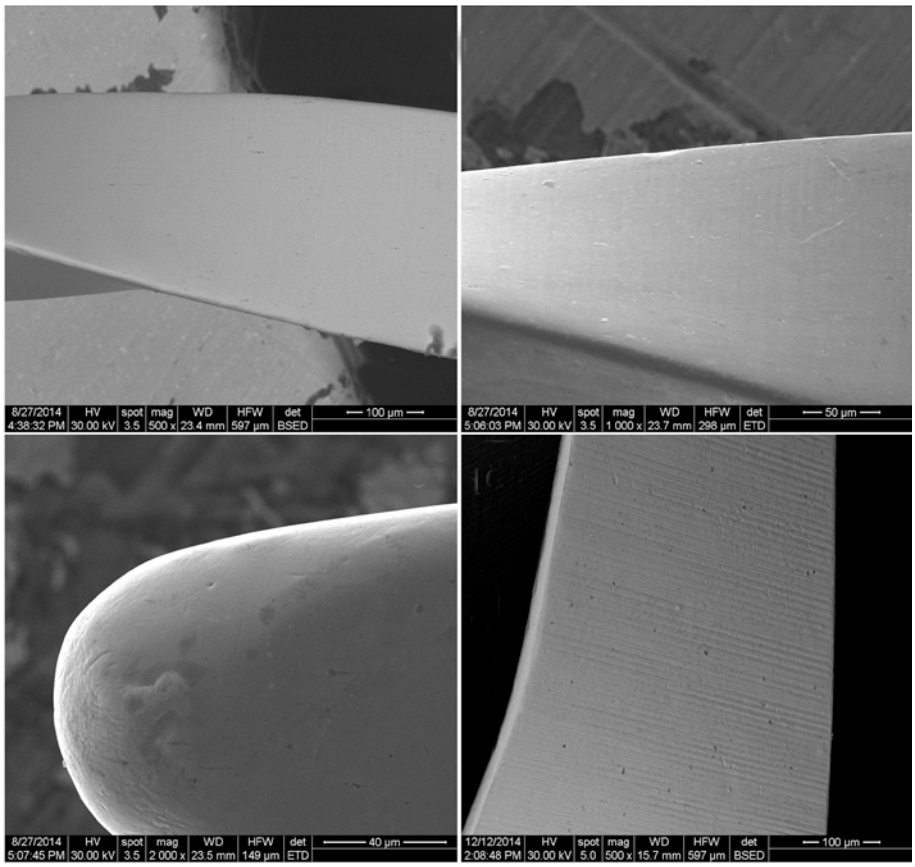
ISSN 1121-4171

November 2019 | 2 | Vol. 33

GIORNALE ITALIANO DI ENDODONZIA



Società Italiana di Endodonzia

ARIES DUE

sweden & martina


F22ALIGNER
BIOLOGIC TEETH ALIGNER
TALMENTE INVISIBILE
CHE VE LO POSSIAMO
SOLO SPIEGARE.
I risultati si vedono,
F22 Aligner no.
sweden & martina

GIORNALE ITALIANO DI ENDODONZIA
Organo Ufficiale della SIE – Società Italiana di Endodonzia

EDITORIAL BOARD

WE KNOW ENDO.

MAILLEFER

TruNatomy™

Ridefinisce il trattamento del canale radicolare

- Più spazio per lo sbrigliamento e l'estrazione dei detriti
- Rispetto dell'anatomia naturale
- Mantenimento dell'integrità degli elementi dentali, favorendo un'adeguata irrigazione, disinfezione ed otturazione.

Per un'esperienza davvero fluida, controllata ed efficiente.


TruNatomy™ Orifice Modifier


TruNatomy™ Glider


TruNatomy™ Prime


TruNatomy™ Prime Absorbent Points


TruNatomy™ Conform Fit Gutta-Percha Points


TruNatomy™ Irrigation Needle

Per saperne di più visita il sito www.simitdental.it
o contatta Simit Next al numero 0376.267811

36° CONGRESSO NAZIONALE SIE - Bologna 7-9 Novembre 2019
Vieni a scoprire le novità presso lo stand SIMIT NEXT

Dentsply Sirona | Simit® NEXT
Endodonzia & Conservativa

GAMMA DI SISTEMI INGRANDENTI

EYE ZOOM™

EYE ZOOM™

NEW

EYE ZOOM MINI™

NON CREDERAI AI TUOI OCCHI!

I PRIMI SISTEMI INGRANDENTI **BREVETTATI** CHE RACCHIUDONO

MOLTEPLICI INGRANDIMENTI IN UN UNICO OCCHIALE!

Per saperne di più visita il sito www.simitdental.it o contatta Simit Dental al numero 0376.267811

ORASCOPTIC™

SIMIT DENTAL

SIE - Società Italiana di Endodonzia
Legal Head Office:
Viale Conti di Tuscolo 14
00044 Frascati (RM)
Headquarters:
Via Pietro Custodi, 3
20136 Milano
Contacts:
Tel. 02.8376799 | ***Fax.*** 02.89424876
segreteria.sie@me.com
info@endodonzia.it
PEC: *segreteria.sie@pec.segreteriasie.it*
Site: www.endodonzia.it
www.giornaleitalianoendodonzia.it

EDITORIAL OFFICE

Gaia Garlaschè
editor.giornale@endodonzia.it

Editorial Director
Filippo Cardinali

PUBLISHING ARIESDUE

Managing Director
Sergio Porro

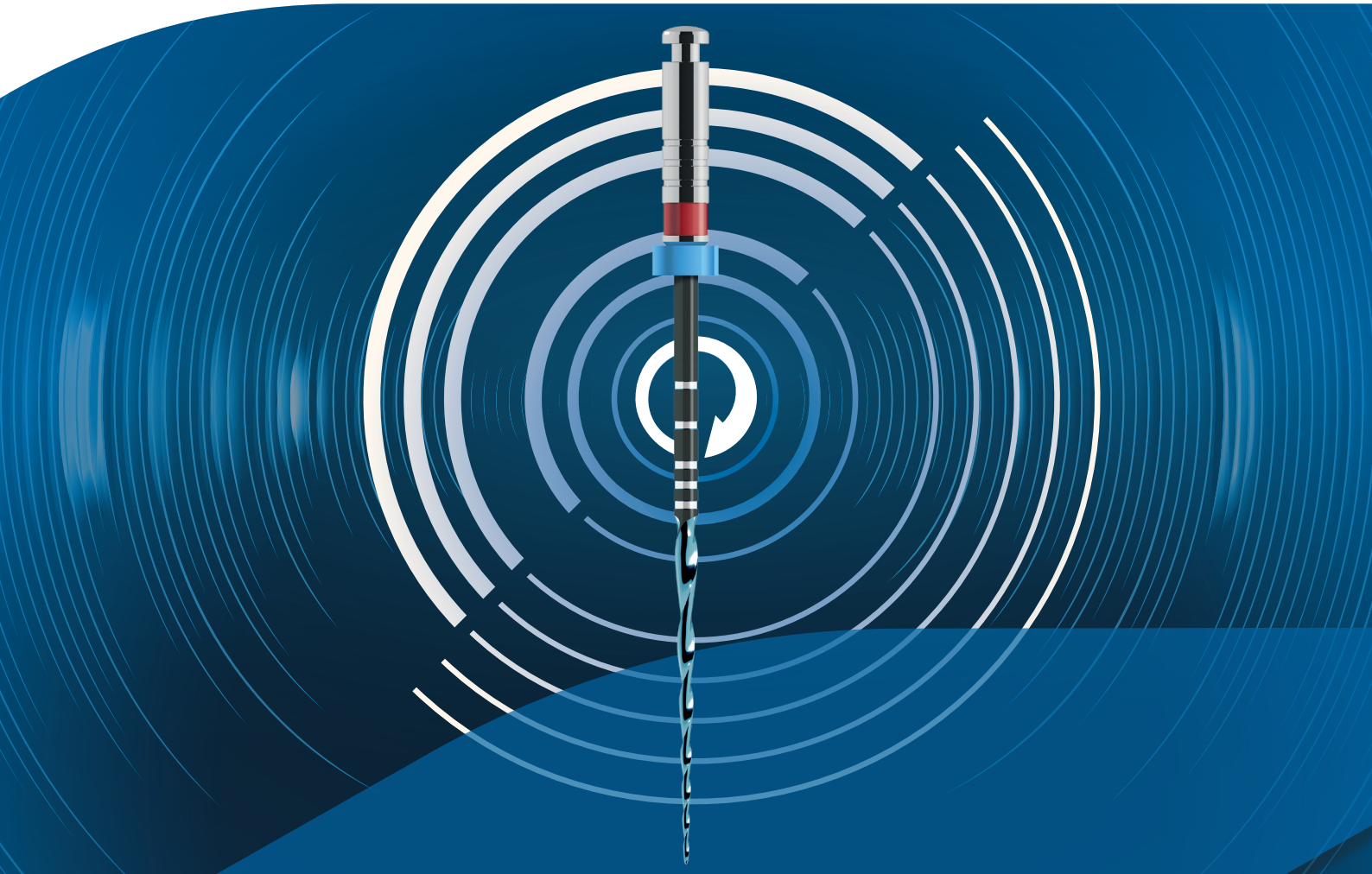
Publishing Support
Stefania Garancini
stefania.garancini@ariesdue.it

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 on ScienceDirect and www.giornaleitalianoendodonzia.it. Giornale Italiano di Endodonzia is an Open Access Journal.*

REGISTRATION Court of Milan n° 89, 3 March 2009

Table OF CONTENTS

VDW®
Endo
Easy
Efficient



VDW.ROTATE™
Sistema endodontico rotante in NiTi

Migliora la qualità delle preparazioni con sistematica rotante

VERSATILITÀ

Sequenza base di soli 3 strumenti, file accessori per creare la tua procedura preferita.

Sii virtuoso!

RISPETTO DELL'ANATOMIA CANALARE

Trattamento termico specifico: elevata flessibilità e efficienza di taglio.*

Rispetta il canale!

EFFICACE RIMOZIONE DEI DETRITI

Sezione trasversale a forma di S decentrata: maggior spazio per la rimozione dei detriti e perfetto controllo per preparazioni veloci, complete e sicure.*, **

Controlla il ritmo!

* confrontato con altri sistemi rotanti VDW
** confrontato con strumenti rotanti a sezione centrata

www.dentsplysirona.com

VDW®

Endo
Easy
Efficient

EDDY®
Sistema innovativo per l'Irrigazione Sonica

Tre benefici in un'unica soluzione

Il potere sonico di EDDY® e il movimento di oscillazione tridimensionale della punta si sono dimostrati efficaci nell'attivazione degli irriganti quanto i sistemi ad ultrasuoni e migliori rispetto all'irrigazione manuale per la rimozione di detriti e dello smear layer.* La punta EDDY® in poliammide è più sicura e flessibile rispetto alle punte in metallo, senza rischi di danneggiamento della dentina.

Prova i benefici clinicamente testati di EDDY® nella tua pratica quotidiana.

Sicuro

Efficace

Clinicamente testato

*Source: Neuhaus, Klaus W, Liebi, Melanie, et. al. Antibacterial Efficacy of a New Sonic Irrigation Device for Root Canal Disinfection. *Journal of Endodontics 2016, 42 (12): 1799-1803.*

www.dentsplysirona.com

Società Italiana di Endodonzia

BOLOGNA, 7-9 NOVEMBRE 2019

36° CONGRESSO NAZIONALE SIE

Palazzo della Cultura e dei Congressi - Piazza della Costituzione, 4/A - 40128 Bologna

Moderna Endodonzia
tra tecnologia ed esperienza

Programma

GIOVEDÌ 7 NOVEMBRE, 14.30 - 18.00

CORSO PRE-CONGRESSO "Trattamento e prognosi a lungo termine dei traumi dentali"
Lorenzo Vanini, Claudio Pisacane

VENERDÌ 8 NOVEMBRE, 8.45 - 19.00

8.45 › **Apertura Lavori e Saluto delle Autorità**

Sessione I

PRESIDENTI DI SESSIONE: Vittorio Franco, Vasilios Kaitsas

9.30 › **Passato presente e futuro in Endodonzia: evoluzione di un'arte e di una tecnica verso una clinica più predicibile** › Carlo Prati

10.15 › **Considerazioni sul recupero a lungo termine di elementi gravemente compromessi in cui è stato utilizzato MTA** › Fabio Gorni

Sessione II

PRESIDENTI DI SESSIONE: Elio Berutti, Francesco Mangani

11.30 › **Innovazioni tecnologiche per una nuova Endodonzia: si puo' chiedere ancora di più?** › Maria Teresa Sberna

12.00 › **Endodonzia digitale: applicazioni cliniche** › Gianluca Gambarini

12.30 › **Moderno approccio all'accesso al sistema canalare: oltre le ninja access** › Alberto Mazzocco

13.00 › **Il riaccesso nel ritrattamento ortogrado** › Enrico Cassai

Sessione III
MASTER CLINICIAN SESSION SPONSORIZZATE

PRESIDENTI DI SESSIONE: Pio Bertani, Katia Greco

14.30-16.30 › **SWEDEN & MARTINA | DENTSPLY SIRONA ITALIA**

SESSIONE FINALE
PREMIO RICCARDO GARBEROGLIO

SESSIONE FINALE
PREMIO GIORGIO LAVAGNOLI

SESSIONE FINALE
PREMIO FRANCESCO RIITANO

11.30-13.30 › **SESSIONE POSTER AFFISSIONI CARTACEE**

14.30-16.30 › **SESSIONE FINALE PREMIO "MIGLIOR POSTER SIE"**

17.00-19.00 › **TEATRI CLINICI**

SABATO 9 NOVEMBRE, 9.00 - 14.00

Sessione V

PRESIDENTI DI SESSIONE: Francesco Riccitiello

9.00 › **Endodonzia Pediatrica: esperienza e/o tecnologia?** › Maurizio Bossù

9.30 › **La dinamica nascosta del Ni-Ti: evidenza e gestione clinica ragionata** › Italo Di Giuseppe

10.00 › **Endodonzia tra nuove tecnologie ed anatomie nascoste** › Giovanni Olivi

10.30 › **Decision making nella fase di otturazione canalare: risultati a distanza** › Franco Ongaro

Sessione VI

PRESIDENTI DI SESSIONE: Mario Badino, Stefano Salgarello

11.30 › **Canali "calcificati": suggerimenti clinici** › Vito Antonio Malagnino

12.00 › **Endodonzia Chirurgica... sotto la lente** › Mauro Rigolone

12.30 › **La gestione e risoluzione dei casi endodontici complessi in età avanzata. Aspetti clinico-pratici** › Andrea Polesel

13.00 › **Quali paradigmi per una migliore prognosi del dente trattato endodonticamente** › Umberto Uccioli

SESSIONE DI RICERCA LIBERA - PARTE I

PRESIDENTI DI SESSIONE: Abdol Hamid Hazini, Denise Irene Karin Pontoriero

SESSIONE DI RICERCA LIBERA - PARTE II

PRESIDENTI DI SESSIONE: Massimo Calapaj, Alfio Pappalardo

13.30 › **Premiazioni VINCITORI DELLE SESSIONI FINALI DEI PREMI SIE: Premio Riccardo Garberoglio - Premio Giorgio Lavagnoli - Premio Francesco Riitano - Premio Miglior Poster... e Contest Fotografici**

14.00 › **Chiusura Lavori e Saluto del Presidente**

www.endodonzia.it

Editorial *Editoriale*

Sandro Rengo
Editor-in-Chief
Giornale Italiano
di Endodonzia
E-mail address:
editor.giornale@endodonzia.it

Nell'ambito del 36° Congresso Nazionale della Società Italiana di Endodonzia (SIE), che si terrà a Bologna dal 7 al 9 novembre 2019, si parlerà di **Moderna Endodonzia tra tecnologia ed esperienza**, con una serie di interventi e presentazioni che tratteranno le più recenti evoluzioni del flusso di lavoro digitale applicato all'Endodonzia.

A seguito della crescente digitalizzazione che si sta verificando in molti ambiti dell'Odontoiatria restaurativa, le tecnologie digitali hanno iniziato a essere applicate su ampia scala anche in Endodonzia.

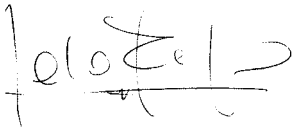
Benché le principali indicazioni cliniche riguardino la diagnosi e l'acquisizione di informazioni radiografiche tridimensionali per mezzo di CBCT, più recentemente sono state mutuate dalla Protesi e dall'Implantologia le tecniche di sovrapposizione virtuale delle scansioni ottenute intraoralmente dalle impronte ottiche (sistemi IOS) e dei set radiologici tridimensionali derivanti dalla CBCT.

Tale approccio consente, oggi, di pianificare anticipatamente un accesso endodontico micro-guidato per mezzo di mascherine prodotte con tecnologie di stampa 3D, particolarmente utili nel caso di canali sclerotici o obliterati o nei casi da trattare per mezzo di Endodonzia micro-chirurgica.

Queste innovazioni esitano in trattamenti sempre più conservativi che permettono di ottenere standardizzazione di qualità e controllo di precisione delle differenti fasi operative, migliorando di conseguenza il comfort e la compliance dei pazienti.

Il flusso di lavoro digitale, ormai routinario nella pratica clinica specialistica, ha semplificato l'approccio clinico anche ai trattamenti complessi, dove un intervento multidisciplinare rappresenta spesso la chiave per il successo a lungo termine.

Vi attendiamo numerosi al 36° Congresso Nazionale della SIE per affrontare gli aspetti scientifici e clinici del flusso di lavoro digitale in Endodonzia.



Peer review under responsibility of Società Italiana di Endodonzia.

10.32067/GIE.2019.33.02.07

Editorial *Editoriale*

During the 36th National Congress of the Italian Society of Endodontics (SIE) to be held in Bologna from 7th to 9th of November 2019, we will talk about ***"Modern Endodontics between technology and experience"****, with a series of discussions and lectures about the most recent developments in the digital workflow applied to Endodontics.*

Following the increasing digitization occurring in many branches of restorative Dentistry, digital technologies have begun to be applied widely also in Endodontics.

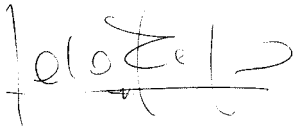
Although the main clinical indications deal with the diagnosis and the acquisition of 3D radiographic information by means of CBCT, more recently the techniques of virtual superimposition of the scans obtained intraorally by optical impressions (IOS systems) and 3D radiological datasets deriving form CBCT were borrowed from Prosthodontics and Implantology.

Today this approach allows to plan in advance micro-guided endodontic accesses by means of templates produced with 3D printing techniques, particularly useful in the case of sclerotic or obliterated root canals or in cases to be treated with micro-surgical Endodontics.

Such innovations result in more conservative treatments that allow to achieve quality standardization and precision control of the different operative steps, thereby improving patients' comfort and compliance.

The digital workflow, nowadays used routinely in specialized daily practice, simplified the clinical approach even in complex treatments, where a multidisciplinary approach is often the key in long-term clinical success.

We look forward to seeing you at the 36th National Congress of SIE to discuss the scientific and clinical aspects of the digital workflow in Endodontics.



Peer review under responsibility of Società Italiana di Endodonzia.

10.32067/GIE.2019.33.02.07

Thinking ahead. Focused on life.

MORITA

Tri Auto ZX2: Semplice, geniale e assolutamente sicuro. Perfetto per qualsiasi canale radicolare.

Il nuovo Tri Auto ZX2 semplifica il trattamento canalare con la massima sicurezza – perfetto per tutti i tuoi pazienti.
Il manipolo con localizzatore apicale integrato è veramente sorprendente per la sua leggerezza: Senza cavo ed ergonomico si adatta perfettamente alla mano e garantisce massima libertà di movimento Il trattamento è sicuro e facile grazie alle nuove funzioni di sicurezza, quali l' Optimum Glide Path (OGP) e l'Optimum Torque Reverse (OTR). L'OPG semplifica la realizzazione del glide path. L'OTR protegge dalla rottura del file e dalle microfratture invertendo automaticamente la direzione di rotazione quando viene superato il livello di torque. In questo modo, Tri Auto ZX2 preserva la sostanza del dente naturale e rende il trattamento ancora più efficiente. Per ulteriori informazioni, vedere **www.jmoritaitalia.com**

GERMAN DESIGN AWARD SPECIAL 2019

REVIEW ARTICLE/**REVIEW**

Current Applications of Lasers in Endodontics

Applicazioni del Laser in Endodonzia

KEYWORDS
Endodontics, Laser Applications, Pulp, Root Canal System, Disinfection

PAROLE CHIAVE
Endodonzia, applicazioni del laser, polpa, sistema canalare, disinfezione

Maryam Kuzekanani[1], Gianluca Plotino[2*], James Leo Gutmann[3]

[1]Department of Endodontics, Kerman Dental School, Kerman University of Medical Sciences and Health Services. Kerman, Iran.
[2]Private practice, Rome, Italy.
[3]Professor Emeritus, Texas A&M University College of Dentistry, Dallas, Texas.

Received 2019, March 17

Accepted 2019, May 10

Abstract

The use of lasers within the scope of endodontic practice and research has increased significantly in the past few years. Lasers are generally classified according to their physical constructions and special wavelengths, which have impacts on their enhanced clinical usage. Lasers according to their physical constructions are divided into three groups. The first type is the solid state laser, so named because the medium, undergoing lasing, is in a solid form. Ruby laser is the prototype of all solid state lasers. By forming crystalline materials that are doped with rare earth elements a wide range of solid state lasers can be produced. Some of the most common types of solid state lasers use the YAG (Yttrium Aluminium Garnet) crystal (Holmium:YAG, Thulium:YAG Neodymium:YAG and Erbium:YAG) and the YSGG (Yttrium Scandium Gallium Garnet) crystal (Er,Cr:YSGG) as their base. The second major family of lasers are the gas lasers. In this group the lasing material that is ionized can be Argon gas, Carbon dioxide gas, Nitrogen gas or a Helium-Neon (He:Ne) gas mixture. The third family of lasers are the Diode lasers, which produce wavelengths in the visible spectrum. The most frequently used lasers in endodontics are: Neodymium:YAG (Nd:YAG), Diode Laser, Erbium:YAG (Er:YAG), Erbium Chromium:YSGG (Er,Cr:YSGG) and He:Ne laser. This paper reviews the most common applications of lasers in endodontics that include Laser Doppler Flowmetry (LDF), treatment of dentinal hypersensitivity, pulpotomy and pulp capping and root canal disinfection through laser activated irrigation and photo-activated root canal disinfection (PAD).

L'uso dei laser nell'ambito della pratica e della ricerca endodontica è aumentato significativamente negli ultimi anni. I laser sono generalmente classificati in base alla loro costruzione fisica e alle lunghezze d'onda utilizzate che hanno avuto un impatto importante sul miglioramento del loro utilizzo clinico. I laser, in base alle loro caratteristiche fisiche, sono divisi in tre gruppi. Il primo tipo è il laser a stato solido, così chiamato perché il mezzo sottoposto a lasing è in una forma solida; il laser a rubino è il prototipo di tutti quelli allo stato solido: formando materiali cristallini che sono drogati con elementi di terre rare si può produrre una vasta gamma di laser a stato solido. Alcuni dei tipi più comuni di laser a stato solido utilizzano il cristallo YAG (Yttrium Aluminum Garnet) (Holmium:YAG, Thulium:YAG Neodymium:YAG and Erbium:YAG) e il cristallo YSGG (Yttrium Scandium Gallio Granato) (Er, Cr: YSGG) come base. La seconda grande famiglia sono i laser a gas: in questo gruppo il materiale lasing che è ionizzato può essere gas Argon, gas di anidride carbonica, gas azoto o una miscela di gas Elio-Neon (He:Ne). La terza famiglia sono i laser a diodi, che producono lunghezze d'onda nello spettro visibile. I laser più frequentemente utilizzati in endodonzia sono: Neodimio:YAG (Nd:YAG), Laser a diodi, Erbio:YAG (Er: YAG), Erbio Cromo:YSGG (Er,Cr:YSGG) e He:Ne laser.
Questo articolo si propone di esaminare le più comuni applicazioni del laser in endodonzia che includono la flussimetria laser doppler Flowmetry, il trattamento dell'ipersensibilità dentinale, la pulpectomia e l'incappucciamento della polpa e la disinfezione del canale radicolare mediante irrigazione attivata mediante laser e disinfezione canalare fotoattivata (PAD).

Introduction

In the past three decades, several important researches have attempted to find and apply new technologies to improve endodontic treatments. Among these investigations studies on lasers with different wavelengths have been of great importance. Light Amplification by Stimulated Emission of Radiation (LASER) uses amplified lights to remove or treat soft and hard tissues in oral cavity. Lasers are generally classified according to their physical constructions and special

Corresponding author
Gianluca Plotino | Via Calabria, 25 00187 Rome Italy | endo@gianlucaplotino.com

Peer review under responsibility of Società Italiana di Endodonzia
10.32067/GIE.2019.33.02.01

wavelengths, which have impacts on their enhanced clinical usage. Lasers according to their physical constructions are divided into three groups. The first type is the solid-state laser, so named because the medium, undergoing lasing, is in a solid form. Ruby laser is the prototype of all solid-state lasers: by forming crystalline materials, which are doped with rare earth elements, a wide range of solid-state lasers can be produced. Some of the most common types of solid state lasers use the YAG (Yttrium Aluminium Garnet) crystal (Holmium:YAG, Thulium:YAG Neodymium:YAG and Erbium:YAG) and the YSGG (Yttrium Scandium Gallium Garnet) crystal (Er,Cr:YSGG) as their base. The second major family of lasers are the gas lasers. In this group the lasing material ionized can be Argon gas, Carbon dioxide gas, Nitrogen gas or a Helium-Neon (He:Ne) gas mixture. The third family of lasers are the Diode lasers, which produce wavelengths in the visible spectrum.

The laser amplified focused light energy has the potential to interact with the biological dental tissues and structures in order to penetrate the surface of the tooth and access to the pulp cavity, clean, disinfect and shape the root canal system and finally help to fill it in three dimensions. The most frequently used lasers in endodontics are: Neodymium:YAG (Nd:YAG), Diode Laser, Erbium:YAG (Er:YAG), Erbium Chromium:YSGG (Er,Cr:YSGG) and He:Ne laser.

A position paper from the American Association of Endodontists states that the application of lasers to disinfect the root canal is more promising than in instrumentation and shaping of it (1).

This paper aims to review the most common applications of lasers in endodontics that include Laser Doppler Flowmetry (LDF), treatment of dentinal hypersensitivity, pulpotomy and pulp capping and root canal disinfection through laser activated irrigation and photo-activated root canal disinfection (PAD).

Laser Doppler Flowmetry (LDF)

This technology was first developed to assess blood flow in microvascular systems such as the retina or skin. It was adapted by Gazelius and Olgaret in 1986 for use on human teeth in order to measure pulpal blood flow (2). This diagnostic tool was especially deemed appropriate to determine pulpal vitality (blood flow) subsequent to tooth trauma when traditional clinical findings were inconclusive. In this technique laser light is scattered by moving blood cells and undergoes a frequency shift according to the Doppler principle. The light is detected and processed to produce a signal that shows the function of the red cell flux (volume of cells X cell velocity) (3). In an additional contemporary application it may become useful in detecting revascularization much earlier than standard sensitivity tests (4). Furthermore it may be useful in detecting transient ischemic episodes and identifying teeth at risk of developing adverse sequelae. An accurate LDF reading can be established at the 12-week follow-up appointment of replanted and splinted avulsed permanent maxillary incisors when the potential for revascularization is diagnosed. However, this finding is based on the clinical and radiographic parameters of vital and non-vital teeth and may not be interpreted as representing the histologic condition of the pulp (5). Ikawa et al. in 2003 stated that age related changes in human pulpal blood flow could be measured by LDF as their findings indicated that the hemodynamic of the human pulp is reduced with age (6). However, LDF has some limitations, as it is expensive, not readily available and requires skill in its application in teeth with large restorations, when the laser light may not reach pulp and measure the true blood flow. The LDF process uses the He-Ne laser at different wavelengths; for example, Morikawa et al. used the He-Ne Laser with 632 nm wave length (7) while Odor et al. used the He-Ne laser at 810 and 633 nm wavelengths. At 810 nm good sensitivity was experienced, as disease or non-vitality could be detected well but with poor specificity, which meant their absence could not be assessed as well (3). At 633 nm Evans et al. claimed equal specificity and sensitivity following using LDF (8). When assessing pulpal vitality with the

LDF a major portion of the signal comes from tissues other than the pulp. The results may be inconsistent in pulp blood flow measurements without taking precautions (such as dental-dam application) (9). Akpinar et al. also indicated the significant effect of gingiva on LDF flow measurements. Indeed they reported that the contribution of labial gingiva to laser Doppler blood flow measurements was more than that of palatal gingiva (10).

Treatment of dentinal hypersensitivity

According to hydrodynamic theory that was postulated by Brännström dentine hypersensitivity occurs when open dentinal tubules are exposed, resulting in a painful sensation due to an intensification of the dentinal permeability. Treatment, therefore, should be based on a decrease of this permeability, achieved by the obliteration or blocking of dentinal tubules (11). Grossman in 1935 mentioned seven original prerequisites for successful treatment of dentinal hypersensitivity using various substances (12), including: non irritating to pulp, relatively painless on application, easily applied, rapid in action, effective for a long time, without staining effects and consistently effective. Several recent studies have compared the effects of the Nd:YAG and Er:YAG lasers in the management of dentinal hypersensitivity (13-17). Lan et al. on the basis of a morphologic study of Nd:YAG laser usage in treatment of dentinal hypersensitivity stated that dentine surface after Nd:YAG laser treatment showed no protrusive rods, in contrast with the presence of numerous rods before laser irradiation. Protrusive rods are a sign of open dentinal tubules and the data obtained supported the hypothesis that Nd:YAG laser irradiation at specifications of 30 mJ, 10 pulses per second and 2 min. is effective in sealing exposed dentinal tubules (13).

Lee et al. indicated that a highly biocompatible material such as bioglass could be melted by laser irradiation to achieve better sealing depth for dentinal tubules (14). The melted bioglass, when bonded to the dentin in a physiological environment, may offer a prolonged therapeutic effect. However the melting point of a modified bioglass composite should be reduced and its use plus Nd:YAG laser has the potential in clinical use to manage dentin hypersensitivity (14). Al-Azzawi and Dayem found no significant difference in the occluding effect of Nd:YAG laser and a tooth paste (15). However the occluding effect of Nd:YAG laser occurs within seconds where as that of the toothpaste takes at least 3 weeks (15). Birang et al. concluded that Nd:YAG laser is more effective than Er:YAG laser in reduction of patients' pain in dentine hypersensitivity management and the effects seemed to last for at least six months (16). Wan-Hong et al. proposed that the mechanism of the Nd:YAG laser effect on dentin is given by thermal energy absorption in dentine that melts the hydroxyl apatite crystals of dentine partly or completely, which results in dentinal tubule occlusion (17). The sealing depth through this process was estimated 4 microns (17).

Aranha *et al.* stated that the Er:YAG at 60 mJ, 2 HZ and the Nd:YAG laser at 1.5 W, 15 HZ are useful for decreasing dentine permeability (18), while Stabholz et al. using Er:YAG laser at different energy levelsì did not find any melting or sealing/occluding of dentinal tubules (19). The authors believed that any reduction in dentine hypersensitivity due to Er:YAG laser irradiation cannot be attributed to occlusion or narrowing of dentinal tubules (19). Two major types of lasers that have been commonly used for the purpose of dentine hypersensitivity treatment are He-Ne and GaAlAs (Gallium/Aluminium/Arsenide) with low output power and the CO_2 and Nd:YAG with medium output power. The mechanism of action for these lasers, known as *desensitization,* is mostly unknown and may be different for each laser type. A low power He-Ne laser may affect the action potential of A-delta and C nociceptor fibers without destroying them, while GaAlAr lasers may block depolarization of the nociceptors (20, 21).

Pulp capping and pulpotomy

Pulp capping represents the boundary between conservative pulpal management and a root canal procedure. Between 1985 and 1987 Melcer et al. suggested that the CO_2 laser could be used for direct pulp capping (2, 22). They also described successful pulp retention after direct capping of inflamed pulps with laser (24). CO_2 laser-assisted pulp capping is an easy, safe and fast method to achieve haemostasis, along with disinfection and coagulation of exposed pulp tissues. The laser beam is applied in a contact free mode using a He-Ne laser to facilitate targeting. Irradiation starts immediately after the exposure of vital pulp and the area is repeatedly irradiated at a power setting of 1 W for 0.1 s with a 1-s interval until haemostasis occurs and the aperture is completely sealed. The lased pulp is then dressed with calcium hydroxide and the cavities filled with glass-ionomer cement. The long-term results of Moritz et al. indicated a success rate of 93%, two years after super pulsed CO_2 laser-assisted pulp capping (25). Suzuki et al. showed that CO_2 laser is effective for pulp capping procedures; however a longer observation time would be required to determine the presence of dentine bridge formation (26).

Er:YAG and Nd:YAG lasers have been successful in pulp capping procedures in several different studies, demonstrating good healing capacity with the formation of a dentine bridge and reparative dentine (27, 28). Docimo compared the effectiveness of the three techniques for pulp capping of deeply decayed permanent teeth, reporting a success rate of 63% for traditional methods, 83% for Er,Cr: YSGG laser-assisted techniques and 75% for Erbium:YAG laser-assisted pulp capping after four years of assessment (29). Therefore, laser technology has been shown to be effective in improving the prognosis of pulp capping procedures even on teeth affected by deep caries (29).

Pulpotomy is defined as the surgical removal of the coronal pulp in attempt to maintain the health of remaining pulp (25, 26). The first report on laser pulpotomy was provided in 1995 by Shoji et al. followed by the study from Figueiredo et al (30, 31). CO_2 laser was used for pulpotomy in dogs and the presence of secondary dentine and a regular odontoblast layer in the tissues of underlying ablated area was observed (32-34). Kimura et al. in a preliminary report on laser pulpotomy stated that the effects on pulp tissues during a pulpotomy procedure by Er:YAG laser irradiation are minimal if appropriate parameters are selected and that it represents a potential therapy for pulp retention in human teeth (35). However, Huth et al. determined a success rate of 78% for Erbium:YAG laser-assisted pulpotomies, 85% for formocresol, 53% for $Ca(OH)_2$ and 86% success rate for ferric sulfate mediated pulpotomies (36). These investigators have also indicated that the validity of this study revealing new data concerning the controlled use of Er:YAG laser for pulpotomies is limited and recommended future studies with a sufficient number of patients and standard parameters of evaluations (36).

The CO_2 laser is not only an effective tool for direct pulp capping but also for the pulpotomy of primary teeth. A success rate of 91 to 98% has been reported for CO_2 laser pulpotomy of primary teeth by Pescheck and Moritz in 2002 (34).

Root canal disinfection and laser-activated irrigation

Presently, Er:YAG, Nd:YAG, ER,CR:YSGG, CO_2 laser and diode laser have been shown to be efficient and effective for the purpose of root canal disinfection and smear layer removal (37). The effects produced by laser light on living cells tissues or organisms may be due to photothermal, photochemical, photoablative or photomechanical actions. High power (Class 4) lasers have been well recognized for their photothermal (heat based) destructive effects on bacteria and this has led to the development of techniques for disinfecting root canal system. These lasers typically use pulsed modes of operation for endodontic root canal disinfection, to reduce the risk of thermal injury to the periodontal ligament cells (37, 38). Undesirable surface effects within the radicular dentine such

as carbonisation and cratering remain a concern with certain laser types such as the Nd:YAG and carbon-dioxide laser; therefore strict protocols must be followed to minimise such effects and any associated thermal stress within the radicular dentin when such lasers are used for root canal disinfection (39).

Folwaczny et al. evaluated the antibacterial effects of pulsed Nd:YAG laser irradiation at different energy settings in root canals without using photosensitizing dye and determined that laser radiation has antimicrobial effects in root canals (40). The results of a similar study by Piccolomini et al. showed an antibacterial effect of Diodium Nd:YAG laser depending on the radiation frequency. However, through their study 5.25% NaOCl was more effective than either laser application (41). An *in vivo* study evaluating the therapeutic effect of Nd:YAG laser in persistent lesions supported the use of laser, since it created an unfavourable environment for the continuing development of microorganisms (42). Gutknecht et al. investigated the antibacterial depth effect of the continuous wave of a 980-nm diode laser irradiation in bovine dentine, showing that laser can eliminate bacteria deep into the dentine (43).

Laser-activated irrigation (LAI) or the Photon-Initiated Photoacoustic Streaming (PIPS) is one of the most prominent applications of laser in the scope of endodontic treatments (44). A research by De Moor et al. has come to the conclusion that LAI techniques using erbium lasers (Er:YAG or Er,Cr:YSGG) for 20 seconds (4×5 seconds) are as efficient as Passive Ultrasonic Irrigation with the intermittent flush technique (3×20 seconds) (45).

Another article has shown that the impact of alkaline solutions of NaOCl and EDTA in endodontics can be highly improved when these are agitated by ultrasonic source of energy or pulsed lasers (46). It creates fluid motion which improves the contact of the irrigant solutions with areas of the root canal walls that cannot be obtained by rotary instruments (46). They also increase the temperature of these irrigants that results in better chemical actions on soft and hard tissues (46).

The effective absorption of the laser light by sodium hypochlorite leads to vaporization of this irrigating solution resulting in formation of vapor bubbles that causes secondary cavitation effects (44). In this procedure the Er:YAG laser creates photoacustic shock-waves within the irrigant inside the root canal system (44). Perin et al. evaluated both Er:YAG laser (7 HZ, 100 mJ, 80 pulses/canal, 11 sec) and 1% NaOCl irrigations capacity against intra-canal microbiota and found its effectiveness to eliminate these microorganisms (47). Vezzani et al. evaluated the degree of disinfection of the Er:YAG laser in root canals contaminated with five intracanal microorganisms at different frequencies and concluded that all the groups showed statistically similar results and no method totally eliminated microorganisms (48). Radatti et al. evaluated the efficacy of an Erbium,-Chromium:Yttrium,Scandium, Gallium,Garnet (Er,Cr:YSGG) laser powered hydrokinetic system (HKS) versus that of rotary instrumentation for root canal debridement. According to their results the debridement efficacy of the HKS with distilled water irrigation was unacceptable with 5.25 percent NaOCl irrigation and it was similar to that of rotary instrumentation. If the HKS was to be used for debridement, then NaOCl irrigation must be used for predictable tissue removal (49). Jha et al. stated both laser and rotary instrumentations are unable to eliminate root canal infections (50). Currently, great emphasis in terms of elimination of root canal infection is focused upon mechanical preparation and ultrasonic and laser activation methods in conjunction with using appropriate irrigation solutions (51, 52).

Takeda et al. in a comparative study of the removal of smear layer using three intracanal irrigants and two types of lasers concluded that the CO_2 laser was useful in removing and melting the smear layer on the instrumented root canal walls and that the Er:YAG laser was the most effective in removing the smear layer from the root canal wall (53). Wang et al. stated that the diode laser irradiation significantly removed the smear layer, resulting in less apical leakage after obturation in compar-

ison to non-laser irradiated root canals (54). Confocal laser scanning microscopy (CLSM) and scanning electron microscope (SEM) three-dimensional images from samples irradiated using Er:YAG laser with different parameters revealed that the root canal walls were not smooth and the root canal dentine surface was ablated. No debris was observed at the dentine surface and strong melting and recrystallization or unusually flat surfaces with open dentinal tubules were obtained. So Er:YAG laser can induce different modifications of root canal surface (55).
Irradiation of dentine with Nd:YAG laser removes smear layer and promotes its fusion and recrystallization, thus decreasing permeability. Santos et al. reported that the increase of power and frequency of the laser produced typical structures that characterize the irradiation of dentine by Nd:YAG laser, such as globular formations, melting and glazing ebullitions. Furthermore, the removal of smear layer increased the number of visible dentinal tubules openings (56). Altundasar et al. evaluated the ultra-morphological and histochemical changes of dentinal walls after ER-,CR:YSGG laser irradiation. SEM observations revealed partial or total removal of the smear layer associated with few small regions of thermal injury, including carbonization and partial melting. Energy dispersive X-ray analysis (SEM-EDX) of affected dentine showed no significant difference between the Ca/P ratios of the tested groups, suggesting absence of changes at a molecular level (57).
Da Costa Ribeiro et al. evaluated the morphological and thermographic effect of 810 nm diode laser irradiation on root canal walls (58).
The SEM images of affected root canal walls revealed closed dentinal tubules especially at the apical regions and the maximum temperature rise at these apical regions, which was assessed by an infrared thermographic camera, was 8.6 °C, thus suggesting that the diode laser can be used in root canal procedures and is safe for periodontal tissues (58). The results of Ishizaki et al. suggested that the temperature rise during Er,Cr:YSGG laser irradiation is minimal to damage to the periodontal and bone tissues (59).

