The Use of Magnification, Loops, and Light Source in Daily Endodontic Practice

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Abstract

Thorough mechanical and chemical cleansing of the entire root canal system and its complete obturation with an inert filling material are one of the most important objectives of successful endodontic treatment. Recent developments in dental equipment have improved the clinician's ability to clean, shape, and obturate almost the entire root canal system thus increasing the quality and the efficiency of root canal treatment. The introduction of magnification devices has resulted in technical changes in the approach to root canal preparation. Along with the development of such devices, the use of magnification and well-focused illumination devices has been recommended to provide the minimum standard of care.

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Introduction

The use of magnification in dental procedures dates back to the late 1800s. Microdentistry was defined by Shanelec as a "*refinement in operative technique by which visual acuity is improved through the use of optical magnification*[1]."

Microsurgery was defined by the SMS (Society of Microsurgical Specialists) as "*surgery performed using a binocular operating microscope at magnification approximating 10x.*" The operating microscope has been used in various medical specialties for many decades and was introduced in dentistry in 1981[2]. Nylen (1921) used a microscope in the operating field when performing a surgical procedure on a patient with chronic otitis[3]. In 1953, the Carl Zeiss Company introduced the first commercial binocular operating microscope into the market, this had a significant impact on the development of modern ear surgery in the 1950s[4]. The next decade was distinguished by the use of the microscope in many branches of surgery such as ophthalmic, vascular, urologic, orthopedic and neurologic surgery[5]. In 1981 Harvey Apotheker introduced the dental operating microscope along with accessory equipment and instruments and coined the term "microdentistry"[4]. This microscope was poorly designed and practically difficult to use. Dr.Gary Carr in 1992 introduced a well configured operating microscope for dentistry in general and endodontics in particular, this provided better magnification, illumination and was easier to use. This type of microscope gained fast acceptance within endodontics and became the instrument of choice not for just endodontics but for all dental disciplines[6].

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Magnification in dentistry

Magnification in the operating field can be mainly obtained by three different ways.

Figure 1. Dental loupes.

Loupes

Historically, dental loupes have been most commonly used for periapical surgery.

They were developed to address the problem of proximity, decreased field depth and eyestrain occasioned by moving closer to the subject [6]. Loupes are basically two monocular microscopes with side by side mounted lenses which are angled inward (convergent optics) to focus on an object. The disadvantage of this arrangement is that the eyes must converge to view the image (**Hata! Başvuru kaynağı bulunamadı.**).

Magnifying loupes can be divided according to the optical method by which they produce magnification. Compound loupes use multiple lenses with intervening air spaces to produce magnification while prism loupes which are the most optically advanced type of loupe magnification use refractive prisms. Both of these methods produce superior magnification, can be custom made and have very good depth of field. The main disadvantage of loupes is that the maximum practical magnification is only up to 4.5x. They are available sometimes with higher magnification but they have a limited field of view, limited depth of field and are relatively heavy. Loupes also require a physical posture which is constrained and if not used properly may result in eye fatigue, head, neck and back strain [7]. Visual acuity is strongly influenced by illumination. An improvement to dental loupes is obtained when a fiberoptic headlamp is added which can increase illumination by as much as four times that of normal dental operatory lights. Another advantage of the headlamp is that the light path is always centered in the visual field since the light is mounted in the center of the forehead [8].

Dental operating microscope

The dental operating microscope was introduced by Apotheker in 1981[4]. This first microscope was ergonomically difficult to use and poorly configured (Figure 2).

Magnification was limited to 8x, it was poorly balanced and positioned on a floor stand, had only straight binoculars and too long a focal length i.e., eye-subject distance[6].

In 1991, Dr Gary Carr introduced an ergonomically configured operating microscope for endodontics which allowed easy use for almost all endodontic procedures. This microscope gained rapid acceptance and is now the instrument of choice not only in endodontics but also in many other dental specialties [6].

