A light at the end of the tunnel?

Professor Liviu Steier asks if there’s a future for bacteria-free dental devices such as implants

Why should a dentist be worried about bacterial contamination or even worse biofilms? And by this, I don’t just mean plaque. Let us have a look on the definition of “biofilm” by the University of Montana under the chairmanship of Dr David Costertone.

It says: “Biofilms form when bacteria adhere to surfaces in aqueous environments and begin to excrete a slimy, glue-like substance that can anchor them to all kinds of material – such as metals, plastics, soil particles, medical implant materials, and tissue. A biofilm can form on any surface exposed to bacteria and some amount of water. Once anchored to a surface, biofilm microorganisms carry out a variety of detrimental or beneficial reactions by (human standards), depending on the surrounding environmental conditions.” (http://www.erc.montana.edu/CBEssentials-SW/6f-basics-99/basics-01.htm).

A dentist’s concern?

Now, why and how should this concern the dental practitioner? A prosthesis, an implant, or any device added to the oral cavity could be surrounded by and even more often biofilms consisting of many species of bacteria, as well as fungi, algae, protozoa, debris and corrosion products. Essentially, biofilm may form on any surface exposed to bacteria and the formation of biofilm are its main focus.

Daily practice

We deal with monomers and polymers in our daily practice. We use materials such as composites for restorations in our daily practice. We use materials such as implants and prostheses and implants. Dr Renate Förch, the spokeswoman of the research group, has outlined the future achievements on polymertechnology and the use of plasma technology (http://www.mfpj-mainz.mpg.de/www/pages/aktuelles/pressemitteilungen/?year=2010&kap,2). Involved in this project are research institutes from Spain, the UK, Switzerland and of course Germany, covered by a grant of the European Community. The biological attachment process of bacteria and the formation of biofilm are its main focus.

Daily practice

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Dr Liviu Steier (PhD) is Specialist for Prosthodontics (www.dgmsk.de) and specialist in Endodontics (GDC-UK). He is an honorary clinical associate professor at Warwick Medical School and course director of the MSc in Endodontics (www.warwick.ac.uk/gdcdirectory). He is a member of the Scientific Advisory Board for the Journal of Endodontics (JAE) and maintains a private referral practice for endodontics, implantology, etc at 20 Wimpole Street, W1G 4JF London (www.modendontist.co.uk).

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The Nobel Active implant

Dr Tidu Mankoo demonstrates the interdisciplinary restoration of six maxillary anterior teeth and a single Nobel Active implant

The goal of any implant therapy in the aesthetic zone is to produce a restoration of the tooth (or teeth) that blends inconspicuously into the patient's smile and maintains stable soft-tissue form over time. It is understood that bone and soft tissue remodelling occurs around all dental implant restorations and while this remodelling has been attributed to a number of factors, it is now commonly accepted that it is probably due to the establishment of a “biologic seal”, commonly described as a “biologic width” between the free gingival margin to the crest of the peri-implant alveolar bone.

A number of factors have been proposed as playing a role in this process and in recent years, new implant designs have been suggested as being potentially helpful to reduce the impact of the remodelling process on the marginal bone; therefore creating enhanced stability of the marginal soft peri-implant soft tissues. While it is clear that the components alone are not the whole story, nevertheless most of the new designs serve to enhance the thickness of the soft tissue cuff around the neck of the implant restoration and create a narrower transmucosal contour often combined with an element of “platform-switching”.

Of course, the clinical management of implant restorations in the aesthetic zone has involved anticipation of the consequences of this remodelling and strategies that reduce or negate the impact of possible soft tissue and bone changes. It is increasingly evident that the volume of bone and the tissue quality, tissue thickness and tissue biotype around our implants in the aesthetic zone play a key part in maintaining long-term aesthetic outcomes.

These new concepts for component designs generally aim to create a transmucosal “under-contour” which logically, in turn, increases the available volume of peri-implant soft tissue and in effect thickens the soft tissue cuff around the implant-abutment complex.