Photo-activated disinfection (PAD) of root canals
In case that persistent bacteria exists within the root canal system, inadequate debridement and disinfection may result in post treatment endodontic diseases (60). Different mechanical instrumentation methods are not able to eliminate the microorganisms inside the root canal system, sufficiently. A wide range of chemical irrigating solutions has been introduced to increase reduction of the microbial load within the root canal system. New technologies and substances have also been proposed to improve root canal disinfection either by replacing contemporary chemo-mechanical procedures or by increasing their effects (61-63).
PAD is an alternative approach to microbial killing in the root canal system by laser light, which involves the use of low-power lasers such as a visible red diode laser with an output power of up to 100 mw, over 60-120 seconds (64). PAD drives photochemical reactions, particularly the production of singlet oxygen, free radicals and other reactive oxygen species from photosensitiser dyes such as Tolunium chloride to kill intracanal bacteria including the resistant *E. faecalis* that is estimated to be the main cause of persistent apical periodontitis following root canal procedures. For maximum effect within the root canal system, the laser energy should be delivered using a photodynamic diffuser tip that gives a cylindrical emission pattern, corresponding to the shape of the root canal system. The appliction of PAD in contemporary root canal procedures relates to its potential for one step high level disinfection of the root canal space as a prelude to single-visit procedures or as a treatment for refractory root canal infections. The low level laser energy of PAD has advantages in that its bactericidal effect could be achieved without damaging the host tissues and with little optical danger to both the operator and patient (64).
Currently several authors recommend

Photo Dynamic Therapy (PDT) as a promising effective disinfection supplement to standard intracanal cleaning and shaping for clinical treatment of periapical lesions, especially in cases undergoing single visit root canal treatment or retreatment (65-67). In fact, both *in vivo* and *ex vivo* studies have shown that PDT is a promising technology to reduce bacterial load or bacterial concentration in the patients undergoing root canal treatment and also in extracted infected teeth (68-70). Although the application of PAD has significant advantages, potential adverse side effects have been reported regarding that (70). Tooth discoloration has been reported to be an adverse effect since the use of methylene blue (MB) as a photosensitizer may intensify discoloration (70-72). Several chemical compounds like 2.5% NaOCl used during cleaning and shaping of the root canals have been reported to be effective in preventing tooth staining caused by the application of MB during PAD (73). Some other authors have reported that MB, when used in concentrations of 100 microgr/mL, minimizes the chances of tooth discoloration (74).

Smear layer formation may decrease the bond strength of root filling materials to dentine by occluding the dentinal tubules (75). According to Souza et al. the use of ultrasonics improves the efficiency of 17% EDTA and QMix to remove the PS from all parts of the root canal walls, following PDT (76).

The species of microorganisms in the root canal system and their growth mode has been reported to influence their sensitivity to PDT in a dose-dependent form (77). Regarding the dose of energy, the highest power observed refers to laser (74-78), probably because of concentration in a small area of high energy dose originated from the light (79). This area of concern should also be carefully analysed, since temperature increase may create trauma to surrounding tissues and causes irreversible defects (80). The use of LED may be suggested, considering its capacity of not changing the temperature together to its high-dose energy supply. One of the advantages of PDT is the absence of thermal-side effects in the periradicular tissues (81). The action of PDT is based on photochemical events and not thermal effects, in contrast with many laser therapy techniques (52).

Additional uses of lasers

Several studies report on the use of Er:YAG laser for the purpose of access cavity and root canal preparation, through a photo ablative action similar to that of cavity preparation. The Er:YAG laser has the ability to open the dentinal tubules and remove the smear layer, so that the root canal sealers can easily penetrate the canal walls during obturation, thereby establishing an optimal seal (25).

Histologic and SEM examination of root canal walls after preparation with special Er:YAG laser microprobes by Kesler et al. in 2002 showed that they are effective in enlarging, shaping and cleaning straight root canals (82). Mazeki et al. in 2003 evaluated the effectiveness of Er:YAG laser irradiation for preparation of root canal orifices in extracted human teeth. SEM observations showed that irradiated surfaces were slightly rough, but essentially free from debris and smear layer. Orifices were successfully prepared and no ledge formation or perforations were observed (83). Kimura et al. in 2002 had stated that the roughness and irregularities of root canal walls prepared by Er:YAG laser do not affect apical leakage after obturation compared with leakage in canals prepared using the traditional methods (84). Lee et al. assessed the thermal effect and morphological changes induced by Er:YAG laser using two kinds of fiber tips to enlarge the root canals and identified that the cone shaped fiber tip of Er:YAG laser produced fewer thermal effects and morphological changes as compared to the flat fiber tip (85). Furthermore, Kimura and Yonaga determined that there were minimal effects of ER:YAG laser irradiations on periodontal and periapical tissues of the related root canal prepared teeth (86). Biedma et al. mentioned that Er:YAG laser combined with rotary and manual techniques may improve the cleanliness of root canals (87). Nd:YAG laser irradiation was

also an effective tool for softening and removal of gutta-percha and root canal obturation materials (88, 89). Moshonov et al. stated that a new Nd:YAP laser with a wavelength that is in the infrared region is absorbed in water better than Nd:YAG and may improve the cleanliness of the root canal walls (90).

Since 2005 evaluation of the efficacy of a Erbium laser family called Er,Cr:YSGG laser for the purpose of cleaning and shaping the root canal system has been subject of several studies (91-93). Hossain et al. compared the efficacy of Er,Cr:YSGG laser with the efficacy of hand instrumentation methods and observed a significant decrease in smear layer or debris in laser prepared canals but canal preparations with the laser device sometimes resulted in ledges, zips, perforations or over instrumentation (91). Matsuka et al. in a morphological study of the Er,Cr:YSGG laser for root canal preparation in mandibular incisors with curved root canals noticed step-like appearances of irradiated walls and openings of dentinal tubules and only root canals having curvatures, less than 10 degrees could be prepared using this technique (92). Jahan et al. in another study stated that because of ledge, zip or perforations observed in the canals prepared by Er,Cr:YSSGG laser further development in this laser device and technique is required to ensure its success in root canal preparation, especially in curved canals (93). Today the results of many research studies on NiTi mechanical instruments recommend these techniques for the purpose of cleaning and shaping the root canal systems (94, 95).

During contemporary root canal obturation, a laser can be used as a heat source to soften gutta-percha in root canals. Park et al. evaluated the effect of Nd:YAG laser irradiation on the apical leakage of obturated root canals using an electrochemical method (96). Their results indicated that laser irradiation following root canal preparation reduces apical leakage following obturation (96, 97). Maden et al. found no difference in the apical leakage of root canals obturated with Nd:YAG laser-softened gutta-percha, system-B and lateral compaction techniques (98). However, the temperature elevation following laser softening of gutta-percha was a concern (98). Nd:YAG laser irradiation has also been recognized to be an effective tool for softening and removal of gutta-percha and root canal obturation materials (98).

Anic et al. measured dentinal heat transmission induced by three different laser softened gutta-percha obturation techniques using a thermovision camera (99). Argon laser produced a rise in temperature of 12.9 °C, the CO_2 laser produced a rise in temperature of 10.3 °C, while the Nd:YAG laser caused the highest temperature elevation of +14.4 °C (99).

Bleaching of root-treated discoloured teeth

Tooth discoloration subsequent to root canal treatment is a common, aesthetic problem particularly in anterior teeth (100). According to Nicholls, the main causes of intrinsic tooth discoloration related to endodontic treatment are decomposition of necrotic pulp tissue, hemorrhage into the pulp chamber, intracanal drugs and filling materials (101). Gutta-percha and different types of sealers if not removed from the pulp chamber after obturation may cause mild to severe discoloration of the tooth. Laser-assisted bleaching technique has been shown to be an efficient method to treat resistant discolorations in less than one hour (102).

Conclusions

Given the numerous applications of lasers described in the present article in the field of the Endodontics, currently most important focus of this technology is on antimicrobial and disinfection efficiency via either PAD or laser-activated irrigation of the root canal systems. The ability of laser as a diagnostic tool as the Laser Doppler Flowmetry, treatment of dentinal hypersensitivity, pulp capping and pulpotomy has been ruled out in the past. In the area of access cavity and root canal preparation today it is believed that mechanical instrumentation is preferable to laser-assisted procedures. Different types of lasers have

been found to be effective to treat severe tooth discolorations, if both their manual and safety issues are carefully considered by the clinicians. More studies are needed regarding the role of lasers in obturation of the root canal systems.

Clinical Relevance

The use of lasers within the scope of endodontic practice and research has increased significantly in the past few years. The most common applications of lasers in endodontics include treatment of dentinal hypersensitivity and root canal disinfection through laser-activated irrigation and photo-activated root canal disinfection.

Conflict of Interest

The author declares there is no conflict of interests.

References

1. *AAE Position Statement on Use Lasers in Dentistry, American Association of Endodontists; 2012. Available from: http://www.aae.org*
2. *Olgaret L, Gazelius G, Lindh-Strömberg U. Non-invasive recording of blood flow in human dental pulp. Int Endod J 1988;2:300-306.*
3. *Odor TM, Pittford TR. Effect of wave length and band width on the clinical reliability of laser Doppler recordings. Dent Traumatol 1996;6:265-3.*
4. *Strobl H, Gojer G, Norer B, Emshoff R. Assessing revascularization of avulsed permanent maxillary incisors by laser Doppler flowmetry. J Am Dent Assoc 2003; 12:1597-603.*
5. *Ritter AL, Ritter AV, Murrah V, Sigurdson A, Trope M. Revascularization of replanted immature dogteeth after treatment with Minocycline and Doxycycline assessed by laser Dopple flowmetry, radiography and histology. Dent Traumatol 2004;20:75-84.*
6. *Ikawa M, Komatsu H, Ikawa K, Mayanagi H, Shimauchi H. Age related changes in the human pulpal blood measured by laser Doppler flowmetry. Dent Traumatol 2003;1:36-40.*
7. *Morikawa S, Johnson CC, Lanz O. Laser Doppler measurements of localized pulsatil fluid Velocity. IEEE Trans Biomed Eng 1971;6:416-20.*
8. *Evans D, Reid J, Strang R, Stirrups D. A comparison of Laser Doppler Flowmetry with other methods of assessing the vitality of traumatized anterior teeth Dent Traumatol 1999;6:284-90.*
9. *Polat S, Akpinar KE, Polat NT. The sources of laser Doppler blood Flow signals recorded from vital and root canal treated teeth. Arch Oral Biol 2004;1:53-7.*
10. *Akpinar KE, Er K. Effect of gingival on laser Doppler pulpal blood flow measurements. J Endod 2004;3:138-40.*
11. *Brännström MA. Hydrodynamic mechanism in the transmission of pain-producing stimuli through the dentin.ì in: Anderson DJ (Ed.) Sensory mechanisms in dentine. Pergamon Press, London; 1963:73-79.*
12. *Grossman LI. The treatment of hypersensitive dentin. J Amer Dent Assoc1935; 22:592-6.*
13. *Lan WH, Lee BS, Liu HC, Lin CP. Morphologic study of Nd:YAG laser usage in treatment of dentinal hypersensitivity. J Endod 2004;30: 131-4.*
14. *Lee BS, Chang CW, Chen WP, Lan WH, Lin CS. In vitro study of dentin hypersensitivity treated by Nd:YAG laser and bioglass. J Dent Mater 2005;21:511-9.*
15. *Al-Azzawi LM, Dayem RN. A comparison between the occluding effects of the NdYAG laser and the desensitising agent sensodyne on permeation through exposed dentinal tubules of endodontically treated teeth: an in vitro study. Arch Oral Biol 2006;7:535-40.*
16. *Birang R, Poursamimi J, Gutknecht N, Lampert F, Mir M. Comparative evaluation of the effects of Nd:YAG laser in dentin hypersensitivity treatment. J Lasers Med Sci 2007;1:2-7.*
17. *Wan-Hong L, Lee BS, Liu HC, Lin CP. Morphologic study of Nd:YAG Laser usage in treatment of dentinal hypersensitivity. JEndod 2004;30:131-4.*
18. *Aranha AC, Domingues FB, Franco VO, Gutknecht N, Eduardo CP. Effects of Er:YAG and Nd:YAG lasers on dentin permeability in root surfaces: a preliminary in vitro study. J Photomed Laser Surg 2005;5:504-8.*
19. *Stabholz AY, Moshonov J. The effect of Er:YAG laser irradiation with and with out water spray on root surfaces of human extracted teeth. Abstract presented at the 8th International congress on Lasers in dentistry, Yokohama, Japan.2002.*
20. *Jarvis D, Tanelian DL, MacIver B. Electrophysiologic recording and thermodynamic modeling demonstrate that helium-neon laser irradiation does not affect peripheral A-Delta or C-fiber nociceptors. Pain 1990; 43:235-42.*
21. *Wakabayashi H, Hamba M, Hamba M, Matsumoto K, Tachibana H. Electro physiological study of irradiation of semiconductor laser on the activity of the trigeminal subnucleus caudal neurons. Journal of Japanese Society for Laser Dentistry1992;3:65-74.*
22. *Melcer J, Chaumette MT, Melcer F, Zeboulon S. Experimental research on the preparation of dentin-pulp tissue of teeth exposed to CO2 laser beams in dogs. CR Soc Biol 1985;179:577-85.*
23. *Melcer J, Chaumette MT, Melcer F. Dental pulp exposed to the CO2 laser beam. Lasers Surg Med 1987;7:347-52.*
24. *Melcer J. Latest treatment in dentistry by means of the CO2 laser beam. Lasers Surg Med 1986;6:396-98.*
25. *Moritz A, Beer F, Walsh LJ. Oral laser application. Berlin Quintessence 2006.*
26. *Suzuki M, Katsumi A, Watanabe R, Shirono M, Katoh Y. Effects of an experimentally developed adhesive resin system and CO2 laser irradiation on direct pulp capping.Oper Dent. 2005;30:702-18.*
27. *Santucci PJ. Dycal versus Nd:YAG laser and vitrebond for direct pulp*

capping in permanent teeth. J Clin Laser Med Surg 1999;17:69-75.
28. Jayawardena JA, Kato J, Moriya K, Takagi Y. Pulpal response to exposure with Er:YAG laser. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2001;91:222-29.
29. Olivi G, Genovese MD, Maturo P, Docimo R. Pulp capping: advantages of using laser technology. Eur J Paediatr Dent2007;2: 89-95.
30. Shoji S, Nakamura M, Horiuchi H. Histological changes in dental pulps irradiated by CO2 laser: A preliminary report on laser pulpotomy. J Endod 1985;9:379-84.
31. Figueiredo JA, Chavantes MC. Pulpotomies with CO2 laser in dogs. Proceedings of the International Society for Optical Engineering 1995:15-19.
32. Wilder-Smith PE, Dang J, Kurosaki T. CO2 laser treatment of traumatic pulpal exposures in dogs. Laser Surg Med1997;5:432-37.
33. Dang J, Wilder-Smith P,George M, Peavy DWM. Clinical preconditions and treatment modality: effects on pulp surgery outcome. Lasers Surg Med 1998;22:25-29.
34. Pescheck A, Pescheck B, Moritz A. Pulpotomy of primary Molars with the use of a CO2 laser: Results of a long-term in vivo study. J Oral Laser Appl 2002;2:165-9.
35. Kimura Y,Yokoyama K, Watanabe H, Wang X, Matsumoto K. Histopathological changes in dental pulp irradiated by Er:YAG Laser:a preliminary report on laser pulpotomy. Clin Laser Med Surg 2003;6:345-50.
36. Huth KC, Paschos E, Hajek-Al-Khatar N, Hollweck R, Crispin A, Hickel R, Folwaczny M. Effectiveness of 4 pulpotomy techniques-randomized controlled trial. J Dent Res 2005;12:1144-8.
37. Walsh LJ. Pulpal safety parameters for irradiation of dental hard tissues with carbon dioxide lasers. Aust Endod Newsletter 1993;19:21-25.
38. Walsh LJ. The current status of low level laser therapy in dentistry. Part 2. Hard tissue Applications. Aust Dent J 1997;42:302-6.
39. Turkmen C, Gunday M, Karaçorlu M, Başaran B. Effect of CO2, Nd:YAG and ArF excimer lasers on dentin morphology and pulp chamber temperature: an in vitro study.J Endod 2000;26:644-48.
40. Folwaczny M, Mehl A, Jordan C, Hickel R. Antibacterial effects of pulsed Nd:YAG laser radiation at different energy settings in root canals. J Endodon 2002;28:24-9.
41. Piccolomini R, Arcangelo C. Bacteriologic evaluateon of the effect of Nd:YAG laserirradiation in experimental infected root canals. J Endod 2002;28:276-8.
42. Ricardo AL, Britto ML, Genovese WJ. In vivo study of the Nd:YAP laser in persistent periapical lesion. J Photomed Laser Surg 2005;23:582-5.
43. Gutknecht N, Franzen R, Schippers M, ampert F. Bactericidal effect of a 980 nm diode laser in root canal wall dentin of bovine teeth. J Clin Laser Med Surg 2004;22:9-13.
44. Plotino G, Cortese T, Grande NM, Leonardi DP, Giorgio DG, Testarelli L, Gambarini G. New technologies to improve root canal disinfection. Brazilian Dental Journal 2016;27:3-8.
45. De Moor RJ, Meire M, Goharkhay K, Moritz A, Vanobbergen J. Efficacy of Ultrasonic versus Laser-activated Irrigation to Remove Artificial placed dentin Debris Plug. J Endod 2010;36:1580-4.
46. Walsh LJ, George R. Activation of Alkaline Irrigation Fluids in Endodontics. Materials 2017;10:1214-24.
47. Perin FM ,Franca Sc, Silva-Sousa YT, Alfredo E, Saquy PC, Estrela C, Sousa-Neto MD. Evaluation of the antimicrobial effect of Er:YAG Laser irradiation versus 1% sodium hypochlorite irrigation for root canal disinfection. Aust Endod J 2004;30:20-2.
48. Vezzani MS, Pietro R Silva-Sousa YT, Brugnera-Junior A, Sousa-Neto MD.Disinfection of root canals using Er:YAG laser at different frequencies. J photomed Laser Surg 2006;24:499-502.
49. Radatti DA, Baumgartner JC, Marshal JG. A comparison of the efficacy of Er,Cr:YSSGG laser and rotary instrumentation in root canal debridement. J Am Dent Assoc 2006;9:1261-6.
50. Jha D, Guerrero A, Ngo T, Helfer A, Hasselgren G. Inability of laser and rotary instrumentation to eliminate root canal infection. J Am Dent Assoc 2006;137:722-24.
51. Plotino G, Grande NM, Pameijer CH, Somma F. Ultrasonics in endodontics: a review of the literature. J Endod 2007;33:81-95.
52. Walsh LJ. The current status of low-level laser therapy in dentistry, part 1, hard tissue applications. Aust Dent J 1997;42:247-54.
53. Takeda FH, Harashima T, Kimura Y, Matsumoto K. A comparative study of the removal of smear layer by 3 endodontic irrigants and two types of laser. Int Endod J 1999;32:32-9.
54. Wang X, Sun Y, Kimura Y, Kinoshita J, Ishizaki NT, Matsumoto K. Effects of Diode laser irradiation on smear layer removal from root Canal walls and apical leakage after obturation. J Photomed Laser Surg 2005;23:575-81.
55. Ebihara A, Majaron B, Liaw L-H.L, Krasieva TB, Wilder-Smith P. Er:YAG laser modification of root canal dentin: influence of Pulse duration, repetitive irradiation and water spray. J Lasers Med Sci 2002;17:198-207.
56. Santos C, Sousa-Neto MD, Alfredo E, Guerisoli DM, Pecora JD, Comelli Lia RF. Morphologic evaluation of the radicular dentin irradiated with Nd:YAG laser under different parameters and angles of incidence. J photomed laser Surg 2005;6:590-5.
57. Altundasar E, Ozcelik B, Cehreli ZC, Matsumoto K. Ultramorphological and histochemical changes after ER,CR:YSGG laser irradiation and 2 different irrigation regimens. J Endod 2006;35:465-8.
58. Da Costa Ribeiro A, Ngueira GE, Antoniazzi JH, Moritz A, Zezell DM. Effects of diode laser 810 nm irradiation on root Canal walls: thermographic and morphological studies. J Endod 2007;33:252-5.
59. Ishizaki NT, Matsumoto K, Kimura Y, Wang X, Kinoshita J, Okano SM, Jayawardena JA. Thermographical and morphological studies of Er-,cr:YSGG laser irradiation on root canal walls. J Photomed Laser Surg 2004;4 :291-7.
60. Siqueira Jr JF. Aetiology of root canal treatment failure: why well-treated teeth can fail? Int Endod J 2001;34:1-10.
61. Peters OA, Schonenberger K, Laib A. Effects of four Ni-Ti preparation techniques on root canal geometry assessed by micro computed tomography. Int Endod J 2001;34:221-30.
62. Zehnder M. Root canal irrigants. J Endod 2006;32:389-98.
63. Siqueira Jr JF, Roc IN. Optimising single-visit disinfection with supplementary approaches: a quest for predictability. Aust Endod J 2011;37:92-8.
64. Lee MT, Birds PS, Walsh LJ. Photo-activated disinfection of the root canal:a new role for lasers in dentistry. Aust Dent J 2004;3:93-98.
65. Silva LA, Novaes Jr A, de Oliveira RR, Nelson-Filho P, Santamaria Jr M, Silva RA. Antimicrobial photodynamic therapy for the treatment of teeth with apical periodontitis: a histopathological evaluation. J Endod 2012;38:360-6.
66. Da Silva CC, Chaves Junior SP, Pereira GLD. Antimicrobial Photodynamic Therapy Associated with Conventional Endodontic Treatment: A Clinical and Molecular Microbiological Study. Photochemistry and Photobiology2018;94:351-6.
67. Asnaashari M, Ashraf H, Rahmati A, Amini N. A comparison between effect of photodynamic therapy by LED and calcium hydroxide therapy for root canal disinfection against Enterococcus faecalis: a randomized controlled trial. Photodiagnosis and Photodynamic Therapy 2017;17:226-32.
68. Rabello DGD, Corazza BJM, Ferreira LL, Santamaria MP, Gomes APM, Martinho FC. Does supplemental photodynamic therapy optimize the disinfection of bacteria and endotoxins in one-visit and two-visit root canal therapy? A randomized clinical trial. Photodiagnosis and Photodynamic Therapy2017;19:205-11.
69. Pourhajibagher M, Raoofian R, Ghorbanzadeh R, Bahador A. An experimental study for rapid detection and quantification of endodontic microbiota following photo-activated disinfection via new multiplex real-time PCR assay. Photodiagnosis and Photodynamic Therapy 2018;21:344-50.
70. Plotino G, Grande NM, Mercade M. Photodynamic therapy in endodontics. Int Endod J 2018;2:1-15.
71. Carvalho Edos S, Mello I, Albergaria SJ, Habitante SM, LageMarques JL, Raldi DP. Effect of chemical substances in removing methylene

blue after photodynamic therapy in root canal treatment. Photomedicine and Laser Surgery 2011;29: 559-63.
72. *Ramalho KM, Cunha SR, Mayer-Santos E. In vitro evaluation of methylene blue removal from root canal after Photodynamic Therapy. Photodiagnosis and Photodynamic Therapy 2017;20:248-52.*
73. *Figueiredo RA, Anami LC, Mello I, Carvalho Edos S, Habitante SM, Raldi DP. Tooth discoloration induced by endodontic phenothiazine dyes in photodynamic therapy. Photomedicine and Laser Surgery 2014;32:458-62.*
74. *Zanin IC, Goncalves RB, Junior AB, Hope CK, Pratten J. Susceptibility of Streptococcus mutans biofilms to photodynamic therapy: an in vitro study. Journal of Antimicrobial Chemotherapy 2005;56:324-30.*
75. *Shahravan A, Haghdoost AA, Adl A, Rahimi H, Shadifar F. Effect of smear layer on sealing ability of canal obturation: a systematic review and meta-analysis. J Endod 2007;33:96-105.*
76. *Souza MA, Pazinatto B, Bischoff KF, Palhano HS, Cecchin D, De Figueiredo JA. Influence of ultrasonic activation over final irrigants in the removal of photosensitizer from root canal walls after photodynamic therapy. Photodiagnosis and Photodynamic Therapy 2017;17:216-20.*
77. *Upadya MH, Kishen A. Influence of bacterial growth modes on the susceptibility to light-activated disinfection. Int Endod J 2010;43:978-87.*
78. *Burns T, Wilson M, Pearson G. Sensitisation of cariogenic bacteria to killing by light from a helium-neon laser. J of Med Microbiol 1993;38:401-5.*
79. *Takasaki AA, Aoki A, Mizutani K. Application of antimicrobial photodynamic therapy in periodontal and peri-implant diseases. Periodontology 2000;51:109-40.*
80. *Nagata JY, Hioka N, Kimura E. Antibacterial photodynamic therapy for dental caries: evaluation of the photosensitizers used and light source properties. Photodiagnosis and Photodynamic Therapy 2012;9:122-31.*
81. *Soukos NS, Chen PS, Morris JT. Photodynamic therapy for endodontic disinfection. J Endod 2006;32:979-84.*
82. *Kesler G, Gal R. Histological and scanning electron microscope examination of root canal after preparation with Er:YAG laser micro probe:a preliminary in vitro study. JClin Laser Med Surg 2002;20:269-77.*
83. *Mazeki K, Kimura Y, Yokoyama K, Matsumoto K. Preparation of root canal orifices by Er:YAG laser irradiation: in vitro and clinical observations. J clin Laser Med Surg 2003;21:85-91.*
84. *Kimura Y, Yonaga K, Yokoyama K, Matsuoka E, Sakai K, Matsumoto K. Apical leakage of obturated canals prepared by Er:YAGLaser. J Endod 2001;27:567-70.*
85. *Lee BS, Jeng JH, Lin CP, Shoji S, Lan WH. Thermal effect and morphological changes induced by Er:YAG Laser with 2 kinds of fiber tips to enlarge the root canals. J Photomed Laser Surg 2004;3:191-7.*
86. *Kimura Y, Yonaga K, Murakoshi M, Yokoyama K, Watanabe H, Matsumoto K. Effects on periradicular periodontal tissues of root canal Irradiation with Er:YAG laser in rats. Photomed Laser Surg 2004;4:335-41.*
87. *Biedma BM, Varela Patino P, Park SA, Barciela Castro N, Magán Muñoz F, González Bahillo JD, Cantatore G. Comparative study of root canals instrumented manually and mechanically, with and without Er:YAG laser. J Photomed Laser Surg 2005;5:465-9.*
88. *Viducic D, Jukic S, Karlovic Z, Bozic Z, Miletic Y, Anic I. Removal of gutta percha from root canals using an Nd:YAGLaser. Int Endod J 2003;10:670-3.*
89. *Anjo T, Ebihara A, Takeda A, Takashina M, Sunakawa M, Suda H. Removal of two types of root canal filling material using pulsed Nd:YAG laser irradiation.J Photomed Laser Surg 2004;22:470-6.*
90. *Moshonov J, Peretz B , Brown T, Rotstein I. Cleaning of the root canal using Nd:YAG Laser and its effect on the mineral content of the dentin. J clin Laser Med Surg 2003;5:279-82.*
91. *Ali MN, Hossain M, Nakamura Y, Matsuoka E, Kinoshita J, Matsumoto K. Efficacy of root canal preparation by Er,Cr:YSGG Laser irradiation with crown down technique in vitro. J Photomed Laser Surg 2005;23:196-201.*
92. *Matsuoka E, Jayawardena JA, Matsumoto K. JA: Morphological study of the Er,Cr:YSGG laser for root Canal preparation in mandibular incisors with curved root canals. J Photomed Laser Surg 2005;23:480-4.*
93. *Jahan KM, Hossain M, Nakamura Y, Yoshishige Y, Kinoshita J, Matsumoto K. An assessment following root canal preparation by Er-,Cr:YSGG laser irradiation in straight and curved roots, in vitro. J Laser Med Sci 2006;21-229-34.*
94. *Kuzekanani M, Walsh LJ, Yousefi MA. Cleaning and shaping curved root canals: Mtwo vs Protaper instruments, a lab comparison. Indian J Dent Res 2009;20:268-70.*
95. *Kuzekanani M. Nickel-Titanium rotary instruments: Development of the single-file systems. J Int Society of Preventive and Community Dentistry 2018;5:386-90.*
96. *Park DS, Lee HJ, Oh TS. Effect of Nd:YAG laser irradiation on the apical leakage of Obturated root canals: an electrochemical study. Int EndodoJ 2001;34:318-21.*
97. *Kovacevsk I, Georgiev Z, Dimova C, Muratovska I. The use of Nd: YAG laser in root canal obturation: In vitro evaluation. In: 19th Congress of the Balkan Stomatological Society (BaSS), 24-27 Apr 2014, Belgrade. Serbia.*
98. *Maden M, Gorgul G, Tinaz AC. Evaluation of apical leakage of root canals obturated with Nd:YAG laser-softened gutta-percha, system-B and lateral condensation techniques. J Contemp Dent Pract 2002;15:16-20.*
99. *Anic I, Matsumoto K. Dentinal heat transmission induced by a laser-softened gutta percha obturation technique. J Endod 1995;21:470-4.*
100. *Sheets CG, Paquette JM, Wright RS.Tooth whitening modalities for pulpless and discoloured teeth. In:Cohen S, Burns RC.Path ways of the pulp.8th ed.London: Mosby;2002. P.751.*
101. *Van der Burgt TP, Mullaney TP, Plasschaert AJ. Tooth discoloration induced by endodontic sealers. Oral Surg Oral Med Oral Pathol 1986;61:84-9.*
102. *Kuzekanani M, Walsh LJ. Quantitative analysis of KTP laser photodynamic bleaching of tetracycline-discolored teeth. Photomed Laser Surg 2009;27:521-5.*

ORIGINAL ARTICLE/**ARTICOLO ORIGINALE**

A systematic review: effect of hand, rotary and reciprocating instrumentation on endodontic postoperative pain

Una revisione sistematica: effetto della strumentazione manuale, meccanica con movimento di rotazione continua e reciprocante sul dolore postoperatorio endodontico

KEYWORDS
Endodontics, Postoperative pain, Systematic review, Root canal preparation, Root canal therapy

PAROLE CHIAVE
Endodonzia, dolore postoperatorio, revisione sistematica, preparazione del canale radicolare, terapia canalare

Andressa Raquel Spohr[1], Rafael Sarkis-Onofre[2], Tatiana Pereira-Cenci[1], Fernanda Geraldo Pappen[1*], Renata Dornelles Morgental[3]

[1]Graduate Program in Dentistry, Federal University of Pelotas.
[2]Graduate Program in Dentistry, Meridional Faculty (IMED) & Graduate Program in Dentistry, Federal University of Pelotas.
[3]Graduate Program in Dental Sciences, Federal University of Santa Maria (UFSM) & Graduate Program in Dentistry, Federal University of Pelotas.

Received 2019, February 24

Accepted 2019, July 18

Abstract

Aim: *This systematic review evaluated the influence of hand, rotary and reciprocating instrumentation on endodontic postoperative pain.*
Methodology: *A protocol was registered on PROSPERO. Electronic searches were conducted in MEDLINE, ISI Web of Science, Scopus and ClinicalTrials.gov. Articles were selected according to the following criteria: randomized clinical trials with patients undergoing endodontic treatment in permanent teeth, comparing instrumentation techniques with different kinematics (hand/rotary/reciprocating) and their effect on postoperative pain incidence, intensity or duration. Data on analgesic intake was also recorded. Risk of bias was evaluated and the GRADE framework was applied to assess the quality of evidence.*
Results: *Twelve studies and 1,659 patients were included in this review. Five studies compared hand instrumentation vs. engine-driven (rotary and/or reciprocating) systems. In three studies, postoperative pain results were worse with hand instruments than with engine-driven systems. In the other two studies, pain results for hand and engine-driven techniques were similar. Seven studies and a dataset from one of the five previous studies were included in the comparison of rotary vs. reciprocating systems, with contrasting results. Postoperative pain results were worse with reciprocating systems in four studies, with rotary systems in two studies and equivalent in other two studies. Data on analgesic intake were controversial. GRADE showed low quality of evidence.*
Conclusions: *Hand instrumentation presented unfavourable postoperative pain results when compared to engine-driven systems. The comparison of rotary and reciprocating systems generate contrasting results. Given the low quality of evidence and conflicting findings, results should be considered with caution and further well-designed randomized clinical trials on the matter are encouraged.*

Obiettivi: *questa revisione sistematica ha valutato l'influenza della strumentazione manuale, rotante e reciprocante sul dolore postoperatorio endodontico.*
Metodologia: *è stato registrato un protocollo su PROSPERO. Le ricerche elettroniche sono state condotte su MEDLINE, ISI Web of Science, Scopus e ClinicalTrials.gov. Gli articoli sono stati selezionati in base ai seguenti criteri: studi clinici randomizzati con pazienti sottoposti a trattamento endodontico in denti permanenti, confrontando tecniche di strumentazione con cinematiche diverse (manuale/rotante/reciprocante) e il loro effetto sull'incidenza, intensità o durata del dolore postoperatorio. Sono stati anche registrati i dati sull'assunzione di analgesici. È stato valutato il rischio di parzialità e il quadro GRADE è stato applicato per valutare la qualità delle prove.*
Risultati: *dodici studi e 1.659 pazienti sono stati inclusi in questa revisione. Cinque studi hanno confrontato la strumentazione manuale con quella meccanica (rotante e/o reciprocante). Tre articoli hanno mostrato peggiori risultati del dolore postoperatorio per la preparazione manuale e due non hanno riscontrato differenze. Sette studi e un set di dati di uno dei cinque precedenti studi sono stati inclusi nel confronto tra sistemi rotanti e reciprocanti, con risultati contrastanti. Quattro articoli mostravano risultati di dolore postoperatorio peggiori per strumenti reciprocanti, due per gli strumenti rotanti e due non hanno riscontrato differenze. I dati sull'assunzione di analgesici sono stati controversi. Il GRADE ha mostrato una scarsa qualità delle prove.*
Conclusioni: *la strumentazione manuale ha presentato risultati di dolore postoperatorio sfavorevoli rispetto ai sistemi meccanici. La comparazione tra gli strumenti reciprocanti e rotanti ha generato risultati contrastanti. Data la bassa qualità delle evidenze e i risultati contrastanti, i risultati dovrebbero essere considerati con cautela e sono incoraggiati ulteriori studi clinici randomizzati ben progettati sull'argomento.*

Corresponding author
Fernanda Geraldo Pappen | Graduate Program in Dentistry, Federal University of Pelotas | Rua Gonçalves Chaves 457, room 507, Pelotas, RS, Brazil, 96015-560
ferpappen@yahoo.com.br

Peer review under responsibility of Società Italiana di Endodonzia
10.32067/GIE.2019.33.02.03

Introduction

Pain associated with endodontic therapy is widely feared by patients (1) and has been extensively investigated (2-7). The prevalence of postoperative pain and flare-up as reported in the literature ranges from 3 to 58% (8). Such unpleasant experience results from a complex multifactorial process, being influenced by inherent aspects of the patient, the tooth to be treated and interventions of the dental operator (9). Several prior endodontic studies have attempted to correlate postoperative pain to intraoperative factors as irrigating solution (10), instrumentation technique (11), intracanal dressing (12), number of visits (8) and obturation technique (13). Extrusion of root canal contents into the periradicular tissues causes inflammation and may be related to postoperative pain (14, 15). The amount of extruded debris and neuropeptides released in the periodontal ligament differ between instrumentation techniques (16) and it has been indicated as a reason why there are differences in postoperative pain experienced by patients. Rotary nickel-titanium (NiTi) systems led to a reduction in debris extrusion when compared to hand stainless-steel instruments (17, 18). NiTi allowed safe and efficient engine-driven systems for cleaning and shaping root canals, especially those with curvatures (19). There is clinical and experimental evidence that such systems reduce the occurrence of operative errors such as deviation and apical transportation due to their remarkable flexibility (20, 21).
Recently, a tendency to greater debris extrusion with NiTi single-file reciprocating systems compared to NiTi multiple-file rotary systems has been reported (16, 22). Continuous rotation movement may improve coronal transportation of dentine chips and infected debris by acting like a screw conveyer (23). However, the development of reciprocating instruments brought potential advantages: increased fatigue life (24), reduced number of instruments, lower cost, shorter preparation time (11), better shaping ability (25) and elimination of cross-contamination associated with single-use instruments.
Controversial findings have been described in two recent systematic reviews of in vitro studies regarding the influence of instrumentation techniques on debris extrusion (16, 22). Moreover, results could change in a clinical situation due to the presence of periapical tissues, which act as a natural barrier providing physical back-pressure (26), thus preventing apical extrusion. Contrasting results are also observed in clinical trials addressing postoperative pain (11, 27-29). In this context, the aim of this study was to systematically review the literature to determine the influence of hand, rotary and reciprocating instrumentation techniques on postoperative pain in patients submitted to endodontic treatment in permanent teeth.

Materials and Methods

A review protocol was registered on PROSPERO (CRD 42016036587). This systematic review was carried out and reported according to recommended guidelines (30, 31). Two research questions were formulated according to a PICOS (population, intervention, comparison, outcome, and study type) framework, considering randomized clinical trials, RCTs. 1) In patients receiving endodontic treatment in permanent teeth, do engine-driven instrumentation techniques using NiTi systems induce equivalent postoperative pain compared to hand preparation using stainless-steel instruments? 2) In patients receiving endodontic treatment in permanent teeth, considering engine-driven NiTi instrumentation, do reciprocating systems induce equivalent postoperative pain compared to rotary systems?

Eligibility criteria
RCTs with patients undergoing endodontic treatment in permanent teeth that compared instrumentation techniques with different kinematics (hand stainless-steel instruments vs. engine-driven NiTi systems or rotary vs. reciprocating engine-driven NiTi systems) and their effect on postoperative pain incidence, intensity

or duration were included in this review. There was no age limit and all pain scales were considered. Observational studies, reviews, case reports, case series, in vitro studies and those without pain measurement outcomes were excluded. Also, RCTs comparing two instrumentation techniques with the same kinematics (e.g. two rotary systems) were excluded.

