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Postoperative pain after single visit root canal treatment using multiple rotary files and single reciprocating file instrumentation techniques in asymptomatic mandibular molars with necrotic pulps: a randomized control clinical trial

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ESE WLADIMIR ADLIVANKINE RESEARCH PRIZE

RP01

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Comparison between continuous wave obturation and cold lateral condensation in C1- and C2-type canals of 3D-printed resin teeth instrumented with Reciproc Blue or Hyflex EDM

Aim To compare the efficiency of cold lateral condensation and continuous wave obturation techniques and filling time in C1- and C2-type canals of 3-dimensional (3D)-printed resin teeth shaped with Reciproc Blue (VDW) or Hyflex EDM (Coltene/Whaledent) and to examine whether they affect the quality of root fillings in specimens with unusual canal forms.
Methodology One tooth with C1-type orifice and root canal morphology and one with C2-type orifice and C2–C3 root canal morphology were selected based on CBCT images. Two replicas of the selected teeth were manufactured with a 3D printer, and their canals were instrumented with Reciproc Blue or Hyflex EDM. These 4 instrumented replicas were scanned with CBCT. Ten identical replicas of each group (total of 40) were produced using a 3D printer and randomly divided into 2 groups ($n = 5$), and root filled with either cold lateral condensation (LC) or continuous wave obturation (CW). Horizontal cross sections of C1 type were made at 2, 4, 6, and 8 mm and C2 type at 2, 4, and 6 mm from the apical foramen. The areas of gutta-percha, sealer and voids were evaluated with image analysis software. Data were analysed using nonparametric Kruskal-Wallis and Mann-Whitney U-tests, and the Factorial ANOVA was used for interaction effects. Time required to fill canals was evaluated using the Mann-Whitney U test.
Results For C1 type, LC had more gutta-percha and less sealer compared to CW in the 2-mm sections ($P < 0.01$). CW had greater percentages of gutta-percha and lower percentages of sealer compared with LC in 4-, 6-, and 8-mm sections and total area ($P < 0.01$). For C2 type, CW had more gutta-percha and less sealer versus LC group in all sections and total area ($P < 0.01$). LC had the least gutta-percha and greatest sealer percentages at 6-mm sections ($P < 0.01$). In both C types, there was no significant difference in the percentages of gutta-percha, sealer and voids between Reciproc Blue and Hyflex EDM-shaped groups at any level ($P > 0.05$). Time spent for the LC technique and filling C1-type was significantly longer than when using the CW technique and filling C2 type ($P < 0.001$).
Conclusions Continuous wave obturation was more effective than lateral condensation in both C1- and C2-type canals, except for the apical 2-mm section of C1-type canals, suggesting the need for a modified CW technique.

RP02

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TGF-β1 levels and distribution in the root dentine of mature and immature human premolars

Aim To compare TGF-β1 levels and view its spatial distribution in the root dentine of mature and immature extracted human premolars.
Methodology Sound premolars with mature ($n = 5$) and immature ($n = 8$) roots were obtained from 13 orthodontic patients, aged 17 ± 1 and 12 ± 1 year, respectively. The width of the minor foramen in the root canals in these teeth was measured using a digital microscope. Roots were deproteinized in 5% NaOCl in an ultrasonic bath. The root dentine was powdered and decalcified in 17% EDTA to determine overall levels of TGF-β1 by enzyme-linked immunosorbent assay (ELISA). TGF-β1 distribution was assessed in root sections from additional contralateral teeth from these patients by immunostaining combined with confocal laser scanning microscopy. Data were compared between groups using Student's *t*-test, alpha = 0.05.
Results With 168 ± 49 μm vs. 557 ± 2 μm, the minor foramen was significantly ($P < 0.05$) smaller in mature compared to immature roots. Both groups released detectable levels of TGF-β1; 74 ± 35 pg was measured per 100 mg of dentine powder from immature roots, compared to 115 ± 31 pg in the mature group ($P > 0.05$). TGF-β1 was similarly distributed in mature and immature roots, with a greater presence towards the root canal. The target protein was clearly associated with peritubular dentine and absent in non-tubular outer dentine.
Conclusions It should be possible to release TGF-β1 in regenerative endodontic procedures from mature as well as from immature roots. The physiological reason for TGF-β1 deposition in peritubular dentine and possible age- and infection-related changes in the availability of this key morphogen clinically awaits further clarification.

RP03

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Influence of model system parameters on the sodium hypochlorite susceptibility of endodontic biofilms

Aim To evaluate the influence of different biofilm model system parameters on the sodium hypochlorite (NaOCl) susceptibility of endodontic biofilms.
Methodology Biofilms were formed in 96-well microtitre plates. First, monospecies *Enterococcus faecalis* biofilms were incubated for 24 h aerobically or anaerobically. In a second experiment, monospecies *E. faecalis* biofilms were anaerobically cultured for 1 or 11 days. Finally, a monospecies *E. faecalis* biofilm and a

multispecies biofilm including *E. faecalis*, *Fusobacterium nucleatum*, *Prevotella intermedia* and *Porphyromonas gingivalis* were grown anaerobically for 11 days. Biofilms were subjected to NaOCl treatment (0.025%, 0.1%, 0.5%, 2.5%, contact time 1 min), and control groups included treatment with purified water. After treatment, biofilms were harvested and the number of CFU was quantified by plate counting using general (monospecies biofilms) or selective media (multispecies biofilms). A one-way ANCOVA was conducted to explore the effect of the model parameters on biofilm eradication.

Results Anaerobically grown *E. faecalis* biofilms were eradicated to a greater extent than aerobically grown *E. faecalis* biofilms, demonstrating a significant effect of oxygen presence during incubation on biofilm CFU count ($P < 0.05$). For all NaOCl concentrations (except 0.025%), one-day-old biofilms were more susceptible than 11-day-old biofilms, showing a significant effect of biofilm age on biofilm survival after NaOCl treatment ($P < 0.05$). Finally, *E. faecalis* was significantly more tolerant to NaOCl treatment when grown in a multispecies biofilm ($P < 0.05$), suggesting the presence of other microorganisms can affect the outcome of treatment of endodontic biofilms with NaOCl.

Conclusions The parameters incubation atmosphere, biofilm age and biofilm composition had a significant influence on the NaOCl susceptibility of the biofilm. These findings emphasize the importance of selecting relevant parameters when designing a biofilm model system.

ESE EDUCATION PRIZE

EP01

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Evaluation of 3D-printed resin premolars in the reproduction of root canal anastomoses

Aim To evaluate the reliability of the 3D printing procedure for the reproduction of anastomoses between two root canals at 3 different levels in maxillary second premolars scanned using Micro-computed Tomography.
Methodology Three undamaged extracted human maxillary second premolars A, B and C were selected, digitalized by Micro-CT and reproduced by a stereolithographic printer. The selected teeth shared the same root canal configuration; two separate canals and one anastomosis but at three different levels. Thirty plastic teeth of each configuration were tested. The printed teeth were scanned and compared with the original specimens. Two-dimensional cross-section measurements using the Trios 3 Color intraoral scan calculated the extent of the distortion of the simulated resin teeth. Pulp chambers within each group accessed followed by the preparation of a glide path and methylene blue staining. The translucent replicas with visible anastomoses were examined by a trained endodontist under microscope magnification X 16 (Zeiss Extaro 300).
Results All of the resin teeth revealed the presence of the anastomosis before and after introduction of the methylene blue dye proving reproducibility of the microanatomy. Resin teeth produced by stereolithographic printing were slightly bigger than the natural extracted teeth. The CT length measurements of the printed teeth were significantly and slightly larger than the reference values at the premolar levels A (0.185 mm; $P < 0.001$), B (0.166 mm; $P < 0.001$) and C (0.064 mm; $P = 0.008$).
Conclusions 3D printing technology using Micro-CT data was capable of reproducing fine details of root canal systems. The accuracy of the printing process is suitable for the production of tooth replicas with anastomoses for endodontic teaching and experimentation.

EP02

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Suitability of different tooth replicas for endodontic training: perceptions and detection of common errors in the performance of postgraduate students

Aim To compare students' perceptions on 5 different tooth replicas and detect common errors in students' performance that might be attributed to a specific tooth replica.
Methodology Five groups ($n = 10$ each) of artificial first maxillary molars (DEPT, DRSK, Nissin, DENTALIKE, TrueTooth) were used in the study. All 50 teeth were individually mounted in opaque containers, distributed in 10 packages containing a sample from each with an assigned random order for students to perform root canal treatments. Ten postgraduate students performed root canal treatment in the 5 teeth, in the assigned order, and completed a satisfaction questionnaire. Three expert raters evaluated their performance and completed a questionnaire to detect common errors attributed to a specific tooth replica. Inter-rater reliability was calculated with the interclass correlation coefficient for both consistency and absolute agreement. A two-way related measures ANOVA was used to assess the interaction among evaluators and tooth groups in average students' score. Post hoc T3 Dunnett was used to compare groups. Students' perceptions among groups were compared with chi-square and linear by linear association tests.
Results Inter-rater reliability was very high for both consistency (ICCC = 0.939; 95% confidence interval (CI) 0.902-0.964) and absolute agreement (ICCA = 0.940; 95% CI 0.904–0.965). No statistical differences were found among evaluators' ratings; however, students performed differently in different tooth replicas ($P < 0.05$). 60% of students preferred DRSK for endodontic training purposes, followed by DENTALIKE (30%). The least preferred was TrueTooth (70% responses) due to complex anatomy and poor resistance to instruments and heat pluggers. Evaluators detected several common errors in specific tooth replicas and preferred tooth replicas manufactured based on microCT scans of natural teeth.
Conclusions Tooth replicas manufactured based on microCT scans of natural teeth (TrueTooth and DENTALIKE) had much better acceptance among evaluators, although students rated and performed worse in TrueTooth replicas due to their higher level of difficulty.

THURSDAY

EDUCATION

R001

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What are the difficulty levels of extracted human teeth used for pre-clinical training in endodontics?

Aim To determine the difficulty of extracted teeth treated by undergraduate students for pre-clinical endodontic training using the American Association of Endodontists (AAE) assessment guidelines.
Methodology An unidentified consecutive sample of 1000 periapical radiographs of extracted human teeth previously used in Endodontic pre-clinical training at the Adelaide Dental School was evaluated using the AAE guidelines by two independent observers. An endodontist assessed the entirety of images while a previously trained third-year Bachelor of Dental Surgery student assessed 10% of the total sample. Chi-square test of adjustment was used to appraise the adjustment of the distribution with a theoretical frequency of one-third per category. Inter-examiner agreement and intra-examiner agreement were calculated via Kappa coefficients. In case of disagreement, the radiographs were re-evaluated until consensus was reached between the observers.
Results Minimal, moderate, and high difficulty teeth represented 23.1%, 52.1%, and 24.8% respectively. Anterior teeth (incisors and canines) ($n = 303$) were classified as minimal (38.5%), moderate (48.5%) or high (9.5%) difficulty. Premolar teeth ($n = 299$) were classified as minimal (34.8%), moderate (48.95) or high (16.3%) difficulty. Molar teeth ($n = 398$) were classified as moderate (57.3%) or high (42.7%) difficulty. The presence of curvature was the most common grading factor, with 'moderate curvature' reported in 28.7%, and 'extreme curvature' reported in 15.6% of the sample. This was followed by 'visible but reduced canals', which was mainly found in anterior teeth with a 21.2% occurrence. A difference in the distribution of frequencies was found, favouring the moderate category ($P < 0.001$). The Inter-examiner strength and intra-examiner strength of agreement were 0.78 (substantial) and 0.86 (almost perfect).
Conclusions Although more than half the teeth were categorised as having moderate complexity, the teeth were of higher difficulty level than recommended for undergraduate pre-clinical training as almost one-quarter of the total sample was categorised as high complexity, and were thus unsuitable.

R002

WITHDRAWN.

R003

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Endodontic tendencies in a very-low-income population area, Northeastern Brazil

Aim To gather information about endodontic treatment profiles including the use of new technologies available for root canal treatment in the cities of Northeastern Brazil, a region that comprises a very-low-income population.
Methodology A questionnaire investigating the routine treatment protocols used by dentists during root canal treatment (e.g. the use of new technologies, time required to conclude the treatment and endodontic continuing education) was randomly distributed to 250 dentists in several cities within the states of Sergipe and Bahia, the Northeastern area of Brazil. The data were analyzed through descriptive statistics and Poisson regression ($P < 0.05$).
Results A total of 199 dentists practicing root canal treatment in the cities of Aracaju ($n = 58$), Salvador ($n = 83$) and the towns of Estância ($n = 8$), Itabaiana ($n = 16$), Itabaianinha ($n = 5$), Lagarto ($n = 10$), Ribeirópolis ($n = 3$), Simão Dias ($n = 6$) and Tobias Barreto ($n = 10$) participated. Most had graduated less than 10 years previously (62%), with nearly 75% of the sample having attended post-graduation courses in the area. The use of rotary or reciprocating systems and the routine use of rubber dam isolation during RCT were 78% and 62% of dentists, respectively, and were significantly more prevalent among dentists who had attended a continuous education programme ($P < 0.05$). There was a significantly greater tendency for dentists who had attended a continuous education programmes in endodontics to undertake root canal treatments in incisors (x3) and molar teeth (x2) in one appointment ($P < 0.05$).
Conclusions Even in an area with a mostly low-income population, many dentists attended post-graduation courses to enhance their knowledge, and followed modern techniques in root canal treatment with most of them employing technological resources to improve the quality and comfort of treatment.

R004

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Students' experience with root canal treatment, their self-confidence levels, and perception of the quality of endodontic education

Aim To investigate undergraduate dental students' experience with root canal treatment (RCT), their self-confidence levels, and their perception of the quality of endodontic education at the Medical Faculty of University of Ljubljana (UL).
Methodology An anonymous online questionnaire was distributed to all ($n = 145$) undergraduate students in years 4–6 at the UL to gather information on the number of RCTs performed,

their confidence at performing RCT (ten-point Likert scale), and their perception of the quality of endodontic education. Data were analyzed using Mann-Whitney and Chi-square tests.
Results The participation rate was 53%. The mean number (±SD) of RCTs completed by the fourth-, fifth-, and sixth-year participants was 5.48 (±3.56), 10.26 (±4.13), and 14.84 (±6.66), respectively. The fourth-, fifth-, and sixth-year participants were confident (≥5 on a Likert scale) performing RCT on anterior teeth in 66.7%, 96.8%, and 100%, respectively; on premolars in 44.4%, 93.5%, and 94.7%, respectively; and on molars in 7.4%, 74.2%, and 94.7%, respectively. The perception of confidence was related to the year of the study ($P = 0.000$) and number of RCTs performed in the laboratory and clinical setting ($P = 0.000$). The amount of time spent on education, quality of practical sessions, and quality of lectures was perceived to be good by 50.6%, 79.2%, and 88.3% of students, respectively.
Conclusions Self-rated confidence levels of undergraduate dental students at the UL when performing RCT increased with years of study and number of RCTs performed in the laboratory and clinical setting. Almost half of the participants felt that insufficient time was devoted to Endodontics. They were satisfied with the quality of lectures and practical sessions.
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R005

WITHDRAWN.

TOOTH AND CANAL ANATOMY

R006

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C-shaped canal configurations in mandibular posterior teeth: An *In vivo* cone-beam computed tomography study

Aim To evaluate the prevalence and morphological differences of C-shaped canals, and to assess the relationship between the presence of C-shaped canal morphology within mandibular premolars and molars in the same individuals.
Methodology Cone-bean computed tomography (CBCT) scans of 208 Saudi patients aged 17–60 years including 1433 mandibular posterior teeth (776 premolars and 657 molars) were evaluated for their external and internal morphology. Axial sections of the roots were acquired at three levels (coronal, middle, and apical) to identify and analyse root canal systems having a C-shaped canal configuration. The same Endodontist examined the CBCT images twice with a 4-week interval between viewings. For inter-rater reliability, two readings of 30% of the study sample were taken. Cohen's Kappa test revealed almost perfect agreement of measurement with a value of 0.85 and $P < 0.001$. The Z-test was used to determine the proportions in the independent groups. All statistical tests were performed at a significant level of $P < 0.05$.
Results The prevalence of C-shaped canals in first premolars was 1.5%, 0.8% in second premolars, and 8% in second molars; the first molars had none. C-shaped type 2 canals were most prevalent in premolars, and type 3 was most prevalent in the second molars. There was no correlation between the presence of C-shaped canals within premolars and molars in the same patients.
Conclusions The prevalence of C-shaped canal configurations in mandibular second molars was significantly greater than in premolars. Teeth with C-shaped canals exhibited unpredictable morphology across the root length, making the use of a small field of view CBCT highly recommended when planning root canal treatment.

R007

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Root and canal morphology of maxillary first premolars in a Polish population using two classification systems: a cone beam computed tomography study

Aim To evaluate the root and canal morphology of permanent maxillary first premolars in a Polish population using two classifications and cone-beam computed tomography scanning (CBCT).
Methodology A total of 350 CBCT images of maxillary first premolars were analyzed. CBCT scans were obtained from 226 patients (131 women and 95 men) who underwent CBCT scanning for diagnostic and dental treatment reasons. The number of roots and root canals was determined. The root canal configurations were classified according to Vertucci and a new system by Ahmed *et al.* (2017). In addition, the level where roots bifurcated were identified. The results were subjected to statistical analysis using chi-square tests with Yates' correction ($P < 0.05$).
Results Most maxillary first premolars had two roots (69.1%), with no significant difference observed between men and women ($P > 0.05$). Most bifurcations were located in the coronal part of the root (44.2%) and the least in the apical part (15.3%). Bifurcation in the coronal part of the root was observed more often in the teeth of men compared to women (58.6% vs 34.3%, $P < 0.05$). Bifurcation in the central or apical part was significantly more common in women than in men (central part: 46.8% vs. 31.3%, apical part: 18.9% vs. 10.1%). The most frequent canal configuration of the maxillary first premolars was type IV (78.2%) according to Vertucci and $^{2}FP\ B^{1}\ P^{1}$ (65.4%) according to the new classification. Among the remaining cases, almost all types of canals according to Vertucci, and many combinations of codes according to the new classification were demonstrated. No significant difference in the incidence of particular types of root canal was observed between men and women.
Conclusions Maxillary first premolars in this Polish population displayed a wide range of root and canal anatomical variations. The new system for classifying root and canal morphology was more accurate and practical compared to the Vertucci classification.
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R008

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The prevalence of distolingual roots in first permanent mandibular molars and the influence of curvature on root canal treatment: A cone-beam computed tomographic study in a Japanese population

Aim To investigate the prevalence and curvature of the distolingual roots of mandibular first permanent molars using cone-beam computed tomographic (CBCT) images in a Japanese population and to evaluate the influence of canal curvature on root canal treatment.

Methodology A total of 356 mandibular first molar CBCT images (Morita 3D Accuitomo F17, Kyoto, Japan) were collected from 300 patients who attended the Okaguchi Dental Clinic, Japan from January 2013 to January 2019. In total, 126 patients were male and 174 female. Bilateral CBCT images were obtained from 56 patients. The prevalence of distolingual roots, gender ratio, right-side and left-side occurrence ratio and a number of untreated distolingual roots of treated teeth were evaluated. The curvature was classified into 3 types (straight < 10°, moderate 10°~25° or severe 25°~70°). Fractured files in treated distolingual root were detected in the sagittal and coronal planes of the CBCT images. The data were analyzed statistically using the chi-square test with significance set at $P < 0.05$.
Results The prevalence of a separate distolingual root was 28.93%. There was no significant difference between males (30.71%) and females (27.59%). Right side incidence (33.69%) was significantly higher than left side (23.83%) ($P < 0.01$). The bilateral prevalence rate of a separate distolingual root was 78.94%. Straight, moderate and severe curvature occurred in 17.47%, 22.33% and 60.19% of canals, respectively. Overall, 63 teeth with distolingual roots were treated. The number of untreated distolingual root canals was 8 teeth (12.7%). Fractured files were found in 10 canals of 55 treated root canals 18.2%).
Conclusions The distolingual root in mandibular first permanent molars had a high prevalence and discovery rate but its management was difficult. It is important that clinicians should take 2 dental radiographs (orthoradial and eccentric projection) and/or CBCT, and check the morphology of the same tooth in the opposite jaw before root canal treatment.

R009

WITHDRAWN.

R010

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Systems for classifying root canal configurations: inter- and intrapersonal consensus in clinical application

Aim To investigate the agreement of several evaluators in the categorisation of root canal configurations of transparent teeth into different classifications.
Methodology Applying specially developed questionnaires, the conventional classifications by Weine et al. and Vertucci et al. were contrasted with a new system authored by Ahmed *et al.* (2017) The questionnaires were used to examine the extent of agreement between 15 evaluators as based on 20 transparent root images with stained canal systems. The questionnaires were filled-out twice at an interval of three months. Inter-rater and intra-rater reliabilities were assessed to determine their practicality in comparative studies.
Results The inter-rater reliability values calculated using Krippendorff's alpha in the first survey wave were 0.634 for the Weine classification, 0.484 for the Vertucci classification, and 0.21 for the system according to Ahmed *et al.* (2017). The second test showed similar results (Weine: 0.676, Vertucci: 0.459, Ahmed: 0.292). Substantial and moderate agreement between the raters was determined for Weine's and Vertucci's classifications, respectively, and fair agreement for Ahmed's system. The evaluators' assessments after a separate survey were constant and widely without statistically significant differences.
Conclusions The degree of agreement of inter-rater reliability decreases with increasing classification options in the respective classification systems. Nevertheless, a statistically sufficient degree of agreement was achievable.

