Evaluation of dental explorer and visual inspection for the detection of residual caries among Greek dentists

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Abstract

Objectives: The objective of this study was to assess the effect of the operator’s degree of clinical experience on the residual caries diagnosis through visual inspection and tactile sensation.

Materials and Methods: The participants were asked about the years of their clinical practice, any further training concerning cariology, their familiarity with the minimal invasive philosophy, and the techniques that they use to remove dental caries and detect when to stop the removal of carious tissues. In addition, an in vitro diagnostic test was conducted. Carious teeth were excavated to a level selected in random. Teeth were examined by each participant individually. Initial examination was performed by visual inspection. Subsequently, a dental explorer was used concerning the potential need for further removal of dental tissues. A sample of 380 dentists and dental school students were selected for the purposes of this study.

Results: Dental students presented statistically significant better sensitivity, than dentists from both age groups, during both visual inspection and tactile sensation of residual caries. Participants’ ability to diagnose residual caries during cavity preparation was independent of their years of experience.

Conclusions: During the removal of carious lesions, with the goal of limiting the sacrifice of healthy structures and the leftover of residual caries, clinicians should combine a selective removal technique and the attentive visual inspection, with at least one further diagnostic method, aside from the dental explorer. Tactile examination of residual caries solely with the dental explorer must be used with attention.

Keywords: Caries excavation; caries removal; dental caries test; dental explorer; residual caries; visual-tactile examination

INTRODUCTION

For the management of dental caries, it is known that the interception of the disease progression and the surgical treatment of the definite necessary tissue promote the longevity of the teeth, taking into consideration that when teeth are restored, they enter a vicious circle of retreatment with progressive enlargement of the restoration area, possible loss of the pulpal, and eventually of the tooth.[1-4]

Minimally invasive caries removal lead to decreased cutoff of unaffected dentinal tubules, which make the operation less painful, the remaining tissue less permeable in caries, and enhance long-term biomimetic function.[5,6] Based on the nature of the lesion, using histologic, biochemical, biomechanical, microscopic, and microbiologic criteria, the caries lesion can be separated into two distinct layers. The superficial layer (“infected dentin”) constituted by psychological uncalcifiable necrotic collagen matrix, which must be eliminated, and the inner layer (“affected dentin”), which has to be preserved, as it retains the cross-banded ultrastructure of its collagen matrix and in...
Until today, no diagnostic tool enabling clear identification between two layers has been discovered. However, the combination of the conventional visual inspection and probing, with the recent available methods, such as laser fluorescence technology and dyeing stains, can save a remarkable amount of tooth tissues in everyday clinical practice and consequently improve the long-term prognosis of the teeth.

The dental explorer is one of the most popular dental instruments and is especially in connection to the diagnosis of dental caries. Many dentists use the dental explorer to determine the presence of residual caries and consequently, whether further removal of dental tissues is warranted. Nowadays, it is proven that the use of the dental explorer during the diagnosis of dental caries can provoke irreversible damage and boost the lesion’s progression. Clinicians are often advised to remove “leathery” dentine tissue until the remain of a firm endpoint, because hard and dry tissues usually present fewer bacteria. As a result, the use of hand instruments during the removal of carious tissue is widespread subject to the operator’s clinical background and experience. In addition, during the test of the dentin’s hardness with hand instruments, the chance for an unexpected pulp perforation is raised. Dental tissue color and surface hardness, usually evaluated by visual inspection, as well as tactile sense through a dental explorer or a dentin excavator, constitute subjective yet widely used criteria, in order to determine the end point of caries removal. Therefore, various operators can end up with a different diagnosis and consequently, treatment. Its effectiveness in diagnosing dental caries was evaluated by different dentists. Only the histologic examination of the lesion can distinguish between the sound, infected, and affected zone of carious tissue, with reproducible results, but its application is restricted mainly in the in vitro study. Therefore, it has been established as the gold standard.

The objectivity of this study was to evaluate the ability of dentists and dental students to determine the caries excavation end point, using conventional visual-tactile examination, and to assess the technique’s subjectivity by associating the results with the operator’s clinical experience. The auxiliary aim was to assess their inclination to perform minimally invasive dentistry, through the methods utilized by Greek dentists and dental students to identify and remove residual caries.

**MATERIALS AND METHODS**

Ethical approval for this study was obtained from the Ethics Committee of Athens University of Dentistry (Ref. 17/2016). The methods reported by Bennet et al. were followed for reporting of this survey. The sample of this interactive, cross-sectional, population-based study was designed to be representative of dentists who are employed in Greece. The capital, Athens, and nearby regions and towns were accessed for this study. Dentists who were exclusively practicing a dental specialization, which was not relevant with the removal of dental caries, were excluded. University dental students, in their 4th and 5th academic year, were also participated.