The Clinical Case

In this example, a 35-year-old female patient with a history of extensive dental treatment required revision of her previously restored maxillary anterior teeth (canine to canine), as well as additional treatment in the posterior regions, which are not relevant to the article. The teeth had been previously crowned in a piece-
meal approach over some years, and the most of the teeth in question were root treated and restored with post crowns.

The overall aesthetic situation was compromised by the appearance of short clinical crowns, giving the teeth (particularly the central incisors) a rather ‘short and broad’ appearance (Fig 1). In addition, there were pre-existing endodontic treatments and post crowns in a number of the teeth and residual apical radiolucencies evident on some of the teeth (Fig 2).

These were asymptomatic (except for the failing left central incisor) the right lateral incisor and canine had been apicected and retrograde root filled a couple of years prior, the right central incisor had been previously root treated and contained a fibre post and composite core although the root filling was difficult to assess radiographically. However, as the tooth was stable and symptom free it was decided to accept the situation as re-treatment would be difficult, and lastly the radiolucency on the left lateral incisor had been symptomless and stable for a number of years and may have been a scar.

Nevertheless, it was clear that the prognosis of some of these teeth was uncertain and that further surgical endodontic treatment may be required in the future for the left lateral and possibly the right central incisor. The patient was made aware of this and the risk of possible future root fractures, particularly in the left lateral incisor where there was a large metallic post.

An additional point to note is that the presence of metallic post and cores and dark root substrate makes ideal colour of the gingival margins tissue difficult to achieve and has to be managed carefully when being restored with all-ceramic restorations to avoid affecting the value of the crowns.

The maxillary left central incisor needed surgical endodontic treatment, but had to be removed shortly after due to root fracture (Fig 5), and it was not possible to place an implant immediately due to the infection and damage to the labial bone.

Soft-tissue healing
A provisional metal-acrylic fixed-partial denture was fabricated and fitted at the time of tooth extraction and soft-tissue healing at six weeks post extraction. Figure 6 shows the damage to the labial bone plate in the area of the tooth extraction and loss of labial contours in that area.

Positioning the implant
The correct three-dimensional
References


positioning of the implant is of critical importance in helping to achieve a lasting aesthetic result and here it is important to place the implant correctly, i.e., three mm apical and two mm palatal to the final gingival margin desired on the implant restoration. In this case the teeth were to be crown lengthened, so it was necessary to recontour the osseous architecture and establish the correct biologic width on the teeth (Figs 7, 9) prior to positioning the implant so that the final gingival margins will harmonise.

In effect, this meant that the implant was placed deeper than would have been in a case where no crown lengthening was required and facilitated a good housing of bone for the implant. Despite this, it was still necessary to augment the labial osseous and soft tissue contours for the purposes of achieving the correct soft tissue aesthetics.

A Nobel Active 4.5 x 13mm implant was placed after preparation of the osteotomy, achieving excellent primary stability, and bone augmentation was carried using the principles described in the previous publications by the author 25 using an organic bovine bone mineral (Nu-Oss, Ace Surgical Co, Brockton, USA) and covered with resorbable collagen membrane (Bio-Gide, Geistlich AG) (Figs 9, 10).

A narrow healing abutment was placed, the bone augmentation carried out and the tissue on the crest of the ridge was deepithelialised and rolled under itself to the labial to create an increase of the soft tissue volume on the labial of the implant healing abutment and the flap sutured using 6-0 mono filament polypropylene sutures (Fig 11). This could be further enhanced with a connective tissue graft if necessary, but in this case, the roll flap created sufficient thickness. The bridge was re-cemented after adjustment of the pontic to fit passively against the augmented ridge and healing abutment, and to allow for a slight tissue excess in the area of the implant.

The healing process begins
After three months of healing, the remaining crowns and provisional crowns were removed and the teeth re-prepared to the new gingival margins. The bridge retainers were relined and provisional crowns made and cemented provisionally to allow for tissue maturation to occur (Figs 12, 15).

