

# Evaluation of Accuracy of DIAGNOdent in Diagnosis of Primary and Secondary Caries in Comparison to Conventional Methods

Hanieh Nokhbatolfoghaie<sup>1</sup>, Marzieh Alikhasi<sup>2</sup>, Nasim Chiniforush<sup>1</sup>, Farzaneh Khoei<sup>1</sup>,  
Nassimeh Safavi<sup>3</sup>, Behnoush Yaghoub Zadeh<sup>4</sup>

<sup>1</sup>Laser Research Center of Dentistry, School of Dentistry, Tehran University of Medical Sciences, Tehran, Iran

<sup>2</sup>Department of Dental Prosthesis and Implants, Laser Research Center of Dentistry, School of Dentistry, Tehran University of Medical Sciences, Tehran, Iran.

<sup>3</sup>Laser Application in Medical Sciences Research Center, Shahid Beheshti University of Medical Sciences, Tehran, Iran

<sup>4</sup>School of Dentistry, Tehran University of Medical Sciences, Tehran, Iran

## Abstract:

**Introduction:** Today the prevalence of teeth decays has considerably decreased. Related organizations and institutions mention several reasons for it such as improvement of decay diagnostic equipment and tools which are even capable of detecting caries in their initial stages. This resulted in reduction of costs for patients and remarkable increase in teeth life span. There are many methods for decay diagnostic, like: visual and radiographic methods, devices with fluorescence such as Quantitative light-induced fluorescence (QLF), Vista proof, Laser fluorescence (LF or DIAGNOdent), Fluorescence Camera (FC) and Digital radiography. Although DIAGNOdent is considered a valuable device for decay diagnostic, there are concerns regarding its efficacy and accuracy. Considering the sensitivity of decay diagnosis and the exorbitant annual expenses supported by government and people for caries treatment, finding the best method for early caries detection is of the most importance. Numerous studies were performed to compare different diagnostic methods with conflicting results. The objective of this study is a comparative review of the efficiency of DIAGNOdent in comparison to visual methods and radiographic methods in the diagnostic of teeth occlusal surfaces.

**Methods:** Search of PubMed, Google Scholar electronic resources was performed in order to find clinical trials in English in the period between 1998 and 2013. Full texts of only 35 articles were available.

**Conclusion:** Considering the sensitivity and specificity reported in the different studies, it seems that DIAGNOdent is an appropriate modality for caries detection as a complementary method beside other methods and its use alone to obtain treatment plan is not enough.

**Keywords:** laser; fluorescence; dental caries

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\***Corresponding Author:** Nasim Chiniforush, DDS; Laser Research Center of Dentistry, School of Dentistry, Tehran University of Medical Sciences, Tehran, Iran. Tel: +98-2188015017; Fax: +98-2188687471; Email: n-chiniforush@farabi.tums.ac.ir

## Introduction

Dental caries are one of the most important problems in world health care. Fortunately in the last decades

its rates have considerably decreased. This could be explained by the increased level of fluoride in drinking water, toothpaste and mouth rinse as well as the improvement in society's hygiene<sup>1-4</sup>. With the increasing

consciousness of people toward their oral and dental hygiene, expectancies from the dentist for early caries detection has grown. On the other hand it has been proven that the local equal application of fluoride has no effect on all dental surfaces and doesn't lead to reduction of caries in dental fissures, in such a way that occlusal caries constitutes more than 90% of caries in children<sup>5,6</sup>. In addition researches have showed that caries detection in pits and fissures is harder. One of the reasons mentioned, is the insolubility of the enamel reinforced by fluoride at the dental surface which results in no observation of decay in it, while in the layer beneath there might be some caries<sup>5,7,8</sup>. Also, different organizations and institutions have mentioned reasons such as technology progress and decay detection equipment, which even capable of detecting caries in their initial stages. This resulted in less expense for patients and considerable improvement in tooth life span.