Table 1

Search strategy used in the Medline database

Search string #1	"Root Canal Preparation"[Mesh] OR "Root Canal Preparation" OR "Canal Preparation, Root" OR "Canal Preparations, Root" OR "Preparation, Root Canal" OR "Preparations, Root Canal" OR "Root Canal Preparations" OR "Root Canal Instrumentation" OR "Hand File" OR "Hand Stainless Steel" OR "Rotary" OR "Rotary File" OR "Rotary Instrument" OR "Rotary Nickel Titanium" OR "Rotary NiTi" OR "Reciprocating File" OR "Reciprocating Instrument" OR "Reciprocating Nickel-Titanium" OR "Reciprocating NiTi"
Search string #2	"Pain"[Mesh] OR "Pain" OR "Pain, Burning" OR "Burning Pain" OR "Burning Pains" OR "Pains, Burning" OR "Suffering, Physical" OR "Physical Suffering" OR "Physical Sufferings" OR "Sufferings, Physical" OR "Pain, Migratory" OR "Migratory Pain" OR "Migratory Pains" OR "Pains, Migratory" OR "Pain, Radiating" OR "Pains, Radiating" OR "Radiating Pain" OR "Radiating Pains" OR "Pain, Splitting" OR "Pains, Splitting" OR "Splitting Pain" OR "Splitting Pains" OR "Ache" OR "Aches" OR "Pain, Crushing" OR "Crushing Pain" OR "Crushing Pains" OR "Pains, Crushing" OR "Pain, Postoperative"[Mesh] OR "Pain, Postoperative" OR "Postoperative Pain" OR "Postoperative Pains" OR "Symptom Flare Up"[Mesh] OR "Symptom Flare Up" OR "Flare Up, Symptom" OR "Flare Ups, Symptom" OR "Symptom Flare Ups" OR "Symptom Flaring Up" OR "Flaring Up, Symptom" OR "Flaring Ups, Symptom" OR "Symptom Flaring Ups" OR "Acute Symptom Flare" OR "Acute Symptom Flares" OR "Flare, Acute Symptom" OR "Flares, Acute Symptom" OR "Symptom Flare, Acute" OR "Symptom Flares, Acute" OR "Symptom Flareup" OR "Flareup, Symptom" OR "Flareups, Symptom" OR "Symptom Flareups" OR "Symptom Flare-up" OR "Flare-up, Symptom" OR "Flare-ups, Symptom" OR "Symptom Flare-ups"
Search string #3	((randomized controlled trial[pt] OR controlled clinical trial[pt] OR randomized controlled trials[mh] OR random allocation[mh] OR double-blind method[mh] OR single-blind method[mh] OR clinical trial[pt] OR clinical trials[mh] OR ("clinical trial"[tw]) OR ((singl*[tw] OR doubl*[tw] OR trebl*[tw] OR tripl*[tw]) OR (mask*[tw] OR blind*[tw])) OR ("latin square"[tw]) OR placebos[mh] OR placebo*[tw] OR random*[tw] OR research design[mh:noexp] OR follow-up studies[mh] OR prospective studies[mh] OR cross-over studies[mh] OR control*[tw] OR prospectiv*[tw] OR volunteer*[tw]) NOT (animal[mh] NOT human[mh]))
Search string #4	#1 AND #2 #1 AND #2 AND #3
Limits	English language and Custom date range (1985-2017)

Search methodology

Searches were conducted in three electronic databases (Medline, ISI Web of Science and Scopus), with English language restriction, from 1985 to 2017. Additional search was performed at www.clinicaltrials.gov to identify finished studies that were not yet published. The last search was carried out in May 2017. The search strategy used in the Medline database via PubMed engine search is described in Table 1. Search words were adjusted for each database. The references of all eligible documents were also hand-searched.

Duplicate search results were excluded (EndNote X7 program, Thompson Reuters, New York, USA) and two independent researchers (A.R.S. and R.D.M.) identified the content of articles first by reviewing titles and abstracts, and the presence of the selection criteria listed above. The articles were classified as: i) include, ii) exclude or iii) uncertain. Full publications of included and uncertain articles were obtained for verification of eligibility by the same two reviewers. Any discrepancies between evaluators were resolved by discussion or by a third party (R.S.O.). In papers with missing information or data, authors were contacted by e-mail.

Data collection process

A standardized scheme was created for data collection, which was conducted by the same two reviewers. The following data were extracted.

- Publication details: author and year of publication.
- General characteristics of the study: age and gender of patients, sample size, group of teeth, pulp and periapical condition, number of operators as well as their clinical experience, number of treatment sessions, irrigating solution, and instrumentation technique (hand, rotatory and/or reciprocating).
- Pain-related information: period of evaluation, pain scale, analgesic drug, analgesic intake and pain results regarding incidence, intensity and/or duration of pain.

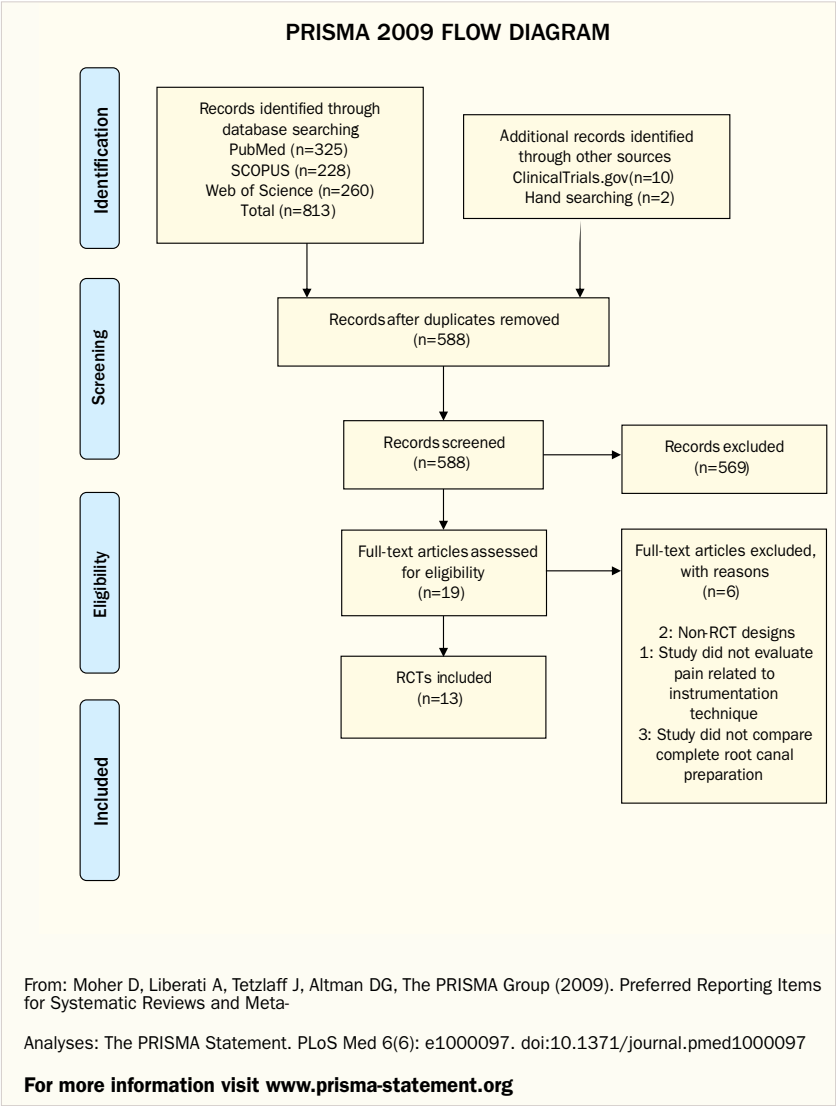


Figure 1
Flow diagram of the study according to the PRISMA Statement.

Risk of bias

The risk of bias of included studies was assessed using the Cochrane risk of bias tool (30) considering the judgment of random sequence generation, allocation concealment, blinding of participants and personnel, blinding of outcome assessment, incomplete outcome data and selective reporting. The assessment was performed by the same two reviewers independently and verified by a third researcher using the Review Manager Software Version 5.3 (The Cochrane Collaboration, London, UK). Publication bias was not statistically assessed, though searches for unpublished studies were performed to minimize the publication bias.

Quality of the body of evidence

The Grading of Recommendations, Assessment, Development and Evaluation (GRADE) framework for systematic reviews was applied to the included trials to assign an overall outcome-specific rating for within-study risk of bias (methodological quality), directness of evidence, heterogeneity, precision of effect estimates and risk of publication bias (32). The assessment was performed by one reviewer and discussed with other two researchers to generate a score.

Data synthesis

Considerable heterogeneity was verified in the selected studies regarding demographic characteristics of patients, endodontic diagnosis, technical procedures, pain scales and pain assessment periods. Also, the e-mails sent regarding missing data/information received no reply. Thus, meta-analysis was considered inappropriate and data were summarized descriptively.

Results

The flowchart for the selection of eligible studies is shown in Figure 1. Initial electronic searches identified 702 studies. The screening of titles and abstracts resulted in 14 manuscripts and two additional papers were found by hand-searching. Four papers were excluded after full-text reading since two studies used non-RCT designs (33, 34); one study did not evaluate pain related to instrumentation technique (35); and one study compared hand and rotary techniques for glide-path procedure, not for complete root canal preparation (36). Ten studies registered at www.clinicaltrials.gov were found, eight in progress and two completed investigations. Of these, one did not provide conclusive data (no statistical analysis) and the other was included in the review (29).

In total 12 studies and 1,659 patients aged between 14 and 73 years old were included in this review (Table 2). Five studies were included in the comparison of hand vs. engine-driven (rotary and/or reciprocating) instrumentation techniques (29, 37-40). Other seven studies (11, 27, 41-45) and a

Table 2

General characteristics of the studies included in the review (N 12)

Author	Year	Age*	Gender (female %)	N (patients)	N (teeth)	Group of teeth	Pulpal/periapical condition	N (operators)	Experience	N (sessions)	Irrigant	Instrumentation technique
Al-Jabreen (37)	2002	18 to 55	n.i.	91	105 35 each	Maxillary central incisors	Pulp necrosis	n.i.	n.i.	1	2.6% NaOCl	HAND (step-back) vs. ROT 1 (Profile 04) vs. ROT 2 (Profile GT)
Ahmed *et al.* (38)	2012	14 to 60	n.i.	102	102 51 each	Single-rooted teeth	Symptomatic irreversible pulpitis and/or acute apical periodontitis	n.i.	n.i.	1	2.5% NaOCl	HAND (step-back) vs. ROT (ProTaper)
Nekoofar *et al.* (11)	2015	15 to 55 40 ROT 38 REC	52.4% ROT 52.4% REC	42	42 21 each	Premolars and molars	Asymptomatic irreversible pulpitis	1	n.i.	2	2% CHX 17% EDTA	ROT (ProTaper) vs. REC (WaveOne)
Neelakantan *et al.* (41)	2015	25 to 40 31 mean	49.6% ROT 49.6% REC	605	1210 605 each	Mandibular molars	Symptomatic irreversible pulpitis	2	Endo-dontists	1	3% NaOCl 17% EDTA	ROT (OneShape) vs. REC (Reciproc)
Kashefinejad *et al.* (39)	2016	17 to 52 30.8 HAND 32.5 for ROT	n.i.	53	60 30 each	Single-rooted teeth	Symptomatic irreversible pulpitis	n.i.	n.i.	1	Normal saline	HAND (step-back) vs. ROT (Mtwo)
Kherlakian *et al.* (42)	2016	19 to 73 47 mean	62.8% ROT 65.7% REC 1 61.4% REC 2	210	210 70 each	Premolars and molars	Vital pulp	5	Endo-dontists	1	2.5% NaOCl 17% EDTA	ROT (ProTaper Next) vs. REC 1 (WaveOne) vs. REC 2 (Reciproc)
Krithikadatta *et al.* (43)	2016	18 to 55	46.9% ROT 1 51% ROT 2 61.2% REC NSD	152	152 49 ROT 1 50 ROT 2 49 REC	Premolars and molars	Asymptomatic or symptomatic irreversible pulpitis or pulp necrosis with or without apical periodontitis	4	Final year post-graduate students	2	5% NaOCl 17% EDTA final flush 2% CHX	ROT 1 (ProTaper Next) vs. ROT 2 (Mtwo) vs. REC (WaveOne)
Zand *et al.* (45)	2016	19 to 59 33.22 ROT 33.73 REC NSD	60% ROT 48.9% REC NSD	90	90 45 each	Mandibular molars	Asymptomatic pulp necrosis	n.i.	n.i.	1	2.5% NaOCl 17% EDTA	ROT (RaCe) vs. REC (Reciproc)
Talebzadeh *et al.* (40)	2016	Over 18	n.i.	96	96 48 each	Mandibular molars	Asymptomatic irreversible pulpitis	1	n.i.	1	5% NaOCl	HAND (step-back) vs. ROT (RaCe)
Pasqualini *et al.* (44)	2016	25%-16 to 30 33%-31 to 45 42%-46 to 60	50%	47	47 23 ROT 24 REC	Single or multi-rooted	Asymptomatic or symptomatic irreversible pulpitis or pulp necrosis	1	Endodontist	1	5% NaOCl 10% EDTA	ROT (ProTaper) vs. REC (WaveOne)

Relvas *et al.* (27)	2016	18 to 64 25.9 ROT 25.8 for REC	Only men	78	78 39 each	Mandibular molars	Asymptomatic pulp necrosis	1	Endodontist	1	2.5% NaOCl 17% EDTA	ROT (ProTaper) vs. REC (Reciproc)
Shokraneh *et al.* (29)	2017	20 to 45 31.7 HAND 29.6 ROT 30.3 REC NSD	50% HAND 51.6% ROT 46.9% REC NSD	93	93 30 HAND 31 ROT 32 REC	Mandibular molars	Asymptomatic pulp necrosis and apical periodontitis	1	Endodontist	1	5.25% NaOCl 17% EDTA	HAND (crown-down) vs. ROT (ProTaper) vs. REC (WaveOne)

Studies are listed in chronological publication order.

**Age range and mean per group (if informed).*

CHX: chlorhexidine; EDTA: ethylenediamine tetraacetic acid; HAND: hand group; NaOCl: sodium hypochlorite; n.i.: not informed; NSD: no significant difference between groups; REC: reciprocating group; ROT: rotary group (continuous rotation motion).

Figure 2
Risk of bias evaluation: (+) low; (?) unclear. Studies are listed in alphabetical order by the Review Manager Software.

	Random sequence generation (selection bias)	Allocation concealment (Selection bias	Blinding of participants and personnel (performance bias)	Blinding of oucome assessment (detection bias)	Incomplete outcome data (attrition bias9	Selective reporting (reporting bias)
Ahmed et al. 2016	+	+	?	?	?	?
Al-Jabreen 2012	?	?	?	?	?	?
KashefineJad et al. 2016	+	?	+	?	?	+
Kherlaklan et al. 2016	+	+	?	?	?	?
Krithkadata et al. 2016	+	+	+	+	+	?
Neelakantan et al. 2015	+	+	?	?	+	?
Nekoofar et al. 2015	?	+	?	?	?	+
Pasqualini et al. 2016	+	+	?	?	+	?
Relvas et al. 2016	+	+	+	+	?	+
Saha et al. 2018	+	+	?	?	?	?
Shokraneh et al. 2016	+	?	?	+	+	+
Talebzadeh et al. 2016	?	?	+	+	+	+
Zand et al. 2016	?	?	+	+	?	+

dataset from one (29) of the five previous studies were included in the comparison of rotary vs. reciprocating systems.

A wide range of pain incidence was observed in the included studies, considering periods of two hours to seven days: 11.4% (37) to 96.7% in hand instrumentation; 0% (37) to 54.8% (29) in rotary instrumentation and 0% (27) to 43.7% (29) in reciprocating instrumentation. Pain intensity or severity was not summarized due to the different pain scales used in the included studies (Table 3). Nevertheless, the highest postoperative pain levels were recorded in the early stages after root canal treatment, especially within the first 24h (11, 27, 29, 40, 42, 43, 45).

Pain-related data of studies comparing hand and engine-driven instrumentation are described in Table 3. In three studies postoperative pain results were worse with hand instruments than with engine-driven systems (29, 37, 39). In the other two studies pain results for hand and engine-driven techniques were similar (38, 40). Three studies evaluated analgesic intake by patients; in two of these investigations the analgesic intake was higher when using hand instruments in comparison to engine-driven systems (29, 30), while the other study showed similar results (40).

Pain-related data of studies comparing rotary and reciprocating instrumentation are also shown in Table 3. The eight included studies revealed contrasting find-

Table 3

Pain-related information in the studies comparing hand vs. engine-driven instrumentation techniques (N=5) and studies comparing rotatory vs. reciprocating instrumentation techniques (N=8)

Author	Year	Period of evaluation	Pain scale	Analgesic drug	Analgesic intake	Pain results
Hand vs. engine-driven techniques						
Al-Jabreen (37)	2002	48 h, 7 days	Categorical	n.i.	n.i.	Pain incidence: HAND>ROT
Ahmed et. al. (38)	2012	48 h	VAS (0-10)	1 mg Paracetamol	n.i.	Pain incidence: HAND=ROT
Kashefinejad et al. (39)	2016	4, 8, 12, 24 h	VAS (0-10)	max. 3,200 mg/ day Ibuprofen	HAND>ROT	Pain incidence/ intensity: HAND>ROT
Talebzadeh et al. (40)	2016	4, 8, 12, 24, 48 h, 7 days	VAS (0-100)	400 mg Ibuprofen	HAND=ROT	Pain intensity: HAND=ROT
Shokraneh et al. (29)	2017	6, 12, 18, 24, 48, 72 h	Heft-Parket VAS (0-170)	400 mg Ibuprofen	HAND> ROT/REC	Pain intensity: HAND>ROT/REC
Rotary vs. reciprocating techniques						
Nekoofar et al. (11)	2015	6, 12, 18, 24, 48, 72 h	NRS (0-10)	400 mg Ibuprofen (+325 mg Paracetamol)	ROT<REC	Pain intensity/duration: ROT<REC
Neelakantan & Sharma (41)	2015	Up to 7 days	Modified VAS (0-10)	400 mg Ibuprofen	ROT>REC	Pain incidence/ intensity/duration: ROT>REC
Kherlakian et al. (42)	2016	24, 48, 72 h, 7 days	VAS (0-100)	400 mg Ibuprofen	ROT=REC	Pain intensity: ROT=REC
Krithikadatta et al. (43)	2016	2, 4, 6, 8, 12, 24, 36, 48 h	VAS (0-10)	400 mg Ibuprofen	n.i.	Pain intensity: ROT<REC
Zand et al. (45)	2016	4, 12, 24, 48, 72 h, 7 days	VAS (0-100)	n.i.	n.i.	Pain intensity: ROT<REC
Pasqualini et al. (44)	2016	7 days	VAS (0-10)	Optional analgesics	ROT=REC	Pain intensity: ROT<REC
Relvas et al. (27)	2016	24, 72 h, 7 days	VRS	n.i.	n.i.	Pain incidence/ intensity: ROT=REC
Shokraneh et al. (29)	2017	6, 12, 18, 24, 48, 72 h	Heft-Parket VAS (0-170)	400 mg Ibuprofen	ROT=REC	Pain intensity: ROT>REC (first 18 h)

Studies are listed in chronological publication order.

HAND: hand group; n.i.: not informed; NRS: Numerical Rating Scale; REC: reciprocating group; ROT: rotary group; VAS: Visual Analogue Scale; VRS: Verbal Rating Scale.

ings. Postoperative pain results were worse with reciprocating systems in four studies (11, 43-45) and with rotary systems in two studies (29, 41). Finally two studies found that postoperative pain is equivalent in both root canal preparation techniques (27, 42). Five studies also evaluated pain-relieving consumption. Of these, three reported that analgesic intake is similar in patients undergoing treatment with rotary and reciprocating systems (29, 42, 44). In one study (11) analgesic intake was higher in the reciprocating group, while in the other (41) it was higher in the rotary group.

Risk of bias evaluation is illustrated in Figure 2. Most studies had unclear risk of bias with regards to the following items: blinding of participants and personnel (58.3%), blinding of outcome assessment (58.3%) and incomplete outcome data (58.3%). Most studies had low risk of bias in terms of random sequence generation (66.6%) and allocation concealment (58.3%). Based on the GRADE approach, quality of evidence was classified as low because of limitations in the design, implementation and indirectness of evidence.

Discussion

This systematic review is the first to summarize and critically analyse the available information about the influence of hand, rotary and reciprocating instrumentation techniques on endodontic postoperative pain. A wide range of pain incidence was observed in the included studies. In general, the results described here were in line with those observed in the systematic review conducted by Pak and White (5), in which pain incidence in the first 24 hours was 40%, decreasing acutely thereafter, reaching 11% at seven days. Pain intensity or severity was not summarized due to the lack of consistency of pain scales used in the included studies. Still, the highest postoperative pain levels were also recorded in the early stages after root canal treatment, especially within the first 24h, as previously reported (5).

Postoperative pain has been associated with the apical extrusion of infected debris, which may occur during any hand or engine-driven instrumentation technique (17, 46, 47). Most studies in this review (29, 37, 39) and others not included herein (36, 48) showed worse postoperative pain results when hand preparation is used comparatively to rotary or reciprocating systems. It is important to note that four out of five studies included in this review (37-40) used hand instruments with a step-back approach. In the step-back or any push-pull filing technique the file acts as a plunger in the apical region and drives debris through the foramen (46), probably exacerbating inflammation and pain. On the contrary, flutes of rotary instruments tend to pull debris back towards the root canal orifice (46, 49).

Comparison of postoperative pain between rotary and reciprocating systems showed conflicting findings in this review, but reciprocation produced worse postoperative pain results, according to four studies (11, 43-45). A recent systematic review (22) found that reciprocating instruments tended to extrude more dentine debris than rotary instruments, but it also showed studies with opposite results. Another systematic review (16) demonstrated that both multiple-file rotary and single-file reciprocating systems generate apical extrusion of debris in laboratory studies and in vivo expression of neuropeptides released from C-type nerve fibres in the periodontal ligament. They supported the hypothesis that the inflammatory reaction and subsequent pain response in the apical area is not influenced by the number of files but the type of movement and instrument design characteristics, as previously suggested (23, 50). It is worth mentioning that rotary and reciprocating systems with different designs were grouped in this review to assess the effects of kinematics.

Controversially, one study with a large sample size (605 patients) showed worse pain results with rotary instrumentation in comparison to reciprocation (41). It was the only study to evaluate a single-file rotary system (OneShape, Micro-Mega, Besancon Cedex, France), while all others assessed multi-file rotary systems (Table 2). A recent meta-analysis of three studies (28) compared the postoperative pain after single-visit root canal preparation with rotary vs. reciprocating instruments and found no difference between techniques considering pain incidence. However, it is important to highlight that they found a high heterogeneity between studies (I2=87%), and a wide confidence interval (0.25-6.52) showing imprecision of the result. In two studies of the present review pain results were similar for rotary and reciprocating systems (27, 42). Aligned with these findings, Martinho et al. (51) reported that files in rotary and reciprocating motion have similar effectiveness in

reducing endotoxins and cultivable bacteria from primarily infected root canals, which could influence postoperative pain. Gender has been suggested to play a role in pain studies (9, 52, 53) and may function as a confounding factor in studies comparing instrumentation techniques. Females have shown to experience higher levels of postoperative pain compared to males (9). In the present review, few studies reported a balanced percentage of men and women in their population (11, 29, 41-43, 45), while one study (27) included only male patients due to insufficient number of female patients during recruitment, resulting in a biased sample. Indeed, the last paper reported low pain incidence (<20%) for both rotary and reciprocating groups (27). The frequency was lower than that observed in studies including men and women (29).
Another confounding factor is the presence of preoperative pain, which may also interfere with postoperative pain (6, 53). Three studies included only symptomatic teeth (38, 39, 41), while five studies selected exclusively asymptomatic cases (11, 27, 29, 40, 45). Other studies elected assorted or undefined samples regarding preoperative pain (37, 42-44). Additionally, Krithikadatta et al. (43) observed that nonvital teeth experienced more pain compared to vital teeth across rotary and reciprocating groups, probably because the extrusion of infected necrotic tissue triggers an acute inflammatory response in the periapical area with subsequent pain (14).
The clinical experience of operators consists in another potential cause of heterogeneity between studies. Endodontists were reported in five papers (27, 29, 41, 42, 44), and final year graduate students in one paper (43), while other studies did not inform about operators' experience (11, 37-40, 45). Previous investigations reported no significant differences in postoperative pain experience after treatment performed by endodontists vs. generalists (54, 55) but patients' general satisfaction was higher after treatment by specialists (55). A positive impact of an expert operator may emerge from shorter operating time and better communication when dealing with patient stress (44, 54).

In this review only two studies (11, 43) performed endodontic treatment in two clinical sessions, with the others reporting single session. According to Attar et al. (56) patients treated with calcium hydroxide dressing vs. obturation did not differ in postoperative pain levels. Even with conflicting results in the literature, systematic reviews on the subject seem to demonstrate that the number of treatment visits does not affect postoperative pain (57-59).
Although pain symptoms have subjective nature and pain measurement represents a challenge in clinical trials (3, 5), pain scales used in the included studies have been previously validated (60). Most studies used the Visual Analogue Scale (VAS) or its variations (38-45). Other authors used the Numerical Rating Scale (NRS) (11), the Verbal Rating Scale (VRS) (27), the Heft-Parket VAS (29), and the categorical scale (37). Fortunately, endodontic pain evaluations using different types of pain scale are known to be highly correlated (56).
Analgesic intake findings usually accompanied those of postoperative pain (53), i.e., if a preparation technique showed worse pain results, it also promoted higher analgesic consumption (Table 3). This situation was not observed in two studies (29, 44). This may be related to psychological variations regarding pain tolerance and urgency to use pain killers (61). From the 12 studies included in this review, seven recommended the use of Ibuprofen in case of postoperative pain (11, 29, 39-43). Nonsteroidal anti-inflammatory drugs have been recommended as first-choice medication for postoperative pain management after endodontic therapy, especially Ibuprofen (62).
Some limitations of this review should be highlighted: 1) most studies had unclear risk of bias with regards to the blinding of participants and personnel, blinding of outcome assessment and incomplete outcome data; 2) general quality of the body of evidence was classified as low, due to limitations in the design, implementation and indirectness of evidence, limiting the extern validation; 3) meta-analysis was not presented due to the heterogeneity in the selected studies regarding demographic characteristics of patients, endodontic

diagnosis, technical procedures, pain assessment methods and periods. In this context, the present review points out some orientation regarding the influence of instrumentation techniques on endodontic postoperative pain, but also highlights the need for additional standardized and well-design clinical trials.

Conclusions

Hand instrumentation led to worse postoperative pain results when compared to engine-driven systems. Among engine-driven instruments with different kinematics, conflicting results are reported. Given the low quality of evidence and contrasting findings, results should be carefully interpreted and cannot generate strong recommendations for clinicians at this moment.

Clinical Relevance

Pain related to endodontic treatment is a concern for professionals and patients. This systematic review provides evidence about the influence of hand, rotary and reciprocating instrumentation on postoperative pain. It also approaches the quality of the included randomized clinical trials.

Conflict of interest

All authors declare that they have no conflicts of interest. In addition, all authors have read and approved the manuscript as submitted, are qualified for authorship, believe the submission represents honest work and take full responsibility for the reported findings.

References

1. *Watkins CA, Logan HL, Kirchner HL. Anticipated and experienced pain associated with endodontic therapy. J Am Dent Assoc 2002;133(1):45-54.*
2. *Harrison JW, Baumgartner JC, Svec TA. Incidence of pain associated with clinical factors during and after root canal therapy. Part 2. Postobturation pain. J Endod 1983;9(10):434-8.*
3. *Genet JM, Wesselink PR, Thoden van Velzen SK. The incidence of preoperative and postoperative pain in endodontic therapy. Int Endod J 1986;19(5):221-9.*
4. *Alves VO. Endodontic flare-ups: a prospective study. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2010;110(5):e68-72.*
5. *Pak JG, White SN. Pain prevalence and severity before, during, and after root canal treatment: a systematic review. J Endod 2011;37(4):429-38.*
6. *Arias A, de la Macorra JC, Hidalgo JJ, Azabal M. Predictive models of pain following root canal treatment: a prospective clinical study. Int Endod J 2013; 46(8):784-93.*
7. *Gomes MS, Böttcher DE, Scarparo RK, Morgental RD, Waltrick SBG, Ghisi AC, et al. Predicting pre- and postoperative pain of endodontic origin in a southern Brazilian subpopulation: an electronic database study. Int Endod J 2017;50(8):729-39.*
8. *Sathorn C, Parashos P, Messer H. The prevalence of postoperative pain and flare-up in single- and multiple-visit endodontic treatment: a systematic review. Int Endod J 2008;41(2):91-9.*
9. *Walton R, Fouad A. Endodontic interappointment flare-ups: a prospective study of incidence and related factors. J Endod 1992;18(4):172-7.*
10. *Fedorowicz Z, Nasser M, Sequeira-Byron P, de Souza RF, Carter B, Heft M. Irrigants for non-surgical root canal treatment in mature permanent teeth. Cochrane Database Syst Rev 2012;(9):CD008948.*
11. *Nekoofar MH, Sheykhrezae MS, Meraji N, Jamee A, Jamee ASJ, Dummer PMH. Comparison of the effect of root canal preparation by using WaveOne and ProTaper on postoperative pain: a randomized clinical trial. J Endod 2015;41(5):575-8.*
12. *Ehrmann EH, Messer HH, Adams GG. The relationship of intracanal medicaments to postoperative pain in endodontics. Int Endod J 2003;36(12):868-75.*
13. *Peng L, Ye L, Tan H, Zhou X. Outcome of root canal obturation by warm gutta-percha versus cold lateral condensation: a meta-analysis. J Endod. 2007 Feb;33(2):106-9.*
14. *Seltzer S, Naidorf IJ. Flare-ups in endodontics: I. Etiological factors. J Endod 1985;11(11):472-8.*
15. *Siqueira JF Jr. Microbial causes of endodontic flare-ups. Int Endod J 2003;36(7):453-63.*
16. *Caviedes-Bucheli J, Castellanos F, Vasquez N, Ulate E, Munoz HR. The influence of two reciprocating single-file and two rotary-file systems on the apical extrusion of debris and its biological relationship with symptomatic apical periodontitis. A systematic review and meta-analysis. Int Endod J 2016;49(3):255-70.*
17. *De-Deus G, Neves A, Silva EJ, Mendonca TA, Lourenco C, Calixto C, et al. Apically extruded dentin debris by reciprocating single-file and multi-file rotary system. Clin Oral Investig 2015;19(2):357-61.*
18. *Topçuoglu, HS, Akti A, Tunkay O, Dinçer AN, Duzgun S, Topçuoglu G. Evaluation of debris extruded apically during the removal of root canal filling material using ProTaper, D-RaCe, and R-Endo rotary nickel-titanium retreatment instruments and hand files. J Endod 2014; 40(12):2066-9.*
19. *Peters OA. Current challenges and concepts in the preparation of root canal systems: A review. J Endod 2004;30(8):559-67.*
20. *Cheung GS, Liu CS. A retrospective study of endodontic treatment outcome between nickel-titanium rotary and stainless steel hand filing techniques. J Endod 2009; 35(7):938-43.*
21. *Peters OA, Paqué F. Current developments in rotary root canal instrument technology and clinical use: a review. Quintessence Int 2010;41(6):479-88.*
22. *Ahn SY, Kim HC, Kim E. Kinematic effects of nickel-titanium instruments with reciprocating or continuous rotation motion: A systematic review of in vitro studies. J Endod 2016;42(7):1009-17.*
23. *Bürklein S, Schäfer E. Apically extruded debris with reciprocating single-file and full-sequence rotary instrumentation systems. J Endod 2012;38(6):850-2.*
24. *Yared G. Canal preparation using only one Ni-Ti rotary instrument: preliminar observations. Int Endod J 2008; 41(4):339-44.*

25. Berutti E, Chiandussi G, Paolino DS, Scotti N, Cantatore G, Castellucci A, et al. Canal shaping with WaveOne Primary reciprocating files and ProTaper system: a comparative study. J Endod 2012;38(4):505-9.
26. Psimma Z1, Boutsioukis C, Vasiliadis L, Kastrinakis E. A new method for real-time quantification of irrigant extrusion during root canal irrigation ex vivo. Int Endod J 2013;46(7):619-31.
27. Relvas JB, Bastos MM, Marques AA, Garrido AD, Sponchiado EC Jr. Assessment of postoperative pain after reciprocating or rotary NiTi instrumentation of root canals: a randomized, controlled clinical trial. Clin Oral Investig 2016;20(8):1987-93.
28. Hou XM, Su Z, Hou BX. Post endodontic pain following single-visit root canal preparation with rotary vs reciprocating instruments: a meta-analysis of randomized clinical trials. BMC Oral Health 2017;17(1):86.
29. Shokraneh A, Ajami M, Farhadi N, Hosseini M, Rohani B. Postoperative endodontic pain of three different instrumentation techniques in asymptomatic necrotic mandibular molars with periapical lesion: A prospective, randomized, double-blind clinical trial. Clin Oral Investig 2017;21(1):413-8.
30. Higgins JPT, Green S. Cochrane handbook for systematic reviews of interventions. Version 5.1.0; 2011 [cited 2017 Jan 10]. Available from: http://handbook.cochrane.org.
31. Moher D, Liberati A, Tetzlaff J, Altman DG, The PRISMA Group. Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. PLoS Med 2009;6(7):e1000097.
32. Guyatt GH, Oxman AD, Vist GE, Kunz R, Falck-Ytter Y, Alonso-Coello P, et al. GRADE: an emerging consensus on rating quality of evidence and strength of recommendations. BMJ 2008;336(7650):924-6.
33. Gambarini G, Testarelli L, De Luca M, Milana V, Plotino G, Grande NM, et al. The influence of three different instrumentation techniques on the incidence of postoperative pain after endodontic treatment. Ann Stomatol (Roma) 2013;4(1):152-5.
34. Bartols A, Reutter CA, Robra BP, Walther W. Reciproc vs. Hand instrumentation in dental practice: a study in routine care. PeerJ 2016;4:e2182.
35. Bıçakcı H, Çapar İD, Genç S, İhtiyar A, Sütçü R. Influence of Rotary instrumentation with continuous irrigation on pain and neuropeptide release levels: a randomized clinical trial. J Endod 2016; 42(11):1613-9.
36. Pasqualini D, Mollo L, Scotti N, Cantatore G, Castellucci A, Migliaretti G, et al. Postoperative pain after manual and mechanical glide path: a randomized clinical trial. J Endod 2012;38(1):32-6.
37. Al-Jabreen TM. Single visit endodontics: Incidence of post-operative pain after instrumentation with three different techniques: An objective evaluation study. Saudi Dent J 2002;14(3):136-9.
38. Ahmed MA, Dall AQ, Khoso NA, Jouhar R. Comparison of postoperative pain after Protaper rotary and manual step-back root canal preparation techniques in single visit endodontics. J Pak Dent Assoc 2012;21(2):103-7.
39. Kashefinejad M, Harandi A, Eram S, Bijani A. Comparison of single visit post endodontic pain using Mtwo rotary and hand K-file instruments: a randomized clinical trial. J Dent (Tehran) 2016;13(1):10-7.
40. Talebzadeh B, Nezafati S, Rahimi S, Shahi S, Lotfi M, Ghasemi N. Comparison of manual and rotary instrumentation on postoperative pain in teeth with asymptomatic irreversible pulpitis: A randomized clinical trial. Iran Endod J 2016;11(4):273-9.
41. Neelakantan P, Sharma S. Pain after single-visit root canal treatment with two single-file systems based on different kinematics - a prospective randomized multicenter clinical study. Clin Oral Invest 2015;19(9):2211-7.
42. Kherlakian D, Cunha RS, Ehrhardt IC, Zuolo ML, Kishen A, da Silveira Bueno CE. Comparison of the incidence of postoperative pain after using 2 reciprocating systems and a continuous rotary system: A prospective randomized clinical trial. J Endod 2016;42(2):171-6.
43. Krithikadatta J, Sekar V, Sudharsan P, Velumurugan N. Influence of three Ni-Ti cleaning and shaping files on postinstrumentation endodontic pain: A triple-blinded, randomized, controlled trial. J Conserv Dent 2016;19(4):311-6.
44. Pasqualini D, Corbella S, Alovisi M, Taschieri S, Del Fabbro M, Migliaretti G, et al. Postoperative quality of life following single-visit root canal treatment performed by rotary or reciprocating instrumentation: a randomized clinical trial. Int Endod J 2016;49(11):1030-9.
45. Zand V, Salem Milani A, Hassani Dehkharghani A, Rahbar M, Tehranchi P. Treatment of necrotic teeth using two engine-driven systems and patient's postoperative pain: A double-blind clinical trial. Iran Endod J 2016;11(4):267-72.
46. Reddy SA, Hicks ML. Apical extrusion of debris using two hand and two rotary instrumentation techniques. J Endod 1998;24(3):180-3.
47. Capar ID, Arslan H, Akcay M, Ertas H. An in vitro comparison of apically extruded debris and instrumentation times with ProTaper universal, ProTaper next, twisted file adaptive, and HyFlex instruments. J Endod 2014;40(10):1638-41.
48. Arias A, de la Macorra JC, Azabal M, Hidalgo J, Peters AO. Prospective case controlled clinical study of post-endodontic pain after rotary root canal preparation performed by a single operator. J Dent 2015;43(3):389-95.
49. Kustarci A, Akdemir N, Siso SH, Altunbas D. Apical extrusion of intracanal debris using two engine driven and step-back instrumentation techniques: An in vitro-study. Eur J Dent 2008;2(4):233-9.
50. Robinson JP, Lumley PJ, Cooper PR, Grover LM, Walmsley AD. Reciprocating root canal technique induces greater debris accumulation than a continuous rotary technique as assessed by 3-dimensional micro-computed tomography. J Endod 2013;39(8):1067-70.
51. Martinho FC, Gomes AP, Fernandes AM, Ferreira NS, Endo MS, Freitas LF, et al. Clinical comparison of the effectiveness of single-file reciprocating systems and rotary systems for removal of endotoxins and cultivable bacteria from primarily infected root canals. J Endod 2014;40(5):625-9.
52. Sadaf D, Ahmad MZ. Factors associated with postoperative pain in endodontic therapy. Int J Biomed Sci 2014;10(4):243-7.
53. Alí A, Olivieri JG, Duran-Sindreu F, Abella F, Roig M, García-Font M. Influence of preoperative pain intensity on postoperative pain after root canal treatment: A prospective clinical study. J. Dent 2016;45:39-42.
54. Dugas NN, Lawrence HP, Teplitsky P, Friedman S. Quality of life and satisfaction outcomes of endodontic treatment. J Endod 2002;28(12):819-27.
55. Hamasha AA, Hatiwsh A. Quality of life and satisfaction of patients after nonsurgical primary root canal treatment provided by undergraduate students, graduate students and endodontic specialists. Int Endod J 2013;46(12):1131-9.
56. Attar S, Bowles WR, Baisden MK, Hodges JS, McClanahan SB. Evaluation of pretreatment analgesia and endodontic treatment for postoperative endodontic pain. J Endod 2008;34(6):652-5.
57. Figini L, Lodi G, Gorni F, Gagliani M. Single versus multiple visits for endodontic treatment of permanent teeth. Cochrane Database Syst Rev 2007;(4):CD005296.
58. Su Y, Wang C, Ye L. Healing rate and post-obturation pain of single-versus multiple-visit endodontic treatment for infected root canals: a systematic review. J Endod 2011; 37(2):125-32.
59. Wong AW, Zhang C, Chu CH. A systematic review of nonsurgical single-visit versus multiple-visit endodontic treatment. Clin Cosmet Investig Dent 2014;6:45-56.
60. Ferreira-Valente MA, Pais-Ribeiro JL, Jensen MP. Validity of four pain intensity rating scales. Pain 2011;152(10):2399-404.
61. Read JK, McClanahan SB, Khan AA, Lunos S, Bowles WR. Effect of Ibuprofen on masking endodontic diagnosis. J Endod 2014;40(8):1058-62.
62. Keiser K, Byrne BE. Endodontic pharmacology. In: Hargreaves KM, Cohen S. Cohen's Pathways of the Pulp. 10th ed. St Louis: Mosby Elsevier; 2011, pp. 671-90.