After six months, final refinement of the tooth preparations (Fig 14) and the achievement of good soft-tissue contours can be seen particularly on the labial aspect of the implant, where a thick collar of labial tissue is evident (Figs 15, 16). The final impressions of the preparations and a transfer impression of the implant were made and subsequent steps to try-in the abutment and bisque bake of crowns were carried out. After all necessary adjustments were made the final Procera alumina crowns were finished and final cementation performed with a glass ionomer cement (Fuji 1, GC) over a period of a few weeks. It is essential that retraction cord is used when cementing the crown (whether provisional or final) on the implant abutment to ensure that no cement excess travels into the sub-mucosal area as this can lead to peri-implantitis and therefore compromise the result.

A Procera Zirconia abutment was fabricated and Fig 17 shows an example of this, demonstrating the ideal contours of the abutment with the scalloped margins resembling a tooth preparation.

This enables crown margins to be ideally placed for cementation. The design of the Nobel Active implant components lend themselves naturally to the creation of the transmucosal under-contour that facilitates a thicker transmucosal tissue cuff and therefore greater stability.

Figs 18, 20 show the final crowns at two-month follow up. It is interesting to note the difficulty in achieving ideal soft-tissue col-
Screw versus cement-retained, implant-supported prosthetic restorations

Professor Liviu Steier discusses passive-fit, cement hydraulics/overhangs and retrievability of implant-supported prosthetics

It was the year 1999 when Kim et al. stated that: 'The use of cement-retained implant prosthesis is increasing because of improved occlusal anatomy, esthetics, and simplified laboratory procedures. Little is known about the biomechanics of cement retained implant prostheses compared with that of screw retained implant prosthesis.'

While comparing, cement-retained versus screw-retained implant restoration, Michalakis et al. reviewed the literature in 2005. His research emphasised the following factors:

1. Ease of fabrication and cost, (2) passivity of the frameworks, (3) retention, (4) occlusion, (5) esthetics, (6) delivery, (7) retrievability.

Weber et al. (2007) could not find enough evidence to prove any significant difference among restoration design and treatment outcome and Chee et al. (British Dental Journal 2006; 201: 501-507) summarised the differences they have identified:

- Screw-retained restorations are more easily retrieved and maintained
- Cemented restorations can accommodate more implant positions
- Screw-retained restorations are easier to manage when immediately loading implants.

Screw loosening is among the biggest post-loading problems. Cavazos et al. (1996) summarise reasons for screw loosening: ‘Screw stretch, less than ideal implant position, inappropriate occlusal scheme or crown anatomy, variations in hex dimension coupled with equal variations in the abutment counterparts, slight differences in fit and accuracy, tension on abutment and cylinder from ill-fitting restorations.’

Several approaches have been researched and suggested to avoid screw loosening, from silicon to resin sealing, from screw material innovation to coating techniques.

Fit variation

As early as 1961, Kurosu and Ide demonstrated that marginal fit of cemented restorations varies between 20 and 90 microns. Wilson et al. proved in 1990 the differences between 20 and 90 microns. Cavazos et al. (1996) summarise reasons for screw loosening: ‘Screw stretch, less than ideal implant position, inappropriate occlusal scheme or crown anatomy, variations in hex dimension coupled with equal variations in the abutment counterparts, slight differences in fit and accuracy, tension on abutment and cylinder from ill-fitting restorations.’

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implant crown when a vertical force was applied.

Researching the literature, only one paper by Schwedhelm et al. (2005) has been identified addressing the cementation problem in implant-supported crowns. He suggested a lateral crown venting to allow elimination of cement excess and reduce deflection/deformation of the prosthesis part as well nocice forces to the implant.

