Review Article

Role of magnification in conservative dentistry and endodontics in today's practice- a review of literature

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Received: 10-02-2016
Revised: 16-03-2016
Accepted: 18-04-2016

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ABSTRACT

Dentistry has become more sophisticated and complex thus requiring precised motor skills and visual acuity. Optical magnification has expanded the horizons of dentistry. During past decades, dentistry has not only evolved clinically but the histological aspects has also played an important part in the development of new materials as well as helped in better evaluation of treatment procedures. Hence this review article details about the possible alternatives of magnification such as magnifying glasses, dental loupes, optical microscopes, electron microscopes, surgical operating microscopes, endoscopes, and orascopes.

Key words: *Magnification, microscopes, types, dentistry, limitations*

Introduction

A necessary attribute in modern dentistry for clinical work is a high level of visual acuity, especially for near vision. A common way to achieve better vision is to effectively magnify the area of interest. Worschech CC et al [1] said that improved lighting, coupled with magnification, provides a clear distinction between surfaces that may look similar in color or texture under traditional working conditions. The clarity and details achieved with magnification are so vivid and revealing that the clinician will immediately recognize the potential for improved precision in both diagnostic and treatment procedures. According to Tascheiri S et al [2] magnification devices are beneficial for patients, in terms of ergonomics, vision, treatment success rate, treatment times, and total costs.

Magnifying Glasses [3]

A magnifying glass is a double convex lens which is mounted in a frame with a handle. (Fig. 1)

Principle: A magnifying glass works by creating a magnified virtual image of an object behind the lens. The distance between the lens and the object must be shorter than the focal length of the lens for this to occur. Otherwise, the image appears smaller and inverted, and can be used to project images onto surfaces. Branson BG et al [4] suggested a quantifiable change in acceptability of posture for clinicians wearing magnification lenses. A typical magnifying glass might have a focal length of 25 cm, corresponding to an optical power of 4 dioptres. Such a magnifier would be sold as a "X2" magnifier. [5]

Fig. 1 Magnifying glass

Loupes

The other most commonly used device for magnification is loupes. Rubinstien R [6] states that loupes are essentially two monocular microscopes with lenses mounted side by side and angled inward (convergent optics) to focus on an object. Pace SL [7] described 2 types of loupes a) the flip-up loupe (Fig.2), which is mounted on a bracket and attached to the frame of the eyeglasses. The attachment may be either a single hinge or a vertical attachment hinge and these can be flipped up when it is not needed. b) through-the-lens (TTL) loupes, (Fig. 3) which are less bulky and more esthetically pleasing. TTL loupes are also referred to as fixed telescopes. Prism loupes are the most optically advanced type of loupe magnification available today. They are actually low-power telescopes that use refractive prisms. Prism loupes produce better magnification, larger fields of view, wider depths of field, and longer working distances than other types of loupes.

Fig.2 Flip-up loupe

Fig.3 Through the lens loupe

Microscopes [8]

Microscopes enable the human beings to see those substances and organisms, which cannot be seen with the naked eye. The basic model of a microscope contains one or more lenses, which facilitates the enlargement of images kept in the focal plane of the lens. There are various types of microscopes, among them most common are called optical or light microscope, which further has three types - simple, compound and stereomicroscope. The others include electron microscopes, which are available as transmission electron microscope (TEM), scanning electron microscope (SEM), reflection electron microscope (REM) and scanning transmission electron microscope (STEM). The only difference between them is that the method of illuminating the objects vary as per the type.