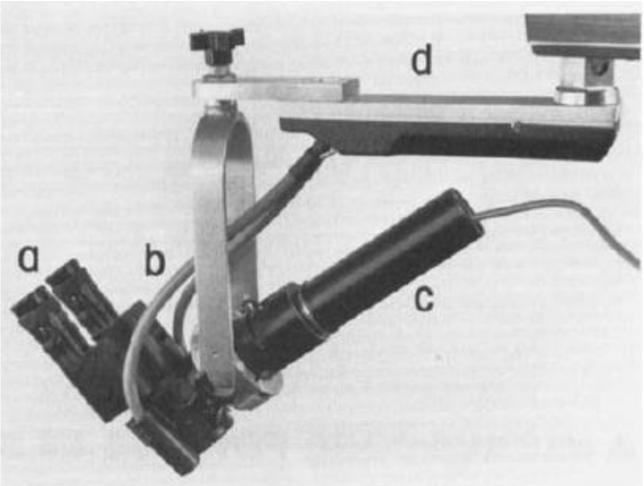

Figure 2. Operating microscope by Apotheker. Components: a=adjustable eyepiece, b=coaxial fibre optic illumination, c=micro video camera, d=suspension system (Apotheker and Jako 1981).

Components

The Dental operating microscope consists of three main components: The supporting structure, the body of the microscope and the light source.

The supporting structure

It is important that the microscope is stable while in operation, yet remains easily manipulated and retains precision, especially when used at high power. The supporting structure can be mounted on the wall, floor or ceiling. The stability of the setup increases as the distance between the fixation point and the body of the microscope decreases. In cases of high ceilings or distant walls, it is preferable to use a floor mount. The arms of the microscope should be precisely set while the built-in springs are tightened according to the weight of the body in order to establish perfect balance in any position. This will allow for precise visualization and renders fine focus unnecessary in most cases [9].

Body of the microscope

Eyepieces are used for magnification and are available in multi powers, ranging from 6.3x to 20x. A rubber cup is placed over the eyepiece and can be lowered for those operators who wear glasses. Adjustable diopter settings are also available for the eyepieces (Figure 3). The binoculars allow adjustment of the interpupillary distance. They contain the eyepieces and are aligned with a small knob or manually until the two divergent light circles combine to establish a single focus. They are available with many tubes; straight, inclined or inclinable. Straight tubes are not suitable for dental use and are usually used in otology. However, clinicians prefer to use inclined or inclinable tubes because they allow a comfortable working position. Inclinable tubes are fully adjustable whereas inclined tubes are fixed at 45 degrees to the line of sight of the microscope. Magnification changers are available as 3-, 5-, or 6-step manual changers, or a power-zoom changer. Manual step changers consist of lenses that are mounted on a turret which is connected to a dial located on the side of the microscope housing. Magnification is changed when the dial is rotated.

Figure 3: Body of the operating microscope (www.globalsurgical.com)

The final optical element is the objective lens, and its focal length determines the working distance between the operating field and the microscope. 100 mm to 400 mm is the range of the focal length. However, a 200-mm focal length allows for 20 cm working distance which is sufficient to be utilized intra-orally [9].

Light source

One of the most important features of an operating microscope is the light source. Light is critical to resolution (i.e., the ability to distinguish two objects close to each other as separate and distinct). The inverse square law determines light intensity and states that *the amount of light received from a source is inversely proportional to the square of the distance*. For instance, if the distance between the light and the subject is decreased by half, the amount of light transferred to the subject increases four times [10]. The light source is a 100-watt xenon halogen bulb and a rheostat controls the light intensity. Through a condensing lens, the light is reflected to a series of prisms and then through the objective lens to the operating field. After the light reaches the operating field, it is reflected back through the objective lens, through the magnification changer lenses, through the binoculars and then exits as two distinct beams of light to the eyes. The separation of the light beam produces the stereoscopic effect (i.e., three-dimensional perception) and allows the operator to see depth of field. The effective aperture of the microscope is decreased as the magnification is increased, and therefore more light is needed. This means that with higher magnification, the operating field appears darker. Furthermore, at higher magnification, optics absorb more light. The illumination of the operating microscope is coaxial with the line of sight. This means that the light is focused between the eyepieces in such a way that eliminates the presence of any shadow. The microscope optics focus at infinity and parallel beams of light are sent to each eye. Because of this, the operator's eyes are at rest during the whole procedure as if he or she were looking into the distance and therefore prolonged procedures can be performed without eye fatigue[11].

Use of the operating microscope in endodontics

The objective of successful endodontic therapy is thorough mechanical and chemical preparation of the entire root canal system, followed by creation of a complete seal and obturation with an inert filling material [12].

Detection of all root canals is one of the most important steps to ensure a successful endodontic outcome. Localizing all canals is not always achievable, and frequently some remain undetected and are consequently untreated.