A clinical case study

Missing tooth 46 was replaced by an implant: Internal Implant BiT, Laser-Lok 4.0 x 12mm, 4.5 Platform (Biohorizons UK, 17 Wellington Business Park, Dukes Ride, Crowthorne, Berkshire RG14 6L5). After adequate osseointegration time (three months after insertion), the second-stage surgery has been performed and the gum sculpted with a provisional.

Clinical picture demonstrating a good emergence profile, nice and healthy gum coloration (as no nocive forces applied), and an excellent aesthetic integration in the remaining tooth arcade. The orthodontic area was closed using composite resins.

The laboratory delivered the prepped abutment mounted into the transfer key. The PFM crown (high precious metal) guarantees a coronal access to the screw. The abutment will be tightened according to the indications of the manufacturer using a torque control device. The abutment access is closed using polytetrafluoroethylene (PTFE) tape (plumber tape) to seal the screw access channel to protect the screw head of the abutment. The retentive remnant of the abutment will ease the removal of the cementation at the crown margins.

The abutment will be tightened according to the indications of the manufacturer using a torque control device. The abutment access is closed using polytetrafluoroethylene (PTFE) tape (plumber tape) to seal the screw access channel to protect the screw head of the abutment as described by Moragüez et al.

The prepped abutment mounted into the transfer key.

The PFM crown with remnant access to the abutment screw.

The author prefers a technique of coronoal venting. The presented crown design addresses the following technology shortcomings:

- Cementation will easier pardon transient discrepancies.
- Coronal access will facilitate and allow screw retightening at any needed time.
- Coronal access will facilitate excess cement evacuation and clearly facilitate a better fitting.

Conclusion

Aside from the prosthetic restorations, endodontics, implantology, etc at The Journal of Endodontics (AAE) and the MSc in Endodontics (www.warwick.ac.uk/dentistry), he is a member of the Scientific Advisory Board for the European Academy of Endodontics (www.eaend.org) and maintains a private referral practice for endodontics, implantology, etc at 20 Wimpole Street, W1G 8GF London (www.meddentistry.co.uk).

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References

Untying the Gordian Knot; Part I

Kenneth Serota discusses the Endodontic Implant Algorithm, which provides highlights in the assessment and identification of determinant factors leading to endodontic failures, in order to help in the decision-making process whether or not it is adequate to implement a new endodontic approach vs. extraction and replacement with dental implants.

Variables

Over the years, endodontics has diminished it-self by enabling the pre-sumption that it is comprised of a narrowly defined service mix; root canal therapy purportedly begins at the apex and ends at the orifice. Nothing could be fur-ther from the truth. It is the cata-lyst and precursor of a multiva-riate continuum, potentially the foundational pillar of all phases of any rehabilitation (Fig 1a, 1b, 1c). Early diagnosis of teeth re-quiring endodontic treatment, prior to the development of peri-iradicular disease, is critical for prior to the development of per-requisite endodontic treatment, obturated. One year later, the lesion has healed. While the retrograde amalgam remained in the root end, its presumed ability to effectively seal a complex apical terminal configur-a-tion was ill-considered. Everything leaks in time; retreatment is always the first choice for resolution of an unsuccessful endodontic procedure where possible.

In 1992, funding from the Cochrane Collaboration was ob-tained for a U.K. Cochrane Cen-ter based in Oxford to facilitate the preparation of systematic reviews of randomised trials of healthcare. The Cochrane Sys-tematic Review is a process that involves locating, appraising, and synthesising evidence from sci-entific studies in order to provide informative empirical answers to scientific research questions. In 1995, the enterprising son of an inventor named Ron Popeil cre-ated infomercials using 50 to 120 second television spots to sell his inexpensive array of useful prod-ucts, including the Pocket Fisher-man and the Veg-O-Matic food cutter. The singular goal of an infomercial was to get the viewer to a phone immediately and have them place their order. No wait- ing weeks, months or even years for the lofty marketing goals of branding to pay off. Somewhere along the way, dentistry morphed the two concepts. Nowhere is this becoming more apparent than in the debate on the endodontic im-plant algorithm.