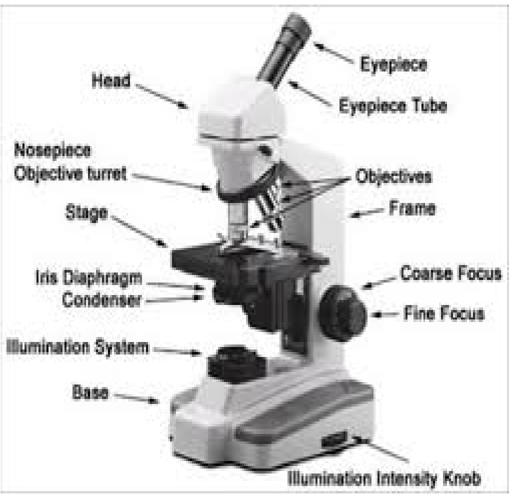

Fig.4 A compound microscope

Fig.5 A stereo microscope

Types of microscopes

Optical Microscopes [9]

The oldest and simplest form of microscope is the light microscope. These microscopes use visible light and a combination of lenses to enlarge the images of the samples. Two basic types of optical microscopes are simple and compound microscopes (Fig.4) The former bears a single lens, whereas the latter uses a combination of lenses. Other types of optical microscopes are stereo or dissecting microscope and digital microscope.

Stereomicroscopes

The stereo or dissecting microscope uses two separate optical paths with two objectives and two eyepieces to provide slightly different viewing angles to the left and right eyes which produce a three-dimensional visualization of the sample. A stereo microscope has a magnification up to X100 (Fig.5). The stereo microscope is often used to study the surfaces of solid specimens or to carry out works such as sorting, dissection, microsurgery, inspection. There are two types of magnification systems in it, a fixed magnification in which primary magnification is achieved by a paired set of objective lenses with a set degree of magnification and the other is zoom or pancratic magnification, which has variable degree of magnification across a set range. A compound microscope can resolve images upto 10 microns to 1.5mm in size, however a stereomicroscope can resolve from 0.5mm to 1.5cm.

Digital Microscopes [9]

Often called "USB" microscopes, they offer high magnifications (up to about X200) without using eyepieces. Such microscopes are less bulky than a conventional microscope and are economical. They can be attached to a laptop or computer.

Electron Microscopes (Fig.6) [10]

They use a beam of highly energetic electrons to illuminate the object and can produce highly magnified images (upto 1 million times). The original version of electron microscope, called transmission electron microscope, makes use of high voltage electron beam for the formation of image. Some parts of the sample may allow the beam to pass through it, while others scatter the beam. This information about the specimen is carried by the beam, which emerges from the sample, which in turn is magnified by the lens system.

Fig.6 Electron Microscope

Scanning Electron Microscope (SEM)

They can produce very high-resolution images of a sample surface, revealing details about less than 1 to 5 nm in size. A wide range of magnifications is possible, from about X10 (about equivalent to that of a powerful hand-lens) to more than X500,000,about X250 the magnification limit of the best light microscopes. The energy exchange between the electron beam and the sample results in the reflection of high-energy electrons by elastic scattering, emission of secondary electrons by inelastic scattering and the emission of electromagnetic radiation, each of which can be detected by specialized detectors. Electronic amplifiers of various types are used to amplify the signals which are displayed as variations in brightness on a cathode ray tube (CRT). The raster scanning of the CRT display is synchronised with that of the beam on the specimen in the microscope, and the resulting image is therefore a distribution map of the intensity of the signal being emitted from the scanned area of the specimen. The image may be captured by photography from a high resolution cathode ray tube, but in modern machines it is digitally captured and displayed on a computer_monitor and saved to a computer's hard disc.

Environmental SEM [11]

The accumulation of electric charge on the surfaces of non-metallic specimens can be avoided by using environmental SEM in which the specimen is placed in an internal chamber at higher pressure than the vacuum in the electron optical column. Positively charged ions generated by beam interactions with the gas, helps to neutralize the negative charge on the specimen surface. The pressure of gas in the chamber can be controlled, and the type of gas used can be varied according to need. Coating is thus unnecessary, and X-ray analysis unhindered. The first commercial ESEMs were produced by the ElectroScan Corporation in USA in 1988. ElectroScan were later taken over by Philips (who later sold their electron-optics division to FEI Company) in 1996. ESEM is especially useful for non-metallic and biological materials because coating with carbon or gold is unnecessary. ESEM may be the preferred for electron microscopy of unique samples from criminal or civil actions, where forensic analysis may need to be repeated by several different experts.