Accordingly, the inability to identify and adequately treat all the canals is a major cause of treatment failure and persistence of periapical diseases [13]. In addition, treatment failure can be attributed to a multitude of reasons, including improper diagnosis, perforations, incomplete instrumentation and obturation, calcifications, ledges and fractured instruments. Prevention of failures and thereby reducing the necessity of retreatments seems to be the best realistic solution [14]. Recent developments in dental equipment have improved the quality and efficiency of root canal treatment. The introduction of the operating microscope into endodontic therapy has been shown to be beneficial to treatment outcome [15]. Its introduction has a significant impact on certain treatment modalities. Use of the microscope has become standard in endodontics and has many advantages such as direct, high intense illumination of the working field, variable magnification, higher precision during work, usefulness to the dental assistant, allows for documentation through video and photo cameras and finally allows for more comfortable working position for the operator [14]. Use of such a device has become a widely accepted practice in both conventional and surgical endodontics. Besides improving the quality of endodontic treatment, a microscope may improve diagnostic capability due to better visualization of the operating field [16].

Diagnosis

Most endodontists would agree that diagnosis is one of the most challenging aspects in endodontics. Therefore an endodontist should be a skilled diagnostician. Furthermore, any equipment that assists in diagnosis is useful, and the microscope definitely meets this criterion [17]. The dental operating microscope can be very useful in helping to assist diagnosis of cracked tooth syndrome and vertical root fracture. In the early stages, a cracked tooth can be misdiagnosed as no pathologic probing depth can be observed and radiographic examination does not yet indicate any sign of bone loss. The use of the microscope in such cases facilitates both visualization and tracing the path of the fracture line [14]. Also the use of methylene blue dye, in addition to light and magnification provided by the microscope, makes visualization of a hairline fracture relatively easy (Figure 4). The capability of the microscope to aid identification of extra or missed canals without the need for removal of excessive tooth structure prevents unnecessary weakness and susceptibility to fracture [17]. Furthermore, detection of microleakage underneath restorations or at the tooth restoration interface may not be easily possible during routine examination. As a result, caries may progress for a lengthy period of time without detection and thus the recognition of damage is may be delayed until the restoration is dislodged or there are symptoms. Using the microscope in these cases may be of great benefit. Also detection of micromovements; when force is directed at the gingival margin of the restoration, is not possible with the naked eye but is evident and easily detectable when magnification is used [18].

Ealuation of soft tissues under magnification can be carried out precisely and the presence of inflammation/infection that cannot be visually or radiographically identified can be easily detected using a microscope. For example, foreign objects which might be wedged and compressed between teeth and beneath pontics can result in swelling and continuous bleeding of the associated tissues, which make the location, identification and removal of these objects challenging and painful. When managing these situations, the naked eye and the normal illumination are inadequate and often result in an unnecessary stress for both the patient and the operator. However, when viewed under the microscope, they are easily identified, grasped and removed.

Figure 4. Cracks and craze lines under magnification.

Non-surgical endodontics

The microscope in endodontics was originally identified as “the surgical operating microscope”. This is a misnomer because it can be used at any time and at any step [17].The microscope provides the capability to visualize and fully evaluate the pulp chamber and canals.

It also enhances identification of the second mesiobuccal canal in the upper first and second molars (Figure 5). A number of studies confirm that this canal exists in up to 96% of cases [19]. When comparing these results with previous studies published 20 years ago, it can be concluded that the increased percentage is not due to anatomical differences but to enhanced identification by clinicians who utilize the operating microscope [18].

