

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

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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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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 hygiene¹⁻⁴. 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^{5,6}. 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^{5,7,8}. 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 points⁹⁻¹². 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 region¹³. 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 process¹³. The use of bitewing radiography for caries detection is reliable if in terms of histology the decay process has reached the dentin besides the enamel¹⁴.

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 investigations¹⁵.

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 caries¹⁶⁻¹⁸. 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 decay¹⁹.

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 products¹⁹. Shi et al in 2000 concluded that if the tooth is cleaned, use of DIAGNOdent provides better results than Bitewing radiography²⁰. 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 treatments⁴⁵. Review of papers that used DIAGNOdent to evaluate primary caries in permanent teeth showed that it has a high sensitivity and low specificity^{26,46}. 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 techniques²⁴. 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 dentin¹¹.

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 difference³⁰. 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^{22,29,41}.

Detection of caries present under restorations is very difficult. Some researches showed that DIAGNOdent can be used to diagnose those cases^{10,33,42}. 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 responses⁴⁷. 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 fluorescence⁴⁸. 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 pulp⁴⁹.

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 dentin⁴⁴.

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) ⁹	In vitro	38 Human molars and premolars	Occlusal	1. Visual method (ICDAS) 2. DIAGNOdent (Pen) 3. Fluorescence camera VistaProof	Histology	1- VistaProof and DIAGNOdent were almost ideal and superior to visual method (ICDAS). 2- Sensitivity of VistaProof superior to clinical method and clinical method sensitivity superior to DIAGNOdent but not statistically significant	= *
2 De Paula AB(2011) ¹⁶	In vitro & In situ	26 Human 3 rd molars (64 regions)	Occlusal	1. Visual method 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) ¹⁷	In vitro	100 Human molars and pre molars (181 regions)	Occlusal	1. Visual method (ICDAS II) 2. DIAGNOdent (LF)	Histology	ICDAS-II diagnosis accuracy is higher than LF when DIAGNOdent can better monitor decayed regions.	=
4 CH.Chu(2010) ²¹	In vivo	144 Human 2 nd molars	Occlusal	1. DIAGNOdent (LF) 2. Radiography (BW) 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. 2. DIAGNOdent with LF base has an acceptable sensitivity and specificity. 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) ²²	In vitro	80 Human premolar	Occlusal	1. DIAGNOdent (LF) 2. Radiography BW 3. Visual method	Histology	Although accuracy and reproducibility of LF method is higher than V1 and BW radiography, it is better to use this method with other methods in order to reduce risks of errors	+**
6 Sridhar N (2009) ²³	In vitro	-	Occlusal	1. DIAGNOdent (LF) 2. Radiography BW 3. Visual method	Histology	Study showed that DIAGNOdent can diagnose occlusal surface caries better than visual method and radiography	R+*** V=
7 Ku" hmsich J (2008) ¹⁵	In vivo	311 Human molars	Occlusal	1. Visual method (ICDAS II) 2. Visual method (WHO) 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) ²⁴	In vivo	199 Human molars and premolars	Occlusal	1. DIAGNOdent (LF) 2. Radiography (BW) 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) ²⁵	In vivo	120 Human molars	Occlusal	1. DIAGNOdent (Pen) 2. Radiography (BW) 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) ²⁶	In vivo	44 Human teeth	Occlusal	1. DIAGNOdent (LF) 2. Radiography (BW) 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) ²⁷	In vitro & In vivo	57 Human molars (110 regions)	Occlusal	1. Visual method 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) ²⁸	In vivo	237 Human molars	Occlusal	1. Visual method 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) ¹³	In vitro	57 Human molars (110 regions)	Occlusal	1. DIAGNOdent (LF) 2. Radiography 3. Visual method	Histology	Accurate visual examination makes the dentist capable of detecting caries changes earlier.	-****
14	Anttonen V (2004) ²⁹	In vivo	423 Human permanent molars and 315 deciduous molars	Occlusal	1. Visual method 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) ³⁰	In vitro	25 Human molars	Occlusal	1. Visual method 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) ¹¹	In vitro	320 Human Premolars	Occlusal	1. Visual method 2. Radiography 3. Digital radiography 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) ³¹	In vivo	332 occlusal surfaces	Occlusal	1. DIAGNOdent (LF) 2. Radiography (BW) 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/ In vivo	Sample Volume	Occlusal/ Proximal	Comparison of Methods	Gold Standard	Results	Conclusion
1 J. F. Souza 2012 ³²	In vitro	79 Human molars	Occlusal	1. Visual method (ICDAS II) 2. Radiography BW 3. DIAGNOdent (LF) 2095 4. DIAGNOdent (LF Pen) 2190 5. Fluorescence camera 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 ³³	In vitro	37 Human molars	Occlusal	1. DIAGNOdent (Pen) 2. DIAGNOdent (LF) 2095 3. Radiography (BW) 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 ¹⁸	In vitro	129 Human molars Occlusal regions (96) Smooth regions (113)	Occlusal Smooth regions	1. DIAGNOdent (LF) 4. DIAGNOdent (LF Pen) 5. Fluorescence camera (FC) 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 ³⁴	In vitro	123 Human molars	Proximal	1. Visual method 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 ³⁵	In vivo	84 first and second molars	Occlusal	1. DIAGNOdent (LF) 2. Radiography (BW) 3. Visual method 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 ³⁶	In vitro	131 Human molars	Proximal	1. Visual method (ICDAS II) 2. Radiography (BW) 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 ³⁷	In vivo	405 Human molars	Occlusal	1. Direct visual method (DV) 2. Indirect visual method (IDV) 3. Radiography BW 4. DIAGNOdent (LF)	fissure 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 ³⁸	In vitro	107 Human molars	Proximal	1. DIAGNOdent (LF) 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 ²⁹	In vivo	423 Human permanent molars 315 Human deciduous molars	Occlusal	1. Visual method 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 Atrill DC 2001 ³⁹	In vitro	58 Human molars	Occlusal	1. DIAGNOdent (LF) 2. Radiography 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

