Magnification's Effect on Endodontic Fine Motor Skills

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Abstract

Introduction: The purpose of this study was to quantitatively investigate the effect of magnification on fine motor skills used in endodontics. **Methods:** This study used a novel manual dexterity test that was performed with and without magnification. An 8× operating microscope and 2.5× dental loupes were used for the magnification tests. Forty subjects, 20 with microscope experience and 20 without, participated in the study. Performance on the test was evaluated by using an accuracy scoring system, and the time needed to complete the test was recorded for each subject. **Results:** A significant increase in accuracy score with each level of magnification was demonstrated ($P \leq .05$). In addition, the use of operating microscope significantly increased the time needed to complete the test among subjects with less than 3 years of microscope experience. **Conclusions:** The use of magnification to enhance fine motor skills was supported in all age groups and experience levels. *(J Endod 2010;36:1135–1138)*

Key Words

Endodontics, loupes, magnification, manual dexterity, operating microscope

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Vision enhancement with magnification has a long and well-documented history in both dentistry and medicine (1–5). Pioneering practitioners first used loupes and then turned to the greater magnification and superior resolution of the operating microscope in the late 1980s (5). During these early years the microscope was originally defined as a surgical operating microscope, but the surgical label was dropped because the microscope was deemed to have value in all endodontic procedures (6). Operating microscope interest and ownership have climbed nearly 40% during the last 8 years. Mines et al (7) surveyed endodontists in 1999 and found microscope ownership at 52%, and a 2008 survey by Kersten (8) found ownership at 90% among endodontists. The endodontists and endodontic residents who participated in this study reported that they performed 20%–60% of their endodontic diagnosis and treatment with a microscope. With the belief that the microscope is essential to facilitate endodontic care and usage continuously increasing, the Commission on Dental Accreditation of the American Dental Association mandated microscopic education in the new Accreditation Standards for Advanced Specialty in Endodontics in 1996 (5).

The benefits of enhanced illumination and magnification in the modern practice of endodontics have been described in many publications (1, 2, 5, 9, 10). These advantages include a more detailed view of root canal intricacies enabling the operator to more efficiently examine, clean, and shape complex anatomy (11); superior resolution aiding in the removal or bypassing of separated instruments and in the detection of minute fractures (7); and improved surgical technique allowing for smaller osteotomies, shallower bevels, and the location of isthmi and other canal irregularities (3, 12, 13). Several studies have examined the benefits of the operating microscope quantitatively by comparing the detection and negotiation of the second mesiobuccal canal (MB-2) in maxillary molars with and without vision enhancement (14–16). Burley et al (15) found that MB-2 detection in maxillary first molars with the microscope, dental loupes, and unaided vision was 71.1%, 62.5%, and 17.2%, respectively. Baldassari-Cruz et al (17) were able to locate MB-2 in 90% of maxillary molars with the operating microscope but only 52% with unaided vision. In 1999, Stropko (18) demonstrated significant increases in MB-2 identification in 1732 maxillary molars treated during an $8\frac{1}{2}$ -year period with increased operating microscope usage. Overall, Stropko found the MB-2 in 73.2% of maxillary first molars, but that identification rose to 93.0% with an operating microscope.

Koch (6) suggested that the operating microscope can enhance endodontic therapy in diagnosis, nonsurgical treatment, surgical endodontics, and in documentation and patient education. Diagnostically, the operating microscope is an indispensable aid in locating cracks and tracking vertically fractured teeth. The operating microscope not only aids in the identification of missed or extra canals but helps minimize gouging during the identification process. In nonsurgical treatment, it enables the operator to detect minute changes in dentin color and texture, which allows for intelligent and strategic removal of excess dentin. Combined with sodium hypochlorite or methylene blue, the operating microscope enables the operator to visualize minute anatomy that is impossible to see with the naked eye (6). Rubenstein and Kim (19) were able to achieve an unprecedented success rate of 96.8% during surgical endodontics by using an operating microscope. The purpose of this study was to objectively evaluate whether the use of magnification can enhance the fine motor skills typically required in endodontic treatment.