Research for studies was conducted in Medline, Scopus, Cochrane Central Register of Controlled Trials and Google; relevant articles were taken into consideration, to increase the validity and reliability of the study. Before its mainstream distribution, the questionnaire was administered to 10 “pilot” respondents, in order to identify potential problems. These correspondents, along with the authors, were excluded from the final selection pool. The interviewers (P., N., N. L.) were calibrated to reduce interviewer bias and were prepared to respond to any contingency. Cronbach’s alpha coefficient was calculated to check internal consistency.

Between the beginning of November 2015 and the end of March 2016, an interview in person with all study participants was arranged in order to complete the questionnaire along with the in vitro diagnostic test. A specific number of participants for each region were determined, based on the sum of dentists working there, in order to represent the region’s population. For this purpose, the local dental association from each region was contacted. The selection of respondents was performed randomly, using a random number engine (Random.org). At the first stage, participants were contacted by telephone. Two communication attempts were performed for every participant. Initially,
the name of our institute (Dental School, Department of Operative Dentistry, XXXXXX University), the purpose of the survey, along with its length and anonymous voluntary character were announced. A personal appointment was arranged, for each dentist who accepted to take part in our study, in their workplace. Permission from the Chair of the total dental care clinic was obtained, and the students were approached discreetly in the university, when they were free from their responsibilities.

The dentists were asked about the years of their clinical practice, any further training concerning cariology, their familiarity with the minimal invasive philosophy, about the sensation that helped them substantially in the diagnosis of residual caries following the fulfillment of the in vitro test, and the techniques that they use to remove dental caries and detect when to stop the removal of carious tissues. Considering that the students use exclusively basic techniques in their clinical practice at dental school, the question regarding the technique to remove the carious tissues was amended into “which technique do you consider optimal for carious tissues removal?” Questionnaires for dentists and students are presented in Figures 1 and 2, respectively.

For the setup of the in vitro diagnostic test, ten freshly extracted human carious teeth \((n = 10)\), 7 molars, and 3 premolars were randomly selected from the pool of teeth. Half of them had occlusal and the rest free smooth caries lesions. The roots of the teeth were encapsulated using denture acrylic resin. The caries was removed, using a slow rotary handpiece and a round bur by an author, to a level selected in random with a slight tendency to over- or under-excavate, to standardize the conditions. After the excavation process, the samples were randomly numbered. A first estimation of the removal result was performed using a quantitative laser fluorescence caries diagnostic device (DIAGNodent, Kavo), so as to confirm that there are still teeth which require further carious tissue removal. The cone-shaped light probe tip with a cutoff limit of 30 was used. The device was first calibrated according to the manufacturer’s instructions. The highest reading from each lesion was recorded. The authors who acted as interviewers remained blind to previous evaluations from others dentists or students. Interviewers were attending the procedure, to confirm that the examiners do not branch off the test areas. Dentists who used magnifying loupes were asked to perform the visual inspection, wearing them, as in their everyday clinical practice. The diagnosis for each tooth was recorded individually. A total of 8 sharp dental explorers (Stoma, Explorer EX8 Ref: 2242.00, Lot: 14005020), one for every 50 participants were used.

**Statistical analysis**

The statistical analysis was performed using the software SPSS (Statistical Package for Social Sciences, Version 13.0, SPSS Inc., Chicago, IL, USA). Kruskal–Wallis one-way analysis of variance was used for independent samples. Mann-Whitney U test was performed on the groups to identify statistically significant outcomes. For each group, the results were described by means of ± standard deviations. Sensitivity and specificity values were calculated for each clinician, experience group, and method. The probability level for statistical significance was set at a five percent (0.05).

**RESULTS**

A sample of 380 dentists and dental school students was selected for the purposes of this study – 56% (220) examiner, who remained blinded to the survey results. The teeth sections were reexamined to prevent examiner bias, after 1 week. The carious sites were photographed macroscopically and microscopically [Figure 3].

Every tooth was examined by each participant individually, initially only with the use of visual inspection and subsequently, in combination with a dental explorer, concerning the potential need for further removal of dental tissues. Each examiner remained blinded to previous evaluations from others dentists or students. Interviewers were attending the procedure, to confirm that the examiners do not branch off the test areas. Dentists who used magnifying loupes were asked to perform the visual inspection, wearing them, as in their everyday clinical practice. The diagnosis for each tooth was recorded individually. A total of 8 sharp dental explorers (Stoma, Explorer EX8 Ref: 2242.00, Lot: 14005020), one for every 50 participants were used.