ORIGINAL ARTICLE/**ARTICOLO ORIGINALE**

Effect of Emdogain coated endodontic materials on viability of human dental pulp stem cells (HDPSCs)

Effetto dei materiali endodontici rivestiti di Emdogain sulla vitalità delle cellule staminali pulpari umane (HDPSCs)

KEYWORDS
Mineral Trioxide Aggregate, Calcium Enriched Mixture Cement, Biodentine, Emdogain, Cell Survival, Human Dental Pulp Stem Cells

PAROLE CHIAVE
Mineral Trioxide Aggregate, cementi a base di calcio, biodentine, emdogain, vitalità cellulare, cellule pulpari staminali umane

Hamed Karkehabadi[1], Shahriar Shahriari[1], Rezvan Najafi[2], Elham Khoshbin[1], Hadiseh Abbaspourrokni[1]*, Zahra Pakseresht[1]

[1]Department of Endodontics, Dental School, Hamadan University of Medical Sciences, Hamadan, Iran
[2]Research center of molecular medicine, Hamadan University of Medical Sciences, Hamadan, Iran

Received 2019, April 10

Accepted 2019, September 4

Abstract

Aim: *Biocompatibility is an important characteristic of dental pulp capping agents. This study aimed to assess the effect of mineral trioxide aggregate (MTA), calcium enriched mixture (CEM) cement and Biodentine with/without Emdogain (EMD) on the viability of human dental pulp stem cells (HDPSCs).*
Methodology: *In this in vitro study, HDPSCs were isolated from the root canal of an extracted impacted third molar tooth and cultured. The cells were exposed to freshly prepared endodontic cements in six groups of MTA, MTA plus EMD, CEM cement, CEM cement plus EMD, Biodentine and Biodentine plus EMD in 24-well plates for 24, 48 and 168 hours (6 wells/repetitions for each material group at each time point). Cell viability was evaluated at each time point using the methyl thiazolyl tetrazolium (MTT) assay. Data were analyzed using the Kruskal-Wallis and Mann-Whitney tests.*
Results: *Cell viability was not significantly different at different time points in any endodontic cement group (p>0.05) except for CEM cement/EMD group (p=0.00). At 24 hours, MTA/EMD and MTA showed the highest cell viability (p=0.001). Similar results were obtained at 48 hours (p=0.000). At 168 hours, MTA/EMD and CEM cement/EMD showed the highest cell viability (p=0.000). Addition of EMD had no significant effect on cell viability in any cement group at 24 or 48 hours. However, addition of EMD to MTA and CEM cement increased the viability of HDPSCs at 168 hours.*
Conclusions: *Addition of EMD to MTA and CEM cement can increase the viability of HDPSCs at 7 days.*

Obiettivo: *la biocompatibilità è una caratteristica importante dei materiali per l'incappucciamento pulpare. Questo studio valutava l'effetto del mineral trioxide aggregate (MTA), del cemento con miscela arricchita di calcio (CEM) e Biodentine con/senza Emdogain (EMD) sulla vitalità delle cellule staminali umane della polpa dentale (HDPSC).*
Metodologia: *in questo studio in vitro le HDPSC sono state isolate dal canale radicolare di un terzo molare estratto e successivamente coltivate. Le cellule sono state esposte, in piastre da 24 pozzetti per 24, 48 e 168 ore, a sei gruppi di cementi endodontici appena preparati: MTA, MTA più EMD, cemento CEM, cemento CEM più EMD, Biodentine e Biodentine più EMD. La vitalità cellulare è stata valutata usando il methyl thiazolyl tetrazolium (MTT) assay. I dati sono stati analizzati utilizzando i test di Kruskal-Wallis e Mann-Whitney.*
Risultati: *la vitalità cellulare non è risultata significativamente differente tra i vari cementi ai tempi analizzati (p>0,05), fatta eccezione per il cemento CEM/gruppo EMD (p=0,00). A 24 ore, MTA/EMD e MTA hanno mostrato la massima vitalità cellulare (p=0,001). Risultati simili sono stati ottenuti a 48 ore (p=0,000). A 168 ore, MTA/EMD e CEM cemento/EMD hanno mostrato la massima vitalità cellulare (p=0,000). L'aggiunta di EMD non ha avuto effetti significativi sulla vitalità cellulare per nessun gruppo di cemento a 24 o 48 ore. Tuttavia, l'aggiunta di EMD a MTA e cemento CEM ha aumentato la vitalità delle HDPSC a 168 ore.*
Conclusioni: *l'aggiunta di EMD a MTA e CEM può aumentare la vitalità degli HDPSC a 7 giorni.*

Introduction

Regenerative endodontics refers to tissue engineering procedures to regenerate the lost or damaged tissues such as the dental pulp, dentin or cementum. In this approach, the differentiation potential of human dental pulp stem cells (HDPSCs) or progenitor cells of a mature pulp is employed for regeneration of dental structure (1). Regenerative endodontic procedures were first introduced in 1952 when a type of calcium hydroxide

Corresponding author
Hadiseh Abbaspourrokni, Postgraduate student of Endodontics, Department of Endodontics, Dental School, Hamadan University of Medical Sciences, Hamadan, Iran.
Email: drhadisehabbaspourrokni@yahoo.com | Fax: +988138381085 | Phone: +989112234269

Peer review under responsibility of Società Italiana di Endodonzia

10.32067/GIE.2019.33.02.04

cement was used to cover the pulp tissue following vital pulp amputation (2).
Vital pulp therapy minimizes the trauma to the pulp tissue by protecting the pulp against the toxic effects of bacterial products as well as mechanical, thermal and chemical stimuli (3). It seals the pulp tissue and induces the formation of tertiary dentin following reversible pulpitis (3). Vital pulp therapy is performed aiming to cover the pulp tissue with a suitable capping agent and promote the dentinogenesis potential of dental pulp cells (3).
Vital pulp therapy seems to be a superior treatment approach for immature teeth with pulp exposure to allow root development prior to the occurrence of pulp necrosis. In vital pulp therapy, dental materials are placed in direct contact with dental pulp. Regeneration of the dentin-pulp complex following severe trauma involves differentiation of HDPSCs to secondary odontoblasts and subsequent dentinogenesis (3-5). Thus, attempts are ongoing to find an ideal endodontic material for vital pulp therapy.
HDPSCs play a fundamental role in regeneration process by differentiating into odontoblast-like cells. These cells are capable of proliferation and differentiation into different cell lines. The ability of dental materials to enhance differentiation and maturation of these cells determines their biocompatibility (6). In vital pulp therapy, the interaction of HDPSCs with the pulp capping agents affects their proliferation and differentiation capacity (7, 8). An ideal material for pulp capping should be able to trigger the healing process and induce dentin-pulp complex regeneration (9). Several materials have been used as pulp capping agents such as modified glass ionomer, tricalcium phosphate, hydrophilic resins and calcium hydroxide. The success of different pulp capping agents is determined based on the thickness and morphology of the formed dentinal bridge, severity of pulpal inflammation, presence of odontoblasts and biocompatibility of the material (10).
Mineral trioxide aggregate (MTA) is a tricalcium silicate-based cement with more reliable effects compared to those of previously applied materials. MTA is commonly used as a root end filling material and a pulp capping agent and also for perforation repair and apexification (3, 10). MTA induces hard tissue formation in cases with pulp exposure (11). Dentinal bridge formation in presence of MTA occurs faster compared to other materials (11). MTA induces the proliferation of undifferentiated cells for the formation of dentinal bridge by decreasing inflammation (10, 12). Also, direct contact of MTA with HDPSCs causes their differentiation to odontoblast-like cells (13). MTA is commonly used for vital pulp therapy, regenerative endodontic procedures, perforation repair, root end filling and apexification due to its excellent properties such as hydrophilicity, adequate radiopacity, high pH, polymerization expansion, low solubility and optimal biocompatibility (13, 14). However, discoloration potential, difficult handling, presence of toxic compounds in its composition, long working time and high cost are among its drawbacks (15, 16).
Biodentine is a recently introduced tricalcium silicate-based cement with mechanical properties resembling those of dentin (17). It enhances pulp regeneration and mineralization by inducing the formation of reactive dentin and dentinal bridge (18). It is supplied in the form of a powder containing tricalcium silicate, calcium silicate, calcium carbonate and zirconium oxide as opaquer and a liquid containing calcium chloride in an aqueous solvent along with polycarboxylate (19). Its short setting time (a few minutes versus a couple of hours for MTA), superior mechanical properties and optimal sealing ability in contact with dentin are among its favorable properties (20). Biodentine was first introduced as a replacement for dentin and the manufacturer claims that it induces the formation of tertiary dentin. However, it can also be used for vital pulp therapy, perforation repair and as a retrograde root filling material in endodontic surgery (21). It can induce the proliferation and differentiation of HDPSCs and can be used in direct contact with dental pulp in regenerative treatments (22).

Enamel Matrix Derivative (Emdogain/EMD) is a material derived from the pig enamel matrix, Amelogenin is its main constituent. EMD can induce migration, attachment and proliferation of periodontal ligament cells (22, 23) and can efficiently participate in regeneration of cementum, periodontal ligament and bone (24). EMD is believed to exert its effects by provision of extracellular matrix and induction of cell adhesion and differentiation (25). Recently, EMD was proposed for induction of dental pulp regeneration (26, 27). A previous study showed that simultaneous exposure of DPSCs to MTA and EMD results in differentiation of stem cells to odontoblast-like cells, which highlights the synergistic effect of these two materials (28).

Calcium enriched mixture (CEM) cement contains calcium oxide, calcium phosphate, calcium carbonate, calcium silicate, calcium sulfate, calcium hydroxide and calcium chloride, and has clinical properties similar to those of MTA (29, 30). It releases calcium hydroxide during and after setting., it has shorter setting time, higher flow and lower film thickness than MTA, it can form hydroxyapatite by use of intrinsic ions and can be applied in contact with vital pulp in endodontic procedures (29, 31-33).

The toxic effects of endodontic cements on stem cells have been previously studied (28, 34). However, search of the literature yielded no previous study on the comparative effect of CEM cement, MTA and Biodentine with/without EMD on the viability of HDPSCs. Thus, this study aimed to assess and compare the effect of CEM cement, MTA and Biodentine with/without EMD on the viability of HDPSCs.

Materials and Methods

Cell culture

In this in vitro study, each experiment was repeated six times (35, 36). The study was approved in the Ethics Committee of Hamadan University of Medical Sciences IR.UMSHA.REC.1397.61. The HDPSCs were isolated from two surgically extracted impacted caries-free immature third molars of a systemically healthy patient after obtaining informed consent (18-25 years of age). Immediately after extraction, the teeth were rinsed and stored in sterile phosphate buffered saline (PBS) (Gibco, GrandIsland, NY, USA). Stem cells were isolated from the root canals by enzymatic digestion using type I collagenase (2 mg/mL; Worthlington Biomedical, Lakewood, NJ, USA) and were transferred to Dulbecco's modified Eagle's medium (Gibco, GrandIsland, NY, USA). The cells were then cultured again in a culture medium containing 15% fetal bovine serum (Gibco, GrandIsland, NY, USA) and 1% Penicillin/Streptomycin (Gibco, GrandIsland, NY, USA). The culture medium was refreshed every 2-3 days during the process of cell culture. After four passages, a homogenous population of cells was obtained. The surface antigens of HDPSCs were analyzed by flow cytometry (Becton Dickinson, San Jose, CA), with 10,000 events being counted for each case. Cells were trypsinized and incubated in phosphate-buffered saline (PBS) with primary antibodies against CD34 (Biolegend, CA, USA, cat # SC-51540), CD90 (Biolegend, CA, USA, cat #SC-53456), CD105 (Biolegend, CA, USA, cat # SC-71043) as mesenchymal cells marker and CD45 (Biolegend, CA, USA, cat #SC-70686) as hematopoietic marker. Insert plates (pore size: 4.0 µm; SPL Life Science, Gyeonggi-do, South Korea) were used to expose the cells to endodontic cements.

Preparation of endodontic cements

CEM cement (BioniqueDent, Tehran, Iran), Biodentine (Septodont, Saint-Maur-des-Fosses, France) and MTA (Dentsply Tulsa Dental Specialties, Tulsa, OK, USA) were prepared according to the manufacturers' instructions under sterile conditions. Biodentine, MTA and CEM cement were mixed and applied in paraffin wax molds with 10 mm diameter and 1 mm thickness, compressed and incubated at 37 °C and 96% humidity for 10 minutes to set. EMD gel (30 mg/mL and 0.7 mL) (Biora AB, Malmo, Sweden) was diluted with sterile distilled water to obtain 100 µg/mL concentration. The study groups were as follows: (I) Biodentine, (II) Biodentine/EMD, (III) CEM cement, (IV) CEM cement/EMD, (V) MTA, (VI) MTA/EMD, and (VII) control group (cells were not exposed to any material).

Table 1

Comparative effect of Biodentine, Biodentine/EMD, CEM cement, CEM cement/EMD, MTA and MTA/EMD on the viability of HDPSCs at 24, 48 and 168 hours

Groups	24 hours		48 hours		168 hours	
	Mean	Std. deviation	Mean	Std. deviation	Mean	Std. deviation
MTA/EMD	128.68*	31.36	103.25*	7.00	145.64*	19.61
MTA	99.82*	8.23	98.53*	18.99	71.95	30.97
Biodentine/EMD	48.16	11.09	32.10	12.92	27.27	4.13
Biodentine	44.30	21.52	33.31	19.21	40.42	27.52
CEM cement/ EMD	69.85	26.50	39.75	8.75	178.75*	24.44
CEM	38.23	10.78	34.91	11.07	36.15	30.72
P value	0.001		0.000		0.000	

In groups II and IV, the surface of set Biodentine, CEM cement and MTA samples was coated with EMD.

To assess the effect of endodontic cements, about 5,000 cells were cultured in each well of insert 24-well plates (SPL Life Science, Gyeonggi-do, South Korea). The plates allowed indirect contact of materials with cells to prevent cell lysis. After preparation of materials as explained earlier, 1 mg of each material was added to each well of a 24-well plate.

The inserts were removed after 24, 48 and 168 hours (34) and the methyl thiazolyl tetrazolium (MTT) salt (Sigma Aldrich, St. Louis, MO, USA) was added to the wells. The intensity of the produced color in this test correlates with the number of viable cells. The cells were incubated (Binder, NY, USA) for 24 hours. The medium was then replaced and the materials were added to the culture medium. After 24 hours, the plates were removed from the incubator and 10 mL of the MTT solution and 90 mL of alpha-Minimum Essential Medium Eagle supplemented with 10% fetal bovine serum were added to each well. The plates were then incubated at 37 °C for 4 hours. The overlaying medium was gently removed and 100 mL of dimethyl sulfoxide (Gibco BRL, Grand Island, NY, USA) was added to each well. After dissolution of formazan crystals, the optical density was read at 540 to 690 nm wavelength using an ELISA reader (BioTek, VT, USA).

Data were first analyzed using descriptive statistics. The three types of cements were compared in 6 groups using the Kruskal-Wallis test. The Mann Whitney U test was applied for pairwise comparisons. All statistical analyses were carried out using SPSS version 24 (SPSS Inc., IL, USA). $P<0.05$ was considered statistically significant.

Results

Table 1 shows the effect of different endodontic cements on the viability of DPSCs after 24, 48 and 168 hours of exposure. The Kruskal-Wallis test showed no significant difference in cell viability at different time points in Biodentine ($p=0.843$), Biodentine/EMG ($p=0.98$), CEM cement ($p=0.979$), MTA ($p=0.277$) or MTA/EMD groups ($p=0.132$). But the difference in this respect was significant in CEM cement/

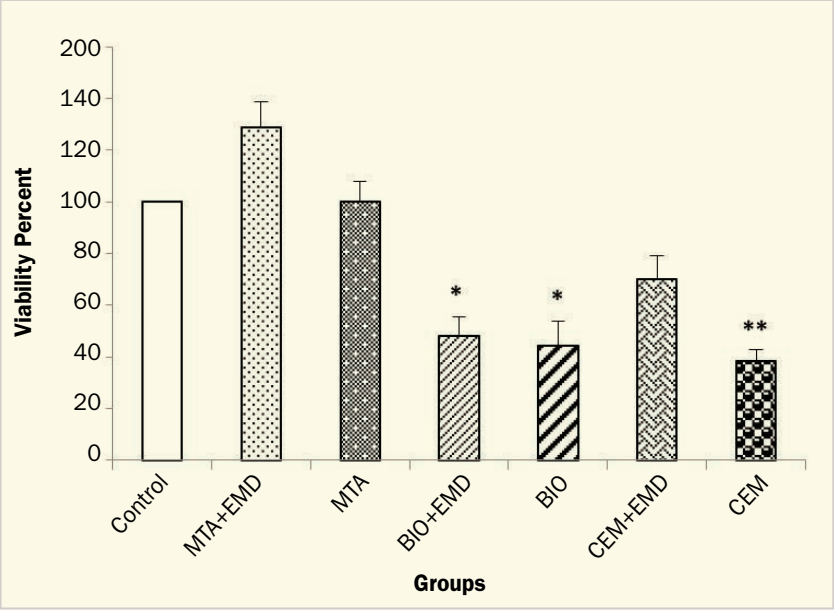
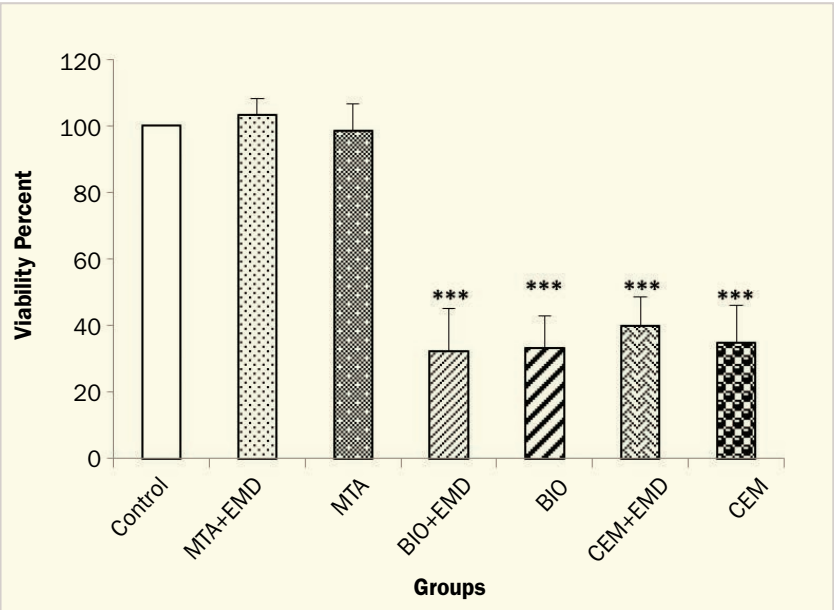


Figure 1
Percentage of HDPSC viability after 24 hours of exposure to endodontic cements

EMD group (p=0.00). Comparison of cell viability following exposure to different materials revealed significant differences among the groups at different time points such that at 24 hours, MTA/EMD and MTA showed the highest cell viability (p=0.001). Similar results were obtained at 48 hours (p=0.000). At 168 hours, MTA/EMD and CEM cement/EMD groups showed the highest cell viability (p=0.000).

Figures 1-3 show the percentage of cell viability in the six groups at 24, 48 and 168 hours. As shown, addition of EMD had no significant effect on cell viability in any cement group at 24 or 48 hours. However, addition of EMD to MTA and CEM cement increased the viability of stem cells at 168 hours.

Figure 2
Percentage of HDPSC viability after 48 hours of exposure to endodontic cements



Discussion

Recently, use of EMD for dental pulp capping has gained attention. Since EMD is in gel form, it does not quickly spread into the pulp tissue (37, 38). Evidence shows that EMD accelerates the formation of reparative dentin and odontoblastic differentiation in pulp capping procedures (39, 40). This study aimed to assess the effect of EMD in combination with commonly used pulp capping agents on the viability of HDPSCs. The results showed that addition of EMD had no significant effect on cell viability in presence of any of the pulp capping agents at 24 or 48 hours. However, after 168 hours (7 days), cell viability in MTA and CEM cement groups significantly increased by the addition of EMD. However, cell viability did not significantly increase in presence of Biodentine/EMD. In general, the highest cell viability was noted in MTA and MTA/EMD groups at 24 and 48 hours while the highest cell viability at 168 hours belonged to the MTA/EMD and CEM cement/EMD groups. The results showed that addition of EMD to MTA and CEM cement resulted in higher level of cell viability; however, this effect became significant after 7 days. A previous study on the toxic effects of endodontic cements namely Biodentine and MTA on mouse fibroblasts revealed that endodontic cements stabilize over time and their toxicity decreases (41). Their findings were in agreement with ours despite the use of a different cell line. Significant effect of addition of EMD to endodontic cements only after 7 days can be due to the fact that cements are toxic during the first 24 and 48 hours but they become chemically stable after 7 days and EMD can then exert its effect.

Our results revealed that at almost all time points, the cell viability in Biodentine and CEM cement groups was less than that in

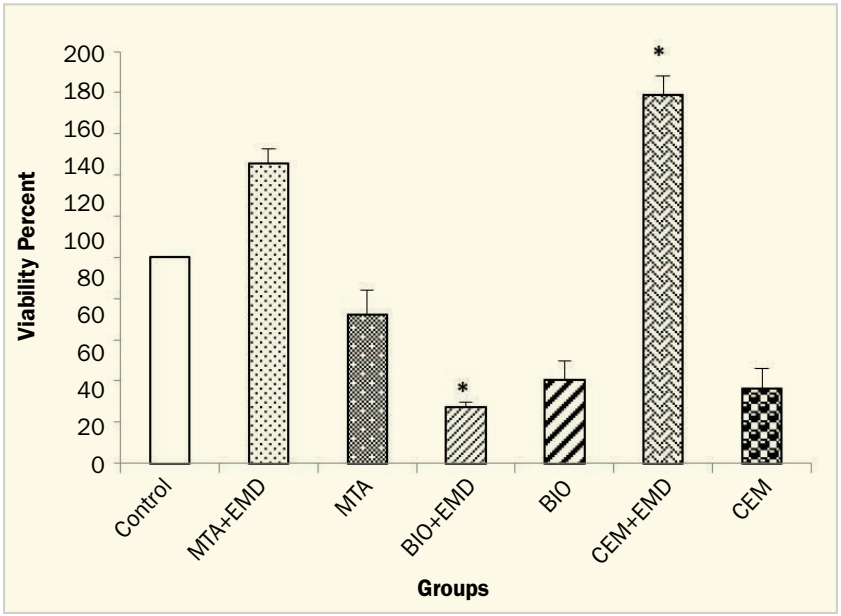


Figure 3
Percentage of HDPSC viability after 168 hours of exposure to endodontic cements

MTA groups. As it has been shown by several investigations, MTA has long term seal, acceptable biocompatibility and dentinal bridge formation which make it the gold standard for vital pulp therapies(42). Similarly, Jung et al. (43) demonstrated that the cell viability in presence of different endodontic cements was not significantly different on day 1 but at 3 days, the cell viability in presence of MTA was significantly greater than that in presence of Biodentine, which was in line with our findings. They measured the amount of heavy metals released from the cements into the surrounding environment and found that the amount of heavy metals released from Biodentine was higher than that released from MTA, which explains the higher cytotoxicity of Biodentine than MTA. They added that Biodentine increased cell viability after 7 days. Another study evaluated the cytotoxicity of Biodentine, glass ionomers and MTA after 1, 3 and 7 days of exposure and concluded that the toxicity of Biodentine and MTA was similar and less than that of glass ionomers (44). This finding was different from our result, which may be attributed to the fact that the cytotoxicity of a material depends on many factors such as the type and concentration of material, passage of time and the type of culture medium used. For example, MSCs derived from dental pulp, periapical cyst, dental follicle and periodontal ligament dreived msc express CD146 as the cell surface antigen. The expression of CD146 level significantly affects on MSCs proliferation and differentiation capacity. Previous study has shown that the number of CD146- positive cells decreases following multiple passage. They found that decreased CD146 expression in human periapical cyst mesenchymal stem cells (hPCy-MSCs) is associated with enhanced cell proliferation, self-renewal, osteogenic differentiation capacity and stemness genes expression (45).

Another factor affects the survival and differentiation of stem cells is the type of scaffold in tissue engineering which was not a variable in this study (46).

In our study, the cytotoxicity of MTA was lower than that of Biodentine and CEM cement at all time points. Saberi et al. (34) evaluated the toxic effects of Biodentine, CEM cement, octacalcium phosphate and MTA on stem cells of the apical papilla. They found that the cytotoxicity of CEM cement was the highest after 24 hours while MTA showed the highest cytotoxicity at 48 and 168 hours. It should be noted that at 168 hours, CEM cement showed the lowest cytotoxicity. In our study, CEM cement/EMD and MTA/EMD showed the least cytotoxicity at 168 hours. They explained that application of calcium silicate-based cements leads to continuous formation of calcium silicate hydrate and deposition of calcium carbonate phosphate. Release of calcium ions can cause toxic inflammatory reactions. On the other hand, release of this ion from silicate cements is important for the viability of mesenchymal stem cells (19). This ion is capable of signaling and plays an important role in regulation of cellular activities. The migration of stem cells is also affected by calcium ions (47, 48). It has been shown that Calcium silicate cements continuously release calcium ions (49). CEM cement, MTA and Biodentine are among the calcium silicate-based cements. Thus, difference in cell viability in presence of different cements at different time points may be due to the release of calcium ions, which has a double action. In our

study, the highest cell viability was noted in MTA and MTA/EMD groups at 24 and 48 hours and CEM cement/EMD group at 168 hours, which indicates that at almost all time points, groups with EMD had the least cytotoxicity and highest cell viability. However, this effect was only significant at 7 days. As explained earlier, it can be due to the high cytotoxicity of materials at 24 and 48 hours, which would mask the efficacy of EMD. On the other hand positive effect of EMD in combination with endodontic cements is dependent on its molecular mechanisms and effects on growth factors releasing (50).

The current results highlight the efficacy of EMD in combination with MTA and CEM cement to increase the viability of HDPSCs. Future studies are required to assess the effect of addition of EMD to endodontic cements on the viability of other cell lines. This study had an in vitro design. Thus, generalization of results to the clinical setting must be done with caution. Further clinical studies are required to assess the efficacy of these compounds in the clinical setting.

Conclusions

Within the limitations of this in vitro study, the results showed lower cell viability in presence of Biodentine compared to MTA and CEM cement. Addition of EMD to endodontic cements had no significant effect on the viability of DPSCs at 24 or 48 hours but it significantly increased cell viability in presence of MTA and CEM cement at 7 days. For further experiments more dental pulp to obtain more MSCs is needed. Data from the present study showed that EMD can be used with endodontic cements in vital pulp therapies and regenerative endodontic treatments, but studies evaluating the in vivo effect of EMD coated cements on HDPSCs viability are needed.

Acknowledgements

The authors would like to extend their gratitude to the Deputy of Research at Hamadan University of Medical Sciences and the Dental Research Center for the financial support provided.

Conflict of interest

The authors deny any conflict of interest.

Clinical relevance

Stem cells play an important role in regenerative endodontic, so it is critical to enhance viability and differentiation of these cells. Coating endodontic materials with Emdogain increased cell viability and can be used in vital pulp therapies and regenerative endodontic treatments.

References

1. *Tziafas D, Kodonas K. Differentiation potential of dental papilla, dental pulp, and apical papilla progenitor cells. J Endod 2010;36:781-9.*
2. *Hermann B. On the reaction of the dental pulp to vital amputation and calxyl capping. DZZ. 1952;7:1446-7.*
3. *Schröder U. Effects of calcium hydroxide-containing pulp-capping agents on pulp cell migration, proliferation, and differentiation. JDR 1985;64:541-8.*
4. *Rafter M. Apexification: a review. Dent Traumatol 2005;21:1-8.*
5. *Andreasen JO, Farik B, Munksgaard EC. Longterm calcium hydroxide as a root canal dressing may increase risk of root fracture. Dent Traumatol 2002;18:134-7.*
6. *Gronthos S, Mankani M, Brahim J et al. Postnatal human dental pulp stem cells (DPSCs) in vitro and in vivo. Proc Natl Acad Sci 2000;97:13625-30.*
7. *Asgary S, Eghbal MJ, Parirokh M et al. A comparative study of histologic response to different pulp capping materials and a novel endodontic cement. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2008;106:609-14.*
8. *Cotti E, Mereu M, Lusso D. Regenerative treatment of an immature, traumatized tooth with apical periodontitis: report of a case. J Endod 2008;34:611-6.*
9. *Murray PE, Garcia-Godoy F, Hargreaves KM. Regenerative endodontics: a review of current status and a call for action. J Endod 2007;33:377-90.*
10. *Holland R, Otoboni Filho JA, de Souza V et al. Mineral trioxide aggregate repair of lateral root perforations. J Endod 2001;27:281-4.*
11. *Andelin WE, Shabahang S, Wright K, Torabinejad M. Identification of hard tissue after experimental pulp capping using dentin sialoprotein (DSP) as a marker. J Endod 2003;29:646-50.*

12. Nair P, Duncan H, Pitt Ford T, Luder H. histological, ultrastructural and quantitative investigations on the response of healthy human pulps to experimental capping with Mineral Trioxide Aggregate: a randomized controlled trial. Int Endod J 2009;42:422-44.
13. Paranjpe A, Zhang H, Johnson JD. Effects of mineral trioxide aggregate on human dental pulp cells after pulp-capping procedures. J Endod 2010;36:1042-7.
14. Madfa AA, Al-Sanabani FA, Al-Kudami NHA-Q. Endodontic repair filling materials: A review article. Br J Med Med Res 2014;4:3059.
15. 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.
16. Parirokh M, Torabinejad M. Mineral trioxide aggregate: a comprehensive literature review-part I: chemical, physical, and antibacterial properties. J Endod 2010;36:16-27.
17. Luo Z, Kohli MR, Yu Q et al. Biodentine induces human dental pulp stem cell differentiation through mitogen-activated protein kinase and calcium-/calmodulin-dependent protein kinase II pathways. J Endod 2014;40:937-42.
18. Grech L, Mallia B, Camilleri J. Characterization of set Intermediate Restorative Material, B iodentine, B ioaggregate and a prototype calcium silicate cement for use as root-end filling materials. Int Endod J 2013;46:632-41.
19. Lee B-N, Lee K-N, Koh J-T et al. Effects of 3 endodontic bioactive cements on osteogenic differentiation in mesenchymal stem cells. J Endod 2014;40:1217-22.
20. Pradelle-Plasse N, Xuan-Vin CT Physico-chemical properties of Biodentine in Biocompatibility or cytotoxic effects of dental composites: Coxmoor Publishing, Oxford; 2009. p. 222.
21. Soundappan S, Sundaramurthy JL, Raghu S, Natanasabapathy V. Biodentine versus mineral trioxide aggregate versus intermediate restorative material for retrograde root end filling: an invitro study. J Dent (Tehran) 2014;11:143.
22. Miron RJ, Caluseru OM, Guillemette V et al. Influence of enamel matrix derivative on cells at different maturation stages of differentiation. PLoS One 2013;8:e71008.
23. Amin HD, Olsen I, Knowles JC et al. Effects of enamel matrix proteins on multi-lineage differentiation of periodontal ligament cells in vitro. Acta Biomater 2013;9:4796-805.
24. Gestrelius S, Andersson C, Lidström D et al. In vitro studies on periodontal ligament cells and enamel matrix derivative. J Clin Periodontol 1997;24:685-92.
25. Suzuki N, Ohyama M, Maeno M et al. Attachment of human periodontal ligament cells to enamel matrix-derived protein is mediated via interaction between BSP-like molecules and integrin $\alpha v\beta 3$. J Periodontol 2001;72:1520-6.
26. Johnson DL, Carnes D, Steffensen B, Cochran DL. Cellular effects of enamel matrix derivative are associated with different molecular weight fractions following separation by size-exclusion chromatography. J Periodontol 2009;80:648-56.
27. Ye L, Le T, Zhu L et al. Amelogenins in human developing and mature dental pulp. JDR 2006;85:814-8.
28. Min K-S, Yang S-H, Kim E-C. The combined effect of mineral trioxide aggregate and enamel matrix derivative on odontoblastic differentiation in human dental pulp cells. J Endod 2009;35:847-51.
29. Asgary S, Shahabi S, Jafarzadeh T et al. The properties of a new endodontic material. J Endod 2008;34:990-3.
30. Gambarini G, Testarelli L, Al-Sudani D et al. In vitro evaluation of the cytotoxicity of different root canal filling materials. Todentj 2011;5:29.
31. Asgary S, Nazarian H, Khojasteh A, Shokouhinejad N. Gene expression and cytokine release during odontogenic differentiation of human dental pulp stem cells induced by 2 endodontic biomaterials. J Endod 2014;40:387-92.
32. Ghasemi N, Rahimi S, Lotfi M et al. Effect of mineral trioxide aggregate, calcium-enriched mixture cement and mineral trioxide aggregate with disodium hydrogen phosphate on BMP-2 production. Iran Endod J 2014;9:220.
33. Mozayeni MA, Milani AS, Marvasti LA, Asgary S. Cytotoxicity of calcium enriched mixture cement compared with mineral trioxide aggregate and intermediate restorative material. AEJ 2012;38:70-5.
34. Saberi EA, Karkehabadi H, Mollashahi NF. Cytotoxicity of various endodontic materials on stem cells of human apical papilla. Iran Endod J 2016;11:17.
35. Gestrelius S, Andersson C, Johansson AC et al. Formulation of enamel matrix derivative for surface coating: kinetics and cell colonization. J Clin Periodontol. 1997;24:678-84.
36. Yoshino P, Nishiyama CK, Modena KCdS et al. In vitro cytotoxicity of white MTA, MTA Fillapex® and Portland cement on human periodontal ligament fibroblasts. Braz Dent J 2013;24:111-6.
37. Nakashima M, Akamine A. The application of tissue engineering to regeneration of pulp and dentin in endodontics. J Endod 2005;31:711-8.
38. Jepsen S, Albers H-K, Fleiner B et al. Recombinant human osteogenic protein-1 induces dentin formation: an experimental study in miniature swine. J Endod 1997;23:378-82.
39. Nakamura Y, Hammarström L, Lundberg E et al. Enamel matrix derivative promotes reparative processes in the dental pulp. Adv Dent Res 2001;15:105-7.
40. Ishizaki NT, Matsumoto K, Kimura Y et al. Histopathological study of dental pulp tissue capped with enamel matrix derivative. J Endod 2003;29:176-9.
41. Ford Trp, Torabinejad M, Abedi HR et al. Using mineral trioxide aggregate as a pulp-capping material. J Am Dent Assoc 1996;127:1491-4.
42. Cervino G, Fiorillo L, Spagnuolo G. et al. Interface between MTA and dental bonding agents: Scanning electron microscope evaluation. J Int Soc Prev Community Dent 2017;7:64.
43. Jung RE, Windisch SI, Eggenschwiler AM et al. A randomized controlled clinical trial evaluating clinical and radiological outcomes after 3 and 5 years of dental implants placed in bone regenerated by means of GBR techniques with or without the addition of BMP2. Clin Oral Implants Res 2009;20:660-6.
44. Zhou H-m, Shen Y, Wang Z-j et al. In vitro cytotoxicity evaluation of a novel root repair material. J Endod 2013;39:478-83.
45. Paduano F, Marrelli M, Palmieri F, Tatullo M. CD146 expression influences periapical cyst mesenchymal stem cell properties. Stem Cell Rev 2016;12:592-603.
46. Tatullo M, Spagnuolo G, Codispoti B et al. PLA-based mineral-doped scaffolds seeded with human periapical cyst-derived MSCs: a Promising tool for Regenerative Healing in Dentistry. Materials 2019;12:597.
47. Wondergem R, Ecay TW, Mahieu F et al. HGF/SF and menthol increase human glioblastoma cell calcium and migration. Biochem Biophys Res Commun 2008;372:210-5.
48. Aguirre A, González A, Planell J, Engel E. Extracellular calcium modulates in vitro bone marrow-derived Flk-1+ CD34+ progenitor cell chemotaxis and differentiation through a calcium-sensing receptor. Biochem Biophys Res Commun 2010;393:156-61.
49. Gandolfi M, Spagnuolo G, Siboni F et al. Calcium silicate/calcium phosphate biphasic cements for vital pulp therapy: chemical-physical properties and human pulp cells response. Clin Oral Investig 2015;19:2075-89.
50. Paduano F, Marrelli M, Amantea M et al. Adipose tissue as a strategic source of mesenchymal stem cells in bone regeneration: A topical review on the most promising craniomaxillofacial applications. Int J Mol Sci 2017;18:2140.

ORIGINAL ARTICLE/**ARTICOLO ORIGINALE**

Ni-Ti alloy remnants after root canal preparation with Ni-Ti engine-driven files: a preliminary report

KEYWORDS
Root Canal, Ni-Ti Instruments, Scanning Electron Microscope, EDX Analysis

PAROLE CHIAVE
Canale radicolare, strumenti Ni-Ti, microscopio elettronico a scansione, analisi EDX

Stefan Vasile Stefanescu[1*], Mugur George Popescu[2], Lucian Barbu Tudoran[3], Haider Al-Saffar[4]

[1]My Dentist, Europa House, Stoneclough Rd., Manchester M26 1GG, United Kingdom
[2]V.Goldis University of West, 86 L.Rebreanu strt, Arad, Romania
[3]Babes-Bolyai University, 1 M.Kogalniceanu strt., Cluj-Napoca, Romania
[4]My Dentist, Europa House, Stoneclough Rd., Manchester M26 1GG, United Kingdom

Received 2019, February 19

Accepted 2019, October 14

Residui di lega di Ni-Ti dopo la preparazione del canale radicolare con file rotanti in Ni-Ti: uno studio preliminare

Abstract

Aim: *Aim of the present study was to assess any signs of Ni-Ti alloy remnants in the root canal after preparation and investigate if this aspect may be influenced by the steam sterilization of the files.*
Materials and Methods: *20 extracted upper first premolars with complete root formation and apical foramina and three kits of BioRace instruments (FKG, Le Chaux-of-Fonds, Switzerland) were used in the present study. The first BioRace kit was used to prepare 10 teeth (20 canals), without sterilization between the root canal preparations, while the second sample group was subjected to steam sterilization after each tooth (two canals) prepared. The third kit of instruments was used as a control group. Files were then analyzed by means of scanning electron microscope (SEM) using magnifications between 500 and 4.000x. Images were taken on sections D1-D8 of each file. Files weight was measured using a precision weight scale with readability of 0,001g to quantify the possible alloy loss and file degradation occurred during their use. Teeth were then sectioned on their length and submitted to EDX analysis in search of possible alloy particles within the root canals, using magnifications between 30 and 300x. In the same manner, the irrigant used during the root shaping was collected and analyzed. Differences in weight were statistically analysed using the independent sample Student t-test (p<0.05).*
Results: *No file separation was registered in both groups analyzed. Weight measurements and SEM micrographs showed signs of higher degradation for samples from group 2. EDX analysis showed some Ni-Ti particles in roots prepared in group 2.*
Conclusions: *Metal strips, weight loss and micro-fractures appeared on the files subjected to steam sterilization between the uses. Ni-Ti particles detached from files, during their intra-canal use were found on the root canal walls.*

Obiettivi: *il presente studio ha lo scopo di valutare eventuali segni di residui di lega di Ni-Ti nel canale radicolare dopo la preparazione e indagare se questo aspetto può essere influenzato dalla sterilizzazione dei file.*
Metodologia: *20 primi premolari superiori estratti con completa formazione delle radici e forame apicale e tre kit di strumenti BioRace (FKG, Le Chaux-of-Fonds, Svizzera) sono stati utilizzati in questo studio. Il primo kit di BioRace è stato utilizzato per preparare 10 denti (20 canali), senza sterilizzazione tra gli utilizzi, mentre il secondo gruppo di campioni è stato sottoposto a sterilizzazione a vapore dopo ciascun dente (due canali) preparato. Il terzo kit di strumenti è stato usato come gruppo di controllo. I file sono stati quindi analizzati mediante microscopio elettronico a scansione (SEM) usando ingrandimenti tra 500 e 4.000x. Le immagini sono state scattate sulle sezioni D1-D8 di ciascun file. Il peso dei file è stato misurato utilizzando una bilancia con precisione di 0,001 g per quantificare la possibile perdita di lega e il degrado dei file durante l'utilizzo. I denti sono stati quindi sezionati sulla loro lunghezza e sottoposti all'analisi EDX alla ricerca di possibili particelle di lega all'interno dei canali radicolari, utilizzando ingrandimenti tra 30 e 300x. Allo stesso modo, l'irrigante utilizzato durante la modellatura della radice è stato raccolto e analizzato. I dati sulla differenza di peso sono stati analizzati statisticamente con test di Student (p<0.05).*
Risultati: *nessuna frattura è stata registrata negli strumenti di entrambi i gruppi analizzati. Le misurazioni del peso e le micrografie SEM hanno mostrato segni di degradazione più elevata per i campioni del gruppo 2. L'analisi EDX ha mostrato alcune particelle di Ni-Ti nelle radici preparate del gruppo 2.*
Conclusioni: *strisce metalliche, perdita di peso e micro-fratture sono apparsi sui file sottoposti a sterilizzazione a vapore tra gli usi. Le particelle di Ni-Ti staccate dai file, durante il loro uso intra-canale, sono state trovate sulle pareti del canale radicolare.*

Corresponding author
Stefan Vasile Stefanescu | 193A Warrington rd, Whiston L35 5AF, Merseyside, UK | Phone: +44-7712702307 | email: amedeo_1@yahoo.com

Peer review under responsibility of Società Italiana di Endodonzia
10.32067/GIE.2019.33.02.05

Introduction

Endodontic treatments involve accessing a sterile or non-sterile pulp chamber and root canal content, following an inflammation of the pulp or a bacterial colonization of the pulp chamber and root canals, as a septic complication of decay. For this purpose stainless-steel instruments were developed in the last century serving for the different purposes during different procedures having the unique goal to clean and seal the root canal respecting the biologic and mechanical principles stated by Schilder (1). Over the last quarter of the century, the place of the stainless-steel instruments were taken slowly and surely by nickel-titanium files, becoming an instrument sine qua non for root canal treatments, even if steel-instruments are still used, mainly at the beginning of the root canal treatment. Nickel-Titanium (Ni-Ti) files are increasingly used by dentists for their properties that overlap those of stainless-steel instruments in facilitating the cleaning and shaping of root canals, during the chemical and mechanical treatment of all kind of pulp diseases. It is well known the fragility and the rigidity of the steel instruments compared with the Ni-Ti ones. These new instruments not only increased the speed of the treatment but also managed to assure a proper shape of the canal preparation and, subsequently, of the canal filling (2). These files proved to be twice as flexible in bending and torsion, having superior resistance to torsional fracturing when compared to similar stainless-steel instruments (2). The use of nickel-titanium (Ni-Ti) rotary instruments has increased the effectiveness and efficiency of root canal preparation. Studies made on extracted teeth proved that there are less debris and smear layer after preparation with nickel–titanium rotary files than after preparation with hand instruments (3, 4, 5, 6, 7).