Several methods are used to diagnose dental caries including visual examination and radiography, QLF, Vista Proof, LF (DIAGNOdent), FC (Fluorescence camera) and Digital Radiography, which present each some specific weak and strong points<sup>9-12</sup>. Reviewing usual methods such as visual examination for detection of caries on occlusal surfaces, it seems that they show low sensitivity and high specificity hence, a lot of efforts have been put to improve their sensitivity. It is accepted that visual examination based on the amount of hardness and color of the decayed area is the best tool to diagnose small size caries, but because of its low sensitivity, it is not able to well detect decayed region<sup>13</sup>. Also the use of the probe during the visual examination can help a lot in the caries diagnosis; it can even damage the fissures and demineralized enamel and result in progress of the decay process<sup>13</sup>. The use of bitewing radiography for caries detection is reliable if in terms of histology the decay process has reached the dentin besides the enamel<sup>14</sup>.

Efforts to improve the usual methods have continued with the introduction of optic fiber and digital radiography, then in 1998 Laser fluorescence (DIAGNOdent) was presented to the market for detection of occlusal caries. In several studies it has been mentioned that the sensitivity and the specificity of the DIAGNOdent was almost equal to radiography in laboratory investigations<sup>15</sup>.

DIAGNOdent is used as a complementary tool beside visual examination for diagnosis of occlusal caries. DIAGNOdent decay detection is based on the principle that when Diode laser with 655nm

wavelength is irradiated on dental surface, it is absorbed by metabolites of intraoral bacteria and these metabolites emit a red fluorescence. This fluorescence reflected by the dental surface is indicated as a number between 0 and 99 on the screen of the device. Greater numbers are an indication of a greater decay area. Therefore Laser fluorescence provides a quantitative and non-invasive method for the diagnosis of dental caries<sup>16-18</sup>. Although DIAGNOdent is considered a valuable tool in the diagnosis of decay, there are some concerns existing regarding its accuracy, for instance, there is no relation between the number showed by the DIAGNOdent and depth of decay<sup>19</sup>.

The first study on the outcome of DIAGNOdent was performed on extracted teeth, Lussi et al in 1999 cleaned the teeth with sodium hypochlorite 2% for two minutes in order to prevent false positive results from plaques and other bacterial products<sup>19</sup>. Shi et al in 2000 concluded that if the tooth is cleaned, use of DIAGNOdent provides better results than Bitewing radiography<sup>20</sup>. Numerous studies exist in order to compare different methods of caries diagnosis, with conflicting results. Because of the sensitivity of this topic and the huge expenses that annually supported by government and people for treatment of caries, finding the best method for early decay detection is of the most importance. The purpose of this review study is the evaluation of the accuracy of DIAGNOdent in the diagnosis of primary and secondary caries in comparison to conventional methods.

## Methods

Search in electronic resources such as PubMed and Google Scholar was performed in order to find clinical studies in English with keywords of "DIAGNOdent", "Laser Florescence", "Primary caries", "Secondary caries" in 1998 to 2013 time period. By investigating papers' titles and abstracts, studies with related topics on DIAGNOdent were selected and full texts were pursued. Only 35 articles' full texts were available. Then a table of Data Extraction was prepared and papers reviewed. Only studies in Case-control format were included. Then, studies were categorized based on deciduous or permanent teeth as well as primary or secondary caries.

Primary caries include caries that appear in teeth without restorations.

Secondary caries are defined as lesions on the borders of restored teeth.

## Results

Studies were divided based on the type of caries (Primary or secondary) and the type of teeth (Deciduous or permanent). 17 of the papers were on primary caries in permanent teeth and 10 articles discussed primary caries in deciduous teeth. Also regarding secondary caries in permanent teeth 7 articles and in deciduous 1 paper were found. (Table 1-4)

Group 1: Primary caries

Group 2: Secondary caries

## Discussion

Systematic evaluation of studies and their qualitative assessment is one of the pillars of evidence based dentistry. The purpose of this review study is the evaluation of the accuracy of DIAGNOdent in the diagnosis of primary and secondary caries in comparison to conventional methods.

Occlusal surface of teeth are one of the areas susceptible to caries while detection of decay in this region is problematic. Different methods have been employed by researchers to evaluate the situation of different caries, but these modalities have numerous limitations. Between these methods, Laser fluorescence has some advantages such as early detection which results in preservation of more dental structure and use of conservative treatments<sup>45</sup>. Review of papers that used DIAGNOdent to evaluate primary caries in permanent teeth showed that it has a high sensitivity and low specificity<sup>26,46</sup>. Having a high sensitivity makes this device suitable for diagnosis, but since the probability of false positive diagnosis is high, its use is recommended in combination with other techniques<sup>24</sup>. Most of these studies were performed in invitro situation, and their results because of existence of influential factors such as plaque, calculus and prophylactic paste effect are not extendable to clinical conditions. Studies that used visual method with probe for detection of caries showed unreliable results with low sensitivity. For radiography also, superimposition of healthy enamel of surrounding cusps is an obstacle to early detection of occlusal surface caries at the enamel level. But this method is recommended as a complementary method to visual evaluation in occlusal surface caries, especially when caries reached the dentin<sup>11</sup>.

