Recent Advances in Endodontics- A Review

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ABSTRACT:
Contemporary endodontics has seen an extraordinary progress in innovation and materials. This article is aimed to review some of challenges and advances in the following sections: (1) Diagnosis of pulp vitality, (2) endodontic imaging, (3) root canal disinfection, (4) root canal preparation, (5) root canal filling and (6) visualization. The above mentioned advances aims to improve the art and science of root canal treatment.

Keywords: Canal preparation, Disinfection, Imaging, Orascope.

INTRODUCTION

Diagnosis in dentistry may be defined as " the process whereby the data obtained from questioning, examining and testing are combined by dentist to identify deviations from the normal".[1] Past couple of decades have witnessed a cascade of most rapid and extensive technological evolution in field of dentistry. Era of diagnosing vitality of pulp and fractures have evolved from conventional technique to modern method, root canal preparation from stainless steel to Ni-Ti files and root canal filling materials in field of endodontics. The scenario in radiographic assessment, which is indispensable adjunct to clinical examination in endodontics has also seen progression from traditional radiology to an advanced and more accurate imaging techniques.

Development of visualization in field of endodontics with the usage of loupes and microscopes have offered a break through. This helped in overcoming the limitations faced with naked eyes in detection of missed canals, incipient caries, fractured tooth, etc. This articles shows a review of recent advances in endodontics.

ADVANCES IN DIAGNOSTIC VITALITY OF PULP

Laser Doppler flowmetry

This is a non-invasive, objective, painless, semi-quantitative method that is more reliable in measuring blood pressure to pulp. Laser light is transmitted to pulp by means of fibro optic probe.[2] Fibro optic probe transmits laser light to pulp. This method uses Helium Neon (HeNe) and Gallium Aluminium (Ga-Al) as semiconductor diode lasers at power of 1 to 2 mW. HeNe has wavelength of 632.8nm and wavelength of semiconductor diode laser is 780 to 820 nm.[3] The ideal position to place the probe is 2 to 3 mm from the gingival margin.[4] The scattered light from moving red blood cells in the circulation will be frequency shifted while those from static tissues remains unshifted.Doppler's shifted and unshifted reflected light is returned via afferent fibres and a signal is produced. Vitality of pulp in both adults and children can be estimated successfully by this technique.[5](Figure 1)

Pulse Oximetry

The determination of percentage of oxygen saturation of the circulating arterial blood is defined as "Oximetry".[6] It is a relatively

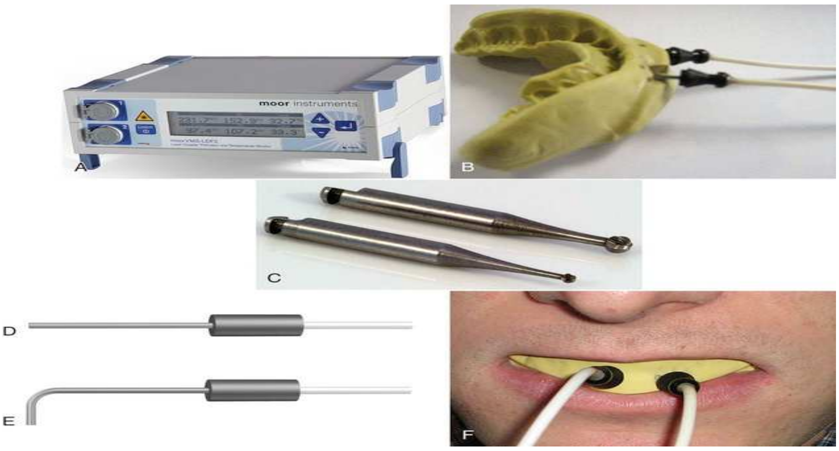

Figure 1: Laser Doppler Flowmetry

inexpensive procedure which is commonly used in anaesthetic procedures.[7] It readily differentiates between vital and non vital teeth. There is color difference between oxygenated haemoglobin and deoxygenated haemoglobin and therefore different amounts of red and infrared lights are absorbed. This method calculates pulse rate and oxygen saturation level in targeted vascular area.[6]