Surgical operating microscope

Most surgical operating microscopes have the capability to go beyond the magnification of X40. The lower magnifications (X2.5 to X8) are used for orientation to the surgical field and allow a wide field of view, mid range magnifications (X10 - X16) are used for operating and higher range magnifications (X20 to X30) are used for observing fine detail.[12] According to Christensen GJ, for procedures that have a limited operating field, use of a clinical microscope at magnification levels up to X20 has been shown to be a significant aid to quality treatment. [13]

According to Rubinstein R [12] areas where the surgical microscope can have great impact and consequence in clinical practice include

- visualization of the surgical field
- evaluation of surgical technique
- use of fewer radiographs
- patient education
- documentation for dental legal purposes
- video libraries for teaching programs
- marketing the dental practice
- less occupational stress

Working of a surgical operating microscope can be discussed under:

Magnification:

It is determined by the power of the eyepiece, the focal length of the binoculars, the magnification changer factor, and the focal length of the objective lens. Eyepieces are generally available in powers of X6.3, X10, X12.5, X16 and X20. Binoculars hold the eyepieces and are available in different focal lengths. The longer the focal length of the binocular, the greater the magnification and narrower the field of view. Straight tube binoculars are oriented so that the tubes are parallel to the head of the microscope. Inclined binoculars are oriented so that the tubes are offset at 45 degrees to the head of the microscope.

Straight tube binoculars are suggested because they allow the operator to look through the microscope directly at the surgical field by allowing the use of direct vision in both the arches. Inclined binocular tubes could be used for maxillary surgery, but the operator would have to use indirect vision through a mirror or position the patient's head sharply to the side while performing mandibular surgery and provide the operator with additional postural comfort during long procedures. The only disadvantages of inclinable tube binoculars is that they are difficult to engineer and as such can be quite costly.

Magnification changers are available as either three or five step manual changers or power zoom changers. A conventional three step changer has one set of lenses and a blank space on the turret without a lens. When the power of the eyepiece, the focal length of binoculars, and the focal length of the objective lens with the magnification changer lenses are factored, three fixed powers of magnification are obtained: two from each lens pair combination and one form from the blank space. The blank space produces magnification by factoring only the eyepiece, the focal length of the binoculars, and the focal length of the objective lens. A five step manual changer has a second set of lenses mounted on the turret and produces five fixed powers of magnification. A power zoom changer is merely a series that move back and forth on a focusing ring to give a wide range of magnification factors. These changers avoid the momentary visual disruption or jump that occurs with three or five step manual changers as the clinician rotates the turret and progresses up or down in magnification. Objective lenses are available with different focal lengths. A 200 mm lens focuses at about 8 inches and a 400 mm lens focuses at about 16 inches. A 200 mm objective lens is recommended because there is adequate room to place surgical instruments and still be close to the patient.

Magnification as it relates to eyepiece power, binocular focal lengths, magnification factors, and objective lenses, to depth of field and field of view can be summarized as follows: This can be explained based on the formula by Khayat BG [14]

TM = (FLT/FLOL) x EP x MV
TM: Total magnification.
FLT: Focal length of the tube
FLOL: Focal length of the objective lens
EP: Eyepiece power
MV: Magnification value

After considering all the factors just described, a typical microscope package could be one with X12.5 eyepieces, 125 mm straight or inclinable tube binoculars, a power zoom magnification changer, and an objective lens of 200 mm. This package would allow a clinician to operate comfortably about 8 inches from the patient and in the magnification range about X3 - X26. The power zoom feature would allow a smooth zoom with an 8:1 ratio.