R011

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Prevalence of taurodontism in molars in a Turkish population

Aim To assess retrospectively the prevalence and classification of taurodontism in molars in a Turkish population living in Istanbul.
Methodology This study was performed using digital panoramic radiographs taken for various treatment purposes of 1018 patients (63.7% females and 36.3% males, aged over 13 years) at the Department of Oral Radiology, Bezmialem Vakif University. The exclusion criteria were root-filled posterior teeth, teeth with large restorations or crowns, poor quality of radiographs, undetectable furcation areas and apical areas, teeth with open apices. A taurodont tooth and classification of three types of taurodontism (meso-, hypo- and hypertaurodontism) were evaluated based on the criteria described by Shifman & Channel. The prevalence of taurodontism was assessed according to gender, maxilla and mandible, and right/left quadrants. The data were analyzed statistically using the Chi-square test ($P < 0.05$).
Results The overall prevalence of taurodontism was 7.7% of all molars examined; 4.7% for females and 3% for males. The association of taurodontism and gender was not significant ($P > 0.05$). In general, 49.7% of taurodont teeth were in the mandible and 50.3% were in the maxilla; this difference was not significant ($P > 0.05$). The prevalence of taurodontism was 53.7% in the left and 46.3% in the right quadrant which was not significantly different ($P > 0.05$). Bilateral taurodontism was found on 32 subjects (42.7% of all taurodont teeth). In terms of severity of taurodontism, 38.79% were hypotaurodont, 44.21% were mesotaurodont and 17% were hypertaurodont.
Conclusions A relatively high prevalence of taurodontism was observed in Istanbul, Turkey with no significant differences between gender; maxilla and mandible; or right/left quadrants. In terms of severity, mesotaurodontism was the most common type.

R012

WITHDRAWN.

R013

WITHDRAWN.

MICROBIOLOGY

R014

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Analysis of microbial contamination of gutta-percha points commonly used in clinical practice: a practical approach

Aim To evaluate the bacterial contamination of gutta-percha points routinely used in clinical practice and the efficacy of a chairside disinfection protocol.
Methodology Gutta-percha points with a 2% taper in sizes 20, 25, 35 and 40 (Dentsply Sirona, Ballaigues, Switzerland and R&S, Tremblay-en-France, France), were randomly sampled from sealed (Group 1–3 of each ISO size) and from open commercial packages in use for 30 days (Group 2–16 of each ISO size) (n = 64). The gutta-percha points were added directly to thioglycolate medium and incubated at 37 °C for 21 days. During this period, the presence of turbidity was evaluated. For disinfection, contaminated gutta-percha points were immersed for 1 min in 10 mL of 3% sodium hypochlorite, 5 min in 10 mL of detergent solution (3% Tween 80 and 5% sodium thiosulfate) and given a final rinse with 10 mL of sterile distilled water. The cones were again incubated in thioglycolate media for 21 days. Data were analysed by the chi-square test at the 5% significance level.
Results No bacterial growth was observed in Group 1. Group 2 had 15% of contaminated samples (9% from the Dentsply® and 6% from the RS®). Considering the total number of contaminated samples, 58% were from the Dentsply® and 42% from RS®. The chairside disinfection protocol resulted in 10% of gutta-percha points remaining contaminated.
Conclusions A small number of gutta-percha points in clinical use for 30 days harboured microorganisms. No significant difference was observed between the two commercial brands of points. Although low numbers of contaminated points were detected, including after the chairside disinfection protocol, awareness in nosocomial contamination control should always be performed during all stages of root canal treatment to better ensure success.

R015

WITHDRAWN.

R016

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Prevalence of the fungal pathogen *Candida* in infected root canals of an Emirati Cohort: a preliminary investigation

Aim To determine the prevalence of *Candida* species in infected root canals of symptomatic primary and post-treatment infection, from patients attending the University Dental Hospital in Sharjah, United Arab Emirates.
Methodology A total of 51 symptomatic patients who presented with infected root canals associated with primary and persistent infection following root canal treatment were aseptically sampled using sterile paper points. The retrieved samples were immediately cultivated, aerobically on brain heart infusion, and Sabouraud Dextrose Agar at 37 °C for 48 h. Additional, cultures on Chromagar as well as Multiplex PCR were performed to identify the Candida species.
Results Only 4 samples of 51 (8%) yielded a growth of *Candida sp*. Of these, 2.5% (1 out of 39) primary infections, and 25% (3 out of 12) of post-treatment infections yielded *Candida sp*. All yeast isolates were confirmed as *Candida albicans* by Multiplex PCR.
Conclusions There is evidence to indicate that fungi play a significant role in endodontic infections and *C. albicans* is the major pathogen involved. The data confirm these findings and corroborate those of others indicating the presence of yeasts in approximately 7.5% of root canal infections. Further, the yeasts appear to be more common in persistent rather than in primary endodontic infections. This is the first report of isolating *C. albicans* from infected root canals from an Emirati cohort. Further studies with more sample size are warranted to substantiate results demonstrated in this study.
Acknowledgements Funded by the University of Sharjah internal research grant for the Oral Microbiome Group.

R017

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Detection of contamination during root canal treatment in cases diagnosed as irreversible pulpitis: A pilot study

Aim To assess the presence, introduction, timing and level of bacterial contamination during root canal treatment from 10 sites throughout treatment of 26 cases diagnosed as irreversible pulpitis and to identify the sources of iatrogenic contamination during root canal treatment.
Methodology Sample collection was carried out under aseptic conditions. The following samples were collected: contamination control, caries, access bur, intracanal sample (initial and final), initial file, endodontic ruler surface, rubber dam surface, gloves and instruments (tip of the tweezer, DG-16 endodontic explorer and flat plastic instrument). Genomic DNA was extracted using Sigma GenElute™ Bacterial Genomic DNA Kits and quantified using a NanoDrop fluorescent quantification station followed by

total bacterial enumeration by Quantitative Polymerase Chain Reaction (qPCR) using Universal primers.
Results A total of 225 samples were collected and analysed. Thirty-six percent of all initial intracanal samples of cases diagnosed as irreversible pulpitis had high levels of bacteria after access. Overall, 42.8% of initial files had moderate to high levels of contamination. At the time of canal filling, 20% of rulers were contaminated while 42% of rubber dam surfaces had moderate to high level of contamination. Also, 30% and 24% of instruments and gloves respectively were contaminated at the time of canal filling. Chi-Squared tests revealed that higher bacterial loads were more likely in intracanal samples before canal filling when instruments were contaminated. Significant difference was noticed ($P = 0.0002$).
Conclusion The current study highlights the possibility of contamination occurring during root canal treatment mainly from the repetitive use of the same patency file, rubber dam surfaces, gloves and instrument used at the time of canal filling. A randomized clinical trial is needed to investigate the effectiveness of introducing a sterile approach to reduce bacterial levels as well as improving the outcomes of root canal treatments.

R018

WITHDRAWN.

R019

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Bacterial and LPS profiles of primary and secondary/persistent endodontic infections

Aim To characterize the microbial and LPS profiles of PI and SI, and to correlate the clinical features with specific bacteria in both groups.
Methodology The involved tooth was isolated from the oral cavity with a rubber dam and the operatory field was then disinfected with 30% hydrogen peroxide followed by 2.5% sodium hypochlorite, which was inactivated with 5% sodium thiosulfate. Samples from 20 root canals (10 PI and 10 SI) were collected. The DNA was extracted and subjected to the checkerboard DNA-DNA hybridization analysis detecting 40 different bacterial species. LPS samples were analysed by Limulus Amebocyte Lysate assay. *T*-test was performed to verify any significant differences in the bacterial/LPS profiles between PI and SI. Pearson's Chi-square test was used to test the null hypothesis that there is no association between clinical features (including exudate, spontaneous pain, pain on palpation, tenderness to percussion and periapical lesion) and the presence of specific bacteria.
Results Bacteria were detected in all samples by checkerboard DNA-DNA hybridization, including Gram-positives and Gram-negatives, facultative and strict anaerobes. The bacterial diversity found in PI and SI was 39 and 36, respectively. Furthermore, a similar average number of species per canal was found in both endodontic infections, 27 species per root canal. LPS levels in the PI group (57.28 EU/mL) were significantly higher than in SI (3.36 EU/mL) ($P < 0.05$). There was no significant association between clinical features and specific bacteria in both groups ($P > 0.05$). In addition, a larger number of positive and negative bacterial associations was observed in the PI group.
Conclusions Both types of infection were associated with a heterogeneous microbiota, the highest levels of LPS being found in PI. No association was found between clinical features and specific bacteria in either group.
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BIOCOMPATIBILITY AND BIOACTIVITY

R020

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Connective tissue reaction to calcium silicate-based and epoxy resin-based root canal sealers: an *in vivo* study

Aim To evaluate the biological properties in the subcutaneous tissue of rats using Sealer Plus BC (BC) compared to AH Plus (AHP), Sealer Plus (SP) and MTA Fillapex (MF).
Methodology For *in vivo* evaluation, polyethylene tubes containing the sealers were implanted in rats' subcutaneous tissue and histologically evaluated after 7, 30 and 90 days. Cellular and inflammatory events were determined by the presence of neutrophils, giant cells, eosinophils and macrophages. Inflammatory infiltrate intensity, abscess and fibre condensation were scored. Statistical analyzes were performed using Kruskal-Wallis test and Dunn's post hoc among materials in the same experimental period, and One-way ANOVA and Tukey's post hoc were used to compare the same material at different periods, considering a 0.05 significance level.
Results No abscesses were found. At 7 days, neutrophils were present in the control and BC groups, without significant difference with the other sealers ($P \geq 0.05$). Giant cells were present at 30 days for MF and BC, without significant difference with the other sealers ($P \geq 0.05$). Fibre condensation formation was observed at 30 and 90 days without a significant difference among the groups ($P \geq 0.05$). At 30 and 90-days, MF and BC had the highest scores for macrophage presence. None of the materials were significantly different for inflammatory infiltrate comparing to the control group at 7-days ($P \geq 0.05$). After 30 days, BC had the greatest presence of inflammatory infiltrate and, after 90 days, MF had the highest score ($P \leq 0.05$) among materials and control group. Eosinophils were observed only at 7 days for MF.
Conclusions Sealer composition influenced its biocompatibility. AHP and SP had adequate tissue response in rat connective tissue. Calcium-silicate-based sealers were associated with greater macrophage activity over time, mainly for MF which also presented giant cells and eosinophils, and had moderate biocompatibility.

R021

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Biological properties of three endodontic bioceramic materials

Aim To evaluate the biological properties of three CSBS: EndoSequence BC Sealer, Ceraseal and Endoseal MTA.
Methodology Human periodontal ligament stem cells (hPDLSCs) were exposed to several eluates of CSBS. The ion release profile and

pH were determined, while metabolic activity and cell migration were assessed using the MTT and wound-healing assays. hPDLSCs were cultured in direct contact with the surface of each material and cell morphology and attachment were analyzed by Scanning Electron Microscopy (SEM). Statistical differences between biomaterials were assessed using one-way ANOVA and Student's *t*-test ($\alpha < 0.05$).
Results All materials had an alkaline pH, although Endoseal exhibited a significantly higher pH compared with the other CSBS ($P < 0.05$). Endosequence BC sealer released significantly more Ca and Si ions ($P < 0.05$) than Ceraseal and Endoseal. Interestingly, Endoseal induced a significant reduction in cell viability and cell migration compared to the control ($P < 0.001$). Moreover, SEM showed abundant cells adhering to Endosequence BC Sealer and Ceraseal surfaces, whereas very few round cells were detected on the surface of Endoseal.
Conclusions The eluates from Endosequence BC Sealer and Ceraseal displayed higher cell viability, cell attachment and migration rates than Endoseal. Endosequence BC Sealer released significantly more Ca and Si ions than Ceraseal and Endoseal.

R022

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Comparison between MTA and Bioceramic as a direct-pulp-capping agents: an animal study

Aim To compare White Mineral Trioxide Aggregate (MTA) and TotalFill BC RRM repair material when used as direct-pulp-capping agents on dogs' teeth utilizing histological observation.
Methodology Eight 2-year-old mongrel dogs were included in the study (80 teeth in total). Teeth were divided into two groups according to the evaluation periods (15 and 60 days). The pulp-capping procedure was performed after surgical pulp exposure using either white ProRoot MTA (Tulsa Dental Products, USA) or TotalFill BC RRM repair material (FKG Dentaire, Switzerland); then cavities were restored with a glass ionomer. After the evaluation periods, dogs were sacrificed, and teeth were obtained and prepared for histological assessment of dentine bridge formation, inflammatory reaction, and pulp status.
Results At two-weeks, the majority of the specimens had slight or no dentine bridge formation. The MTA group had significantly less inflammatory reaction compared to the bioceramic group ($P = 0.000$). Pulpal status revealed significantly more dilated lymphatic vessels in the bioceramic group compared to the MTA group ($P = 0.000$), on the other hand, 33% of the specimens capped with MTA had significantly more dilated blood vessels ($P = 0.000$). At two months, both capping agents induced complete dentine bridge formation ($P = 0.348$), with no signs of an inflammatory reaction. Empty pulp spaces were seen in some specimens of both groups, and the pulp architecture was not preserved in 13% of the teeth capped with the bioceramic ($P = 0.002$).
Conclusions White ProRoot MTA resulted in significantly better histological reactions at the two evaluation periods. TotalFill BC RRM repair material as a direct-pulp-capping agent resulted in significantly dilated lymphatic vessels after 15 days, and alteration of the original pulp architecture after 60 days.

R023

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A comparison of pulpal response to MTA, Portland Cement, and Propolis-based cement in partial pulpotomy procedures: an animal model study

Aim To evaluate the response of the dental pulp to MTA, Portland cement, Portland cement/ propolis, and zinc oxide/ propolis cement, in partially pulpotomized dogs' teeth.
Methodology The research protocol was approved by the Animal Care and Use Committee (ACUC), animal approval number (16/4/21/431). Dental pulps of 96 teeth of six locally bred dogs were partially pulpotomized via class V cavities. Bleeding was controlled using 2.5% sodium hypochlorite. In every animal, each quadrant was assigned to receive one of the capping materials. Group I: zinc oxide/propolis, group II: MTA, group III: Portland cement, group IV: Portland cement/propolis. One untreated tooth in each animal was used as a control ($n = 6$). The cavities were sealed with glass ionomer. A baseline radiograph was taken to detect any changes in pulpal and periapical tissues. Three animals were followed up for a period of four weeks and three for eight weeks. Animals were sacrificed and teeth were radiographed and demineralized for three to four weeks. Teeth were prepared histologically and stained to be examined under light microscope, to evaluate and grade the formed dentine bridges, pulpal inflammation, the presence of odontoblast layer, calcifications, necrosis, and abscess formation.
Results All materials tested except zinc oxide/propolis formed dentine bridges. Portland cement and its mixture with propolis were comparable to MTA with regard to the type, intensity and extension of pulpal inflammation, and the thickness of the odontoblast layer. Portland cement/propolis mixture had superior results over MTA in terms of the quality of the formed bridge. Calcification appears to be a significant factor when comparing the two follow-up durations.
Conclusions Portland cement and Portland cement/propolis were comparable to MTA, having the potential to be used as pulp capping materials. Pulp calcification appears to be a concern.
Acknowledgements This study was supported by research funding from Deanship of research, Jordan University of Science and Technology number 11/141.

R024

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Biocompatibility of bone morphogenetic proteins at various concentrations for use during Regenerative Endodontic Treatments

Aim To evaluate the biocompatibility of several concentrations of Bone Morphogenetic Proteins(BMPs) combined with Mineral Trioxide Aggregate (MTA).
Methodology Three sample groups were prepared based on BMP (rhBMP-2, Novosis, Korea) concentrations: 0 (control), 2 μg/mL (BMP2), 20 μg/mL (BMP20). Each sample consisted of BMP (or normal saline) soaked collagen membrane (AteloPlug, Bioland, Korea), and MTA (ProRoot MTA, Dentsply, USA). Four samples were prepared for each group. Changes in pH and solubility were obtained after 3 days of immersion in 10 mL of distilled water. For implantation tests, 26 specimens were prepared with dentine disks,

collagen sheets soaked with BMP (2, 20 μg/mL, or normal saline), and MTA. Specimens of three groups (0, 2, and 20 μg/mL BMP) were inserted subcutaneously into the dorsal connective tissue of 16 BLAB/c mice. After 7 (subgroup 7D) and 28 (subgroup 28D) days, the animals were sacrificed. Tissue samples were stained with haematoxylin-eosin with 5 μm sections for histologic examination. Inflammatory reaction was observed and graded with I-IV range under the light microscope. Kruskal-Wallis H test was used to assess significant differences among groups ($P < 0.05$).

Results No significant differences in solubility were detected among all groups ($P > 0.05$). Both BMP2 and BMP20 groups had significantly higher pH compared to control group, but there was no significant difference between the two experimental groups. Generally, the 7D subgroup presented moderate-to-high, and the 28D subgroup expressed mild inflammatory reactions. Subgroup 7D and 28D resulted in statistically significant difference, while noticeable differences were not detected within each subgroup.

Conclusions Although BMP groups had considerably reduced inflammatory reactions after four weeks, no significant difference was detected compared to the control group or between the two concentrations. BMP may have an influence in the field of regenerative endodontics regardless of concentration.

R025

WITHDRAWN.

R026

WITHDRAWN.

R027

WITHDRAWN.

R028

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Biocompatibility and bioactivity of a novel bone graft material developed from the dentine of waste bovine teeth

Aim To evaluate the biocompatibility and bioactivity of the bovine dentine derived hydroxyapatite (BDHA) material and its possible cytotoxic effects on human osteoblast-like cells.

Methodology Cell adhesion and morphology of the Saos-2 cells were investigated using scanning electron microscopy (SEM). The cell viability of the BDHA was assessed using a modified direct method with Saos-2 cells in conjunction with the LIVE/DEAD® cytotoxicity kit. The cell proliferation was determined using the MTS assay. The osteoinductive character of the BDHA scaffold was evaluated using immunofluorescence to observe the expression of the bone protein osteonectin. In addition, the *in vitro* chemical stability and degradation of the prepared BDHA scaffolds were assessed using simulated body fluid (SBF).

Results SEM analysis revealed that Saos-2 cells adhered to the BDHA scaffold and exhibited a spindle-like morphology. The LIVE/DEAD assay suggested that the material was non-toxic allowing the cells to adhere and proliferate. The MTS assay revealed that the cell numbers gradually increased with time and maintained high cellular viability. The BDHA was immunopositive for osteonectin and the Saos-2 cells expressed specific fluorescence reactions when grown on the surface of the BDHA scaffold after 14 days. After 28 days of incubation in SBF, the pH value only fluctuated between 7.4–7.9 and the BDHA scaffold did not degrade significantly by weight indicating the scaffold had excellent chemical and structural stability.

Conclusions *In vitro* experiments demonstrated that the bovine dentine derived hydroxyapatite scaffold stimulated cell adhesion, proliferation and osteoblast differentiation. However, further research should be conducted to evaluate its feasibility as a bone substitute for clinical applications.

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R029

WITHDRAWN.

R030

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Ageing of bioceramic and MTA-based sealers in simulated body fluid

Aim To evaluate the bioactivity of Total Fill BC and MTA Fillapex.

Methodology Sixty horizontal root sections were enlarged to size 5 Gates Glidden and randomly divided into six groups ($n = 10$ each). In Groups 1, 2, and 3 sections were filled with Total Fill BC sealer, while sections in groups 4, 5 and 6 were filled with MTA Fillapex sealer. Specimens of groups 1 and 4 were soaked in simulated body fluid (SBF) for one day, those of groups 2 and 5 for one week, and those of groups 3 and 6 for two months. All specimens were processed for surface electron microscope (SEM) examination. Apatite precipitation on sealer and sealer-dentine interfaces were quantified using image analysis software (ImageJ). Energy dispersive x-ray (EDX) was used to analyze the calcium and phosphate content of surface precipitation, based on which the calcium phosphate (Ca/p) ratio was calculated.

Results Total Fill BC samples, regardless of the SBF soaking duration, had a significantly greater surface area of precipitation compared to MTA Fillapex ($P < 0.05$); such precipitation increased over time and the difference between the three timepoints was also significant. Following one day of SBF soaking, MTA Fillapex samples had only limited precipitation, which started to appear after one week. EDX revealed that the Ca content and Ca/P ratio of surface deposits on Total Fill BC samples increased over time with no difference between one week and two months of SBF soaking. The Ca content and Ca/P ratio of surface deposits on MTA Fillapex were significantly lower than that of Total Fill BC samples regardless of the SBF soaking time.

Conclusions Aging Total Fill sealer in SPF induced considerable apatite formation. In addition, the Total Fill surface had a high Ca ion release reflected in apatite formation with a high Ca/P ratio, and these bioactivity features increased over time. In comparison, the MTA Fillapex sealer had low and delayed bioactivity.

R031

WITHDRAWN.

IMAGING

R032

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Revisiting the PAI scoring system to produce a reliable and reproducible evaluation of the outcome of root canal treatment

Aim To verify the reliability and reproducibility of a new interpretation of the PAI scoring system used by French undergraduate students.
Methodology The Brynolff study was revisited to propose a new guide for PAI scoring based on the radiological appearance of the lamina dura and periapical structures. This guide was used by 62 undergraduates who took part in a 1-h tutorial on the PAI score assessment. In the following week, they were trained *ad libitum* on a website on scoring 40 images of roots. Then, they had to assess PAI scores for 100 images of root-filled and non-root-filled teeth on two occasions, each divided by an interval of one week (Test and Retest phase). Gold Standard values of PAI scores were obtained by the consensus of 3 experienced lecturers in Endodontics.
Results The success rates reached 64.6% and 66.1% respectively during the Test and Re-test phase. The reliability of the assessment of the PAI scores for the students was good for both Test and Re-test phases (respectively: ICC 95% = 0.78, $P < 0.001$; ICC 95% = 0.82, $P < 0.001$). The stability was also excellent (ICC 95% = 0.81, $P < 0.001$). Standard tooth factors and the presence of endodontic treatment did not influence concordance scores between students and experts for evaluation during the test phase.
Conclusions The guide for interpretation could be used by clinicians to produce a reliable and reproducible measure for the evaluation of the outcome of root canal treatment.