The principle on which pulp oximetry works is, the use of photoelectric diode that transmits light into wavelengths. The probe is placed on labial surface of tooth crown and palatal surface has sensor on it. Ideally probe is placed on the middle third of crown as disturbance from gingival circulation or any gingival trauma or bleeding will interfere with readings if placed on gingival third. This is useful in cases of impact injuries where nerve supply is damaged. Pulpal circulation can be detected independent of gingival circulation. Vital teeth with pulpal inflammation can be detected by this method.[8](Figure 2)

Figure 2: Pulp Oximetry

Dual Wavelength Spectro-Photometry

This method is not dependent of a pulsatile circulation. Detection of pulse in pulp space is difficult as arterioles are encapsulated by rigid dentin and enamel. This method measures oxygenation change in capillary bed. At 760nm and 850 nm, DWLS detects presences or absences of oxygenated blood.[9](Figure 3)

Figure 3: Dual Wavelength Spectrophotometry

Ultrasound Doppler or Color Power Doppler

This method detects and elicits the direction of blood flow within the tissue observed. Power Doppler in accordance with Color Doppler enhances its sensitivity to low flow rates. It works on principle of integrated power spectrum and can disclose the smaller vessels. Recent assessment of this device shows origin of the signals could also be detected with the aid of different Doppler graphic wave forms and sounds in vital teeth as well as non-vital teeth. "Pulsating" wave form is seen in vital teeth while linear non pulsed wave form is seen in root canal treated teeth.[10] Echogenicity of area of interest is further increased by injecting contrast media intra venously.[11,12](Figure 4)

Figure 4: Ultrasound Doppler Or Color Power Doppler

Photoplethyesmography

It detects blood volume anomalies in micro vascular bed of tissue by optical measure technique. Opto-electronic components require are: (1) A light source to illuminate the tissue (2) To measure the small changes in light intensity in relation with the changes in perfusion photo-detector is used. The circulatory anomalies in the human dental pulp can be detected by photoplethyesmography. Haemoglobin absorbs specific wavelength of light and remaining light passes through the tooth and is detected by receptor. Cholesteric Liquid Crystals (chiral-nematic liquid crystals) are helical structured, arranged along the long axis. As they are thermochromic, these crystals are easily affected by temperature or pressure because of their fluidity. Howell et al in Lexington 1970 studied this and stated that detection of pulp vitality is based in principle that the teeth in intact pulp blood supply would have higher tooth surface temperature compared with the teeth that had no blood supply.[13](Figure 5)

Figure 5: Photoplethyesmography

RECENT ADVANCES IN IMAGING

Radio-visio-graphy(RVG)

Radio-visio-graphy (RVG, formerly Trex-trophy Radiology Inc., Marrietta, GA)was the very first system that was introduced in digital radiography in dentistry by Trophy in France in 1987. Digital radiography refers to a method that captures radiographic images with the help of sensor of a solid-state technology that breaks it into electronic pieces, and presents and stores the images through a computer. The currently available digital radiography system for use in dental imaging are: (1) CCD - Charged Couple Device (direct system), (2)CMOS- Complementary Metal Oxide Semiconductor(direct system), (3)PSP- Photo Stimulable phosphor (indirect system). When compared to conventional plain film radiography it has 80% reduction in radiation dose which is one of the most commonly cited positive features. The range of 50-60% is the estimated dose reduction for intraoral digital imaging when compared to E-speed film for extra oral digital imaging, 50-70% when compared to film screen combinations. The short processing time, i.e. the ability to view the image more quickly, the elimination of darkroom, processing chemical and the errors associated with improper dark room maintenance, chemical handling, solution replenishment and replacement are few of the other obvious advantages.This allows manipulation of image without any additional radiation exposure.[14]

Computer tomography(CT)

