEPTED

Original Scientific Articles: must describe significant and original experimental observations and provide sufficient detail so that the observations can be critically evaluated and, if necessary, repeated. Original Scientific Articles must conform to the highest international standards in the field.

Review Articles: are accepted for their broad general interest; all are refereed by experts in the field who are asked to comment on issues such as timeliness, general interest and balanced treatment of controversies, as well as on scientific accuracy. Reviews should generally include a clearly defined search strategy and take a broad view of the field rather than merely summarizing the authors´ own previous work. Extensive or unbalanced citation of the authors´ own publications is discouraged.

Mini Review Articles: are accepted to address current evidence on well-defined clinical, research or methodological topics. All are refereed by experts in the field who are asked to comment on timeliness, general interest, balanced treatment of controversies, and scientific rigor. A clear research question, search strategy and balanced synthesis of the evidence is expected. Manuscripts are limited in terms of word-length and number of figures.

Clinical Articles: are suited to describe significant improvements in clinical practice such as the report of a novel technique, a breakthrough in technology or practical approaches to recognised clinical challenges. They should conform to the highest scientific and clinical practice standards.

Case Reports: illustrating unusual and clinically relevant observations are acceptable but they must be of sufficiently high quality to be considered worthy of publication in the Journal. On rare occasions, completed cases displaying non-obvious solutions to significant clinical challenges will be considered. Illustrative material must be of the highest quality and healing outcomes, if appropriate, should be demonstrated.

5. MANUSCRIPT FORMAT AND STRUCTURE

5.1. Format

Language: The language of publication is English. It is preferred that manuscript is professionally edited. All services are paid for and arranged by the author, and use of one of these services does not guarantee acceptance or preference for publication

Presentation: Authors should pay special attention to the presentation of their research findings or clinical reports so that they may be communicated clearly. Technical jargon should be avoided as much as possible and clearly explained where its use is unavoidable. Abbreviations should also be kept to a minimum, particularly those that are not standard. The background and hypotheses underlying the study, as well as its main conclusions, should be clearly explained. Titles and abstracts especially should be written in language that will be readily intelligible to any scientist.

Abbreviations: Giornale Italiano di Endodonzia adheres to the conventions outlined in Units, Symbols and Abbreviations: A Guide for Medical and Scientific Editors and Authors. When non-standard terms appearing 3 or more times in the manuscript are to be abbreviated, they should be written out completely in the text when first used with the abbreviation in parenthesis.

5.2. Structure

All manuscripts submitted to Giornale Italiano di Endodonzia should include Title Page, Abstract, Main Text, References and Acknowledgements, Tables, Figures and Figure Legends as appropriate

Title Page: The title page should bear: (i) Title, which should be concise as well as descriptive; (ii) Initial(s) and last (family) name of each author; (iii) Name and address of department, hospital or institution to which work should be attributed; (iv) Running title (no more than 30 letters and spaces); (v) No more than six keywords (in alphabetical order); (vi) Name, full postal address, telephone, fax number and e-mail address of author responsible for correspondence.

Abstract for Original Scientific Articles should be no more than 250 words giving details of what was done using the following structure:

- **Aim:** Give a clear statement of the main aim of the study and the main hypothesis tested, if any.
- **Methodology:** Describe the methods adopted including, as appropriate, the design of the study, the setting, entry requirements for subjects, use of materials, outcome measures and statistical tests.
- **Results:** Give the main results of the study, including the outcome of any statistical analysis.
- **Conclusions:** State the primary conclusions of the study and their implications. Suggest areas for further research, if appropriate.

Abstract for Review Articles should be non-structured of no more than 250 words giving details of what was done including the literature search strategy.

Abstract for Mini Review Articles should be non-structured of no more than 250 words, including a clear research question, details of the literature search strategy and clear conclusions.

Abstract for Case Reports should be no more than 250 words using the following structure:

- **Aim:** Give a clear statement of the main aim of the report and the clinical problem which is addressed.
- **Summary:** Describe the methods adopted including, as appropriate, the design of the study, the setting, entry requirements for subjects, use of materials, outcome measures and analysis if any.
- **Key learning points:** Provide up to 5 short, bullet-pointed statements to highlight the key messages of the report. All points must be fully justified by material presented in the report.

Abstract for Clinical Articles should be no more than 250 words using the following structure:

- **Aim:** Give a clear statement of the main aim of the report and the clinical problem which is addressed.
- **Methodology:** Describe the methods adopted.
- **Results:** Give the main results of the study.
- **Conclusions:** State the primary conclusions of the study.

Main Text of Original Scientific Article should include Introduction, Materials and Methods, Results, Discussion and Conclusion.

Introduction: should be focused, outlining the historical or logical origins of the study and gaps in knowledge. Exhaustive literature reviews are not appropriate. It should close with the explicit statement of the specific aims of the investigation, or hypothesis to be tested.

Material and Methods: must contain sufficient detail such that, in combination with the references cited, all clinical trials and experiments reported can be fully reproduced.

(i) Clinical Trials should be reported using the CONSORT guidelines available at www.consort-statement.org. A CONSORT checklist and flow diagram (as a Figure) should also be included in the submission material.

(ii) Experimental Subjects: experimentation involving human subjects will only be published if such research has been conducted in full accordance with ethical principles, including the World Medical Association Declaration of Helsinki (version 2008) and the additional requirements, if any, of the country where the research has been carried out. Manuscripts must be accompanied by a statement that the experiments were undertaken with the understanding and written consent of each subject and according to the above mentioned principles. A statement regarding the fact that the study has been independently reviewed and approved by an ethical board should also be included. Editors reserve the right to reject papers if there are doubts as to whether appropriate procedures have been used.

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All studies using human or animal subjects should include an explicit statement in the Material and Methods section identifying the review and ethics committee approval for each study, if applicable.
Editors reserve the right to reject papers if there is doubt as to whether appropriate procedures have been used.

(iii) Suppliers: Suppliers of materials should be named and their location (Company, town/city, state, country) included.

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Corporate author
British Endodontic Society - Guidelines for root canal treatment. Giornale Italiano di Endodonzia 1979 ; 16: 192-5.

Journal supplement
Frumin AM, Nussbaum J, Esposito M () Functional asplenia: demonstration of splenic activity by bone marrow scan (Abstract). Blood 1979; 54 (Suppl. 1): 26a.

Books and other monographs

Personal author(s)
Gutmann J, Harrison JW Surgical Endodontics, 1st edn Boston, MA, USA: Blackwell Scientific Publications, 1991.

Chapter in a book
Wesselink P Conventional root-canal therapy III: root filling. In: Harty FJ, ed. Endodontics in Clinical Practice, (1990) , 3rd edn; pp. 186-223. London, UK: Butterworth.

Published proceedings paper
DuPont B Bone marrow transplantation in severe combined immunodeficiency with an unrelated MLC compatible donor. In: White HJ, Smith R, eds. Proceedings of the Third Annual Meeting of the International Society for Experimental Rematology; (1974), pp. 44-46. Houston, TX, USA: International Society for Experimental Hematology.

Agency publication
Ranofsky AL Surgical Operations in Short-Stay Hospitals: United States-1975 (1978). DHEW publication no. (PHS) 78-1785 (Vital and Health Statistics; Series 13; no. 34.) Hyattsville, MD, USA: National Centre for Health Statistics.8

Dissertation or thesis
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