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![Figure 1: 1st row Teeth lesions after the random removal of carious tissue. 2nd row Stained lesions after the application of caries detector dye. 3rd row Histopathology after the longitudinal section of the teeth](image-url)
dentists and 44% (160) students. From the sample of 280 dentists, 78% (220) took part in this study, 7% (20) refused to, and 15% (40) were unavailable. About 51% (112) of the participating dentists were male and 49% (108) female. In parallel, from the sample of 160 students, equally distributed in the two last years of dental school, 100% (160) took part in this study, 38% (60) of the participating students were male, and 62% (100) female. All questionnaires were fully completed with no missing data. The experience of the examiners ranged from the undergraduate level to 41 years of clinical practice. Undergraduate students were classified according to their year of clinical practice. Dentists were assorted in two segments, based on their clinical experience; dentists with 20 years, or more, comprised the first segment, due to their significant clinical experience, as well as the fact that their primary dental education was significantly different from that of the least experienced segment, which includes the remaining clinicians.

DIAGNo dent analysis provided that 3 out of 10 teeth were underexcavated. Caries detector dye indicated the presence of residual caries in 6 out of 10 teeth. Histological analysis revealed that 5 out of 10 teeth had residual carries, of which 5 with infected dentin, 3 with affected dentin, whereas 2 being free of residual caries. The analysis was carried out using digital microscope and the photos of historical images were taken using Leica LED2500 digital camera.

Table 1 presents the results of questionnaires, regarding the familiarity of dentists with the minimal invasive philosophy, the preferred caries removal techniques, and approach to distinguish the caries excavation end point, compared to the years of dental clinical experience. In order to distinguish the carious tissue removal end point, probing with a dental explorer is preferred by most of the students (78.7%) and dentists (88.1%), while the optical inspection is employed by 52.5% and 21.8%, respectively. Color was the parameter assessed in the majority of visual inspections, toward a diagnosis. The use of a round carbide bur in a low-speed handpiece was the most popular choice (60.6%) as regards the optimal technique to remove dental caries among students and also the most frequent removal technique among dentists (88.6%). Both the majority of students (84.3%) and experienced professionals (69.9%) were familiar with the concept of minimal invasive dentistry, with the later however indicating statistically insignificant lower MID awareness [Table 2].

Table 3 presents the results of the in vitro test for both dentists and dental students. The final analysis was performed against histological data, which are characterized as the gold standard. Dental students presented statistically significant better sensitivity than dentists from both age groups, during both visual inspection and tactile sensation of residual caries. Contrarily, dentists presented better specificity, in the identification of residual caries with the use of both visual inspection and tactile sensation. The gender of the participant did not statistically affect the residual caries detection results. Table 3 shows the results for each diagnostic approach.
Table 1: Favorable approach to distinguish caries excavation end point

| Technique to distinguish caries end point | Group level of experience (%) |
|----------------------------------------|--------------------------------|
|                                        | Students 4th year | Students 5th year | Dentists ≤20 years | Dentists >20 years |
| Visual inspection                       | 41.3              | 53.8              | 30.7              | 9.7               |
| Dental explorer                         | 78.8              | 78.8              | 88.2              | 88.2              |
| Excavator                               | 55                | 57.5              | 57.5              | 55.9              |
| Carbide bur selectivity                 | 22.5              | 33.8              | 44.1              | 38.7              |
| Radiograph                              | 13.8              | 25                | 13.4              | 10.8              |
| Caries-detector dyes                    | 3.8               | 3.8               | 17.3              | 7.5               |
| Light-emitting device                   | 1.3               | 2.5               | 0.8               | 3.2               |

Table 2: Familiarity with minimal invasive philosophy

| Group                  | Familiar with minimal invasive philosophy (%) |
|------------------------|----------------------------------------------|
| Students 1st year      | 81.3                                         |
| Students 2nd year      | 87.5                                         |
| Dentists ≤20 years     | 80.3                                         |
| Dentists >20 years     | 69.9                                         |

Table 3: Results of the in vitro test

| Group                  | Mean/median |
|------------------------|-------------|
|                        | Sensitivity | Specificity |
|                        | Visual explorer | (%) | Visual explorer | (%) | Visual explorer | (%) | Visual explorer | (%) |
| Students 1st year      | 5.4/5       | 56.7    | 54    | 52.3    | 52    |
| Students 2nd year      | 5.2/5       | 56.5    | 57.2  | 49     | 50    |
| Dentists ≤20 years     | 5.58/6      | 49.6    | 41.9  | 62     | 60.1  |
| Dentists >20 years     | 5.61/6      | 45.4    | 42.6  | 66.5   | 59.1  |