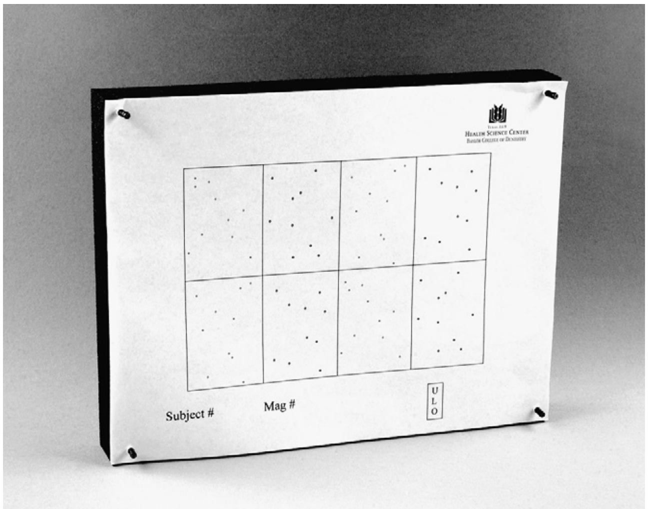

Figure 1. Precision manual dexterity Test (PMD).

Materials and Methods

Forty subjects, 20 with microscope experience and 20 without microscope experience, participated in this study. Endodontists, endodontic faculty, and endodontic residents comprised the group with microscope experience. General dentists and periodontic, pedodontic, and orthodontic residents, none of whom had operating microscope experience, comprised the group with no microscope experience. Each subject performed 3 identical precision manual dexterity (PMD) tests by using unaided vision, dental loupes with 2.5× magnification (Orascoptic, Middleton, WI), and the operating microscope with 8.0× magnification (Global G6 Surgical Operating Microscope, St Louis, MO). A new #10 C-File (Maillefer Dentsply, Johnson City, TN) from the same pack was used for each test. Each subject was randomly assigned a test order number that was generated from an Excel random number generator (Microsoft, Redmond, WA). All tests were performed at the Baylor College of Dentistry Graduate Endodontics clinic with overhead fluorescent light supplemented with an A-dec 571 dental light (A-dec, Inc., Newberg, OR). The 2.5× loupes test included a Zeon Lumen Arc Light System (Orascoptic), and the 8× operating microscope included self-contained additional illumination. The working distance for the loupes was set by the manufacturer at 16.5 inches. The distance from the subject's eye to the test sheet was measured before and during the unaided test to ensure that a standard working length of 16.5 inches was maintained.

The PMD test consisted of accurately penetrating a series of fine targets printed on a sheet of soft paper (Figure 1). Canson 30-pound newsprint was chosen for the test material because it was soft enough to be penetrated with #10 C-File but firm enough to allow for laser printing. Participants were given a practice test with complete instructions and allowed to practice at each level of magnification until they felt confident with the testing procedure. The test sheets were printed on an HP Laser Jet 4350N printer (Hewlett-Packard Co, Palo Alto, CA). The test sheet was made up of 8 target fields, with 4 fields containing 10 circular 0.3-mm targets and 4 fields containing 10 circular 0.35-mm targets (Figure 1). The smaller target size was selected to be 150% greater than unaided human visual resolution (20). The position of each target within the field was determined by an Excel random number generator. Each test sheet was attached to a 1.5- × 3- × 5-inch foam backing to support the paper during the test (Figure 1). The objective of the test was to accurately penetrate the center of each target with 21-mm #10 C-File. Preliminary studies demonstrated that the 0.1-mm tip of #10 C-File could penetrate completely inside both the 0.3-mm and the 0.35-mm targets. Participants were instructed to completely penetrate the paper perpendicular to the surface. A grading system was used to give an accuracy score to each test sheet. Target scores ranged from 0–3, with 0 being the least accurate and 3 being the most accurate. A score of 3 was recorded if the file penetration was completely within the target. A score of 2 was recorded if the penetration touched the target border and was more than 50% within the target. If the penetration touched the target border but was more than 50% outside the target, a score of 1 was recorded. A 0 score was recorded if the target was completely untouched by the penetration or if the subject neglected to penetrate the target. If the target was penetrated twice, the lower score penetration was used. The score criteria are depicted in Table 1. Completed test sheets were placed on a radiograph view box (Apollo LB101, Ronkonkoma, NY) and evaluated with 12.8× magnification (Global G6 operating microscope). The sum of all 80 individual target scores was recorded for each subject. A maximum possible sheet score was 240. Sheet scores were graded by 2 calibrated blinded evaluators. Evaluators were calibrated by comparing test sheets from trial studies. The evaluators were blinded to the level of magnification. Time was measured from when the subject penetrated the first target until the last target was penetrated. Statistical analysis was performed by SPSS (SPSS Inc, Chicago, IL) by using one-way analysis of variance and post hoc Student-Newman-Keuls test, and P value ≤.05 was considered statistically significant.