Despite the reports published on high sensitivity for

DIAGNOdent, Fung et al in comparing visual method and DIAGNOdent in three different groups showed that DIAGNOdent has a low sensitivity, and observed little matching between histology and DIAGNOdent results. Obtaining high numbers by DIAGNOdent in hypomineralized enamel as well as in white and opaque lesions causes this difference<sup>30</sup>. Most studies didn't show a significant difference between DIAGNOdent and other methods and in most cases application of DIAGNOdent beside other methods is recommended to compensate for its low specificity<sup>22,29,41</sup>.

Detection of caries present under restorations is very difficult. Some researches showed that DIAGNOdent can be used to diagnose those cases<sup>10,33,42</sup>. It seems that radiation emitted by laser has the potential to cross composite and can identify caries under composite restorations, but many confounding factors can affect the number obtained by the device that has to be taken into account. For instance, it is suggested that before measurement it is better to perform polishing procedure on the filling in order for the stain existing on the restorations to not limit and create false responses<sup>47</sup>. Of course other factors existing in in vitro studies have to be considered. Antiseptic solutions and tooth restoring solutions may provoke changes in the tooth structure and affect the response obtained from fluorescence<sup>48</sup>. On the other hand, Krause et al showed that DIAGNOdent has limitations in the evaluation of remaining caries near the pulp, this factor has to be considered for extended restorations and those closed to the pulp<sup>49</sup>.

Since use of conventional method for caries detection in children need their cooperation, finding a modality which wouldn't be dependent on patient collaboration could lead to more accurate evaluation of the caries situation. DIAGNOdent is simple device to use and doesn't need a lot of cooperation from the child and in a short time (few seconds) numbers obtained determine the condition of the caries. In addition repetitive use of this device has no harm for the child.

Braga et al in their study by using DIAGNOdent and visual method to evaluate secondary caries around amalgam restorations reached the conclusion that visual method has the best results in the diagnosis of secondary caries in enamel and dentin of deciduous teeth. Based on their claims if only a method had to be used for detection of secondary caries, the method has to have a high sensitivity for diagnosis of enamel caries and high specificity for deep lesions in dentin<sup>44</sup>.