Statistical significant difference between Students and Dentists (P<0.05)

**DISCUSSION**

An ideal diagnostic method should combine both high specificity and sensitivity. Visual-tactile methods provide high specificity but poor sensitivity. When a diagnostic device presents increased sensitivity, commonly its specificity is also impaired. However, high specificity, despite coming of the expense of sensitivity, is considered to be more important, as the risk for overtreatment is lower. Infected dentin remnants are not a threat for the tooth when the restoration seals the lesion effectively. The clinical data are limited, due to the absence of histological examinations of sound teeth surfaces.

The majority of dentists use high-speed handpieces to gain sufficient access to carious dentin and remove it with low-speed handpiece. Even though these instruments are effective in terms of total caries removal, the control of the excavation process with rotary instruments is difficult as the removal process simultaneously targets both infected and affected dentin and can extend to the underlying sound dentin with limited and subjective tactile feedback. Polymer burs have been introduced to improve the minimal invasive capabilities of rotary instruments as they are made of materials harder than carious infected dentin but softer than affected dentin. Based on the results of the current survey, no dentist uses polymer burs and the majority have no knowledge of them. Overexcavation can be reduced by the combination of hand instruments and low-speed steel burs, but this combination still leads to subjective and nonselective removal.

The degree of clinical experience differed between dentists who took part in this study. Caries lesion color and hardness are subjective variables. The reliability of the dental explorer depends on the experience of operator and his familiarity with this method. Tactile perception with fingertips is a subjective method, as sensor and nerve functions are employed. In addition, sound dentin presents different levels of hardness, depending on its anatomical location. A great variety of dental explorers with different weight, shape, handle thickness, and tip sharpness is available. Dental explorers abrade over time and become dull. The reliability of the dental explorer depends on the experience of the operator and his familiarity with this method. All these parameters can make the tactile sensation increasingly subjective. Every dentist applies different probing pressure and has a different sensation of hard and soft feeling. Clinicians use a hand instrument and remove carious dentin until the proper level of hardness. The use of dental explorer in order to estimate the caries excavation end point seems to be a subjective method, which can lead either to underpreparation or overpreparation, as it is open to personal interpretation. The application of pressure greatly differs between clinicians, with most of them applying intense force, which can frequently lead to pulp exposure.

Ideally, a diagnostic method should assess the presence of bacteria, in order to clearly distinguish between infected and affected dentin. Tactile sense through a sharp dental explorer did not improve the diagnostic accuracy both for residual and initial caries compared to visual inspection. The low learning curve can be partially explained by the fact that misdiagnosis may be discovered at a future time. If underexcavation has taken place, its effect may appear immediately or later on, with the potential to be misdiagnosed as secondary caries. The effect of over-excavation in tooth’s retreatment cycle, is often not considered as clinician’s fault. The practitioner’s diagnosis is mainly based on the hardness of dentin, through the tactile sense with dental instruments, while more subjective criteria, as color, darkness, and moisture of the remaining dentin are often ignored. Discoloration is not strictly correlated with the level of infection; in acute caries, bacterial invasion extends beyond any possible discoloration. During the excavation procedure, both color and hardness changes are continuous, which make the differences very subtle. More experienced professionals...
displayed statistical significant higher specificity, compared to young probe and visual inspection. Dental students present statistical significant superior sensitivity both in visual identification and tactile sensation of residual caries, which can be explained by the fact that the XXXXXX Dental School in the past 5 years had reformed the curriculum and gave greater focus on the optical assessment of carries and minimal invasive philosophy. Therefore, it can be concluded that dental education has a significant impact in future dentists’ clinical practice.

The operator’s variability can influence different clinical procedures including the diagnostic process. In this study, clinicians with a great variety of clinical experience are involved. Dental students are taught a wide range of diagnostic techniques for caries detection, and for caries removal end point assessment, special focus is placed on the latest minimal invasive techniques on a theoretical level; however, their application in the dental school clinical practice is still limited. The caries treatment curriculum differs significantly among dental schools. The traditional visual-tactile method, in combination with new caries diagnostic methods, has to be available, in order to reduce the objective effect of the former, to standardize the training procedure, and to help students be more confident during caries removal procedures.