New treatment modalities

Scientific doctrine is the corner-stone of Endodontic therapeutics. However, of late, anecdotal testi-mony has become the default set-ting for new paradigms to justify endodontic treatment modalities and an encomium to technologic advan-tages. The strength of the arch of this or any specialty’s in-tegrity and relevance must rely on a keystone of randomised clinical trials and evidence-based treatment outcomes. Expert opin-ions reflected through the looking glass of business models or global tours cannot replace stringently controlled clinical assessments distilled from exacting independ-ent investigations. Science cannot be applied through a McLuhanis-tic rearview mirror of technology. The two must symbiotically oc-upy the same space regardless of whether that is antithetical to the Pauli Exclusion Principle, one of the most accepted laws of phys-ics; no two objects can simultane-ously occupy the same space.

In December 2004, Salehrabi and Rotstein published an empirical study on endodon-tic treatment outcomes in a large patient population. The outcomes of initial endodontic treatment done by general practitioners and endodontists participating in the Delta Dental Insurance plan on 1,462,936 teeth of 1,126,288 pa-tients from 50 states across the USA were assessed in an eight year timeline. Ninety seven per-cent of teeth were retained in the oral cavity subsequent to nonsur-gical endodontic treatment over this period. The combined inci-dence of untoward events such as retracments, apical surgeries, and extractions was three per cent and occurred primarily within three years from the completion of treatment. Analysis of the ex-tracted teeth revealed that 85 per-cent had no full coronal coverage. A statistically significant differ-ence was found between covered and uncovered teeth for all tooth groups tested which is consistent with the findings from numerous investiga-tions.

The purpose of this publica-tion is to evaluate current trends and perceptions pertaining to the standard of care in endodontics and provide an evidence-based consensus on their relevance and application. Part II will address the algorithm by which sacrifice of natural structures for ortho-biotic replacements can be vali-dated and the engineering princi-ples and designs that best mimic clinical dictates.

Evolutionary paradigm shifts

Three surveys have been con-ducted with the membership of the American Association of En-
odontists since the late 1970s. The first reflected what is now an anachronistic view of emergency procedures and the standard of care defining non-surgical therapy during that period (7); the second, done prior to the technologic advances of the last decade of the 20th century, was hallmarked by a dramatic decrease in leaving pulpless teeth open in emergency situations and a significant decline in the use of culturing prior to obturation (8). The report indicated that the concept of “debridement and disinfection” versus “cleaning and shaping” was now the focus of the biologic therapeutic imperative and the need for expansive microbial strategies was recognised as being of paramount importance (Fig 5). The primary patho-physiologic vectors of pulpal disease and the myriad complexity of the root canal system had always been understood; as the century closed, clinicians were provided with new tools and technology to expand the boundaries and limitations of endodontic treatment procedures (Fig 4a, 4b).

Root canal infections are polymicrobial, characterised predominantly by both facultative and obligate anaerobic bacteria (9). The necrotic pulp becomes a reservoir of pathogens, toxic consequences and their resultant infection is isolated from the patient's immune response. Eventually, the microflora and their by-products will produce a periapical inflammatory response. With microbial invasion of the periapical tissues, an abscess and cellulitis may develop. The resultant inflammatory response will initiate either a protective and/or immuno-
Opportunistic effect; additionally, it may destroy surrounding tissue resulting in the five classic signs and symptoms of inflammation; calor, dolor, rubor, tumor and pain. Patient evaluation and the appropriate diagnosis/treatment of the source of an infection are of utmost importance.