During the time many techniques were tried to further enhance instrument resistance to cyclic fatigue and cutting efficiency, resulting in a variety of strategies including heat-treatment and electro-polishing (8). Being so useful, reliable, resistant and ultimately, not cheap, the initially single-use instruments got to be reused by a wide number of practitioners for at least five times, with great success, being assured by the manufacturers that both files and the tooth are safe. There are reports that experimented to reuse the same file on 12 (9) or 24 (10) extracted roots having medium curvature. Legislation worldwide is not prohibiting the reuse nor imposing the single-use, with very few exceptions. However, reusing the endodontic files raises many debates and questions. First of all there is the issue of cross-infection then the debate on sterilization and its effect on the Ni-Ti alloy itself and not ultimately the file mechanical resistance threshold. According to Walia (11), a material will fail by torsion when the ultimate shear strength is exceeded. Others stated that being a ductile material, a NI-Ti instrument would deform plastically and will fracture if its ultimate strength is exceeded (12, 13, 14, 15) or if a fracture line has extended to such an extent that the remaining intact cross-section of file is unable to bear the functional load (16), thus complicating the whole treatment. While stainless-steel instruments separate due to excessive torque, in case of the Ni-Ti files, the combined stress exerted by torsional and cyclic fatigue is to be blamed for the separation that occurs (16, 17, 18). Since Buehler (19) discovered the equiatomic Ni-Ti alloy and Walia (11) first reports on the use of Ni-Ti in endodontics, a large number of studies were made to assess the effect of steam or dry sterilization on Ni-Ti files. The idea that sterilization might work as a heat-treatment, inducing a "regeneration" of the used file served as ground for file reuse. Although a sterilization cycle might be assumed as a thermal treatment that should enhance the endurance of Ni-Ti files, this might be valid only in case of dry sterilization to some extent, considering that thermal treatment means heating up the

alloy to approximately 550 ºC (20). However, for the best practice in decontamination and cross-infection control, vacuum steam autoclaving is recommended, not dry heat. Several studies were made to assess the effect of sterilization process on the fatigue life of Ni-Ti rotary files, some of them with no significant effects (22). Others have found a better fatigue life after five cycles of dry-heat sterilization at 180 ºC (21). But there are also reports where the sterilization proved to affect the Ni-Ti files by decreasing the cutting efficiency, increasing the depth of surface irregularities and surface roughness and crack initiation and propagation (23, 24, 25).

Many studies concluded that instrument usage can significantly influence the potential for fracture (10, 26, 27, 28). Although new instruments can fracture at their first canal use, those that are used for three or more canals may have a higher susceptibility for fracture. Even if fracture incidence is relatively low in clinical practice, the fracture rates in reused files are very high and it can occur with any Ni-Ti rotary instrument (29). Some reports found that the incidence of separation of unused rotary Ni-Ti files is about 1% (30, 31, 32, 33, 34, 35) while distortion was noticed to occur in up to 60% of the instruments used (36), but it is estimated that the incidence of instrument fracture in instruments used multiple times varies between 0.39% and 21% (12, 14, 15, 29, 37, 38, 39). It has been also reported that 55.7% of these fractures are due to torsional mechanism and the rest of 44.3%, to cyclic fatigue (12).

Endodontic irrigants are substances used, both as liquids as well as gels, to eliminate microorganisms, smear layer and pulp tissue from the endodontic system, due to the anatomic complexity. For this purpose sodium hypochlorite (NaOCl) and Ethylenediaminetetraacetic acid (EDTA) are widely used, for its antibacterial and protheolytic effect, as well as for its chelating properties. It was shown that during extended periods of time in NaOCl solutions, corrosion may be enhanced (38) or minimized depending on the pH of the environment (41). Though the impact of NaOCl did not show any difference in the cutting efficiency or resistance to fracture of Ni-Ti instruments (42, 43) it did result in a reduced resistance to cyclic fatigue (44, 45) and the presence of corrosion (21). There are also studies that showed that a sterilization cycle along with immersion in NaOCl did not result any substantial instrument changes (46).

Since no studies are present on Ni-Ti files degradation, aim of the present study was to evaluate the degradation of Ni-Ti rotary files, after root canal preparation, by measuring their weight and by means of scanning electron microscope (SEM) evaluation and energy dispersive X-ray spectroscopy(EDX) examination of the prepared canal.

Materials and Methods

20 extracted upper first bicuspids with complete root formation and two separate canals were used in present study. After the access cavity was prepared, the canals were negotiated to the working length with stainless-steel hand K-files up to size 15, confirming the apical patency. Standardized pre-operative radiographs were taken in both projections with the 15 K-file inserted into the canal, using a radiographic paralleling device attached to a Minray (Soredex, Milwaukee, United States) 70 kV, 8 mA X-ray generator. Teeth were included in a silicon-based material (Zetaplus, Zhermack, Badia Polesine, Italy) in order to maintain position, the X-ray tube was aligned perpendicular to the root canal, with an object to film distance of 3 mm and the exposure time was set at 0,2 seconds. Digora Optime UV intraoral imaging plate system (Soredex, Milwaukee, United States) was used to capture the images. The degree of the canal curvature was determined using the Digora DfW2.6 and Scanora (Soredex, Milwaukee, United States) image processing software. Schneider's method (47) was used to determine the canal

curvature drawing two lines, one parallel to the long axis of the root canal and the second one crossing the foramen and intersecting the first line when it began to leave the long axis of the canal. Only canals categorized as moderately curved (10-20°) were selected for the present study. Since upper bicuspid usually has two root canals, both needed to have a curvature of 10-200, thus every tooth had two xrays done, with both canals having a size 15 K-file inserted one at a time. Teeth exclusion criteria were also: teeth with open apices, single root canal, previous restorative and endodontic treatment, developmental defects, abnormalities in root canal shape, root resorption, calcified canals. The 20 teeth were then divided in two groups of 10.

Three kits of BioRace instruments (FKG, Le Chaux-of-Fonds, Switzerland) consisting of six files each (BR0 tip size 25/.08 taper, BR1 15/.05, BR2 24/.04, BR3 25/.06, BR4 35/.04, BR5 40/.04) were used in present study. The six instruments of the first BioRace kit sample (group 1) were used in sequence without sterilization between their use in the preparation of 20 root canals (10 teeth), while the second kit sample of six instruments (group 2) was used in 20 root canals (10 teeth) and subjected to steam sterilization (Alphaclave23, HMCE, Taillis-France) for 70 minutes, after each two root canals prepared, a total of 10 cycles of sterilization. The third kit of six new instruments was used as a control group.

Teeth were decoronated at the cemento-enamel junction (CEJ) to avoid coronal interferences during root canal preparation, using a diamond disc (Besqual, Meta Dental Corp, Glendale, USA). The BioRace engine-driven endodontic files were used to prepare the root canals using the crown-down preparation technique by the same experienced operator, using an electric NSK NLXplus motor (NSK Europe, Maidenhead, UK) having a 20:1 reduction hand-piece NSK Ti-Max X-SG20L, at 300 rpm and torque set at 1 N/cm as recommended by the manufacturer.

Each root canal was irrigated copiously with 2 ml of both 5,25% NaOCl (Cerkamed PPH, Stalowa Wola, Poland) and 17% EDTA (ethylene-diamine-tetra-acetic acid) (Meta-Biomed Co Ltd., Chungbuk, Korea), after each instrument was used. Irrigation was carried out above a Berzelius glass, one for each sample group. Collected liquid was analyzed by means of Energy-dispersive X-ray spectroscopy (EDS, EDX or XEDS). After the liquid was analyzed, it was filtered using a filter paper and sediment left to dry at room temperature and then analyzed by means of Energy-dispersive X-ray spectroscopy. Broken files were registered and the instrument and the tooth involved were excluded from further examination and substituted.

After root canal instrumentation the files were cleaned in ultrasonic bath (Hygea2850VM, Ultrawave Ltd., Cardiff, U.K.) in alcohol, for eight minutes, then all the instruments, including the control group, were subjected to weight measurement using a precision weight scale (Partner AS.3Y, Partner SRL, Bucharest, Romania), with readability of 0,001 g. Each file of the sample kit tested was subjected to three consecutive measurements and the mean value was calculated to evaluate differences among new files and the instruments used with and without sterilization.

Then, roots were decalcified in 10% EDTA aqueous solution for 30 days, sectioned along their long axis and prepared for SEM analysis. SEM analysis was performed on each Ni-Ti file used and on the prepared roots, using a High-Resolution Scanning Electron Microscope (Hitachi SU8230, Chiyoda, Japan) equipped with a cold field emission gun. For morphological analysis the samples were deposited on aluminum stubs and sputter-coated with 10 nm gold on a Q150T ES Quorum. Loss of integrity, surface modifications, crack line propagation and deformations of the instruments were analyzed by means of SEM, using magnifications between 500 and 4.000x.

Energy-dispersive X-ray spectroscopy (EDX, EDS or XEDS) was conducted us-

ing an EDX System (X-Max N80TLE Silicon Drift Detector, Oxford Instruments, Abingdon, Oxfordshire, UK) to identify microscopic alloy fragments inside the roots or in the irrigating agent. Roots were analyzed in search of Ni-Ti alloy fragments on the inner surface of the root canals using magnifications between 30 and 300x to identify their existence in the roots prepared, to identify the group in which this phenomenon happened more and the moment of degradation to better understand if the phenomenon happened in all the roots prepared, or only by the end of instruments life. Differences between the weight measurements at the baseline and after treatment for both groups were tested for distribution using the Kolmogorov-Smirnoff test. They had normal (gaussian) distribution, which allowed using the independent sample Student t-test to compare the data ($p<0.05$).

Results

No file separation was registered in both groups analyzed. Weight measurements of the different instruments are shown in Table 1 and there were no statistical differences between two groups ($p=0.9140$). In fact, a minimum weight loss was registered in both groups of instruments used, with respect to the control group (0,1-0,2 mg for instruments from group 1 and 0,1-0,5 mg for instruments from group 2), except for BR5 instruments, which recorded a higher weight loss (3 mg and 2,5 mg for samples from group 1 and 2 respectively).
SEM microphotographs of the tested instruments showed that the files from group 2 presented higher degradation with respect to files from group 1. At SEM analysis, instruments from the control group did not report any sign of degradation (fig. 1), while slight structure disruptions, cutting edge disruption, metal strips and

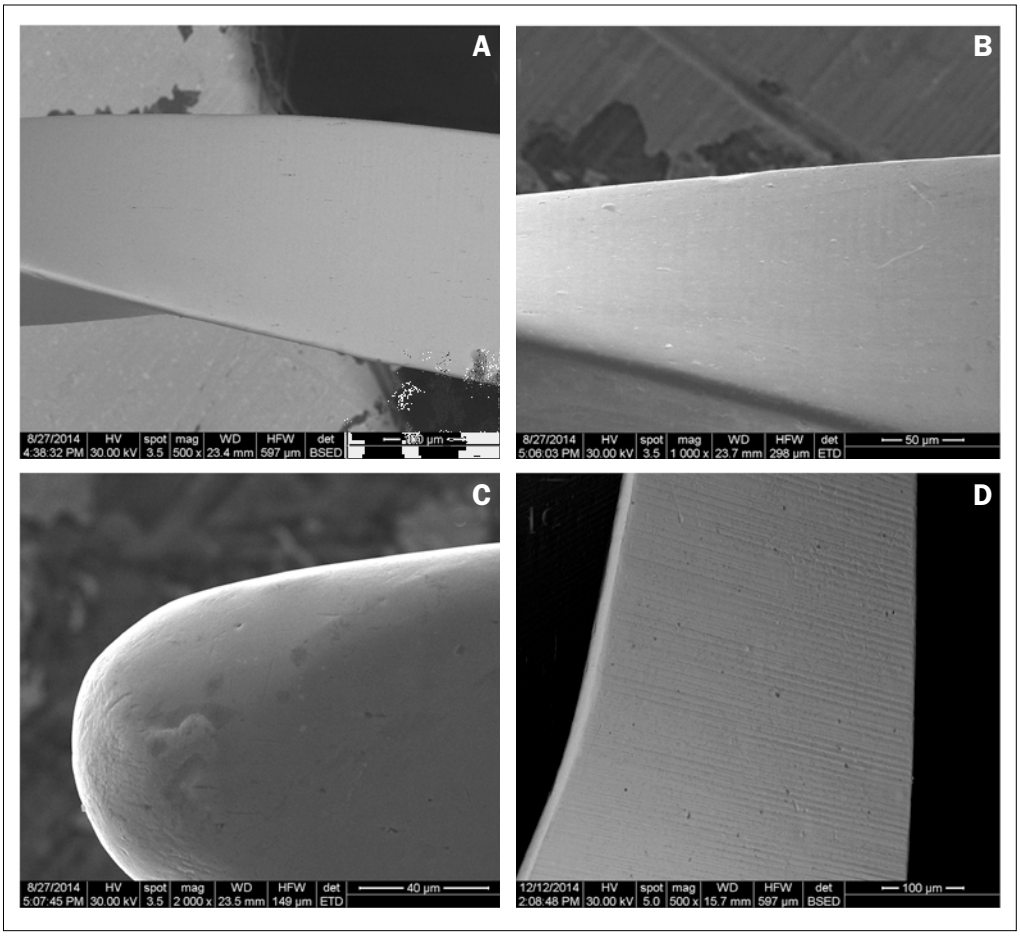


Figure 1
Surface of new files: BRO (**A**), BR1 (**B**), BR2 (**C**) and BR3 (**D**).

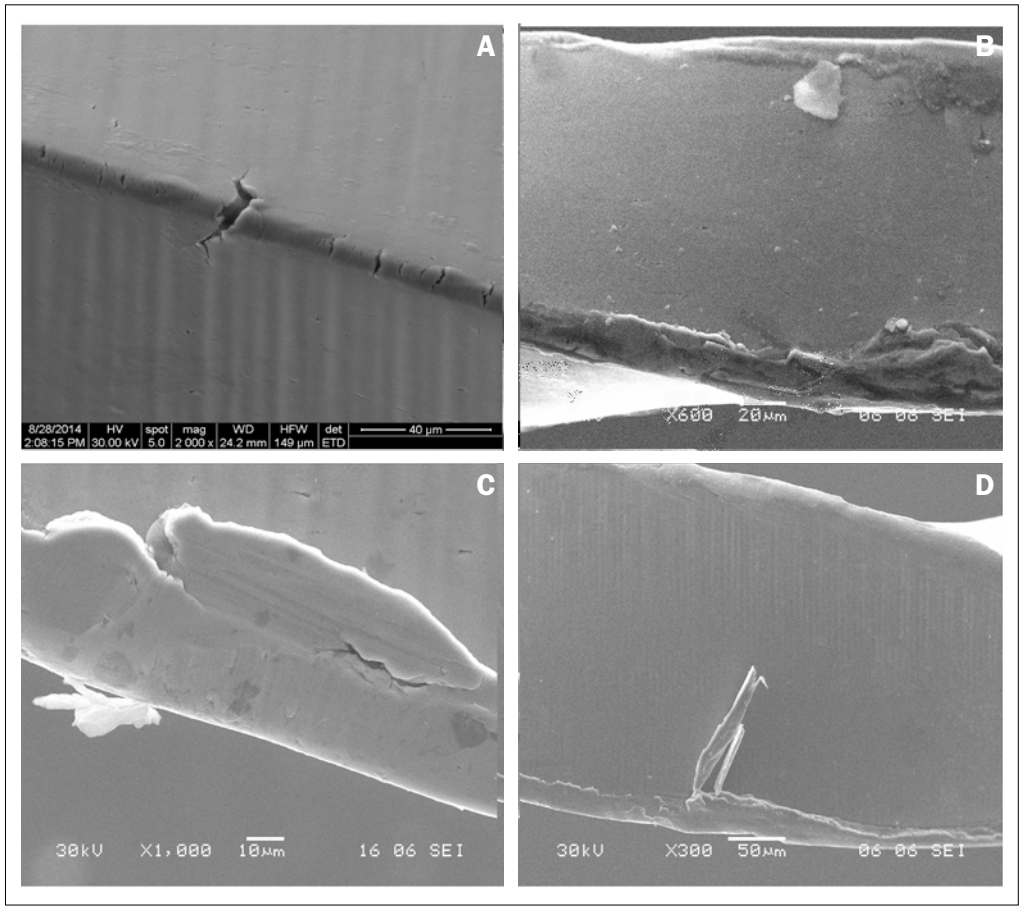
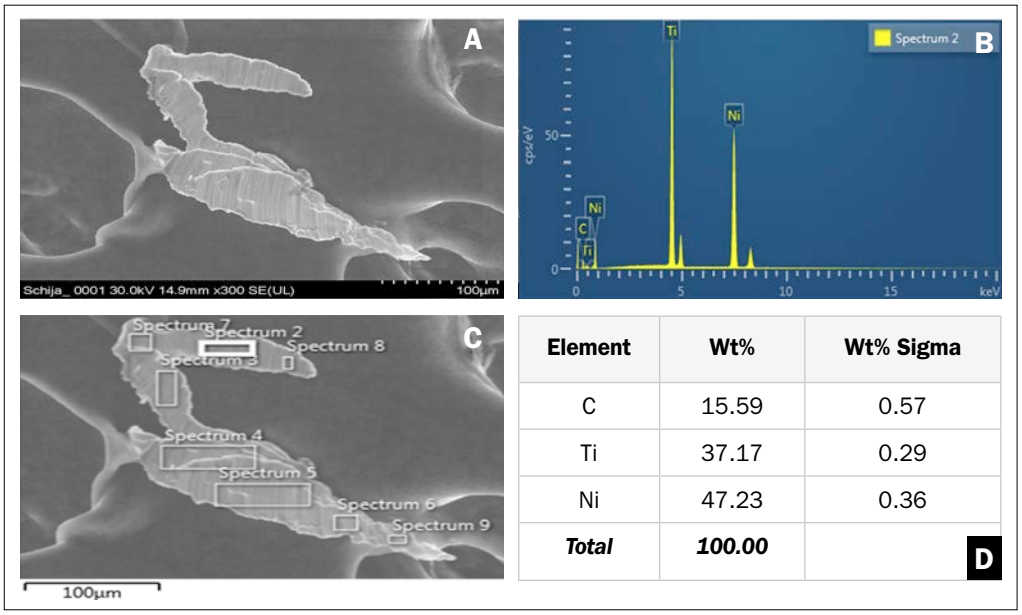


Figure 2
Cutting edge disruption, metal strips and heavy surface degradation on BR3 file from group 1 (**A**); same file from sample group 2 (**B**); BR5 file from sample group 1 (**C**); same file from sample group 2 (**D**).

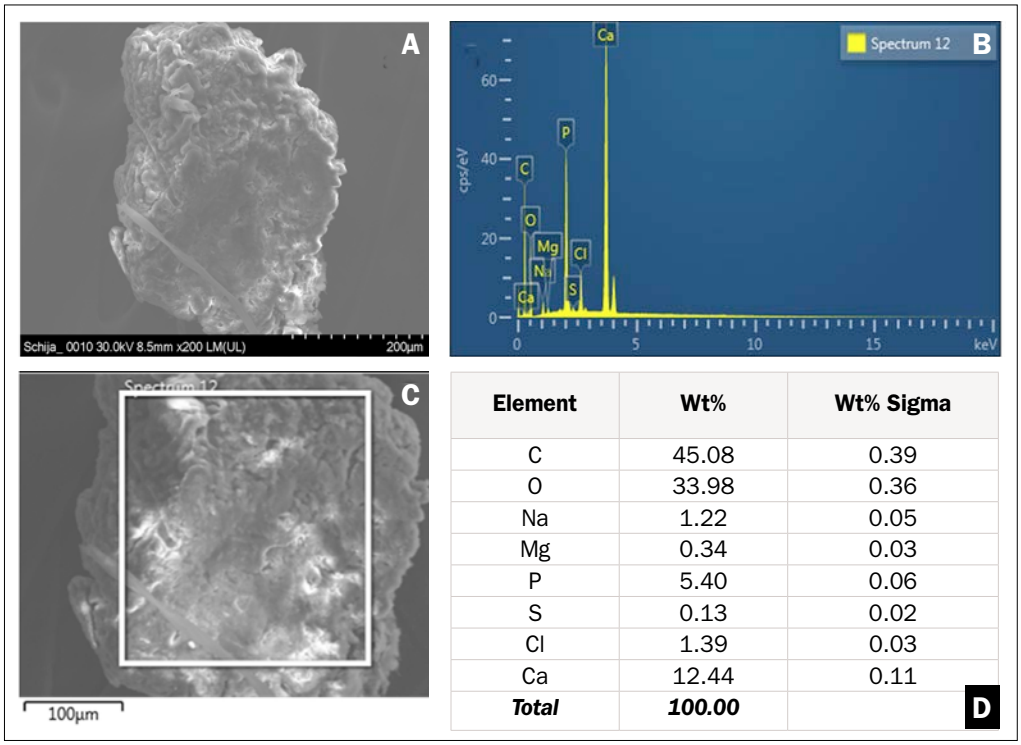
heavy surface degradation (fig. 2) maybe seen in both groups analyzed.
EDX analysis revealed the presence of metal strips in the irrigating sample collected form group 2 (fig. 3), while only organic and inorganic debris could be found in the irrigating sample collected from group 1 (fig. 4). SEM analysis revealed



Element	Wt%	Wt% Sigma
C	15.59	0.57
Ti	37.17	0.29
Ni	47.23	0.36
Total	***100.00***	

D

Figure 3
EDX analysis results on the alloy fragment found in a tooth sample from group 2. (**A**) Alloy fragment collected in the rising agent; (**B**) Elements weight ratio in metal fragment; (**C**) EDX sampling on Ni-Ti fragment; (**D**) Elements atomic ratio in metal fragment.



Element	Wt%	Wt% Sigma
C	45.08	0.39
O	33.98	0.36
Na	1.22	0.05
Mg	0.34	0.03
P	5.40	0.06
S	0.13	0.02
Cl	1.39	0.03
Ca	12.44	0.11
Total	***100.00***	

Figure 4
EDX analysis on the debris structure from a sample of group 1. (**A**) Calcic debris collected in the rinsing agent; (**B**) Elements weight ratio in debris fragment; (**C**) EDX sampling of debris; (**D**) Elements atomic ratio in debris fragment.

that the last four roots prepared with files from group 2 were richer in particles then other roots prepared before in the same group, as well as then all the roots prepared with files from group 1.
Small scattered Ni-Ti particles may be seen on EDX layered images on the internal walls of the root canals in two samples from group 2 (fig. 5A, C) compared to the unlayered SEM image of the same section of the canals (fig. 5B). Elements atomic ration of the analysed canal segment is displayed in fig. 5D, where Nickel and Titanium elements are clearly identified by the EDX technique.

Discussion

Ni-Ti rotary files have two mechanisms of fracture: shear (torsional) and accumulation of metal fatigue (12, 14, 15). Metal, being a ductile material, would deform plastically before a fracture occurs, if its yield stress is exceeded (13, 14, 15). Studies have clas-

Table 1. Mean weight (in mg) of the different files analyzed in the three different groups.

BioRace	Control group (mg)	Group 1 (mg)	Group 2 (mg)
BR0	435,7	435,6	435,4
BR1	436,8	436,7	436,5
BR2	436,2	436,0	435,7
BR3	456,3	456,1	455,9
BR4	430,9	430,8	430,8
BR5	445,1	442,1	442,6

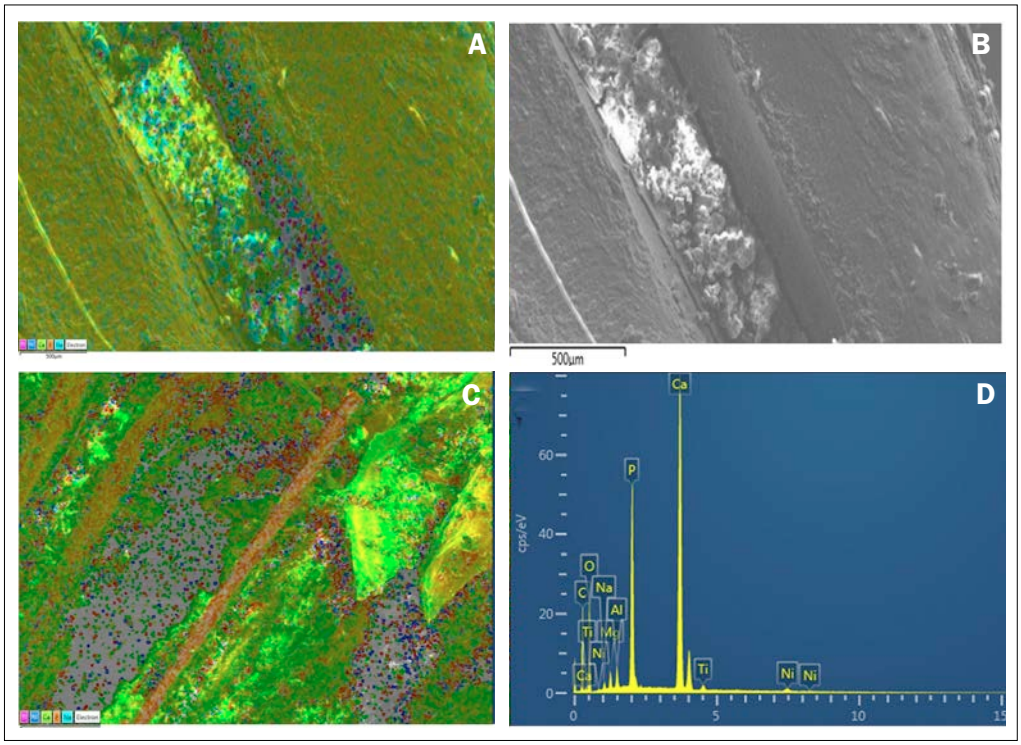


Figure 5
(**A**) EDX layered image of root canal section with multiple Ni-Ti particles; (**B**) SEM image on the apical third of the root, without EDS layering; (**C**) EDX layered image of root canal section with multiple Ni-Ti particles; (**D**) Elements atomic ratio of root canal section presented in sections (**A**) and (**B**).

sified the mechanism of instrument breakage into "torsional" when macroscopic, plastic deformation is present (13, 14, 15), even if such plastic deformations may not always appear when the instrument undergoes shear failure (49, 50). On the other hand, a detailed examination of the fracture surface of an instrument that fails purely due to fatigue would reveal the presence of one or more crack origins, an area of steady fatigue-crack growth adjacent to each crack origin, an area of rapid crack growth manifested as microscopic dimples of irregular size and shape and, occasionally, a shear lip where the rapid crack-growth region meets the periphery of the cross-section (10). Corrosion pits (the result of corrosive attacks on the material) may be found in specimens fatigued in hypochlorite solution (10, 28, 33). The fatigue-crack origins are usually situated at or near the cutting edge (in cross-section) or on some flaws of the surface such as machining grooves, or subsurface defects, such as microscopic fatigue striations (9). These inner structure changes may lead also to surface defects, besides those inflicted mechanically and through chemical corrosion (10, 21, 40, 42, 43, 44, 45).

As it may be assumed that structure disintegration leads to weight loss that is measurable with precise equipment, the present study focused on weight loss assessment and identification of the sample group that suffered the most for this phenomenon. The purpose of this study was to assess the degradation of the Ni-Ti files by measuring them before and after use. The present study found Ni-Ti fragments in the collected and filtered rinsing agent and smaller fragments on the inner surface of the dentinal root canal walls of the prepared teeth. The alloy fragments collected in the irrigating solutions were probably detached from the cutting edge of the files, having comparable sizes with similar fragments found still attached on the cutting surface of files from the same group in the SEM micrographs. Smaller sized particles having similar or smaller size then the dentinal tubules were trapped in the tubules as it can be noticed in the EDX images. EDX analysis made possible through different staining to identify the alloy particles and to create an idea about their presence and location. Energy-dispersive X-ray spectroscopy (EDS, EDX, or XEDS) is an analytical technique used for the elemental analysis

or chemical characterization of a sample. Its characterization capabilities are due to the fundamental principle that each element has a unique atomic structure allowing a unique set of peaks on its X-ray emission spectrum. To stimulate the emission of characteristic X-rays from a specimen, a high-energy beam of charged particles such as electrons or protons or a beam of X-rays is focused into the sample being studied. At rest, an atom within the sample contains ground state (or unexcited) electrons in discrete energy levels or electron shells bound to the nucleus. The incident beam may excite an electron in an inner shell, ejecting it from the shell while creating an electron-hole where the electron was. An electron from an outer, higher-energy shell then fills the hole and the difference in energy between the higher-energy shell and the lower energy shell may be released in the form of an X-ray. The number and energy of the X-rays emitted from a specimen can be measured by an energy-dispersive spectrometer. As the energies of the X-rays are characteristic of the difference in energy between the two shells and of the atomic structure of the emitting element, EDS allows the elemental composition of the specimen to be measured (51).

Instruments from the kit used in group 1 and not autoclaved presented distortion and bluntness rather than disruption of the cutting edge, while instrument samples from the kit used in group 2 and submitted to sequential autoclave sterilization presented metal chips and cutting edge disruption. Thus, files from group 2 seemed to be more affected structurally, by weight calculation, SEM images and EDX measurements. Given the fact that instruments from both groups were used in similar clinical conditions, on a similar number of root canals, with a similar degree of curvature, these differences may be due to environmental conditions and the inner transformation that alloy suffered during steam sterilization. A limitation of the present study is given by the small sample size and by the fact that samples from group 1 were tested in a clinically non-reproducible condition, meaning the absence of sterilization. Previous studies reported that multiple cycles of autoclave sterilization significantly decrease the cyclic fatigue resistance of the Twisted File (52), decreased instruments cutting efficiency, increased the depth of surface irregularities and surface roughness and evidenced crack initiation and propagation (22, 23, 24). In an another study (10), steam sterilization affected the inner structure of nitinol, so that files with increased taper seemed to be more fragile than files with a smaller taper from the same file kit, due to decreased flexibility. However, there are studies that showed no influence of autoclave on cyclic fatigue resistance of the files, while others (53) identified the same type of increased resistance to cyclic fatigue, although the thermal applications did not alter instrument surface morphology, but resulted in significant changes in the instrument bulk with the appearance of an R-phase and improved fatigue resistance.

In the present study, instruments were used to prepare 10 roots and 20 root canals because the findings of a previous study reported that files subjected to intermediate steam sterilization separated preparing the 12th root canal (10) while in another study (9), where no sterilization was used, the same instruments used in the previous study were managed to prepare 24 root canals. It may be assumed that this damages happened when a certain load was applied after a certain number of rotations, being torque and fatigue dependent (14, 29, 47, 48).

Another aspect that needs to be addressed is the aspect of cross-infection. It has been a long time argued about the chances of prion cross-infection by means of dental instruments. Those who argued in favor of possible transmission based their theory on prion's alleged transmission from the neural tissues to the tissues located in the mouth, due to prion accumulation in the perioral ganglia system of patients with this disease (54). The assumptions followed the logical conclusion that since dental pulp originates from the neural crest, theoretically, the dental pulp of people suffering from any type of Creutzfeldt-Jakob Disease could be infectious. There were reported cases of infected laboratory animals that

developed certain contagiousness in the oral tissues (55, 56). It was stressed that even if the oral tissues are of merely not detectable contagiousness and the presence of prion protein in these tissues has not been confirmed in humans, we cannot rule out the nosocomial transmission of prions during dental treatments (57). It was reported that classic sterilization methods like steam sterilization or by ethylene gas are ineffective against prion agents (58, 59). Therefore instruments that can be reused have to pass through strict decontamination protocols before cleaning and then to be subjected to steam sterilization at 134 ºC for 10-18 minutes in a vacuum environment. However, in a later report, dentists are requested to use endodontic files as single-use instruments regardless of the case (60).

On the other hand, as there is no instrument that prevents apical extrusion (61), the present study reports on the possibility for apical extrusion of Ni-Ti particles along with dentin debris, even if the periodontal space is a closed system, being different with the open system used during this study. It is therefore assumable that such metal particles may migrate through the foramens being able to create an allergic reaction (59).

In endodontics the potential allergens are haptens which can turn in full antigens in certain conditions. New researches showed that Type I reactions can be triggered by haptenic substances like metal ions (60), with the possible creation of an immediate or delayed dermal or mucosal reaction (62). If the individual is initially sensitized the reaction can have anaphylactic symptoms due to cross-reaction with barrier equipment (rubber dam, gloves etc.) which also contains allergens (59). These reactions can be the result of previous sensitization. It is known that dermal exposure to metallic allergens is more likely to trigger an allergic reaction than mucosal exposure, therefore allergic reactions in endodontics is extremely low if we take in consideration only the type 1 reactions. But if we take into account the side effects of allergic reactions which are almost neglected as symptoms, like delayed apical healing, persisting discomfort after root filling, post operatory urticaria, or allergy to Nickel, their number may increase considerably. There are cases of allergic reactions due to cross-reactions between natural rubber latex and gutta-percha using the chloroform technique (63, 64) or between NRL and antibodies to avocado or bananas. Braun et al. (65) presented arguments in favor of possible sensitization to formaldehyde after several root canal treatments. A reaction between the metal ions and the sealer haptens combined with the residual pulp tissue proteins can form allergens that trigger systemic or local reactions (59). Although it is difficult to prove the link between a failed root canal treatment and a suspected local reaction to an allergen, there are cases described in the literature (63, 64) where the symptoms (urticaria, persisting discomfort) required the removal of the root filling after which the symptoms disappeared.

Conclusions

Although no file separated in any of the groups, metal strips, weight loss and micro-fractures appeared more frequently on the files subjected to steam sterilization between the uses. Ni-Ti particles detached from the files during their intra-canal use were found in the irrigating solutions and on the root canal walls. Single-use of Ni-Ti endodontic engine-driven files is always advisable in order to reduce instruments wear due to their excessive use and reduce the chances of cross-infection and unwanted reactions.

Clinical Relevance

The results of this study should warn the dentist about the risks of multiple-use of endodontic files encouraging them to consider Ni-Ti files as single-use equipment.

Conflict of Interest

The authors deny any conflict of interest related to this study. There were no other contributors to the article. The article was funded from authors' self sources.