Reaching a general conclusion might very difficult,

Table 1. Investigation of DIAGNOdent in primary caries of permanent teeth

| First author's Name/year                 | In vitro\ In vivo  | Sample volume                                 | Occlusal/ Proximal | Comparison of Methods  | Gold Standard                  | Results   | Conclusion  |
|--|--------------------|---|--------------------|--|--------------------------------|---|-------------|
| 1 Achilleos EE (2012) <sup>9</sup>       | In vitro           | 38 Human molars and premolars                 | Occlusal           | 1. Visual method (ICDAS)<br>2. DIAGNOdent (Pen)<br>3. Fluorescence camera VistaProof | Histology                      | 1- VistaProof and DIAGNOdent were almost ideal and superior to visual method (ICDAS).<br>2- Sensitivity of VistaProof superior to clinical method and clinical method sensitivity superior to DIAGNOdent but not statistically significant  | = *         |
| 2 De Paula AB(2011) <sup>16</sup>        | In vitro & In situ | 26 Human 3 <sup>rd</sup> molars (64 regions)  | Occlusal           | 1. Visual method<br>2. DIAGNOdent, Laser fluorescence (LF)                           | Histology                      | Visual method and LF were more efficient in In vitro studies compared to In situ. It can be concluded that visual method and LF show different efficiencies when used in In vitro and In situ which means attention should be paid to the fact that laboratory results are different to clinical. Therefore more In vitro and In situ studies are required to evaluate the validity of this method in clinical setting.   | =           |
| 3 Jablonski-Momeni A(2011) <sup>17</sup> | In vitro           | 100 Human molars and pre molars (181 regions) | Occlusal           | 1. Visual method (ICDAS II)<br>2. DIAGNOdent (LF)                                    | Histology                      | ICDAS-II diagnosis accuracy is higher than LF when DIAGNOdent can better monitor decayed regions.   | =           |
| 4 CH.Chu(2010) <sup>21</sup>             | In vivo            | 144 Human 2 <sup>nd</sup> molars              | Occlusal           | 1. DIAGNOdent (LF)<br>2. Radiography (BW)<br>3. Visual method                        | Sulcus opening                 | 1. Observation of opacity or color change after drying in young adults during visual examination is a sensitive tool in caries diagnosis, but specificity is low.<br>2. DIAGNOdent with LF base has an acceptable sensitivity and specificity.<br>3. Caries diagnosis made on the basis of a combination of visual method and DIAGNOdent shows a good level of sensitivity and specificity and can be considered an appropriate method for diagnosis of decayed dentin. | =           |
| 5 Pourhashemi SJ(2009) <sup>22</sup>     | In vitro           | 80 Human premolar                             | Occlusal           | 1. DIAGNOdent (LF)<br>2. Radiography BW<br>3. Visual method                          | Histology                      | Although accuracy and reproducibility of LF method is higher than VI and BW radiography, it is better to use this method with other methods in order to reduce risks of errors  | +**         |
| 6 Sridhar N (2009) <sup>23</sup>         | In vitro           | -   | Occlusal           | 1. DIAGNOdent (LF)<br>2. Radiography BW<br>3. Visual method                          | Histology                      | Study showed that DIAGNOdent can diagnose occlusal surface caries better than visual method and radiography   | R+***<br>V= |
| 7 Ku"hmisch J (2008) <sup>15</sup>       | In vivo            | 311 Human molars                              | Occlusal           | 1. Visual method (ICDAS II)<br>2. Visual method (WHO)<br>3. DIAGNOdent (LF)          | -                              | When ICDAS II criteria are used in vivo, it seemed that LF didn't detect any finding. While it caused more work and costs. Use of DIAGNOdent in field study in which visual criteria were applied seemed to provide limited additional information  | =           |
| 8 Costa AM (2008) <sup>24</sup>          | In vivo            | 199 Human molars and premolars                | Occlusal           | 1. DIAGNOdent (LF)<br>2. Radiography (BW)<br>3. Visual method                        | Opening of Caries              | Results of research shows that although use of laser shows acceptable sensitivity and specificity, it has been recommended to use laser in combination with visual method in order to reduce the possibility of false positive results. Long research for diagnosis of occlusal surface caries using laser and patient follow up has been recommended   | =           |
| 9 Huth KC(2008) <sup>25</sup>            | In vivo            | 120 Human molars                              | Occlusal           | 1. DIAGNOdent (Pen)<br>2. Radiography (BW)<br>3. Visual method                       | Caries depth after its removal | Considering this study, caries diagnosis by DIAGNOdent was moderate to good and it is possible to use it as a complementary device for occlusal surfaces caries   | =           |