Illumination:

The light source is a 100 watt xenon halogen bulb. The light intensity is controlled by a rheostat and cooled by a fan. The light is then reflected through a condensing lens to a series of prisms and then through the objective lens to the surgical field. After the light reaches the surgical field, it is reflected back through the objective lens, through the magnification changer lenses and through the binoculars and then exits to the eyes as two separate beams of light. The separation of the light beams is what produces the stereoscopic effect that allows the clinician to see depth of field. Khayat BG [14] states that in order to deflect a certain percentage of light from the eyepiece towards the accessories, a beam splitter can be inserted in the pathway of light it returns to the operator's eyes. The function of a beam splitter is to split the beam at a 50:50 ratio (i.e. half of the light is always available to the operator and rest of the light is provided to the accessories so that assistants can follow the procedures precisely and efficiently).

Two light source systems are commonly available: the xenon halogen bulb used in a fan cooled system and the quartz halogen bulb, which is found in the fibreoptic light system used by ophthalmologists. A fan cooled xenon halogen light system is recommended because fibreoptic cables absorb light and have a tendency to be light deficient. In addition xenon halogen is brighter and warmer than quartz halogen against bone and soft tissues.

Documentation:

The ability to produce quality slides and videos is proportional to the quality of the magnification and illumination systems within the microscope. The beam splitter, which provides the illumination for photographic and video documentation, can be connected to photo and cine adapters. The function of these adapters is to attach the 35 mm video cameras to the beam splitter. Photo and cine adapters also provide the necessary focal length so that the cameras record an image with the same magnification and field of view as seen by the operator.

Accessories:

Pistol grips of bicycle handles can be attached to the bottom of the head of the microscope to facilitate movement during surgery. An eyepiece with a reticle field can prove an invaluable aid for alignment during videotaping and 354 mm photography. Observation ports can be added to the microscope by a beam splitter that can be helpful in teaching situations. Auxiliary monocular or articulating binoculars or a liquid crystal display (LCD) screen can also be added and used by a dental assistant.

Learning to use an operating microscope

Worschech CC et al [1] have said that microscope must be placed in a position that allows maneuverability around the head of the patient without restricting the clinician's access to the oral cavity. The arms of the microscope must support the weight of the binocular head and any accessories and there must be enough space for all the parts to move freely. The clinical procedure is most efficient when the patient's head, the mirror or the chair are moved during the treatment, rather than microscope's head or arm. Most general practitioners feel that an operating position that approximates the 12 O' clock position is the most convenient when working with operating microscope.

Friedmann MJ and Landesman HM [15] said that although the learning curve can be lengthy and difficult, the authors believe that the clinical benefits of Microscope - Assisted Precision Dentistry for the patient, the operator and the profession are well worth the efforts required. Kim S and Baek S [16] have mentioned the key prerequisites for the use of the microscope in nonsurgical endodontic procedures as rubber dam placement, indirect view and patient head position, mouth mirror placement, and some key instruments. Specially designed microinstruments help in performing conservative procedures more efficiently. Files specially designed by Maileffer, called micro-openers, with different sized tips and can be extremely useful. These hand held files allow the clinician to negotiate and confirm its presence at the area where it was suspected.

Limitations of a surgical operating microscopes [12]

Magnification:

Working at higher magnification is extremely difficult because slight movement by a patient makes the field out of view and out of focus. A constant recentering and refocusing the microscope wastes a lot of time and creates unnecessary eye fatigue.

Illumination:

As magnification is increased the effective aperture of the microscope is decreased and therefore the amount of light that can reach the surgeon's eyes is limited, this means that as higher magnifications are selected, the surgical field appears darker. In addition if a beam splitter is attached to the microscope, less light is available for the photo adapters and auxiliary binoculars.

Depth Perception:

Learning depth perception and orientation to the microscope takes time and patience. Coordination and muscle memory are easily forgotten if the microscope is used infrequently.

Access:

The surgical microscope does not improve access to the surgical field. If access is limited for conventional surgery, it is even more limited when the microscope is placed between the surgeon and the surgical field.

Flap design and suturing:

Reflecting soft tissue flaps and suturing them back in place are not high magnification procedures. Although the microscope could be used at low magnification, little is gained from its use in these applications.