Results

The subjects in this study included 20 operating microscope experienced volunteers aged 25–64 years (mean, 41.8) and 20 inexperienced volunteers aged 25–61 years (mean, 36.1). There was a significant increase in accuracy scores with the use of an operating microscope compared with unaided vision and loupes (Figure 2). Accuracy scores increased 17.5% with 2.5× loupes and 57.7% with the 8× operating microscope compared with unaided vision. The 17.5% increase in accuracy scores with loupes was significant for the

TABLE 1. Scoring criteria

Represents the tip of #10 C-File

	3 - completely within the target		2 - > 50% inside the target
	1 - > 50% outside the target		0 – completely outside the target

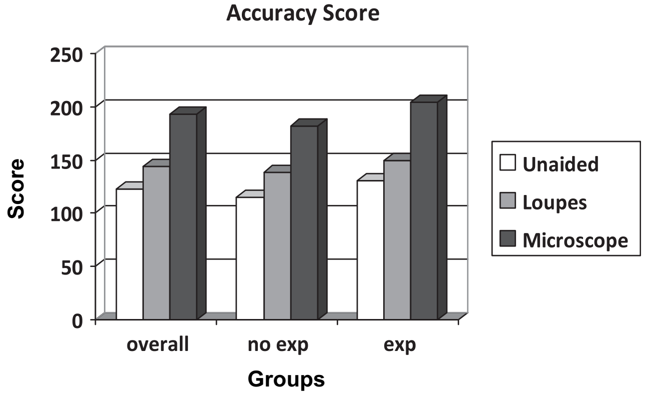

Figure 2. Accuracy scores in different groups. Accuracy scores were significantly different ($P = .05$) overall and between experienced and inexperienced groups.

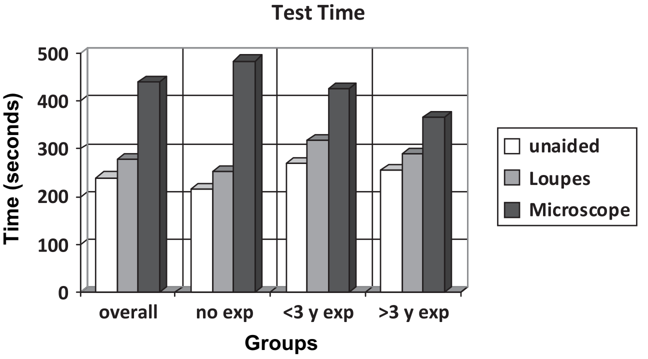

Figure 3. Test time in different groups. There was a significant difference ($P = .05$) in overall time and groups with no experience or less than 3 years of experience. The difference in time was not significant for those subjects with more than 3 years of experience.

entire test group; however, subjects older than 35 years did not demonstrate a statistically significant improvement in score with loupes over unaided vision.

Overall, the use of the operating microscope significantly increased the time to complete the test ($P \leq .05$). The average time to complete the unaided vision test was 240.08 seconds, which increased to 440.55 seconds with the operating microscope (Figure 3). There was no significant difference in time between the unaided vision test and the loupe test. Subjects without microscope experience took 92.4% longer to complete the operating microscope test compared with their unaided vision test. However, the increase in time with increased magnification was not significant among subjects with more than 3 years of microscope experience. Subjects with more than 3 years of microscope experience performed the microscope test 32.1% faster than those without microscope experience ($P \leq .05$).

Discussion

Considerable literature has been written suggesting that the operating microscope has become a hallmark of the modern endodontic office (2, 13, 21, 22). Carr (1) has stated that "the microscope is simply an avenue for greater competence and that there are *some* procedures that can only be performed with a microscope and almost *all* procedures are performed more competently using a microscope." Castellucci (2) has remarked that "the introduction and use of the operating microscope in endodontics represents a qualitative leap for the profession". It is the praise of Carr, Castellucci, and others that has ushered in the Microscopic Age of Endodontics. Several studies have clearly demonstrated that microscope usage increased the likelihood of locating MB-2 canals in maxillary molars (16, 23). However, whether enhanced magnification leads to any improvement in manual dexterity has not been investigated. The results of this study indicate that magnification does enhance the execution of fine motor skills by enabling a more precise placement of endodontic instruments within an operating field. All groups performed the test more accurately with the microscope. This improvement was independent of prior microscope experience. Subjects without microscopic experience were able to score 59% higher with the microscope than with their unaided vision test (Table 2). This finding is consistent with the work of Rampado et al (24), who assessed access cavity quality and canal identification in undergraduate dental students with and without an operating microscope. The results of their study indicated that those students who used an operating microscope outscored those students without an operating microscope in both measures.