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 ³³	In vitro	75 Human molars	Proximal	1. DIAGNOdent (LF) 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 ⁴⁰	In vitro	100 Human molars	Occlusal	1. DIAGNOdent (LF) 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 ⁴¹	In vitro	43 Human molars (60 regions)	Proximal	1. Visual method (VE) 2. Radiography (BW) 3. Visual method and radiography (VEBW) 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 ⁴²	In vivo	51 Human premolars and molars	Occlusal and Proximal	1. DIAGNOdent (LF) 2. Radiography BW 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 ⁴⁰	In vitro	50 Human premolar and molars	Occlusal and Proximal	1. DIAGNOdent (LF) 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 ⁴²	In vitro	66 Teeth	Occlusal	1. DIAGNOdent (LF) 2. Radiography Digital (BW)	Histology	Results showed that DIAGNOdent could be a beneficial tool in the detection of secondary caries	=
7	Boston DW 2003 ⁴³	In vitro	15 Teeth (30 regions)	-	1. DIAGNOdent (LF) 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 ⁴⁴	In vitro	54 Human molars (73 regions)	Occlusal	1. DIAGNOdent (LF) 2. Radiography (BW) 3. Visual method 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.

References

1. Silva BB, Severo NB, Maltz M. Validity of diode laser to monitor carious lesions in pits and fissures. *J Dent*. 2007;35(8):679-82.
2. Petersson GH, Bratthall D. The caries decline: a review of reviews. *Eur J Oral Sci*. 1996;104(4 (Pt 2)):436-43.
3. Bratthall D, Hansel-Petersson G, Sundberg H. Reasons for the caries decline: what do the experts believe? *Eur J Oral Sci*. 1996;104(4 (Pt 2)):416-22; discussion 23-5, 30-2.
4. Lussi A, Hellwig E. Performance of a new laser fluorescence device for the detection of occlusal caries in vitro. *J Dent*. 2006;34(7):467-71.
5. Baseren NM, Gokalp S. Validity of a laser fluorescence system (DIAGNOdent) for detection of occlusal caries in third molars: an in vitro study. *J Oral Rehabil*. 2003;30(12):1190-4.
6. Ingram GS, Edgar WM. Interaction of fluoride and non-fluoride agents with the caries process. *Adv Dent Res*. 1994;8:158-65.
7. Tam LE, McComb D. Diagnosis of occlusal caries: Part II. Recent diagnostic technologies. *J Can Dent Assoc*. 2001;67(8):459-63.
8. Hamilton JC, Gregory WA, Valentine JB. DIAGNOdent measurements and correlation with the depth and volume of minimally invasive cavity preparations. *Oper Dent*. 2006 May;31(3):291-6.
9. Achilleos EE, Rahiotis C, Kakaboura A, Vougiouklakis G. Evaluation of a new fluorescence-based device in the detection of incipient occlusal caries lesions. *Lasers Med Sci*. 2013;28(1):193-201.
10. Ando M, Gonzalez-Cabezas C, Isaacs RL, Eckert GJ, Stookey GK. Evaluation of several techniques for the detection of secondary caries adjacent to amalgam restorations. *Caries Res*. 2004;38(4):350-6.