Benefits of a microscope [17]

1. Visualization of pathological findings for new patients –communication support.
2. Comfortable treatment and Ergonomics.

3. For conservative, adhesive restorations after systematic caries excavation minutest of infected areas can be distinguished.
4. Periodontal therapy in visually barely accessible (subgingival) root sections. In closed or open periodontitis therapy, it is possible to detect and remove any clinging islands of biofilm.
5. Orthograde and retrograde endodontics-the domain of dental microscope:. The shadow-free, bright xenon light enables the straight canal sections to be examined right down to the constriction.

   Ledges, branches, fractured instruments, perforations, foreign bodies, and even isthmus-like branch lines can be localized and simultaneously treated with slender ultrasonic tips under optimal, magnifying vision. The localization of absent canals, pulp denticles, tooth–colored restorations in the pulp chamber, and the removal of old, insufficient root canal fillings is much more reliable when using magnification systems such as dental microscopes or medical loupes. SOM is also a great help in apical microsurgery and to locate inaccessible apical ramifications in an orthograde root canal filling. Again, the filigree apical portion of the root can be removed under optical illumination and the leakage delta responsible for the inflammation prepared with ultrasonic tips and ligated with suture. Diagnosis of minute longitudinal fractures is often only possible at a magnification level exceeding X12 to X15.
6. Precise control of prosthetic preparations and impressions.
7. Helpful in precisely treating teeth with complex anatomy and anatomical aberrations.

USES [18]

In Diagnosis

- Cracked Tooth Syndrome
- Marginal Leakage.
- Soft Tissue Evaluation
- Occlusal caries detection

In Restorative Dentistry

1. Under high levels of magnification, the floor of the cavity may be judiciously explored and appropriate interceptive pulpal treatment (eg. pulp capping, pulpotomy, pulpectomy) when necessary may be immediately instituted.

2. Minute discrepancies in marginal finish during coronal preparation can mean the loss of gingival integrity and an uncomplimentary exposure of the crown-root interface. Precision is essential to prevent adverse tissue responses and to achieve patient satisfaction.

3. Examining the impression surface for imperfections, distortions, and marginal inadequacies under high magnification at the time the impression is taken, eliminates laboratory guesswork and avoids redoing the restoration at a later appointment.

4. Surface irregularities under the indirect metal or ceramic restorations which can interfere with the seating of the restoration, alter occlusion, and, if seated, invite marginal leakage. Hence SOM helps in evaluating the restoration undersurface.

5. Examining the surfaces with a high level of magnification and illumination is the only way one can be assured of crown-root interface cleanliness and a well polished restoration.

6. SOM helps to evaluate the surface texture of the finished crestal edge in a bonded restoration hence assuring healthy gingival tissues without inflammation, recession, or exposure of the critical root-filling interface post –operatively.

In Endodontic Therapy

1. Age changes in pulp tissue like deposition of layers of amorphic calcified dentin or in a chamber that has obliterated itself with

secondary and tertiary dentin, errors like perforating the floor during endodontic coronal access can be prevented with the aid of magnification.

2. The floor of a chamber when magnified properly exposes a series of troughs that virtually outlines pathways to the various canal orifices which cannot be easily detected with the naked eye.
3. A high-powered microscope provides the enhanced vision and illumination for finding and removing the canal blocking obstacles without perforating the root. Troughing without magnification invites perforation and failure.

   Gencoglu N and Helvacioglu D [19] stated that operating dental microscopes are essential for the removal of fractured instruments.
4. Repairing Iatrogenic and Idiopathic Perforations: Locating and repairing canal-periodontal ligament communications through a precise intracanal access can only be accomplished with enhanced vision and illumination from a high-powered microscope.
5. The success of endodontic surgery is often compromised by anatomic restrictions and root aberrations (i.e. the number and location of canal exits). To improve the chances of clinically detecting multiple exits and isthmi and to parallel the retro-preparation and root-end filling to the root axis, one must depend on intense illumination and an unobstructed magnified view.