Table 1. Continue

| 10 | Toraman Alkurt MT (2008) <sup>26</sup> | In vivo            | 44 Human teeth                                      | Occlusal | 1. DIAGNOdent (LF)<br>2. Radiography (BW)<br>3. Visual method                       | Measuring lesion depth | Result is that LF can be beneficial as a complement to visual examination and it appears that this device is efficient for diagnosis of occlusal caries  | +      |  |  |
|----|--|--------------------|---|----------|---|------------------------|--|--------|--|--|
| 11 | Reis A (2006) <sup>27</sup>            | In vitro & In vivo | 57 Human molars (110 regions)                       | Occlusal | 1. Visual method<br>2. DIAGNOdent, (LF)   | Histology              | Caries diagnostic methods in clinic and laboratory are not different in terms of execution, especially in visual method. LF method efficiency was a little different, probably because of change in amount of organic substances after tooth extraction  | =      |  |  |
| 12 | Tomasik M (2005) <sup>28</sup>         | In vivo            | 237 Human molars                                    | Occlusal | 1. Visual method<br>2. DIAGNOdent, (LF)   | Histology              | Use of DIAGNOdent eases primary detection in fissures. In addition it is beneficial in limiting unnecessary preparation of healthy teeth in cases where visual exam alone is not enough. In fact DIAGNOdent is a beneficial, sensitive, and non-invasive method in diagnosis of occlusal caries, especially in children  | =      |  |  |
| 13 | Angnes G (2005) <sup>13</sup>          | In vitro           | 57 Human molars (110 regions)                       | Occlusal | 1. DIAGNOdent (LF)<br>2. Radiography<br>3. Visual method                            | Histology              | Accurate visual examination makes the dentist capable of detecting caries changes earlier.   | -.**** |  |  |
| 14 | Anttonen V (2004) <sup>29</sup>        | In vivo            | 423 Human permanent molars and 315 deciduous molars | Occlusal | 1. Visual method<br>2. DIAGNOdent, (LF)   | -                      | Results show that the application of DIAGNOdent accompanied by visual method is a beneficial tool for dentist with less experience for caries diagnosis in deciduous and permanent molar teeth   | =      |  |  |
| 15 | Fung L (2004) <sup>30</sup>            | In vitro           | 25 Human molars                                     | Occlusal | 1. Visual method<br>2. DIAGNOdent, (LF)   | Histology              | Different results were obtained from 2 diagnostic methods, although sensitivity was relatively high in visual method and specificity was high in DIAGNOdent, which prevents unnecessary treatments in low risk caries  | -      |  |  |
| 16 | Chong MJ (2003) <sup>11</sup>          | In vitro           | 320 Human Premolars                                 | Occlusal | 1. Visual method<br>2. Radiography<br>3. Digital radiography<br>4. DIAGNOdent, (LF) | Histology              | Although diagnosis of dentinal hidden caries can be better with DIAGNOdent, but combination of visual-tactile method and any usual method or digital radiography can detect up to 80% of lesions   | -      |  |  |
| 17 | Lussi A (2001) <sup>31</sup>           | In vivo            | 332 occlusal surfaces                               | Occlusal | 1. DIAGNOdent (LF)<br>2. Radiography (BW)<br>3. Visual method                       | Histology              | This study clearly shows that clinical and visual exam in occlusal surfaces has enough sensitivity in vivo. Despite it, DIAGNOdent based on fluorescence has excellent sensitivity. In case after drying there are doubts left regarding a specific region, laser device can be used as a complementary valuable device. If laser is used with visual exam we will have a high sensitivity as well as high specificity | +      |  |  |

\*Meaning of = is that DIAGNOdent has no significant difference in comparison to other methods for detection of caries

\*\*Meaning of + is that DIAGNOdent has a better results compared to other methods for diagnosis of caries

\*\*\*R= Radiographic methods V= Visual method

\*\*\*\*Meaning of - is that other methods have better results compared to DIAGNOdent for diagnosis of caries