R033

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Accuracy of CBCT images in detecting the isthmus in mandibular molars

Aim To compare the sensitivity and accuracy of CBCT images in the visualization of root canal anatomy of mandibular molars with an isthmus, using microCT as validation.
Methodology Fourteen mandibular molars with an isthmus in the mesial root were scanned with microCT and three CBCT devices: Accuitomo, NewTom 5G e NewTom VGi evo. The CBCT images were used for qualitative evaluation of the mesial root anatomy according to Vertucci's classification; isthmus classification according to Hsu & Kim (1997) in the cervical, middle and apical thirds, and quantitative analysis of the area, perimeter, circularity, major and minor diameter. MeVisLab software was used for standardization of the images, which were evaluated by two calibrated examiners. Qualitative data were analyzed statistically using the Kappa test, and the quantitative data by ANOVA and Tukey test. The concordance between the data was verified by the intraclass correlation coefficient (ICC) and simple linear regression.
Results For Vertucci's classification, the Kappa test revealed a moderate agreement (k = 0.41) between microCT and the CBCT devices and almost perfect agreement (k = 0.91) between CBCT devices. Types I, III, IV and V were the most prevalent in all devices, and 2 types not included in Vertucci's classification were observed. For isthmus classification in cervical and middle thirds, the prevalence of type I (absence of isthmus) was greater in CBCT images compared to microCT, which indicates that the isthmus may be missed in CBCT images. For quantitative analysis, there was satisfactory reproducibility between microCT and CBCT, as shown by the values of perimeter, circularity, major and minor diameters ($0.41 < ICC > 0.74$), and this correlation/reproducibility was lower for the circularity parameter.
Conclusions CBCT images aid in the diagnosis and planning of root canal treatment; however, it is important to know their limitations in order to improve the prognosis of treatment.
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R034

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A retrospective clinical study of the referral reasons for CBCT imaging at a private endodontic practice during a one-year observation period

Aim To assess the percentage of cases referred for CBCT imaging from a private Endodontic practice during a one-year observation period and to discuss the referral reasons for CBCT scanning.
Methodology Two experienced endodontists practicing for more than ten years referred cases for CBCT imaging. The data of all patients referred for endodontic treatment from 05/01/2018 to 23/12/2018 were scanned individually to determine how many patients were further referred for CBCT and the main reason of referral. The clinical and radiographic features of each case were recorded to provide additional information with possible common characteristics among endodontic cases referred for CBCT imaging. The final diagnosis after CBCT interpretation as well as the treatment planning and the management of each case were also recorded.
Results Of a total of 1029 patients (1269 teeth) referred for endodontic treatment in 2018, 85 patients were further referred for CBCT imaging (8.3% of the patients). A total of 104 teeth (8.2% of the teeth) were scanned. 15 patients were referred for the scanning of more than one teeth. The most prevalent reason of referral for CBCT scanning was surgical treatment planning (46 teeth cases), followed by endodontic diagnosis-nonsurgical treatment planning (27 cases), evaluation of inflammatory resorptive defects (14 cases), preoperative anatomy assessment (3 cases) and endodontic diagnosis related to the assessment of procedural complications (7 cases) and possible detection of vertical root fractures (7 cases). Based on the final diagnosis after CBCT interpretation, 47 teeth were treated surgically, 24 were treated conventionally, 2 were managed both conventionally and surgically, 21 were extracted and 10 were scheduled for follow-up examinations without any clinical intervention.

Conclusions Only a small percentage of the patients referred for endodontic treatment or retreatment were further referred by endodontic specialists for CBCT imaging. CBCT scanning seems to be a prerequisite for surgical treatment planning and evaluation of inflammatory resorptive defects based on the total number of cases evaluated during the observation period.

TREATMENT PLANNING

R035

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Investigating the appropriateness of surgical endodontic referrals and procedural standards in a secondary care setting

Aim To improve understanding and compliance with the Royal College of Surgeons (UK) guidelines and highlight when further correspondence with the referring clinician is needed to obtain the best surgical outcome for the patient.

Methodology A retrospective review of all surgical endodontic referrals made to Queen Victoria Hospital between the period 01/01/2016 – 01/01/2019 was completed. This was inclusive of all referrals made via the NHS Rego system and GDP/GP referral letters. The quality of these referrals was qualitatively analysed as indicated or contraindicated in accordance with the 2012 RCS guidelines.

Results Results from the pilot study found a significant proportion of referrals did not meet the 2012 RCS criteria. Predominantly this was due to poor quality root canal treatment, periodontal disease compromising the long-term success of treatment and a poor coronal seal deeming the tooth unrestorable post-surgical intervention.

Conclusions A more efficient surgical endodontic referral system will aid resource allocation within the NHS service. These results will be a first step to aiding necessary modification of the NHS primary care referral pathway. This will lead to a more effective service for patients with an improved acceptance rate of referrals and better surgical outcomes.

LOCAL ANAESTHESIA AND PAIN CONTROL

R036

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Anaesthetic Efficacy of 2% Mepivacaine vs. 4% Articaine for Inferior Alveolar Nerve Blocks in patients with symptomatic irreversible pulpitis in mandibular molars: A randomized clinical trial

Aim To compare the anesthetic efficiency of 2% Mepivacaine (Scandonest 2%, Septodont, France) and 4% Articaine (Septanest 4%, Septodont) for inferior alveolar nerve blocks in patients with symptomatic irreversible pulpitis in mandibular molars during access cavity preparation and instrumentation.
Methodology Sixty-six eligible patients diagnosed clinically and radiographically with symptomatic irreversible pulpitis in mandibular posterior teeth received a single-visit root canal treatment using ProTaper Universal rotary system. The patients were randomly divided into two groups (n = 33/group) according to the anaesthetic solution used, either Group M (3.6 mL Mepivacaine hydrochloride 2% with 1:100 000 epinephrine) or Group A (3.4 mL Articaine hydrochloride 4% with 1:100 000 epinephrine). Pain intensity was assessed preoperatively, during access cavity preparation and during root canal negotiation and instrumentation using a numerical rating scale (NRS). The need for supplemental anaesthesia was also recorded. The Mann-Whitney test was used for statistical comparison between the groups; Friedman test and Wilcoxon rank test were used to compare over time within groups. For categorical variables, the Chi-square and Fisher's exact tests were used.
Results There was a similarity between both groups in terms of age, gender distribution and tooth type. There was no difference in pain level between the groups at the different observation times ($P \geq 0.05$). There was an observable drop in pain levels in both groups during access cavity preparation and instrumentation compared to the preoperative pain ($P \leq 0.05$). The success rates were similar in both groups (39.4% and 45.5% in Mepivacaine and Articaine groups, respectively) and there was no significant difference in the need for supplemental anaesthesia between the groups ($P \geq 0.05$).
Conclusions Anesthetic efficacy of Mepivacaine and Articaine were similar when used in patients with symptomatic irreversible pulpitis in mandibular posterior teeth.

R037

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Effect of premedication using Diclofenac Potassium on anaesthetic success of articaine buccal infiltrations for mandibular molars with symptomatic irreversible pulpitis: a randomized placebo-controlled trial

Aim This prospective, randomized, double-blind, clinical trial aimed to assess the effect of a preoperative, single, oral dose of 50 mg diclofenac potassium (DP; Cataflam, NOVARTIS Pharma Societe Anonyme Egyptienne, Egypt) on the anaesthetic success of articaine buccal infiltration with 4% articaine for mandibular molars with symptomatic irreversible pulpitis.
Methodology Seventy endodontic emergency patients with moderate-to-severe pain, rated using a 170-mm Heft-Parker visual analogue scale, randomly received either 50 mg DP or placebo (n = 35/group) one hour before initiating root canal treatment. Each patient received a buccal infiltration of 4% articaine with epinephrine 1:200 000 15 min before access preparation. Intra-appointment pain was assessed and successful anaesthesia was defined as no-to-mild pain (≤54) during access preparation. For failed cases, the stage of failure was identified as "within dentine" or "within pulp". Data were analyzed statistically using the Chi-square test with the significance level (α) set at 0.05.
Results Data of 68 patients were analyzed, 34 in both groups. The success rate for both groups was 41.2% (14/34) (P = 1.000). Overall, 45% (9/20) of the failure cases in the DP group occurred within dentine and 55% (11/20) within pulp, while 80% (16/20) in the placebo group occurred within dentine and 20% (4/20) within pulp (P = 0.002).
Conclusions Preoperative administration of a single, oral dose of 50 mg DP did not affect the success of 4% articaine buccal infiltration in mandibular molars with symptomatic irreversible pulpitis, but delayed the stage of anaesthetic failure until pulp exposure during access cavity preparation.

ACCESS CAVITY PREPARATION

R038

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Impact of ultraconservative endodontic cavities on root canal treatment efficacy and fracture resistance of maxillary premolars mounted in mannequin heads

Aim To evaluate the influence of ultraconservative endodontic cavities (UECs) on root canal detection, instrumentation efficacy and fracture resistance assessed in 2-rooted maxillary premolars. Traditional endodontic cavities (TECs) were used as reference for comparison.
Methodology Twenty extracted intact 2-rooted maxillary premolars were scanned with micro-computed tomographic imaging, matched based on similar anatomic features of the canals, and assigned to the UEC or TEC group (n = 10/group). Then, teeth were mounted on mannequin heads and accessed accordingly. Root canal detection was performed under an operating microscope and ultrasonic troughing. After root canal preparation with Reciproc Blue R25 instruments, the specimens were scanned again. Non-instrumented canal area and accumulation of hard tissue debris were analyzed. After root canal filling and cavity restoration, the total time required to perform root canal treatment was recorded and the specimens were loaded to fracture in a universal testing machine. The maximum load at fracture and fracture pattern (restorable or unrestorable) were recorded. Data were statistically analyzed using Shapiro-Wilk and Student's t test with a significance level of 5%.
Results All root canal were localized for both access modalities. The percentage of non-instrumented canal areas did not differ significantly between UEC and TEC groups ($P > 0.05$). However, UEC group was associated with a greater percentage of

accumulated hard tissue debris after preparation when compared to TEC group ($P < 0.05$). Time required to perform root canal treatment was longer in the UEC group ($P < 0.05$). There was no difference regarding the mean load at fracture among the UEC and TEC groups ($P > 0.05$). Unrestorable fractures were observed in all specimens of both groups.

Conclusions The current results did not show benefits associated with UECs. This access modality in biradicular maxillary premolars resulted in a greater percentage of accumulated hard tissue debris after preparation and required a longer time to perform root canal treatment. UECs did not increase the fracture strength of root-filled teeth.

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R039

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The use of dental magnification loupes and effect on tooth tissue removal during endodontic access procedures

Aim To investigate the effect of using dental magnification loupes on the amount of tooth structure removed during endodontic access cavity procedures.

Methodology A cross-over randomized study was conducted at the School of Dentistry, University of Liverpool, UK. Ethical approval was sought and granted. Twenty undergraduate dental students, who had not previously used any magnification were recruited and were split into two groups. Both groups had an introduction and brief training using presentations including a video showing how to carry out access cavity preparation and the use of magnification loupes prior to conducting the study. The students performed the study under simulated clinical conditions in the operative skills suite. All the teeth were set up in the mandibular right quadrant of the phantom head. The first group prepared endodontic accesses cavities on three 3D printed teeth (1 mandibular 1st molar, 1 maxillary 1st premolar, and 1 maxillary central incisor) utilizing dental loupes at $\times 3.5$ magnification. The second group performed an endodontic access on three 3D printed teeth (1 mandibular 1st molar, 1 maxillary 1st premolar, and 1 maxillary central incisor), without using dental loupes. Cone beam Computed tomography (CBCT) was used for scanning the prepared teeth and Mimic software package was used for image analysis.

Results Mean volume change for maxillary central incisor with loupes was 31.736 mm^3 (10%) compared with 21.658 mm^3 (7%) without loupes. The mean volume change for maxillary first premolars was 62.214 mm^3 (21%) with loupes compared with 65.852 mm^3 (22%) without loupes. The mean volume change in the mandibular molars was 110.155 mm^3 (23%) with loupes compared with 117.634 mm^3 (24%) without loupes.

Conclusions Initial results showed that no major difference in the amount of tooth tissue removed occurred when using dental loupes compared with no magnification during endodontic access cavity procedures.

R040

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Effect of conservative interproximal caries-driven endodontic access cavity preparation on the fracture strength of maxillary and mandibular premolar and molar teeth

Aim To compare the fracture strength of maxillary and mandibular premolar and molar teeth with either a traditional mesio-occlusal endodontic access cavity (TEC) or a caries-driven interproximal endodontic access cavity (CDEC).

Methodology Ninety-six maxillary and mandibular premolar and molar teeth were randomly divided into 4 groups and 3 subgroups. Group 1 maxillary premolar teeth, in group 2 maxillary molar teeth, in group 3 mandibular premolar teeth, in group 4 mandibular molar teeth. In subgroups 1 teeth were kept intact. In subgroups 2 TECs and in subgroups 3 CDECs were prepared. Then, the teeth were restored using composite resin. All specimens in each group were exposed to 1.2 million cycles of thermomechanical fatigue loading in a computer-controlled dual-axis chewing simulator. All specimens that did not fracture during the dynamic loading were loaded until fracture in a universal testing machine. Data were analyzed using two-way analysis of variance and Tukey tests at 5% significance level.

Results In all groups the intact tooth groups had the greatest fracture strength values compared to the experimental groups ($P < 0.05$). There was no significant difference between TEC and CDEC groups ($P > 0.05$) in maxillary and mandibular premolar and molar groups.

Conclusions Within the limitation of the present study, interproximal conservative access cavity preparations (CDEC) did not improve the fracture strength values of premolars or molars compared to traditional access cavity preparations (TEC).

ELECTRONIC APEX LOCATORS AND WORKING LENGTH ESTIMATION

R041

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A laboratory-based evaluation of different functions and motions of the TriAuto ZX2 in controlling the apical limit of instrumentation

Aim To evaluate the efficacy of the new endodontic motor Tri Auto ZX2 in maintaining the working length (WL) during root canal preparation, when using different combinations of apical action functions [Auto Apical Reverse (AAR) or Optimum Apical Stop (OAS)] and shaping motions [continuous rotation (CR) or optimal torque reverse (OTR)].

Methodology Sixty-four extracted single-rooted mandibular premolars were standardized and randomly divided into four groups. Each group ($n = 16$) was assigned a combination of a shaping motion (CR or OTR) and an apical action function (AAR or OAS).

The teeth were embedded in alginate and irrigated with sodium hypochlorite. A size 15 K-file was used to create a glide path before started canal instrumentation. The root canals were prepared using ProTaper files, activated by the auto start of the motor (300 rpm) using the apical control functions set at the 0.5 mark. The actual post-instrumentation length (AL2) was measured by placing a size 15 K-file up to the apical foramen. Mean differences between the WL and the AL2 were calculated for each group. The distributions and percentages of differences between the WL and AL2 values in mm obtained for each group were compared.

Results There was no difference in the mean WL for the different motions, types of apical controls, or their combinations (ANOVA, $P > 0.05$). A Chi-square test revealed no significant differences among the groups when the distributions and percentages of differences between WL and AL2 were compared ($P > 0.05$).

Conclusions For the Tri Auto ZX2, in a laboratory setting, all combinations of motion and apical control functions provided an adequate apical limit of preparation with no evidence of over-instrumentation.

R042

WITHDRAWN

R043

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Evaluation of the accuracy of three methods to determine working length in a laboratory setting

Aim To compare reliability of different procedures to measure working length (WL) during root canal treatment.

Methodology Twenty single-rooted extracted teeth were used. Teeth were mounted in a wax arch and a Cone Beam Computed Tomography (CBCT) image was obtained. Measurement of the length was done using the computer software (Carestream 3D), and the measure was recoded (CBCT-LG). The access cavities were prepared and a size 15 K-file was inserted into the canal. When the file tip was seen at the apical foramen, a rubber stop of the file was positioned at the occlusal reference point. The file was removed and its length measured using calipers and recorded as working length (WL). After retracting 0.5 mm of the WL (WL-0.5 mm), a canal length radiograph was obtained. Canals were irrigated with 5% NaOCL, and the canal length was measured using an electronic apex locator (Propex IQ) and recorded as EAL. For this, the alginate in a plastic container was prepared and allowed to set with the tooth and labial clip inside. The K file was fixed with Loctite and the apex was removed carefully until the tip of the file was seen. The distance between the anatomical apex and the tip of the file was measured; this value was subtracted from the WL and recoded (A-WL). Mean values and SD of each measurement was obtained and correlated using Pearson coefficient correlation.

Results Values obtained for each measurement were CBCT-LG 20.76 ± 2.62, WL 21.22 ± 2.56, WL-0.5 mm 20.72 ± 2.56, EAL 20.92 ± 2.59, A-WL 20.44 ± 2.59. There was a significant correlation between all measurements ($P < 0.001$). High level of correlation was observed, ranging between 0.88 and 0.97.

Conclusions CBCT, electronic length determination with an apex locator and length measurement radiographs were all reliable for working length determination.

R044

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Repeatability of three electronic apex locators. An *in vivo* concordance study

Aim To compare *in vivo* the repeatability of three electronic apex locators in maxillary anterior teeth.

Methodology An *in vivo* concordance study, approved by the local ethics committee, was conducted between three electronic apex locators: Root ZX (J. Morita MFG Corp, Kyoto, Japan) (RZX), Canal Pro (Colténe-Endo, Cuyahoga Falls, OH, USA) (CNP) and RomiApex A-15 (Romidan Ltd, Kiryat Ono, Israel) (RA). Thirty anterior maxillary teeth in healthy adult patients of both sexes with a need for root canal treatment were included. In each canal, all three electronic apex locators were used to determine working length, defined as the "zero" reading on the display. Six root canal measurements were performed on each patient; two consecutive measurements with each electronic apex locator. Operator 1 performed the electronic measurements and operator 2, blinded to the apex locator being used, measured the endodontic file with a digital caliper. The difference between each pair of measurements was calculated and data were analyzed using the Bland-Altman test and the Friedman test with Conover multiple comparison.

Results The mean difference (limits of agreement) of each pair of measurements made by Root ZX, Canal Pro and RomiApex A-15 were 0.05 (±0.37), 0.19 (±1.02), and 0.06 (±0.94) mm, respectively. Additionally, the mean (standard deviation) of absolute differences were 0.15 (0.12), 0.46 (0.30) and 0.40 (0.25) mm, respectively. Significant differences were found between the RZX and CNP ($P < 0.001$) and between the RZX and RA ($P < 0.001$) regarding absolute differences between each pair of measurements. No difference was found between CNP and RA ($P = 1.0$).

Conclusions Root ZX exhibited the greatest repeatability and the smallest mean difference between pairs of measurements.

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R045

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Accuracy and precision of three electronic apex locators, *ex vivo*

Aim To evaluate the accuracy and precision of three electronic apex locators, *ex vivo*.

Methodology Thirty-five single-canaled extracted human teeth with mature apices were fixed to a mounting model and the apical third of the roots submerged in saline solution. Root ZX II (RZX)(J. Morita Corp.), Propex Pixi (PXI) (Dentsply Maillefer), and RomiApex (RMA)(Romiapex A-15) were used in the study. A 25 mm K-file was advanced into the root canal until the flashing bar was at "Apex" (RZX) or "Over" (PXI and RMA)) and then withdrawn until the "0.0", "0.5" or "1.0" display mark remained stable for 5 s. Each tooth was measured 9 times for each EAL; 3 times at each display mark. Precision was calculated by comparing the three measurements obtained for each EAL at each

display mark and accuracy was determined by comparing the actual length (AL) with the mean of three electronic measurements for each EAL at each display mark using Intraclass Correlation Coefficient (ICC). The Friedman test with Conover post hoc test was run to determine if the median differences between the AL and the mean electronic measurement were statistically significant.

Results All 3 EALs had excellent precision (ICC > 0.98) and accuracy (ICC > 0.94) at the three display marks. Median differences between the AL and the EAL length for RMA, RZX and PXI were −0.35, −0.23 and −0.29 mm at "0.0"; −0.51, −0.39 and −0.39 mm at "0.5"; and −0.61, −0.49 and −0.69 mm at the "1.0" display mark, respectively. The Friedman test with Conover post hoc test revealed significant differences between the EALs at each display mark.

Conclusions The three EALs had excellent precision and accuracy. The median distance between the AL and the electronic measurements was smallest at the "0.0" display mark and for RZX, and greatest at the "1.0" display mark and for PXI.

FRIDAY

IRRIGANTS/MEDICAMENTS – CANAL CLEANING

R046

WITHDRAWN.

R047

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Penetration depth of irrigants into root dentine after sonic, ultrasonic and photoacoustic activation *ex vivo*

Aim To compare penetration depths of endodontic irrigants into dentinal tubules after different activation methods *ex vivo*.
Methodology Root canals of 90 extracted teeth were prepared to size 40, 0.06 taper. Teeth were divided into 6 groups, and final irrigation was performed with EDTA and sodium hypochlorite as follows: (I) manual dynamic activation, (II) Ultrasonic, (III) Sonic, (IV) PIPS (photon-induced photoacoustic streaming, (V) SWEEPS (shock-wave enhanced emission photoacoustic streaming) and (0) control without final irrigation or activation. Subsequently, methylene blue was injected into the canals and activated. Teeth were sectioned horizontally, imaged under a light microscope, and dye penetration depths were measured in 6 sections per tooth and 24 points on a virtual clock-face per section. Data were analyzed statistically by nonparametric tests for whole teeth and separately for coronal, middle and apical thirds.
Results Penetration of dye into the dentinal tubules was lowest for controls. Median penetration depths amounted to 700–900 μm for groups I–V with significant differences in apical thirds between group I and all other test groups. Minimum penetration depths were significantly greater for PIPS in the apical thirds.
Conclusions Greater penetration depths are evident in apical thirds for ultrasonic, sonic and laser-induced activation compared to manual dynamic activation. PIPS was superior to all other tested methods regarding the minimally achievable penetration depth of irrigants. The novel SWEEPS mode did not increase irrigant penetration.