References

1. Schilder H, Cleaning and shaping the root canal. Dental Clinics of North America, 18 (1974), 269-296.
2. Hulsmann M, Peters OA, Dummer PMH. Mechanical preparation of root canals: shaping goals, techniques and means. Endodontic Topics, 10 (2005), pp. 30-76.
3. Orstavik D. Time-course and risk analysis of the development and healing of chronic apical periodontitis in man. Int Endod J, 29 (1996), pp. 150-5.
4. De Paula Silva FWG, Hassan B, Bezerra da Silva LA, Leonardo MR, Wu M-K. Outcome of root canal treatment in dogs determined by periapical radiography and cone-beam computed tomography scans. J Endod, 35 (2009), pp. 723-6.
5. Salehrabi R, Rotstein I. Endodontic Treatment Outcomes in a Large Patient Population in the USA: An Epidemiological Study. J Endod, 30 (2004), pp. 846-50.
6. Dammaschke T, Steven D, Kaup M, Ott KH. Long-term survival of root-canal-treated teeth: a retrospective study over 10 years. J Endod, 29 (2003) pp. 638-43.
7. Stoll R, Betke K, Stachniss V. The influence of different factors on the survival of root canal fillings: a 10-year retrospective study. J Endod, 31 (2005) pp. 783-90.
8. Bürklein S, Schäfer E. Critical evaluation of root canal transportation by instrumentation. Endodontic Topics 29 (2013), pp. 110-124.
9. Stefanescu T, Antoniac IV, Popovici RA, Galuscan A, Tirca T (2016) Ni-Ti rotary instrument fracture analysis after clinical use. Structure changes in used instruments. EEMJ, 15(2016), pp. 981-88.
10. Stefanescu T, Galuscan A, Tudoran LB, Monea MD, Jumanca D. Environmental effect on Ni-Ti rotary files: Steam sterilization & corrosion. A SEM study. Rev. Chim, 67(2016), pp. 2114-18.
11. Walia HM, Brantley WA, Gerstein H. An initial investigation of the bending and torsional properties of Nitinol root canal files. J Endod, 14(1988), 346-51.
12. Sattapan B, Palamara JE, Messer HH. Torque during canal instrumentation using rotary nickel–titanium files. J Endod, 26(2000), 156-60.
13. Sattapan B, Nervo GJ, Palamara JE, Messer HH. Defects in rotary nickel-titanium files after clinical use. J Endod 26(2000), 161-5.
14. Parashos P, Gordon I, Messer HH. Factors influencing defects of rotary nickel-titanium endodontic instruments after clinical use. J Endod, 30(2004), pp.722-5.
15. Peng B, Shen Y, Cheung GS, Xia TJ. Defects in ProTaper S1 instruments after clinical use: longitudinal examination. Int Endod J, 38(2005), pp. 550-7
16. Cheung GSP. Instrument fracture: mechanisms, removal of fragments, and clinical outcomes. Endodontic Topics, 16(2009), 1-26.
17. Dalton BC, Ørstavik D, Phillips C, Pettiette M, Trope M. Bacterial reduction with nickel–titanium rotary instrumentation. J Endod 24(1998), 763-767.
18. Gulabivala K., Stock C.J.R. Root canal system preparation. In: Stock CJR, Gulabivala K, Walker RT, eds. Endodontics, 3rd Edn. Edinburgh (2004): Mosby, 135-172.
19. Buehler WJ, Gilfrich JW, Wiley RC. Effects of Low-Temperature Phase Changes on the Mechanical Properties of Alloys Near Composition TiNi. Journal of Applied Physics 34 (5) (1963): 1475-1477-
20. Liu Y, Xie ZL, Van Humbeeck J, Dalaey L. Effect of texture orientation on the martensite deformation of NiTi shape memory alloy sheet. Acta Materialia 47(1999): 645-660.
21. Sonntag D, Peters OA. Effect of prion decontamination protocols on nickel-titanium rotary surfaces. J Endod 33(2007), 442-6.
22. Mize SB, Clement DJ, Pruett JP, Carnes DL Jr. Effect of sterilization on cyclic fatigue of rotary nickel-titanium endodontic instruments. J Endod 24(1998), 843-7.
23. Alexandrou GB, Chrissafis K, Vasiliadis LP, Pavlidou E, Polychroniadis EK. SEM observations and differential scanning calorimetric studies of new and sterilized nickeltitanium rotary endodontic instruments. J Endod 32(2006), 675-9.
24. Valois CR, Silva LP, Azevedo RB. Multiple autoclave cycles affect the surface of rotary nickel-titanium files: an atomic force microscopy study. J Endod 34(2008), 859-62.
25. Viana AC, Gonzalez BM, Buono VT, Bahia MG. Influence of sterilization on mechanical properties and fatigue resistance of nickel–titanium rotary endodontic instruments. Int Endod J 39(2006): 709-715.
26. Gambarini G. Cyclic fatigue of ProFile rotary instruments after prolonged clinical use. Int Endod J 34(2001), 386-9.
27. Yared GM. In vitro study of the torsional properties of new and used ProFile nickel–titanium rotary files. J Endod 30(2004), 410-2.
28. Yared GM, Kulkarni GK. An in vitro study of the torsional properties of new and used rotary nickel–titanium files in plastic blocks. Oral Surg Oral Med Oral Path 96(2003), 466-71.
29. Di Fiore PM, Genov KA, Komaroff E, Li Y, Lin L. Nickel-Titanium rotary instrument fracture: a clinical practice assessment. Int Endod J, 39(2006), 700-708.
30. Ankrum MT, Hartwell GR, Truitt JE. K3 Endo, ProTaper, and ProFile systems: breakage and distortion in severely curved roots of molars. J Endod, 30(2004), 234-237.
31. Paqué F, Musch U, Hülsmann M, Comparison of root canal preparation using RaCe and ProTaper rotary NiTi instruments. Int Endod J, 38(2005), 8-16.
32. Rangel S, Cremonese R, Bryant S, Dummer P. Shaping ability of RaCe rotary nickel–titanium instruments in simulated root canal. J Endod, 31(2005), 460463.
33. Schäfer E, Schlingemann R. Efficiency of rotary nickel-titanium K3 instruments compared with stainless-steel hand K-Flexofile. Part 2. Cleaning effectiveness and instrumentation results in severely curved root canals of extracted teeth. Int Endod J, 36 (2003), 208-217.
34. Schäfer E., Vlassis M. Comparative investigation of two rotary nickel-titanium instruments: ProTaper versus RaCe. Part 2. Cleaning effectiveness and instrumentation results in severely curved root canals

of extracted teeth. Int Endod J, 37(2004), 239-248.
35. Yoshimine Y, Ono M, Akamine A. The shaping effects of three nickel-titanium rotary instruments in simulated S-shaped canals. J Endod, 31(2005), 373-375.
36. Stewart JT, Lafkowitz S, Appelbaum K, Hartwell G. Distortion and breakage of Liberator, EndoSequence, and ProFile systems in severely curved roots of molars. J Endod, 36(2010), 729-731.
37. Alapati SB, Brantley WA, Svec TA, Powers JM, Nusstein JM, Daehn GS. SEM observations of nickel-titanium rotary endodontic instruments that fractured during clinical Use. J Endod, 31 (2005), pp. 40-3.
38. Shen Y, Cheung GS, Bian Z, Peng B. Comparison of defects in ProFile and ProTaper systems after clinical use. J Endod, 32(2006), pp.61-5.
39. Shen Y, Cheung GS, Peng B, Haapasalo M. Defects in nickel-titanium instruments after clinical use. Part 2: fractographic analysis of fractured surface in a cohort study. J Endod, 35(2009), pp.133-6.
40. O'Hoy PY, Messer HH, Palamara JE. The effect of cleaning procedures on fracture properties and corrosion of NiTi files. Int Endod J 36(2003), 724-32.
41. Novoa XR, Martin-Biedma B, Varela-Patino P. The corrosion of nickel-titanium rotary endodontic instruments in sodium hypochlorite. Int Endod J 40(2007), 36-44.
42. Ormiga Galvao Barbosa F, Antonio da Cunha Ponciano Gomes J, Pimenta de Araujo MC. Influence of sodium hypochlorite on mechanical properties of K3 nickel-titanium rotary instruments. J Endod 33(2007), 982-5.
43. Cavalleri G, Cantatore G, Costa A, Grillenzoni M, Comin Chiaramonti L, Gerosa R. The corrosive effects of sodium hypochlorite on nickel-titanium endodontic instruments: assessment by digital scanning microscope. Minerva Stomatologica 58(2009), 225-31.
44. Berutti E, Angelini E, Rigolone M, Migliaretti G, Pasqualini D. Influence of sodium hypochlorite on fracture properties and corrosion of ProTaper Rotary instruments. Int Endod J 39(2006), 693-9.
45. Peters OA, Roehlike JO, Baumann MA. Effect of immersion in sodium hypochlorite on torque and fatigue resistance of nickel-titanium instruments. J Endod 33(2007), 589-93.
46. Haikel Y, Serfaty R, Wilson P, Speisser JM, Allemann C. Mechanical properties of nickel–titanium endodontic instruments and the effect o sodium hypochlorite treatment. J Endod, 24(1998): 731735.
47. Schneider SS, A comparison of canal preparations in straight and curved root canals. Oral Surg Oral Med Oral Path, 32 (1971), pp. 271-5.
48. Lopes HP, Ferreira AA, Elias CN, Moreira EJ, de Oliveira JC, Siqueira JF Jr. Influence of rotational speed on the cyclic fatigue of rotary nickel-titanium endodontic instruments. JOE, 35 (2009), pp. 1013-6.
49. Cheung GSP, Peng B, Bian Z, Shen Y, Darvell BW. Defects in ProTaper S1 instruments after clinical use: fractographic examination. IEJ, 38 (2005), pp. 802-809.
50. Wei X, Ling J, Jiang J, Huang X, Liu L. Modes of failure of ProTaper nickel–titanium rotary instruments after clinical use. JOE, 33 (2007), pp. 276-279.
51. Wikipedia; https://en.wikipedia.org/wiki/Energy-dispersive_X-ray_spectroscopy
52. Hilfer PB, Bergeron BE, Mayerchak MJ, Roberts HW, Jeansonne BG. Multiple autoclave cycle effects on cyclic fatigue of nickel-titanium rotary files produced by new manufacturing methods. JOE, 37 (2011), pp.72-4.
53. Condorelli GG, Bonaccorso A, Smecca E, Schäfer E, Cantatore G, Tripi TR. Improvement of the fatigue resistance of NiTi endodontic files by surface and bulk modifications. IEJ 43(2010), 866-73.
54. Guiroy DC, Shankar SK, Gibbs J, Messenheimer JA, Das S, Gajdusek DC. Neuronal degeneration and neurofilament accumulation in the trigeminal ganglia in Creutzfedt- Jakob disease. Annals of Neurololgy, 25(1989), 102-6.
55. Advisory Committee on Dangerous Pathogens. Spongiform Encephalopathy Advisory Committee. Transmissible spongiform encephalopathy agents: Safe working and the prevention of infection. London: The Stationery Office (1998), 1-54.
56. Flechsig E, Hegyi I, Enari M, Schwarz P, Collinge J, Weissmann C. Transmission of scrapie by steelsurface- bound prions. Journal of Molecular Medicine, 7(2001), 679-84.
57. Bali Z, Bali RK, Nagrath S. Prion diseases: risks, characteristics, and infection control considerations in dentistry. Journal of Investigative and Clinical Dentistry, 2(2011), 236-240.
58. Brown SA, Merritt K. Use of containment pans and lids for autoclaving caustic solutions. American Journal of Infection Control, 31(2003), 257.
59. Lodi G, Porter SR, Scully C. Hepatitis C virus infection: review and implications for the dentist. Oral Surgery, Oral Medicine, Oral Pathology, Oral Radiology and Endodontology, 86(1998), 8-22.
60. Department of Health, UK. Commissioning and Systems Management. Health Technical Memorandum 01–05: Decontamination in primary care dental practices. London, UK: Department of Health (2009).
61. Ingle JI, Bakland LK, Peters DL, Buchanan LS, Mullaney TP. Endodontic cavity preparation. In: Ingle JI, Bakland LK, eds. Endodontics. 4th Edn. Baltimore: Williams & Wilkins, 1994.
62. Hensten A, Jacobsen N. Allergic reactions in endodontic practice. Endodontic Topics, 12(2005), 44-51.
63. Hostynek JJ. Aspects of nickel allergy: epidemiology, etiology, immnune reactions, prevention, and therapy. In: Hostynek JJ, Maibach HI, eds. Nickel and the Skin. Absorption, Immunology, Epidemiology and Metallurgy (Chapter 1). Boca Raton: CRC Press, 2002: 1-38.
64. Kelly KJ, Banerjee B. Natural rubber latex allergy. In: Grammer LC, Greenberger PA, eds. Petterson's Allergic Diseases (Chapter 31), 6th edn. Philadelphia: Lippincott Williams & Wilkins, 2002: 653-671.
65. Gazelius B, Olgart L, Wrangsjö K. Unexpected symptoms to root filling with gutta-percha: a case report. Int Endod J 19(1986), 202-204.
66. Boxer MB, Grammer LC, Orfan N. Gutta-percha allergy in a health care worker with latex allergy. J Allergy Clin Immunol 93(1994), 943-944.
67. Braun JJ, Zana H, Purohit J, Valfrey A, Scherer J, Haikel Y, de Blay F, Pauli G. Anaphylactic reactions to formaldehyde in root canal sealant after endodontic treatment: four cases of anaphylactic shock and three of generalized urticaria. Allergy 58(2003), 1210-1215.

ORIGINAL ARTICLE/**ARTICOLO ORIGINALE**

Effect of chlorhexidine and isopropyl alcohol on immediate and delayed bond strength of glass fiber posts

Effetto della clorexidina e dell'alcool isopropilico sulla forza di adesione immediata e ritardata dei perni in fibra di vetro

KEYWORDS
Chlorhexidine, Isopropyl Alcohol, Post and Core Technique, Root Canal Irrigants, Root Canal Preparation

PAROLE CHIAVE
Clorexidina, alcool isopropilico, tecnica post e core, irriganti canalari, preparazione canalare

Ellizandra Anater Lecardelli[1], Victório Poletto-Neto[1], Fernanda Geraldo Pappen[1], Tatiana Pereira-Cenci[1], Renata Dornelles Morgental[1,2*]

[1]*Graduate Program in Dentistry, Federal University of Pelotas (UFPel), Gonçalves Chaves St. 457, Pelotas, 96015560, RS, Brazil*
[2]*Graduate Program in Dental Science, Federal University of Santa Maria, Marechal Floriano Peixoto St. 1184, Santa Maria, 97015372, RS, Brazil*

Received 2018, September 19

Accepted 2019, October 15

Abstract

Aim: *To investigate the effects of dentinal treatment with chlorhexidine and isopropyl alcohol, alone or associated, on the bond strength and bond stability of glass fiber posts cemented with a self-adhesive resin cement.*

Materials and Methods: *Forty bovine teeth were endodontically treated and randomly distributed into four groups, according to the dentinal treatment after post space preparation: distilled water (Control); 2% chlorhexidine (CHX); isopropyl alcohol (ISO); 2% chlorhexidine + isopropyl alcohol (CHX+ISO). Glass fiber posts were cemented with a self-adhesive resin cement and after 24 h specimens were cut into six 1.5 mm-thick slices. One slice of each root third (i.e. apical, middle and coronal) was subjected to immediate push-out test and the other was stored in distilled water at 37 °C for six months for delayed push-out test. Bond strength was registered in megapascal (MPa). Failure mode was evaluated by a stereomicroscope, with 40x magnification. Data analysis was performed using Kruskal-Wallis and Friedman tests, with 5% significance level.*

Results: *No significant differences were detected between experimental groups or between root thirds in the same group in the immediate evaluation. After six months of aging, all groups showed a significant decrease in bond strength values, but ISO group presented higher bond strength than Control and CHX groups (p=0.0001). The most common type of failure for all groups was adhesive between resin cement and root dentine.*

Conclusions: *Dentinal treatment with CHX and ISO, isolated or combined, did not affect the immediate bond strength of glass fiber posts, but the ISO group presented better bond stability after six-month aging.*

Obiettivi: *studiare gli effetti del trattamento della dentina con clorexidina e alcol isopropilico, da soli o associati, sulla resistenza e sulla stabilità del legame dei perni in fibra di vetro cementati con un cemento resinoso autoadesivo.*

Metodologia: *quaranta denti di bovino sono stati trattati endodonticamente e distribuiti casualmente in quattro gruppi, in base al trattamento dentinale dopo la preparazione del post space: acqua distillata (controllo); 2% clorexidina (CHX); alcool isopropilico (ISO); Clorexidina al 2% + alcool isopropilico (CHX+ISO). I perni in fibra di vetro sono stati cementati con un cemento resinoso autoadesivo e dopo 24 ore i campioni sono stati tagliati in sei sezioni di 1,5 mm di spessore. Una porzione di ogni terzo è stata sottoposta a test di push-out e l'altra è stata conservata in acqua distillata a 37 °C per sei mesi per il test di push-up ritardato. La forza del legame è stata registrata in megapascal (MPa). Il tipo di fallimento è stato valutato da uno stereomicroscopio, con 40x di ingrandimento. L'analisi dei dati è stata eseguita utilizzando i test di Kruskal-Wallis e Friedman, con un livello di significatività del 5%.*

Risultati: *non sono state rilevate differenze significative tra i gruppi sperimentali o tra terzi dello stesso gruppo nella valutazione immediata. Dopo sei mesi di invecchiamento, tutti i gruppi hanno mostrato una significativa diminuzione dei valori di forza di legame, ma il gruppo ISO ha presentato una forza di legame superiore rispetto ai gruppi di controllo e CHX (p=0,0001). Il tipo più comune di fallimento riscontrato tra i gruppi era di tipo adesivo tra cemento resinoso e dentina radicolare.*

Conclusioni: *il trattamento dentinale con CHX e ISO, isolati o combinati, non ha influenzato la forza di legame immediata dei perni in fibra di vetro, ma il gruppo ISO ha presentato una migliore stabilità del legame dopo un invecchiamento di sei mesi.*

Corresponding author
Renata Dornelles Morgental | Graduate Program in Dental Science, Federal University of Santa Maria (UFSM) | Marechal Floriano Peixoto St. 1184, Santa Maria | Brazil | Phone: +55 5532209272 | Email: remorgental@hotmail.com

Peer review under responsibility of Società Italiana di Endodonzia

10.32067/GIE.2019.33.02.06

Introduction

Quality of coronal restoration is an important factor for success in endodontically treated teeth. Furthermore, the rehabilitation of weakened teeth is still a challenge and there is a lack of consensus in the literature on the best way to restore them. In cases where there is total or partial loss of the dental crown, rehabilitation becomes even more complex and it may be necessary to use intraradicular posts to assist retention of restorative material (1, 2).

Glass fiber posts are an alternative to cast posts and core and have been widely used. In addition to the aesthetic advantages, this alternative is justified due to the similarity in the modulus of elasticity between the post and dentin, which allows a more homogeneous tension distribution in comparison to more rigid posts (3). Also, most of the clinical failures involving glass fiber posts occur by debonding of the cement/post assembly from the root canal walls (4).

The literature demonstrates that adhesion of self-adhesive resin cements to root dentin can be affected by the moisture condition of dentin, with a partial moist being favorable to the adhesion mechanism of these cements (5). Manufacturer's instructions provide information on the proper use of these materials; however, there is no clear reference to the required dentin moisture condition or irrigation solutions to be used prior to the cementation procedures (6).

Several chemical substances, including alcohols in different concentrations, have been tested in the pre-treatment of dentin to control dentin moisture and promote effective adhesion (7, 8). The use of isopropyl alcohol (C_3H_7OH) has already shown a beneficial effect on the adhesive strength of endodontic sealers (9, 10) but has not yet been evaluated in relation to glass fiber post cementation.

NaOCl and chlorhexidine gluconate are the most used endodontic irrigants due to their antimicrobial capacity. They are also recommended as irrigating solutions prior to post cementation (11). A recent systematic review demonstrated that dentinal treatment is an important variable in the retention of fiber posts (12). Still, some studies have shown a negative effect of NaOCl on the adhesion of resin cements to intraradicular dentin when used alone (13), while chlorhexidine could enhance bonding stability through the inhibition of metalloproteinases (14).

Its beneficial effect was reported before the application of total-etch and also self-adhesive resin cements (15). Thus, the aim of this study was to evaluate the effect of dentin treatment with chlorhexidine and isopropyl alcohol, alone or associated, on the bond strength and durability of bonding of glass fiber posts cemented with a self-adhesive resin cement to the root dentin of bovine teeth, also considering root thirds. The null hypothesis tested was that different irrigating solutions would result in the same immediate or delayed bond strength of glass fiber posts, even at different root thirds.

Materials and Methods

Sample size calculation was based on previous studies (16, 17). Forty bovine incisors were selected for this study. Teeth were cleaned and stored in 0.5% chloramine T solution (Sigma-Aldrich Brasil LTDA, Duque de Caxias, RJ, Brazil) for disinfection. Crowns were removed using a slow-speed, water-cooled diamond disc (LabCut 1010; Extec Corp, Enfield, CT, EUA), and the length of the roots were standardized in 16 mm. Specimen preparation is illustrated in figure 1. A size 30 K file (Dentsply-Maillefer, Ballaigues, Switzerland) was used for canal exploration and removal of possible pulp remnants. The working length was set at 15 mm.

Chemomechanical preparation was performed with hand instrumentation using the crown-down technique. Cervical and middle thirds of root canals were enlarged with #5, #4 and #3 Gates Glidden drills (Dentsply-Maillefer, Petrópolis, RJ, Brazil), followed by instrumentation with K files in the apical third (Dentsply-Maillefer, Petrópolis, RJ, Brazil). Irrigation was per-

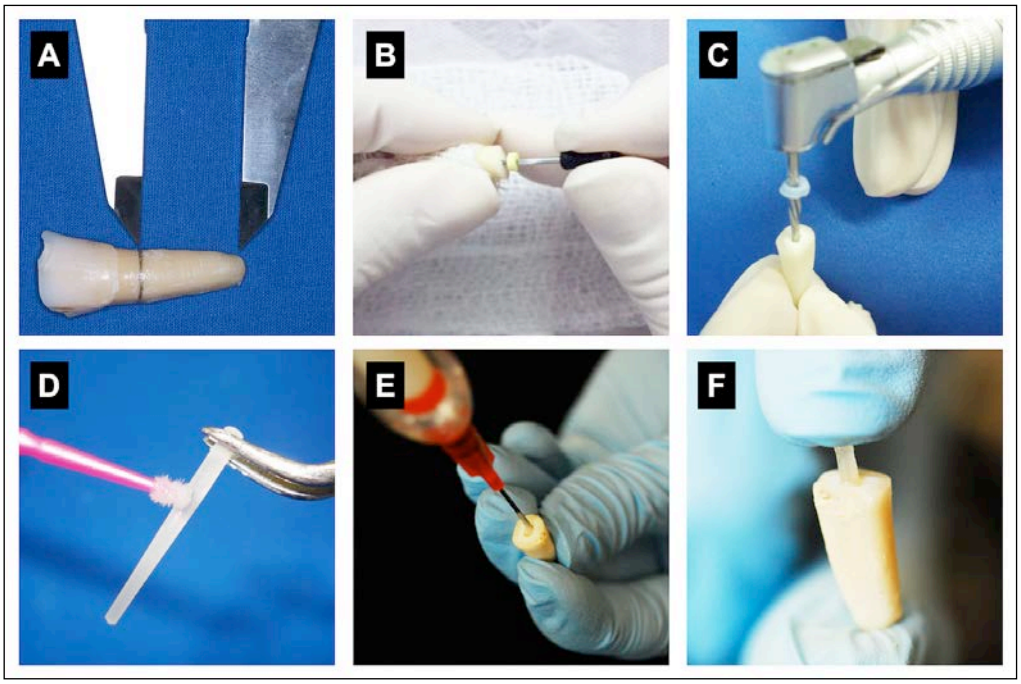


Figure 1
Specimen preparation: **(A)** Root length standardized in 16 mm; **(B)** Root canal preparation until a size 80 K-file; **(C)** Post space preparation with specific low-speed drill; **(D)** Silane application; **(E)** Resinous cement insertion with a Centrix syringe; **(F)** Cementation procedure followed by digital pressure.

formed with 2 mL of 2.5% NaOCl (Asfer, São Caetano do Sul, SP, Brazil) after the use of each instrument. The final apical size was 0.80 mm. To remove the smear layer, the root canals were irrigated with 5 mL of 17% EDTA (Asfer, São Caetano do Sul, SP, Brazil) for 5 minutes and finally flushed with 5 mL of 2.5% NaOCl. Root canals were completely dried with absorbent paper points (Tanari, Manacapuru, AM, Brazil) and filled using gutta-percha points and the epoxy resin-based endodontic sealer AH Plus (Dentsply DeTrey, Konstanz, Germany) in the lateral condensation technique. The coronal portion of the roots was temporarily sealed and stored in 100% humidity for a week.

Roots were prepared for post-placement using a low-speed drill (#2 Angelus, Londrina, PR, Brazil). A standardized 12 mm post-space was drilled in each root canal, and not less than 3 mm of apical seal was maintained. Specimens were randomly distributed into four groups (n=10) according to the irrigating solution used after post space preparation. Control group: distilled water; CHX group: 2% chlorhexidine; ISO group: isopropyl alcohol; CHX+ISO group: 2% chlorhexidine + isopropyl alcohol. Root canals were rinsed with 5 mL distilled water to remove the remaining debris, and then each group received 5 mL of the respective irrigant for one minute.

Glass fiber posts were previously cleaned with 70% ethanol and treated with silane (Angelus, Londrina, PR, Brazil). Root canals were dried with paper points and the resinous cement was inserted into the root canals with a Centrix syringe (DFL Indústria e Comércio SA, Rio de Janeiro, RJ, Brazil). Self-adhesive resin cement (RelyX U200 3M ESPE, Seefeld, Germany) was used for the cementation procedure according to manufacturer's instructions. After cementation, cervical dentin and post received a composite resin coverage and teeth were stored in distilled water at 37 °C for 24 h until bond strength specimen preparation.

Each root was horizontally cut with a slow-speed, water-cooled diamond disc (Isomet, Buehler Ltd., Lake Bluff, IL, USA) to produce two 1.5 mm-thick slices for each root third (i.e. apical, middle and coronal). The first coronal slice of 0.5 mm was excluded. Then, the six remaining slices were considered from each root canal (n=60 per group). One slice of each root third was considered for immediate push-out subgroup and the other was maintained in water storage 37 °C for six months for aged push-out subgroup (n=30).

The push-out test was performed in a universal testing machine (model DL-1000, EMIC Equipamentos e Sistemas de Ensaio Ltda., São José dos Pinhais, PR, Brazil). Root slices were positioned and then submitted to compression loading with a 1 mm-diameter metallic cylindrical plunger touching the cemented fiber-post center, in an apex-crown direction at a 1 mm/min speed with 1.000 N until dislodgment of the post. The bond strength (σ) in megapascal (MPa) was obtained as previously reported (16).
The following formula was applied:
$\sigma=F/A$
where
F=sample rupture load (N)
and
A=area of adhesion (mm^2)
To determine the adhesion area, a formula was used to calculate the lateral area of a straight circular cone with parallel bases, that is
$A=2\ \pi g\ (R1+R2)$
where
$\pi=3.14$
g=inclined height
R1=lower radius of the base
R2=largest base of the area
To determine sloping height, the following calculation was used
$g^2=(H2+[R1-R2]2)$
where
H=section height
R1 and R2 were obtained by measuring with a digital caliper (Mitutoyo, Suzano, SP, Brazil) the internal diameters of the smallest and largest base, respectively, which corresponds to the internal diameter of the root canal walls.
The failure mode was verified by using a stereomicroscope at 40x magnification (Stereo Discovery V20; Zeiss, Oberkochen, Germany). Failures were classified into five categories: 1) adhesive between post and resin cement (no resin cement visible around the post); 2) mixed, with resin cement covering 0%-50% of the post surface; 3) mixed, with resin cement covering between 50% and 100% of the post surface; 4) adhesive between resin cement and root dentin (post enveloped by resin cement); and 5) cohesive within the resin cement.
After push-out test, the mean values of bond strength were calculated for each root third (cervical, middle and apical) and for each tooth (average of three thirds) within each experimental group. Data were analyzed using the statistical software BioEstat 5.0 (CNPq, Brasília, DF, Brazil). For comparison between groups, the Kruskal-Wallis test was applied and for specimens of different root thirds, in the same group, the Friedman test was used. The comparison between immediate and after six months aged groups was performed with the Wilcoxon test. The significance level was set at 5% for all statistical analyses.

Results

Mean bond strength and respective standard deviation are presented in Table 1. In the immediate evaluation, similar bond strength values were found for all dentinal

Table 1
Bond strength means and standard deviations (MPa) obtained in each experimental group and condition (n=30)

Groups	Irrigants	Immediate (MPa)	6-month aging (MPa)
Control	Distilled Water	2.57±2.00^{Aa}	1.37±0.93^{Ba}
CHX	2% Chlorhexidine	3.27±2.36^{Aa}	1.35±1.01^{Ba}
ISO	Isopropyl alcohol	4.04±2.87^{Aa}	2.20±0.91^{Bb}
CHX+ISO	2% Chlorhexidine + isopropyl alcohol	3.59±2.28^{Aa}	1.90±0.89^{Bab}

Means followed by different uppercase letters (row) or lowercase letters (column) are significantly different (p<0.05).

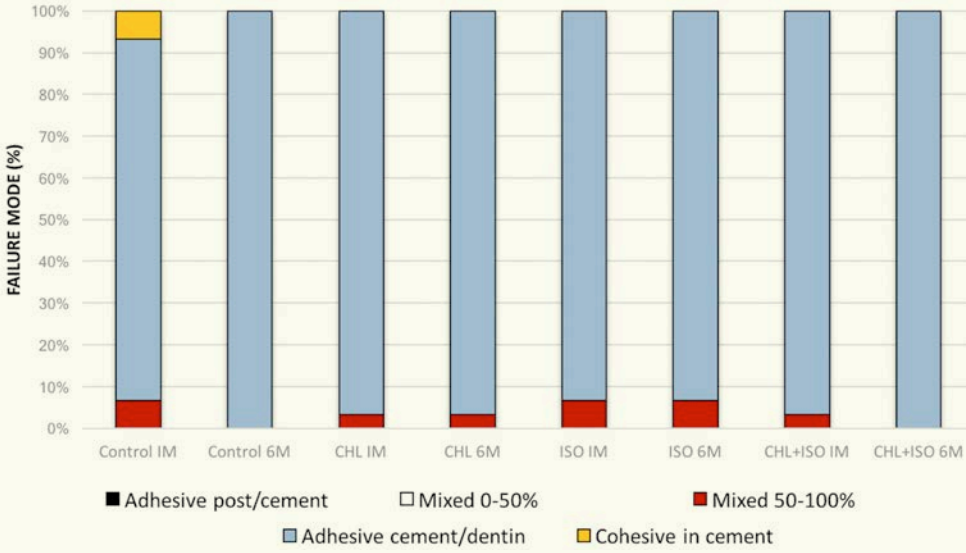


Figure 2
Failure mode distribution in the experimental groups and conditions. CHX: 2% Chlorhexidine; CHX+ISO: 2% Chlorhexidine + isopropyl alcohol; ISO: isopropyl alcohol; IM: immediate; 6M: six-month aging.

The five possible categories of failure mode in the chart legend are the most found in the literature. However, two of these categories were not observed in our samples.

treatments. However, after six months of aging, ISO group presented higher bond strength than Control and CHX groups (p=0.0001). In the intragroup comparisons, all dentinal treatments showed a significant decrease in bond strength values from immediate to six-month evaluation. The comparison between root thirds did not show statistical significant differences in any group in the immediate analysis: Control (p=1.00); CHX (p=0.90); ISO (p=0.27); CHX+ISO (p=0.67); and in the delayed analysis: Control (p=0.90); CHX (p=0.06); ISO (p=0.74); CHX+ISO (p=0.20). Figure 2 shows the failure mode distribution in the tested groups, being adhesive failures between root canal and resin cement (figure 3) the most frequent pattern obtained for all groups.

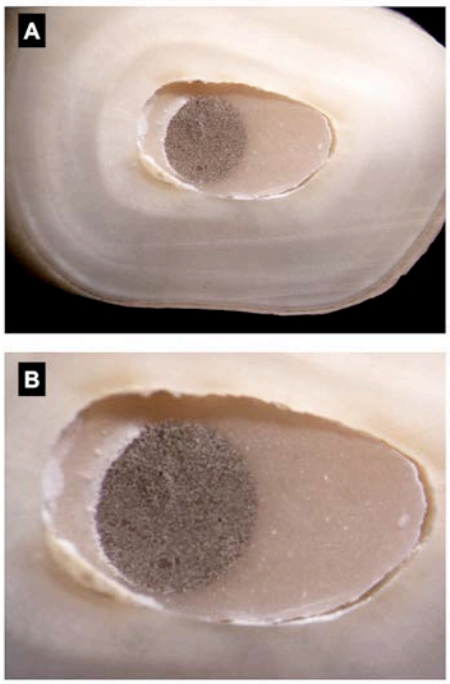


Figure 3
Stereomicroscope images illustrating an adhesive failure between root canal and resin cement at 15x **(A)** and 40x magnification **(B)**.

Discussion

There is a lack of consensus in the literature about the solution used prior to glass fiber post cementation. Scientifically based clinical protocols with standardization of these solutions for each type of cement are necessary to increase the bond strength of posts and consequently the longevity of restorations. The use of isopropyl alcohol was expected to control the excess water of the dentinal tubules. This has not happened immediately, although the bond strength values were slightly higher. However, isopropyl alcohol performed better than control and chlorhexidine groups after six months of aging. Also, all groups presented a significant decrease in bond strength values after the aging process. Thus, the null hypothesis was rejected.

Dias et al. (9) proposed a protocol to dry the canal with isopropyl alcohol and assessed its influence on the bond strength of an epoxy resin-based endodontic sealer prior to root canal filling. In their study, the use of this substance as an irrigating solution promoted higher bond values and greater penetration of the sealer in the dentinal tubules when compared to groups dried with paper points, corroborating our findings. Despite this, the direct comparison between endodontic sealer and self-adhesive resin cement is not possible, since the formulation and role played by these materials are different. Thus, to our knowledge, the present study is the first to use isopropyl alcohol in the intraradicular dentin cleaning protocol prior to glass fiber post cementation.

When a suitable control of dentin moisture is obtained, greater penetration of resin cement on dentinal walls should be expected (18). This way, the higher bond strength values of isopropyl alcohol group after aging could be explained due to its capacity of promoting a smaller water replacement of the dentinal tubules, increasing the wettability of the dentin and allowing more effective conversion of resin monomers (8).

Irrigation of post space using 2% chlorhexidine was proposed due to its beneficial effect prior to the use of total-etch and self-adhesive resin cements (15). However, its application did not alter the immediate bond strength when compared to the Control group in this study, which agrees with other studies using total-etch and self-adhesive resin cements (7, 17, 19, 20). After six months of aging, bond strength stability was not preserved in chlorhexidine groups (CHX and CHX+ISO). However, as reported in a published systematic review (21), there is high heterogeneity among studies where water-storage aging process was applied and the lack of bond strength stability could be addressed to the aging method.

Also, longer times of aging have already been evaluated and the results did not support bond strength stability when chlorhexidine was used as pre-treatment for post cementation, even after one year of aging in artificial saliva. Other authors even found a negative effect when using chlorhexidine prior to a self-adhesive resin cement (11, 22, 23).

These inconsistent findings may be explained by differences in the methodology, where a simple additional rinse with water after using the irrigating solution could remove a possible residual effect of the latter. Even knowing that self-adhesive resin cements adhere to tooth surface trough a chemical interaction with hydroxyapatite, it is important to understand that these methodological differences could be the main reason for discrepancies in the literature.

In the present study, the comparison between root thirds did not show statistical differences in any group. The explanation for this homogeneous behavior along the entire root canal length would be its dual-cure nature, which allows polymerization where the light does not reach (24). Some authors reported that RelyX Unicem (3M ESPE, Seefeld, Germany), the first self-adhesive resin cement released on the market, has behaved homogeneously along the root canal (25), as found in our study with U200. Another explanation would be the use of the Centrix syringe, which may have contributed to an adequate distribution of the cement on the apical root third (26).

The adhesive failure between resin cement and root dentin was the most common failure mode in all groups, as reported in past studies (27). They have shown that the bond strength in the cement/dentin interface is lower than in the cement/post assembly. Moreover, post cleaning and its pre-treatment with silane may have reduced possible failures within the cement/post interface (28).

Although well delineated, this laboratory study can only estimate an increase or reduction in bond strength performance in a period of six months, which should be complemented by long-term in vitro studies and further confirmed by clinical trials, to assess the clinical behavior of such irrigating solutions before adhesive cementation of glass fiber posts.

Conclusions

Despite the limitations of this in vitro study, the results confirm that regardless

of the dentinal treatment applied, immediate bond strength values were not enhanced. However, considering the six-month aging period, the application of isopropyl alcohol as irrigant agent prior to glass fiber post cementation presented better bond strength stability.

Clinical Relevance

Dentinal treatment is an important variable in the retention of fiber posts. This study showed that isopropyl alcohol alone promoted better bond stability after six months when compared to chlorhexidine, alone or associated with isopropyl alcohol.

Conflict of Interest

All authors declare that they have no conflicts of interest. In addition, all authors have read and approved the manuscript as submitted, are qualified for authorship, believe the submission represents honest work and take full responsibility for the reported findings.

References

1. Gillen BM, Looney SW, Gu LS et al. Impact of the quality of coronal restoration versus the quality of root canal fillings on success of root canal treatment: a systematic review and meta-analysis. J Endod. 2011;37(7):895-902.
2. Sequeira-Byron P, Fedorowicz Z, Carter B, Nasser M, Alrowaili EF. Single crowns versus conventional fillings for the restoration of root-filled teeth. Cochrane Database Syst Rev. 20159):CD009109.
3. Calapaj M, Cicciù M, Nicita F, Alibrandi A, Giudice GL. Survival of hollow metal post-retained restorations:A long term clinical follow-up. J Osseointegration 2017;9(2):263-268
4. Lo Giudice G, Cagidiaco EF, Lo Giudice R, Puleio F, Nicita F, Calapaj M. Evaluation of mechanical properties of a hollow endodontic post by three point test and SEM analysis: A pilot study. Mater 2019;12(12).
5. Aktemur Turker S, Uzunoglu E, Yilmaz Z. Effects of dentin moisture on the push-out bond strength of a fiber post luted with different self-adhesive resin cements. Restor Dent Endod. 2013;38(4):234-40.
6. Lo Giudice G, Lizio A, Lo Giudice R, Centofanti A, Rizzo G, Runci M, et al. The effect of different cleaning protocols on post space: A SEM study. Int J Dent 2016;2016.
7. Cecchin D, de Almeida JF, Gomes BP, Zaia AA, Ferraz CC. Effect of chlorhexidine and ethanol on the durability of the adhesion of the fiber post relined with resin composite to the root canal. J Endod. 2011;37(5):678-83.
8. Zmener O, Pameijer CH, Serrano SA, Vidueira M, Macchi RL. Significance of moist root canal dentin with the use of methacrylate-based endodontic sealers: an in vitro coronal dye leakage study. J Endod. 2008;34(1):76-9.
9. Dias KC, Soares CJ, Steier L et al. Influence of drying protocol with isopropyl alcohol on the bond strength of resin-based sealers to the root dentin. J Endod. 2014;40(9):1454-8.
10. Paula AC, Brito-Junior M, Araujo CC, Sousa-Neto MD, Cruz-Filho AM. Drying protocol influence on the bond strength and apical sealing of three different endodontic sealers. Braz Oral Res. 2016;30(1).
11. Mohammadi Z, Giardino L, Palazzi F, Shalavi S, Alikhani MY, Giudice GL, et al. Effect of sodium hypochlorite on the substantivity of chlorhexidine. Int J Clin Dent 2013;6(2):173-178.
12. Skupien JA, Sarkis-Onofre R, Cenci MS, Moraes RR, Pereira-Cenci T. A systematic review of factors associated with the retention of glass fiber posts. Braz Oral Res. 2015;29(
13. Erdemir A, Ari H, Gungunes H, Belli S. Effect of medications for root canal treatment on bonding to root canal dentin. J Endod. 2004;30(2):113-6.
14. Carrilho MR, Carvalho RM, Tay FR, Yiu C, Pashley DH. Durability of resin-dentin bonds related to water and oil storage. Am J Dent. 2005;18(6):315-9.
15. Durski M, Metz M, Crim G, Hass S, Mazur R, Vieira S. Effect of chlorhexidine treatment prior to fiber post cementation on long-term resin cement bond strength. Oper Dent. 2018;43(2):E72-E80.
16. Arisu HD, Kivanc BH, Saglam BC, Simsek E, Gorgul G. Effect of post-space treatments on the push-out bond strength and failure modes of glass fibre posts. Aust Endod J. 2013;39(1):19-24.
17. Cecchin D, Giacomin M, Farina AP, Bhering CL, Mesquita MF, Ferraz CC. Effect of chlorhexidine and ethanol on push-out bond strength of fiber posts under cyclic loading. J Adhes Dent. 2014;16(1):87-92.
18. Prado M, Simao RA, Gomes BP. Effect of different irrigation protocols on resin sealer bond strength to dentin. J Endod. 2013;39(5):689-92.
19. Cecchin D, de Almeida JF, Gomes BP, Zaia AA, Ferraz CC. Influence of chlorhexidine and ethanol on the bond strength and durability of the adhesion of the fiber posts to root dentin using a total etching adhesive system. J Endod. 2011;37(9):1310-5.
20. Angeloni V, Mazzoni A, Marchesi G et al. Role of chlorhexidine on long-term bond strength of self-adhesive composite cements to intraradicular dentin. J Adhes Dent. 2017;19(4):341-8.
21. Montagner AF, Sarkis-Onofre R, Pereira-Cenci T, Cenci MS. MMP Inhibitors on dentin stability: A systematic review and meta-analysis. J Dent Res. 2014;93(8):733-43.
22. Di Hipolito V, Rodrigues FP, Piveta FB et al. Effectiveness of self-adhesive luting cements in bonding to chlorhexidine-treated dentin. Dent Mater. 2012;28(5):495-501.
23. Lo Giudice R, Puleio F, Rizzo D, Alibrandi A, Lo Giudice G, Centofanti A, et al. Comparative investigation of cutting devices on bone blocks: An SEM morphological analysis. Appl Sci 2019;9(2).
24. Haddad MF, Rocha EP, Assuncao WG. Cementation of prosthetic restorations: from conventional cementation to dental bonding concept. J Craniofac Surg. 2011;22(3):952-8.
25. Cantoro A, Goracci C, Vichi A, Mazzoni A, Fadda GM, Ferrari M. Retentive strength and sealing ability of new self-adhesive resin cements in fiber post luting. Dent Mater. 2011;27(10):e197-204.
26. Souza AC, Goncalves Fde C, Anami LC, Melo RM, Bottino MA, Valandro LF. Influence of insertion techniques for resin cement and mechanical cycling on the bond strength between fiber posts and root dentin. J Adhes Dent. 2015;17(2):175-80.
27. Simoes TC, Luque-Martinez I, Moraes RR, Sa A, Loguercio AD, Moura SK. Longevity of bonding of self-adhesive resin cement to dentin. Oper Dent. 2016;41(3):e64-72.
28. Moraes AP, Sarkis-Onofre R, Moraes RR, Cenci MS, Soares CJ, Pereira-Cenci T. Can silanization increase the retention of glass-fiber posts? A systematic review and meta-analysis of in vitro studies. Oper Dent. 2015;40(6):567-80.