It works on principle of multiple exposures around an object by a narrow fan shaped beam that reveals its internal structures which help the clinician to view morphologic and pathologic features in three dimensions.[15]The mesio-distal and bucco-lingual extent of the pathology is determined by it. CTs have four generations. The Hounsfield's unit was first generation CT scanner that utilised single detector element to capture the beam of X-rays. In 1975 CT systems were introduced that used more than one detector and used small fan beam. Translate-rotate design was used in 1st and 2nd generation CTs. These were used to scan only head. A large arc shaped detector that acquires an entire projection without the need for translation, which is most commonly used today in 3rd generation CT introduced in 1976. Replacement of arc shaped detector is made by fourth generation scanner. The development of power slip ring facilitated development of spiral (or helical or volumetric) CT in the late 1980s. Multi-sclice CT scanner utilized presently have a straight cluster of numerous locators (upto 64 columns) that at the same time secure tomographic information at various cut areas. Not withstanding, they are costly and may have restricted utilization in maxillofacial finding. CT was the primary innovation to permit representation of both hard and delicate tissues of the facial bones by picture preparing upgrade and the capacity to procure various, non-superimposed cross sectional pictures. CT pictures can demonstrate cuts of a given tissue, with every cut thickness (1-2mmm) and area picked by the administrator.[16]CT displays consummate perception of impacted teeth and their relationship to the close-by anatomical structures, which is basic requirement for surgical expulsion of impacted teeth.CT helps to prevent endodontic treatment failure by detecting multiple extra root canals. CT has been used as research tool for comparison of the volume of root canals before and after instrumentation with different rotary nickel-titanium[17] systems and for volumetric analysis of root filling using various obturation systems.[18](Figure 6)

Figure 6: Computed Tomography

Tuned aperture computed tomography (TACT)

Developed by webber and colleagues, this is a faster method is by which tomographic images can be re-established.[19] It runs on principle of tomo-synthesis and optical-aperture theory.[20] Its overall radiation is not higher than 1-2 times that of a conventional periapical X-ray film. Its resolution is similar to 2-D radiographs. Webber et al[21] in 1999 also found it to be diagnostically more informative. This type of computed tomography had proved to be effective determination of fracture, especially vertical fracture. It lies at the trial organize in dental application.

Cone beam computed tomography(CBCT)

The principle behind this imaging technique is a cone-shaped X-ray beam centred on a 2D detector. Aboudara et al[22] in 1984 developed a modified version of the original cone beamed algorithm in which single rotation is performed by the beam around the object and produces a series of 2D images which are reorganised in 3D image. Its subjective image quality is higher than helical computed tomography. It elicits a high special resolution of bone and teeth which makes it better, to understand about the relationship of adjacent structures. Various cysts, cancerous lesion, infections, developmental discrepancies and traumatic injuries involving the maxillofacial structures can be identified by the help of its high resolution. It relies on upon different viewpoints, for example, the size and state of detector, beam projection, geometry and the capacity to gather the beam. Vast field of view units ranges from 15-23 cm. These units have most beneficial applications in endodontics.[23](Figure 7)

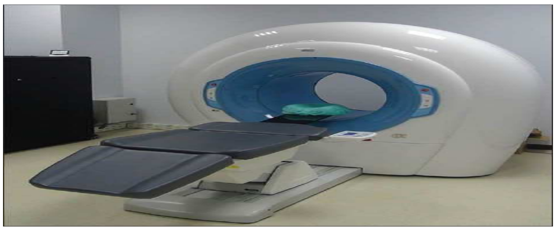

Figure 7: Cone beam computed tomography

ADVANCES IN ROOT CANAL DISINFECTION

The key challenge for effectiveness of disinfection in endodontics are root canal system and structures and composition of dentin.Sodium hypochlorite (a topical antimicrobial) that is usually utilized as a part of battle microbial biofilms. Its powerlessness to take out biofilm microbes in the anatomical complexities and uninstrumented segments of root canal would trade off their viability in root canal treatment. Along these lines, steps taken to enhance the delivery of irrigation (irrigation dynamics) inside the root canal framework are pivotal to accomplish the most extreme viability out of antimicrobials.[24]

Antibacterial Nanoparticles

These are microscopic particles with one or more dimensions in the range of 1-100nm. They have properties that are very unique form their bulk counterparts. They have been found to have a broad spectrum of antimicrobial activity and far lower propensity to induce microbial resistance.The loss of permeability of membrane and quick loss of membrane capacity is because of the electrostatic interaction between emphatically charged NPs and adversely charged bacterial cells, and the amassing of the vast number of NPs on the bacterial cell film.[25] Superior ability to diffuse the antibacterial component deep into the dentin is shown by sealers loaded with NP.[26]Right now practically NPs are being created to take out microorganisms all the more particularly without harming host cells(targeted antibacterial efficacy) and to repair already infected dentin matrix.[27]