The simulation of clinical conditions in this laboratory study could lead to study results comparable or more positive than equivalent clinical results, due to control of bias. Examination of intraoral confined space and tooth sites, which require indirect inspection, could not be simulated in this study. In order to confirm that the continuous probing will not soften the tooth tissue and increase the number of positive diagnoses, the results were validated every 25 examinations.

Our study results confirm that the use of dental explorer, one of the mostly widely utilized instruments for the identification of the caries end point, suffers from subjectivity, inherent between dentists, with a great potential either for over preparation and underpreparation. Diagnosis of residual caries with the use of a sharp dental explorer varied significantly among practitioners. Current techniques cannot determine the precise level of dentin that ought to be removed, and as a result, control methods have to be combined, to increase the potential for selective dentin removal. Despite the advances in residual caries diagnostic and removal methods, most Greek dentists still solely use traditional methods.

Students, as well as the dentists with <20 years of clinical experience, exhibited more familiarity concerning MID. This can be explained by the fact that the XXXXXXX Dental School adopted minimal invasive philosophy into its curriculum in 2006. Most of the experienced professionals considered the minimal invasive philosophy to be associated with the avoidance of retention-shaped cavities at the expense of the healthy dental tissues formation. Dental schools should introduce students to the minimal invasive philosophy and bring them in contact with a variety of diagnostic and selective caries removal techniques, in order to broaden the horizons for future dentists and orient in the direction of the minimal intervention rationale.

DIAGNOdent demonstrated greater sensitivity but lower specificity compared to visual caries diagnosis. Due to the number of false-positive diagnoses, DIAGNOdent is suggested to be used supplementary to clinical diagnostic examination methods. The aforementioned results of the present study must be accepted with caution, as our thymol storage solution could decrease the fluorescence cutoff values. DIAGNOdent can be used both as a diagnostic apparatus to identify carious lesions and at excavationable dentin. DIAGNOdent values appear to correspond to the rates of bacterial detection in arrested dentinal carious lesions. The use of DIAGNOdent to assist caries excavation can be influenced by residual dentin stains. Krause et al. claimed that the lesion’s proximity to dental pulp can result in increased DIAGNOdent measurement values; contrarily, de Almeida Neves et al. conclude that the measurement values are not affected by the lesion’s distance from dental pulp but from the staining of residual caries. However, it can complement the traditional diagnostic techniques with consistent results, considering no method available can objectively identify the carious tissue. Further evaluations are required to improve its ability to selectively detect carious residual dentin, both through a better specified cutoff values and enhanced technology.

Caries-detector dyes were designed, to enable the identification of infected dentin, but this has not been confirmed by clinical research. These dyes can stain the organic matrix of less mineralized dentin, as in the normal circumpulpal dentin and in the enamel-dentine junction. As a result, caries dyes can lead to a high degree of overtreatment, when clinicians adopt them, without consideration. In our study, caries-detector resulted in 40% correct diagnosis, with 60% sensitivity and 80% specificity. A combination of DIAGNOdent and caries detector dye can assist clinician’s traditional visual-tactile diagnostic methods and give them the confidence to become more precise and selective in caries removal. Supplementary tissues that proceed the more conservative end points can aid the preservation of dental pulp and maintain increased levels of dental hard tissue over the re-restoration tooth cycle.

New specific, reliable, and valid diagnostic techniques should be developed, independent from the subjective
variables of carries lesion color and hardness, to avoid accidental invasive treatment. The optimization of current diagnostic means requires the improvement of current diagnostic criteria, as a lever to provide fewer false-positive diagnosis and remove residual bacteria, resulting to the smallest possible cavity size. Removal techniques ought to be developed taking into account biological concepts and tooth preservation as significant challenges remain. [55] Dentists should remain aware of current evidence, especially in diagnostic field, to reduce the gap between treatment required and actual treatment.

CONCLUSIONS

Participants’ ability to diagnose residual caries during cavity preparation was independent of their years of experience. Research has to continue toward new more objective, conservative techniques, in order to standardize and simplify the selective removal of carious tissues and consequently improve the long-term survival of the tooth. The effect of the examiner’s subjectivity on the diagnosis of residual caries has to be considered in future research, as it impairs the comparison between traditional and newer caries removal techniques and can result in significant differences in the quantity and quality of dental tissue removed by different clinicians. During the removal of carious lesions, with the goal of limiting the sacrifice of healthy structures and the leftover of residual caries, clinicians should combine a selective removal technique and the attentive visual inspection, with at least one further diagnostic method, aside from the dental explorer. Tactile examination of residual caries solely with the dental explorer must be used with attention.

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Conflicts of interest

There are no conflicts of interest.

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