11. Chong MJ, Seow WK, Purdie DM, Cheng E, Wan V. Visual-tactile examination compared with conventional radiography, digital radiography, and DIAGNOdent in the diagnosis of occlusal occult caries in extracted premolars. *Pediatr Dent*. 2003;25(4):341-9.
12. Bamzahim M, Shi XQ, Angmar-Mansson B. Secondary caries detection by DIAGNOdent and radiography: a comparative in vitro study. *Acta Odontol Scand*. 2004;62(1):61-4.
13. Angnes G, Angnes V, Grande RH, Battistella M, Loguercio AD, Reis A. Occlusal caries diagnosis in permanent teeth: an in vitro study. *Braz Oral Res*. 2005;19(4):243-8.
14. Wenzle A FE, Hintze H. Patient discomfort and cross-infection control in bitewing examination with a storage phosphor plate and a CCD-based sensor. *J Dent*. 1999.
15. Kuhnisch J, Berger S, Goddon I, Senkel H, Pitts N, Heinrich-Weltzien R. Occlusal caries detection in permanent molars according to WHO basic methods, ICDAS II and laser fluorescence measurements. *Community Dent Oral Epidemiol*. 2008;36(6):475-84.
16. De Paula AB, Campos JA, Diniz MB, Hebling J, Rodrigues JA. In situ and in vitro comparison of laser fluorescence with visual inspection in detecting occlusal caries lesions. *Lasers Med Sci*. 2011;26(1):1-5.
17. Jablonski-Momeni A, Ricketts DN, Rolfsen S, Stoll R, Heinzel-Gutenbrunner M, Stachniss V, et al. Performance of laser fluorescence at tooth surface and histological section. *Lasers Med Sci*. 2011;26(2):171-8.
18. De Benedetto MS, Morais CC, Novaes TF, de Almeida Rodrigues J, Braga MM, Mendes FM. Comparing the reliability of a new fluorescence camera with conventional laser fluorescence devices in detecting caries lesions in occlusal and smooth surfaces of primary teeth. *Lasers Med Sci*. 2011;26(2):157-62.
19. Lussi A, Imwinkelried S, Pitts N, Longbottom C, Reich E. Performance and reproducibility of a laser fluorescence system for detection of occlusal caries in vitro. *Caries Research* 1999;33:261-6.
20. Shi XQ, Welander U, Angmar-Mansson B. Occlusal caries detection with KaVo DIAGNOdent and radiography: an in vitro comparison. *Caries Res*. 2000;34(2):151-8.
21. Chu CH, Lo EC, You DS. Clinical diagnosis of fissure caries with conventional and laser-induced fluorescence techniques. *Lasers Med Sci*. 2010;25(3):355-62.
22. Pourhashemi SJ, Jafari A, Motahhari P, Panjnoosh M, Kharrazi Fard MJ, Sanati I, et al. An in-vitro comparison of visual inspection, bite-wing radiography, and laser fluorescence methods for the diagnosis of occlusal caries. *J Indian Soc Pedod Prev Dent*. 2009;27(2):90-3.
23. Sridhar N, Tandon S, Rao N. A comparative evaluation of DIAGNOdent with visual and radiography for detection of occlusal caries: an in vitro study. *Indian J Dent Res*. 2009;20(3):326-31.