Antimicrobial Photodynamic Therapy

It is a two-step procedure that involves (1) the application of photosensitiser (PS), (2) followed by light illumination of sensitized tissue, which generates a toxic photochemistry on the target cell causing microbial killing. It is considered a possible supplement rather than an alternative to the existing protocol of root canal disinfection.[25] In an approach to adapt and improve the antimicrobial efficacy of APDT in endodontics. Recent researches display their effectiveness in penetration into dentinal tubules, anatomical complexities and antibiofilm properties.[28, 29]

Photon- Induced Photoacoustic Streaming

It depends on the immediate shock wave produced by erbium:YAG (ER:YAG) laser (Fidelis AT; Fotona, Ljubljana, Slovenia)in a fluid irrigant. It has laser framework outfitted with a fiber-optic conveyance tip and sub ablative parameters to deliver the wanted impact. At the point when enacted in a restricted volume of liquid, the high absorption of ER:YAG wavelength combined with the high peak power derived from the short pulse duration brought about an improvement bubble progression, which irrigant flowdynamics inside the root canal. The present writing presents clashing discoveries on this innovation.[30-32]

Gentlewave Irrrigation

It has been developed and tested for root canal irrigation. It delivers sodium hypochlorite into root canal under pressure through a specialized handpiece, which is activated by a broad spectrum acoustic waves and simultaneously suction removes the outflowing fluid through the handpiece. A tight seal is created by silicon ring surrounding the extremity of handpiece with a flat tooth surface. A vented and closed loop fluid flow within the root canal is established by this. GW system to disinfect root canal biofilm is still under trial.[33]

ADVANCES IN ROOT CANAL PREPARATION

Antimicrobial effectiveness[34] assesses all treatment steps in endodontic need and canal preparation is not an exception. Intra-canal tissue (in vital cases) and necrotic material including microbial biofilms (in necrotic cases) is removed by root canal preparation. Irrigation solution as well as interappointement medication is accepted by an adequately shaped canal and is ultimately filled optimally.

Endodontist use engine driven instrumentation more frequently as compared to hand instruments. At this point, several trend which are observed in the market place are as follows:

a. Usage of more flexible alloys, which not only promises better canal negotiation but also extends the fatigue life.
b. Practice of reciprocation motion and potentiallylessening of the quantity of instruments utilized per patients.
c. Introduction of instruments that are designed to instruments a larger area of the canal wall and decrease the need for coronal flaring.[24]

Nickel-titanium (Ni-Ti) alloy has specific metallurgical properties which makes it to be manufactured, for example, predominantly at body temperature it is either in austenitic or martensitic crystal configuration.[35] Crystal configurations of these two have distinctly different properties, with austenite being less flexible but allowing upto 7% recoverable elastic deformation range.[36] Martensite conversely can be dead-soft and very flexible but only allows 2% linear strain before non-recoverable plastic deformation occurs. It is observed that martensitic files have significantly extended life spans because of these differences in flexibility, distinct differences in fatigue resistance.[37] Some martensitic instruments are designed to have deformation removed during sterilization cycles while re-processing; however, regular certain residual deformation still remains. Production and development of specific heat treatment continues that includes fine tuning of crystal conversion temperature, making instruments on shelf very flexible and behaving more rigidly when placed in root canals.[38]

Electric motors are currently being used by most practitioners to power rotary instruments. These motors are also under development process. Most electric motors have ability to set a torque limit but many models currently allows reciprocating action.[39] Several Ni-Ti instruments have been developed entirely for reciprocation motion with unequal angles of rotation. Efficiency and safety has been shown by reciprocation movements.[40] Fatigue lifespan in particular, of a file is extended with reciprocation design.(Table 1)

ROOT CANAL FILLING

Synthetic materials fills up the root canal system to complete a root canal treatment in a mature tooth. An anticipated other option to this system is right now tricky. In the future it may be possible to attract pulp like tissue into the cleaned and shaped root canals.[41]The interpretation of tissue engineering concepts to regular clinics has however not yet been madeand thus to fill the root canals the current focus will still remain to improve the conventional approach.