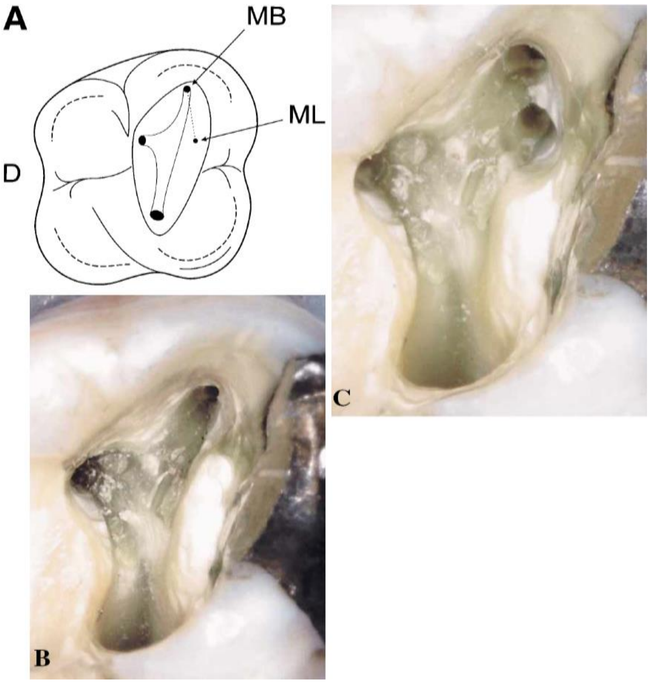

Figure 5. Location of MB2 canal (A) Drawing of access to demonstrate typical location of the mesiolingual canal (MB2) in relationship to mesiobuccal, distobuccal and palatal canals in maxillary molars. Photographs under magnification of maxillary molar before (B) and after (C) canal localization (Baldassari-Cruz, Lilly et al. 2002).

Amorphic calcified dentine is a common pulp tissue response to age, repeated restorative treatments, trauma and occlusal wear. It manifests itself as obliteration of the pulp chamber with secondary or tertiary dentine deposition. The possibility of perforating the pulpal floor during coronal access in these cases becomes a real issue. However, using the operating microscope when approaching the pulpal floor makes it easier to discern the roof of the chamber from the natural floor and invites less opportunity of perforation and subsequent failure [18].

The microscope also helps in the identification of calcified canals. The color change related to calcified canals is something that can be easily seen under magnification. This renders identification and instrumentation of such a canal easier. It is a definite fact that a microscope in these cases offers enhanced visibility and therefore optimizes the likelihood of locating the canal [17]. Another way to locate calcified canals is to look for bubbles generated by irrigation with sodium hypochlorite. Usually these bubbles are difficult if not impossible to be seen by the naked eye.

Separation of an instrument inside the root canal is an acceptable, but unfortunate complication associated with endodontic treatment [6]. With the more frequent use of nickel-titanium rotary instruments in general practice, the incidence of file separation within the canal has increased [20] . The use of the microscope to facilitate retrieval of broken instruments and posts goes hand in hand with ultrasonic technology (Figure 6). Finding and removing these canal-blocking obstacles without perforating the root needs enhanced vision and illumination, and the careful and circumferential troughing of the overlying dentine with an appropriate ultrasonic tip. Troughing without magnification increases the risk of perforation and failure [18].

Another use of the operating microscope in conventional endodontic treatment is in the facilitation of location and repairing canal-periodontal ligament communications (i.e., perforations) through a small and precise intracanal access.

Figure 6. Broken instrument retrieval using ultrasonic technology under magnification (Ruddle 2002).

In the past, perforations were mainly repaired through surgical interventions or extraction, but now with the advent of the operating microscope, they can be conventionally repaired and even prevented. Furthermore, as the number of retreatment cases increases, utilization of the microscope has brought significant advantages and has expanded the scope of indications using a non-surgical approach [9]. Every single procedure in the past that was made by chance or performed using tactile sensation can today be carried out with complete control and vision. Any difficulty existing in either the straight or the most apical portion of the canal, can be easily managed using the microscope with magnification and coaxial illumination [7]. Certainly, using the operating microscope minimizes the chance of iatrogenic errors and makes both the prevention and management of such errors considerably more reliable and realistic [9].

Finally, using the microscope is useful in the final examination of the canal preparation. It takes a simple step to check whether a canal is completely cleaned. Under magnification, a small amount of sodium hypochlorite may be deposited and observed carefully. If there are bubbles coming through the prepared canal, then there is still remnant debris and thus the canal needs more cleaning [20].

Surgical endodontics

The operating microscope was first recommended for surgical applications in endodontics. This procedure has benefited the most from a microsurgical approach. “The introduction in 1990 by Excellence in Endodontics (EIE) of a dedicated microsurgical armamentarium has revolutionized surgical techniques and vastly improved the skill level of an entire specialty” [7]. The use of the microscope for surgical procedures was promoted in the late 1980s and early 1990s by Carr, Kim, Percora, and Rubinstein. This was the first time that dentists could truly visualize the root end anatomy and understand the causes of failure and errors and how to avoid them. The failure rate has been so reduced that Kim and Rubinstein in 1995 completed a study on 94 teeth treated surgically and concluded that the overall success rate, including scarring, was 96%. This high success rate was not only related to the skill of the practitioners, but also to the methodology including the use of magnification [21]. Every step of surgical endodontics benefits from enhanced magnification and illumination. Periapical curettage is facilitated, since bone margins can be accurately inspected for completeness of tissue removal. Also the apicoectomy can be carried out by using a high-speed handpiece and performed perpendicular to the long axis of the root thus ensuring the preservation of the root length. Furthermore, the resected surface is examined carefully with a micromirror for the presence of any ramification or isthmus [9].