R048

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The effectiveness of different final irrigation protocols on the removal of dentine debris from simulated grooves within root canal walls

Aim To compare the effectiveness of syringe irrigation, passive ultrasonic irrigation (PUI) and XP-endo Finisher file (FKG Dentaire, Switzerland) to remove dentine debris from simulated irregularities in prepared root canals.
Methodology The root canals of thirty mandibular premolars were instrumented using the ProTaper Universal system (Dentsply Sirona, Switzerland) up to size 30, 0.09 taper. The teeth were split longitudinally and three semicircular cavities with a diameter of 2 mm were created at 2, 6 and 8 mm from the apex on each half of the roots. The cavities were filled with dentine debris mixed with 2% NaOCl. The root halves were reassembled using Rubber-Dam liquid (Cerkamed, Poland) and fixed in an impression material (Zetaplus, Zhermack). The root canals were flushed with 5 mL 5.25% NaOCl and divided into three groups ($n = 10$) according to the irrigation protocols: group 1: syringe irrigation, no activation; group 2: passive ultrasonic irrigation (PUI) with Irrisafe (Acteon, France); group 3: XP-endo Finisher file (FKG Dentaire, Switzerland). Before and after final irrigation, images of the two halves of the canal were taken using a microscope and digital camera. The artificial grooves were evaluated using a score system between 0 – 3. Data analysis were performed using the Kruskal-Wallis and Mann–Whitney U- tests, with a significance level of 0.05.
Results Less dentine debris remained in the grooves after PUI irrigation ($P < 0.05$) and XP-endo Finisher ($P < 0.05$). In the apical third, significantly more debris was present only for specimens from group 1 ($P < 0.05$), comparative to the middle and coronal third. There was no significant difference amongst group 2 and 3 for debris removal at all levels of the root.
Conclusions Activation with PUI and XP-endo Finisher file had the greatest effect in removal of dental debris, in comparison to syringe irrigation.

R049

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The relationship between root canal diameter and efficacy of Ca(OH)2 removal using irrigant agitation technique with the Gentle Brush

Aim To evaluate efficacy of removing calcium hydroxide paste using NaOCl activation using the Gentle Brush from wide and narrow root canals in extracted teeth.
Methodology Fifty extracted premolar roots were standardized up to 15 mm length and divided into 2 groups depending on the initial apical file size, respectively: large canals (Group LC) and narrow canals (Group NC). After chemo-mechanical canal preparation, a material based on calcium hydroxide was placed and accessed cavities were restored with a temporary restoration. Specimens were stored for 14 days at 37°C in relative humidity.

Before and after dressing removal, digital radiographs projecting the bucco-lingual and mesio-distal plane of each tooth were taken (GXS-700, USA). Radiographs were uploaded into the graphic software, roots were divided into 3 parts: apical, middle and coronal and a criss-cross pattern superimposed. Every square field located on the course of the canal was calculated and evaluated in term of absence or presence of canal dressing. This pilot study presents the percentage of clean canal fields accomplished using rinsing agitation with Gentle Brush (Medic NRG, Israel) compared in group LC ($n = 8$) and NC ($n = 8$) with reference to the canal level. For comparison of individual proportions, the N-1 Chi-square test was used. To compare the proportions between the 3 groups, the chi-square test with the Monte Carlo analysis was used, while the Marascuilo procedure determined the significance between particular comparison pairs. $P < 0.05$ was assumed as the statistical significance level.

Results The difference between the percentage of the uncleaned area remaining in groups LC and NC in apical to coronal level was: 39.51% (52.12% vs 12.61%), 46.77%(83.13% vs 36.35%) and 48.08% (58.41% vs 10.32%), respectively. The significant difference between efficacy of Ca(OH)2 removal observed in comparison of middle and coronal levels in group LC was 0.130/critical test value = 0.077, in comparison of apical and middle level = 0.141/0.106 and coronal and middle level = 0.163/0.082.

Conclusions Activation of irrigation with the Gentle Brush was more beneficial in removing Ca(OH)2 in narrow canals. Cleaning was more efficient in middle levels of both groups.

R050

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Analysis of the irrigant penetration in lateral canals and the level of extrusion in a semi-closed environment

Aim To compare the penetration in lateral canals and extrusion level of irrigants using seven different activation systems during the final irrigation.

Methodology A total of 105 transparent artificial maxillary molars were used whose design included a lateral canal in the apical third of the palatal root. The palatal canal was instrumented to a working length of 21 mm using ProTaper Next system up to the X4 file, and subsequently, the lateral canal was permeabilized with a size 10 K-file. Teeth were immersed in a clear vessel filled with 0.2% agarose gel to create a semi-closed environment. Later, teeth were randomly divided into 7 groups ($n = 15$) according to the final irrigation method: LVN group (closed-ended, lateral vent needle Max-i-Probe®), EA (EndoActivator®), EDDY (EDDY®), EV (EndoVac®), XPENDO (XPENDO® finisher), PUI (passive ultrasonic irrigation – Irrisafe®), and CB (Canal Brush®). After the application of different irrigation protocols (using 5.25% sodium hypochlorite with Indian ink as irrigant), standardized photographs were taken and analyzed (using ImageJ software) to determine the percentage of the lateral canal filled by the irrigant solution and if there were extrusion or not. The results were statistically analyzed using the Kruskal Wallis and Chi-Cuadrado tests (SPSS 22).

Results Mean percentages of irrigant penetration in lateral canals were: 92.3% for PUI, 82% for XPENDO, 72.2% for EDDY, 66.3% for EA, 63.5% for LVN group, 36.1% for EV, and 24.5% for CB.

Significant differences ($P < 0.05$) were observed between those groups: EV-PUI, EV-XPENDO, CB-EDDY, CB-XPENDO and CB-PUI. Extrusion levels were increased for PUI and EDDY groups and decreased for EV and CB groups according to the media.

Conclusions Different irrigation systems had varying percentages of penetration in lateral canals and levels of extrusion.

R051

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Efficacy of laser-activated irrigation with PIPS vs SWEEPS in removing biofilm-mimicking hydrogel from an isthmus model

Aim To evaluate the efficacy of laser-activated irrigation with PIPS and SWEEPS in removing a biofilm-mimicking hydrogel (BMH) from the isthmus in an artificial root canal model.

Methodology Transparent resin blocks containing 2 standardized root canals (apical diameter of 0.3 mm, 6% taper, 15 mm long, with a coronal reservoir) connected by an isthmus (0.15 mm wide, 2 mm high) were used as the test model. The isthmus was filled with an artificial biofilm (hydrogel containing dentine debris). The canals were filled with water, and subjected to two modalities of laser-activated irrigation (LAI) with a 2940 nm Er:YAG laser: PIPS tip (size 600/9) at canal entrance (20 Hz, 20 mJ, 50 μs) ($n = 30$) and SWEEPS tip (size 600) at canal entrance (20 Hz, 20 mJ, AutoSWEEPS) ($n = 30$). All irrigation methods were executed for 3 × 20 s. Needle irrigation (NI) with a 27G needle served as the control ($n = 30$). Standardized images of the isthmus were taken before, after 20 s, 40 s and 60 s, and the proportion of BMH removal was determined using image analysis software and compared across groups using Kruskal Wallis Test ($P \leq 0.05$).

Results After 20 s, BMH removal was significantly higher with SWEEPS-LAI (56.1%) than with PIPS-LAI (23.3%) and NI (18.6%) ($P < 0.05$). There was no significant difference between PIPS-LAI and NI ($P > 0.05$). After 40 and 60 s, BMH removal was significantly higher in SWEEPS-LAI (82.2% and 90.2% respectively) compared to PIPS-LAI (resp 50.5% and 61.8%) and NI (resp 25.5% and 31.7%) ($P < 0.05$). At these time points, PIPS-LAI was significantly higher than NI ($P < 0.05$).

Conclusions SWEEPS-LAI resulted in faster and greater BMH removal. PIPS-LAI needed more time for BMH removal.

R052

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Hard-tissue debris removal from the mesial root canal system of mandibular molars with a new sonic irrigation device: a micro-computed tomography study

Aim To investigate removal of accumulated hard tissue debris (AHTD) from the mesial root canal system of mandibular molars by a new sonic irrigant activation device (Eddy, VDW, Munich, Germany), using micro-computed tomography analysis.

Methodology Thirty mesial roots of extracted human mandibular molars with two canals connected by an isthmus were selected based on micro-CT scans. The mesial roots were mechanically instrumented to an apical diameter of ISO 30 using rotary NiTi files (ProTaper Next). Teeth were randomly divided into

three final irrigation groups ($n = 10$): passive sonic irrigation (PSI) using Eddy (VDW) for 3 × 20 s, ultrasonically activated irrigation (UAI) using size 20 Irrisafe file for 3 × 20 s and manual irrigation (MI) using a syringe and 30G needle. NaOCl (2.5%) was used as an irrigant. Micro-CT scans (12 μm resolution) were taken before and after instrumentation and after final irrigation. After reconstruction and image processing, the volume filled with hard tissue debris (vol% AHTD) before and after irrigant activation was calculated, and the mean percentage reduction of AHTD after final irrigation was compared pre- and post-operatively and across groups using Paired Samples *T*-test and One-way ANOVA.

Results A significant reduction in vol% AHTD after final irrigation was observed in all groups. The mean AHTD reduction was 25.2% for MI, 47.4% for PSI and 60.7% for UAI. AHTD reduction with UAI was significantly greater than with MI ($P < 0.05$). No other significant differences were observed.

Conclusions All final irrigation protocols resulted in a significant AHTD reduction, but none of them completely removed AHTD from mesial root canals systems. Passive sonic irrigation performed similar to manual or ultrasonically activated irrigation.

IRRIGANTS/MEDICAMENTS – ANTIMICROBIAL ACTIVITY

R053

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Antibacterial effect of silver nanoparticles mixed with calcium hydroxide or chlorhexidine on multispecies biofilms

Aim To investigate the antibacterial effect of silver nanoparticles (AgNP) mixed with calcium hydroxide ($Ca(OH)_2$) or chlorhexidine gel (CHX) against a multispecies biofilm on root canal dentine, by confocal laser scanning microscopy (CLSM) and culture-based analysis.

Methodology Dentine blocks were inoculated *with Enterococcus faecalis, Streptococcus mutans, Lactobacillus acidophilus* and *Actinomyces naeslundii* by centrifugation of the bacterial suspension into the dentinal tubules. After one week of cultivation, fifty infected dentine blocks were randomly divided into groups according to medication; saline solution (SS), $Ca(OH)_2$ (Ultracal XS Ultradent), $Ca(OH)_2$+AgNP (Nanografi) (1:1), 2% CHX gel (Gluco-Chex Cerkamed) and 2% CHX gel+AgNP (1:1) and time of application: 1 and 7 days (all groups, $n = 5$). Samples for bacterial culture were collected with sterile paper points before and after medication to quantify the bacterial load. Biofilm elimination was quantitatively analysed by Live/Dead BacLight Bacterial Viability staining and CLSM. All images were processed using ImageJ software to measure the percentage of viable bacteria and the data were analysed statistically by the Kruskal-Wallis and Dunn post hoc tests (α=0.05). The bacterial reduction was calculated and analysed statistically using the factorial Analysis of Variance (ANOVA) and Tukey tests (α=0.05).

Results Scanning electron microscopy revealed a dense multispecies biofilm on dentine blocks after 1 week of cultivation. Culture-based analysis revealed that the addition of AgNP to CHX and $Ca(OH)_2$ increased the effectiveness of both medicaments in terms of bacterial reduction ($P > 0.05$ and $P < 0.05$, respectively) in both application times (1 and 7 days). The CLSM images revealed that mixture of AgNP with CHX killed significantly more bacteria on the root canal surfaces when compared with all other medicaments at 1 and 7 day application periods. The efficacy of CHX or $Ca(OH)_2$ mixed with AgNP was superior to CHX or $Ca(OH)_2$ used alone in 1 day of application ($P < 0.05$). A significant decrease in bacterial viability occurred in the following order: CHX+AgNP≤CHX≤$Ca(OH)_2$+AgNP<$Ca(OH)_2$<SS in 7 days of application.

Conclusions The use of silver nanoparticles as a mixture with calcium hydroxide or chlorhexidine gel increased the antibacterial effectiveness of the medicaments on multispecies biofilms. The mixture of AgNP and CHX was the most effective medicament, especially after short term applications.

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R054

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The effect of debridement on the treatment outcome of vital pulp therapy: a systematic review

Aim To systematically review the different procedures used for pulp tissue debridement in the vital pulp therapy of cariously exposed human permanent teeth and their influence on pulp survival.

Methodology An electronic search on clinical trials, defined as prospective studies with a test and a control treatment, was conducted in November 2018 using Medline, Biosis, Cochrane, Embase and Web of Science databases. No language restrictions were applied. Two independent referees screened titles and abstracts. All the articles selected by either referee were included. A quality assessment of the included studies was performed.

Results Sixty articles were analysed in full text, of which 36 could be included in the review. Most of the articles (26/36) were randomized clinical trials (RCTs)/pseudo RCTs, or clinical trials (10/36). Methods for pulp tissue debridement included rinsing with tap water, saline, sterile saline, sodium hypochlorite (NaOCl) and the topical application of cotton pellets or laser irradiation. Most of the included studies compared the influence of capping materials. Only 4 articles examined the effect of pulp tissue debridement on pulp survival, they were underpowered and showed a high risk of bias. In one RCT 2.5% NaOCl was compared to saline, whilst 2 RCTs and one clinical trial assessed the effect of laser irradiation on pulp survival. A positive influence of debridement on pulp survival could be seen in 2 of these publications.

Conclusions Various methods have been described for pulp tissue debridement in vital pulp therapy, but the issue has not been studied in detail. However, some of the identified studies showed a positive effect of pulp tissue debridement on pulp survival.

IRRIGANTS/MEDICAMENTS – DENTINE DISINFECTION

R055

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Endodontic application of an anti-cancer metallo-drug

Aim To compare the antimicrobial ability of an anti-cancer gold compound, to the most common root canal medicament, calcium

hydroxide, in an *ex vivo* study using dentine discs infected with *Enterococcus faecalis*.

Methodology Dentine discs (4 × 3 × 1 mm ± 0.2 mm) were sectioned from single-rooted anterior teeth, sterilised and incubated for 4-weeks with *E. faecalis* under anaerobic conditions. The gold compound was diluted in sterile distilled water to the minimum bactericidal concentration for *E. faecalis*, 4.833 mg/mL. Three millilitres of either the gold compound solution or calcium hydroxide solution (1.6 mg/mL) were dispensed into 16 wells of a microtitre plate. Discs were randomly selected and incubated at 37°C for 24 h. Sterile water was placed into four wells as positive controls. After the medication period, the roots were crushed aseptically, sampled, diluted and plated onto Colombia blood agar. Following incubation at 37°C for 24 h, the colony forming units (CFU/disc) were determined.

Results The positive controls generated $\approx 7 \times 10^5$ CFU/disc. The gold compound solution completely inhibited bacterial growth in all eight samples; however, an orange-brown discoloration of dentine was noted. Two of the calcium hydroxide discs were incompletely disinfected, with microbial growth of $\approx 1 \times 10^3$ CFU/disc.

Conclusions The current *ex vivo* study demonstrates that the gold compound solution is superior to calcium hydroxide in predictably eliminating *E. faecalis* within an infected dentine disc model after 24 h. The discoloration of dentine discs exposed to the gold compound was due to photo-catalytic oxidation of the aqueous phenol compound on exposure to light. Further research is aimed at determining the antimicrobial ability to other planktonic microorganisms and biofilms, and incorporating the gold compound into a gel-releasing medicament for clinical application.

Acknowledgements We thank Amira Salem (University of Otago) for her expertise in the microbiology laboratory.

R056

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The effect of irrigant activation on sodium hypochlorite penetration into root dentine

Aim To evaluate the effects of irrigant activation, concentration and contact-time on the penetration of sodium hypochlorite (NaOCl) into root dentine.

Methodology One-hundred human maxillary permanent canines were decoronated to a length of 15 mm and the root canals instrumented up to a F4 ProTaper rotary file. Roots were dyed with crystal violet, embedded in silicone and randomly distributed into 16 groups ($n = 5$) according to the Irrigant Activation Technique (IAT) used, namely Conventional Needle Irrigation (CNI), Manual Dynamic Activation (MDA), Passive Ultrasonic Irrigation (PUI) and Sonic Irrigation (SI), NaOCl concentration (%) and irrigant contact-time (min) as follows: 1.CNI/2%/10 min, 2.CNI/2%/20 min, 3.CNI/5.25%/10 min, 4.CNI/5.25%/20 min, 5.MDA/2%/10 min, 6.MDA/2%/20 min, 7.MDA/5.25%/10 min, 8.MDA/5.25%/20 min, 9.PUI/2%/10 min, 10.PUI/2%/20 min, 11.PUI/2%/10 min, 12.PUI/5.25%/20 min, 13.SI/2%/10 min, 14.SI/2%/20 min, 15.SI/2%/10 min and 16.SI/5.25%/20 min. The IATs were used in the last minute of each group. The CNI groups acted as controls and 4 teeth were not exposed to NaOCl to evaluate dentine staining (negative control). Specimens were subsequently sectioned transversely into coronal, middle and apical thirds and again longitudinally in the mesio-distal and bucco-lingual planes producing 10 segments per tooth (4 coronal, 4 middle and 2 apical). These were observed by a blinded assessor under a light microscope. The average NaOCl penetration depth (μm) for each segment was then determined using ImageJ software by measuring the width of the bleached zone of dentine. Statistical comparisons were made using one-way ANOVA followed by post hoc Tukey and Dunnett's tests with appropriate Bonferroni correction ($\alpha<0.05$).

Results In all thirds, MDA, PUI and SI consistently resulted in greater NaOCl penetration than CNI ($P < 0.01$). The deepest NaOCl penetration in coronal, middle and apical thirds was measured in group 8 (379.0 μm ± 110.8, 411.0 μm ± 132.3, 232.7 μm ± 78.2) and least in group 1 (179.9 μm ± 67.2, 158.7 μm ± 70.3, 24.4 μm ± 23.2). Penetration was always less apically within each group ($P < 0.001$); however, no significant differences were found between the mesio-distal and bucco-lingual planes. Increasing irrigant contact-time improved penetration for most groups using 2% NaOCl ($P < 0.01$), but few using 5.25%. Increasing NaOCl concentration improved penetration for all groups with 10 min irrigant contact-time ($P < 0.01$), but less for those using 20 min.

Conclusions The MDA, PUI and SI techniques significantly improved tubular penetration of NaOCl throughout the canal when compared to CNI. Increased irrigant contact-time and NaOCl concentration further improved tubule penetration with each IAT.

IRRIGANTS/MEDICAMENTS – OTHER

R057

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Ex vivo detection and quantification of volatile compounds and disinfection by-products by SIFT-MS, during chemomechanical preparation of infected root canals

Aim To assess the release of volatile compounds (VOCs) and disinfection by-products (DBPs) during instrumentation and irrigation of artificially infected root canal specimens, with 2.5% sodium hypochlorite (NaOCl) and 17% ethylenediaminetetraacetic acid (EDTA), in a novel tooth model.

Methodology Forty-two single-rooted human teeth were decoronated to obtain 15 mm-long root specimens and working length was determined 1 mm short of the root apex. All specimens were initially preflared up to instrument size ProTaper F1, to create sufficient conical space for the inoculation of the root canals with 5 selected endodontic pathogens and the development of a nutrient-stressed multispecies biofilm. Then they were randomly assigned into three groups. In group 1 ($n = 14$), no endodontic intervention was performed (control). In group 2 ($n = 14$), root specimens were instrumented with rotary files (ProTaper Gold F1, F2 and F3) and irrigated with sterile saline. In group 3 ($n = 14$), root specimens were instrumented with rotary files (ProTaper Gold F1, F2 and F3) and irrigated with 2.5% NaOCl and 17% EDTA. A customised experimental model apparatus was fabricated for each specimen, with the apical root third inserted in a glass vial filled with sterile ultrapure water, to simulate high-compliance periradicular space. A portable suction was used to aspirate the effluent during irrigation procedures. The reaction products of the aliquots obtained from the glass vials and the collected effluents were analysed in real time, by selected ion flow tube mass spectrometry (SIFT-MS) in triplicates. Two-way analysis of variance (ANOVA) with post hoc Tukey tests were used for data analysis. The level of statistical significance was set at $P < 0.05$.

Results The chemomechanical preparation of root canals in groups 2 and 3 resulted in the apical extrusion of VOCs and DBPs. In group 3, the aliquots obtained from periradicular space and the collected effluent released high concentrations of methanol, propanol, ammonia, chloroform, together with unexpected higher levels of formaldehyde, which were statistically significant compared to group 2 ($P < 0.05$). In group 1, VOCs and DBPs were not detected.
Conclusions The mechanical preparation and irrigation of artificially infected root canals with rotary NiTi files, 2.5% NaOCl and 17% EDTA resulted in the formation of VOCs and DBPs in a water-closed periradicular space and aspirated effluent aliquots.