A hermetic seal against microorganism is primarily expected to be provided by the root filling which is tissue friendly, easy to apply, monitored, and retrieve in case of treatment failure. Current filling materials doesn't always meet up these requirements. A so called hermetic seal is not easy and to achieve it is core of the problem with current materials.[42, 43]

To improve and simplify root-filling procedure two related concepts have evolved over the recent years. To use a calcium silicate cement based sealer is the first approach, which are sealers that are initially flowable and express bioactive properties,[44,45] i.e., they promote Ca/P precipitation in a wet environment. In inherently wet root canal system the use of bioactive filling materials is logical.[46] Calcium phosphate is the interface that forms between sealer and root canal wall and thus, mimics nature. A core material is still necessary as calcium silicate cements sets hard, which remains to be gutta-percha.[45] Consequently, root fillings with calcium silicate cements still have two interfaces:

a. Between the sealer and canal wall, and
b. Between the sealer and gutta purcha.[47]

Hence, the root filling conundrum is not solved by calcium silicate sealers.

Bioactive particles were embedded in the matrix in (polycaprolactone) of the core filling material in the recent approach.[48] This matrix material was thermo plasticized and used as the sole material to fill the root canals thus lessening the interface amongst filling and tooth to one, with rather encouraging outcomes in vitro. However, as it is biodegradable,[49] polycaprolactone doesn't appear to be an ideal material for root fillings. Nanomatric bioactive glass particles of the 45S5 type embedded in gutta percha matrix was used in later approach.[50] Immediate sealing properties when applied in heated form were shown by these materials in contrast to conventional gutta percha. The self-adhesiveness of a premarket radiopaque material to the root dentin and its tissue compatibilitywas later introduced and tested. Though the initial in vitro results were promising, these material has yet to be scrutinized clinically before final recommendation.[51]

Some of the challenges in current root filling are complex application schemes and uncontrolled/extended thermal shrinkage. Newer nanomaterial based approaches are showing promise for the future.

Resilon Epiphany

One relatively recent approach to enhance the sealing ability of root filling comes from the field of obturation materials. Based on dentin adhesion technologies borrowed from restorative dentistry obturation materials and sealers were developed. The resilon epiphany obturation system (pentro clinical technologies, Wallingford, CT,USA) introduction has challenged the traditional gutta percha obtuartion materials.[52]

The epiphany primer (sulfonic acid-terminated functional monomer, 2- hydroxethyle methacrylate, water, and polymerisation initiator) conditions the dentinal surface of root canal, demineralising it, and exposing the collagen matrix. The epiphany sealer (bisphenlyglycidildimethacrylate, ethyoxy-latededbisphenylglycidyl dimethacrylate, urethane dimethacrylate, hydrophilic difunctional methacrylates, calcium hydroxide, barium sulfate, barium glass, bismuth oxychloride, and silica) bonds to both the root dentine and relison cones (polycaprolactone, bioactive glass, bismuth oxychloride, and barium sulfate) to form a single unit, termed a "monoblock". The clinical use of this material is exactly like gutta percha in that it can be applied with warm and cold obturation techniques.[52]

RECENT ADVANCES IN VISUALI-ZATION

Endoscopes

Hippocrates in 377 BC used primitive tube like instruments for endoscopy.[53] In 1960 a breakthrough in optical quality was achieved by an English physician, Hopkins. He made bar focal point arrangement that prompted to imperative headway in the field of view, magnification, and focal length of the endoscope, bringing about a clearer picture.[54]

The use of rod lens endoscope in endodontics were helpful in diagnosing dental fractures. Rigid glass rods used in apical surgery and non-surgical endodontics are traditional endoscopes used in medical procedures. As compared to the microscopes and the loupes it gives better magnification and better clarity. The non fixed field of vision are provided by rod lens endoscopes.[55,56](Figure 8)