CASE REPORT/**CASO CLINICO**

A mandibular molar with four independent mesial roots: a case report

Un molare mandibolare con quattro canali mesiali indipendenti: un case report

KEYWORDS
Endodontic therapy, Mandibular molar, Tooth anatomy

PAROLE CHIAVE
Terapia endodontica, molare mandibolare, anatomia dentaria

Claudio Maniglia-Ferreira[1], Fábio de Almeida-Gomes[1*], Eduardo Diogo Gurgel Filho[1], Natália de Santiago[2], Fernanda Geraldo Pappen[3]

[1]*Adjunct professor, Department of Endodontics, University of Fortaleza, CE, Brazil*
[2]*Student, Department of Endodontics, University of Fortaleza, CE, Brazil*
[3]*Associate professor, Department of Endodontics, Federal University of Pelotas, RS, Brazil*

Received 2018, November 05

Accepted 2019, 8 July 08

Abstract

Aim: *The most common anatomical configuration of the mandibular molar is to present two roots and three or four canals, but it's possible to find many different configurations. A case of unusual mandibular molar is presented to illustrate the anatomic root canal variation.*
Summary: *Endodontic treatment was performed in a mandibular third molar with five roots, four in the mesial portion and one in the distal portion. The x-ray examination showed an abnormal root canal anatomy, suggesting the presence of extra mesial roots. Cone-beam computed tomography (CBCT) imaging revealed five roots and five root canals, with four independent roots in the mesial portion and one in the distal portion, indicating a rare anatomic configuration. This case report presents the importance of searching for extra canals and the unusual canal morphology, because the knowledge of the most common anatomic characteristics and their possible variations is fundamental to the endodontic treatment success.*
Key learning points: *(A) The major cause of failure in root canal therapy is the inability to localize and treat all of the canals of the root canal system. (B) Mandibular molars may have complex canal systems and variations. (C) The operating microscope and CBCT interpretation are fundamental in confirming and preventing mistakes about the configuration of root canals.*

Obiettivo: *la configurazione anatomica più comune del molare mandibolare è costituita da due radici e tre o quattro canali, ma è possibile trovare molte configurazioni diverse. Viene presentato un raro caso di molare mandibolare per mostrare la variabilità dell'anatomia radicolare.*
Riassunto: *il trattamento endodontico è stato eseguito in un terzo molare mandibolare con quattro radici nella porzione mesiale e una nella porzione distale. L'esame radiografico ha mostrato un'anomalia dell'anatomia radicolare che suggeriva la presenza di altre radici mesiali. Le sezioni della tomografia computerizzata (CBCT) hanno rivelato cinque radici e cinque canali radicolari, con quattro radici indipendenti nella porzione mesiale e una nella parte distale, una rara configurazione anatomica. Questo caso riporta l'importanza della ricerca dei canali accessori e della morfologia inusuale dell'anatomia radicolare, poiché la conoscenza delle più comuni caratteristiche anatomiche e delle loro possibili variabilità è fondamentale per il successo del trattamento endodontico.*
Punti chiave: *(A) La principale causa di fallimento di una terapia canalare è l'incapacità di localizzare e trattare tutti i canali del sistema canalare. (B) I molari inferiori possono avere varianti e sistemi canalari complessi. (C) Il microscopio operativo e la CBCT sono fondamentali per confermare e prevenire errori sulla morfologia dei canali radicolari.*

Introduction

Variation in pulp cavity morphology, especially in multirooted teeth, is a constant challenge for diagnosis and successful endodontic therapy (1). Knowledge of the most common anatomical characteristics and their possible variations is fundamental, because nontreatment of even one canal can lead to endodontic treatment failure.
The main objectives of root canal treatment are thorough cleaning and shaping of all pulp space and its complete obturation with an inert filling material and a coronal filling, preventing ingress of microorganisms (2).

Corresponding author
Fábio de Almeida-Gomes
University of Fortaleza. Av. Washington Soares, 1321 | Edson Queiroz, Fortaleza - CE, 60811-905 | fabiogomesce@yahoo.com.br

Peer review under responsibility of Società Italiana di Endodonzia
10.32067/GIE.2019.33.02.02

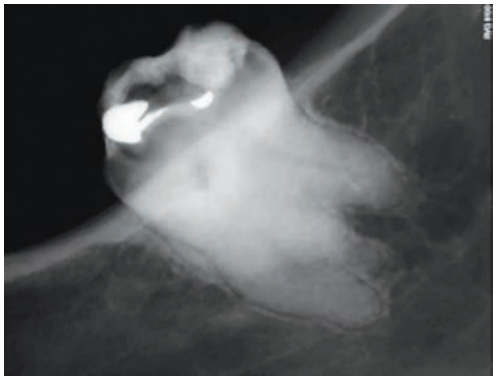


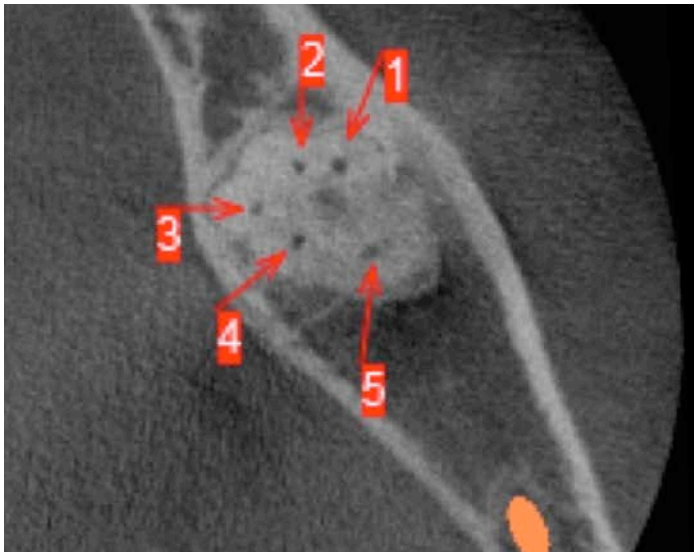
Figure 1
Pretreatment radiograph showingan abnormal root canal anatomy,suggesting the presence of extra mesial roots.

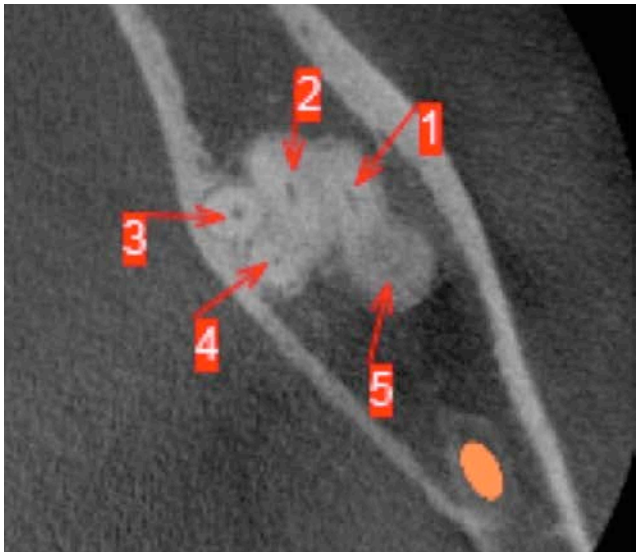
The mandibular first molar usually has two roots, one mesial and one distal, and three or four canals (3, 4). The mesial root has two canals with an isthmus between them (3, 5, 6, 7). This system may have an accessory mesial canal at a prevalence that ranges from 0% to 17% (8, 9). Kottoor (10) and Ahmed (11) found a prevalence rate of 4% and 3% for 3 canals in mesial and distal roots. Therefore, this occurrence in the same tooth is rare (12, 13).
According to Mannocci (14) the morphology of mesial canals in mandibular molars is complex, with a high frequency of intercanal communications. Numerous case reports have described aberrant canals in the mesial root of the mandibular molar (15-18). In the literature, the occurrence of three independent canals in the mesial root has been frequently reported, whether the tooth has one (16), two (17) or three roots (18), but a literature search evidences that the occurrence of four mesial canals in four separate mesial roots has never been described, which indicates a rare anatomical configuration. The purpose of this article was to describe an unusual case of an endodontic treatment of a mandibular molar with five canals in five roots, distributed as four independent mesial roots and one distal root.

Case Report

A 51-year-old female with noncontributory medical history was referred to our dental office complaining of discomfort associated with the left mandible.
Clinical examination revealed the presence of cavity in the left mandibular third molar. The clinical diagnosis was necrotic pulp. History revealed pain on mastication. Neither fistula nor edema was observed in the soft tissue. There was no pain or tenderness on palpation, tooth mobility was within physiological limits, and gingival attachment was normal. The tooth was tender to vertical percussion. Thermal pulp testing (Endo-Frost, Coltène-Whaledent, Langenau, Germany) elicited a negative response.
Pretreatment radiographic evaluation of the tooth showed an abnormal root canal anatomy, suggesting the presence of extra

Figure 2
Computed tomography (CT) scanslices revealing five roots and fiveroot canals.





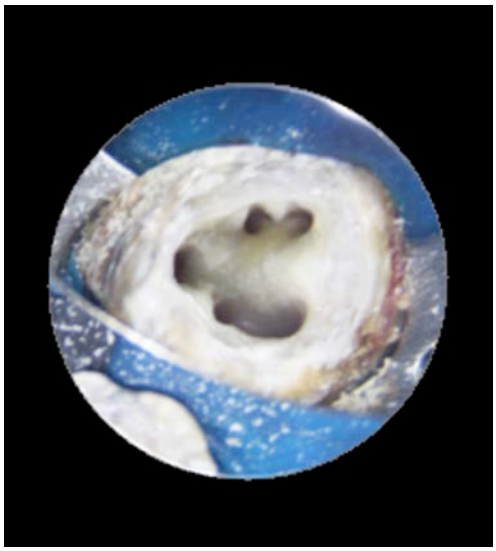


Figure 3
Entry into the pulp chamber evidencing five different canal orifices

mesial roots (figure 1). Cone-beam computed tomography (CBCT) imaging revealed five roots and five root canals, four of which in the mesial portion, and one in the distal portion (figure 2). CBCT images provided valuable information regarding the canal configuration and confirmed the five root canals that were not clearly seen in the conventional radiograph.
The tooth was anesthetized using the standard inferior alveolar nerve blocks with 1.8 ml of 4% articaine with 1:100.000 epinephrine (Articaine, DFL Ind e Com Ltda, Rio de Janeiro, Brazil). After the administration of the local anesthetic, the tooth was isolated, the coronal access was prepared, and the pulp tissue was removed.
During the entry to the pulp chamber, five different canal orifices were revealed, four mesial ones and a distal one (figure 3). The canals were cleansed and the length of each root canal was determined using an electronic apex locator Root ZX (J. Morita, Kyoto, Japan). The root canals were prepared using the Reciproc R25 endodontic file. Sodium hypochlorite (2.5%) and EDTA (17%) solutions were used as irrigants. After cleaning and shaping, the canals were dried and filled using Tagger's technique, with gutta-percha points and root canal sealer (Endofill, Denstply, Petropolis, Rio de Janeiro, Brazil). A final radiograph was taken to establish the quality of the obturation (figure 4).

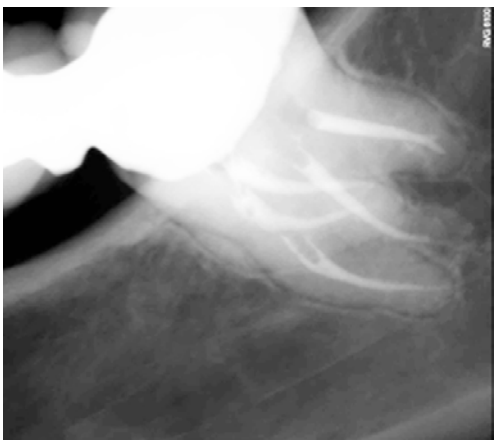


Figure 4
A final radiograph after the completion of the endodontic treatment.

Discussion

The objective of root canal treatment is the thorough mechanical and chemical cleansing of the entire pulp cavity and its complete obturation with an inert filling material and a coronal filling, thus preventing ingress of microorganisms. One of the most important causes of endodontic treatment failure is the incomplete obturation of the root canal system (16). Similarly, Vertucci (4) reported that a considerable number of failures could be assigned to anatomical variations such as the presence of canals that are not usually found. Therefore, the correct location, thorough debridement, cleaning, shaping, and obturation of the entire root canal system are indispensable procedures.
Variation in pulp cavity morphology, especially in multirooted teeth, is a constant challenge for diagnosis and successful endodontic therapy. Knowledge of the most common anatomical characteristics and their possible variations is fundamental, because nontreatment of even one canal can lead to endodontic treatment failure (19).
Teeth anatomy is not always normal, and lack of knowledge of these possible variations in the internal anatomy of human teeth could lead to failure of the endodontic treatment. Case reports are therefore valuable because they remind us that the situation is not always normal and, during each treatment, we must expect many variations (20). The mandibular molar usually has a mesial root with two canals; a

third canal (middle mesial) in the mesial root can be found sporadically; the distal root may have one or two canals, with the presence of a single canal being most prevalent (21).

This case report presents the endodontic treatment of a third molar with abnormal anatomy. Third molars are often extracted but, in some situations, its maintenance becomes important, for being the pillar of a prosthetic restoration, as observed in this case report.

The recent development of technologies for endodontic treatment has focused largely on improving the quality of treatments (22). The introduction of apical locators, nickel-titanium (NiTi) rotary instruments, operating microscopes, digital radiography, and cone-beam computed tomography greatly improved the ability to detect, clean and shape root canals (16, 17, 22, 23).

Plotino (18) presented a case of a mandibular third molar showing four canals in four independent roots, three of which in the mesial portion. The case reported in this article was rare, showing five canals in five roots, four of which in the mesial portion and one in the distal portion, and there are no reports in the literature of such anatomical variation. To accomplish that endodontic treatment, CBCT imaging was essential, making it possible to identify the number of canals and anatomy of the roots, so the use of this exame must be increasingly frequent in endodontics.

Conclusion

This clinical case report describes the endodontic treatment of a mandibular molar with five canals in five roots, distributed as four independent mesial roots and one distal root. Mandibular molars with five root canals and five independent roots are rare, but each case should undergo a careful clinical, radiography and tomography assessment in order to detect any anatomical anomalies. Possible variations in the internal anatomy of human teeth should be known to ensure successful endodontic treatment. Also, accessory canals in mandibular molars should be detected and negotiated to provide access for irrigation and filling materials into otherwise inaccessible isthmus.

Clinical Relevance

This case report shows how a correct interpretation of tomography images and the knowledge of root anatomy and its variations are fundamental to perform a successful endodontic treatment.

Conflict of Interest

The authors declare no conflict of interest.

Acknowledgements

Special thanks to the University of Fortaleza and the Federal University of Pelotas for their continued support.

References

1. *Malagnino V, Gallottini L, Passariello P. Some unusual clinical cases on root anatomy of permanent maxillary molars. J Endod 1997;23:127-8.*
2. *Vertucci FJ. Root canal morphology and its relationship to endodontic procedures. Endod Top 2005;10:3-29.*
3. *De-Pablo OV, Estevez R, Sánchez MP, Heilborn C, Cohenca N. Root anatomy and canal configuration of the permanent mandibular first molar: a systematic review. J Endod 2010;36:1919-31.*
4. *Vertucci FJ. Root canal anatomy of the human permanent teeth. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 1984;58:589-99.*
5. *Huang RY, Cheng WC, Chen CJ, Lin CD, Lai TM, Shen EC, Chiang CY, Chiu HC, Fu E. Three-dimensional analysis of the root morphology of mandibular first molars with distolingual roots. Int Endod J 2010;43:478-84.*
6. *Al-Qudah AA, Awawdeh LA. Root and canal morphology of mandibular first and second molar teeth in a Jordanian population. Int Endod J 2009;42:775-784.*
7. *Pineda F, Kuttler Y. Mesiodistal and buccolingual roentgenographic investigation of 7,275 root canals. Oral Surg Oral Med Oral Pathol 1972;33:101-110.*
8. *Pomeranz HH, Eidelman DL, Goldberg MG. Treatment considerations of the middle mesial canal*

of mandibular first and second molars. J Endod 1981;7:565-8.
9. Karapinar-Kazandag M, Basrani BR, Friedman S. The operating microscope enhances detection and negotiation of accessory mesial canals in mandibular molars. J Endod 2010;36:1289-94.
10. Kottor J, Paul KK, Mathew J, George S, Mathew J, Roy A. A permanent mandibular second molar with seven root canal systems. Quintessence Int. 2014;45:381-3.
11. Ahmed HA, Abu-Bakr NH, Yahia NA, Ibrahim YE. Root and canal morphology of permanent mandibular molars in a Sudanese population. Int Endod J 2007;40:766-71.
12. Ryan JL, Bowles WR, Baisden MK, McClanahan SB. Mandibular first molar with six separated canals. J Endod 2011;37:878-80.
13. Subbiva A, Kumar KS, Vivekanandhan P, Prakash V. Management of mandibular first molar with four canals in mesial root. J Conserv Dent. 2013;16:471-3.
14. Mannocci F, Peru M, Sheriff, Cook R, Pitt Ford TR. The isthmuses of the mesial root of mandibular molars: a micro-computed tomographic study. Int Endod J. 2005, 38, 558-63.
15. Baugh D, Wallace J. Middle mesial canal of the mandibular first molar: A case report and literature review. J Endod 2004;30:185-6.
16. Maniglia-Ferreira C, Almeida-Gomes F, Sousa BC. Management of Six Root Canals in Mandibular First Molar. Case Report Med 2015:1-5.
17. Maniglia-Ferreira C., de Almeida-Gomes F., de Sousa B. C., Dos Santos Acioli Lins C. C., Dos Santos R. A. A case of unusual anatomy in second mandibular molar with four canals. Eur J Dent. 2008;2:217-9.
18. Plotino G. A mandibular third molar with three mesial roots: A case report. J Endod 2008;34:224-6.
19. Almeida-Gomes F, Maniglia-Ferreira C, Carvalho-Susa B, Santos RA. Six roots canals in maxillary first molar. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2009;108:e157-159.
20. Ghoddusi J, Naghavi N, Zarei M, Rohani E. Mandibular first molar with four distal canals. J Endod 2007;33(12):1481-1483.
21. Pablo OV, Estevez R, Sánchez MP, Heilborn C, Cohenca N. Root anatomy and canal configuration of the permanent mandibular first molar: a systematic review. Journal of Endodontics. 2010;36:1919-1931.
22. Karapinar-Kazandag M, Basrani BR, Friedman S. The operating microscope enhances detection and negotiation of accessory mesial canals in mandibular molars. Journal of Endodontics. 2010;36:1289-1294.
23. Demirbuga S, Sekerci AE, Dinçer AN, Cayabatmaz M, Zorba YO (2013) Use of cone-beam computed tomography to evaluate root and canal morphology of mandibular first and second molars in Turkish individuals.

Lettera DEL PRESIDENTE

Quest'anno torniamo nell'amata sede di Bologna, il Palazzo della Cultura e dei Congressi, una sede prestigiosa e facilmente raggiungibile che ci auguriamo risulti gradita a tutti i nostri Soci e amici.

Come nostra tradizione e come da nostra Mission, rimaniamo strettamente attaccati all'Endodonzia: il titolo del Congresso ***Moderna Endodonzia tra tecnologia ed esperienza*** descrive perfettamente l'intento del Consiglio Direttivo, dare ai partecipanti una chiara visione di dove l'Endodonzia sia e di dove stia andando.

Il programma è come sempre ricco e interessante, a partire dal Corso Pre-Congresso sui traumi dentali che sarà tenuto dal nostro bravissimo Socio Claudio Pisacane e da Lorenzo Vanini.

Abbiamo selezionato tra i nostri Soci dei Relatori di alto livello che possano dare informazioni chiare e utili ai partecipanti: Maurizio Bossù, Enrico Cassai, Italo Di Giuseppe, Gianluca Gambarini, Fabio Gorni, Vito Antonio Malagnino, Carlo Prati, Alberto Mazzocco, Giovanni Olivi, Franco Ongaro, Andrea Polesel, Mauro Rigolone, Maria Teresa Sberna e Umberto Uccioli – elencati in stretto ordine alfabetico – si alterneranno sul podio della sala principale con relazioni di grande interesse e di grande qualità.

Quest'anno la tradizionale sessione pomeridiana delle Tavole Cliniche sarà ulteriormente potenziata, con più spazi e una maggiore distribuzione negli spazi congressuali al fine di migliorare l'acustica e l'accessibilità. Cercheremo inoltre di coordinare meglio le tempistiche così da dare ai partecipanti la possibilità di assistere a più di una tavola/teatro e portare a casa più nozioni possibili: occhio alla sirena!

Infine i consueti Premi SIE: anche quest'anno al Congresso, in parallelo al programma della sala principale, potrete assistere o partecipare ai nostri quattro premi, Riccardo Garberoglio, Giorgio Lavagnoli, Francesco Riitano e il Miglior Poster SIE.

Concludo con pochi ma sentiti ringraziamenti: a Carlo Prati, prezioso padrone di casa, a Lele Ambu, sempre disponibile e generoso con noi e con la sua amata Bologna.

Vi aspettiamo a Bologna!

Vittorio Franco
Presidente SIE

STRUTTURA SOCIETARIA

RESPONSABILE SCIENTIFICO
E COORDINATORE CULTURALE SIE

Andrea Polesel
P.zza Golgi, 16/1 - 16011 Arenzano GE
Tel. 010-9124625 - 338-1289165
andrea.polesel1971@gmail.com
andrea.polesel@libero.it

COORDINATORI MACROAREE IN CARICA NEL BIENNIO 2019-2020

SIE MacroArea Nord-Est

Stefano Gaffuri
Via Napoleone, 50
25039 Travagilato BS
tel. studio 030-6864844
cell. 335-5866543
fax 030-6866189
stefanogaffuri@libero.it
info@gaffurigalvaniodontoiatri.it

SIE MacroArea Nord-Ovest

Davide Fabio Castro
Via Oioli, 6B
28013 Gattico NO
tel. 0331-735276
cell. 338-7075126
davidefabio.castro@gmail.com

SIE MacroArea Centro

Luigi Scagnoli
Via Graziano, 57
00165 Roma RM
tel. 06-8607899
cell. 393-3316543
fax 06-8607899
luigiscagnoli@gmail.com

SIE MacroArea Sud

Giorgio Vittoria
Largo Francesco Torraca, 71
80133 Napoli NA
tel. 081-5529419
cell. 347-3848922
fax 081-5424251
giorgio.vittoria@gmail.com

STRUTTURA SOCIETARIA

SOCI ONORARI

Borsotti Prof. Gianfranco
Bresciano Dott. Bartolo
Cavalleri Prof. Giacomo
Pecora Prof. Gabriele
Perrini Dott. Nicola
Vignoletti Dott. Gianfranco

SOCI ATTIVI

Agresti Dott. Daniele
Altamura Dott. Carlo
Amato Prof. Massimo
Ambu Dott. Emanuele
Amoroso D'Aragona Dott.ssa Eva
Ascione Dott.ssa Maria Rosaria
Autieri Dott. Giorgio
Badino Dott. Mario
Barattolo Dott. Raniero
Barboni Dott.ssa Maria Giovanna
Becciani Dott. Riccardo
Beccio Dott. Roberto
Bertani Dott. Pio
Berutti Prof. Elio
Bonaccorso Dott. Antonino Maria
Bonacossa Dott. Lorenzo
Bonelli Bassano Dott. Marco
Borrelli Dott. Marino
Boschi Dott. Maurizio
Bottacchiari Dott. Renato Stefano
Botticelli Dott. Claudio
Brenna Dott. Franco
Buda Dott. Massimo
Bugea Dott. Calogero
Cabiddu Dott. Mauro
Calapaj Dott. Massimo
Calderoli Dott. Stefano
Campo Dott.ssa Simonetta
Cantatore Prof. Giuseppe
Capelli Dott. Matteo
Cardinali Dott. Filippo
Cardosi Carrara Dott. Fabrizio
Carmignani Dott. Enrico
Carratù Dott.ssa Paola
Carrieri Dott. Giuseppe
Cascone Dott. Andrea
Cassai Dott. Enrico
Castellucci Dott. Arnaldo
Castro Dott. Davide Fabio
Cavalli Dott. Giovanni
Cecchinato Dott. Luigi
Cerutti Prof. Antonio
Cinelli Dott. Marco
Ciunci Dott. Renato Pasquale
Colla Dott. Marco
Conconi Dott. Marcello
Coraini Dott. Cristian
Cortellazzi Dott. Gianluca
Cotti Prof.ssa Elisabetta
Cozzani Dott.ssa Marina
D'Agostino Dott.ssa Alessandra
Daniele Dott. Lucio
Del Mastro Dott. Giulio
Dettori Prof.ssa Claudia
Di Ferrante Dott. Giancarlo
Di Giuseppe Dott. Italo
Donati Dott. Paolo
Dorigato Dott.ssa Alessandra
Fabbri Dott. Massimiliano
Fabiani Dott. Cristiano
Faitelli Dott.ssa Emanuela
Fassi Dott. Angelo
Favatà Dott. Pasquale Massimo
Fermani Dott. Giorgio
Ferraioli Dott. Gennaro
Ferrari Dott. Paolo
Ferrini Dott. Francesco
Foce Dott. Edoardo
Forestali Dott. Marco
Fornara Dott. Roberto
Fortunato Prof. Leonzio
Franchi Dott.ssa Irene
Franco Dott. Vittorio
Fumei Dott. Gianluca
Fuschino Dott. Ciro
Gaffuri Dott. Stefano
Gagliani Prof. Massimo
Gallo Dott. Roberto
Gallottini Prof. Livio
Gambarini Prof. Gianluca
Generali Dott. Paolo
Gesi Dott. Andrea
Giacomelli Dott.ssa Grazia
Giovarruscio Dott. Massimo
Gnoli Dott.ssa Rita
Gorni Dott. Fabio
Greco Dott.ssa Katia
Gullà Dott. Renato
Hazini Dott. Abdol Hamid
Iacono Dott. Francesco
Iandolo Dott. Alfredo
Ivaldi Dott. Luca
Kaitsas Dott. Roberto
Kaitsas Prof. Vassilios
Lamorgese Dott. Vincenzo
Lendini Dott. Mario
Libotte Dott. Fabrizio
Maggiore Dott. Francesco
Malagnino Dott. Giovanni Pietro Vito
Malagnino Prof. Vito Antonio
Malentacca Dott. Augusto
Mancini Dott. Roberto
Mancini Dott. Mario
Mancini Dott. Manuele
Manfredonia Dott. Massimo Francesco
Manfrini Dott.ssa Francesca
Mangani Prof. Francesco
Martignoni Dott. Marco
Mazzocco Dott. Alberto
Messina Dott. Giovanni
Migliau Dott. Guido
Monza Dott. Daniele
Mori Dott. Massimo
Multari Dott. Giuseppe
Mura Dott. Giovanni
Natalini Dott. Daniele
Negro Dott. Alfonso Roberto
Olivi Prof. Giovanni
Ongaro Dott. Franco
Orsi Dott.ssa Maria Veronica
Padovan Dott. Piero
Palazzi Dott. Flavio
Palmeri Dott. Mario
Pansecchi Dott. Davide
Papaleoni Dott. Matteo
Pappalardo Dott. Alfio
Parente Dott. Bruno
Pasqualini Dott. Damiano
Piferi Dott. Marco
Pilotti Dott. Emilio
Pirani Dott.ssa Chiara
Pisacane Dott. Claudio
Polesel Dott. Andrea
Pollastro Dott. Giuseppe
Pongione Dott. Giancarlo
Pontoriero Dott.ssa Denise Irene Karin
Portulano Dott. Francesco
Pracella Dott. Pasquale
Preti Dott. Riccardo
Pulella Dott. Carmelo
Puttini Dott.ssa Monica
Raffaelli Dott. Renzo
Raia Dott. Roberto
Rapisarda Prof. Ernesto Guido
Re Prof. Dino
Reggio Dott.ssa Lucia
Rengo Prof. Sandro
Riccitiello Prof. Francesco
Rieppi Dott. Alberto
Rigolone Dott. Mauro
Rizzoli Dott. Sergio
Roggero Dott. Emilio
Russo Dott. Ernesto
Santarcangelo Dott. Filippo Sergio
Sbardella Dott.ssa Maria Elvira
Sberna Dott.ssa Maria Teresa
Scagnoli Dott. Luigi
Schianchi Dott. Giovanni
Schirosa Dott. Pier Luigi
Serra Dott. Stefano
Sforza Dott. Francesco
Simeone Prof. Michele
Smorto Dott.ssa Natalia
Sonaglia Dott. Angelo
Squeo Dott. Giuseppe
Storti Dott.ssa Paola
Strafella Dott. Roberto
Stuffer Dott. Franz
Taglioretti Dott. Vito
Taschieri Dott. Silvio
Tavernise Dott. Salvatore
Tiberi Dott. Claudio
Tocchio Dott. Carlo
Tonini Dott. Riccardo
Tosco Dott. Eugenio
Tripi Dott.ssa Valeria Romana
Uberti Dott.ssa Manuela
Uccioli Dott. Umberto
Vecchi Dott. Stefano
Venturi Dott. Mauro
Venturi Dott. Giuseppe
Venuti Dott. Luca
Veralli Dott. Eduardo
Vittoria Dott. Giorgio
Volpi Dott. Luca Fedele
Zaccheo Dott. Francesco
Zaccheo Dott. Fabrizio
Zerbinati Dott. Massimo
Zilocchi Dott. Franco
Zuffetti Dott. Francesco

SOCI AGGREGATI

Castorani Dott. Giuseppe
Cuppini Dott.ssa Elisa
D'Alessandro Dott. Alfonso
Fordellone Dott. Francesco
Giovinazzo Dott. Luca
Lamparelli Dott. Andrea
Milani Dott. Stefano
Paone Dott. Pasquale

CONSIGLIO DIRETTIVO SIE BIENNIO 2019-2020

Past President
Riccitiello Prof. Francesco
Presidente
Franco Dott. Vittorio
Presidente Eletto
Fornara Dott. Roberto
Vice Presidente
Sberna Dott.ssa Maria Teresa
Segretario
Cardinali Dott. Filippo
Tesoriere
Coraini Dott. Cristian
Coordinatore Culturale
Polesel Dott. Andrea
Coordinatore della Comunicazione
Pontoriero Dott.ssa Denise Irene Karin
Revisore dei Conti
Greco Dott.ssa Katia
Revisore dei Conti
Ongaro Dott. Franco

SOCI SCOMPARSI

Ricordiamo con affetto e gratitudine i Soci scomparsi:

Attanasio Dott. Salvatore
Socio Attivo
Castagnola Prof. Luigi
Socio Onorario
De Fazio Prof. Pietro
Socio Attivo
Dolci Prof. Giovanni
Socio Onorario
Duillo Dott. Sergio
Socio Onorario
Garberoglio Dott. Riccardo
Socio Onorario
Lavagnoli Dott. Giorgio
Socio Onorario
Mantero Prof. Franco
Socio Onorario
Malvano Dott. Mariano
Socio Attivo
Pecchioni Prof. Augusto
Socio Onorario
Riitano Dott. Francesco
Socio Onorario
Spina Dott. Vincenzo
Socio Onorario
Zerosi Prof. Carlo
Socio Onorario

COME DIVENTARE SOCIO ATTIVO/AGGREGATO

Scaricabile dal sito **www.endodonzia.it**

SOCIO AGGREGATO

Per avere lo status di Socio Aggregato si dovrà presentare la documentazione descritta nel sito www.endodonzia.it che sarà valutata dalla Commissione Accettazione Soci. La documentazione che verrà presentata dovrà mostrare con rigore, attraverso casi clinici, l'interessamento del candidato alla disciplina endodontica.
Un meccanismo a punti è stato introdotto per valutare l'ammissibilità del candidato allo "status" di Socio Aggregato: i punti saranno attribuiti in base al tipo di documentazione presentata. Possono accedere alla qualifica di Socio Aggregato tutti i Soci Ordinari della SIE, in regola con le quote associative degli ultimi tre anni, che completino e forniscano la documentazione alla Segreteria Nazionale (Via Pietro Custodi 3, 20136 Milano) entro i termini che verranno indicati all'indirizzo web: www.endodonzia.it.
La domanda dovrà essere firmata da un Socio Attivo, in regola con la quota associativa per l'anno in corso, il quale è responsabile della correttezza clinica e formale della documentazione presentata.

DOCUMENTAZIONE NECESSARIA PER DIVENTARE SOCIO AGGREGATO

Qualsiasi Socio Ordinario, con i requisiti necessari, può presentare la documentazione per ottenere la qualifica di Socio Aggregato. Un meccanismo a punti è stato introdotto per valutare il candidato: un minimo di 80 punti è richiesto per divenire Socio Aggregato.
La documentazione clinica per ottenere la qualifica di Socio Aggregato dovrà presentare almeno sei casi, di cui non più di tre senza lesione visibile nella radiografia preoperatoria e non più di uno di Endodonzia Chirurgica Retrograda.
Nella domanda non potranno essere presentati casi la cui somma superi i 120 punti per la qualifica di Socio Aggregato.
L'aspirante Socio Aggregato potrà presentare la documentazione clinica in più volte, con un minimo di 40 punti per presentazione, in un arco massimo di cinque anni. Il mancato rinnovo della quota associativa, anche per un solo anno, annulla l'iter di presentazione dei casi.

SOCIO ATTIVO

Per avere lo status di Socio Attivo si dovrà presentare la documentazione descritta nel sito www.endodonzia.it che sarà valutata dalla Commissione Accettazione Soci. La documentazione che verrà presentata dovrà mostrare con rigore, attraverso documentazione scientifica e casi clinici, l'interessamento del candidato alla disciplina endodontica.
Un meccanismo a punti è stato introdotto per valutare l'ammissibilità del candidato allo status di Socio Attivo: i punti saranno attribuiti in base al tipo di documentazione clinica e scientifica presentata. Possono accedere alla qualifica di Socio Attivo tutti i Soci Ordinari della SIE, in regola con le quote associative degli ultimi tre anni, che completino e forniscano la documentazione alla Segreteria Nazionale (Via Pietro Custodi 3, 20136 Milano) entro i termini che verranno indicati all'indirizzo web: www.endodonzia.it.
La domanda di ammissione allo status di Socio Attivo rivolta al Presidente della SIE dovrà essere firmata da un Socio Attivo in regola con la quota associativa per l'anno in corso, il quale dovrà aver esaminato e approvato la documentazione. Quest'ultimo è responsabile della correttezza clinica e formale della documentazione presentata.

DOCUMENTAZIONE NECESSARIA PER DIVENTARE SOCIO ATTIVO

Qualsiasi Socio Ordinario, con i requisiti necessari, può presentare la documentazione per ottenere la qualifica di Socio Attivo. Il Socio Aggregato che volesse presentare la documentazione scientifica e clinica a integrazione di quella clinica già approvata dalla CAS per lo status di socio Aggregato, potrà farlo già dall'anno successivo all'ottenimento della sua qualifica.
Un meccanismo a punti è stato introdotto per valutare il candidato a Socio Attivo. Un minimo di 200 punti è richiesto per divenire Socio Attivo.
Nella domanda non potranno essere presentati casi la cui somma superi i 240 punti per la qualifica di Socio Attivo.
La documentazione scientifica potrà essere presentata, a completamento della documentazione clinica, solo per la domanda per divenire Socio Attivo e non potrà superare i 100 punti.
La documentazione clinica dovrà presentare un minimo di sei casi, di cui almeno 4 di molari pluriradicolati con delle precise tipologie: tra questi casi almeno uno deve essere un ritrattamento con lesione visibile nella radiografia preoperatoria e dei restanti tre almeno due devono avere una lesione visibile nella radiografia preoperatoria.
La documentazione clinica non deve presentare più di un caso di Endodonzia Chirurgica Retrograda con immagini e non più di uno senza immagini.
La documentazione scientifica non potrà presentare più di due articoli come coautore.

MODALITÀ DI DOCUMENTAZIONE DEI CASI CLINICI

Criteri e modalità per la valutazione dei casi clinici idonei ad accedere alle qualifiche di Socio Aggregato e di Socio Attivo sono espressi nell'apposita sezione del Regolamento della Società Italiana di Endodonzia (SIE) all'indirizzo web: www.endodonzia.it.

CRITERI DI VALUTAZIONE

I casi clinici verranno valutati nel loro complesso, coerentemente con gli scopi e fini della SIE, e devono essere presentati dai Candidati considerando non solo l'aspetto clinico, ma anche quello formale della documentazione presentata.
La documentazione scientifica verrà valutata considerando la classificazione ANVUR delle Riviste Scientifiche, i documenti scientifici dovranno essere tutti di pertinenza endodontica.

ADEMPIMENTI DEL CANDIDATO

La domanda di ammissione allo status di Socio Aggregato/Attivo, rivolta al Presidente della SIE, dovrà pervenire, insieme alla documentazione di seguito elencata, alla Segreteria 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. La domanda dovrà essere firmata da un Socio Attivo in regola con la quota associativa per l'anno in corso, il quale dovrà aver esaminato e approvato la documentazione. Quest'ultimo è responsabile della correttezza clinica e formale della documentazione presentata.

PRESENTAZIONE DEI CASI ALLA COMMISSIONE

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) è formata cinque Membri di indiscussa esperienza clinica, quattro Soci Attivi con almeno cinque anni di anzianità in questo ruolo eletti a ogni scadenza elettorale dall'Assemblea dei Soci Attivi e Onorari e uno dei Past President della Società incaricato dal CD a ogni riunione. Compito della CAS è quello di esaminare e valutare la documentazione presentata dagli aspiranti Soci Aggregati e Soci Attivi. Per rispetto del lavoro dei Candidati e per omogeneità di giudizio, in ogni riunione CAS verranno valutati non più di 12 candidati a Socio Attivo; resta libero, invece, il numero dei candidati a Socio Aggregato valutabile in una singola riunione. Il Consiglio Direttivo (CD) incaricando la Commissione Accettazione Soci (CAS) la rende responsabile dell'applicazione delle regole descritte nell'articolo 2 del regolamento. Il giudizio della CAS è insindacabile.

MEMBRI DELLA COMMISSIONE ACCETTAZIONE SOCI 2019

Past President della Società
Dott. **Enrico Cassai**
Dott. **Marco Colla**
Dott. **Mario Mancini**
Dott. **Pier Luigi Schirosa**

F22ALIGNER
BIOLOGIC TEETH ALIGNER

L'allineatore invisibile, confortevole, preciso

Con oltre 10.000 casi trattati il sistema F22, frutto di oltre 25 anni di esperienza e 15 anni di ricerche della Scuola di Specializzazione in Ortognatodonzia dell'**Università di Ferrara,** consente a tutti i medici dentisti e odontoiatri, anche non specialisti in ortodonzia, di proporre un trattamento estetico-funzionale sotto la guida esperta di Ortodontisti specializzati.
Il sistema è composto da una serie di sottili apparecchi ortodontici rimovibili (allineatori), su misura, realizzati nei moderni ed evoluti reparti produttivi di Sweden & Martina utilizzando un esclusivo materiale plastico trasparente: essi consentono lo spostamento graduale e progressivo dei denti verso la posizione ottimale, grazie a un monitoraggio continuo, raggiungendo un'occlusione esteticamente gradevole e funzionalmente valida.
La programmazione di F22 differisce sostanzialmente da quella degli altri allineatori disponibili sul mercato: il team di ortodontisti della Scuola di Specializzazione, guidato dal direttore, il Professor Giuseppe Siciliani, studia analiticamente ogni singolo caso, ne progetta il set-up e guida il medico fino alla fine del trattamento; insieme al prodotto, quindi, è offerta una **consulenza gratuita altamente qualificata anche a medici non specialisti in ortodonzia,** seguendo puntualmente criteri biomeccanici estremamente precisi.
Grazie al set-up digitale e al **visualizzatore 3D** è possibile analizzare e visualizzare ogni singolo step di trattamento, per condividerlo con i pazienti, illustrando facilmente il piano approvato.
Rispetto agli altri allineatori disponibili F22 Aligner ha dei plus sostanziali: il 20% in più di trasparenza; **fitting ottimale** e ritenzione perfetta (lo spazio tra allineatore e denti è inferiore a 40 micron); il 20% in più di elasticità, grazie alla quale sono trasmesse forze leggere e costanti; una superficie eccezionalmente liscia e **margini arrotondati** e rifiniti a mano, per un maggiore comfort del paziente; elevata resistenza alla rottura.