Table 2. Evaluation of DIAGNOdent in primary caries of deciduous teeth

| First author's Name/year            | In vitro/<br>In vivo | Sample Volume   | Occlusal/<br>Proximal             | Comparison of Methods   | Gold Standard      | Results  | Conclusion |
|-------------------------------------|----------------------|---|-----------------------------------|---|--------------------|--|------------|
| 1 J. F. Souza 2012 <sup>32</sup>    | In vitro             | 79 Human molars   | Occlusal                          | 1. Visual method (ICDAS II)<br>2. Radiography BW<br>3. DIAGNOdent (LF) 2095<br>4. DIAGNOdent (LF Pen) 2190<br>5. Fluorescence camera<br>VistaProof (FC) | Histology          | ICDAS and FC showed better accuracy in detection of enamel and dentin caries lesions. While ICDAS, LF, LF Pen and FC had no significant statistical difference in the diagnosis of lesions in occlusal surfaces of deciduous teeth, attention has to be paid to this important point that new methods such as methods based on fluorescence should be considered as complementary methods in the detection of caries                             | =*         |
| 2 Neuhaus K W 2011 <sup>33</sup>    | In vitro             | 37 Human molars   | Occlusal                          | 1. DIAGNOdent (Pen)<br>2. DIAGNOdent (LF) 2095<br>3. Radiography (BW)<br>4. Visual Method (ICDAS)   | Histology          | After primary visual examination with ICDAS or without it, use of LF Pen could be helpful in the diagnosis of deciduous occlusal caries. Bitewing radiography could only show proximal caries  | =          |
| 3 DeBenedetto MS 2011 <sup>18</sup> | In vitro             | 129 Human molars<br>Occlusal regions<br>(96)<br>Smooth regions<br>(113) | Occlusal and<br>Smooth<br>regions | 1. DIAGNOdent (LF)<br>4. DIAGNOdent (LF Pen)<br>5. Fluorescence camera (FC)<br>Vistaproof   | -                  | In general when FC is used on occlusal and smooth surfaces, it has a higher efficiency, just like any other device operating with fluorescent light  | =          |
| 4 Celiberto P 2010 <sup>34</sup>    | In vitro             | 123 Human molars  | Proximal                          | 1. Visual method<br>2. DIAGNOdent (Pen)   | Histology          | LF is not able to evaluate and the depth of proximal caries and shows that it is not reliable in deciduous molar teeth. Therefore the result is that this method is not suitable to detect proximal caries in deciduous molars and especially in regions not cu.   | -**        |
| 5 Goel A 2009 <sup>35</sup>         | In vivo              | 84 first and second molars  | Occlusal                          | 1. DIAGNOdent (LF)<br>2. Radiography (BW)<br>3. Visual method<br>4. Tactile   | Histology          | DIAGNOdent showed that it has superior sensitivity and accuracy in diagnosis of dental caries compared to other usual methods. Although DIAGNOdent had a high sensitivity for dental caries detection, but it was similar to other caries diagnostic methods.  | +***       |
| 6 Braga MM 2009 <sup>36</sup>       | In vitro             | 131 Human molars  | Proximal                          | 1. Visual method (ICDAS II)<br>2. Radiography (BW)<br>3. DIAGNOdent (Pen)   | Histology          | Visual method has showed better results in these in vitro studies for diagnosis of proximal caries in deciduous teeth. Even though both methods Radiography and LF Pen had a good efficiency particularly in detecting advanced caries   | -          |
| 7 Kavvadia K 2008 <sup>37</sup>     | In vivo              | 405 Human molars  | Occlusal                          | 1. Direct visual method (DV)<br>2. Indirect visual method (IDV)<br>3. Radiography BW<br>4. DIAGNOdent (LF)  | fissure<br>opening | DIAGNOdent is very reliable in detection of occlusal caries in deciduous teeth and its efficiency is similar to direct visual method and radiography   | =          |
| 8 Virajsilp V 2005 <sup>38</sup>    | In vitro             | 107 Human molars  | Proximal                          | 1. DIAGNOdent (LF)<br>2. Radiography (BW)   | Histology          | DIAGNOdent is very reliable and the validity of its diagnostic (sensitivity and specificity) was higher than radiography bitewing in the detection of proximal caries in deciduous teeth   | +          |
| 9 Anttonen V 2004 <sup>29</sup>     | In vivo              | 423 Human permanent molars<br>315 Human deciduous molars                | Occlusal                          | 1. Visual method<br>2. DIAGNOdent (LF)  | -                  | Results showed that DIAGNOdent in combination to visual method is beneficial tool for dentists with less experience for the diagnosis of caries in deciduous and permanent molar teeth.  | =          |
| 10 Attrill DC 2001 <sup>39</sup>    | In vitro             | 58 Human molars   | Occlusal                          | 1. DIAGNOdent (LF)<br>2. Radiography<br>3. Visual method  | Histology          | DIAGNOdent is the more accurate evaluation system for the detection of occlusal surfaces dental caries in deciduous molars. The efficiency of DIAGNOdent in terms of statistics was not significant compared to visual method in teeth without cavity preparation. DIAGNOdent can be considered as a beneficial clinical tool, although with proper training visual method could have similar results without any needs for additional equipment | =          |

\* Meaning of = is that DIAGNOdent has no significant difference in comparison to other methods for detection of caries

\*\* Meaning of - is that other methods have better results compared to DIAGNOdent for diagnosis of caries

\*\*\* Meaning of + is that DIAGNOdent has a better results compared to other methods for diagnosis of caries