Table: 1 File systems introduced after 2010

Name of File	Year of Introduction	Tip	Taper	Unique Features
Self Adjusting File(SAF)	2010	Pointed cylinder	Adapts to canal	Design Up & down, back &froth motion
Bioracce	2011	Non-cutting safety tip	Constant taper	Electrochemical surface treatment Alternating cutting edge
Hyflex	2012	Safety tips	Constant taper	Controlled memory NiTi files
Wave one	2012	Modified tip	Variable taper	Reciprocating motion
Revo-S	2012	Inactive tip	Constant taper	Different radiuses, R1, R2 and R3
One Shape	2013	Safety tips	Constant taper	Variable cross section
ProTaperNext	2013	Modified tip	Variable taper	Unique Asymmetric Rotary M wire technology

Use of Dental Endoscopes

- As a diagnostic tool
- To enhance visualization
- Apical surgery[57]
- Trans illumination[58]

Endoscopic Observation during Endodontic Treatment

- To detect and remove the remaining dental pulp tissue following cleaning and shaping of the root canal walls
- Lateral canals and microscopic roots cracks are usually detected with high accuracy, providing better intra-operative judgement and facilitating adequate treatment.

Orascope

For intracanal visibility an adaptable fibro optic orascope having a point 0.8mm tip measurement, lens having 0° focal point, and a working segment that is 15mm long is prescribed. Use of either the rigid rod lens and endoscope or the flexible orascope in the oral cavity describes the term oroscopy. It is used in endodontics for visualization in conventional and surgical endodontic treatment.[55](Figure 9)

A camera, light source and a monitor and conjugated with orascope and endoscope. The documentation can be maintained with the help of printer or a digital recorder.

Fiberoptics are made up of glass or plastic. The advantages of fiberoptics in endodontics are significant, they are:

1. Small
2. Lightweight
3. Very flexible

Orascopic Visualization Technique For Conventional Endodontics Treatment

Visualization within the canal system is done by 0.8mm orascope. Penetration into a canal by orascope is enabled by a smaller fiber-optic. Coronal 15 mm of the canal must be prepared to a size of no.90 file before the placement of 0.8mm fiber-optic scope. A wedging of the probe may occur if the canal is not instrumented to this diameter, harming a portion of the filaments inside the scope. Full 15mm of the orascope will penetrate within the canal by appropriate preparation. Because of its limited flexibility the orascope may not be able to visualized a curved canal. Canal must be dried before utilization of the 0.8mm extension. This permits the orascope to give imaging of the apical third of the root without really being situated inside this locale of the canal.[55]

Endodontics Visualization System

This system which is recently introduced incorporates both endoscopy and orascopy into one unit. Two methods of documentation are possible by EVS. S-video camera is used in the EVS which helps in documentation.

Currently introduced the **EVS-II** combines the fiberoptic orascope and a rigid endoscope. Optimal illumination and magnification for visualization during endodontic procedures is provided by this system. Design of this system provides comfort and high quality images.[59]

Dental loupes

It is most commonly used in magnification for apical surgery, these are basically two monocular magnifying lens with focal points mounted one next to the other and angled inwards to centre an object. Magnifying telescopes are sometimes called as 'loupes'. Types of loupes available are: (1) Simple as a flat, single-element magnifier (2) complex as a multiple element telescope. Classification of loupes is done by optical method in which they produce magnification.

Single Lens: it is made up of simple magnifying lens. It offers the advantage of being inexpensive but at the same time are less desirable because of their plastic lenses that are used are not always optically correct. It can also compromise on posture and create stresses and abnormalities in musculoskeletal system.[55]

Galileian Lens Loupes: Galileian magnification ranging from 2X to 4.5X is provided by this loupes. It is a small, light and very compact system.

Prism Loupes: Prism is optically advanced type of loupe magnification available today. Refractive prisms which are actually telescopes with complicated light paths, providing magnification upto 6X are used in this system. Prism loupes provide larger field of view, wider depth and longer working distance than other types of loupes.[59]

Operating Microscope

Otolaryngology pioneered the use of surgical operating microscope around 1950, followed by neurosurgery in 1960s, and endodontics in early 1990s. Magnification of 40X is obtained of most microscopes. Fractures, POEs and canal isthmuses can be readily seen and dealt in better way by surgical operating microscope.

Recent improvements in microscope devices are: positioning on surgical field, balancing over complete range of movement, obtaining proper focus, as an educational tool.[59](fig-10)

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