Soft tissue management

The most common error in flap management in endodontic surgery is unnecessary trauma during incision, reflection, retraction and suturing. This usually impairs both healing and aesthetic outcome. Many management procedures have changed from the traditional techniques. First, the most popular flap design technique with anterior teeth, the semilunar incision, is no longer recommended because of limited access and scar formation [22]. Secondly, suture removal is done within 48 hours not a week. Third, monofilaments are new suture materials with a gauge size of 5-0 and 6-0 and allow for fast healing [23]. Fourth, the papilla base incision (PBI) has been introduced to prevent both loss of interdental papilla height and recession with sulcular incisions (Figure 7) [Velvart 2002]. Finally, a resting groove in the bone is utilized to facilitate flap retraction during surgery [23]. Basically, the flap designs are very similar to those of the traditional techniques: the sulcular full-thickness flap, the mucogingival flap and vertical releasing incisions [24].

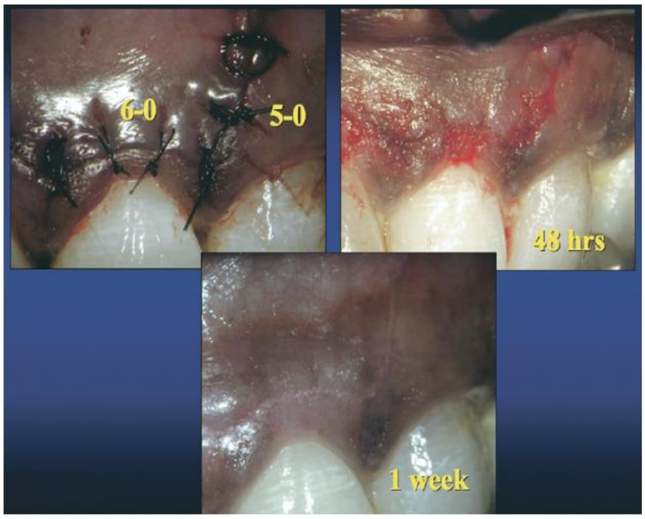

Figure 7. Micro-suturing with 5-0 and 6-0 monofilament sutures; notice the papilla base incision (top left). Suture removal after 2 days (top right). Tissue healing after 1 week (bottom), (Kim 2006).

When a sulcular incision is made, the sulcular epithelium is usually crushed or removed. Preserving this tissue is probably the single most important factor in ensuring proper and rapid wound healing. Utilizing the microsurgical approach enables the operator to make a sulcular incision without damaging the epithelial lining of the sulcus [6]. When operating under the microscope, sharp dissections and atraumatic elevation of the papilla is attained. In addition, handling the flap under magnification lessens physical trauma and allows for gentle manipulation. Microsurgical suturing techniques take benefit from smaller gauge tapered needles and smaller sutures; size 6-0 and 7-0. These are handled with ease and are placed more accurately than with the naked eye. If an atraumatic microsurgical flap management technique is followed properly, sutures can be removed after 48 hrs and rapid wound healing is anticipated [6]. The operating microscope can be used also to facilitate suture removal at low-range magnification. Microsurgical scissors and tweezers should be utilized to cut and remove the sutures, but care should be taken during removal so as not to damage the suture site [25].

Root-end procedures

Surgical endodontics has always been a true microsurgical procedure although the introduction of the operating microscope is fairly recent. It is extremely technique sensitive with only a small margin for error. Previously, these procedures were performed without proper lighting and magnification, however, the evaluation, preparation and filling of the root apex is a true microsurgical procedure and simply cannot be predictably done without magnification. Because the operating microscope enhances vision, bone removal can be very conservative as it becomes easier to distinguish the surrounding bone from the root tip. It would be ideal to locate the root tip accurately all the time. This step is important for keeping the size of the osteotomy small. In addition, a recent study on healing showed that there is a direct relationship between the size of the osteotomy and the speed of healing: the smaller the osteotomy, the faster the healing[26]. Thus, the osteotomy should be as small as possible but as larger as necessary to satisfy the clinical objectives (Figure 8). With the microsurgical techniques, the size of osteotomy is significantly reduced just 3 to 4mm in diameter[27].