## Diagnodent in Decay diagnostic

**Table 3.** Evaluation of DIAGNOdent in secondary carie in permanent teeth

|   | First author's Name/year             | In vitro\ In vivo | Sample volume                 | Occlusal/ Proximal    | Method Comparison  | Gold Standard                             | Results   | Conclusion |
|---|--------------------------------------|-------------------|-------------------------------|-----------------------|--|---|---|------------|
| 1 | K. W. Neuhaus 2012 <sup>33</sup>     | In vitro          | 75 Human molars               | Proximal              | 1. DIAGNOdent (LF)<br>2. Radiography BW  | Histology                                 | Results showed that use of LF in comparison with BW for proximal in the cervical region of margins of amalgam restorations led to better detection of secondary caries which had not extended to CEJ  | +*         |
| 2 | Kositbowornchai S 2012 <sup>40</sup> | In vitro          | 100 Human molars              | Occlusal              | 1. DIAGNOdent (LF)<br>2. Radiography Digital   | Histology                                 | Use of Diagnodent in comparison to digital radiography in the diagnosis of caries under posterior composite restorations had no significant difference  | **         |
| 3 | Rodrigues JA 2010 <sup>41</sup>      | In vitro          | 43 Human molars (60 regions)  | Proximal              | 1. Visual method (VE)<br>2. Radiography (BW)<br>3. Visual method and radiography (VEBW)<br>4. DIAGNOdent (Pen) | Histology and hardness measuring          | DIAGNOdent has to be considered as a complementary method in the diagnosis of secondary proximal caries in relation to composite restorations   | =          |
| 4 | Bamzahim M 2005 <sup>42</sup>        | In vivo           | 51 Human premolars and molars | Occlusal and Proximal | 1. DIAGNOdent (LF)<br>2. Radiography BW<br>3. Visual method  | Visual and Tactile                        | Results of this study showed that treatment decision shouldn't be made of the basis of DIAGNOdent findings alone. Even if this device could be used as a valuable complementary tool for usual methods in the diagnosis of secondary caries of teeth restored with amalgam. | =          |
| 5 | Ando M 2004 <sup>10</sup>            | In vitro          | 50 Human premolar and molars  | Occlusal and Proximal | 1. DIAGNOdent (LF)<br>2. Visual method   | CLSM (confocal laser scanning microscopy) | Results obtained from this study suggest that LF and QLF could improve the ability to diagnose secondary caries around amalgam restorations   | +          |
| 6 | Bamzahim M 2004 <sup>12</sup>        | In vitro          | 66 Teeth                      | Occlusal              | 1. DIAGNOdent (LF)<br>2. Radiography Digital (BW)  | Histology                                 | Results showed that DIAGNOdent could be a beneficial tool in the detection of secondary caries  | =          |
| 7 | Boston DW 2003 <sup>43</sup>         | In vitro          | 15 Teeth (30 regions)         | -                     | 1. DIAGNOdent (LF)<br>2. Visual method   | Histology                                 | DIAGNOdent is better than visual method in the diagnosis of secondary caries of dentin compared to visual method, but with no significant difference  | =          |

\* Meaning of + is that DIAGNOdent has a better results compared to other methods for diagnosis of caries

\*\* Meaning of = is that DIAGNOdent has no significant difference in comparison to other methods for detection of caries

**Table 4.** Evaluation of DIAGNOdent in secondary caries of deciduous teeth

|   | First author's Name/year    | In vitro\ In vivo | Sample Volume                | Occlusal/ Proximal | Method Comparison   | Gold Standard | Results  | Conclusion |
|---|-----------------------------|-------------------|------------------------------|--------------------|---|---------------|--|------------|
| 1 | Braga MM 2010 <sup>44</sup> | In vitro          | 54 Human molars (73 regions) | Occlusal           | 1. DIAGNOdent (LF)<br>2. Radiography (BW)<br>3. Visual method<br>4. Tactile | -             | Visual method is the best for diagnosis of secondary caries in enamel and dentin of amalgam restorations | -*         |

\*Meaning of - is that other methods have better results compared to DIAGNOdent for diagnosis of caries

considering the many different systems of categorization of visual method and DIAGNOdent in the evaluation of caries, type of tooth (deciduous, permanent), the evaluating surface (occlusal, proximal), conditions of teeth conservation in in vitro studies, skill level of the operator using the DIAGNOdent device and the different analysis methods. More standard in vitro and in vivo studies are required for their results to be applied in Clinical settings.

## Conclusion

Considering the reported sensitivity and specificity in different studies, it seems that DIAGNOdent is a suitable device for detection of caries in complement of other methods and its use alone is not enough to provide treatment plan. Considering the expansion of advanced technologies in the caries diagnosis, more studies are required in order to compare this system to other new methods.

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