Patients demonstrating signs and symptoms associated with severe endodontic infection (Table I) should have the root canal system filled with calcium hydroxide and the access sealed. In the event of copious drainage, the access can be left open for no longer than 24 hours, the tooth then isolated with rubber dam, the canals irrigated and dried and calcium hydroxide inserted into the root canal space and the access sealed (10). The antibiotic of choice for periradicular abscess remains Penicillin VK; however, recent studies have reported that amoxicillin in combination with clavulinate (1gm loading dose with 500mg q8h for seven days) was a more effective therapeutic regimen (11). Systemic antibiotic administration should be considered if there is a spreading infection that signals failure of local host responses in abating the dispersion of bacterial irritants, or if the patient's medical history indicates conditions or diseases known to reduce the host defense mechanisms or expose the patient to higher systemic risks. Antibiotic treatment is generally not recommended for healthy patients with irreversible pulpitis or localised endodontic infections (Table II).

Numerous studies with well-defined diagnosis and inclusion criteria failed to demonstrate enhanced pain resolution beyond the placebo effect (12, 13). Systemic antibiotic administration should be considered if there is a spreading infection that signals failure of local host responses in abating the dispersion of bacterial irritants, or if the patient’s medical history indicates conditions or diseases known to reduce the host defense mechanisms or expose the patient to higher systemic risks. Antibiotic treatment is generally not recommended for healthy patients with irreversible pulpitis or localised endodontic infections.

The sophistication of endodontic equipment, materials and techniques has been steadily iterated and innovated since the second survey. The microscope first introduced to otolaryngology around 1950, then to neurosurgery in the 1960s, is now standard of care for the voyage into the microcosmic world of the root canal space. Recursions in the micro-processing technologies of electronic foramenal locators brought unprecedented accuracy lev-
els, improved digital radiographic sensors and software enhanced diagnostic acumen, and ultrasonic units with a variety of tips designed specifically for use when performing both nonsurgical and surgical endodontic procedures minimised damage to coronal and radicular tooth structure in the effort to locate the pathways of the pulp. The treatment outcome of non-surgical root canal therapy at this point in time is far more predictable than at any other period in our history.

Diagnosis

Of all the technologic innovations embraced by endodontics, digital radiography should have generated the greatest impact; however, its value remains limited in diagnosis, treatment planning, intraoperative control and outcome assessment. Flat field sensors still require three to four parallax images of the area of interest to establish better perception of depth and spatial orientation of osseous or dental pathology. These three-dimensional information deficits, geometric distortion and the masking of areas of interest by overlying anatomy or anatomic noise are of strategic relevance to treatment planning in general and in endodontics specifically (14), (Fig 5a, 5b).

Cone beam computed tomography (cbCT) produces up to 580 individual projection images with isotropic submillimeter spatial resolution enhanced by advanced image receptor sensors; it is ideally suited for dedicated dento-maxillofacial CT scanning. When combined with application-specific software tools, cone beam computed tomography can provide a complete solution for performing specific diagnostic and surgical tasks. The images can be resliced at any angle, producing a new set of reconstructed orthogonal images and studies have shown that the scans accurately reflect the volume of anatomic defects. The limited volume cbCT scanners best suited for endodontics require an effective radiation dose comparable to two or three conventional periapical radiographs and as such are set to revolutionise endodontics (15, 16) (Fig 6).

Three dimensional pre-surgical assessment of the approximations of root apices to the inferior dental canal, mental foramen and maxillary sinus are essential to treatment planning. The ability of cbCT to diagnose and manage dento-alveolar trauma using multiplanar views, the determination of the root canal anatomy and the number of canals, the detection of the true nature and exact location of resorptive lesions and the discovery of the existence of vertical and horizontal fractures outweigh concerns about the degree of ionising radiation and the risks posed (17). Provided cbCT is used in situations where the information from conventional imaging systems is inadequate, the benefits are essential for optimisation of the standard of care.