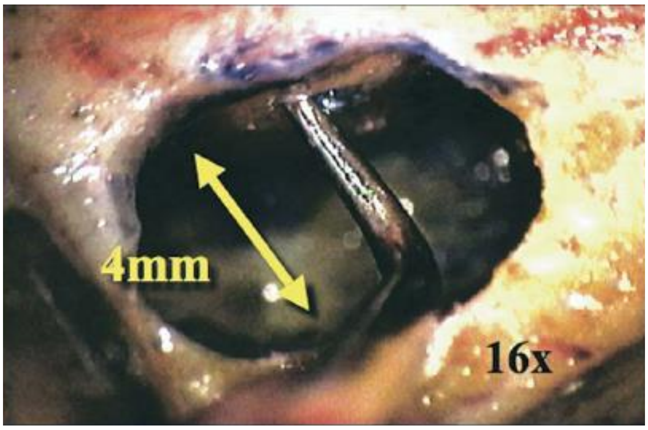

Figure 8. The ideal size of osteotomy (Kim 2006).

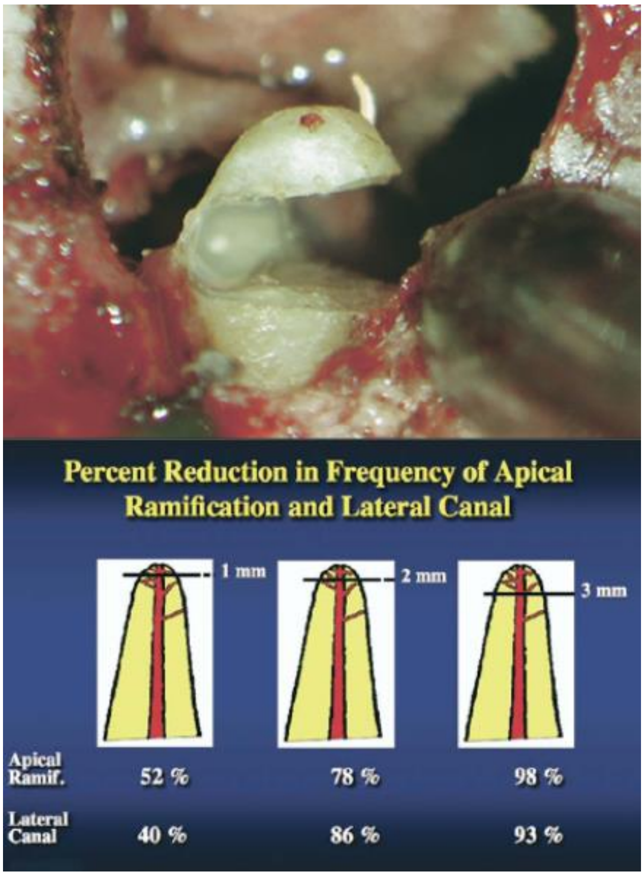

Figure 9: Three mm apical resection is needed to eliminate the majority of apical ramification and lateral canals (Kim 2006).

Handpiece such as the Impact Air 45™ are suggested for apical surgery because they allow for better access to the apices of maxillary and mandibular molars, can be used in limited spaces and provide no pressurized air or water thus reducing the chances of producing emphysema. With the use of an operating microscope, the Impact Air 45™ along with its surgical burs can be placed in areas of anatomical jeopardy yet used with a high degree of accuracy and confidence[8]. Furthermore, periapical curettage is facilitated as bony margins can be examined for completeness of tissue removal. The more the tissue that can be removed, the less wound healing is necessary [25].

One of the main causes of failure in conventional endodontic treatment is the inability to adequately clean, shape and obturate the entire root canal system [28]. The majority of this uncleansed anatomy is located in the apical 3mm and for this reason a 3mm resection is recommended [29]. Also a 3mm of the root-end (Figure 9) should be removed because this will remove 98% of the apical ramifications and 93% of the lateral canals [27]. As these percentages are very similar at 4mm from the apex, root-end resection of 3mm is recommended as this leaves 7 to 9mm of the root, providing sufficient strength and stability [27].

Traditionally, a long bevel was preferred in order to provide access for the microhead handpiece. However, with the introduction of both the microscope and periapical ultrasonic which have 0.25mm diameter tips and approximately a 3mm length, little or no bevel is needed (Figure10). This results in less exposure of dentinal tubules and therefore less chance of leakage. (Table 1) shows a comparison of bevel angles created by the traditional rotary bur technique and the perpendicular preparation (no bevel) using microsurgical technique.