R058

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The effect of irrigant activation on push-out bond strength

Aim To investigate the effect of irrigant activation on push out bond strength of the root canals.
Methodology Twenty single-rooted maxillary central teeth were sectioned below cementoenamel junction in a length of 12 mm. Root canals were prepared with ProTaper rotary system (Dentsply Sirona, Switzerland). 2.5% NaOCl and 17% EDTA solutions were used for final irrigation in all canals. Root canals were randomly divided into four groups ($n = 5$). Irrigation solutions were used with syringe in group 1 (Control, without activation). Irrigation solutions were activated with ultrasonic device (EMS mini Piezon, Swiss) in group 2 and Er:YAG laser (Fotona, LightWalker®, Slovenia) with photon-induced photoacoustic streaming (PIPS™) technique using two different parameters (Group 3, 0.6 W 15 Hz 40 mJ) (Group 4, 0.3 W 15 Hz 20 mJ). The root canals were filled with root canal sealer (AH Plus, Dentsply, UK) and were kept in a 37°C, 100% humidity environment for one week. Thereafter the specimens were transversally sectioned and all slices from coronal and apical regions were subjected to push-out bond tests. The data were calculated as megapascals. Statistical analysis of the data was performed by two-way analysis of variance (ANOVA).
Results The lowest bond strength was observed in the control group (Group 1) ($P < 0.05$). The greatest bond strength was found in the Er:YAG groups (Group 3 and Group 4), ($P < 0.05$). However, no significant difference was found between group 3 and group 4 ($P > 0.05$). In group 2, which was activated by ultrasonics, the bond strength was less than the laser groups, but greater than group 1 ($P < 0.05$). The coronal root region had a greater bond strength in all groups than the apical region ($P < 0.05$).
Conclusions Use of PIPS technique with Er:YAG laser was an effective method for irrigant activation. However, different parameters used in Er:YAG laser did not affect the push-out bond results.

R059

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Is calcium hydroxide capable of decreasing short-term discoloration induced by Ledermix?

Aim To investigate the relative colour change (ΔE) of standardized enamel-dentine-blocks after a 3-week dressing with either Ledermix (LED) or Odontopaste (ODO) followed by a 3-week calcium hydroxide dressing (Ca(OH)2) using an established bovine tooth model.
Methodology Eighty bovine enamel-dentine-blocks were prepared according to standardized dimensions comprising a central cavity (Ø 2.5 mm; 1.5 mm depth). The specimens were randomly assigned to 2 control groups: NEG (empty) and POS (blood), and 2 test groups: LED and ODO ($n = 20$). Specimens were irrigated according to a standardized protocol (1% NaOCl, 17% EDTA, 1% NaOCl) and the materials were placed in the cavities with subsequent sealing using a self-adhesive composite resin. After 3 weeks, a Ca(OH)2 dressing was applied to all groups and incubated for another 3 weeks. Finally, the cavities were restored with composite resin. Colour measurements were taken with a spectrophotometer and ΔE values were calculated. A Tukey's multiple comparison test was used to assess significant differences within the treatment groups at several time intervals ($P < 0.05$).
Results At the 3-week time point, severe discolorations were present in LED (ΔE 29.14 ± 6.55) and POS (ΔE 18.05 ± 7.03), while ODO and NEG remained colour stable (ΔE 2.3 ± 1.16 and ΔE 3.2 ± 1.36). The following 3-week Ca(OH)2 dressing revealed a slight decrease in discoloration for POS (ΔE 15.93 ± 6.63; $P = 0.37$), whereas LED showed a further increase (ΔE 39.55; $P < 0.0001$). Between the end of the Ca(OH)2 dressing and the final restoration no significant colour change was observed in any group ($P > 0.9$).
Conclusions The discoloring potential of Ledermix progressed over 3 weeks after being removed from the cavity despite rinsing the specimens between treatment steps and replacing the dressing with Ca(OH)2. In order to avoid aesthetical limitations, the coronal pulp cavity should essentially be free from Ledermix during the entire treatment procedure and/or the alternative preparation Odontopaste should be used if available.

CANAL PREPARATION – APICAL EXTRUSION

R060

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Apical extrusion of debris during root canal preparation with instruments utilising different movement kinematics – an *ex vivo* study

Aim To assess the weight of apically extruded debris during root canal preparation with instruments that utilise different movement kinematics (rotary, reciprocating, and adaptive motion).
Methodology The study was performed using the Myers and Montgomery model for measuring the weight of extruded debris. Sixty freshly extracted human premolars were inserted into preweighed Eppendorf tubes and randomly classified into three groups. Each group was instrumented to working length set 1 mm short of the anatomical apex using the standard sequence provided by the manufacturers. For group 1, the teeth were prepared using rotary instruments (ProTaper Next, Dentsply Sirona) to the size corresponding to the PTN X2 file. In group 2, the root canals were prepared using reciprocating instruments (WaveOne Gold, Dentsply Sirona) until the WOG Primary file reached WL. In group 3, the root canals were prepared with Twisted Files (Kerr Dental Co) using adaptive motion to SM3. Root canals were irrigated with 1 mL of 0.9% NaCl solution between each file insertion. Afterwards, the tubes with collected debris were stored in an incubator at 70°C for

5 days. Quantification of the weight of extruded debris was performed by subtracting the preinstrumentation from the postinstrumentation weight of the Eppendorf tubes. The results were analysed with Kruskal-Wallis ANOVA, with significance level set at 0.05.

Results The weight of extruded debris was 0.00034 g ± 0.00015 for Group 1; 0.00031 g ± 0.0002 for Group 2, 0.00035 g ± 0.00013 for Group 3. The results between the groups were not significantly different ($P = 0.253$).

Conclusions Engine-driven root canal preparation with the use of instrument that utilise different movement kinematics (rotary, reciprocating, adaptive motion) was associated with apical extrusion of debris to a similar extent.

CANAL PREPARATION – SHAPING ABILITY

R061

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Effects of three reciprocating single-file NiTi-systems on root canal geometry – a micro-CT analysis

Aim To evaluate and compare the shaping ability of three single-file reciprocating NiTi-systems: Reciproc R25 (VDW, Munich, Germany), WaveOne Gold Primary (Dentsply Sirona, Ballaigues, Switzerland), S1 Superflex Standard (Sendoline, Täby, Sweden) using micro-computed tomography.

Methodology Seventy-five mandibular molars with separate mesial root canals were divided into three experimental groups ($n = 25$): S1 Superflex Standard size 25, 0.06 taper (SUP), WaveOne Gold Primary size 25, 0.07 taper (WOG), Reciproc 25 (REC). Teeth were assigned by forming matched triples according to curvature (15–40°), radius (≤18 mm) and type of curvature (single-curved, sc; double-curved, dc). During preparation according to the manufacturers' instructions, a total volume of 15 mL NaOCl (3%) and 5 mL EDTA (17%) was used for irrigation. Teeth were scanned before and after root canal preparation with a resolution of 10.5 μm using micro-computed tomography (Bruker SkyScan 1272, Bruker Corporation, Belgium). The following parameters were assessed: changes in root canal volume, percentage of unshaped canal walls and degree of canal transportation. Data were analysed using two-way ANOVA and Tukey's post hoc tests. The level of significance was set at α=0.05.

Results Preoperatively, there were no differences regarding root canal volume ($P = 0.97$) and surface area ($P = 0.81$) between the experimental groups. Concerning mean dentine removal, there were no significant differences among the groups ($P = 0.92$), nor between sc and dc root canals prepared with the same NiTi-instrument ($P < 0.08$). None of the three NiTi-instruments was able to shape the root canal system completely, with no significant differences among groups ($P = 0.73$) nor between sc and dc root canals within the same group ($P < 0.78$). Mean value of canal transportation was significantly greater for REC compared to SUP ($P = 0.0094$) and WOG ($P = 0.0038$). There were no significant differences regarding canal transportation between sc and dc root canals within the same NiTi group ($P < 0.65$).

Conclusions None of the three evaluated reciprocating NiTi-systems was able to instrument the entire root canal. Preparation with Reciproc resulted in significantly greater canal transportation than preparation with WaveOne Gold and S1 Superflex.

R062

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Comparative analysis of surface roughness and plastic deformation of WaveOne Gold and EdgeOne reciprocating instruments after clinical single use

Aim To compare the changes in surface topography and plastic deformation of contemporary reciprocating instruments (WaveOne Gold (WOG) and EdgeOne (EO)) produced after clinical use.

Methodology Root canal treatments were performed in the first mandibular molars of 40 patients after approval from Ethics Committee and informed consent of patients. 20 WOG and 20 EO reciprocating instruments were randomly assigned to shape the root canal system of a single molar after glide path preparation. 5% NaOCl was used during shaping. Fracture of instruments was registered. Photographs of the instruments were obtained at two magnifications and the distance from the tip of the instrument to the defect was measured. Images were randomly ordered for evaluation. Two blinded calibrated examiners evaluated if plastic deformation was present in the instruments. Inter-observer agreement was calculated with Kappa coefficient. Two new and 2 used instruments randomly selected from those previously used, were analyzed with a 3D Optodigital Microscope to detect changes in surface roughness in a set of points. The Chi-square test was used to compare plastic deformation between the two reciprocating systems and the odds ratio (OR) was calculated.

Results Inter-rater level of agreement was very high (K = 0.89). No fracture of instrument was observed; however, a significantly greater ($P < 0.001$) percentage of EO instruments suffered plastic deformation (60%) in comparison with WOG (10%) with an OR = 11.09 (CI 95% 2.6–56.3). Additionally, the distance from the tip to the start of plastic deformation varied between both reciprocating systems (mean (SD) = 2.03 (0.9) mm and 4.04 (1.6) mm from the tip respectively for EO and WOG). A slight variation in surface roughness was detected between used and new EO instruments. This was not evident for WOG.

Conclusions Single use of EO instruments in clinical scenarios produced significantly higher chances of plastic deformation and a slight variation in surface roughness compared to WO.

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CANAL FILLING – GENERAL

R063

WITHDRAWN.

CANAL FILLING – LEAKAGE

R064

WITHDRAWN.

R065

WITHDRAWN.

R066

WITHDRAWN.

CANAL FILLING – SEALERS

R067

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Transforaminal and systemic diffusion of an active agent from a hydrocortisone-based root canal sealer in an *in vivo* model

Aim To analyze and quantify, in a relevant mouse model, the *in vivo* release of hydrocortisone acetate (HCA) contained in a zinc oxide eugenol-based endodontic sealer (Endomethasone N, Septodont®, Saint Maur des Fossés) in the periapical tissue and then in different organs.
Methodology Human root canals, shaped with One Shape® single-file and filled with Endomethasone N, previously radiolabelled with tritium (3H-HCA), were implanted in the back of 24 mice. Two human dental roots were implanted in the back of each mouse. Mice were sacrificed at 4, 8, 24 and 48 h to evaluate and quantify the amount of radioactive HCA in the periapical tissues, blood, spleen, kidneys, liver and urine.
Results HCA was released from the apex of the tooth into the periapical tissues with a peak measured at 2 h post-implantation (2.25% of the initial radioactivity). This quantity decreased significantly over time ($P < 0.05$). Radioactivity was still measured up to 48 h in the periapical tissues. The same pattern of kinetics was observed for all organs. The total quantity of radioactivity significantly decreased over time from 8.5% ± 1% measured 2 h post-implantation to 1.32% at 24 and 48 h. Finally, about 10% of the initial HCA from Endomethasone N used to fill the root canal was retrieved after 48 h in the urine.
Conclusions This study demonstrated that HCA from Endomethasone N can diffuse through the apex of the root canal and follows a conventional pharmacokinetic. HCA is absorbed and distributed in the different organs and is finally excreted in the urine.
Acknowledgements This study was funded by Septodont SAS (Saint-Maur-des-Fossés, Val-de-Marne, France).

CANAL FILLING – MTA/CALCIUM SILICATE CEMENTS

R068

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Physicochemical properties and antimicrobial evaluation of high-plasticity tricalcium silicate-based biomaterials

Aim To evaluate the colour stability of novel reparative cements in contact with dentine, their physicochemical properties and antimicrobial activity.
Methodology Five materials were tested: MTA HP (Angelus), MTA Flow (Ultradent), MTA Flow containing 5% zinc oxide (ZnO) to prevent colour alteration, Biodentine (Septodont), and an Experimental cement composed of tricalcium silicate, bismuth oxide, 5% ZnO and liquid of distilled water + water soluble polymer. Colour change (ΔE) and luminosity (L) of materials were assessed in contact with bovine teeth ($n = 5$), before, 24 h, 28 days and 90 days after filling. Physicochemical properties were tested regarding volume change, radiopacity, setting time, standard and volumetric flow, calcium release and pH. Antimicrobial activity was assessed over agar plates inoculated with *Enterococcus faecalis* (ATCC29212) aerobically and *Porphyromonas gingivalis* (ATCC49417) anaerobically after 24, 48 h and 7 days of contact with cements. Statistical analysis was performed using Kruskal–Wallis and ANOVA ($P < 0.05$).
Results Higher L values were found for MTA HP, Biodentine and Experimental in comparison to MTA Flow. ZnO inhibited dental staining of MTA Flow. Bismuth and silicon migrated to dentine. Cements had proper radiopacity and alkaline pH. Biodentine and Experimental had the greatest calcium release and volume change. MTA HP had the shortest setting time. MTA HP and Biodentine had the highest volumetric cavity filling values. No bacterial inhibition was observed for any cement.
Conclusions MTA Flow exhibited potential for tooth discoloration, which was inhibited by the ZnO. Tested formulations had proper physicochemical properties. No antimicrobial activity was observed. ZnO addition did not significantly alter the cement properties.
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R069

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Influence of smear layer presence on the push-out bond strength of calcium silicate-based root canal sealers

Aim To investigate the influence of smear layer on the push-out bond strength of BioRoot RCS (Septodont, France), MTA Fillapex (Angelus, Brasil) and AH plus (Dentsply, Germany) root canal sealers.
Methodology Twenty dentine discs were obtained from the middle thirds of twenty extracted third maxillary molars with fused

roots. Three 1.2 mm diameter holes were drilled in each dentine disc. Group 1 (n = 10) was rinsed with 10% citric acid followed by 2.5% NaOCl. Group 2 (n = 10) was rinsed with 2.5% NaOCl. All slices were immersed for 30 s in the selected solutions and then rinsed with distilled water and dried with absorbent paper. Then, the three holes of the same dentine slice were filled with three different sealers. Following setting, the push-out test was performed using a universal testing machine at a cross-head speed of 1 mm/min. Bond strength values (MPa) were calculated as force (N) divided by area (mm^2). Data were compared using two-way and one-way ANOVA with Tukey's post hoc test (α=0.05).

Results Regarding the smear layer presence, there were no significant differences in bond strengths values of sealers ($P > 0.05$). In group 1, AH Plus had significantly greater values of bond strength than calcium silicate-based root canal sealers ($P < 0.05$). There were no significant differences in bond strength values between BioRoot RCS and MTA Fillapex ($P > 0.05$). Group 2 had similar results; again, AH Plus exhibited higher values of bond strength than calcium silicate-based root canal sealers ($P < 0.05$).

Conclusions Smear layer did not affect the adhesion of the sealers. AH Plus had a greater dislocation resistance than calcium silicate-based sealers.

R070

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Immediate and long-term porosity of calcium silicate-based sealers

Aim To quantify and compare the internal and external porosity of calcium silicate-based sealers and to ascertain the long-term effect of storage in simulated body fluid on sealer microstructure.

Methodology The root canals of sixteen single-rooted-teeth were cleaned, shaped and randomly allocated into four groups (n = 4). Canals were filled with gutta-percha (GP) and different root canal sealers: (1) BioRoot RCS (Septodont) (BR), (2) EndoSequence BC (BC) (Brasseler), (3) MTAFillapex (Angelus) (MTA) and (4) AH Plus (Dentsply) (AH). Filled roots were stored at 37°C in Hank's balanced salt solution used to simulate body fluid. Following sealer setting, roots were scanned after 7 days and after 6 months with a micro-computed tomography system at an isotropic resolution of 9.9 μm. Total, open and closed porosity were calculated and data were analyzed statistically using a general linear model (GLM), one-way and two-way ANOVA and paired t-test (α=0.05).

Results A significantly greater percentage of open than closed porosity was found in all groups ($P < 0.05$). Initially, significantly greater open and total porosity were found for MTA Fillapex (around 6%) than for AH which had an initial porosity around 3% ($P < 0.05$). After 6 months of storage, the percentage of open and total porosity increased in BR and MTA, whereas this parameter decreased in AH and BC, albeit no significant difference was detected within each sealer, initially and after storage ($P > 0.05$). Both initially and after storage, the coronal region of all sealers had significantly greater total porosity ($P < 0.05$) than middle and apical regions which were comparable ($P > 0.05$).

Conclusions None of the root fillings were void free. All groups of sealers had a significantly greater percentage of open than closed porosities. The sealers had no uniform performance in terms of porosity changes over time.

R071

WITHDRAWN.

R072

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Quality of single-cone root canal fillings with a contemporary tricalcium silicate sealer

Aim To evaluate the quality of single-cone root fillings with a contemporary tricalcium silicate cement in round canals.

Methodology Eighty intact maxillary incisors with fully developed roots were selected. After instrumentation, they were divided into 4 groups (n = 20). The first group served as the gold standard and was filled using a lateral condensation technique with Topseal (Dentsply Sirona, Switzerland) (G1). All other groups were filled using single cone technique with a tapered gutta-percha cone and BioRoot RCS (Septodont, France). BioRoot RCS was mixed and applied with a gutta-percha point as instructed by the manufacturer (G2), or applied with a lentulo at 300 rpm (G3) or with a 30G syringe (G4). After setting, the roots were sectioned at 2, 4 and 6 mm from working length and digital photographs of the sections were made. By means of image analysis software, the percentage of sealer, voids and gutta-percha was determined. Statistical analysis was performed using Kruskal-Wallis and Mann-Whitney U tests, and level of significance was set at 0.05.

Results At 2, 4 and 6 mm the median percentage of voids for G1 was respectively 0%, 0% and 0%, for G2 1.03%, 1.14% and 1.38%, for G3 0.5%, 1.39% and 0% and for G4 1.15%, 0.51% and 0.27%. Only at 2 mm a significant difference was found between G1 and G2 and between G1 and G4 (less voids in G1). No significant differences were found between the different levels within the groups.

The percentage of gutta-percha and sealer was respectively higher and lower in the lateral condensation group.

Conclusions Concerning the percentage of voids, the quality of single cone root fillings with a tricalcium silicate sealer in round canals appears to be comparable to the gold standard. Application of this type of sealer seems to be most reliable using a lentulo.

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R073

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Filling ability of an orthograde mineral trioxide aggregate placement technique to simplify the subsequent surgical procedures: a computed microtomography study

Aim To compare the filling quality obtained with standard retrograde procedures with that of a technique with the potential to simplify the surgical manoeuvres, namely the orthograde placement of 6 mm of mineral trioxide aggregate (MTA) followed by the root-end resection after cement setting.

Methodology Sample size was calculated referring to previously published data ($\alpha = 0.05$; $\beta = 0.20$; $\delta = 3.0$; $\sigma = 1.5$). Accordingly, 12 freshly extracted single-rooted teeth were selected and transversally cut to obtain 12 mm long roots. Roots with aberrant anatomy were discarded. After manual scouting and mechanical glide path establishment, canals were shaped with HyFlex instruments up to size 40, 0.04 taper. The roots were randomly assigned to an experimental group (n = 6), where MTA was placed with a carrier and compacted with manual pluggers up to 6 mm from the working length, or to a control group that entailed filling with the single cone technique (n = 6). After 24 h, the roots in the experimental group received backfilling with thermoplasticised gutta-percha and apical resection. In the control group, the roots were resected apically and underwent standard retrograde ultrasonic preparation and MTA filling. The formation of internal and external voids was quantified by means of a computed microtomographic analysis. The normality of the distribution and the equality of variance of the datasets were tested; afterwards, the groups were compared statistically with an independent sample *t*-test ($P = 0.05$).
Results Void formation was minimal in both experimental and control groups, ranging from 0.00% to 4.42% of the canal volume. In the control group, the voids ($1.88 \pm 1.49\%$) were mainly external and related to sealer porosities. In the experimental group, the voids ($1.08 \pm 0.50\%$) prevalently accumulated inside the MTA mass and at the interface between MTA and gutta-percha. The differences between the groups were not significant ($P = 0.244$).
Conclusions The orthograde placement of MTA followed by apical resection may constitute a valid alternative to the standard surgical practice to simplify the surgical phases in selected cases.

R074

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Influence of ultrasonic activation of calcium silicate cements on marginal adaptation in an open apex model

Aim To evaluate the marginal adaptation of calcium silicate cements as an apical barrier in an open apex model with or without ultrasonic activation.
Methodology Sixty human singled-rooted teeth were sectioned to obtain 12 mm lengths. An artificial open apex was prepared using a No. 6-No. 1 Gate Glidden drills respectively in a crown down manner until No. 1 GGD passed through the foramen. Subsequently, a 2 mm apical resection was performed and then Protaper NEXT X2 was used to prepare a root end to form a divergent open apex. They were randomly allocated into 3 groups, 20 teeth each, according to the type of calcium silicate cement: ProRoot MTA, Biodentine and Retro MTA. Apical barrier of each group was performed on the teeth assigned with 2 techniques, manually (n = 10) or ultrasonically (n = 10). The apical part of the root was observed under scanning electron microscope and the gap between material and dentine interface was measured at 6 predetermined points. Data were analyzed statistically by two-way analysis of variance with Tukey test.
Results The smallest gap was found in the Retro MTA apical barrier with ultrasonic activation while the largest gap occurred in the ProRoot MTA apical barrier without ultrasonic activation. No significant differences in gaps between ProRoot MTA, Biodentine and Retro MTA groups were revealed ($p>0.05$). Ultrasonic activation increased the marginal adaptability as compared to manual apical compaction of each material ($p<0$ 0.05).
Conclusions Use of ultrasonic application was more beneficial than manual compaction of calcium silicate cements when used as an apical barrier.