In this study, the accuracy score was increased with the use of operating microscope at the expense of time; it took significantly longer to complete the test by using the operating microscope among subjects without microscope experience. However, this difference diminished within the group with more than 3 years of experience. This time difference between operating microscope, loupes, and unaided vision in subjects with 3 or more years of experience was not statistically significant. This suggests that the decrease in efficiency in precision manipulation with microscope usage can be mitigated with experience and practice.

The increased accuracy scores and increased time with microscope usage generally mirror the 1999 results of Stropko (18). He demonstrated that as operators became more familiar with the microscope and as they scheduled sufficient clinical time, MB-2 localization increased significantly. The results of this study definitively illustrate that accuracy and time significantly increase with operating microscope usage; however with more experience, the increase in time diminishes.

The PMD test was developed by using several trial studies. Preliminary trials included several paper types before selecting Canson 30-pound newsprint. Standard copy paper, 20-pound bond, caused

TABLE 2. Difference in Accuracy Scores among Different Groups

	Percent increase in accuracy score					
	Overall	No experience	Operating microscope experience	Age <35 y	Age 35–55 y	Age >55 y
Unaided loupes	17.5%	20.7%	14.7%	20.5%	NS	NS
Loupes, microscope	34.2%	24.1%	36.4%	30.5%	37.5%	41.7%
Unaided, microscope	57.0%	59.0%	56.5%	57.2%	59.3%	57.0%

NS, not significant ($P > .05$).

Similar improvements in accuracy score were demonstrated comparing unaided vision with microscope in all groups.

the #10 C-File to bow excessively and dull prematurely. Lighter weight tissue paper printed unreliably. Preliminary trials also included targets of varying sizes, positions, and shapes. The final targets are simply the lowercase letter "o" font Calibri size 2 and 2.5 (Microsoft Word). Calibri produced a round target with uniform thickness. Final target size was approximately 0.3 mm and 0.35 mm when printed with an HP Laser Jet 4350N printer. Preliminary trials demonstrated that these target sizes randomly positioned in the target fields produced the widest range of possible scores. Smaller targets tended to skew score low and decreased scoring reliability. Larger targets tended to skew scores higher. The #10 C-File was chosen over other files because it was able to penetrate the paper 80 times without significant dulling or bowing. Less rigid files would bow before penetration and then "snap" through the paper, creating less uniform and less precise punctures. The test sheet was composed of 2 rows of 4 fields. Each row consisted of the same target fields but in a different order. Field 1 in the top row was field 3 in the bottom row. The design was intended to assess whether subjects would improve as they became more familiar with the test. There was no significant difference in score between the top row and the bottom in any test or subject group. The order in which the subjects completed the tests was randomly assigned, and there was no significant difference in accuracy score or time with test order ($P \leq .05$).

The length of the test was designed to be about 6 minutes on the basis of the results of trial studies. Individuals who participated in trial runs believed that they were able to concentrate on 3 tests of this length without fatigue or eye strain. The overall mean test time was 5.3 ± 2.3 (standard deviation) minutes for each test. The relatively large standard deviation can be attributed to the overall significant difference in time between the 3 tests.

To minimize variation, this study used a standard set of $2.5\times$ loupes with an adjustable interpupillary distance. Subjects were instructed on how to adjust the loupes for maximum benefit, and they were allowed to practice until they believed that they were confident with both the loupes and the test. However, subjects who had used both these adjustable loupes and custom loupes suggested that they would be able to perform better with their personal custom loupes.

Two individuals were unable to adjust the test loupes to focus at the manufacturer's working length and were excluded from this study. Both of these individuals had no trouble with using the microscope within the parameters of the study.

The objective in the creation of the PMD test was to develop an instrument that could quantitatively measure fine motor skills typically required in endodontic treatment. Preliminary trials included a variety of instruments and techniques that lacked reliability in assessment. The selection of #10 C-File and orifice-like targets represented critical endodontic movements, a measure that could be reliably assessed. The validity of the PMD test was attributed to the accuracy scores measured in preliminary trials correlating with the skill level of the subjects. Subjects with endodontic experience consistently outscored subjects with minimal experience ($P \leq .05$). Future studies could include larger sample sizes of subjects tested at one level of magnification with varying skill levels, the use of customized loupes compared with the microscope, and the effect of different forms and sources of illumination.

Conclusions

Within the parameters of this study the use of magnification was proved to enhance the fine motor skills typically required in endodontic treatment. The results of this study reinforce and potentiate the previously untested benefits that have been credited to microscopic dentistry.

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