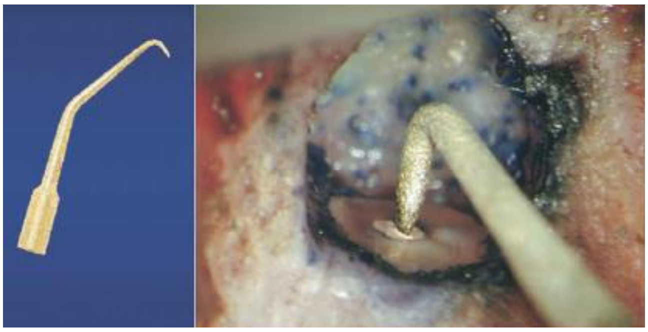

Figure 10. Microsurgical root-end preparation of a maxillary canine with an ultrasonic diamond tip. Notice the perpendicular resection with 0^o bevel (Kim 2006)

The use of the microscope with the help of micromirrors, allow the operator to examine the beveled root apex precisely. This brings a whole new world of detail into focus. Poorly compacted gutta percha, irregular canal shapes, uninstrumented isthmus areas, accessory canals and canal fins and circumferential resorption of prior retrofilling materials, all become very clear, helping the operator to correctly design his\her retropreparation[6].

Microsurgical Technique	Traditional Technique
No bevel or less than 10 degrees	Acute bevel (45-60 degrees)
Few dentinal tubules exposed	Many tubules exposed
Small osteotomy	Large osteotomy
Minimal loss of buccal plate	Greater loss of buccal plate
No danger of periodontal communication	Great danger of periodontal communication
Easy identification of apices	Frequent missing of lingual apex
No lingual perforation	Easy lingual perforation

Table 1. Comparison of bevel angles created by traditional and microsurgical techniques (Kim 2006).

Accordingly, it has been suggested that the most significant problem in apical surgery which led to failure is poor design and preparation of the retropreparation itself, because previously the instruments were not available to allow preparation down the long axis of the root and almost all preparations were made obliquely into the root. This has the disadvantage of relying on the axial wall of the preparation to do the sealing, when it should be ideally the pulpal floor of the preparation, as the axial walls are only used for retention. Using the operating microscope and micromirrors enable modification of the bevel and make it easier to section roots more perpendicular to the long axis of the tooth. Also the retropreparation can be placed down the longitudinal axis of the pulp space and can be extended to the correct bucco-lingual dimension easily. This technique reduces the probability of lingual root perforations especially when the retropreparation is to be extended lingual[6].

Once a root tip is resected perpendicular to the long axis of the root, proper identification and examination of anatomical details and their management are some of the most important and unique steps in microsurgery[23]. This surgical procedure unfortunately cannot be done adequately and accurately with unaided vision or even with loupes. Only the high magnification of a microscope provides the light and magnification necessary to see the anatomical details of the resected root surface. One of the major drawbacks of the traditional root-end surgery without magnification is the inability to inspect and adequately manage the anatomical details of the root surface. By contrast, with the illumination and the range of magnification of the operating microscope from 4x to 25x, the root-end surface can be examined precisely. It is the inspection of the resected root surface, which reveals why and how the traditional techniques were highly inadequate[27]. As known, the anatomical details of the resected root surface are complex (Figure 11). All types of shapes and irregularities can be found in the canal system. When resecting the root perpendicularly, round, oval, horseshoe shaped s-shaped, two to five small round and oval shaped canals and isthmuses, and so forth, can be observed. Accordingly, the isthmus area between confluent canal systems can be easily inspected, adequately prepared and sealed under magnification. This important step in microsurgery is not considered at all in the traditional surgical techniques[27].