R075

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Characterisation of MTA Flow: SEM and micro-CT analysis

Aim To characterise the thin mixture of MTA Flow by scanning electron microscopy (SEM) and evaluate the porosity of the material as an apical plug in artificially perforated roots of mandibular molars using micro-computed tomography (μCT).
Methodology A thin mixture of MTA Flow was prepared and characterised immediately after mixing and after immersion in Hank's balanced salt solution (HBSS) for 28 days. The SEM was used in back-scatter electron mode to observe the material microstructure and pore distribution at x500, x2000 magnifications. Twenty curved mesial root canals were shaped with ProTaper NEXT X1-X5 files 2 mm beyond the apex to simulate apical perforation. The MTA Flow was injected into the root canal as a 5 mm apical plug using 29-G NaviTip needle and Skini syringe. The specimens were scanned before and after root filling using a high-resolution μCT scanner at an isotropic resolution of 9.9 μm. The volumetric analysis of void volume and the percentage volume of voids in the fillings were calculated.
Results The SEM evaluation revealed the high porosity of the material, which decreased after 28 days but was still evident; the pores were small but widely distributed. The freshly mixed MTA Flow exhibited a composite microstructure composed of cement and radiopacifier. The μCT evaluation confirmed a high porosity of the material: internal and external voids of various sizes, as well as gaps between the filling material and dentinal walls, were identified. Overall, the volume of voids was 0.72 ± 0.32 mm^3 while the percentage volume of voids reached $19.06 \pm 9.57\%$.
Conclusions Within the limitations of this laboratory study, both evaluation methods detected the high porosity of a thin mixture of MTA Flow in all specimens. Voids reduced over time in the presence of simulated body fluid but remained evident. Further studies are needed to investigate if the porosity of the thin consistency of MTA Flow has a significant impact on clinical outcomes when used *in vivo*.
Acknowledgements The authors are grateful to Dr. Jianguo Liu for help with the SEM analysis.

R076

WITHDRAWN.

R077

WITHDRAWN.

RESTORATION OF ROOT FILLED TEETH

R078

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Fracture resistance of root filled teeth restored with different post and core materials using CAD/CAM technology

Aim To measure fracture resistance forces of root-filled teeth restored with post and cores using three different materials and CAD/CAM technology.
Methodology The study samples (forty intact extracted maxillary central incisors) were treated endodontically; the access cavity of teeth in the control group ($n = 10$) were restored with composite resin after root canal treatment. The teeth in the experimental groups were sectioned to a root length of 16 mm and then divided into three groups ($n = 10$ each) according to the mean of dimensions at the cervical part of the root. The post and core fabricated with CAD/CAM technology using metal, zirconia, and polymer-infiltrated ceramic network (PICN) material. The posts and cores were luted using resin cement, metal crowned, and subjected to a compression test at a crosshead speed of 1 mm/min. The samples were examined under a stereomicroscope to evaluate the apical extension of root fracture. Statistical analysis of the data was performed using one-way analysis of variance (ANOVA) and multiple comparison post hoc Tukey tests ($P < 0.05$).
Results The mean (± standard deviation) of fracture resistance forces was the highest in the control group (375.1 ± 103.9 N), followed by metal, zirconia, and PICN groups (324.05 ± 71.47 N, 328.06 ± 54.37 N, and 271.06 ± 69.57 N, respectively). There was no significant difference in force of fracture resistance between the experimental groups.
Conclusions All customized posts and cores used in the experimental groups performed similarly in term of fracture resistance. The specimens in PICN group had less apical extension of root fracture compared to metal and zirconia specimens.

R079

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Self-adhesive cement debonding at the interface between post-and-core restorations and dentine: a 3D phase-contrast μCT study

Aim To non-destructively assess the interface between dentine and cement at the cervical root areas of post and core restorations comprising self-adhesive resin cement and fiberglass posts.
Methodology Seven root-filled central incisors restored with Fiberglass posts cemented with RelyX Unicem 2 were imaged by phase contrast-enhanced microCT in a Synchrotron facility (ID19, ESRF) at a 0.64 μm pixel resolution. Due to enhanced contrast, reconstructions revealed exquisite detail. These were used to measure canal, cement and post perimeters and cross-sectional areas, interfacial gaps and to assess remnants of canal sealer (AH Plus).
Results Interfacial gaps were found in 46% (± 11%) of the interfaces between dentine and cement, along the three dimensions of the cervical area of the restoration. Debonding was positively correlated to the canal area filled by cement (Pearson coefficient, $R = 0.602$, $P < 0.01$) and to the canal perimeter ($R = 0.63$, $P < 0.01$). There was a uniform interface between posts and cement. The presence of AH Plus in 8% (± 6%) of the canal walls was not correlated to cement bonding (Pearson coefficient, $R = 0.3211$, $P < 0.05$).
Conclusions PCE-CT proved to be an excellent tool to study interfaces within the root canal. RelyX Unicem 2 presented debonding along 46% of its interface with dentine. Although remnants of sealer were present, they did not correlate to the bonding between tooth and cement.
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R080

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Influence of restorative material and margin relocation on the fracture resistance of teeth restored with CAD/CAM endocrowns

Aim To evaluate the resistance to load of composite and lithium silicate CAD/CAM endocrowns cemented on maxillary molars with or without margin relocation in a standardised proximal box.
Methodology Sample size was calculated making reference to the results of a preliminary study (α=0.05; β=0.20; δ=500.0; σ=280.0). Thirty-two intact extracted maxillary molars of comparable size were root-filled and randomly allocated to four experimental groups ($n = 8$): composite endocrown without margin relocation; composite endocrown with margin relocation; lithium silicate without margin relocation; lithium silicate with margin relocation. The tested CAD/CAM materials were Lava Ultimate and Celtra DUO for composite and lithium silicate groups, respectively. The margin relocation procedure involved the preparation of a standardized mesial box and restoration with a flowable composite. The endocrowns were obtained with the Cerec 3 CAD/CAM system making use of a custom-designed phantom model and luted with self-adhesive cement. The restored teeth underwent thermomechanical aging (1 250 000 cycles, 1 Hz, 5–55°C) and were axially loaded to fracture with a universal testing machine. Fracture types were qualitatively assessed. Maximum load to fracture were compared amongst groups with a two-way analysis of variance and Duncan post hoc test ($P < 0.05$).
Results No specimens exhibited appreciable defects after the thermomechanical aging. The mean maximum load values exceeded the threshold of the masticatory forces in all the tested groups. The composite endocrown without margin relocation obtained the greatest resistance values (1910.6 ± 373.1 N), while the lithium silicate with margin relocation obtained the lowest (1314.9 ± 326.1 N). For both tested materials, margin relocation slightly but not significantly reduced the resistance values. Most specimens had non-restorable fractures.
Conclusions Under the conditions of the present study, margin relocation did not influence the resistance to fracture of teeth restored with CAD/CAM endocrowns. A trend of improved

resistance to load of endocrown restorations was observed for the tested composite material in comparison to lithium silicate.

R081

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What is the effectiveness of direct and indirect coronal restorations, without posts, for the restoration of root filled posterior teeth? A systematic review

Aim To investigate the relative effectiveness of direct and indirect coronal restorations, without posts, for the restoration of root-filled posterior teeth.
Methodology MEDLINE, PubMed, EMBASE, Scopus, Web of Science and Central from inception to December 2017 were searched. Randomised and non-randomised studies in which adults with root-filled molar and premolars were treated with either direct restorations or indirect restorations without posts were included. Studies with subgroups of patients who had restorations with posts in any arm were also included. Studies in which bridge retainers or partial dentures were used, teeth were periodontally compromised and in which all teeth were treated with posts were excluded. Key outcomes were clinical and radiographical failure of the restoration. Down's and Black quality assessment checklist was used to assess the quality of the included studies.
Results A total of 10 166 non-duplicate articles were identified and the study inclusion criteria applied to 124 articles. 12 studies (6 comparative and 6 non-comparative) were included in the narrative review. The majority of the studies were of poor to fair quality and the heterogenous nature of the studies precluded statistical data synthesis. One retrospective study compared direct versus indirect restorations for root-filled posterior teeth without posts; however, the robustness of the study results was limited due to the low number of patients in the indirect restoration group (partial gold crown, $n = 24$) compared with the direct restoration group (glass ionomer, $n = 100$; amalgam, $n = 98$ and composite, $n = 37$). No other studies were identified that could directly answer the review question. All of the other studies were either non-comparative and examined the effectiveness of one single type of restoration or were comparative and compared direct restorations with other direct restorations; when the studies compared one type of restoration with another, there was always one group that contained restorations with posts.
Conclusions There is limited evidence to suggest that direct restorations are more effective than indirect restorations (or *vice versa*) in root-filled posterior teeth without posts. More research into this important area is needed.

R082

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Phase contrast-enhanced *ex vivo* radiography reveals flow and shrinkage dynamics of post-endodontic core build-up composite restorations

Aim To characterize the dynamics and to measure the effects of polymerization in post-endodontic composite core build-up restorations placed within narrow and wider cavities, using phase contrast-enhanced *ex vivo* radiography.
Methodology Three mm deep cavities with two diameters (d1 = 1.25 mm; d2 = 1.75) were prepared in the canal orifices of 20 human root-filled incisors for standardized resin core-build up fillings using two ($n = 10$ each) dual-curing materials (Rebilda DC, VOCO; Luxacore dual, DMG). The materials were injected into the cavities after application of a dual curing multi-mode adhesive (Futurabond U, VOCO). Within 60–90 s after placement, phase contrast-enhanced radiography (ID19, ESRF) was used to monitor particles and gaps in the curing restorations in situ. The *T*-test was used to analyse the statistical differences between the groups.
Results The following 'setting phenomena' were observed irrespective of the composite material used: 1) an initial, inward-downward flux of composite particles, more prominent near the geometric centre of the cavity, ceasing within 30 s; 2) gap formation was observed in 70% and 30% and inward tooth deformation observed in 60% and 90% of the d1 and d2 cavities, respectively; 3) small, omnipresent "pullout" of gutta-percha (d1: 4.6 ± 2.6 μm; d2: 2.1 ± 1 μm) with a significant difference between the tested diameters ($P < 0.05$).
Conclusions Within minutes after composite placement, real-time phase contrast-enhanced radiography revealed interactions between the composite core build-up material and tooth structures as a result of polymerization shrinkage. These effects include composite particle flow, gap formation and deformation as well as microscopic root filling pull-out: The phenomena are partly affected by the size of the cavity, leaning towards stronger effects in the smaller cavities. This highlights possible problems of bonding to radicular dentine in the canal orifice as a consequence of polymerization shrinkage.

R083

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Quantitative evaluation of the volume gaps and voids in endodontically treated teeth with conservative access cavities restored with different composite materials

Aim To evaluate and compare the quantitative volume of the gaps and voids formed in root-filled teeth with conservative access cavities restored with a bulkfill flowable material (SDR), with a bulkfill material (SonicFill) and a traditional resin composite (EsthetX).

Methodology Conservative access cavities were performed in 30 maxillary and 30 mandibular molars, selected based on similar dimensions. After cleaning, shaping and filling of the root canals and adhesive procedures, specimens were assigned to 3 subgroups for each tooth type ($n = 10$): Group A: access cavities were restored with a traditional resin composite (EsthetX; Dentsply-Italy, Rome, Italy); Group B: access cavities were restored with a bulkfill flowable composite (SDR; Dentsply-Italy). Group C: access cavities were restored with a bulkfill composite (SonicFill; Kerr-California, USA). Restorations of the access cavities were performed according to the manufacturer's instructions. After composite restorations, the specimens were scanned with CBCT (iCAT). The sliced image data were exported as DICOM-file and imported into the MeVisLab framework system for segmentation and volume measurement. After segmentation based on thresholds of gaps, composite and dentine, volumes of the gaps created at the tooth-resin composite interface and inside the resin composite of the filling itself were measured. The data were subjected to statistical analyses of variance.
Results There were no significant differences between the three groups. The volume of the gaps was similar between teeth restored with traditional resin composite and teeth restored with the two different bulk-fill composites ($P > 0.05$).
Conclusions In root-filled teeth with conservative access cavities, bulk-fill resin composite restorations had similar gap formation to the ones with gradual light-curing protocols.

ROOT CANAL RETREATMENT

R084

WITHDRAWN.

R085

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A comparison of the efficacy of digital periapical radiographs and the use of a dental operating microscope in the detection of procedural errors during endodontic retreatment procedures

Aim To evaluate and compare the diagnostic efficacy of digital periapical radiographs with the use of a dental operating microscope in the detection of procedural errors during endodontic retreatment procedures.
Methodology A total of 165 teeth referred for retreatment were included. Two digital periapical radiographs were taken before retreatment procedures: one radiograph was taken with the long cone parallel technique, the second one was taken using 20° mesial horizontal beam angulation. During retreatment procedures, all teeth were examined using a microscope. The following procedural errors were recorded: incorrect access cavity, perforations, ledges, transportations, fractured instruments, missed root canals, inadequate length and insufficient condensation of root filling material. McNemar test was used for data analysis. Level of significance was set at $P < 0.05$.
Results There were no significant differences in the efficacy to detect procedural errors such as incorrect access cavity, furcation and root perforations, transportations, fractured instruments, inadequate length and insufficient condensation of root filling material between the three diagnostic techniques. However, significant differences were found between the use of radiographs and a dental operating microscope in identifying ledges and missed root canals. 21.2% more ledges were detected using a microscope in comparison to parallel radiographic technique and 20.6% in comparison to 20° angle radiographic technique ($P < 0.05$). Significantly more missed root canals were identified using a microscope in comparison to parallel (33.9%) and 20° angle (23%) radiographs respectively ($P < 0.05$).
Conclusions The efficacy of different radiographic techniques and a dental microscope to detect procedural errors was comparable. However, the use of a dental microscope significantly increased the capability to identify missed root canals and previously formed ledges.

R086

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Effect of different retreatment techniques on push-out bond strength of root canals

Aim To evaluate the effect of different retreatment techniques on push-out bond strength of root canals.
Methodology The root canals of 60 mandibular premolars were prepared by using the ProTaper system (Dentsply, Switzerland) to size F3. The root canals were randomly divided into 6 groups ($n = 10$). 10 root canals were separated as a control group (Group 1), and the remaining 50 root canals were filled with gutta-percha and AH Plus (Dentsply, Germany). After 1 week, root canal filling materials were removed with ProTaper Universal Retreatment instruments (PTUR, Group 2), Chloroform+PTUR (Group 3), System-B+PTUR (Group 4), Nd:YAG laser (Fotona, Slovenia) (Group 5) and Er:Cr:YSGG laser (Waterlase, USA) (Group 6). After retreatment procedures, 50 root canals were prepared with ProTaper system to size F3. Root canals in these 6 groups were divided into 2 subgroups with 5 samples in each group. The canals in the A subgroup were left as F3 file size, the remaining root canals in the B subgroups were prepared to F5 file size. Then the canals were filled with gutta-percha and AH Plus. After one week, four 1 mm thick dentine slices were obtained from each root region (coronal and medial). A push-out test was performed. The data were statistically analyzed using three-way analysis of variance and post hoc Tukey test.
Results The greatest push-out bond strength occurred in the control group with no retreatment. The greatest bond strength among the groups with retreatment was seen in the PTUR group. The bond strength of reprepared canals with ProTaper F5 was higher than in those reprepared with ProTaper F3.
Conclusions The use of chloroform, System-B and lasers in the retreatment procedures decreased the gutta-percha push-out bond strength. Re-instrumentation of canals with up to two size larger files increased the bond strength.

R087

WITHDRAWN.

ENDODONTIC SURGERY

R088

WITHDRAWN.

SATURDAY

CLINICAL OUTCOME STUDIES – ROOT CANAL TREATMENT AND RETREATMENT

R089

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Postoperative pain after single visit root canal treatment using multiple rotary files and single reciprocating file instrumentation techniques in asymptomatic mandibular molars with necrotic pulps: a randomized control clinical trial

Aim This prospective clinical study compared postoperative pain following single visit root canal treatment in patients with asymptomatic mandibular molar teeth with necrotic pulps using two different instrumentation techniques: multi-file rotary (ProTaper Universal), and reciprocating single-file (WaveOne) techniques.
Methodology Forty patients, who fulfilled specific inclusion criteria were randomly and equally assigned to 2 groups according to the root canal instrumentation technique used. All treatments were performed in one appointment. Patients were asked to complete a numerical rating scale (NRS) for recording pain levels at 6, 12, 24, 72 h and at 1 week postoperative intervals. In addition, the Face Pain Scale was associated with the form to simplify the recording of pain for the patients. The patients were instructed to use mild analgesics if required and asked to record the number of analgesic tablets on their NRS forms. The data were analysed using Chi-square test to compare between the tested groups with a significance set at $P < 0.05$.
Results The mean NRS pain scores recorded at all periods were not significantly different for both instrumentation techniques ($P > 0.05$). Also, the mean analgesic consumption with both systems was not significantly different ($P > 0.05$).
Conclusions In patients with asymptomatic mandibular molars with necrotic pulps, root canal preparation with either ProTaper or the Wave-One instrumentation techniques was not associated with a significant difference in postoperative pain or analgesic consumption.

R090

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Clinical outcomes of root canal retreatment of teeth with pre-existing fractured instruments

Aim To evaluate clinical outcomes of root canal retreatment of teeth with pre-existing fractured instruments using multiple outcome measures.
Methodology This prospective study consisted of 1) 334 teeth from 328 patients included for fractured instrument retrieval outcome; and 2) 278 teeth from 273 patients, followed up for 12 – 162 months for the periapical healing outcome. Pre -, intra – and post-operative data were collected prospectively. Bivariate chi-square tests and logistic regression models were used to analyse the effects of potential prognostic factors.
Results Pre-existing fractured instruments were removed in 29% of cases, bypassed in 28% and retained in the rest. Instrument removal was significantly affected by the instrument type and its location (corono-apical and relation to curvature), length & distance from canal orifice ($P < 0.0001$). The instrument was more likely to be removed successfully when its presence had been declared in the referral letter ($P = 0.03$) along with details ($P = 0.004$), it was fractured during coronal flaring ($P = 0.05$), and there was absence of a pre-existing perforation ($P = 0.01$). The healed and healing rates were 50% and 77%, respectively. The healed rate was significantly better when: pre-operative periapical radiolucency was absent ($P = 0.009$) or smaller ($P = 0.01$); the fractured instrument was successfully removed or bypassed ($P = 0.005$); and patency at the canal terminus was achieved ($P = 0.001$).
Conclusions The chance for removal or bypassing of the instruments was moderate (57%) and significantly influenced by its length, distance from canal orifice and location related to curvature. The healing rate was good (77%). Presence and size of preoperative radiolucency and ability to achieve patency at the canal terminus were significant prognostic factors for complete healing.

R091

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Postoperative pain and success rate after root canal retreatment of asymptomatic cases treated in single or two visits. A randomised clinical trial

Aim The purpose of this study was to evaluate the postoperative pain and success rate after retreatment procedures in either one or two visits in asymptomatic failed endodontic cases.
Methodology A total of one hundred fifty-eight failed endodontic cases were selected. The selected cases were asymptomatic, clinically restorable and feasible for conventional root canal retreatment procedures. All cases were evaluated using CBCT. After removing the previous root filling materials and mechanical preparation of root canals, patients were randomly assigned to either the one-visit or two-visit group. Teeth were root-filled using AH plus sealer and vertically compacted gutta-percha in the same visit for the single visit group and after one week of calcium hydroxide medication for the two-visit group. The presence of postoperative pain was assessed daily for 7 days after treatment. Cases were monitored clinically and radiographically for one year. CBCT was performed after 12 months for evaluation of periapical healing. Data were analysed statistically using the chi-squared test.
Results No significant difference was found between the two groups on the first three days ($P > 0.05$). Postoperative pain was significantly higher in the two- visit group ($P \leq 0.05$) starting from the 4th day of assessment up to the 6th day ending with comparable results on the 7th day. Both groups exhibited equally favourable periapical healing after one year. The success rates were 94% and 92% for single and two visit groups respectively with no significant differences between them ($P > 0.05$).
Conclusions Under the conditions of this study, single visit root canal retreatment of asymptomatic failed cases exhibited less postoperative pain with similar success rates to the cases treated in two visits.

R092

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R093

WITHDRAWN.

R094

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Radiographic healing after single-visit root canal treatment irrigated with QMix 2 in 1: A randomized controlled trial

Aim To compare the radiographic outcome of a root canal treatment with and without additional use of QMix 2 in 1 irrigation solution after 12 months recall.
Methodology Sixty single-rooted teeth with periapical radiolucency of 60 patients were randomized into two groups using a randomized block design with block sizes of 10 patients each. Root canals were prepared with WaveOne Gold and irrigation was performed with 5 mL 2.5% NaOCl using side-vented needles during instrumentation. Final irrigation protocol was performed using 5 mL 2.5% NaOCl (n = 30) or 5 ml QMix 2 in 1 (n = 30). Then the root canals were irrigated with 5 mL of distilled water and filled with gutta-percha and AH Plus sealer, using the cold lateral compaction technique. The patients were recalled after 12 months and evaluated radiographically according to PAI scores. Pre and post-treatment PAI scores were compared and teeth were considered 'healthy' (PAI $\leq$ 2) or 'diseased' (PAI $\geq$ 3). Whitney U test was used to compare the differences between the post-operative and follow-up images of treatment groups. Wilcoxon signed rank test was conducted to examine the changes in PAI score from base line to the follow-up evaluation in each group.
Results Forty-five patients were reexamined after 12 months. Overall, a significant decrease was seen in PAI score at the follow-up evaluation in 43 of 45 teeth ($P < 0.001$). In the QMix 2 in1 and NaOCl group, absence or reduction of the radiolucency were observed respectively in 23 of 25 teeth (92%) and 20 of 20 teeth (100%). Two teeth were unhealed in the QMix 2 in1 group. There was no significant difference between the groups according to the decrease in PAI score from the base line to the follow-up evaluation ($P = 0.508$).
Conclusions Root canal treatments with and without QMix 2 in1 irrigation contributed equally to periapical healing.
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CLINICAL OUTCOME STUDIES – VITAL PULP THERAPIES

R095

WITHDRAWN.