   Rubinstein R and Kim S [20] demonstrated one year healing rates of endodontic surgery performed under the surgical operating microscope in conjunction with microsurgical technique was 96.8 percent. In 2002, a long-term follow up of these cases showed that 91.5 percent of these cases remained healed after five to seven years.

Recent advances in magnification

Endoscopes and Orascopes

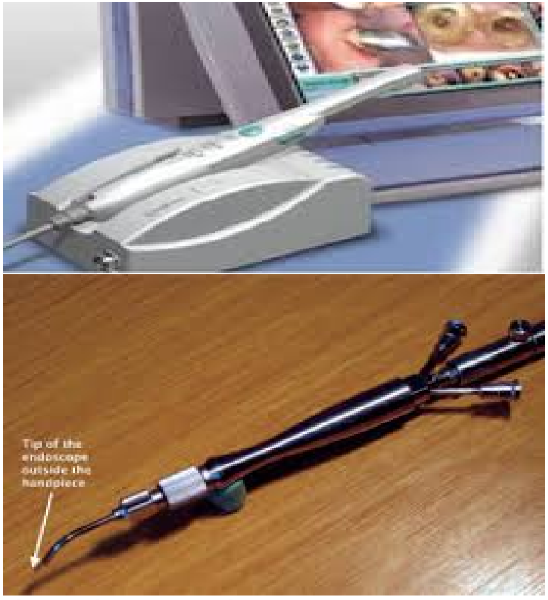

Fig.7 Endoscopes and Orascopes

Endoscopy is a surgical procedure whereby a long tube is inserted into the body usually through a small incision. Orascopy is a procedure that uses an orascope or rod-lens endoscope for visualization in the oral cavity. Clinicians who use orascopic technology appreciate the fact that it has a non-fixed field of focus, which allows visualization of the treatment field at various angles and distances without losing focus and depth of field. Moving the lens closer to the point of observation creates various levels of magnification. This equates to greater clarity at higher magnification, often in the range of X30 – X40.

The difference between an orascope and an endoscope (Fig. 7) is that an orascope utilizes fiber optics and is flexible , whereas the endoscope utilizes rods of glass and iskml rigid. The orascope is used to visualize within a root canal system, while the endoscope is used to visualize canal access in conventional endodontic therapy and in surgical endodontic treatment. The orascope and endoscope work in conjunction with a camera, light source, and monitor. The option of a printer or digital recorder can be added to the system for documentation purposes. [21] A 2.7-mm-lens-diameter, 70° angulation, 3-cm-length-rod-lens endoscope and a 4-mm-lens-diameter, 30° angulation, 4-cm-length-rod-lens endoscope are both used for surgical endodontic visualization. The aforementioned endoscopes best fit the ergonomic and logistical considerations for endodontic visualization. The latter configuration (4-mm-lens-diameter, 30° angulation, 4-cm length rod lens endoscope) is also used for conventional endodontic visualization.

The device is small, lightweight, and flexible. This allows for ease of use in a nonfixed treatment field of vision. It is important to emphasize that image quality from a fiber-optic device is directly correlated with the number of fibers and size of the lens used in an orascope. The greater the amount of visual fibers in conjunction with a larger lens, the more image of a particular treatment field is captured by the camera and hence displayed on the monitor.

The fiber-optic orascope used for intracanal visualization has a 0.8-mm-tip-diameter, a 0° lens (a flat lens that does not have any angulation), and the working portion is 15 mm in length. The orascope has 10,000 parallel visual fibers. Each visual fiber is between 3.7 and 5 μm in diameter. To allow for illumination of the treatment field, a ring of larger, light-transmitting fibers surrounds the visual fibers.

General Orascopic Visualization Technique [22]

The orascope or endoscope is used in a closer proximity to the field of treatment which means that blood and condensation on the scope will have an effect on the clarity of the image. Therefore, use of the orascope or endoscope requires good control of hemostasis and condensation.