F22 Aligner è indicato per il trattamento di affollamenti, diastemi, discrepanze dell'indice di Bolton che necessitano di restauri protesici o di stripping per una completa correzione, festonature gengivali irregolari in pazienti con denti usurati o irregolari, morsi aperti o morsi profondi di lieve o moderata entità.
L'invio e lo studio dei casi avviene online, fino all'approvazione del set-up virtuale, sul quale sono realizzati i modelli e gli allineatori trasparenti F22 per ciascuna fase del piano di trattamento del paziente.

sweden & martina

Sweden & Martina S.p.A.
www.f22aligner.com | infof22@sweden-martina.com

Dentsply Sirona lancia TruNatomy™ per il trattamento del canale radicolare

Combinando precisione svizzera e ingegneria avanzata, la gamma **TruNatomy™** offre al clinico una soluzione che fornisce prestazioni efficienti e un maggiore rispetto dell'anatomia del dente, combinata con la facilità d'uso, ridefinendo così il trattamento del canale radicolare.

Con una serie di caratteristiche uniche TruNatomy™ offre una serie di vantaggi

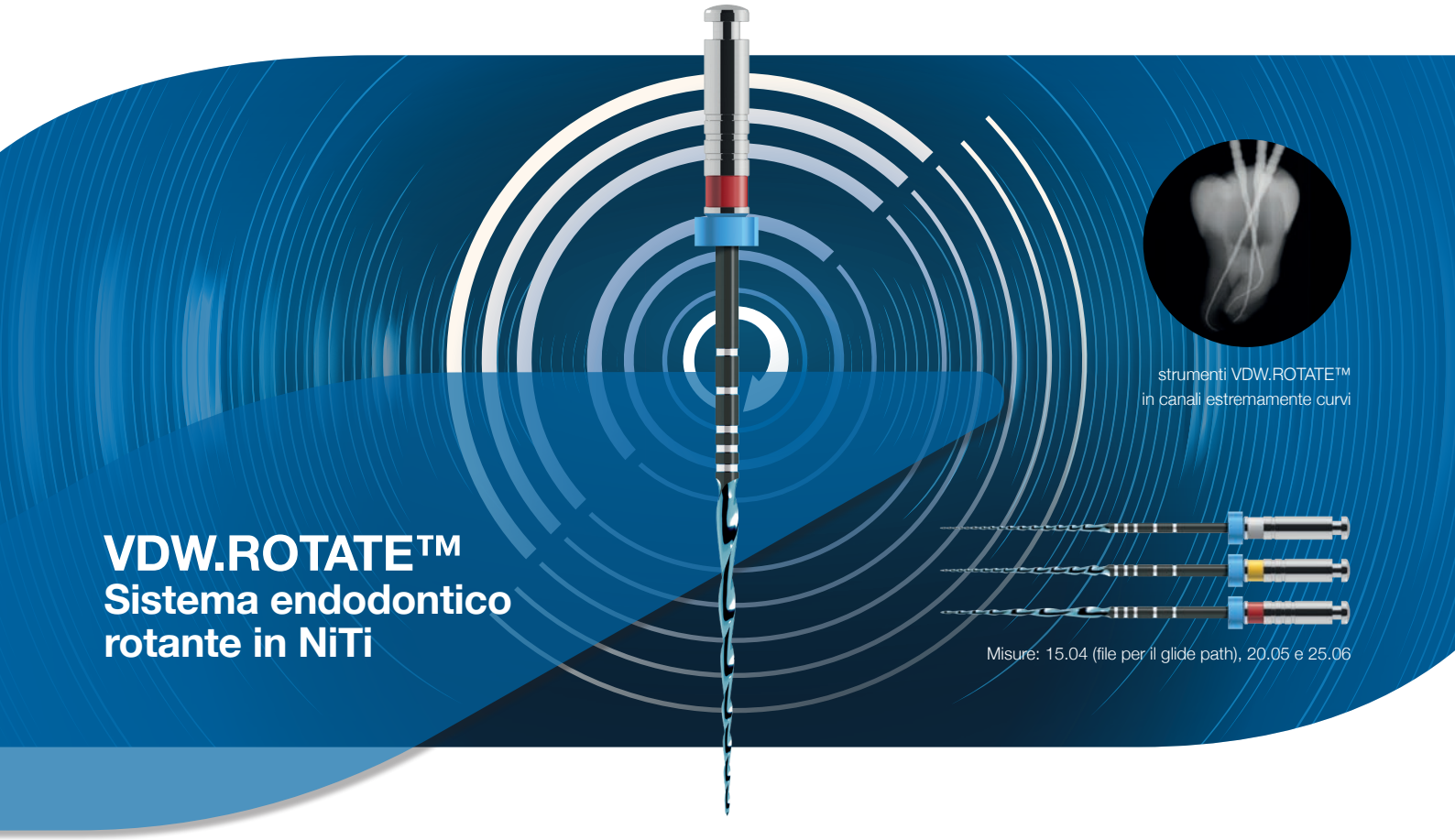
- ✔ Migliori prestazioni e più spazio per lo sbrigliamento e la rimozione dei detriti grazie al nuovo design dello strumento con una sezione trasversale eccentrica migliorata, una lega NiTi più sottile e sottoposta a speciale trattamento termico. La sua maggiore velocità (500 rpm) garantisce una maggiore efficienza con meno torque.
- ✔ Rispetto dell'anatomia naturale del dente grazie alla sua superiore capacità di centratura del canale: lo strumento si adatta al canale (e non viceversa).
- ✔ Mantenimento dell'integrità del dente grazie alla combinazione tra la geometria dello strumento, la lega sottile, la maggiore flessibilità e un manico più corto (9,5 mm): è possibile eseguire trattamenti canalari efficienti senza accesso diretto, rimuovendo la dentina solo dove clinicamente necessario.
- ✔ È un sistema completo che comprende, oltre agli strumenti per la preparazione e la sagomatura del canale, anche un puntale dedicato all'irrigazione, punte di carta corrispondenti e punte di guttaperca dedicate prodotte con la nuova tecnologia Conform Fit per una migliore adattamento e la precisa risposta di tug back.

Per saperne di più visita il sito www.dentsplysirona.com o contatta Simit Next al numero 0376.267811

THE DENTAL SOLUTIONS COMPANY™

Dentsply Sirona | Simit® NEXT Endodonzia & Conservativa

VDW®
Endo
Easy
Efficient



strumenti VDW.ROTATE™
in canali estremamente curvi

Misure: 15.04 (file per il glide path), 20.05 e 25.06

VDW.ROTATE™
Sistema endodontico rotante in NiTi

Migliora la qualità delle preparazioni con sistematica rotante: con il nuovo file VDW.ROTATE™

Roma, settembre 2019 | Confermando la nostra storia di successo in campo endodontico, abbiamo sviluppato un nuovo sistema di file rotanti a movimento continuo partendo dai risultati raggiunti con i sistemi endodontici precedenti e integrandoli con le ultime innovazioni tecnologiche nel campo dei materiali e del design dello strumento, in modo da ridefinire gli standard della strumentazione canalare rotante e portarla ad un livello qualitativo superiore.

VDW.ROTATE™ è un sistema di file rotanti a movimento continuo che consente di lavorare al massimo delle potenzialità in tutte le situazioni cliniche, da quelle più semplici a quelle più complesse.
Confermando il nostro approccio di offerta di sistema, la linea VDW.ROTATE™ include punte di carta e otturatori delle medesime dimensioni degli strumenti.

La sintesi perfetta di benefici fondamentali
La nuova linea di strumenti rotanti in NiTi VDW.ROTATE™ offre molteplici benefici per un trattamento endodontico semplificato ed efficiente, grazie ad una sequenza base intuitiva formata solo da 3 strumenti: un file per il glide path e due file per la sagomatura. Inoltre, la vasta gamma di diametri e conicità di file accessori disponibili consente al clinico di creare la propria sequenza personalizzata in funzione dell'anatomia canalare.
Confrontato con altri sistemi rotanti della VDW, il nuovo trattamento termico della lega consente una maggiore flessibilità dello strumento senza comprometterne l'efficienza di taglio.
La combinazione tra flessibilità ed efficienza con la sezione trasversale a forma di S decentrata di VDW.ROTATE™ assicura una rimozione dei detriti più efficace*.

Per ulteriori informazioni contatta il tuo rappresentante Dentsply Sirona di fiducia o il nostro servizio clienti al numero gratuito 800.310.333

* confrontato con strumenti rotanti a sezione centrata

Endodonzia Sicura… passo per passo

Il primo passo in ogni trattamento endodontico di successo è **una diagnosi precisa** basata su immagini 3D accurate ad alta risoluzione fornite dalla tomografia computerizzata a cone-beam (CBCT).
Morita supporta questi obiettivi diagnostici con il suo nuovo sistema a raggi X **Veraview X800** per immagini 3D, panoramiche e cefalometriche.

Vantaggi

- Questo apparecchio offre un livello di qualità dell'immagine senza precedenti in un sistema di imaging 2D/3D (risoluzione: 2,5 LP/mm MTF).
- È versatile! Non solo produce immagini rapide e accurate, ma fornisce anche la massima sicurezza per l'operatore e il paziente con dosi minime efficaci (ALARA). Infatti il sistema utilizza il collaudato campo R100 di riduzione della dose con la sua forma Ruleaux (triangolare).
- Esposizioni in modalità di 180 gradi e 360 gradi, esposizioni cefalometriche veloci in soli 3,5 secondi, o una funzione di ricostruzione dello zoom che crea una registrazione di 80 µm da una registrazione voxel 125 µm senza richiedere un Retake.

Morita è inoltre sinonimo di…

Precisione e sicurezza per il canale radicolare: una volta che l'endodontista procede alle effettive procedure intraorali, sono disponibili diversi strumenti di alta qualità per assistere il suo delicato lavoro. Per una comoda preparazione della cavità di accesso, Morita offre le **potenti turbine TwinPower** e i **manipoli della serie TorqTech e Tokyo**; offrendo una coppia massima a piccoli diametri dello strumento, forniscono una buona vista dell'area di lavoro e spazio sufficiente durante il trattamento dei molari.

Nelle fasi successive essenziali del trattamento – misurazione, strumentazione, riempimento e polimerizzazione – Morita offre una soluzione innovativa per tutti questi tre step, **il nuovo motore endodontico TriAuto ZX2 con localizzatore Apicale.**
ITriAuto ZX2 è l'unico sistema del suo genere che integra la localizzazione Apicale e la preparazione del canale radicolare in un unico manipolo: è stato progettato per la massima sicurezza ed è dotato sia della funzione OTR che della nuova funzione ottimale glidepath.
L'OTR cambia la direzione di rotazione del file non appena viene superato il livello di coppia pre-impostato singolarmente. Dopo aver invertito la rotazione di 90 gradi, torna a ruotare nella direzione di taglio; se la coppia è ancora troppo alta, il processo viene ripetuto tre-quattro volte dopo un ulteriore 180 gradi. Questo sistema aiuta a conservare la morfologia originale del sistema dei canali radicolari e facilita la rimozione affidabile dei detriti. Tutti questi fattori si combinano per abbreviare il tempo di trattamento.
L'OGP fornisce una preparazione rapida e automatizzata del glide-path, che è la prima fase di preparazione effettiva, e quindi prepara il canale radicolare per procedure endodontiche sicure. In combinazione con la funzione del dispositivo, il clinico può portare lo strumento endodontico fino alla lunghezza di lavoro senza fratture, ostruzione o formazione di sporgenza. Semplicemente ingegnoso e assolutamente sicuro. Un display LCD fornisce un feedback completo dal canale radicolare mostrando i dati di misura esatti acquisiti dal manipolo, soprattutto la distanza del file dall'apice.
Quindi il TriAuto ZX2 conserva la struttura dentale naturale e rende il trattamento ancora più efficiente perché è richiesto solo un numero limitato di file.
Un'altra caratteristica sorprendente di questo sistema endodontico è la sua **piccola testina e il peso ridotto** (140 g), che lo rende molto maneggevole. Essendo un **apparecchio cordless** migliora significativamente la flessibilità di trattamento e ottimizza il flusso di lavoro clinico. Il funzionamento semplice e intuitivo e le funzioni automatizzate assicurano risultati affidabili e sicuri in ogni momento.

LA MISSION DI MORITA

Morita offre un portfolio completo di prodotti di alta qualità che coprono tutte le fasi del trattamento, dalla diagnosi al controllo, permettendo di lavorare sempre in modo efficiente, ergonomico e sicuro. I dentisti apprezzeranno la convenienza e i pazienti apprezzeranno il comfort di un trattamento migliorato. Il nuovo sistema di imaging Veraview X800 2D/3D e il nuovo motore TriAuto ZX2 endo con localizzatore Apex mettono in primo piano la sicurezza e rappresentano nuovi standard nei loro segmenti. Queste soluzioni sottolineano l'impegno di Morita: rispondere alle esigenze degli utenti e dei pazienti in ogni fase e continuare a fornire il "Gold standard" per il successo del trattamento nella pratica endodontica.

VITA SOCIETARIA

Closed Meeting SIE 2019

Galzignano Terme, 14-16 giugno 2019
Hotel Majestic | Radisson Blu Resort Terme di Galzignano

*Resoconto a cura della Dott.ssa **Denise Pontoriero,** Coordinatore della Comunicazione SIE*

Come ogni anno è tempo di bilanci e di progetti, è tempo di Closed Meeting! Il Closed Meeting non è soltanto momento di incontro culturale e conviviale, ma anche l'evento in cui si possono unire forze e idee per rendere sempre più grande la nostra Società.
La SIE è la prima Società Scientifica Endodontica in Italia e la seconda più grande in Europa, è quindi necessario lavorare con impegno ed entusiasmo per mantenere il livello di qualità scientifico-culturale altissimo, non dimenticando il significato di aggregazione e divertimento che ha da sempre contraddistinto questo momento di vita societaria.
I tanti Soci Attivi che hanno partecipato al Closed Meeting si sono riuniti in una location ormai familiare per la SIE, il Radisson Blu Resort Terme di Galzignano, un incantevole resort dove soci e accompagnatori hanno potuto praticare numerosi sport, rilassarsi nelle diverse piscine termali o raggiungere comodamente la vicina Padova.
Il Consiglio Direttivo si è riunito già dal mattino di venerdì 14 inaugurando il Closed Meeting con la consueta riunione programmatica, questa volta aperta ai Coordinatori di MacroArea, al Coordinatore di Commissione e all'Editor in Chief del GIE.
L'ordine del giorno, fitto di argomenti da discutere e attività scientifiche da organizzare, ha impedito di terminare la riunione nel tempo previsto, quindi è stata interrotta per permettere a tutti di partecipare al programma culturale che è iniziato alle ore 15.00 con l'eccellente Dott. **Federico Michelini**, il quale ci ha illustrato il suo case report vincitore del concorso **"Miglior Caso Clinico Under 32"**.
Il pomeriggio è poi continuato con la straordinaria e frizzante presentazione dal titolo **"Riassorbimenti esterni invasivi: soluzioni chirurgico-restaurative in elementi anteriori e posteriori"**, in cui il bravissimo conservatore Dott. **Marco Veneziani** ci ha illustrato come affronta casi al limite dell'estrazione nella sua pratica clinica. In seguito la Dottoressa **Maria Teresa Sberna** ha presentato il nuovo progetto **SIE Academy** che consolida la già ottima collaborazione della nostra Società con le Istituzioni Universitarie.
In seno a questo progetto il Dottor **Marco Cinelli**, nuovo Socio Attivo, ha esposto in modo chiaro ed esaustivo la sua presentazione dal titolo **"Mantenibilità dei denti trattati endodonticamente attraverso la Chirurgia**

1 | La Cena del Consiglio e dei Coordinatori di Commissione

2 | Il Dott. Federico Michelini con Presidente e Segretario SIE

3 | Il Dott. Federico Michelini, Vincitore del concorso "Miglior Caso Clinico Under 32"

VITA SOCIETARIA

4 | Il Dott. Marco Veneziani con Presidente, Segretario e Coordinatore Culturale SIE

5 | Il Dott. Marco Veneziani con la Platea dei Soci Attivi SIE

6 | Il Dott. Marco Cinelli, nuovo Socio Attivo, con la Commissione SIE Academy

Endodontica mini-invasiva".
Al termine del pomeriggio il Coordinatore Culturale Andrea Polesel e i Coordinatori di MacroArea Davide Castro, Stefano Gaffuri, Luigi Scagnoli e Giorgio Vittoria si sono incontrati, anticipando la consueta riunione del sabato.
I "Soci calciatori" hanno dato spettacolo con la mitica Partita di Calcetto: SIE MacroAree League 2019, MacroAree Nord-Est e Nord-Ovest VS Centro e Sud, vinta dalla squadra delle MacroAree del Nord.
La giornata è terminata con l'elegante cena al Ristorante "La Montanella".
Nel frattempo gli accompagnatori e i Soci Attivi interessati hanno potuto partecipare alla visita guidata di Padova, perfettamente organizzata dalla nostra super segretaria Gaia.
La giornata è terminata con un'ottima cena presso la suggestiva cornice del Ristorante "Antica Trattoria Ballotta dal 1605".

Sabato 15 è stato dedicato alle riunioni delle varie Commissioni

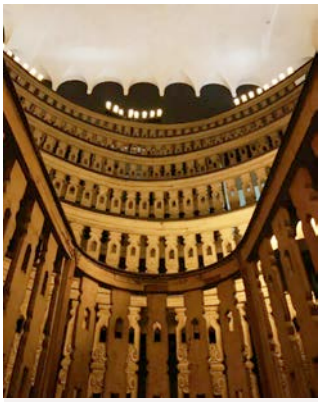
Riunione della Commissione Culturale, Premi Riitano, Lavagnoli, Poster ***Coordinatore: Massimo Giovarruscio***

Riunione della Commissione Culturale, Premio Garberoglio ***Responsabile: Manuele Mancini***

Riunione della Commissione per la Comunicazione ***Coordinatore della Comunicazione: Denise Pontoriero***

Riunione della Commissione Accettazione Soci ***CAS e Past President: Enrico Cassai, Marco Colla, Mario Mancini Francesco Riccitiello e Sandro Rengo*** si sono riuniti per discutere del Regolamento per la sottomissione dei casi.

Riunione del Consiglio Direttivo – prosecuzione – che si è protratta fino alle ore 16.00.



7 | Il teatro anatomico di Padova (visita guidata)

La domenica mattina è stata dedicata al relax in piscina, alle chiacchiere e ai saluti, con la soddisfazione di aver fatto un buon lavoro e in attesa di incontrarsi tutti a Bologna in occasione del 36° Congresso Nazionale SIE, che si terrà dal 7 al 9 novembre.

8 | La divisa della SIE MacroArea League 2019

9 | I performanti calciatori del Torneo di MacroAree

10 | Momenti di meritato relax dopo le lunghe riunioni di commissione

VITA SOCIETARIA

09/03/2019 - 13/04/2019 - 18/05/2019 - 08/06/2019 - 21/09/2019

Corsi di formazione teorico-pratici della Società Italiana di Endodonzia

SIE Endodontic Courses - Sede Bari

Coordinatore di MacroArea Sud, Dott. Giorgio Vittoria

Il 21 settembre 2019 si è concluso il ciclo di lezioni teorico pratiche dell'Endodontic Course della SIE iniziato il 9 marzo 2019 presso l'Hotel Palace di Bari.
La risposta del territorio è stata elevata, 14 iscritti, che hanno seguito con puntualità, attenzione e spirito propositivo le lezioni dei tanti Soci Attivi che hanno dato vita a questo corso: Massimo Francesco Manfredonia, Pier Luigi Schirosa, Raniero Barattolo, Eduardo Veralli, Katia Greco, Eva Amoroso D'Aragona, Alfredo Iandolo, Giuseppe Squeo, Cristian Coraini, Giovanni Messina, Roberto Fornara e Bruno Parente.
Anche i workshop pratici hanno riscosso successo e ringrazio i relatori per la loro disponibilità a contribuire a tale successo.
Possiamo affermare che alla fine di questo corso base tutti i colleghi che hanno partecipato, sia studenti che odontoiatri con maggiore anzianità lavorativa, hanno acquisito i concetti fondamentali dell'Endodonzia moderna che la nostra Società vuole trasmettere e difendere, e questo è motivo di grande soddisfazione.
Merita una menzione d'onore il Dott. Giuseppe Zito che raggiunge la terza partecipazione a un Endodontic Course della SIE (con questo di Bari) a dimostrazione che c'è sempre qualcosa da imparare.
Un ultimo ringraziamento al Dott. Giuseppe Squeo per aver egregiamente gestito la logistica e i rapporti con l'Hotel Palace, alla Dott.ssa Katia Greco per la disponibilità a coprire più di una lezione e svariati chilometri in automobile e alla Dott.ssa Eva Amoroso D'Aragona per avermi supportato sempre e comunque.

Arrivederci a Bologna per la lezione conclusiva dell'Endodontic Course!

1 | I Relatori del Corso insieme al Coordinatore di MacroArea Sud, il Dott. Giorgio Vittoria

2 | Il Dott. Bruno Parente durante un momento in aula

3 | I Partecipanti dell'Endodontic Course di Bari

4 | I Relatori dell'Endodontic Course di Bari

VITA SOCIETARIA

19/03/2019 - 09/04/2019 - 14/05/2019 - 13/06/2019 - 17/09/2019

Corsi di formazione teorico-pratici della Società Italiana di Endodonzia

SIE Endodontic Courses - Sede Brescia

Coordinatore di MacroArea Nord-Est, Dott. Stefano Gaffuri

Con il quinto incontro svoltosi il 17 settembre 2019 si è conclusa a Brescia, presso l'Hotel Ambasciatori, la terza edizione dell'Endodontic Course a cura della MacroArea Nord-Est della SIE. Come nelle precedenti edizioni, anche quest'anno il successo del Corso è stato decretato non solo dal folto numero di partecipanti, ma anche dal loro grande interesse dimostrato in ogni incontro. Numerosissimi i giovani, sia studenti che neo-laureati, ma anche professionisti esperti, tutti determinati nell'apprendere i più moderni orientamenti in Endodonzia. Si sono succeduti come Relatori alcuni Soci Attivi della nostra Società, sempre pronti a prodigarsi nel mettere a disposizione degli iscritti la loro esperienza clinica.
Il Dott. Giovanni Cavalli nel primo incontro del 19 marzo ha affrontato la tematica della diagnosi e il piano di trattamento in Endodonzia. A seguire il Dott. Stefano Gaffuri ha trattato l'argomento dell'esecuzione di una corretta cavità di accesso e dell'anatomia endodontica. Il 9 aprile il Dott. Giuseppe Venturi ha parlato dell'importanza dell'utilizzo della diga di gomma, con relativa esercitazione pratica e nel pomeriggio il Dott. Riccardo Tonini ci ha fatto avventurare nei segreti del mondo dell'irrigazione, proponendo nuovi protocolli operativi. Il Dott. Luigi Cecchinato, nel successivo appuntamento, ha trattato la sagomatura dei canali mentre l'otturazione è stata argomento a cura del Dott. Gaffuri e del Dott. Giuseppe Venturi.
Il Dott. Cristian Coraini, come nelle precedenti edizioni, ha trattato magistralmente l'importante tema della ricostruzione post-endodontica.
Il quinto incontro ha visto come Relatori il Dott. Roberto Fornara, che ha spiegato l'importanza e la chiave di lettura dell'immagine radiografica in 3D ottenuta con la CBCT e il Dott. Gaffuri, che ha concluso l'incontro trattando dei ritrattamenti ortogradi e retrogradi.
Tra gli interventi si sono svolti anche i workshop pratici che hanno offerto ai partecipanti la possibilità di testare strumenti e motori dedicati alla moderna Endodonzia.

1 | I Partecipanti e il Dott. Giovanni Cavalli, Relatore del Corso insieme al Coordinatore di MacroArea Nord-Est, il Dott. Stefano Gaffuri

2 | I Partecipanti e il Dott. Riccardo Tonini, Relatore del Corso insieme al Coordinatore di MacroArea Nord-Est, il Dott. Stefano Gaffuri

3 | I Partecipanti e il Dott. Luigi Cecchinato, Relatore del Corso insieme al Coordinatore di MacroArea Nord-Est, il Dott. Stefano Gaffuri

4 | I Partecipanti e il Dott. Roberto Fornara, Relatore del Corso insieme al Coordinatore di MacroArea Nord-Est, il Dott. Stefano Gaffuri

VITA SOCIETARIA

09/03/2019 - 06/04/2019 - 18/05/2019 - 08/06/2019 - 21/09/2019

Corsi di formazione teorico-pratici della Società Italiana di Endodonzia

SIE Endodontic Courses - Sede Genova

Coordinatore di MacroArea Nord-Ovest, Dott. Davide Castro

Resoconto a cura del Referente Locale e organizzatore, Dott. Luca Ivaldi

Nelle consuete salette della Facoltà di Odontoiatria al padiglione n. 4 dell'Ospedale San Martino si è svolto per il secondo anno consecutivo l'Endodontic Course SIE, che in questa edizione è stato sviluppato in forma "basic". Corsisti e Studenti, tutti molto interessati, hanno potuto apprendere le tecniche base per sviluppare un'Endodonzia predicibile e sicura.
Un ringraziamento sentito all'Università di Genova, specie nella figura del Prof. Stefano Benedicenti, per la gentile concessione delle aule.

1 | I Ralatori del Corso e i Partecipanti

06/04/2019 - 04/05/2019 - 25/05/2019 - 13/07/2019 - 28/09/2019

Corsi di formazione teorico-pratici della Società Italiana di Endodonzia

SIE Endodontic Courses - Sede Spoleto

Coordinatore di MacroArea Centro, Dott. Luigi Scagnoli

1 | I Relatori del Corso insieme ai Partecipanti

2 | Un momento in aula

Si è conclusa a Spoleto la prima fase del'Endodontic Course 2019 della MacroArea Centro della SIE. La location è stata scelta in funzione della scarsa presenza di soci della regione Umbria all'interno della Società, per cui volevamo sensibilizzare i colleghi a rendersi parte attiva delle manifestazioni organizzate dalla SIE e, di conseguenza, pubblicizzare la nostra presenza.

La risposta è stata, a mio avviso, soddisfacente, riunendo un gruppo di otto partecipanti, da neo laureati a professionisti affermati. Ovviamente, inserendo relatori di chiara fama, è stato più semplice avere adesioni, ma soprattutto riscontri positivi sulle tematiche svolte. L'impostazione didattica discorsiva, con possibilità di interloquire direttamente fra oratore e platea in qualsiasi momento, ha permesso di rendere ancora più piacevole e costruttivo l'intero percorso delle cinque giornate svolte. Anche la presenza di sponsor importanti è stato un ulteriore incentivo per i partecipanti, che hanno potuto testare direttamente la validità degli strumenti presentati nei vari workshop. Con l'occasione porgo a nome mio e della SIE un ringraziamento particolare ai relatori che, per amore nei confronti della Società, hanno dato la loro completa disponibilità, mettendo a disposizione dei partecipanti tutta la propria esperienza, sia culturale che clinica. Direi, quindi, che la scommessa fatta su Spoleto si possa considerare assolutamente vinta!

GUIDELINES FOR AUTHORS

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 marticles 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 **www.giornaleitalianoendodonzia.it** for further information on the preparation and submission of articles and figures.

Ethical guidelines

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

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.

Manuscript preparation

Manuscripts should be uploaded as Word (.doc) or Rich Text Format (.rtf) files (not write-protected) plus separate figure files: TIF, EPS, JPEG files are acceptable for submission.
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.
Please note that **manuscripts must be written in English**. Authors whose native language is not English are strongly advised to have their manuscript checked by a language editing service or by a native English speaker prior to submission.

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 or **Case Series** 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 nonobvious solutions to significant clinical challenges will be considered. Illustrative material must be of the highest quality and healing outcomes, if appropriate, should be demonstrated.

Manuscript Format

The **official language** of the 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.
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. 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 three 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. If abbreviations are used in the text, authors are required to write full name+abbreviation in brackets [e.g. Multiple Myeloma (MM)] the first time they are used, then only abbreviations can be written (apart from titles; in this case authors have to write always the full name). If names of equipment or substances are mentioned in the text, brand, company names and locations (city and state) for equipment and substances should be included in parentheses within the text.
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.

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 should bear:

I. Title, which should be concise as well as descriptive (no more than 150 letters and spaces);
II. Initial(s) and last (family) name of each author;
III. Name and address of department, hospital or institution to which the work should be attributed;
IV. Running title (no more than 30 letters and spaces);
V. Three to five key words (in alphabetical order);
VI. Name, full postal address, telephone, fax number and e-mail address of author responsible for correspondence (Corresponding Author).

Abstracts should be no more than 250 words giving details of what was done: please choose
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 and **Case Series** 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 five 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.

THE STRUCTURE

Main text for Original Scientific Articles

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. 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.

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

Results should present the observations with minimal reference to earlier literature or to possible interpretations. Data should not be duplicated in Tables and Figures.

Discussion: may usefully start with a brief summary of the major findings, but repetition of parts of the abstract or of the results section should be avoided. The Discussion section should progress with a review of the methodology before discussing the results in light of previous work in the field. The Discussion should end with a brief conclusion and a comment on the potential clinical relevance of the findings. Statements and interpretation of the data should be appropriately supported by original references.

Conclusions should contain a summary of the findings.

Main Text of Review Articles

should be divided into Introduction, Review and Conclusions.

The **Introduction** section should be focused to place the subject matter in context and to justify the need for the review. The **Review** section should be divided into logical subsections in order to improve readability and enhance understanding. Search strategies must be described and the use of state-of-the-art evidence-based systematic approaches is expected. The use of tabulated and illustrative material is encouraged. The **Conclusion** section should reach clear conclusions and/or recommendations on the basis of the evidence presented.

Main Text of Mini Review Articles

should be divided into Introduction, Review and Conclusions; please note that the **Conclusions section** should present clear statements/recommendations and suggestions for further work. The manuscript, including references and figure legends, should not normally exceed 4,000 words.

Main Text of Case Reports and Clinical Articles

should be divided into Introduction, Report, Discussion and Conclusion. They should be well illustrated with clinical images, radiographs, diagrams and, where appropriate, supporting tables and graphs. However, all illustrations must be of the highest quality.

IMPORTANT TO KNOW

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** which menas that 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.

Acknowledgements: 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. Acknowledgments should be brief and should not include thanks to anonymous referees and editors. Under this section please specify contributors to the article other than the authors accredited. Please also include specifications of the source of funding for the study.

References: It is the policy of the Journal to encourage reference to the original papers rather than to literature reviews. Authors should therefore keep citations of reviews to the absolute minimum.
References should be prepared according to the **Vancouver style**. References must be numbered consecutively in the order in which they are first cited in the text (not alphabetical order), and they must be identified in the text

by Arabic numerals in brackets [example (34)]. References to personal communications and unpublished data should be incorporated in the text and not placed under the numbered references [Example: (Wright 2011, unpublished data) or (Wright 2011, personal communication)]. Where available, URLs for the references should be provided directly within the MS-Word document.

References in the References section must be prepared as follows:

I. more than three authors cite 3 authors et al. If the paper has only 4 authors, cite all authors;
e.g. *Prati G, Lotti M, Russo F et al.*
II. title style: please use a capital letter only for the first word of the title;
III. journal titles mentioned in the References list should be abbreviated according to the following websites:
a. ISI Journal Abbreviations Index (https://www.library.caltech.edu/journal-title-abbreviations);
b. Biological Journals and Abbreviations (http://home.ncifcrf.gov/research/bja);
c. Medline List of Journal Titles (https://www.nlm.nih.gov/bsd/serfile_addedinfo.html);
IV. put year after the journal name;
V. never put month and day in the last part of the references;
VI. cite only the volume (not the issue in brackets);
VII. pages have to be abbreviated, e.g. 351-8.

We recommend the use of a tool such as EndNote or Reference Manager for reference management and formatting. EndNote reference styles can be searched for here: www.endnote.com/support/ enstyles.asp. To ensure the correct citation format, please check your references in the PubMed database (http://www.ncbi.nlm.nih.gov/pubmed).

Examples of correct forms of reference follow.

Standard journal article
(1) Somma F, Cammarota G, Plotino G, Grande NM, Pameijer CH. The effectiveness of manual and mechanical instrumentation for the retreatment of three different root canal filling materials. J Endod 2008;34:466-9.

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 rootcanal 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
Saunders EM In vitro and in vivo investigations into root-canal obturation using thermally softened gutta-percha techniques (PhD Thesis) (1988). Dundee, UK: University of Dundee.

URLs
Full reference details must be given along with the URL, i.e. authorship, year, title of document/report and URL. If this information is not available, the reference should be removed and only the web address cited in the text.

Tables, Figures and Figure Legends

Tables should be submitted as word format, numbered and cited in the text of the manuscript. Units of measurements must be included in the column title or in the figure legend or caption. Figure files accepted: TIF, EPS, JPEG.

- color (saved as CMYK): minimum 300 dpi;
- black and white/grays: minimum 600 dpi;
- one column width (8.0 cm) or 1.5 column widths (13.0 cm) or 2 columns widths (17.0 cm).

A different **caption** for each figure must be provided at the end of the manuscript, not included in the figure file. Authors must obtain **written permission** for the reproduction and adaptation of material which has already been published. A copy of the written permission has to be provided before publication (otherwise the paper cannot be published) and appropriately cited in the figure caption. The procedure for requesting the permission is the responsibility of the Authors; *PAGEPress* will not refund any costs incurred in obtaining permission. Alternatively, it is advisable to use materials from other (free) sources.

Figure legends should begin with a brief title for the whole figure and continue with a short description of each panel and the symbols used; they should not contain any details of methods.

Authorship

All persons designated as authors should qualify for authorship according to the ICMJE criteria. Each author should have participated sufficiently in the work to take public responsibility for the content. Authorship credit should only be based on substantial contributions to

i) conception and design, or analysis and interpretation of data;
ii) drafting the article or revising it critically for important intellectual content;
iii) final approval of the version to be published.

These three conditions must all be met. Participation solely in the acquisition of funding or the collection of data does not justify authorship. General supervision of the research group is not sufficient for authorship. Any part of an article critical to its main conclusions must be the responsibility of at least one author. Authors should provide a brief description of their individual contributions.

Obligation to Register Clinical Trials
http://www.icmje.org/#clin_trials
The ICMJE believes that it is important to foster a comprehensive, publicly available database of clinical trials.
The ICMJE defines a clinical trial as any research project that prospectively assigns human subjects to intervention or concurrent comparison or control groups to study the cause-and-effect relationship between a medical intervention and a health outcome. Medical interventions include drugs, surgical procedures, devices, behavioral treatments, process-of-care changes, etc.
Our journals require, as a condition of consideration for publication, registration in a public trials registry.
The journal considers a trial for publication only if it has been registered before the enrollment of the first patient.
The journal does not advocate one particular registry, but requires authors to register their trial in a registry that meets several criteria.
The registry must be accessible to the public at no charge. It must be open to all prospective registrants and managed by a non-profit organization.
There must be a mechanism to ensure the validity of the registration data, and the registry should be electronically searchable.
An acceptable registry must include a minimum of data elements (http://www.icmje.org/#clin_trials).
For example http://www.clinicaltrials.gov, sponsored by the United States National Library of Medicine, meets these requirements.

Protection of Human Subjects and Animals in Research
When reporting experiments on human subjects, authors should indicate whether the procedures followed were in accordance with the ethical standards of the responsible committee on human experimentation (institutional and national) and with the Helsinki Declaration of 1975, as revised in 2013 (https://www.wma.net/policies-post/wma-declaration-of-helsinki-ethical-principles-for-medical-research-involving-human-subjects). If doubt exists whether the research was conducted in accordance with the Helsinki Declaration, the authors must explain the rationale for their approach and demonstrate that the institutional review body explicitly approved the doubtful aspects of the study. When reporting experiments on animals, authors should indicate whether institutional and national standards for the care and use of laboratory animals were followed. Further guidance on animal research ethics is available from the World Medical Association and from the International Association of Veterinary Editors' Consensus Author Guidelines on Animal Ethics and Welfare.
When reporting experiments on ecosystems involving non-native species, Authors are bound to ensure compliance with the institutional and national guide for the preservation of native biodiversity.

Open Jurnals System
An Open Access publication is one that meets the following two conditions:
1. The author(s) and copyright holder(s) grant(s) to all users a free, irrevocable, worldwide, perpetual right of access to, and a license to copy, use, distribute, transmit and display the work publicly and to make and distribute derivative works, in any digital medium for any responsible purpose, subject to proper attribution of authorship, as well as the right to make small numbers of printed copies for their personal use.
2. A complete version of the work and all supplemental materials, including a copy of the permission as stated above, in a suitable standard electronic format is deposited immediately upon initial publication in at least one online repository that is supported by an academic institution, scholarly society, government agency, or other well-established organization that seeks to enable open access, unrestricted distribution, interoperability, and long-term archiving.

Publishing your research as Open Access gives a number of advantages:
- Higher and faster visibility: Open Access articles are viewed on a global scale, and contents are available to everyone.
- Wider impact: thanks to a permissive license like CC BY, scientists and scholars are endowed to make progress on existing researches, thus facilitating the generation of new data.
- Increased citation: studies have shown that Open Access articles are regarded and cited more often than established paywall journals/articles.
- Perpetual accessibility: Open Access articles are hosted on dedicated servers, being accessible to everyone endlessly.
- Funding opportunities: an increasing number of funding bodies and agencies requires their grant holders to publish their researches as Open Access articles to be comprehensively available, free and without restrictions on re-use.

PAGEPress has chosen to apply the **Creative Commons Attribution - NonCommercial 4.0 International License** (CC BY-NC 4.0) to all manuscripts to be published under its name.

For authors
To make a submission to an OJS journal, after registering to the website, the authors will be required to follow a procedure via the system. Once the paper has been submitted, the authors will receive a confirmation email from the Managing Editor of the Journal.
When receiving a new submission, the Managing Editor assigns it to her/himself and to the Editor-in-Chief (EiC). After a quick in-house evaluation, if the EiC thinks that the paper is compliant with the guidelines and fits with the scope of the Journal, he/she send it out for the **peer-review phase** (=he/she assigns reviewers). Alternatively, the EiC can assign a Section/Deputy Editor for the paper.
Once the review process is completed (*i.e.* all the assigned Reviewers have provided their comments and recommendations on the paper), the authors will be notified via email by the editors of the editorial decision: **Accepted, Rejected, Decline Submission, Minor revisions, Major revisions.**
Depending on the editorial decision, and basing on the reviewers' comments, authors are required to upload their revised version (+ covering letter) within a specific deadline. At this point, they simply need to wait to hear back from the editor as to whether the revisions are acceptable. *If the editor's decision is to resubmit for review (=Major revisions or Minor revisons), the revised paper may undergo a "second round" of peer-review.*
Once a paper is accepted for publication, the authors will be notified via email and their paper is moved to the "Copyediting phase", where it is improved by the work of a copyeditor. Authors can be given the opportunity to review the copyedits.
Lastly, once the copyedits are completed and approved, the submission moves to "Production stage". In Production, the copyedited files are converted to galleys (PDF). Again, the authors have the opportunity to proofread the galleys. Once everyone is satisfied, the submission is scheduled for publication in a future issue.
The online journal management system that we are using allows authors to track the progress of their manuscript through the editorial process by simply logging into the Journal website.

Peer-review policy
All manuscripts submitted to our journal are critically assessed by external and/or in-house experts in accordance with the principles of peer review (http://www.icmje.org/#peer), which is fundamental to the scientific publication process and the dissemination of sound science. Each paper is first assigned by the Editors to an appropriate Associate Editor who has knowledge of the field discussed in the manuscript. The first step of manuscript selection takes place entirely in-house and has two major objectives: i) to establish the article appropriateness for our journals readership; ii) to define the manuscript priority ranking relative to other manuscripts under consideration, since the number of papers that the journal receives is much greater than it can publish. If a manuscript does not receive a sufficiently high priority score to warrant publication, the editors will proceed to a quick rejection. The remaining articles are reviewed by at least two different external referees (second step or classical peer review). Manuscripts should be prepared according to the Uniform Requirements established by the International Committee of Medical Journal Editors (ICMJE) (http://www.icmje.org/#prepare).

ISTRUZIONI AGLI AUTORI

Il Giornale Italiano di Endodonzia è una pubblicazione esclusivamente disponibile in formato elettronico e rappresenta l'organo ufficiale della Società Italiana di Endodonzia. Si appoggia, per la sua diffusione ad ARIESDUE e gli articoli in esso pubblicati sono reperibili su **www.giornaleitalianoendodonzia.it**. La cadenza di pubblicazione è semestrale: giugno e novembre.