R096

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A biologically oriented treatment protocol for posterior teeth exhibiting symptomatic irreversible pulpits and associated apical periodontitis

Aim To assess the outcome of a novel treatment protocol (EndoVital) in permanent mature mandibular molar teeth exhibiting symptomatic irreversible pulpitis and associated apical periodontitis.
Methodology Institutional ethical clearance was obtained. Mandibular molar teeth (n = 40) with a definitive pulp and periradicular diagnosis of symptomatic irreversible pulpitis and associated apical periodontitis with a radiographic periapical index score (PAI) of 3 in either one of the roots (distal or mesial) were included. A block randomization was used for allocation of teeth. Group I (n = 20, control) single visit non-surgical endodontic therapy (NSET) was performed using a standardized operating protocol. In group II (n = 20, case) subsequent to full pulpotomy, NSET was performed in the root exhibiting PAI score 3. The adjacent root, where a vital pulp was observed (as determined by arrest of pulpal bleed within ten minutes of application of pressure pack), a MTA radicular barrier was placed. The pulp chamber floor was covered with light-cured resin-modified glass ionomer cement. The teeth were restored with an adhesive restorative material. Postoperative pain was assessed on VAS scale. The teeth were followed up clinically and radiographically at twelve months. Presence/absence of symptoms and change in PAI scores were noted.
Results Group II (EndoVital), sixteen teeth (80%) had a positive response to electric pulp testing. All teeth exhibited a VAS score between 0 and 3 on vertical percussion. Roots in fifteen teeth (75%) treated with NSET exhibited radiographic evidence of healing as evident by decrease in PAI score. The adjacent roots treated by MTA radicular barrier did not exhibit emergence of periapical pathosis. In group I, all teeth were clinically asymptomatic and seventeen teeth had evidence of radiographic healing.
Conclusions The combination of NSET and vital pulp therapy (EndoVital) is a viable biologically based minimally invasive treatment option for multi-rooted teeth.

EPIDEMIOLOGY

R097

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Periapical status of non-root filled teeth related to the type and clinical quality of coronal restoration

Aim To investigate possible differences in the prevalence of apical periodontitis (AP) in non-root-filled teeth related to the type and clinical quality of coronal restoration.
Methodology The cross-sectional study involved 599 adult patients presenting consecutively at the University Dental Clinic of the Rijeka Clinical Hospital Centre. The type, material and the quality of coronal restorations for non-root-filled teeth were evaluated by clinical examination. The quality of coronal restoration was assessed according to modified Ryge criteria. Periapical status was analysed from panoramic radiographs using the periapical index scoring system (PAI). Chi-square tests and logistic regression (stepwise) were used to analyse the association between the periapical status and type, material, and quality of coronal restoration.
Results Out of 13402 examined non-root-filled teeth, 36.7% were restored with coronal fillings and 2.9% with crowns. Teeth restored with full crowns had a significantly greater frequency of AP than teeth restored with coronal fillings (11.7% and 4.9% respectively; $P < 0.001$). No significant difference in the frequency of AP between teeth restored with amalgam or resin composite was found. A tooth with secondary caries was 3 times more likely to have AP than the tooth without caries (95% CI: 2.35–3.94; $P < 0.0001$). If the tooth had unacceptable anatomical features of coronal restoration it was 2.4 times more likely to have AP than tooth with acceptable anatomy of coronal restoration (95% CI: 1.83–3.6; $P < 0.0001$). Teeth restored with coronal fillings were 0.4 times more likely to be periapically healthy than teeth restored with crowns (95% CI: 0.27–0.49; $P < 0.0001$).
Conclusions Although AP was diagnosed in a significantly greater proportion of teeth restored with crowns, the clinical finding of secondary caries was the most important predictive variable for the presence of AP, regardless of the type of coronal restoration.

R098

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Frequency of failures in relation to the number of root filled canals in molar teeth in the Swedish adult population

Aim To investigate the frequency of failures, defined as extraction, non-surgical retreatment and root-end surgery, in relation to the number of root-filled canals in teeth registered as root filled in Sweden during a 5-year observational period.
Methodology The Regional Ethical Review Board at Lund University, Lund, Sweden (Dnr 2011/800) approved the study. The Swedish Social Insurance Agency database was searched using treatment codes corresponding to completions of root fillings of teeth with one to four root-filled canals (501, 502, 503, 504). The cohort included first and second molars in adult individuals who in 2009 were registered with a root filling. Codes registered during the subsequent 5 years in conjunction with extraction, non-surgical retreatment or root-end surgery on these specific teeth were used to identify failures. To detect significant differences in the frequency of failure based on the number of root-filled canals, the Chi-square test was applied. Differences were considered significant at $P < 0.05$.
Results In 2009, root fillings on a first or second molar tooth were registered in 100 720 individuals. During the 5-year observation period, 11.3% of the teeth were extracted, and the total failure rate was 14.3%. First maxillary molar teeth registered with 1–3 root-filled canals failed more frequently than teeth with four root-filled canals (15.2% compared to 12.7%, $P = 0.002$). The same applied to second maxillary molar teeth (13.8% vs. 9.1%, $P = 0.007$) and first mandibular molar teeth (14.0% vs. 10.7%, $P < 0.001$). This pattern was not detected in second mandibular molar teeth (15.6% vs. 13.7%, $P = 0.200$).
Conclusions Following root filling, the 5-year follow-up shows the frequency of failures to be significantly higher in first and second maxillary molar and first mandibular molar teeth when three or less root canals were filled compared to four canals.

R099

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Calibration for increased reliability in assessment of endodontic variables in panoramic radiographs

Aim To evaluate the influence of calibration on examiner variation in assessment of endodontic variables in panoramic radiographs.
Methodology Panoramic radiographs of 1593 individuals, representing patients with recent experience of a myocardial infarction ($n = 797$) and matched controls ($n = 796$) were obtained from a database. Variables to be assessed were; number of remaining teeth, number of root-filled teeth, number of teeth with periapical bone lesions and DMFT-score. A sample of 100 panoramic radiographs was randomly selected for this reliability study, being the first part of a case-control study. Two observers, one endodontist and one radiologist, did two separate assessments of the sample. The same examiners later assessed any disagreement cases jointly and the results were considered as the gold standard. Three other observers, one general dentist and two under-graduate students, did three separate assessments of the sample. The first assessment was done without any prior training, the second assessment was preceded by a calibration towards the gold standard and the third assessment was performed with the sample randomly hidden in the complete material of 1593 panoramic radiographs. Agreement was calculated and presented as Weighted Cohen's Kappa (κ).
Results Only the variable periapical lesions showed any significant disagreement between the observers. The endodontist and the radiologist showed an inter-agreement of $\kappa = 0.53$ in their initial assessments. The first assessment by the general dentist and the under-graduate students revealed κ ranging from 0.22 to

0.60 when compared to the gold standard. Following calibration in the second assessment agreement increased for all observers to κ between 0.59 and 0.80. The third assessment revealed still acceptable agreement with the gold standard (κ = 0.54 to 0.75). However, all observers exhibited a tendency in the direction towards the first assessment.
Conclusions Calibration towards a predetermined gold standard leads to an increased reliability in the assessment of apical lesions in panoramic radiographs; however, the long-term effect of such an intervention is uncertain.

R100

WITHDRAWN.

R101

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The influence of biologic medications on apical periodontitis. A retrospective clinical study

Aim To evaluate the oral health status and the prevalence of apical periodontitis (AP) in patients on Biologic Medication (BM).
Methodology The study group consisted of 90 patients on BM (37 men and 53 women, age 47 ± 14 years), referred from the Rheumatology and Gastroenterology Units of the University Hospital. Ninety controls (40 men and 50 women, age 39.7 ± 13) registered for a check-up at the Dental Clinic, matched with the study group for age, sex and physical characteristics, but without any systemic disease and under no pharmacological treatment were selected. Each patient underwent a complete dental clinical and radiographic examination. The Periapical Index Score (PAI) and the Decayed-Missing-Filled Teeth score (DMFT) were calculated. Chi-square and Student T tests were used as appropriate. $P \leq 0.05$ was considered statistically significant.
Results When the two groups were compared, the prevalence of AP was similar (BM group 51.1% -Controls 56.7%). Considering the gender stratification analysis in both groups, females had a significantly larger number of teeth with AP than males ($P < 0.05$). Average PAI score was significantly higher in the BM group compared to the Controls (2.8–1.5 $P < 0.001$), whilst DMFT scores were comparable in the two groups (BMs group 8.2 – Controls 8.8).
Conclusions These findings show that even though DMFT and the prevalence of AP were similar in the two groups, females on BM had more lesions and all BM patients had a higher PAI. The action of BMs on the immunitary system seems to affect the periapical reaction, especially in women. The results of this retrospective cross-sectional study must be interpreted with caution since a larger sample is needed to reach more certain conclusions.
Acknowledgements The authors deny any conflicts of interest related to this study.

R102

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Changes in endodontic status in the adult Danish population from 1997 to 2009. A repeated cross-sectional study

Aim To compare the periapical and endodontic status of two randomly selected samples of an adult Danish population.
Methodology Two random samples from Aarhus County were systematically drawn from 'The Civil Registration System' (CRS) in 1997 and in 2009, using birth dates and the year of birth as extraction keys. In 1997, 618 individuals participated (16 018 teeth) and in 2009, 398 individuals participated (10 668 teeth). In both populations, age was 20–60 years. All participants had a full-mouth intraoral radiographic examination. In the radiographs, the following was assessed: number of teeth, presence and quality of root fillings, quality of coronal restorations, and caries. Periapical status was evaluated using the Periapical Index. Chi-squared tests and logistic regressions were performed to analyze changes in prevalence of root fillings and apical periodontitis between the two populations.
Results The persons in the 2009 sample were slightly older than those in the 1997 sample (mean age 44.7 vs. 42.3 years), and the number of teeth was higher (mean 26.8 vs. 26.0). The prevalence of apical periodontitis did not differ significantly (45.0% in 2009 and 42.0% in 1997), but the proportion of individuals with root fillings was lower in the 2009 sample (45.0% in 2009 and 51.8% in 1997, $P = 0.03$). On a tooth level, the proportion of teeth with apical periodontitis did not differ substantially (3.6% in 2009 and 3.3% in 1997), while the proportion of teeth with root fillings was significantly lower in 2009 (3.6% vs. 4.8% in 1997, $P = 0.004$). In root-filled teeth, the prevalence of apical periodontitis did not differ significantly, with 53.0% in 2009 and 51.8% in 1997.
Conclusions When comparing two identically selected populations, the prevalence of root fillings was lower in 2009 than in 1997, while the prevalence of apical periodontitis remained the same.
Acknowledgements Aarhus University, European Society of Endodontology, Danish Dental Association, Danish Endodontic Society, Nordic Institute of Dental Materials.

R103

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In-depth analysis of painful root filled teeth: preliminary data on pain origin and association with patient-related factors

Aim To compare (i) pain characteristics in painful root-filled teeth displaying signs of apical periodontitis (odontogenic pain) and teeth without such signs (non-odontogenic pain), (ii) patient and clinical

characteristics between the two pain groups and (iii) between patients with and without pain from their root-filled tooth.
Methodology In this practice-based observational study, patients with ≥ 1 root-filled tooth scheduled for a routine check-up who agreed to participate were examined clinically and radiographically, and answered an interviewer-assisted questionnaire covering general health, bodily pain, self-reported TMD pain (3Q/TMD screening questions) and presence and characteristics of tooth pain. All patients who reported pain from their root-filled tooth were included in the in-depth analysis. Pain groups were patients with either odontogenic pain (OP), defined as painful teeth displaying clinical or radiological evidence of periapical disease (apical radiolucency, swelling, sinus-tract, pocket depth ≥ 6 mm), or non-odontogenic pain (NOP), defined as painful teeth without such evidence. Chi-square and independent *t*-tests compared pain groups and also patients with and without painful teeth.
Results In total, 550 patients with 1256 root-filled teeth agreed to participate and were examined. Of these, 53 patients (9.6%) reported pain from 63 teeth and were distributed as: OP $n = 36$ (67.9%), NOP $n = 12$ (22.6%). Three patients (5.7%) had painful teeth from both groups, and data were missing for 2 patients (3.8%). Pain groups did not differ significantly regarding gender, age, bodily pain, or frequency, intensity or duration of the experienced pain, or self-reported TMD pain ($P = 0.156$–1.000). TMD pain was more frequent in patients with painful teeth compared to patients with non-painful teeth ($P \leq 0.001$–0.022).
Conclusions Patients with odontogenic and non-odontogenic tooth pain did not differ significantly in any of the variables analysed. Overall, pain from a root-filled tooth was associated with experiencing TMD pain, which may suggest either a causal relationship or mutual mechanisms.
Acknowledgements European Society of Endodontology and the Public Dental Service in Region Örebro County.

R104

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Prevalence of endodontic treatment in an adult Ukrainian population

Aim The aim of this study was to establish the prevalence of endodontic treatment in an adult Ukrainian population.
Methodology A total of 435 digital panoramic radiographs of adults (aged 18 to 72 years) who visited the dental clinic for the first time in 2017 and had no endodontic treatment at least 12 months prior to radiography were examined. Endodontic status of 5787 maxillary and 5725 mandible teeth in 435 subjects was recorded. A tooth was qualified as endodontically treated, if the radiograph revealed radiopaque root filling material in the pulp chamber and/or in the root canals. Data were analyzed by Pearson's chi-squared test ($\chi 2$) and Spearman's rank correlation.
Results Endodontically treated teeth were seen in 82.5% of patients. A clear tendency towards an increasing proportion of patients with previously performed endodontic treatment, from 45.5% in the youngest age group to 100% in the 55- to 64-year-olds, was found. 822 teeth (14.2%) in the maxilla and 569 (9.9%) in the mandible had signs of prior endodontic treatment and the difference between numbers of maxillary and mandibular teeth was significant ($P < 0.0001$ for $\chi 2 = 49$ and df = 1). The first molars in the mandible (39.3%) and first molars in the maxilla (26.7%) were the most often endodontically treated.
Conclusions Mandibular and maxillary first molars were the most often endodontically treated teeth in Ukrainian adults. Awareness of endodontic treatment prevalence can be helpful for enhancing the practical skills for Ukrainian undergraduate and postgraduate students.

R105

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Assessment of reporting quality in systematic reviews in the field of Endodontology

Aim To update the reporting quality of SRs conducted in the field of Endodontology.
Methodology Two reviewers (AF, VB) independently handsearched the issues of three endodontic journals and the Cochrane Database of Systematic Reviews from January 2000 to and including December 2018 to identify SRs. Records were screened and full texts assessed for eligibility by the two reviewers. Data extraction was performed independently by the same two reviewers using pre-determined data extraction sheets, the items of which were drawn from the PRISMA statement. A subgroup analysis was performed between the studies following reporting guidelines (e.g. PRISMA, QUOROM, etc.) and those that did not.
Results One hundred thirty-seven records met the inclusion criteria and were included for analysis. The most common countries of origin of the corresponding authors were the USA, China and Brazil. Prospective protocol registration was lacking in the vast majority of included SRs. Deficiencies were identified with regard to eligibility criteria, screening, data extraction and quality assessment procedures as well as meta-analysis model and heterogeneity assessment. Systematic reviews reported according to established reporting guidelines exhibited superior reporting performance.
Conclusions In accordance with previous studies, SRs in Endodontology exhibited significant reporting limitations. Critical steps need to be taken in order to improve reporting quality, such as adherence to reporting guidelines.

R106

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Prevalence of apical periodontitis and root canal treatment in an adult Ukrainian population found on cone-beam computed tomographic images

Aim To determine the prevalence of apical periodontitis (AP) and root-filled teeth found on cone-beam computed tomography (CBCT) scans of Ukrainian adults.
Methodology The sample consisted of 170 CBCT scans of adult patients (91 females and 79 males) aged 18–82 years who visited a private dental clinic in the city of Lviv (Ukraine) during one year. Three-dimensional radiographic images of 4329 teeth (2021 in males and 2308 in females) were analyzed for presence of signs of root canal treatment and apical periodontitis. Periapical status of each tooth was assessed according to the age and gender, dental arch, tooth type, presence and quality of root

fillings. Data were analyzed statistically using odds ratio, confidence intervals and chi-square test.
Results Root-filled teeth were detected on CBCT images in 135 out of 170 (79.4%) examined patients. Radiographic signs of AP of at least one tooth in a permanent dentition were found in 105 (61.8%) patients. A total of 260 teeth (6.0%) had radiographic signs of AP and 591 teeth (13.6%) had been root-filled. AP was present in 31 (0.8%) of the 4169 non-root-filled teeth and in 229 (38.7%) of the 591 root-filled teeth. Based on CBCT images analysis 247 (41.8%) of root-filled teeth were characterized as adequately root-filled. The prevalence of apical periodontitis in teeth with adequate root fillings was relatively low – 12.1%, whereas findings of apical periodontitis increased to 57.8% in teeth with inadequate treatment.
Conclusions The prevalence of apical periodontitis in an adult Ukrainian population was comparable with findings in other epidemiological studies carried out in European countries. Root-filled teeth were significantly more often associated with apical periodontitis than non-root-filled teeth. The results of the study emphasize the need for undergraduate and postgraduate education in endodontology to develop the clinical skills of dental practitioners.

EVALUATION OF A TECHNIQUE/ MATERIALS

R107

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Efficacy of the new rotary instrument XP Finisher in removing calcium hydroxide intracanal medicament in combination with different irrigation techniques: A micro-CT study

Aim To evaluate the efficacy of a new rotary instrument XP finisher in removing Calcium hydroxide Ca(OH)2 intracanal medicament from inside the root canal in combination with different irrigation regimens.
Methodology Sixteen double-rooted human maxillary premolar teeth were selected. 32 root canals were prepared using the ProTaper Next rotary system up to X3 and then filled with Ca(OH)2. All teeth were then scanned using micro-CT machine to measure the volume of Ca(OH)2 present inside the canals. After that, the teeth were randomly allocated into 2 experimental groups ($n = 16$ canals) according to the type of file used for Ca(OH)2 removal. Each group was further subdivided into two subgroups based on the sodium hypochlorite irrigation protocol used. In group A, Ca(OH)2 was removed by the master apical file (X3). In group B, Ca(OH)2 was removed using XP finisher file. In half of groups A and B ($n = 8$), syringe irrigation (SI) was used whilst passive ultrasonic irrigation (PUI) was used in the other half of groups A and B. After removal of Ca(OH)2, the teeth were scanned again to measure the volume of Ca(OH)2 remaining inside the canals. All data were analyzed using two-way ANOVA with Tukey's Post hoc test.
Results Remnants of Ca(OH)2 were found in all experimental groups. The percentages of remaining Ca(OH)2 in the apical thirds of all canals were greater compared to the middle and coronal thirds in all groups ($P < 0.05$). XP finisher file in conjunction with PUI removed significantly more Ca(OH)2 than XP with SI, X3 with PUI, and X3 with SI. The mean percentage of remaining Ca(OH)2 was greater in the group without PUI.
Conclusions The combination of XP finisher and passive ultrasonic irrigation was more effective in the removal of Ca(OH)2 from root canals in apical third with significant differences compared to X3 file and syringe irrigation.

R108

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How altering manipulation of Biodentine™ affects its physical characteristics

Aim To investigate if altering the manufacturer's instructions regarding the mixing of Biodentine™ (Septodont, Saint-Maur-des-Fosses, France) (BD) would affect its setting time (ST).
Methodology Six groups were created with 1 specimen per group and in each 1 capsule of BD was mixed with: G1 (control): 5 drops of BD liquid (BDL) and vibrated for 30 s in the BD vibrator (BDV) (manufacturer's instructions); G2: 5 drops of BDL and vibrated for 30 s in an amalgamator (Amg); G3: full amount of BDL and vibrated in the BDV; G4: full amount of BDL and vibrated for 30 s in the Amg; G5: 6 drops of tap water manually mixed on a glass plate; G6: 6 drops of BDL manually mixed on a glass plate. For each group, the specimens were kept at 37C and relative humidity of 95 ± 5% for 5 minutes. Initial and final ST was determined as suggested by ISO 6876 (2012). The initial ST was defined as the time elapsed between the end of mixing and when the 100 g needle failed to make a visible indentation on the test cement; final ST was defined as the time elapsed between the end of mixing and the time when the 400 g needle failed to make a visible indentation. The results for initial and final ST for each group were recorded in minutes (min).
Results The initial ST and final ST were as follows: Group 1: 12 min/19 min; Group 2: 16 min/27 min; Group 3: 21 min/36 min; Group 4: 25 min/41 min; Group 5: 6 min/11 min and Group 6: 6 min/14 min.
Conclusions Manipulation of Biodentine resulted in alterations to both the initial and final setting time and reinforces the importance of adhering to manufacturer's instructions in the manipulation of this material.