24. Costa AM, Paula LM, Bezerra AC. Use of DIAGNOdent for diagnosis of non-cavitated occlusal dentin caries. *J Appl Oral Sci.* 2008;16(1):18-23.
25. Huth KC, Neuhaus KW, Gyax M, Bucher K, Crispin A, Paschos E, et al. Clinical performance of a new laser fluorescence device for detection of occlusal caries lesions in permanent molars. *J Dent.* 2008;36(12):1033-40.
26. Toraman Alkurt M, Peker I, Deniz Arisu H, Bala O, Altunkaynak B. In vivo comparison of laser fluorescence measurements with conventional methods for occlusal caries detection. *Lasers Med Sci.* 2008;23(3):307-12.
27. Reis A, Mendes FM, Angnes V, Angnes G, Grande RH, Loguercio AD. Performance of methods of occlusal caries detection in permanent teeth under clinical and laboratory conditions. *J Dent.* 2006;34(2):89-96.
28. Tomasik M, Weyna E, Tomasik E, Lipski M, Woźniak K, H R. Comparison of visual and laser examination of first permanent molars in patients aged 6-7 years. *Durham Anthropology Journal.* 2005;12(2-3).
29. Anttonen V, Seppä L, Hausen H. A follow-up study of the use of DIAGNOdent for monitoring fissure caries in children. *Community Dent Oral Epidemiol.* 2004;32(4):312-8.
30. Fung L, Smales R, Ngo H, Moun G. Diagnostic comparison of three groups of examiners using visual and laser fluorescence methods to detect occlusal caries in vitro. *Aust Dent J.* 2004;49(2):67-71; quiz 101.
31. Lussi A, Megert B, Longbottom C, Reich E, Francescut P. Clinical performance of a laser fluorescence device for detection of occlusal caries lesions. *Eur J Oral Sci.* 2001;109(1):14-9.
32. Souza J F Bt, Diniz M B, Rodrigues J A, Lussi A, Cordeiro R C L. Traditional and novel methods for occlusal caries detection: performance on primary teeth. *Lasers Med Sci.* 2013;28:287-95.
33. Neuhaus KW, Rodrigues JA, Seemann R, Lussi A. Detection of proximal secondary caries at cervical class II-amalgam restoration margins in vitro. *J Dent.* 2012;40(6):493-9.
34. Celiberti P, Leamari VM, Imparato JC, Braga MM, Mendes FM. In vitro ability of a laser fluorescence device in quantifying approximal caries lesions in primary molars. *J Dent.* 2010;38(8):666-70.
35. Goel A, Chawla HS, Gauba K, Goyal A. Comparison of validity of DIAGNOdent with conventional methods for detection of occlusal caries in primary molars using the histological gold standard: an in vivo study. *J Indian Soc Pedod Prev Dent.* 2009;27(4):227-34.
36. Braga MM, Morais CC, Nakama RC, Leamari VM, Siqueira WL, Mendes FM. In vitro performance of methods of approximal caries detection in primary molars. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod.* 2009;108(4):e35-41.
37. Kavvadia K, Lagouvardos P. Clinical performance of a diode laser fluorescence device for the detection of occlusal caries in primary teeth. *Int J Paediatr Dent.* 2008;18(3):197-204.
38. Virajsilp V, Thearmontree A, Aryatawong S, Paiboonwarachat D. Comparison of proximal caries detection in primary teeth between laser fluorescence and bitewing radiography. *Pediatr Dent.* 2005;27(6):493-9.
39. Attrill DC, Ashley PF. Occlusal caries detection in primary teeth: a comparison of DIAGNOdent with conventional methods. *Br Dent J.* 2001 28;190(8):440-3.
40. Kositbowornchai S, Sukanya C, Tidarat T, Chanoggarn T. Caries detection under composite restorations by laser fluorescence and digital radiography. *Clin Oral Investig.* 2012 Dec 16.
41. Rodrigues JA, Neuhaus KW, Hug I, Stich H, Seemann R, Lussi A. In vitro detection of secondary caries associated with composite restorations on approximal surfaces using laser fluorescence. *Oper Dent.* 2010;35(5):564-71.
42. Bamzahim M, Aljehani A, Shi XQ. Clinical performance of DIAGNOdent in the detection of secondary carious lesions. *Acta Odontol Scand.* 2005;63(1):26-30.
43. Boston DW. Initial in vitro evaluation of DIAGNOdent for detecting secondary carious lesions associated with resin composite restorations. *Quintessence Int.* 2003;34(2):109-16.
44. Braga MM, Chiarotti AP, Imparato JC, Mendes FM. Validity and reliability of methods for the detection of secondary caries around amalgam restorations in primary teeth. *Braz Oral Res.* 2010;24(1):102-7.
45. Pinheiro I MM, Ferreira M, Lima K. Use of laser fluorescence (DIAGNOdent) for in vivo diagnosis of occlusal caries: A systematic review. *J Appl Oral Sci.* 2004;12:177-81.
46. Bader JD, Shugars DA. A systematic review of the performance of a laser fluorescence device for detecting caries. *J Am Dent Assoc.* 2004;135(10):1413-26.
47. Hitij T, Fidler A. Effect of dental material fluorescence on DIAGNOdent readings. *Acta Odontol Scand.* 2008;66(1):13-7.
48. Francescut P, Zimmerli B, Lussi A. Influence of different storage methods on laser fluorescence values: a two-year study. *Caries Res.* 2006;40(3):181-5.
49. Krause F, Braun A, Eberhard J, Jepsen S. Laser fluorescence measurements compared to electrical resistance of residual dentine in excavated cavities in vivo. *Caries Res.* 2007;41(2):135-40.