Patel reported that periapical disease can be detected sooner and more accurately using cbCT compared with traditional periapical views and that the true size, extent, nature and position of periapical and resorptive lesions can be accurately assessed (18). Using a new periapical index based on cone beam computed tomography for identification of apical periodontitis, periapical lesions were identified in 59.5 per cent by radiography and 60.9 per cent of cases by cbCT respectively (P < .01). Simon et al compared the differential diagnosis of large periradicular lesions with traditional biopsy. The results suggested that cbCT might provide a faster method to differentially diagnose a solid from a fluid-filled lesion or cavity, without invasive surgery (19). In spite of the presence of artifacts, the learning curve related to image manipulation and the cost, cone beam tomography will invariably be the accepted standard of diagnostic care and treatment planning in endodontics in the very near future.

Access

An improperly designed access cavity will hamper facilitation of optimal root canal therapy. If the orientation, extension, angulations and depth are inaccurate, retention of the native anatomy of the root canal space becomes precarious. The requirements of access cavity design can be achieved by conceptual and technical regression of the existing configuration to that which one would logically expect to have seen prior to the insults of restoration, function and aging.

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Despite research supporting the effectiveness of coronal barriers and the need for their immediate placement as a component of the completion phase of root canal treatment, a universally accepted protocol does not exist. Schwartz and Fransman have described a clinical strategy for coronal sealing of the endodontic access preparation that lists the following considerations in the protocol:

- Use bonded materials (4th generation (three step) resin adhesive systems are preferred because they provide a better bond and allow more resin to infiltrate the dentin that require fewer steps)
- “The etch and rinse” adhesives are preferred to “self etching” adhesive systems if a syngel containing sealer or temporary material is used, “self etching” adhesives should not be used with self-cure or dual-cure restorative composites, when restoring access cavities, the best esthetics and highest initial strength are obtained with an incrementally filled technique with composite resin, a more efficient technique which provides acceptable esthetics is to bulk fill with a glass ionomer material to within two mm to three mm of the cavo-surface margin, followed by two increments of light-cure composite and a retention of a crown or bridge abutment is a concern after root canal treatment, post placement increases retention to greater than the original state (19)

**Irrigation**

The complex anatomy of the root canal space presents a daunting challenge to the clinician who must debride and disinfect the corridors of sepsis with asepsis to achieve a successful treatment outcome (see Fig 10). In addition, the absence of a cell-mediated defense (phagocytosis, a functional host response) in necrotic teeth means the microorganisms residual in tubuli, cul de sacs and arborisations are mainly affected by the redox potential (reduction potential) that reflects the oxidation-reduction state of the environment – aero- bic microflora can only be active at a positive Eh, whereas strict anaerobes can only be active at negative Eh values) and availability of nutrients in the various parts of the root canal (23). While our knowledge of persistent infections is limited, the need for their immediate removal as a component of the canal seal system (24, 25).

If tertiary dentin were perceived of as “irritational dentin” or dystrophic calcification considered “decay”, the chamber outline could be used to blueprint an inlay configuration for the access design that literally replicates the “virgin” tooth (Fig 7).

Removal of the existing restoration in its entirety and/or preliminary preparation of the coronal tooth structure for the subsequent full coverage restora tion will identify decay, fractures, unsupported tooth structure and expose the anatomy of the underlying root trunk periphery which assists in discovery of the spatial orientation and morphology of the roots. The pulp chamber ceiling and pulp stones can be peeled away with a football diamond bur to grossly identify the primary orifices. Micro-etching (Danville Materials, San Ramon CA) the floor of the chamber, perhaps the most underused of all access tools, is invaluable in the exposure of fusion lines and grooves in order to identify accessory orifices.

Troughing with ultrasonic tips of any design is used solely to trace fusion lines, not effect gross removal. The use of ultrasونics to “jackhammer” pulp stones is simply too risky as one approaches the floor of the chamber, particularly if there are no water ports on the tips. Orifice lengthening and widening enables straight line glide path to the apical third. The strategic objective is not to impede the file, stainless steel or nickel-titanium rotary along the axial walls with minimal denoi removal (Fig 8a, 8b).