It is recommended that X2 to X2.5 loupes be used for visualization prior to the use of the orascope or endoscope. Loupes should be used in conventional endodontic treatment to access canals and in surgical endodontic treatment to reflect gingival tissue, remove cortical and medullary bone, and isolate the root end. Once the soft tissue has been removed from the pulp chamber, the 4-mm-lens-diameter, 30° endoscope can be used to examine the pulpal floor when it is necessary to have higher magnification. The reason the orascope is not used in this treatment scenario is because the endoscope will provide better image clarity and a wider field of view. The clinician holds the endoscope instead of the dental mirror when using instrumentation or during examination of a conventional endodontic field. When using an instrument or handpiece in conjunction with the endoscope, it is recommended that the endoscope be stabilized by resting it on a cusp tip. If this is not possible due to tooth morphology, a rest in the enamel can be created with a high-speed handpiece and bur. The camera has a digital zoom that allows enhanced magnification of the treatment field. A personal LCD monitor allows the clinician to view the treatment field without looking at the monitor. Although there is a slight loss of image clarity, the personal LCD improves ergonomics.

The 0.8-mm orascope is used to visualize within the canal system (F. The small fiber-optic size enables the orascope to actually go down into a canal. Prior to the placement of the 0.8-mm fiber-optic scope, the canal must be prepared to a size No. 90 file in the coronal 15 mm of the canal. If the canal is not instrumented to this diameter, a wedging of the probe may occur, damaging some of the fibers within the scope. Appropriate preparation also allows the full 15 mm of the orascope to penetrate within the canal. If a canal is curved, the orascope may not be able to visualize around the curve because of limited flexibility. Also, if the canal is not properly prepared to a size No. 90 file in the coronal 15 mm of the canal, the orascope will not be able to be placed properly within a canal; hence, intracanal visualization will be hindered. The focus and depth of field of an orascope is zero mm to infinity. This allows the orascope to provide imaging of the apical third of the root without actually having to be positioned within this region of the canal. It is important to note that the canal must be dried prior to usage of the 0.8-mm orascope although it can be used when sodium hypochlorite is present in the canal as this solution has a high light refractory index. Further, the intracanal environment is relatively warm and humid. Temperature and humidity differences between the dental operatory and the canal can result in moisture condensing on the orascope lens, resulting in fogging. The use of a sterile antifog solution eliminates this problem.

Methylene blue stain can be used in conjunction with visualization instruments during surgery. This stain helps the clinician identify the etiology of the lesion; the defect stains a bluish color, which allows for enhanced visualization with the endoscope. As with conventional endodontic orascopic application, the clinician should hold the endoscope while the assistant retracts gingival tissue and suctions during the surgical procedure.

Documentation of Procedures [22] The recent technological advancements in digtal recording have allowed high- quality, digital record-keeping of procedures accomplished with an orascope or endoscope. The digital recordings demonstrate minimal degradation over time, and high-quality paper images can be selectively printed using a digital printer.

Conclusion

This review aimed to give clinicians a brief overview of magnification in dentistry and how they may benefit from the enhanced precision and quality dental procedures. The most important benefits when using an operating microscope are increased precision in cavity preparations, better vision of tiny details and imperfections, more precise execution of all techniques, better treatments of patients, less iatrogenic occurrences, less removal of sound tooth structure, better communication between clinicians and patients and laboratory techniques, and improved documentation of each treatment case. Needless to say, Microscope Enhanced Dentistry is a wonderful revolution and is the direction in which dentistry is moving. Higher magnification allows the dentist to see better. This is a win-win for both the practitioner and the patient.

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Cite this article as: Arora L, Kaur M, Kumar A. Role of magnification in conservative dentistry and endodontics in today's practice- a review of literature. Int J Med and Dent Sci 2016;5(2):1329-1340.

Source of Support: Nil
Conflict of Interest: No