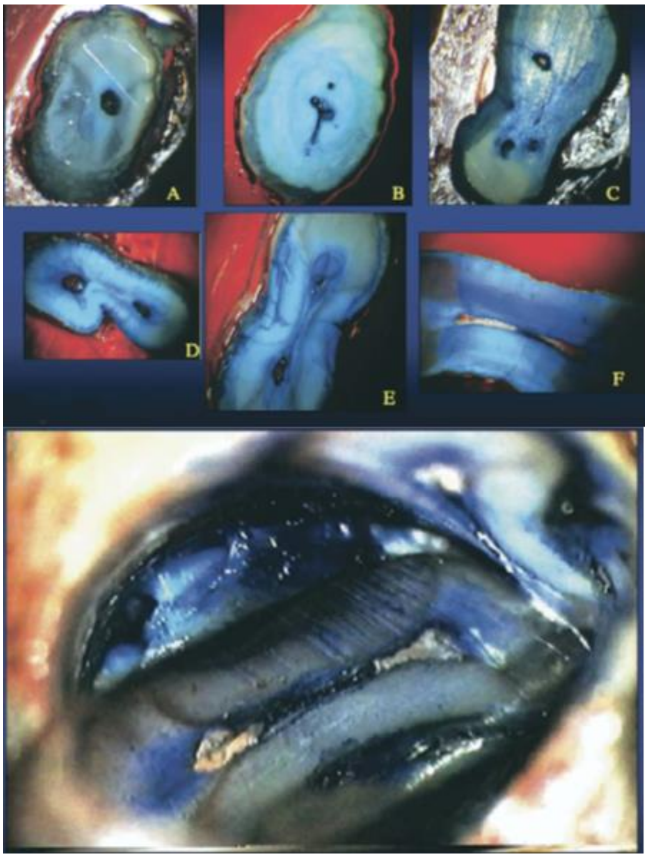

Figure 11. Several types of apical configurations and isthmi (Kim 2006).

After ultrasonic preparation of the apical 3mm of the root surface, it should be filled with a biocompatible material that guarantees a hermetic seal. Mineral trioxide aggregate (MTA) has been suggested recently as having many properties of the ideal root-end filling material (Figure 12). Because of its sealing ability, stability in moisture and biocompatibility, MTA is gaining popularity among endodontist[29]. Retrofilling materials including MTA are placed into the apical preparation using instruments and carriers that allow for direct observation to inspect the material's performance during placement. These instruments should not have large diameters, instead, should be small enough to fit into the apical preparation without obscuring the vision. The recently introduced Micro Apical Placement System (MAP) addressed these problems. It consists of various delivery tips with cross-sectional diameters ranging from 0.9mm for small preparations to 1.5mm for use in open apices. When placing the retrofilling material under magnification, these instruments will fit into the apical preparation thus preventing the material from being spilled into the bony crypt. After that, visual inspection at mid-range magnification is used to check for marginal integrity and to assure that the bony crypt is free from debris.

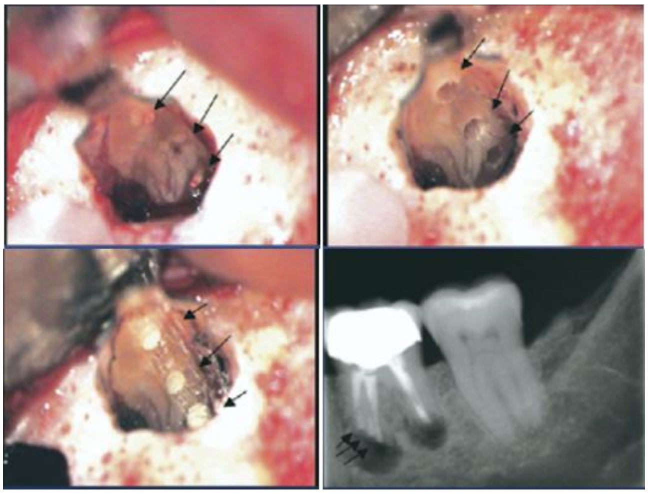
Figure 12. Inspection, preparation and filling with MTA of a resected root surface (Kim 2006)

Conclusions

This review addressed the role of magnification in both conventional and surgical endodontics. It could be concluded that:

- The introduction of the operating microscope has enhanced the treatment possibilities in conventional and surgical endodontics.
- The operating microscope has enabled the clinician to work in a more comfortable ergonomic position, for longer period of time, and with increased precision.
- Treatment modalities that were not possible in

the past have become predictable and reliable.

- Difficult cases can today be treated with a higher degree of confidence and clinical success.
- Microsurgical approaches offer predictable outcomes in the healing of lesions of endodontic origin.
- Endodontic microsurgery using MTA, ultrasonic technology, and magnification is a predictable procedure to save teeth and has demonstrated a favorable outcome.
- Enhanced vision has broadened the spectrum of treatment modalities being solved by non surgical means.
- The introduction of micro-endodontics has broadened the treatment spectrum.

Declaration of Interest

The authors report no conflict of interest.

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