It is equally as important to produce a high quality coronal restoration at the time of sealing the root canal system (26, 27).
however, the protocols used today cannot predictably provide sterile canals. As none of the elements of endodontic therapy (host defense system, systemic antibiotic therapy, instrumentation and irrigation, interappointment medicaments, permanent root filling, and coronal restoration) can alone guarantee complete disinfection, it is of utmost importance to aim at the highest possible quality at every phase of the treatment. In the classic study by Sjögren et al, 55 single-rooted teeth with apical periodontitis were instrumented and irrigated with sodium hypochlorite and citric acid. Post-treatment cultures yielded no bacteria in 94 per cent of cases, which was more effective at solubilizing organic dentin particles and powdering den- tin than EDTA. In addition, citric acid has demonstrated antibacterial effectiveness.

NaOCl is the most widely used irrigating solution. It is a potent antimicrobial agent and lubricant, which effectively dissolves pulpal remnants and organic components of dentin thus preventing packing infected hard and soft tissue into the apical con- fines. Hypochlorous acid (HClO) and hypochlorite (ClO⁻) are the active moiety responsible for bacterial inactivation. NaOCl is used in concentrations varying from 0.5 per cent to 5.25 per cent. The in vitro and in vivo studies differ significantly in terms of the effectiveness of the range of concentrations as the in vitro experiments provide direct access to microbes, higher volumes are used and the chemical milieu complexity of the natural canal space are absent than in the in vivo experimentation. A study by Siqueira et al 26 showed no differ- ence (in vitro) between one per cent, 2.5 per cent and give per cent NaOCl solutions in reducing the number of bacteria during instrumentation. What has been shown is that the tissue dissolving effects are directly related to the concentration used 26.

Perhaps the most misunder- stood aspect of NaOCl irrigation is the need for the quantities of irrigation required due to the morphologic and anatomic vari- ations in the volumetric size of the root canal anatomy. Siqueira showed that regular exchange and the use of large amounts of irrigant should maintain the antibacterial effectiveness of the NaOCl solution, compensating for the effects of concentration 26. Numerous devices have appeared in the endodontic arma- mentarium to address this situation; EndoVac (Discus Dental) – a negative pressure differen- tial device designed to deliver high volumes of irriga- tion solution while using apical nega- tive pressure through the officer high volume evacuation system, Negative Pressure Safety Irriga- tor (Vista Dental, Racine WI) – device is similar to EndoVac, Rinseendo (Air Techniques, Co- rona CA) uses pressure suction technology; 6/5ml of irrigant are automatically drawn from the attached syringe and aspirated into the canal (pressure created is lower than manual irrigation), Viberinge (Bisco Canada, Rich- mond BC) – sonic flow technolo- gy facilitates enhanced irrigation through the myriad complexities of the root canal system (Fig 11).

NaOCl cannot dissolve in- organic dentin particles and thus prevent smear layer for- mation during instrumentation 26, Chelators such as EDTA and citric acid are recommended as adjuvants in root canal ther- apy. It is probable that biofilms are detached with the use of che- lators; however, they have lit- tle if any antibacterial activity. Several studies have shown that citric acid in concentrations ranging as high as 50 per cent was more effective at solubilizing inorganic smear layer components and powdered den- tin than EDTA. In addition, citric acid has demonstrated antibacte- rial effectiveness.

Technology and innovation will not negate the need for op- timal preparation (debridement and disinfection) to eliminate microbial content and its impact on a necrotic root canal system. We as a discipline need to be bet- ter; however, by the same token, endodontics has shown its com- mitment to endless reinvention. In time, that will restructure the role of natural teeth in founda- tional dentistry, currently di- minished by the market forces of implant driven dentistry. Or- thodontic replacement is not a panacea as random clinical trials increasingly show; the se- verity of peri-implantitis lesions demonstrates significant vari- ability and as such no treatment modality has shown superiority. The pendulum will continue to swing as the endodontic implant algorithm becomes increasingly multivalued. 27, 28 Part 2 in next issue, including references

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