R109

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The efficacy of different cleaning protocols for the sealer-contaminated premolar pulp chamber

Aim To evaluate the efficacy of different cleaning protocols for the sealer-contaminated premolar pulp chamber.
Methodology After standard access cavity preparation, the root canals of 50 extracted human premolars (25 single-rooted and 25 bi-rooted) were chemomechanically prepared and filled with warm vertically condensed gutta-percha and epoxy-resin sealer (AH Plus, Dentsply Sirona). Teeth were randomly assigned to one control (air/water spray) and four test groups, representing different pulp chamber cleaning protocols ($n = 10$): scrubbing with an ethanol-saturated microbrush (Microbrush International, size Fine, 1.5 mm), scrubbing with an AH Plus cleaner-saturated

microbrush, and the combination of these with air polishing (ProphyFlex, KaVo). All cleaning protocols were followed by application of air/water spray. Each crown was split sagittally, and standardized pictures of both pulp chamber halves were taken before and after cleaning. The sealer-covered access cavity area (SCA) in each picture was determined using image analysis software (Fiji) and compared pre- and post-operatively and across groups using Paired Samples *T*-test and One-way ANOVA.
Results The SCA after treatment was significantly lower than the preoperative SCA in all groups (Paired Samples *T*-test, $P < 0.05$). The SCA reduction in the control group was significantly lower than the SCA reduction in the experimental groups (ANOVA, $P < 0.05$). Between the 4 test groups, no significant differences were observed.
Conclusions Scrubbing with a microbrush saturated with either ethanol or AH Plus cleaner resulted in premolar pulp chambers with very little remaining AH Plus sealer.

INSTRUMENTS – CYCLIC FATIGUE AND FRACTURE

R110

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Cyclic fatigue resistance of Reciproc Blue instruments used with different motions under controlled temperature conditions

Aim To evaluate the effect of different motions on the cyclic fatigue resistance of Reciproc Blue reciprocating files simulating the temperature of the clinical environment.
Methodology After sample size calculation considering preliminary experimental data (α=0.05; β=0.20; δ=30.0; σ=32.0), 69 new R25 Reciproc Blue files were divided into three groups of 23 files each according to the tested motion: continuous rotation at 300 rpm, "RECIPROC" mode, and "WAVEONE" mode. All files were activated until fracture inside a stainless-steel artificial canal with 60° angle and 5 mm radius of curvature. The temperature was kept at 35°C and controlled with an internal thermometer inside the testing device. For each file, a single blinded operator measured the time to failure with a digital chronometer and the length of the fractured fragment with a digital calliper. A qualitative fractographic analysis was performed by observing the surface of the fractured files at the scanning electron microscope. The scalar data were tested for the assumptions for using parametric tests and then underwent a statistical analysis with a one-way analysis of variance and Tukey post hoc test ($P = 0.05$).
Results The shortest lifespan of the files was registered in the continuous rotation group (204.1 ± 24.2 s to failure). Both reciprocating motions led to significantly improved fatigue resistance. The "RECIPROC" mode performed better than the "WAVEONE" mode, exhibiting 329.8 ± 31.5 s and 252.9 ± 43.7 s to failure, respectively. No difference in fragment length was observed, confirming the correct positioning of the files inside the artificial canal. The scanning electron microscopic analysis confirmed that all the observed specimens fractured due to cyclic fatigue.
Conclusions The results of the present study seem to encourage the use of R25 Reciproc Blue files preferably with their native motion to reduce the fracture risk in the clinical setting.

R111

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Impact of controlled memory alloy manufacturing technology on cyclic fatigue resistance of three Nickel Titanium files

Aim To evaluate the impact of three controlled memory files (Hyflex CM (HCM), Hyflex EDM (HEDM), One Curve (OC)) on cyclic fatigue resistance compared to shape memory files (2Shape (2S), ProTaper Gold (PTG)).
Methodology A total of 50 files were rotated in simulated stainless steel curved canals reproducing the size and taper of the files with 45 angle of curvature and 5 mm radius of curvature. The time to fracture (TTF) was recorded in seconds, the number of cycles to fracture was calculated (NCF) and the length of the fractured fragments was measured. Data were analysed statistically using IBM SPSS software package version 20.0. Quantitative data were described using mean and standard deviation for parametric data after testing normality using Kolmogorov-Smirnov test. Significance of the obtained results was judged at the 5% level.
Results When comparing the TTF of all the tested files, the data obtained from statistical analysis showed that the resistance to cyclic fatigue of the files arranged from highest to lowest was HEDM, HCM, PTG, 2S and OC respectively. When the NCF values were taken into consideration HEDM and HCM reported a significant higher cyclic fatigue resistance than PTG ($P < 0.05$), OC and 2S reported the lowest resistance to cyclic fatigue among the tested files with no significant difference between OC and 2S ($P > 0.05$). There was no significant difference between PTG and OC when comparing NCF ($P > 0.05$). No significant difference was found in the length of the fractured fragments of the files ($P > 0.05$).
Conclusions Within the limitations of the present study, HEDM and HCM NiTi files had the greatest resistance to cyclic fatigue among the tested files.

R112

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Effect of ambient temperature on torsional fatigue resistance of nickel-titanium rotary and reciprocating single files

Aim To compare the effect of different ambient temperatures on the torsional fatigue resistance of the OneShape (OS), One Curve (OC), Reciproc (RPC), Reciproc Blue (RPC Blue), WaveOne (WO), and WaveOne Gold (WO Gold) nickel-titanium (NiTi) rotary and reciprocating files.
Methodology A total of 120 NiTi instruments ($n = 20$) were evaluated: OS, OC, RPC, RPC Blue R25, WO Primary, and WO Gold Primary were used at room temperature (25°C) and intracanal temperature (37°C). Torque and angle of rotation at failure of new instruments ($n = 10$) the 3 mm from the tip were measured during torsional testing according to ISO 3630-1. The fractured surface of each fragment was examined by scanning

electron microscopy. Data were analyzed using two-way analysis of variance and Tukey tests at 5% significance level.
Results The RPC and RPC Blue had significantly greater torsional strength values at both temperatures compared to the other groups ($P < 0.05$). The OC showed significantly lower torsional strength value compared to the other groups ($P < 0.05$). The temperature did not significantly affect the torsional resistance of the files. In relation to the angle of rotation, OC had the highest angle values ($P < 0.05$). The WO, WO Gold, and RPC had the lowest angle values in comparison with all the groups ($P < 0.05$).
Conclusions Within the limitation of the present study RPC and RPC Blue instruments had significantly higher torsional resistance than the other instruments in both ambient temperatures. The ambient temperature did not affect the torsional resistance of the tested files.

R113

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Cutting ability of Reciproc and Reciproc blue NiTi instruments at different incidence angles

Aim To evaluate the cutting efficiency of two single file systems – Reciproc R25 (REC) (VDW, Munich, Germany) and Reciproc blue R25 (REB) at different inclinations.
Methodology Sixty new REC and REB files were used. The experimental groups ($n = 10$), depending on type of instrument and cutting angle selected, were organized as follows: groups 1, 2, 3 included REC tested at 90°, 70° and 45° of inclination with respect to the sample, respectively; groups 4, 5, 6 included REB tested at 90°, 70° and 45°, respectively. The cutting test was performed using a customized machine in which all instruments were activated in reciprocating motion against standardized gypsum blocks for 120 s. The movement tested had 300 rpm with 150° CCW (counter-clockwise) and 30° CW (clockwise) angles following the parameters declared by the manufacturers for the Reciproc preset program known as "Reciproc ALL". The cutting efficiency was determined by measuring the weight loss of the block using an analytical balance ($\pm 1 \times 10^{-4}$ g, Balance E42-B, Gibertini, Italy) and by measuring the length of the surface cut in the block using a digital caliper (10^{4} m). The results were expressed as means and standard deviations (SD) for each group and data were analyzed statistically by two-way ANOVA and Bonferroni *t*-test, with the level of significance set at $P < 0.05$.
Results No difference was observed for REC among 90°, 70° and 45° ($P > 0.05$). REB had no significant difference between 90° and 70° ($P > 0.05$) while its cutting efficiency increased significantly at 45° ($P < 0.05$). A significant difference was observed between REC and REB at 45° only ($P < 0.05$).
Conclusions Within the limits of the present study, increased file inclination to 45° and blue heat-treatment improved the cutting efficiency of size R25 Reciproc files.

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Evaluation of cyclic fatigue and wear analysis of OneShape and OneCurve instruments

Aim This laboratory study compared cyclic fatigue resistance and wear analysis of OneCurve and OneShape instruments.
Methodology Cyclic fatigue tests were performed on 40 new OneCurve ($n = 20$) and OneShape ($n = 20$) instruments using an artificial canal with a 5.0 mm curvature radius, 90° angle 5.0 mm from the tip. Time to fracture was video-recorded, and the number of cycles to fracture (NCF) was calculated as follows: NCF=(time failure (s) × rotational speed (rpm))/60 s. New OneCurve ($n = 2$) and OneShape ($n = 2$) files were subjected to wear in straight canals from a pool of extracted human teeth. Patency was verified with a size 10 K-file. An X-Smart micromotor was used following the manufacturer's recommendations. OneFlare and OneG were utilized to achieve a glidepath. Irrigation was performed with 3 mL of 5% NaOCl and 3 mL of 10% EDTA. Each instrument was used in 5 canals, washed in an ultrasonic bath and autoclaved. SEM was used to evaluate the new and used instruments at the same points and angulations to identify wear features. Micrographs were taken on the tip and on cutting edges at 5 mm from the tip. Fractures and the presence of unwinding, microcracks, blade disruption and tip deformation were sought. Mann-Whitney statistical analysis was performed ($P = 0.05$).
Results OneCurve files exhibited a significantly greater cyclic fatigue resistance compared to OneShape ($P < 0.01$). No significant differences were found concerning the length of the fractured instruments. No instrument fracture occurred during simulated clinical use. Spiral distortions and microcracks were absent in both instruments. Dentinal debris was found on the surface of used instruments. Superficial analysis on new files revealed a smooth regular texture with milling grooves flattened by the electropolishing process that remained well-defined and rounded with an absence of wear signs.
Conclusions OneCurve instruments had greater NCF and longer time to failure suggesting safer use in difficult clinical conditions including severely curved canals. These heat-treated NiTi instruments were significantly more fatigue resistant compared to conventional NiTi OneShape. Both instruments had high wear resistance.

PULP AND PERIAPICAL TISSUE BIOLOGY AND PATHOLOGY

R115

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Anti-inflammatory effect of Thai propolis extract in human dental pulp cells

Aim To determine the anti-inflammatory effect of Thai propolis extract in human dental pulp cells (HDPCs) in response to

stimulation with interleukin-1 beta (IL-1β) by determining mRNA expressions of cyclooxygenase-1 (COX-1) and cyclooxygenase-2 (COX-2).

Methodology HDPCs were cultured in Dulbecco's Modified Eagle medium and treated with or without Thai propolis extract at 5, 2.5, 1.25 and 0.625 mg/mL or 10% (v/v) dimethyl sulfoxide, as a positive control for cell toxicity, for 24 or 72 h. The Prestoblue assay was conducted to examine cytotoxicity. Thereafter, HDPCs were first treated with 10 ng/mL of IL-1β for 24 h and then with non-toxic doses of Thai propolis extract for another 24 h. IL-1 β -treated HDPCs were incubated with 10 M of indomethacin for 24 h as a positive control for anti-inflammation. Total RNA was isolated, and expressions of COX-1 and COX-2 mRNA, normalized by that of glyceraldehyde 3-phosphate dehydrogenase as a housekeeping gene, were analyzed by real-time RT-PCR with their specific primer pairs. One-way ANOVA with the Bonferroni test was used to compare average cell numbers and degrees of mRNA expressions among different samples.

Results Thai propolis extract at 2.5, 1.25 and 0.625 mg/mL was not toxic to HDPCs even after treatment for 72 h. Thai propolis extract at 1.25 and 0.625 mg/mL significantly reduced COX-2 mRNA up-regulation in HDPCs induced by IL-1 β treatment ($P < 0.001$), but could not decrease expression of COX-1 mRNA ($P = 1.000$).

Conclusions Thai propolis extract possessed an anti-inflammatory property in HDPCs via COX-2 reduction without exhibiting cytotoxicity; hence, the extract may be applied clinically as a pulp capping material in the future.

R116

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The influences of Type 2 diabetes on clinically normal dental pulp tissues

Aim 1) To compare the histomorphology of normal dental pulp tissue from Type 2 diabetes (T2D) and non-diabetic participants; 2) To examine the expression and distribution of AGE, RAGE, inflammatory markers and immune cells using immunohistochemistry.

Methodology Ethical approval was obtained from the University of Otago Human Ethics Committee (H16/069). Twenty permanent extracted teeth (10 T2D, 10 non-T2D) that had been diagnosed clinically with a normal dental pulp were decalcified in 10% EDTA, and embedded in paraffin. Sections were stained with haematoxylin and eosin, and special stains (Massons Trichrome, van Gieson, silver stain) for histological evaluation. Immunohistochemistry using anti-AGE, anti-RAGE, anti-IL1-β, anti-IL6, anti-TNF-α, anti-CD4 (T-helper (Th) cell marker), anti-FOXP3 (forkhead box transcription factor), anti-CD68 (monocyte marker) and anti-CD83 (T cells and dendritic cells) was visualized with the chromogen DAB. Appropriate positive control tissues were included and non-specific anti-IgG was the isotype negative control. Qualitative and quantitative analyses were performed to evaluate pulpal morphology and protein expression. Data analyses were performed with GraphPad Prism, using Student's *t*-test at $P < 0.05$.

Results The pulp of T2D had fewer blood vessels and was less cellular. Blood vessel walls were thickened and pulp calcifications were common in the central pulp. There was increased collagen and less elastin compared with non-T2D. IHC revealed that T2D was associated with significantly greater expression of AGE, RAGE, IL1-β, TNF-α, CD68 ($P \leq 0.001$), IL6, CD-4 ($P = 0.02$), CD83 ($P = 0.048$), and decreased expression of FOXP3 ($P = 0.01$). FOXP3 was expressed in the subodontoblast region and on endothelial cells while AGE was strongly expressed in collagen fibres throughout the pulp. Immunity markers were expressed throughout the pulp but Th cells were most common within the central pulp.

Conclusions T2D altered the morphology and immune response of the dental pulp suggesting this systemic disease may influence pulpal healing following injury or infection.

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R117

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Gene expression pattern of S100-proteins in healthy and irreversibly inflamed human dental pulps

Aim To evaluate the expression of various S100 genes in specimens of healthy and inflamed dental pulps by quantitative real-time polymerase chain reaction (qPCR).

Methodology Tissue samples of human dental pulps were used with fifteen clinically diagnosed as symptomatic irreversible pulpitis (SIP), seven as asymptomatic irreversible pulpitis (AIP), and nineteen as healthy pulp (HP). S100 gene expression was evaluated quantitatively using the qPCR technique. In order to monitor the status of inflammation and degradation of pulp tissues, IL-8, COX-2, and HMGB-1 gene expression was also analyzed. Expression of endogenous GAPDH served as reference gene. Differential expression rates for each target gene between SIP, AIP, and HP were calculated by analysis of variance (ANOVA) followed by Bonferroni post hoc test ($P < 0.05$).

Results Significantly reduced gene expression levels in SIP for S100A1, A2, A3, A4, A6, A10, A13, and for HMGB-1, could be detected compared to HP, while gene expression of S100A8, A14, and IL-8 was significantly increased. Transcript levels for S100A9 and COX-2 could also be observed to be up-regulated but not at 5 per cent significance level. In AIP, significantly increased expression levels were only detected for S100A14, A16, and for IL-8. Further differences (increase and reduction) could be observed but without a significant difference.

Conclusions The present study revealed significant differences in the gene expression pattern of S100 proteins comparing HP with SIP and AIP. More differences between HP and SIP, than between HP and AIP were examined.

R118

WITHDRAWN.

R119

WITHDRAWN.

R120

WITHDRAWN.

R121

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Macrophages hyper-activation in sustained exposure to *Enterococcus faecalis*

Aim To examine the impact of sustained *E. faecalis* infection on macrophages as the dominant inflammatory cells in endodontic lesions.
Methodology THP-1 cells (human monocytes) were differentiated into mature macrophages *in vitro*. At baseline, cells were inoculated with *E. faecalis* for up to 4 days. Bacterial intra-cellular survival and macrophage response to the infection was measured using fluorescent staining and flow cytometry. Oxidative stress and cytokines expression (TNFα, OPG and RANKL) by the macrophages were tested using fluorescent plate reader and ELISA.
Results Macrophages phagocytosed *E. faecalis*, but failed to clear the bacteria for 4 days post-infection. A gradual decrease in macrophage viability was observed, while their mitochondrial, internal oxidative stress and TNFα expression increased in the infected cells. Furthermore, elevation in RANKL and decrease in OPG were observed over-time, indicating promotion of osteoclastogenesis.
Conclusions While macrophages attempt to clear *E. faecalis* in an *in vitro* model, the bacteria endured inside the cells. The sustained infection leads to tissue destruction pathways, such as oxidative stress, pro-inflammatory cytokine expression and promotion of pro-osteoclastogenesis cytokines.

CASE REPORT OR CASE SERIES

R122

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Selective root canal treatment: A case series of a novel attempt on minimal invasive endodontics

Aim To report the results of selective root canal treatment in multi-rooted teeth, which allows the preservation of vital pulp tissue in specific roots.
Methodology A series of 9 cases including multi-rooted teeth with acute apical periodontitis and with vital pulps in at least in one root were selected. Teeth with bleeding from the pulp tissue that could not be arrested indicating an irreversible pulpitis were excluded. The patients were aged between 20–73 years. After the informed consent from the patients, rubber dam application and local anaesthesia, the vital pulps in roots of the teeth were treated with total pulp amputation using MTA. The roots with non-vital pulps, periapical lesion or acute symptoms were chemo-mechanically instrumented after two days and filled following symptom resolution. Coronal restorations were performed with glass ionomer base and direct composite fillings. A comprehensive literature search was undertaken to find any clinical studies reporting this clinical scenario; however, no case or study was found.
Results The case series findings revealed that multirooted 7 teeth (5 molars and 2 premolars) healed and survived. In 3-year follow-up of the case numbers 1-5 (molars), symptoms were resolved and the periapical lesions of nonvital roots had healed. The roots with preserved pulp vitality demonstrated vitality signs clinically and had radiographically healthy periapices. The premolars with two root canals (case 6 and case 7) had the similar healing prognosis with one vital root, which was also proven with electrical pulp testing, cold testing and from the radiographic evaluation. Two of the cases (2 molars, case 8 and case 9) demonstrated poor prognosis of healing such as severe pain in a short term, thus required further endodontic intervention.
Conclusions Selective root canal treatment in multi-rooted teeth can take place in minimally invasive endodontics, since it is targeting at maintaining vital pulp as long as possible. Additional clinical studies are necessary to highlight this new approach.

R123

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Cemento-Osseous Dysplasia – an endodontic consideration. The diagnosis, management and treatment of a case

Aim To highlight the importance of the inclusion of cemento-osseous dysplasia as a differential diagnosis in Endodontics, the significance of a thorough dental and medical history, as well as, appropriate clinical and radiographic investigations.
Methodology Cemento-osseous Dysplasias (COD) are the most commonly diagnosed fibro-osseous lesions of the jaws. Clinically, they predominate in the mandible with varying presentation and are usually asymptomatic; however, they can cause localised jaw expansion and discomfort. Radiographic presentation is dependent on lesion maturity with early lesions being radiolucent, developing into mixed radiolucent/radiopaque and finally radiopaque in the later stage lesions.
Results This case report focuses on a rare presentation of COD in a 57-year-old caucasian woman with a history of breast cancer. She presented at her General Dental Practitioner with symptomatic unrestored mandibular incisors, which when radiographed revealed a multiple periapical radiolucencies. Following referral to the joint Oral Surgery / Endodontic clinic and subsequent clinical and radiographic investigations with the aid of CBCT imaging, a diagnosis of COD was made. The patient is being kept under regular review at the dental hospital, with the view to biopsy if there are significant clinical or radiographic changes.
Conclusions The primary diagnosis of early-stage COD is difficult due to clinical and radiographic findings comparable to that of other odontogenic and non-odontogenic lesions. Correct diagnosis in order to avoid unnecessary and irreversible dental treatment including endodontic therapy is crucial. Currently, there is no standardized accepted treatment modality for COD, with most cases being kept under regular specialist clinical and radiographic review, in order to prevent and manage serious complications such as osteomyelitis.

ENDODONTIC REVITALIZATION/ REGENERATION

R124

WITHDRAWN.

OTHER

R125

WITHDRAWN.

R126

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Assessment of outcome measures used in high-ranked endodontic journals according to a hierarchical model

Aim The aim is two-fold: (1) to develop a hierarchical model on outcome measures related to endodontic treatments and (2) systematically assess the outcome measures used in studies on treatment(s) in high-ranked endodontic journals according to the developed hierarchical model.
Methodology Based on the Fryback and Thornbury hierarchical model of efficacy used in diagnostic imaging, a conceptual model on treatment effect/efficacy/effectiveness was developed. Consecutive numbers of the two highest ranked endodontic journals, the International Endodontic Journal and the Journal of Endodontics, were individually reviewed by the authors to identify original scientific studies and systematic reviews correlated to any form of treatment. After reading the articles in full-text and using a predefined protocol, the reported treatment outcomes were assessed to be on a certain level on the conceptual model. Consensus was reached by discussion.
Results The highest level in the proposed model is 'Societal', exemplified by the outcome measure cost-effectiveness. The lowest level in the proposed model is 'Technical', exemplified by the outcome measure torsional fracture of endodontic instruments in an *ex vivo* model. Preliminary results indicate few original scientific studies or systematic reviews to report outcome measures on the higher levels of the hierarchical model and the majority of studies were assessed to be on the lower levels.
Conclusions The preliminary results of this study propose that the majority of studies on endodontic treatments are designed to evaluate technical aspects of treatment procedures and few evaluate treatments from a societal perspective. This does not necessarily mean that the quality *per se* of the studies is poor, or that the studies are redundant.